वार्षिक प्रतिवेदन
ANNUAL REPORT
2014-2015

वै.औ.अ.प.-राष्ट्रीय वनस्पति अनुसंधान संस्थान, लखनऊ
CSIR - NATIONAL BOTANICAL RESEARCH INSTITUTE, LUCKNOW

CSIR-NBRI

Published by
Director
CSIR-National Botanical Research Institute
Rana Pratap Marg, Lucknow-226001

Editors
KN Nair
PA Shirke
SA Ranade
Yogendra Misra

Compilation
Yogendra Misra
Kamla Kulshreshtha
CS Mohanty

Cover Design & Photographs
Avinash Little

Hindi Translation
KK Rawat
Yogendra Misra
K M Maurya
Sayyada Khatoon
Bijendra Singh
Kamla Kulshreshtha

Acknowledgement
Research and Management Councils,
R & D Agencies,
Decision Unit Leaders, Nodal Scientists,
Project Leaders, Scientists,
and Administration for guidance, cooperation,
and for providing information

Front Cover **: New Plant Varieties, Floral Craft and Herbal Formulation developed by CSIR-NBRI**
1. Chrysanthemum ' NBRI- Kesar'- A new gamma irradiation mutant of *Chrysanthemum morifolium* 'Puja'
2. Gladiolus ' NBRI- Lalima '- A new hybrid variety of Gladiolus ('Jester'× 'Fedelio')
3. Floral craft made from dried plant materials
4. NBRMAP-DB- A safe hypo-glycaemic herbal formulation for diabetes management

वार्षिक प्रतिवेदन
Annual Report
2014-2015

With best compliments from :

Director
CSIR-NBRI
Lucknow

CSIR-NBRI

सीएसआईआर–राष्ट्रीय वनस्पति अनुसंधान संस्थान
(वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद, नई दिल्ली)
राणा प्रताप मार्ग, लखनऊ – 226 001, उ.प्र., भारत

CSIR-National Botanical Research Institute
(Council of Scientific & Industrial Research, New Delhi)
Rana Pratap Marg, Lucknow - 226 001, U.P., India
Phones : 0522-2205848, 0522-2297802 **Fax :** 0522-2205839
E-mail : director@nbri.res.in **Website:** http://www.nbri.res.in

Institute at a Glance

Publications	
Total Research Papers	198
Papers in SCI Journals	137
Books/Bulletins/Monographs	07
Chapters in Books/Proceedings	12
Popular Scientific Articles	46
Patents	
Granted	01
Filed	10
Technologies Transferred	01
Scientists Deputed Abroad	08
Projects in Hand	
OLP	13
BSC	10
ISC	01
GAP	66
CNP	01
TLP	01
TSP	01
SSP	01
RSP	01
Current Periodicals	167
New Varieties/ Cultivars Developed	02
PhD	
Awarded	16
Submitted	12
Manpower (Filled up Positions)	
Group IV	70
Group III	55
Group II	65
Group I	66
Administration	105

Contents

निदेशक की कलम से.........

जैव संसाधन तथा उनसे संबधित पारंपरिक ज्ञान ही सतत विकास का आधार स्तम्भ हैं। किसी भी देश की सामाजिक एवं आर्थिक प्रगति तथा मानव जीवन में गुणवत्ता में वृद्धि के लिए यह ज्ञान समुचित वैज्ञानिक एवं तकनीकी हस्तक्षेप के माध्यम से असीमित अवसर प्रदान करता है। सीएसआईआर-एनबीआरआई, लखनऊ अपने बहु-आयामी शोध तथा विकास संबन्धित कार्यक्रमों के द्वारा जैव संरक्षण, उनके व्यवस्थित प्रलेखन व जैव पूर्वेक्षण द्वारा जाने एवं अंजाने पौध समूहों तथा सूक्ष्म रोगाणुओं के क्षेत्र में पूर्णतया अध्ययन रत है । संस्थान ने जेनेटिक इंजीनियरिंग, मानव स्वास्थ-सुरक्षा, कृषि एवं पर्यावरण संरक्षण तथा इनकी वौद्धिक संपदा, आनुवांशिक शोध तथा इनसे विकसित ज्ञान के आधार पर विश्व-स्तर पर सम्मानित विशेषाधिकारपूर्ण प्रभावशाली स्थान प्राप्त किया है। मुझे समग्र रूप से विकसित प्रगतिशील संस्थान की 2014-15 का वार्षिक प्रतिवेदन प्रस्तुत करते हुए अत्यन्त गर्व महसूस हो रहा है।

यह वार्षिक प्रतिवेदन संस्थान के बुनियादी और अनुप्रयुक्त संयंत्र विज्ञान अनुसंधान के क्षेत्र में अपने विभिन्न अनुसंधान और विकास के साथ ही संबन्धित दूरस्थ कार्यक्रमों में अप्रैल 2014 से मार्च 2015 के दौरान हासिल की गई प्रमुख उपलब्धियां प्रस्तुत कर रहा है । प्रतिवेदन के अनुसार इस वर्ष अनुसंधान एवं प्रकाशनों के कार्यक्षेत्र में नई विकसित प्रौद्योगिकियाँ एवं फूलों की नई किस्मों और डेटाबेस के आवेदन की गुणवत्ता के वृद्धि में महत्वपूर्ण प्रगति हुई है। नए एवं उच्च कोटि की बुनियादी सुविधाओं को व्यापक रूप से ग्रामीण अंचल के सामाजिक और आर्थिक विकास के साथ ही शहरी आबादी के लिए संयंत्र तथा माइक्रोबियल संसाधनों के सतत उपयोग से संस्थान द्वारा आयोजित जागरूकता कार्यक्रम अत्यंत लाभकारी सिद्ध हुए हैं। मैं भारत वर्ष के एक प्रमुख औद्योगिक एवं विज्ञान अनुसंधान केंद्र सीएसआईआर-एनबीआरआई के निरंतर विकास और प्रदर्शन हेतु योगदान करने तथा उसमें सक्रिय रुचि एवं सहयोग के लिए अपने सभी सहयोगियों और साथियों का हृदय से आभारी हूँ ।

यह संस्थान, नई तकनीकी जानकारी तथा संयंत्र और माइक्रोबियल संसाधनों से टिकाऊ प्रौद्योगिकी विकसित करने की अपनी नवाचार संचालित अनुसंधान के क्षेत्र में इस वर्ष भी अच्छी प्रगति की है। वर्ष 2014-2015 में NBRMAP DB नामक हर्बल उत्पाद सीएसआईआर-एनबीआरआई तथा सीएसआईआर-सीमैप के संयुक्त उद्यम के रूप में मधुमेह रोग के प्रबंधन हेतु विकसित किया गया, जिस पर हम गर्वित हो रहे हैं। राष्ट्रीय प्रौद्योगिकी दिवस 13 मई, 2014 के अवसर पर मधुमेह के प्रबंधन हेतु सुरक्षित हाइपो ग्लाइसेमिक सूत्रीकरण द्वारा इस प्रभावी हर्बल उत्पाद की तकनीकी जानकारी एमिल फार्मासियूटीकल्स कंपनी, नई दिल्ली के हस्तान्तरित भी की गई। एक अन्य हर्बल जेल कास्मेटिक उत्पाद जो “कैन्डीडेसिस” के प्रबन्धन में सहायक ‘हर्बल सिंदूर’ अपनी सुरक्षा और प्रभावकारिता हेतु परीक्षण के अंतिम चरण में है। मुझे खुशी है कि सीएसआईआर-एनबीआरआई, लखनऊ तथा राइस रिसर्च स्टेशन, चिनसुरा, पश्चिम बंगाल के संयुक्त प्रयास द्वारा एक आर्सेनिक मुक्त चावल की किस्म (सी एन -1794-2-सीएसआईआर-एनबीआरआई) “मुक्ताश्री” विकसित की गई जिसको पश्चिम बंगाल के आर्सेनिक प्रदूषित खेतों उगाने के लिए जल्द ही जारी किया जाएगा। सीएसआईआर-एनबीआरआई के अन्य दो प्रमुख योगदान हैं। ऑनलाइन व्यापक कपास जीनोमिक डेटाबेस तथा एक Withania & WITHANOME ट्रांसक्रिपटोम डेटाबेस के विकास हेतु वैश्विक जीनोम डेटाबेस को समृद्ध बनाने की दिशा में आगे आया है।

वर्ष 2014-2015 में संस्थान ने कुल 95 अनुसंधान एवं विकास परियोजनाओं पर कार्य किया जो कि विभिन्न संस्थानों द्वारा, आंतरिक, उच्च संस्थागत एवं निमिटली द्वारा प्रायोजित थी। संस्थान के वैज्ञानिकों द्वारा कुल 198 शोध पत्र राष्ट्रीय एवं अंतर्राष्ट्रीय शोध पत्रिकाओं में प्रकाशित किए गए। इनमें से कुल 137 शोध पत्र SCI पत्रिकाओं में प्रकाशित हुए जिनका औसत इम्पैक्ट फैक्टर 2.2 प्रति प्रकाशन था तथा यह कुल 298.78 था। वर्तमान वर्ष में कुल 1 पेटेंट अनुमोदित हुआ, 10 नए पेटेंट दाखिल किए गए, 22

नई परियोजनायें प्रारम्भ हुयीं, 1 प्रौद्योगिकी हस्तांतरित की गई तथा 12 समझौता पत्रों पर हस्ताक्षर किये गये। 16 छात्रों को वाचस्पति (Ph.D.) की उपाधि प्रदत्त हुई तथा 12 छात्रों ने अपने अनुसंधान ग्रंथ Ph.D. हेतु अग्रेषित किए। ये उपलब्धियां संस्थान की उत्तरोत्तर प्रगति को दर्शाती हैं।

सीएसआईआर-एनबीआरआई में किए गए उच्च कोटि के वैज्ञानिक शोध कार्य तथा रिपोर्टिंग वर्ष के दौरान वैज्ञानिको द्वारा प्राप्त किए गए पुरस्कार एवं मान्यतायें संस्थान के महत्व को दर्शाती है। विज्ञान और प्रौद्योगिकी (डीएसटी) विभाग, विज्ञान एवं प्रौद्योगिकी मंत्रालय, भारत सरकार द्वारा एक प्रतिष्ठित 'जे सी बोस नेशनल फेलोशिप' से मुझे नवाजा गया जो पारिस्थितिकी तंत्र के अनुकूल प्रौद्योगिकियों के विकास के क्षेत्र में किए गए योगदान के संबंध में था, जो रोगाणुओं को कम करके पौधों की वृद्धि में सहायक होता है । डॉ. पी के त्रिवेदी, प्रधान वैज्ञानिक को भारत की राष्ट्रीय अकादमी (NASI) द्वारा FNASc फेलो से सम्मानित किया गया। डॉ. पुनीत सिंह चौहान, वरिष्ठ वैज्ञानिक को सस्टेनेबल एग्रीकल्चर भारत के एशियाई पी. जी. पी. आर. सोसाइटी द्वारा 'अभिनव युवा वैज्ञानिक पुरस्कार' से सम्मानित किया गया । डॉ ए के गोयल, मुख्य वैज्ञानिक और डॉ तारिक हुसैन, वरिष्ठ प्रधान वैज्ञानिक को 'बी ए राजी' पदक से नवाजा गया तथा डॉ पी बी खरे, मुख्य वैज्ञानिक को एपीटीए संयंत्र की एसोसिएशन ऑफ इंडिया द्वारा स्थापित 'एस एस बीर' पदक प्रदान किया गया।

समीक्षाधीन वर्ष में सीएसआईआर-एनबीआरआई ने दो सजावटी पौधों की किस्में जारी कीं जिनके नाम क्रमशः गुलदाउदी एनबीआरआई-केसर व ग्लाडिओलस एनबीआरआई-लालिमा रखे गए (केसर खूबसूरत पीले गुलाबी रंग लिए नई गामा विकिरण उत्परिवर्ती किस्म तथा दूसरा अद्वितीय गुलाबी और बैंगनी बौछार लिए एक नया संकर किस्म था)। देर से खिलने वाले पौधों के प्रभाग में गमलों में लगाने हेतु ये पौधे आदर्श सिद्ध हुए। एनबीआरआई के वनस्पति उद्यान में विकसित एक नई प्रदर्शन सुविधा "घरों में उगाये जाने वाले पौधों की दुनिया", विभिन्न किस्मों के पौधों के संकलन से बनाया गया। इस वनस्पति उद्यान की अपनी विशिष्टता, एकरूपता एवं स्थिरता परीक्षण (DUS) केंद्र के रूप में मान्यता प्राप्त है। पीपीवीएफआरए, भारत सरकार द्वारा चयनित बोगेनविलिया, कैना तथा ग्लैडिओलस के लिए हैं। इन DUS परीक्षण केन्द्र में बोगेनविलिया तथा कैना के परीक्षण के दिशा निर्देश तैयार किए गए तथा जो PPVFRA द्वारा अनुमोदित भी कर दिया गया।

पादप तथा लाईकेन संसाधनों की जैविकता एवं इनके व्यवस्थित प्रलेखन के क्षेत्र में की गईं मुख्य आकर्षक उपलब्धियां इस प्रकार हैं : उत्तराखंड के गोविंद वन्यजीवन अभयारण्य से शैवाल प्रजातियों के 127 टेक्सा, लाईकेन की 98 प्रजातियाँ, ब्रायोफाइटा की 35 प्रजातियाँ एवम टेरिडोफाइटा की 55 प्रजातियाँ एकत्रित की गईं। हिमालय के पश्चिमी क्षेत्र में पाये जाने वाले औषधीय पौधे *Berginia ciliata* के आनुवंशिक विविधता का मूल्यांकन किया गया। *Ficus krishnae* के वर्गीकरण का पुनर्मूल्यांकन किया गया। 11 औषधीय पौधों एवम लाईकेन *Citrelia* की 10 प्रजातियों के DNA बारकोडिंग की गई। हिमांचल प्रदेश से नई प्रजाति *Delphenium lahulensis* की खोज हुई और विवरण बनाया गया। 14 लाईकेन प्रजातियों तथा 4 Bryophytes जो क्रमशः गंगा के मैदानी इलाकों और पूर्वी घाट से पहली बार खोजे गए उनके नए क्षेत्रीय भौगोलिक रिकार्ड बनाए गये। भारत के भिन्न भिन्न क्षेत्रों से प्राप्त *Hedychium spicatum* के सत की जैविकता जाँची गई जिसकी कैंसर विरोधी तथा दीमक विरोधी गतिविधियां उपयोगी पाई गई। एक शुद्ध जलीय शैवाल *Golenkinia radiata* का पोषण विश्लेषण किया गया। एक विशेष लाईकेन *Usnea longissima* द्वारा नैनो योगों के लिए स्ट्रेप्टोकोकस उत्परिवर्ती कोरम संवेदन के रूप में शक्तिशाली अवरोध उत्पन्न करनेवाला स्वर्ण आधारित धातु कोलाइड मिला। सीएसआईआर-एनबीआरआई का पादपालय, पुष्पीय और अपुष्पीय वाले पौधों की 1390 नए नमूनों से युक्त है तथा वर्तमान में इसकी कुल संग्रहित संख्या 2,90,966 नमूनों तक पहुँच गई है।

जलवायु परिवर्तन के लिए पौधों की अनुकूली प्रतिक्रियाओं पर प्रयोगात्मक सबूत के लिए किए गए खोज में, अनेकानेक अजैव और जैविक परिवर्तन एवम बढ़े हुए कार्बन डाईआक्साइड की दशा में, पारिस्थितिकी और पर्यावरण विज्ञान समूह ने, गुग्गुल (*Commiphora wightii*) में पृथक रासायनिक विविध मेटाबोलाइट्स की पहचान की। पश्चिमी हिमालय क्षेत्र के *Arabidopsis thaliana* के तीन विभिन्न नमूनों की miRNA अनुक्रम विश्लेषण के माध्यम से एल्टीट्यूडल अनुकूलन की जांच की। ग्वार पौधे के विविध जर्मप्लाज्म में आणविक विविधता और शारीरिक प्रतिक्रियाओं का मूल्यांकन भी किया गया। आर्सेनाइट मिथाइल ट्रांस्फरेज (arsM) का क्लोन करके एक नोवेल जीन का परीक्षण किया गया जिससे आर्सेनिक द्वारा दूषित मिट्टी की योग्यता बनी रही और इस जैविक उपचार को बढ़ावा देने के लिए एक संयंत्र का विकास भी किया गया। मिट्टी में पालीएरोमैटिक हाइड्रोकार्बन (पाइरीन और फिनेन्थ्रीन) के लिए दो महत्वपूर्ण जीवाणु उपभेदों (*स्यूडोमोनास स्टटजरी* BP10 और *Ochrobactrum* के मध्य p2) की बायोडिग्रेडिंग क्षमता की जांच की गई। उत्तर प्रदेश के आर्सेनिक दूषित क्षेत्रों से पाँच आर्सेनिक सहिष्णु जीवाणु उपभेदों के पहचान की गई तथा हेक्साकोसीन के लिए अत्यधिक कुशल जैव अपघट के रूप में, पेट्रोलियम स्लज से पृथक दो जीवाणु उपभेदों (*स्यूडोमोनास* की प्रजाति बीपी10 और *Stenotrophomonas nitrireducen*) पृथक की गई।

जेनेटिक इंजीनियरिंग, ट्रांस्क्रिप्टोमिक्स तथा प्रोटेओमिक्स के क्षेत्र में आनुवंशिकी और आणविक जीव विज्ञान समूह ने विविध transdisciplinary शोध कार्यक्रमों में उल्लेखनीय योगदान दिए जिनकी मुख्य बिन्दुएँ निम्नलिखित हैं। एक पौधे से जीन एन्कोडिंग करके तथा कीटनाशी प्रोटीन का उपयोग कर whitefly प्रतिरोधी ट्रांसजेनिक कपास लाइनों के विकास का कार्य किया गया । पौधों में संकर ताकत के लिए एक कुशल नर बाँझपन - उर्वरता बहाली प्रणाली के आधिक्य का भी प्रयास हुआ। कपास में फाइबर उपज में सुधार के लिए एक गैर-GM प्रौद्योगिकी के रूप में एनाकार्डिक एसिड के उपयोग के सत्यापन की कोशिश भी हुई। *एराबिडोप्सिस* की AtMYB12 प्रतिलेखनकारिता व्यक्त करने के लिए फ्लेवोन्वायड घनी ट्रांसजेनिक टमाटर का विकास हुआ तथा विभिन्न प्रकार की As III तथा As V की पहचान के रूप में चावल की किस्मों की जमते आर्सेनिक विषम में माइक्रो आरएनए व्यक्त करने का प्रयास हुआ। अफीम में पेपेवरिन तथा थीबेन के विकास का भी कार्य किया गया। द्विलिंगी औषधीय पौधे गिलोय की नर और मादा पौधों के भेद के लिए लिंग विशिष्ट पीसीआर प्रोफाइल का पता लगाने के प्रयास हुए। फलों की नरमी, सुगंध उत्पादन और एथिलीन जैवसंश्लेषण में शामिल विभिन्न व्यक्त जीनों की पहचान भी की गई। चावल की इंडिका और *जपोनिका* किस्मों में अंतर में शामिल नियामक जीन में एक की पहचान हुई। गुलाब से इनड्यूसिबिल प्रमोटर के लक्षण वर्णन के कार्य हुए तथा कैना के बीज अंकुरण प्रोटोकॉल का मानकीकरण किया गया।

विषाणु विज्ञान समूह ने वायरस और संयंत्र रोगों पर कई नई रिपोर्ट और उनके आणविक निदान बनाए। भारत में *Crinum asiaticum* पर Nerine यलो स्ट्राइप वायरस (NeYSU) की स्वतः उपस्थिति रिपोर्ट की गई और केना में बीन यलो मोजैइक वाइरस पाया गया। इसके अलावा *जटरोफा* एवं *हालीहाक* में यलो मोजैइक वाइरस रोग के साथ जुड़े *बेगमोवाइरस* की आणविक लक्षण की वर्णन की भी चेष्टा हुई तथा वायरस मुक्त जरबेरा पौधों को भी (विराजोल के माध्यम से) इन विट्रो कीमोथेरेपी के द्वारा से सफलतापूर्वक विकसित किया गया।

पादप सूक्ष्म जीव समन्वयन समूह ने संयंत्र के सूक्ष्म जीव इंटर-एक्शन के पीछे कार्य कर रहे जटिल तंत्र को समझने के लिए, फसली पौधों के जैविक उपचार द्वारा पौधों की वृद्धि की क्षमता और उत्पादकता बढ़ाने तथा इसे लाभकारी बनाने के लिए निरंतर किए गए प्रयासों को जारी रखा। इस समूह ने *Psudomonas putida* (NBRI 1108T) की एक उत्परिवर्ती मेटाबोलाइट की एक रूपरेखा तैयार की जिसे उच्च सूखे की स्थिति में तापमान सहिष्णुता प्रदान करने के लिए व फसलों की उत्पादकता बढ़ाने के लिए प्रयोग किया जा सकता है। सोने के नैनोकणों के जैवसंश्लेषण के लिए 10 मिनट की एक छोटी सी अवधि में एक विधि जिसमें ट्राइकोडर्मा का उपयोग किया गया तथा पौधों की वृद्धि और संयंत्र रोगजनक/नियंत्रण एजेंट की तरह एक कुशल जैव उत्प्रेरक का उपयोग कर विकसित किया गया है। इस बढ़े स्तर के CO_2 की दशा में पीएच, नमक और सूखे की स्थिति के खिलाफ अजैव प्रतिरोध युक्त आठ संभावित उपभेदों की पहचान के परिणामस्वरूप माइक्रोबियल नमूनों की स्क्रीनिंग हुई ।

भेषज विज्ञान और पादप रसायन समूह सक्रिय रूप से पारंपरिक ज्ञान पर और देशी संयंत्र संसाधनों से आधारित मूल्य वर्धित हर्बल उत्पादों के विकास में निरंतर प्रयासरत रहा । कैंडिडिआसिस और हर्बल सिंदूर के लिए हर्बल उत्पाद की तैयारी के लिए तकनीकी जानकारी के मानकीकरण के अलावा, समूह ने दो महत्वपूर्ण औषधीय पौधों *Gloriosa superba* और *Coleus forskohlii* के संभ्रांत कीमोटाइप्स की पहचान की है। Guggul पौधे से विविध मेटाबालिक पाथवे की पहचान के साथ साथ 118 रासायनिक विविध मेटाबोलाइट्स, कैंसर विरोधी यौगिकों, बास्ट्रोसीन और डीमाक्सीबास्ट्रीसीन की उच्च मात्रा का विश्लेषण भी किया गया जो Guggul से एक नए फंगल एनडोफाइट (*निग्रोस्पोरा* प्रजाति) रिपोर्ट की गई।

संस्थान ने सीएसआईआर - 800 और अन्य परियोजनाओं के तहत आयोजित समूह प्रशिक्षण और कार्यशालाओं सहित अपने आउटरीच गतिविधियों में उत्कृष्ट प्रदर्शन किया है। इन प्रशिक्षण कार्यक्रमों में व्यवसायिक फूलों की खेती, एग्रोतकनीक, बायोफर्टीलाजर, पुष्प के निर्जलीकरण, पान की खेती, औषधीय और सुगंधित पौधों की खेती के रूप में विविध विषयों की एक विस्तृत क्षेत्र को सम्मिलित किया। प्रशिक्षण कार्यक्रमों से लाभान्वित होने वाले लाभार्थियों में जैवउर्वरक इकाइयों के अधिकारी, किसानों, शिक्षकों और छात्रों के समूह शामिल हैं। इसके अतिरिक्त विज्ञान में विभिन्न विषयों पर, विभिन्न विश्वविद्यालयों के परास्नातक छात्रों तथा संस्थानों के उभरते वैज्ञानिकों को भी प्रशिक्षण दिया गया।

संस्थान की समग्र प्रगति और विकास के सतत समर्थन और प्रतिबद्धता के लिए मैं वैज्ञानिक और प्रशासनिक सहयोगियों के सहयोग हेतु आभार व्यक्त करता हूँ क्योंकि यह उन सबके बिना संभव नहीं हो सकता था। मैं संस्थान के सफल S&T प्रबंधन के लिए डॉ परम वीर सिंह आहूजा तथा डॉ एम ओ गर्ग, सीएसआईआर के महानिदेशक द्वारा समय समय पर मिले उचित मार्गदर्शन, सलाह और समर्थन के लिए भी आभारी हूँ। संस्थान के अनुसंधान परिषद के अध्यक्ष प्रोफेसर एसके सोपोरी का संस्थान के शोध व विकास परियोजनाओं को तैयार करने और लागू करने में उनके मार्गदर्शन के लिए तथा अनुसंधान और प्रबंधन परिषद के सभी प्रतिष्ठित सदस्यों का भी आभारी हूँ। मैं एक बार फिर अपने सभी साथियों, शुभचिंतकों का प्रगतिशील संस्थान को विकास की एक फास्ट ट्रैक पर को लाने में मदद की है उन सभी को उनकी मदद और सहायता के लिए धन्यवाद। मुझे विश्वास है कि यह वार्षिक रिपोर्ट पिछले एक वर्ष के दौरान संस्थान की प्रगति पर एक अद्यतन सूचना के कारण पाठकों को अपने शोध में मदद मिलेगी। हम आप सभी से बहुमूल्य मार्गदर्शन एवं सुझाव की अपेक्षा करते है जिससे संस्थान के गुणवत्ता और मानकों को आगे बढ़ाने में सहायता मिलेगी।

चन्द्र शेखर नौटियाल

(चन्द्र शेखर नौटियाल)
निदेशक

From the Director's Desk ....

Bioresources and associated traditional knowledge are the bedrock for sustainable development. Leveraging this knowledge and harnessing the resources through appropriate scientific and technological intervention offers unlimited opportunities for development of new knowledge, technologies and services that can help improve the quality of human life and the socio-economic progress of the country. CSIR-National Botanical Research Institute (CSIR-NBRI), Lucknow has been engaged in multidisciplinary research and development programs aimed at systematic documentation, conservation and bioprospecting of the unexplored and underexplored diversity in plants and microbes of India. The Institute has carved out a special niche in the arena of transdisciplinary and translational research by enriching the knowledge base, intellectual property, and innovations in developing affordable herbal, microbial and genetic engineering technologies for human health care, agriculture and environmental protection. I take pride in having the responsibility to steer this vibrant institute towards continued excellence and all-round progress and consider it as a great honour and privilege to present the Annual Report of CSIR-NBRI for the year 2014-15.

This report presents the salient achievements of the Institute during April 2014 to March 2015 in its various research and development as well as outreach programs in basic and applied plant science research. The year under report witnessed significant progress as increased quality of research publications, the number of patents filed, enhancement of the scope and application of new technologies and new plant varieties developed, the number of PhDs awarded and submitted, the new infrastructure and facilities created, and the extensive out-reach and awareness programs conducted by the Institute on sustainable use of plant and microbial resources for societal and economic development of the rural as well as urban population of India. I am grateful to all my colleagues and peers for their active interest and support in contributing towards the sustained growth and performance of CSIR-NBRI as a leading plant science research centre in India.

The Institute progressed well this year too in its innovation–driven research, generating new knowhow and sustainable technologies from plant and microbial resources. As a joint venture of CSIR-NBRI and CSIR-CIMAP, we developed and released the herbal formulation - 'NBRMAP-DB' for the management of diabetes during 2013-14. The technology for this safe hypo-glycaemic formulation was transferred to M/s Aimil Pharmaceuticals Ltd., New Delhi on the occasion of the National Technology Day on 13th May 2014. The knowhow for a novel herbal gel-based formulation for the management of Candidiasis, and another herbal cosmetic product – 'Herbal Sindoor' are also in the final stages of testing for their safety and efficacy. I am also delighted that the 'Arsenic-free rice variety (CN-1794-2-CSIR-NBRI)' named "Muktashree", developed by CSIR-NBRI and the Rice Research Station, Chinsurah, West Bengal, will be released soon for cultivation in the arsenic contaminated fields in West Bengal. Development of an online Comprehensive Cotton Genomic Database and a Comprehensive Transcriptome Database on Withania – WITHANOME - are the two other major contributions of CSIR-NBRI towards enriching the global genome databases.

This year, the Institute undertook a wide range of research activities under 95 R&D projects (including in-house, supra-institutional, network, NMITLI and other externally funded projects) spanning almost the entire range of disciplines in plant sciences. The scientists of the Institute published 198 research papers in leading national and international journals. Out of these, 137 were in SCI journals with an average impact factor of 2.2 and cumulative IF of 298.78. This year, one patent was granted, 10 patents were filed, 22 new projects received, one technology was transferred, 12 MoUs / Agreements were signed, 16 students were awarded their Ph.D. degrees and 12 students submitted their research work for the Ph.D. degree.

The significance and impact of the good science carried out at CSIR-NBRI can also be gauged by the distinct honours, awards and other recognitions the scientists of the Institute received during the reporting year. These include the prestigious 'J. C. Bose National Fellowship' conferred to myself by the Department of Science and Technology (DST), Ministry of Science and Technology, Government of India, in recognition of our contributions in the field of developing ecosystem-friendly technologies for rapid screening and selection of useful plant growth promoting microbes that can impart to plants tolerance to salt, drought and pathogenic microorganisms. Dr. PK Trivedi, Principal Scientist, was conferred FNASc by the National Academy of Science (NASI), Allahabd, India. Dr Puneet Singh Chauhan, Senior Scientist was awarded the 'Innovative Young Scientist Award' by the Asian PGPR Society for Sustainable Agriculture, India. Dr. AK Goel, Chief Scientist and Dr Tariq Husain, Senior Principal Scientist won the 'BA Razi Medal', and Dr PB Khare, Chief Scientist, received the 'SS Bir Medal' instituted by the Association of Plant Taxonomy (APT), India.

In this year, CSIR-NBRI developed and released two novel ornamental plant varieties: 'Chrysanthemum- NBRI-Kesar'- a new gamma irradiation mutant with beautiful yellow-pink bi-colored florets and a larger capitulum; and 'NBRI – Lalima'- a new hybrid variety of Gladiolus having unique pinkish-red and purplish splashes on the tip of florets. Both of these varieties are new addition to the late blooming section and are ideal for potted plants and cut-flower purposes. A new demonstration facility in the NBRI Botanic Garden – The World of House Plants, was created with aesthetic display of various categories of house plants. The Botanic Garden of NBRI has been recognized as the centre for Distinctiveness, Uniformity and Stability (DUS) test for three mandated crops: Bouaginvillea, Canna and Gladiolus, by the Protection of Plant Varieties and Farmers Rights Authority (PPVFRA), Government of India. As part of this activity, DUS test guidelines were prepared for Bougainvillea and Canna and these were approved by the PPVFRA.

In the area of systematic documentation and bioprospecting of plant and lichen resources, the major highlights include: documentation of 127 algal taxa, 98 species of lichens, 35 species of bryophytes, and 55 species of pteridophytes from the Govind Wildlife Sanctuary in Uttarakhand; genetic diversity assessment of the West Himalayan medicinal plant *Bergenia ciliata*; taxonomic reappraisal of *Ficus krishane*; DNA barcodes for 11 medicinal plants and 10 species of the lichen genus *Citrelia*; discovery and description of a new species – *Delphenium lahulensis* from Himachal Pradesh; and new regional geographic records of 14 species of lichens, and four species of bryophytes from Indo-gangetic Plains and the Eastern Ghats, respectively. Bioprospecting studies resulted in detecting significant anti-cancerous activities and anti-termite properties in the extracts of *Hedychium spicatum* sampled from different locations of India, and nutritional analysis of a fresh water alga – *Golenkinia radiata*, besides leads for a novel swarna- based herbo-metallic colloid nano-formulations as potent inhibitor of *Streptococcus* mutant quorum sensing from the lichen - *Usnea longissima*. CSIR-NBRI herbarium has been enriched with addition of 1,390 new specimens of flowering and non-flowering plants and has now reached total holdings of 2,90,966 specimens.

In search for experimental evidences on adaptive responses of plants to climate change, elevated CO_2 and other abiotic and biotic stresses, the Ecology and Environmental Sciences Group isolated and identified chemically diverse metabolites from Guggul (*Commiphora wightii*); examined altitudinal adaptation of three diverse samples of *Arabidopsis thaliana* in the West Himalayas through miRNA sequence analysis; assessed molecular diversity and physiological responses in diverse germplasms of guar plant; cloned and characterized novel arsenite methyl transferase (arsM) genes and tested them for their plant growth promoting abilities and bioremediation of arsenic contaminated soils; examined the biodegrading potentials of two promising bacterial strains (*Pseudomonas stutzeri* BP10 and *Ochrobactrum intermedium* P2) against poly aromatic hydrocarbons (pyrenes and phenantherene) in soils; and identified five arsenic tolerant bacterial strains from arsenic contaminated areas of Uttar Pradesh, and two bacterial strains (*Pseudomonas* sp. BP10 and *Stenotrophomonas nitrireducen*), isolated from petroleum sludge, as highly efficient biodegrading agents for hexacosane.

The Genetics and Molecular Biology Group carried out several transdisciplinary research programs in the areas of genetic engineering, transcriptomics and proteomics. The notable achievements from these studies include: development of whitefly resistant transgenic cotton lines using gene encoding insecticidal protein from a plant; development of a novel and efficient male sterility – fertility restoration system for hybrid vigor in plants; validation of the use of Anacardic acid as a non-GM technology for improvement of fibre yield in cotton; development of flavonoid rich transgenic tomato lines expressing AtMYB12 transcription factor of the Arabidopsis; identification of differentially expressed Micro RNAs in contrasting Arsenic accumulating rice varieties in response to As III and As V stress; development of papaverine and thebane rich lines of Opium poppy; detection of gender- specific PCR profiles for differentiation of male and female plants of the dioecious medicinal plant, *Tinospora cordifolia*; identification of differentially expressed genes involved in fruit softening, aroma production and ethylene biosynthesis; identification of a number of regulatory genes involved in differential embryogenesis in Indica and Japonica varieties of rice; characterization of a novel early wound inducible promoter from rose; and standardization of seed germination protocol of Canna.

The Virology Group made several new reports and molecular diagnostics on viruses and plant diseases. They reported the natural occurrence of Nerine Yellow Stripe Virus (NeYSU) on *Crinum asiaticum* in India, and bean yellow mosaic virus in Canna, besides the detection and molecular characterization of begamovirus associated with yellow mosaic disease in Jatropha and in Hollyhock. Virus- free gerbera plants were also developed successfully through *in vitro* chemotherapy (through virazole).

The Plant Microbe Interaction Group continued with their sustained efforts to understand the intricate mechanisms behind plant- microbe interactions, beneficial to enhance the plant growth abilities and productivity in crop plants and bioremediation. The group carried out metabolite profiling of a mutant of *Pseudomonas putida* (NBRI 1108T), which revealed that the mutant confers high drought and temperature tolerance and can therefore be used for enhancement of high crop productivity under drought stress conditions. A rapid method for biosynthesis of gold –nanoparticles within in a short span of 10 minutes has been developed using *Trichoderma*, a plant growth promoting and plant pathogen control agent and an efficient biocatalyst. Screening of microbial samples under elevated CO_2 resulted in identification of eight potential bacterial strains showing abiotic resistance against pH, salt and drought stresses.

The Pharmacognosy and Phytochemistry Group have been actively involved in development of value added herbal products based on traditional knowledge and from native plant resources. Besides standardizing the knowhow for preparation of herbal formulation for candidiasis and Herbal Sindoor, the group has identified elite chemotypes of two important medicinal plants, *Gloriosa superba* and *Coleus forskohlii*; standardized quality parameters of the herbal drug 'Shankupushpi' and its adulterants; identified 118 chemically diverse metabolites having diverse metabolic pathways from Guggul; reported a new fungal endophyte (*Nigrospora* sp.) from Guggul, which produced higher amount of anticancer compounds: bostrycin and deoxybostrycin.

The Institute also excelled in its outreach activities including the group trainings and workshops conducted under CSIR-800 and other projects. These training programs covered a wide range of subjects such as commercial floriculture, agrotechniques, biofertilizers, dehydration of flowers and floral crafts, betel vine cultivation, cultivation of medicinal and aromatic plants. The personnel who benefitted from the training programs include farmers, teachers and students, and officers of Biofertilizer units. Additionally, post-graduate students of different universities/institutes were also imparted training on various topics in plant sciences.

I am glad to acknowledge that the overall progress and development of the Institute would not have been possible without the unstinted support, commitment and cooperation of my scientific and administrative colleagues. I am also grateful to the guidance, advice and support received from time to time from Dr. PS Ahuja and Dr. MO Garg, Director Generals of CSIR for successful S & T management of the institute. The institute is greatly indebted to Prof. SK Sopory, Chairman, Research Council and all the distinguished members of the Research and Management Councils for their guidance in formulating and implementing the research and development projects of the Institute. It is our peers and well wishers who have helped to put CSIR- NBRI on the fast track of progressive growth and development. I sincerely hope that the Annual Report will help the readers to catch up with an update on the progress of the institute during the last one year. We look forward to your valuable guidance, advice and suggestions that can help us improve our quality and standards in achieving further progress in our future endeavors.

(C. S. Nautiyal)
Director

अनुसंधान एवं विकास

उच्च संस्थागत नेटवर्क परियोजनाएं

1. पादप संपदा एवं अन्य प्राकृतिक संसाधनों का पूर्वेक्षण

गोविन्द वन्य जीव अभयारण्य (GWLS) के जैविक संसाधनों का मापन

उत्तराखंड के गोविन्द वन्य जीव अभयारण्य (GWLS) के जैविक संसाधनों के मापन कार्य में 154 से अधिक शैवाल नमूनों को 1300 मी. से 4150 मी. के मध्य विभिन्न ऊंचाइयों से एकत्रित किया गया। इन नमूनों के अध्ययन से 127 शैवालों की पहचान की गई जो कि इस अभयारण्य से पहली बार वर्णित किए गए हैं। अभयारण्य के शैवालों में क्लोरोफायसी, सायनोफायसी, बैसिलेरियोफायसी एवं यूग्लीनियोफायसी वर्ग के शैवाल प्रचुरता में मौजूद थे।

शैकों (लाईकेन) के 18 वंशों एवं 43 कुलों की कुल 98 प्रजातियों को अभयारण्य से खोजा गया। अभयारण्य में पार्मेलिएसी, फीसिएसी एवं पाइरेनूलेसी सर्वाधिक प्रचुरता से पाये जाने वाले वंश तथा हेटेरोडर्मिया तथा *फियोफीसिया* सबसे प्रचुर कुल के रूप देखे गए।

ब्रायोफाइटा समूह के 45 वंशों एवं 86 कुलों की कुल 135 प्रजातियों को अभयारण्य में खोजा गया जिनमें से 25 वंशों एवं 57 कुलों की 84 प्रजातियाँ मास की, 18 वंशों एवं 27 कुलों की 49 प्रजातियाँ लिवरवर्ट की एवं 2 वंशों एवं 2 कुलों की 2 प्रजातियाँ हॉर्नवर्ट की हैं। 6 प्रजातियाँः *सोलेनोस्टोमा फ्लैजेलेरिस, अलैकोपाइलम ग्लाकम, टेट्रालोफोजिया फिलीफोर्मिस, लेप्टोटेरिगायनेण्ड्रम डिकलर, होमैलोथेसियम नेकेरोयडिस* एवं *माइक्रोकैम्पाइलोपस खासियानस* पहली बार भारत के उत्तरी हिमालय क्षेत्र में देखी गईं।

अभयारण्य से टेरिडोफाइटा समूह के 85 नमूने संग्रहित किए गए जिनमें 15 वंशों एवं 26 कुलों की 55 प्रजातियों की पहचान की गई।

अभयारण्य की विभिन्न ऊंचाइयों पर *कैल्था पैलुस्ट्रिस* पौधे की प्रजनन जैविकी का अध्ययन किया गया तथा यह देखा गया कि अधिक ऊंचाई पर प्रजनन संबन्धित गतिविधियां धीमी हो जाती हैं। अधिक ऊंचाई पर कम गतिविधि के बावजूद *कैल्था पैलुस्ट्रिस* की मुख्य परागणकर्ता 'सिरफिड मक्खियाँ' सभी ऊंचाइयों पर सबसे ज्यादा विचरण करने वाले कीटों के रूप में देखी गईं। हालांकि ऊंचाई बढ़ने के साथ-साथ *कैल्था पैलुस्ट्रिस* में स्पष्ट विभिन्नताएँ प्रदर्शित होती हैं, किन्तु संभवतः बीज विकास के दौरान कठिन परिस्थितियों के कारण निषेचन के पश्चात उच्च मात्रा (86%) में गर्भपात होने से प्रजनन सफलता सभी ऊंचाइयों पर समान रूप से प्रभावित होती है।

बर्जीनिया सीलिएटा की उत्तरी हिमालय की प्रजातियों में आनुवांशिक विभिन्नता का निर्धारण

बर्जीनिया सीलिएटा की आठ आबादियों क्रमशः गोविंद वन्य जीव अभयारण्य (GWLS), नैनीताल (NTL), रानीखेत (RNKT), बिनसर वन्य जीव अभयारण्य (BWLS), शिमला (SHMA), कुफरी (KFRI), कुल्लू (KULLU) तथा पिथोरागढ़ (PTH) के 74 नमूनों में आनुवांशिक विभिन्नता के अध्ययन हेतु DAMD एवं ISSR मार्करों का प्रयोग किया गया। अध्ययन से विभिन्न आबादियों के मध्य आनुवांशिक भिन्नता के निम्न स्तर (GST=0.33) तथा उच्च आनुवंशिक प्रवाह (Nm = 1.02) का पता चला। इन आंकणों से पता चला कि उच्च आनुवांशिक प्रवाह निम्न आनुवंशिक भिन्नता के लिए जिम्मेदार मुख्य कारकों में से एक है। *बर्जीनिया सीलिएटा* की DAMD एवं ISSR प्रोफाइल आबादियों में नमूनों के त्वरित अभिलक्षणन की साधन हैं, और इस प्रकार इस पौधे के संरक्षण एवं पूर्वेक्षण कार्यक्रमों में उपयोग हेतु उपयुक्त नमूनों के चयन में सहायक हैं।

जम्मू एवं कश्मीर, हिमाचल प्रदेश, उत्तराखंड, सिक्किम, दार्जिलिंग (प. बंगाल) से *बर्जीनिया* कुल की 11 प्रजातियों के 180 नमूनों को जीनोटिपिक एवं कीमोटिपिक विश्लेषण के लिए एकत्र किया गया।

गोविंद वन्य जीव अभयारण्य के तीन विभिन्न ऊंचाई के क्षेत्रों (उपोष्णकटिबंधीय, शीतोष्णकटिबंधीय एवं अल्पाइन) में वृक्षों का फाइटोसोशियोलाजिकल विश्लेषण किया गया।

फाइकस का वर्गिकी अध्ययन

भारत में फाइकस की 115 प्रजातियाँ ज्ञात हैं जिनमें से 46 प्रजातियाँ गंगा के मैदानों में पाई जाती हैं। *फाइकस* की कुछ प्रजातियों की आकारिकीय विभिन्नता का अध्ययन किया गया। *फाइकस कृष्णाई* को विविधता अध्ययन एवं *फाइकस बेंगालेन्सिस* से संबंध के अध्ययन के लिए चुना गया। आकारिकीय, आंतरिक एवं कोशिकीय अध्ययनों के आधार पर *फाइकस कृष्णाई* को एक वास्तविक प्रजाति के रूप में पुनः स्थापित किया गया।

शैक (लाईकेन) से नैनोफार्मूलेशन

गोविंद वन्य जीव अभयारण्य से एकत्रित किए गए शैक *अस्निया लोंगिसिमा* के बायोएक्टिव मेटाबोलाइट का प्रयोग करते हुये स्ट्रेप्टोकाकस म्यूटेंट के लिए प्रभावी निरोधक के रूप में एक नवीन स्वर्ण-आधारित पादप-धातु कोलायडल नैनो फोर्मूलेशन का विकास किया गया।

गोविंद वन्यजीव अभयारण्य के संभावित कैंसर रोधी पौधों की मेटाबोलिक प्रोफाइलिंग एवं मेटाबोलाइट फिंगरप्रिंटिंग

तीन पादप अर्को NBC 11, NBC 12 एवं NBC 14 में कोशिकीय विषाक्तता देखी गई। NBC 14 में विभिन्न कैंसर कोशिकाओं के प्रति कोशिकीय विषाक्तता देखी गई। NBC 14 के अंश का सीएसआईआर-सीडीआरआई के डीटीडीडी डिवीजन में अध्ययन किया जा रहा है।

संभावित औषधीय क्षमता वाले पौधों की फाइटोकेमिकल प्रोफाइलिंग

हिमालय के विभिन्न क्षेत्रों से एकत्र किए गए *बेटुला यूटिलिस* की छाल, *बर्जीनिया सीलिएटा* एवं *हेडेकियम स्पीकेटम* की फाइटोकेमिकल प्रोफाइलिंग की गई। मेटाबोलिक प्रोफाइलिंग हेतु बड़े/छोटे, ज्ञात/अज्ञात बायोक्टिव मार्करों की पहचान एवं मात्रा निर्धारण के लिए तेल, शर्करा, अम्ल एवं फेनोलिक मार्करों का विकास किया गया। उपयोगी पादप-रसायनों की मात्रा निर्धारण का कार्य किया गया एवं एंटी आक्सीडेंट क्षमता निर्धारित की गई। विकसित किए गए बेटुला मार्करों का अध्ययन का काम जारी है।

2. पादप विविधता : उपयोगी बायोएक्टिव हेतु औषधीय रूप से महत्त्वपूर्ण पौधों को समझने/दोहन करने हेतु अनुकूलन विज्ञान का अध्ययन

पौधों की मेटाबोलाइट प्रोफाइलिंग एवं आर्थिक रूप से महत्त्वपूर्ण अणुओं पर केन्द्रित मेटाबोलाइट की उत्पत्ति के लिए जिम्मेदार जैव संश्लेषक पाथवे की पहचान

राजस्थान के शुष्क एवं अर्ध शुष्क क्षेत्रों (बाड़मेर, जैसलमेर एवं जोधपुर) से एकत्रित *कमीफोरा वाइटाइ* (गुग्गल) के 3 नमूनों की मेटाबोलाइट प्रोफाइलिंग अध्ययन किए गए जिनमें नमूनों के तनों में विविध मेटाबोलाइट देखे गए।

अराबिडाप्सिस थैलियाना में ऊंचे स्थानों में अनुकूलन

उत्तरी हिमालय में समुद्र तल से 700 मी. से लेकर 3400 मी. की विभिन्न ऊंचाईयों क्रमशः देहरादून (700 मी.), मुनस्यारी (1829 मी.) एवं छितकुल (3453 मी.) से *अराबिडाप्सिस थैलियाना* के पौधों को एकत्र किया गया। प्रत्येक स्थान से प्राप्त पुष्पन अवस्था के पौधों से पत्तियों को एकत्र किया गया। अगरोस जेल एवं बायो-एनलाइजर की सहायता से आरएनए नमूनों की मात्रा एवं गुणवत्ता का विश्लेषण किया गया।

छोटे आरएनए की सीक्वेंसिंग आंकड़ों का विश्लेषण

छोटे आरएनए की 7 लाइब्रेरीयों का निर्माण किया गया, जिनमें से 3 खेतों में उगाये गए पौधों से तथा 4 घर में उगाये गए पौधों जिनमें Col 0 भी सम्मिलित है, से निर्मित हैं।

लक्ष्य अनुमान एवं क्रियात्मक निरूपण

लक्षित जींस एवं उनकी क्रियाओं के द्वारा miRNA की जैविक भूमिका को बेहतर तरीके से समझा जा सकता है। अतः इस कार्य हेतु छोटे आरएनए को लक्ष्य करने वाले उपकरणः psRNA&Target को विभिन्न मानक सेटिंगों पर प्रयोग करते हुये लक्षित जींस की तलाश की गई। आगे चलकर किए जाने वाले विश्लेषणों से भिन्न-भिन्न ऊंचाइयों पर विभिन्न चरम वातावरणीय परिस्थितियों जैसे तापमान, पराबैंगनी विकिरण तथा अन्य अजैविक तनाव का सामना करने वाले पौधों के अनुकूलन में इन miRNA की भूमिका के संकेत प्राप्त हो सकेंगे।

शुष्क/अर्ध शुष्क क्षेत्र में *सायमोप्सिस टेट्रागोनोलोबा* (ग्वार) का अनुकूलन

शुष्क/अर्ध शुष्क क्षेत्र के *सायमोप्सिस टेट्रागोनोलोबा* (ग्वार) जर्मप्लाज्म की RAPD जांच

RAPD पीसीआर से प्राप्त ग्वार के विभिन्न नमूनों के डीएनए की एगरोस जेल प्रोफाइल में सभी नमूनों में अधिकांशतः एकरूपी प्रोफाइल पाई गई। अतः भिन्न PCR स्थितियाँ, अधिक प्राइमर, ISSR प्राइमर को प्रयोग किया गया ताकि अधिकतम बहुरूपी बैंड की प्राप्ति हो सके जिससे जर्मप्लाज्म में विविधता की जांच की जा सके एवं अनुकूलन जाँचों के लिए विभिन्न जर्मप्लाज्म का चयन किया जा सके।

विभिन्न ग्वार किस्मों का शरीर-क्रियात्मक प्रदर्शन

लखनऊ की परिस्थितियों में प्रदर्शन के अध्ययन के लिए खेतों में ग्वार के 28 नमूनों को उगाया गया। "पत्ती सुखाने की विधि" के द्वारा इन नमूनों में सूखे के प्रति सहनशीलता का अध्ययन किया गया। 5 नमूनों को आगे के अध्ययनों के लिए चयनित किया गया। ग्वार पौधों के तीन सप्ताह पुराने पौधों RGC-1066, RGC-1002 एवं RGC-1038 को 10 दिनों तक पानी की कमी में रखा गया जिससे पता चला कि RGC-1002 सूखे के प्रति सर्वाधिक सहनशील है।

FACE में उच्च CO_2 स्तर के प्रति लक्षित प्रजातियों (टीक एवं ग्वार) की प्रतिक्रिया

ग्वार का शरीर-क्रियात्मक अध्ययन

ग्वार की दो प्रजातियों (RGC-1002 एवं RGC-1066) को CO_2 के उच्च स्तर पर गर्मी के मौसम में उगाया गया एवं प्रकाश-संश्लेषण मानकों का अध्ययन किया गया एवं CO_2 के उच्च स्तर पर दो किस्मों में अधिकतम प्रकाश संश्लेषण दरों की तुलना की गई।

ग्वार का प्रोटियोमिक अध्ययन

ग्वार की दो किस्मों RGC1066 एवं RGC1002 की पट्टियों की प्रोटीन को पृथक किया गया एवं आइसोइलेक्ट्रिक फोकसिंग अध्ययनों से पता चला कि RGC1066 के 50 विभिन्न प्रोटीनों में 23 उच्चनियंत्रित एवं 27 निम्ननियंत्रित जबकि RGC1002 की 32 प्रोटीनों में से 19 उच्चनियंत्रित एवं 13 निम्ननियंत्रित थीं।

टीक का शरीर-क्रियात्मक अध्ययन

वर्षा ऋतु में नियंत्रित एवं उच्च FACE स्तरों, दोनों ही में टीक पौधों का "लीफ एरिया सूचक" (LAI) मापा गया। साथ ही टीक के लगभग 2 वर्ष के वृक्षों में नियंत्रित एवं उच्च FACE स्तरों, दोनों ही में सतह के ऊपर एवं सतह के नीचे का जैवभार का आंकलन किया गया। नियंत्रित की अपेक्षा उच्च FACE स्तरों के वृक्षों में उच्च लीफ एरिया सूचक एवं उच्च जैवभार देखा गया।

3. स्वास्थ्य, पर्यावरण एवं पर्यावरणीय विषालुता हेतु अगली पीढ़ी की समन्वित परियोजनाएं

आर्सेनिक का पादप-निष्कर्षण तथा धान के दानों में कम आर्सेनिक के लिए अनुकूलन हेतु योजना

दानों में कम आर्सेनिक वाली धान की किस्म CN1794-2-CSIR-NBRI को दानों में आर्सेनिक के न्यूनतम सान्द्रण वाली सर्वोत्तम किस्म के रूप में चुना गया। इसे शीघ्र ही पश्चिम बंगाल सरकार द्वारा आर्सेनिक सुरक्षित किस्म के रूप में जारी किया जाएगा।

धान के पौधों में आर्सेनिक कम करने में शैवालों की भूमिका

शैवाल *क्लोरेल्ला वल्गेरिस* एवं *नैनोक्लोरोप्सिस* प्रजाति के टीकाकरण से धान में आर्सेनिक की सांद्रता पर काफी प्रभाव पड़ा तथा गैर-उपचारित पौधों की अपेक्षा अधिक जैवभार उपलब्ध हुआ, तनों में आर्सेनिक के सान्द्रण में कमी आई एवं कोशिकीय विषाक्तता में कमी आई जिससे धान में आर्सेनिक विषाक्तता में कमी आई। *नैनोक्लोरोप्सिस* से उपचारित धान में आर्सेनिक तनाव के विरुद्ध बेहतर एंटीआक्सीडेंट एंजाइम प्रतिक्रिया देखी गई।

उत्तर प्रदेश के आर्सेनिक से दूषित क्षेत्रों के धान की जड़ों के राइजोस्फेरिक क्षेत्रों से आर्सेनिक सहिष्णु नवीन जीवाणु प्रभेदों का पृथ्थकीकरण

उत्तर प्रदेश के आर्सेनिक से दूषित क्षेत्रों के धान की जड़ों के राइजोस्फेरिक क्षेत्रों से आर्सेनिक सहिष्णु नवीन जीवाणु प्रभेदों का पृथ्थकीकरण किया गया। ऐसे 24 प्रभेदों को उनके आर्सेनिक के प्रति सहिष्णुता स्तर हेतु जांचा गया। इनमें से 5 प्रभेद (NBRI-011, -012, -013, -014, -015) ने संवर्धन पात्रों में उच्च आर्सेनिक सान्द्रताओं में अच्छी वृद्धि प्रदर्शित की। सभी में पादप वृद्धि वर्धक प्रतिक्रिया देखी गई। 16s rDNA विश्लेषण एवं आकारिकीय, जैव-रासायनिक तथा शरीर-क्रियाशीलता लक्षणों के आधार पर तीन उच्च सहनशील जीवाणु प्रभेदों NBRI-011 (*बेसिलस आर्यभट्टाइ*), NBRI-012 (*ब्रिवंडीमोनास डिमिनूटा*) तथा NBRI-013 (*वर्गीबेसीलस स्रूमियाई*) को पहचाना गया तथा शेष दो की पहचान की जा रही है।

जैव-निष्कर्षण एवं जीवाणु प्रभेदों का आर्सेनिक स्थिरीकरण

पाँच पृथक किए गए प्रभेदों को धान की जड़ों के क्षेत्र में टीकाकरण किया गया। NBRI-011, NBRI-012, NBRI-013 ने पौधों के अंगों में आर्सेनिक के सान्द्रण को कम किया तथा पौधों की जड़ों में आर्सेनिक के स्थिरीकरण को बढ़ाया जिससे पौधों में आर्सेनिक के प्रति सहनशीलता बढ़ी एवं पौधों की वृद्धि दर में भी बढ़त देखी गई। वहीं NBRI-014 एवं NBRI-015 के प्रयोग ने जड़ों एवं तनों में आर्सेनिक संचयन की गति बढ़ा दी जिस से पौधे की पादप-निष्कर्षण क्षमता बढ़ाने में सहायता मिल सकती है। आर्सेनिक उपचारित पौधों की अपेक्षा इन प्रभेदों के प्रयोग से आर्सेनिक संचयन में कुल 30-40% की गिरावट देखी गई।

फसलों के साथ उगाये गए चिन्हित आर्सेनिक संचायकों के प्रभाव का आंकलन

भूमि प्रदूषण चिंता का विषय है क्योंकि यह न सिर्फ पौधों की वृद्धि को प्रभावित करता है बल्कि मानव स्वास्थ्य पर भी प्रभाव डालता है। यहाँ एक बड़ी चिंता यह भी है कि जैव-सुधार तकनीकी का प्रयोग इस प्रकार किया जाय कि उगाई गई फसलों के दानों में आर्सेनिक की सांद्रता सुरक्षित स्तर अथवा शून्य हो। इसे ध्यान में रखते हुये एक प्रयोग किया गया जिसमें उच्च संचायक/संग्राहक फसलों के साथ उगाये गए। तीन ज्ञात उच्च संचायक *टेरिस विटाटा, फ्रेग्माइटिस* तथा *वेटिवेरिया* को धान एवं गेहूं की फसलों के साथ आर्सेनिक दूषित भूमि में उगाया गया। धान के साथ उच्च संचायकों को उगाने पर भूमि के आर्सेनिक में 56-63% कमी देखी गई जबकि दानों की उपज में कमी जो कि 30% तक हो गई थी वह घटकर 6-14% तक आ गई।

धान की भूसी के अपघटन के द्वारा भूमि में कार्बन जब्ती हेतु जीवाणु

कोशिका भित्ति को नष्ट करने वाले एंजाइमों के उत्पादन के लिए जीवाणु एवं ट्राइकोडर्मा के विभिन्न प्रभेदों की लगातार प्रयोगशाला में जांच करने के बाद धान की भूसी का तेजी से अपघटन करने वाले प्रभेदों को पहचाना गया तथा छटनी की गई। केवल 6 जीवाणु समूहों, जिनमें *ट्राइकोडर्मा, बेसिलस, फेनेरोकीट* शामिल हैं, को आगे के अध्ययन के लिए चुना गया। 60 दिन के अपघटन के पश्चात इन समूहों द्वारा भूमि में पोषक तत्वों की मात्रा में वृद्धि देखी गई। छांव में 48x28 सेमी. के गढढों में आगे के अपघटन प्रयोगों और उनके विकास के लिए चुनिन्दा समूहों को प्रयोग किया गया एवं *ट्राइकोडर्मा हार्जियानम, ट्राइकोडर्मा एस्पर्लुम, बेसिलस पुमिलस* तथा *फेनेरोकीट क्राइसोस्पोरियम* के समूहों को प्रभावी अपघटक के रूप में पाया गया। इन चुनिन्दा जीवाणु समूहों के द्वारा मक्के के पौधों में बेहतर पादप वृद्धि भी देखी गई।

पेट्रोलियम हाइड्रोकार्बन के तीव्र अपघटन के लिए जीवाणु आधारित योजना का विकास

हेक्साकोसेन का जैव-अपघटन

पेट्रोलियम कीचड़ से पृथक किए गए दो जीवाणु प्रभेदों, *स्यूडोमोनास* BP10 एवं *स्टेनोट्रोफोमोनस नाइट्रीरीड्युसेंस* E9 के द्वारा प्रयोगशाला में अलग-अलग एवं साथ-साथ एक HMW n-एलकेन, हेक्साकोसेन ($C_{26}H_{54}$) के अपघटन का अध्ययन किया गया। नतीजों से पता चला कि ये दोनों अलग-अलग प्रयोग करने पर हेक्साकोसेन (50 पीपीएम) को 83% तक तथा एक साथ प्रयोग करने पर 98% तक अपघटित कर सकते हैं।

4. औषधीय पौधों एवं कृषि दृष्टि से उत्तम अवयवों का जीनोमिक अध्ययन

पेपावेरीन जैव-संश्लेषण को समझने के लिए, जींस के पूरी लंबाई के cDNA को क्लोन किया गया। विभिन्न निर्माणों का विकास किया गया एवं वाइरस आधारित जीन साइलेंसिंग (VIGS) तथा मेटाबोलाइट सामग्री के माडुलन के अध्ययन में प्रयोग किया गया।

अराबिडाप्सिस के AtMYB12 ट्रांसक्रिप्शन फैक्टर को व्यक्त करने वाली पारजीनी, फ्लेवनोइड से प्रचुर टमाटर पौधों का विकास किया गया। इनमें पट्टियों एवं फलों में फ्लेवनोल एवं क्लोरोजेनिक अम्ल (CGA) का संचयन बढ़ी मात्रा में प्रदर्शित हुआ।

फलों के पकने एवं फूलों की पंखुड़ियों के गिरने के जटिल जीन नियंत्रण को समझने के लिए केले तथा आम के फल एवं गुलाब की पत्तियों के ट्रांस्क्रिप्टोम सीक्वेंस निर्धारित कर विस्तार से विश्लेषित किए गए। कच्चे एवं पके केले के फलों के ट्रांस्क्रिप्टोम के तुलनात्मक अध्ययन से संकेत मिले हैं कि फलों के मुलायम होने, सुगंध उत्पन्न होने तथा एथेलीन जैव संश्लेषण के साथ-साथ केले के फलों के पकने के दौरान संवेदन, जीन के भिन्न रूप से अभिव्यक्तकरण से संबन्धित होते हैं।

एक द्विलिंगी औषधीय पौधे *टीनोस्पोरा कार्डीफोलिया* में लिंग भेद के आणुविक आधार के अध्ययन के लिए लिंग भेद के आकारिकीय एवं आंतरिक लक्षणों के साथ-साथ लिंग-निर्धारित PCR प्रोफाइल को मार्कर के रूप में सुनिश्चित करने हेतु अध्ययन किया गया।

कपास जीनोमिक के क्षेत्र में कपास के रेशों की गुणवत्ता के नियंत्रकों को पहचानने एवं अभिलक्षण हेतु NBRI-समेकित कपास जीनोमिक डाटाबेस विकसित किया गया एवं ट्रांसक्रिप्शन फैक्टरों तथा एपिजेनिक मॉडुलन से संबन्धित जींस की पहचान की गई। कपास के रेशों के विकास में एपिजेनिक मोडीफायर्स के प्रभाव का पता लगाने हेतु प्रयोगशाला में अंडाणु संवर्धन से पता लगा कि एनकार्डिक अम्ल, हिस्टोन रूपान्तरण के जरिये कपास के रेशे की उपज बढ़ा सकता है। इन नतीजों की खेतों में पुष्टि की जा चुकी है तथा रेशों की मात्रा एवं गुणवत्ता में वृद्धि हेतु अनाकार्डिक अम्ल का एक गैर-जीएम तकनीकी के रूप में खेतों में प्रयोग प्रस्तावित है।

धान की जेपोनिका एवं इंडिका किस्मों में भेदक सोमेटिक भ्रूण विकास को नियंत्रित करने वाले आनुवांशिक परिवर्तनों को समझने के लिए धान के कैलस की विभिन्न अवस्थाओं एवं पुनुर्त्पादन की जीनोम स्तर पर अभिव्यक्ति का विश्लेषण किया गया। विस्तृत विश्लेषण से बहुत से नियंत्रक जींस का पता चला जो इंडिका एवं जेपोनिका किस्मों में भेदक भ्रूण विकास को नियंत्रित करने में सम्मिलित रहते हैं। बहुत से जींस एवं प्रोमोटर्स का भारी धातु तनाव सहिष्णुता एवं एकत्रीकरण सहित अजैविक तनाव में भागीदारी के लिए क्रियात्मक अभिलक्षणन किया गया।

एक नवीन शीघ्र-क्रियाशील वुण्ड इंड्यूसिबल प्रोमोटर के अभिलक्षणन के क्षेत्र में, गुलाब से एक प्रोमोटर का विस्तृत अभिलक्षणन किया गया। इस प्रोमोटर के व्यवहार को विभिन्न पौधों में तथा कीट संक्रमण के समय देखा गया।

सीएसआईआर-एनबीआरआई ने Tma12 प्रोटीन को कोड करने वाले जीन के प्रयोग से कपास की ट्रांसजीनिक लाइनें विकसित की हैं जिनमें सफेद-मक्खी के संक्रमण के विरुद्ध उनके जीवन चक्र में हस्तक्षेप के माध्यम से उच्च सहनशीलता प्रदर्शित की। विषालुता अध्ययनों से संकेत मिले हैं कि तीव्र एवं मध्यम अनावरण का सामना करने वाले चूहों में प्रोटीन से कोई परिवर्तन नहीं हुआ। यह तकनीक फसलों को सफेद-मक्खी एवं इससे समबंधित बीमारियों से सुरक्षा प्रदान करने में सक्षम है।

5. महिलाओं एवं बच्चों में कुपोषण से मुकाबला करने के लिए वैज्ञानिक एवं तकनीकी हस्तक्षेप

सीएसआईआर-एनबीआरआई द्वारा विकसित उत्पाद न्यूट्री-जैम के साथ वैज्ञानिक एवं तकनीकी के माध्यम से हस्तक्षेप द्वारा कुपोषण का मुकाबला करने हेतु करने के लिए दो ग्राम दाऊ (उन्नाव) एवं दफेदार का पुरवा (बाराबंकी) को चुना गया। ग्रामीण जनता में स्वास्थ्य के प्रति जागरूकता फैलाने हेतु सब्जियों, फलों, अनाजों एवं औषधीय पौधों आदि के महत्त्व से संबन्धित विभिन्न पहलुओं पर आधारित पोस्टर तैयार किए गए तथा दाऊ ग्राम के प्राथमिक विद्यालय के कक्षों में प्रदर्शित किए गए। स्कूल के बच्चों को सब्जियों, फलों आदि की पोषकता तथा महत्त्व एवं औषधीय पौधों और उनके प्रयोग के बारे में शिक्षित किया गया।

संस्थान ने इस वर्ष सीएसआईआर-सीमैप द्वारा 14 अगस्त, 2014 को दाऊ ग्राम एवं 10 जनवरी, 2015 को लखनऊ में आयोजित दो स्वास्थ्य शिविरों में भाग लिया गया। दाऊ शिविर में संस्थान द्वारा विकसित पोषण संबन्धित उत्पाद एवं पोस्टरों को प्रदर्शित किया गया।

6. हिमालयी क्षेत्र एवं भारतीय गांगेय मैदानों में बदलते पर्यावरण एवं इसके प्रभावों का विश्लेषण

गेहूं (कुन्दन किस्म) पर उच्चीकृत CO_2 स्तर का प्रभाव

गेहूं (*ट्रीटिकम एस्टिवम*) विश्व की एक प्रमुख फसल है, जो सम्पूर्ण कैलोरीज का 20% एवं मानव खुराक में कुल प्रोटीन का 22% प्रदान करती है।

गेहूं के पौधे फ्री एयर कान्सन्ट्रेशन एनरिचमेंट (FACE) छल्लों में उगाये गए। तीन छल्लों में उच्चीकृत CO_2 दी गई जबकी तीन छल्ले नियंत्रित (सामान्य वायु) रखे गए। जैव भार एवं उपज, प्रकाश संश्लेषण, रंध्र चालन तथा प्रोटीओमिक्स अध्ययन किए गए। उच्चीकृत CO_2 में उगाये गए पौधों में जैव भार के साथ अन्य सभी मानकों में वृद्धि देखी गई।

गेहूं की पत्ती का प्रोटियोमिक अध्ययन

गेहूं की पत्ती में, 50 प्रोटीन भिन्न रूप से व्यक्त होती हैं जिनमें 20 उच्च नियंत्रित एवं 30 निम्न नियंत्रित होती हैं। 30 प्रोटीनों को MALDI TOF TOF के जरिये पहचाना गया। उच्च नियंत्रित प्रोटीन, सुरक्षा, प्रकाश संश्लेषण, ऊर्जा उपापचय (ATP सिन्थेस) आदि से संबन्धित थीं जबकि निम्न नियंत्रित प्रोटीनों में एक Chl a/b बाईंडिंग प्रोटीन, कई RUBISCO प्रोटीन एवं ग्लाइकोलिसिस एवं ग्लूकोनियोजेनेसिस से संबन्धित कई प्रोटीन थीं।

गेहूं के दानों का प्रोटियोमिक अध्ययन

हमारे अध्ययनों में ड़िफ्रेंसियल एक्स्प्रेशन प्रोटीन प्रोफाइलिंग से पता चला कि उच्चीकृत CO_2 स्थितियों में गेहूं के दानों की 49 भिन्न रूप से व्यक्त प्रोटीनों में से 24 उच्च नियंत्रित एवं 25 निम्न नियंत्रित थीं। ये मुख्यतः कार्बन उपापचय, भंडारण, सुरक्षा एवं प्रोटीन अपघटन से संबंधित थीं।

ग्लूटेन प्रोटीन

ग्लूटेन प्रोटीनें सामान्यतः उच्च गुणवत्ता, मुख्यतः आटे की लोई की शक्ति और लोच, से संबन्धित होती हैं। उच्चीकृत CO_2 में गेहूं के दानों में उच्च आण्विक भार वाली ग्लूटेनिन एवं स्डँ ग्लूटेनिन प्रोटीनें अधिक अभिव्यक्त हुईं। गेहूं के दानों में ग्लूटेनिन अनुपात में अंतर से लोई की गुणवत्ता पर विपरीत प्रभाव पड़ सकते हैं।

मृदा सूक्ष्मजैविकी अध्ययन

- उच्चीकृत CO_2 स्थितियों की उच्च सांद्रता से अजैविक तनाव सहनशील सूक्ष्मजीवों का पृथक्कीकरण एवं जांच
- CO_2 संतृप्त मृदा के कार्बन स्रोत उपयोग पैटर्न का अध्ययन
- सूक्ष्मजीव (ट्राइकोडर्मा) की उपस्थिति एवं अनुपस्थिति में कार्बन जब्ती का अध्ययन

CO_2 की अधिक सांद्रता पर मृदा के नमूनों में सूक्ष्मजीवों की जनसंख्या पर प्रभाव पड़ता है जबकि *ट्राइकोडर्मा* की संख्या अप्रभावी रहती है। *ट्राइकोडर्मा* मृदा के सूक्ष्मजीवों को बनाए रखने में महत्वपूर्ण भूमिका निभाता है। बिना *ट्राइकोडर्मा* उपचार के उच्च CO_2 सांद्रता की स्तिथियों में सूक्ष्मजीवों की गतिविधियों में कमी देखी गई।

7. पादप सूक्ष्म जीव एवं मृदा संबंध

जरबेरा एवं *ग्लैडिओलस* पौधों की गुणवत्ता में सुधार हेतु *जरबेरा* का कुकुमोवाइरस एवं *ग्लैडिओलस* का पाटीवाइरस के साथ संबंध

सीएसआईआर-एनबीरआरआई, लखनऊ के पालीहाऊस में एक सर्वेक्षण में *जरबेरा जेम्सोनाई* की दो किस्मों *जिंगारों* एवं *सिल्वेस्टर* के कई पौधों में क्लोरोटिक मोजैक बीमारी देखी गई। वेस्टर्न ब्लाट इम्यूनोएसे के द्वारा ब्डट-एंटीबाडीज का प्रयोग करते हुये ब्डट का संक्रामण देखा गया एवं RT-PCR के द्वारा CMV कोट प्रोटीन जीन विशिष्ट प्राइमरों के प्रयोग से इसे सुनिश्चित किया गया।

वाइरस मुक्त *जरबेरा* पौधों का विकास

CMV को काफी महत्वपूर्ण माना जाता है क्यूंकि यह पौधों में गंभीर विकृतियाँ उत्पन्न करता है जिससे जरबेरा फूलों के बाजार मूल्य में काफी कमी आ जाती है। अतः प्रयोगशाला में रसायन चिकित्सा (विराजोल के प्रयोग) के

द्वारा CMV संक्रमण को दूर करने के प्रयास किए गए। CMV-मुक्त पौधों में बेहतर वृद्धि देखी गई। यह भारत में अपनी तरह का प्रथम प्रयोग है।

ग्लैडिओलस के पौधों को संक्रमित करने वाले बीन येलो मोजैक पाटीवाइरस के पूर्ण जीनोम की क्लोनिंग एवं सीक्वेंसिंग

ग्लैडिओलस (किस्म सिलविया) को संक्रमित करने वाले बीन येलो मोजैक पाटीवाइरस (BYMV) के पृथक किए गए नमूने के ~9-5kb के पूर्ण जीनोम को वर्धित कर सीक्वेंस किया गया।

8. जड़ जैविकी एवं इसका सतत पादप विकास एवं मृदा उर्वरता से सह-संबंध

मेटाबोलाइट प्रोफाइलिंग से *स्यूडोमोनास पुटिडा* के Tn5 म्यूटेंट में जैविक तनाव सहनशीलता का ज्ञान

शुष्क एवं अर्ध शुष्क क्षेत्रों में सूखे एवं गर्मी से वृद्धि एवं फसल उत्पादकता सीमित हो जाती है। यह तनाव पादप वृद्धि प्रेरक राइजोबैक्टीरिया की क्रियाशीलता पर भी प्रभाव डालता है। *स्यूडोमोनास* एक प्रभावी पादप वृद्धि प्रेरक राइजोबैक्टीरिया है। हालांकि, सूखे के प्रति असहनशीलता एवं उच्च तापमान कृषि में इसके एक जैव-टीके के रूप में प्रयोग को सीमित कर देते हैं। लगभग 10,000 ट्रान्सकंजूगेंट्स की जांच के बाद NBRI1108 से उत्पन्न एक म्यूटेंट NBRI1108T को चुना गया तथा सडर्न हाईब्रिडाइजेशन अध्ययन के द्वारा यह सुनिश्चित किया गया कि इसमें एक अकेला Tn5 इन्सर्ट मौजूद है, इसने उच्च तापमान एवं सूखे के प्रति महत्वपूर्ण सहनशीलता प्रदर्शित की।

सूखे के प्रति सहनशीलता, ग्रीनहाउस प्रयोगों में मक्के के पौधों पर प्रयोग के द्वारा सुनिश्चित किया गया जिसमें NBRI1108T ने सूखे की स्तिथियों में तुलनात्मक रूप से अधिक जैव भार प्रदर्शित किया। सूखे के प्रति इस सहनशीलता के जरिये पौधों में म्यूटेंट सहजीवों के माध्यम से उत्पादकता बढ़ाने के प्रति एक नई राह मिली है।

ट्राइकोडर्मा से संश्लेषित किए गए सोने के नैनोकणों की जैव-उत्प्रेरक एवं सूक्ष्मजीवरोधी क्रियाएँ

जीवाणुओं में एंटीबीओटिक्स के प्रति बढ़ती सहनशीलता के कारण सोने के नैनोकणों ने नए सूक्ष्मजैवरोधी एजेंट के रूप में महत्वपूर्ण वैज्ञानिक रूचि को आकर्षित किया है। वैसे तो इन कणों के संश्लेषण के लिए अनेकों रासायनिक एवं भौतिक तरीके ज्ञात हैं किन्तु अब जैवसंश्लेषण की आसान तरीकों की उपलब्धता एवं जटिल रासायनिक क्रियाओं के कारण नवीन हरित प्रौद्योगिकियों की ओर ध्यान केन्द्रित हुआ है। इस दिशा में एक महत्वपूर्ण पादप वृद्धि प्रेरक ट्राइकोडर्मा को प्रयोग किया गया। इस अध्ययन में *ट्राइकोडर्मा विरिडी* एवं हाइपोक्रिलिक्सी के कोशिका रहित अर्क को सोने के नैनो कणों के अत्यधिक तीव्रता से उत्पादन के लिए प्रयोग किया गया जिसमें 30 °C एवं 100 °C पर 10 मिनट का समय लगा। यह पद्धति अत्यधिक तीव्र है तथा इसमें आगे किसी प्रसंस्करण की आवश्यकता नहीं होती। यह अपने आप में इस प्रकार की पहली खोज है।

9. एकीकृत जीव विज्ञान के लिए जीनोमिक्स एवं सूचना-विज्ञान समाधान

PHP एवं MySQL के प्रयोग के द्वारा एक नए साफ्टवेयर का विकास किया गया। यह साफ्टवेयर जैविक नमूनों के विवरण के आंकड़ों, उच्चींत वर्गिकी आंकड़ों, GIS आंकड़ों, चित्र आंकड़ों, चलचित्रों एवं जीनोमिक आंकड़ों की प्रविष्टि में सहायक होगा।

10. आर्थिक रूप से महत्वपूर्ण पौधों की स्थापना, सुधार एवं खेती

पादप सुधार हेतु *बिक्सा* एवं *करकुमा* के जर्मप्लाज्म संग्रह का आंकलन

करकुमा (हल्दी)

विभिन्न भू-जैविक क्षेत्रों से एकत्र किए गए *करकुमा लांगा* के 34 नमूनों को बंथरा शोध केंद्र पर संरक्षित किया जा रहा है। 24 नमूनों के जैव-रासायनिकी अध्ययन किए जा चुके हैं। *करकुमा* की वृद्धि, उपज एवं गुणवत्ता पर सामनी एवं ऊसर मृदा के प्रभावों को देखने के लिए *करकुमा लांगा* के 3 नमूनों (NBH-3, NBH-10 एवं NBH-18) को उद्यान की सामान्य मृदा एवं कुछ हद तक उपचार कर सुधारी गई ऊसर मृदा में उगाया गया ताकि उत्तरी भारत में विशेषकर ऊसर भूमि में इसकी खेती के लिए बेहतर उपज एवं गुणवत्ता वाले विशिष्ट जीनोटाइप को पहचाना एवं चयनित किया जा सके। NBH-10 ने ऊसर मृदा एवं NBH-18 ने सामान्य मृदा में सर्वोत्तम कंद उपज प्रदर्शित की।

NBH-2, NBH-3, NBH-8, NBH-10, NBH-12, NBH-17, NBH-18 एवं प्रभा को कर्कुमीनोइड मात्रा एवं उपज की मात्रा में अच्छी एवं निम्न गुणवत्ता के आधार पर चयनित किया गया। पत्तियों की विंति, बौनी एवं ज्यादा वृद्धि तथा क्लोरोफिल उत्परिवर्तन के आधार पर 8 म्यूटेंट की पहचान की गई। इनकी आनुवंशिकता, जीनोटिपिक कोफीशियंट, फीनोटिपिक कोफीशियंट, आनुवांशिक बढ़त आदि का भी अध्ययन किया गया। कुल कर्कुमीनोइड मात्रा का HPLC के द्वारा आंकलन किया गया जो कि 2 म्यूटेंट में अधिक पाई गई जबकि दो में इसकी मात्रा में कमी देखी गई।

बिक्सा ओरेलाना

बिक्सा की मुख्यतः इसके बीजों से प्राप्त होने वाले रंग के लिए आर्थिक खेती की जाती है। देशी औषधि पद्धतियों में औषधीय प्रयोग के अतिरिक्त इसका मुख्य उत्पाद अनाटो रंग है जिसका प्रयोग मुख्यतः डेयरी उद्योग में मक्खन, पनीर, घी, चाकलेट, आइसक्रीम को रंगने, कपास, रेशमी वस्त्रों एवं चमड़े, औषधियों को रंगने तथा जूतों की पालिश बनाने में होता है। इस रंग का प्रयोग बिंदी या कुमकुम बनाने में भी होता है। कुल मिलाकर यह एक बहुपयोगी वृक्ष है जिसकी छाल, पत्तियाँ, जड़ें एवं बीजों को औषधीय, प्रसाधन, एवं खाने योग्य रंग हेतु प्रयोग किया जाता है।

विभिन्न भू-जैविक क्षेत्रों से एकत्र किए गए बिक्सा के 17 नमूनों को उनकी वृद्धि, उपज एवं गुणवत्ता के अध्ययन के लिए बंथरा शोध केंद्र में उगाया गया है। पौधों में आकारिकीय लक्षणों (पत्तियों का आकार, पुष्पों का रंग, कैप्सूल का आकार, माप एवं रंग आदि), उपज (प्रति पौधा कैप्सूल की संख्या, प्रति कैप्सूल बीजों की संख्या एवं भार) तथा गुणवत्ता (बिक्सिन मात्रा) में विभिन्नता देखने को मिली है। आकारिकीय अभिलक्षणन के आधार पर सारे नमूनों को 7 समूहों में बांटा गया है। इन समूहों का आण्विक अभिलक्षणन भी किया जा रहा है। 5 सर्वोत्तम बिक्सा नमूनों के बीजों को संक्षिप्त तकनीकी विवरण के साथ बहु-स्थानीय जाँचों के लिए सीएसआईआर-सीमैप, लखनऊ; सीएसआईआर-आईएचबीटी, पालमपुर; सीएसआईआर-एनईआईएसटी भेजा गया है।

वानस्पतिक उद्यान एवं दूरस्थ अनुसंधान केन्द्र

बोगेनविलिया के आनुवंशिक विकास एवं जर्मप्लाज्म संग्रह केन्द्र की स्थापना

बोगेनविलिया की चयनित किस्मों का उपचार अलग-2, गामा किरणों द्वारा किया गया एवं उनका विभिन्न खेतों में उनके प्रभाव के अध्ययन एवं आंकलन किया गया। जिसका मुख्य उद्देश्य आनुवांशिक बौने पौधों को पॉट कल्चर (Pot culture) संवर्धन द्वारा विकसित करना है नये उत्परिवर्तक की पहचान की गई और उन्हें नई किस्मों के विकास में सहायक पाया गया। उचित पहचान के पश्चात् नई किस्मों की आकारकीय लक्षणों का प्रलेखन किया गया। नई किस्मों को सी.एस.आई.आर.-एन.बी.आर.आई. के राष्ट्रीय जर्मप्लाज्म संग्रह केन्द्र में उपस्थित किस्मों के साथ उचित लेवल (Level) तथा लेआउट (Layout) लगाकर जमा किया गया।

बोगेनविलिया, कैना तथा ग्लैडियोलस हेतु सी.एस.आई.आर.-एन.बी.आर.आई., लखनऊ में DUS (परीक्षण) केन्द्र की स्थापना

बोगेनविलिया की 200 किस्मों (*बी. स्पेक्टेलिस*), *बी. ग्लैबरा बी. पेरूवियाना* एवं *बी. ब्यूटीआना*; कैना की 50 किस्मों (*सी. इंडिका, सी. जेनेरेलिस, सी. लेसिडा, सी. लैटीफोलिया, सी. इडुलिस* एवं *सी. वार्सबिजी* का रख-रखाव DUS परीक्षण केन्द्र में किया जा चुका है। इन किस्मों का आकारकीय लक्षणों का अध्ययन भी किया जा चुका है। नई किस्मों के पंजीकरण के लिए निर्देश DUS के अनुसार बनाया गया अैर पी.पी.वी. एवं एफ.आर.ए. से अनुमोदित करया जा चुका है।

उत्तर प्रदेश के सोडिक बंजर भूमि में औषधीय पौधों के रोपण का मूल्यांकन

बंजर भूमि के आर्थिक उपयोग हेतु गैर-पारम्परिक अश्वगंधा एवं कालमेघ का बंथरा अनुसंधान केन्द्र के प्रायोगिक भूमि में अलग-अलग स्तरों पर 10.0, 13.0, 17.5, 25.0, 30.0 एवं 35.0 ESP पर लगाया गया, जिसका परिणाम यह प्राप्त हुआ कि ESP का स्तर बढ़ने से पौधें के वृद्धि पर कोई प्रभाव 30.0 ESP तक नहीं पड़ता। कालमेघ को 8,, 12, 16, 20, 24, 32, ESP भूमि में उगाया गया इससे यह परिणाम प्राप्त हुआ कि कालमेघ 16 ESP के ऊपर कोई आर्थिक (उपज) पैदावार की प्राप्ति नहीं होती। जो 16 ESP पर ही खेती का बंजर भूमि में संकेत देता है।

कालमेघ की बायोमॉस उपज एंव कार्बनिक पदार्थों की गुणवत्ता का विभिन्न स्रोतों एवं स्तरों पर प्रभाव तथा अध्ययन

कालमेघ की विभिन्न स्तरों का अध्ययन कार्बनिक जैसे FYM, Press Mud तथा वर्मी कम्पोस्ट का प्रयोग किया गया, प्रयोग में FYM (30t ha^{-1}), Press mud (upto 15 t ha^{-1}) or vermi (upto 15 t ha^{-1}) का प्रयोग किया गया जिसका परिणाम यह पाया गया कि पौधे की लम्बाई शाखाओं की संख्या, तना का व्यास, पौधे का फैलाव आदि में उल्लेखनीय वृद्धि मापी गयी। समस्त परीक्षणों के दौरान खाद की मात्रा बढ़ाने पर एरोबिक विषाणुओं में वृद्धि होती है। जिसके कारण अपघटन, न्यूट्रीएंट मिनिराइलेजशन तथा मृदा एंजाइम में वृद्धि होती है।

उत्तर प्रदेश में हल्दी (*Curcuma longa*) के प्रोटोकाल एवं आर्गेनिक खेती का मानकीकरण

हल्दी (*Curcuma*) के दो अलग-2 प्रयोगों द्वारा अध्ययन किया गया:-

(a) अधिकतम उपज हेतु आर्गेनिक खेती का मानकीकरण।

(b) कार्बनिक रोग नियंत्रण तथा कीटप्रबंधन हेतु उपचार का मानकीरण अलग-अलग तरीके से किया गया।

दोनों ही प्रयोगों में यह पाया गया कि उसकी उपज पर प्रति हेक्टेयर T7-100% वर्मी कम्पोस्ट PSB Seat तथा दूसरे प्रयोग में ट्राइकोडर्मा ज्यादा प्रभावी पाये गये जो रोगाणु रहित थे।

ऊसर मृदा में औषधीय एवं सगंध पौधों की खेती में औद्योगिक कचरे का प्रयोग

ऊसर मृदा में *Vetiveria zizanoides, Cymbopogon flexuosus, Andrographis panculatia* एवं *Plantago ovata* की खेती पर विभिन्न प्रयोगों द्वारा उड़नराख (flyash), Press mud का प्रयोग, विभिन्न स्तरों पर किया गया तथा यह पाया गया कि Flyash के प्रयोग से *A. paniculata* की उपज में वृद्धि आंकी गयी, जबकि *C. flexuosus, V. zizanoides* एवं *P. ovata* में वृद्धि पर उतना प्रभाव नहीं पाया गया।

जर्म-प्लाज्म वृद्धि, अभिलक्षण, नई किस्मों का विकास तथा उनका व्यावसायिक समुपयोजन

दो पुष्प प्रजातियों की नई प्रविष्टियाँ, दक्षिणी अमेरिका की *Erythrina cristagalli* ('cockspur coral tree' 'cry-baby tree' - Fabaceae) एवं उष्णकटिबन्धीय अफ्रीका क्षेत्र का *Vernonia amygdalina* (BitterLeaf', Insulin Plant'; Asteraceae) एवं दो भारतीय फर्न *Helminthostachys-zeylanica* और *Asplenium nidus* को संस्थान के वनस्पति उद्यान में रोपित व समावेशित किया गया।

संरक्षण एवं उत्पादन

लगभग 11 फर्न प्रजातियों को संजीवनी बूटी सहित (*Selginella bryopteris*) को फर्न गृह में उगाया गया तथा उनका संरक्षण किया गया, जिनमें मुख्यतः निम्न फर्न सम्मिलित थे : *Adiantum peruvianum, Anemia rotundifolia, Athyrium pectinatum, Asplenium nidus, Microsorum scolopendrium, Lepisorus* sp.

वनस्पति उद्यान के संरक्षण गृह का नवीनीकरण

परसी लैंकास्टर द्वारा 1953-59 में बनाई गई सबसे पुरानी संरक्षण गृह का आधुनिकीकरण किया गया, जिसका प्रमुख उद्देश्य शैक्षणिक तथा उद्देश्यपूर्ण बनाना था। The world of House Plant के नाम से एक नई दिर्घा दर्शकों के लिए प्रदर्शन सुविधा Glass House के रूप में विकसित किया गया।

नई किस्मों का विकास

एन.बी.आर.आई.-केसर (गुलदाउदी की एक नई किस्म) और एन.बी.आर.आई-लालिमा (ग्लैडियोलस की एक नई किस्म) जिसका विकास एवं विमोचन समीक्षा वर्ष में किया गया।

दूरस्थ अनुसंधान केन्द्र (बंथरा शोध केन्द्र)

दूरस्थ अनुसंधान केन्द्र (बंथरा शोध केन्द्र) संस्थान की एक प्रयोगात्मक क्षेत्र की इकाई है। इस केन्द्र पर आर्थिक रूप से महत्वपूर्ण औषधीय पौधे, गुलदाउदी की किस्में, HT-गुलाब, कैना एंव संगध पौधों पर शोध एवं विकास तथा कृषि हेतु मानकीकरण किया गया है। यहाँ पर औषधीय पौधों की लगभग 200 प्रजातियाँ संग्रहित है।

ग्लैडियोलस की सोडिसिटीरोधी प्रजातियों की पहचान तथा समेकित पोषक तत्व प्रबन्धन

तीन विभिन्न पोषक प्रबंधन प्रैक्टिसेज को मुख्य कारक तथा 12 ग्लैडियोलस प्रजातियों को उप कारक लेकर एक प्रयोग गेहरू केन्द्र पर किया गया जिसमें यह पाया गया कि जिन खेतों में सड़े हुए कार्बनिक खाद तथा फास्फोरस घोल जीवाणुओं तथा ट्राइकोडर्मा द्वारा उपचारित फार्म में किया गया उनमें अच्छी वृद्धि तथा पृष्पन हुआ स्पाइक्स की संख्याप्रति पादप अधिक थी। मूल्यांकित किये गये प्रजातियों 'टाइगर फ्लेम' व 'बिग टाइम सुप्रीम' में जबकि सोडिक भूमि दशा में महत्वपूर्ण रूप से उच्च कार्य उत्पादकता/प्रति पादप 'बिग टाइम सुपर' में पायी गई।

सोडिक मृदा में कैना प्रजाति का मूल्यांकन

तीन विभिन्न प्रकार की निषेचन ट्रायल में कैना 'रेड डेजलर' की वृद्धि क्षमता का मूल्यांकन किया गया - i) सम्पूर्ण रासायनिक उर्वरक का प्रयोग ii) एफवाईएम, पीएमबी एवं iii) ट्राईकोडर्मा तथा दोनों का संयोग (पीएसबी+ट्राइकोडर्मा) में प्रभाव ज्यादा अच्छा मिला। कैना की सीएसआईआर-एनबीआरआई में उपलब्ध प्रजातियों में से पाँच 'कल्टोलेना', 'पिंग सनराइज', 'फैक्सेडा', 'ब्लैक नाइट' व 'बेन्गाल टाइगर' सोडिक मृदा हेतु उचित पाये गये।

चावल की प्रजातियों में सूखा रोधी गुणों की स्क्रीनिंग

धान की दो प्रजातियों-हीना व किरन को अलग अलग जल स्ट्रेस स्तर पर उगाकर प्रयोग किया गयां हीना ने अलग-अलग जल स्ट्रेस स्तर पर अच्छा परफार्म किया। धान के सूखा रोधी प्रजातियों की स्क्रीनिंग तथा वर्षा की दशा में इसके वृद्धि व उत्पादन पर जीपीआर एवं के रेस्पान्स को अध्ययन करने हेतु एक और प्रयोग किया गया। धान की प्रजातियों में से तुलनात्मक रूप से उच्चतर स्तर के हार्वेस्ट इन्डेक्स के कारण एनडी 350 ने शुष्क सम्राट की तुलना में महत्वपूर्ण रूप से अधिक उत्पादन किया।

संरक्षण व प्रोपोगेशन : फील्ड जीन बैंक में 2 हेक्टेयर क्षेत्रफल में विभिन्न वृक्ष जातियां (80) झाड़ी/शाक (30), 30 RET जातियां सहित मेन्टेन की गई रिपोर्टिंग वर्ष में पाँच नई जातियाँ फील्ड जीन बैंक में बढ़ा (जोड़) दी गई। *निम्फिया स्टीलेटा* के बढ़ा दिये जाने तथा व्यापक पैमाने पर मल्टीप्लेकेशन के कारण निम्फिया संग्रह प्रचुर हो गया। आर एण्ड डी व विक्रय के उद्देश्य से विभिन्न कृषि बागवानी फसलों जैसे सजावटी, गृह पादप, औषधीय व सगंध पादप का क्रमिक प्रजनन भी कराया गया।

विभिन्न कार्बनिक स्तर पर अश्व गंधा (*विथानिया सोम्नीफेरा*) व कालमेघ (*एण्ड्रोग्राफिस पैनिकुलेटा*) का मूल्यांकन

पिछले वर्ष के बचे हुए कार्बनिक खाद के प्रभाव में अश्वगंधा व कालमेघ को कार्बन के विभिन्न स्तरों (06-0.5%-3.5% अश्वगंधा में, α-0-5%-4.0% कालमेघ में) पर अश्वगंधा व कालमेघ का मूल्यांकन किया गया दोनों ही मामलों में बढ़ती हुई आर्गेनिक कार्बन की मात्रा के अनुसार पादप ऊँचाई, जड़ व तना की लम्बाई जड़ व तने का भार भी बढ़े पाये गये।

सोडिक मृदा में *एलो* प्रजाति का संग्रहण अनुकूलन, मल्टीप्लीकेशन व जर्मप्लाज्म बैंक की स्थापना

एलो की 26 जातियों को संग्रहित, अनुकूलित, बहुगुणित किया गया तथा क्रमिक सोडिसिटी स्क्रीनिंग व कल्टीवेशन के लिए जर्मप्लाज्म बैंक की स्थापना की गई। जेल के स्वाद के आधार पर तीन सर्वाधिक बिक्री वाली एलो जातियों जैसे कि *एलो वेरा* (सामान्यतः कावा), *ए. फेरोक्स* (अत्यधिक कड़वा) व *ए. मैकुलेटा* (कड़वारहित) को प्रकृति रूप से चार मृदा पीएच जैसे 8.0, (कण्ट्रोल, 8.50, 9.10 व 9066) पर वृद्धि मानकों तथा जेल उत्पाद के लिए जाँचा गया। सभी तीनों प्रजातियों में पादप वृद्धि महत्वपूर्ण रूप से 9.1 पीएच. स्तर तक पीएच बढ़ने के साथ बढ़ी फिर 9.56 पीएच पर घटकर कण्ट्रोल (8.0) पीएच के बराबर हो गई। कण्ट्रोल माध्यम से उच्चतम सोडिम स्तर (9.65) में पादप वृद्धि सर्वाधिक *ए. वेरा* में थी उसके बाद क्रमशः *ए. मैकुलेटा* तथा *ए. फेराक्स* में थी। तीनों जातियों में जेल उत्पादन का भी वही ट्रेन्ड रहा जो वृद्धि में था।

सोडिसिटी स्ट्रेस की स्थिति में एलो की सात जातियों(*ए फेराक्स, .* ए. ग्रेटहेडाई, *ए. हारलाना, ए. नोबिलिस, ए. आर्थोलोफा, ए. स्पिकेटा एवं ए. वेरा*) में पुष्पन का अध्ययन किया गया। एलो में बीज वायबिलिटी व अंकुरण का भी शुभारम्भ किया गया। बन्थरा दूरस्थ शोध केन्द्र में सोडिक मृदा में उगाये हुए एलो जातियों में जीवाणु व कवक जनित के अध्ययन ने यह प्रकट किया कि *ए. मैकुलेटा* व *ए. स्पिकेटा* में ज्यादातर ग्रीष्म ऋतु में कवक (फफूँद) की बीमारी होती है जबकि जीवाणुजनित बीमारी वर्षा ऋतु में *ए. ग्रेरहेडाई* व *ए नोबिलिस* में होती है।

पादप विविधता, वर्गिकी एवं पादपालय

शैवाल ब्लूम्स का अध्ययन, उनका अभिलक्षणन एवं उनके निर्माण को प्रभावित करने वाले कारक

चार शैवाल प्रभेदों, *क्लैमाइडोमोनास* प्रजाति (NBRI-077), *नैनोक्लोरोप्सिस* प्रजाति (NBRI-078), *क्लोरेल्ला* प्रजाति (NBRI-079) एवं *सेनेडेस्मस* प्रजाति (NBRI-080) को दो भिन्न संवर्धन माध्यमों (TAP एवं BG11) में संवर्धित किया गया। लिपिड एवं प्रोटीन आंकलन से *नैनोक्लोरोप्सिस* प्रजाति में अधिकतम लिपिड एवं *क्लोरेल्ला* में अधिकतम प्रोटीन प्रदर्शित हुआ।

सीएसआईआर-एनबीआरआई के मत्स्य कुंड के खुले तंत्र एवं संस्थान के अन्य तालाबों में चयनित शैवाल प्रभेदों (*नियोक्लोरिस* प्रजाति NBRI-081 एवं *नैनोक्लोरोप्सिस* प्रजाति NBRI-082) का सामूहिक संवर्धन किया गया।

सेनेडेस्मस प्रजाति (NBRI-080) को तीन पौष्टिक स्तिथियों क्रमशः स्वपोषी, परपोषी एवं मिश्रित में उगाया गया। शैवाल प्रभेदों के संवर्धन हेतु pH (5, 6, 7, 8, 9) एवं प्रकाश तीव्रता (3000, 4000, 5000, 6000 लक्स) को भी अनुकूलित किया गया। अधिकतम जैव भार 5000 लक्स प्रकाश तीव्रता एवं pH 7 पर प्राप्त हुआ जबकि अधिकतम लिपिड प्रतिशत pH 5 एवं 4000 लक्स प्रकाश तीव्रता पर प्राप्त हुआ। नाइट्रोजन स्रोत के रूप में NH_4Cl को प्रयुक्त करने पर अधिकतम जैवभार एवं लिपिड मात्रा प्राप्त हुई।

सेनेडेस्मस प्रजाति (NBRI-080) की खेती के लिए विभिन्न सांद्रता (25%, 50%, 75% एवं 100%) प्राप्त करने के लिए अपशिष्ट जल एवं TAP माध्यम के विभिन्न अनुपातों जैसे 1:3, 1:1, 3:1 एवं 1:0 को प्रयोग किया गया। 50% अपशिष्ट जल एवं 50% TAP माध्यम के सम्मिश्रण में अधिकतम जैवभार एवं लिपिड की मात्रा उत्पन्न हुई।

आनुवांशिक संशोधन द्वारा जैव-हाइड्रोजन पीढ़ी का सुधार एवं सूक्ष्मजीवों से प्रक्रिया अनुकूलन

6 सूक्ष्म शैवाल आइसोलेट (*क्लैमाइडोमोनास* प्रजाति, *क्लोरेल्ला* प्रजाति, *सेनेडेस्मस* प्रजाति, *क्लोरोकाकम* प्रजाति, *नैनोक्लोरोप्सिस* प्रजाति, *फोर्मीडियम* प्रजाति) को फूरियर ट्रान्स्फोर्म इंफ्रारेड स्पेक्ट्रोस्कोपिक (FTIR) आंकलन के द्वारा जैव-अणुओं के लिए जांचा गया। इन आइसोलेट की तीन अलग अलग संवर्धन माध्यमों BG11, BBM एवं TAP में जैवभार, कार्बोहाइड्रेट एवं लिपिड मात्रा हेतु तुलना की गई। सर्वाधिक जैवभार, कार्बोहाइड्रेट एवं लिपिड मात्रा TAP माध्यम में देखा गया। अधिकतम जैव भार एवं लिपिड मात्रा *क्लोरेल्ला* प्रजाति (NBRI-029) में एवं उसके पश्चात *सेनेडेस्मस* प्रजाति (NBRI-012) में देखी गई।

अवायवीय स्तिथियों में फोटोबायोरिएक्टर से जुड़े H_2 सेंसर द्वारा तथा इन आइसोलेट द्वारा हाइड्रोजन उत्पादन को माना गया। *सेनेडेस्मस* प्रजाति (NBRI-012) ने किण्वन के छठे दिन अधिकतम हाइड्रोजन प्रतिशत (17-22%) प्रदर्शित किया, जबकि *क्लोरेला* प्रजाति (NBRI-029) ने किण्वन के चौथे दिन 9-56% हाइड्रोजन उत्पादन प्रदर्शित किया। यह अनुमान लगाया गया कि हाइड्रोजन उत्पादन के समय सल्फर की कमी से लिपिड की मात्रा बढ़ी। अतः सल्फर की कमी वाले जैवभार से लिपिड की अच्छी मात्रा प्राप्त की जा सकती है।

सायनोटोक्सिन (माइक्रोटाक्सिन) का अभिलक्षणन एवं उनके प्रभावी उपयोग का गुणात्मक विश्लेषण

स्वच्छ जल के सूक्ष्म शैवालों को अलग कर, शुद्धीकृत कर, BG11 माध्यम में संवर्धन कक्ष की मानक वृद्धि स्तिथियों में रखा गया। एंटीबैक्टीरियल एवं एंटीकैंसर एसे से पता चला कि *सेनेडेस्मस* प्रजाति, *आसीलेटोरिया* प्रजाति एवं *फोर्मीडियम* प्रजाति प्रभावी एंटीबैक्टीरियल एवं एंटीकैंसर गतिविधियां युक्त हैं। HPTLC एवं HPLC आंकलन द्वारा क्रियात्मक यौगिकों को चिन्हित किया गया। कानपुर में गंगा नदी से प्राप्त *आसीलेटोरिया टेन्यूइस* में WHO की मानक मात्रा से काफी अधिक माइक्रोटाक्सिन सांद्रता पाई गई।

जैव ईंधन हेतु सक्षम शैवाल प्रजातियों की जांच एवं उच्च लिपिड संग्रहण हेतु वृद्धि स्तिथियों का आंकलन

बड़ी मात्रा में स्वच्छ जल के सूक्ष्म शैवालों को अलग किया गया जिनमें से *सेनेडेस्मस अबंडेंस* को एक जैव-ईंधन हेतु एक अच्छे स्रोत के रूप में पाया गया। सर्वोत्तम लिपिड निष्कर्षण के साथ साथ ट्रांस-ईस्ट्रीफिकेशन प्रक्रिया तथा सर्वोत्तम pH स्तिथियों का आंकलन किया गया। अधिकतम जैव भार उत्पादकता एवं लिपिड मात्रा उत्पादन हेतु अन्य संवर्धन स्तिथियों जैसे प्रकाश तीव्रता, संवर्धन माध्यम में फास्फेट की सांद्रता आदि को भी अध्ययन किया गया।

सूक्ष्मजीव प्रतिरोधी एवं जैव ईंधन हेतु क्षमता आंकलन हेतु कालीन उद्योग के अपशिष्ट जल से सूक्ष्म शैवालों का अभिलक्षणन

भदोही जिले के कालीन उद्योग के अपशिष्ट जल से शैवाल के नमूने एकत्र कर के उन्हें अलग कर, शुद्धिकृत कर, मानक तरीकों से संवर्धित किया गया। इन शैवालीय अर्कों को जीवाणुरोधी एसे एवं लिपिड अनुमापन हेतु प्रयोग किया गया। *नास्टाक* प्रजाति एवं *आसीलेटोरिया* प्रजाति एक अर्कों में स्पष्ट जीवाणुरोधी क्रिया प्रदर्शित की।

आशाजनक शैवाल प्रभेदों का पृथक्कीकरण, जांच एवं पोषण रूपरेखा

एक देशज सूक्ष्म शैवाल *गोलेनिकिया रेडिएटा* का सर्वप्रथम पोषण आंकलन किया गया। इस प्रोफाइल में कार्बोहाइड्रेट (40.39%), प्रोटीन (13.3%), लिपिड (12.9%), प्रति 500 मिग्रा. जैव भार पर 64.9 मिग्रा. कुल लिपिड, एवं प्रति 100 ग्रा. जैव भार पर 1385.24 किलोजूल ऊर्जा सम्मिलित हैं।

भारतीय हिमालय में अल्पाइन पारिस्थितिक गतिकी एवं जलवायु परिवर्तन का प्रभाव

सिक्किम एवं जम्मू और कश्मीर में सर्वोच्च शिखर बिन्दुओं (HSP) का उनकी लाईकेन विविधता हेतु 3 मी., 5 मी. एवं 10 मी. शिखर क्षेत्र खंडों में सर्वेक्षण किया गया। सात लाईकेन प्रजातियों की स्पेक्ट्रम जांच की

गई। सिक्किम के कुपूप एवं थांगू क्षेत्रों एवं जम्मू और कश्मीर के गांदरबल जिले के थाजीवास ग्लेशियर में चट्टानों पर बहुतायत में उगने वाले एक सामान्य क्रस्टोज लाईकेन *राइजोकार्पान गियोग्राफिकम* के व्यास का आंकलन करते हुये लाइकेनोमेट्री अध्ययन किए गए। यह अनुमान प्राप्त हुये कि भारत के पश्चिमोत्तर हिमालयी क्षेत्रों की तुलना में सिक्किम में ग्लेशियरों के पीछे खिसकने की दर अधिक तीव्र है।

उत्तर प्रदेश के संरक्षित क्षेत्रों में लाईकेन सर्वेक्षण एवं उनके संरक्षण हेतु जागरूकता प्रसार

हस्तिनापुर वन्य जीव अभयारण्य, सूर सरोवर वन्य जीव अभयारण्य, राष्ट्रीय चंबल अभयारण्य एवं उत्तर प्रदेश के कुछ पश्चिमी जिलों में लाईकेन खोज हेतु सर्वेक्षण किए गए एवं 14 वंशों एवं 21 कुलों से संबन्धित 200 लाईकेन नमूने एकत्र किए गए। उत्तर प्रदेश में सात लाईकेन प्रजातियों को पहली बार देखा गया।

दुधवा बाघ संरक्षण क्षेत्र में वन कर्मचारियों हेतु तथा मेवालाल राम रुलारी विद्या मंदिर इंटर कालेज, मझगैन, खीरी एवं इलाहाबाद विश्वविद्यालय के वनस्पति विज्ञान संकाय में विद्यार्थियों हेतु तीन एक-दिवसीय 'जैव-विविधता जागरूकता कार्यशालाएं' आयोजित की गईं।

गुजरात में मैंनग्रूव लाइकेनों का विविधता आंकलन

गुजरात के चिन्हित स्थानों के सर्वेक्षणों में 30 प्रजातियों के 150 लाईकेन नमूने एकत्र किए गए। ये नमूने मुख्यतः समुद्र किनारे की वनस्पतियों एवं चट्टानों से एकत्र किए गए। कच्छ जिले में मैंनग्रूव लाईकेन की बहुत कम विविधता देखी गई। रोसेलेसी समूह की सात प्रजातियाँ गुजरात में प्रथम बार देखी गईं।

लाईकेन पर राष्ट्रीय नेटवर्क कार्यक्रम : द्वीतयक यौगिकों का जैव-पूर्वेक्षण एवं संग्रहों और संवर्धनों की स्थापना

द्वितीयक मेटाबोलाइट के लिए माइकोबियाण्ट संवर्धन जांच के जरिये लाईकेन की 15 औषधीय महत्व की प्रजातियों के समूह संवर्धन स्थापित किए गए।

चुनिन्दा लाईकेन प्रजातियों के अर्कों एवं अंशों में 200 एवं 400 मिग्रा. प्रति किग्रा. की मात्रा पर पैरासीटामाल प्रेरित हिपैटोप्रोटेक्टिव एवं एंटीआक्सीडेंट क्रियाओं से पता चला कि *क्लैडोनिया फर्काटा* के हाइड्रो-एथेनोलिक अर्क में महत्वपूर्ण एंटीआक्सीडेंट गुण एवं पाचक अम्ल स्रावण पर दमनकारी प्रभाव है।

क्लैडोनिया फर्काटा (L3), *पार्मोट्रीमा नील्घेरेन्से* (L4), *एवरनीएस्ट्रम सिरेटम* (L5), *लोबेरिया रेटीजेरा* (L6), *फ्लैवोपार्मेलिया कैपेराटा* (L7) से प्राप्त अर्कों को गुणात्मक एवं मात्रात्मक एसे एवं द्वीतयक यौगिकों जैसे वसा अम्ल, फ्लेवानोइड, शर्कराओं, कैरेटिनोइड्स, टर्पेनोइड्स एवं एंथ्राक्विनोन्स, डेप्सोंस, डेप्साइड्स एवं लाईकेन अम्लों के लिए अभिलक्षणित किया गया।

एक औषधीय रूप से महत्वपूर्ण लाईकेन प्रजाति *एवरनीएस्ट्रम सिरेटम* को ISSR-PCR एवं DAMD-PCR सूचकों के द्वारा जांचा गया। *एवर्नीएस्ट्रम सिरेटम* के 45 नमूनों में आनुवांशिक विविधता आंकलन हेतु 14 प्राइमर (10 ISSR एवं 4 DAMD) प्रयुक्त किए गए। इस अध्ययन से *एवरनीएस्ट्रम सिरेटम* के सभी नमूनों में 94.95% बहुरूपता एवं उच्च आनुवांशिक विभिन्नता (0.19-0.85; औसत 0.65) प्रदर्शित हुई।

भारत में लाईकेन के माध्यम से जलवायु परिवर्तन पर नजर रखने हेतु एक तंत्र का विकास

पश्चिम बंगाल के दार्जीलिंग जिले में 40 वर्षों के अंतराल पर किए गए सर्वेक्षण से ज्ञात हुआ कि इस स्थान की लाईकेन विविधता में स्पष्ट परिवर्तन आए हैं। ये परिवर्तन संभवतः वातावरण की परिस्थितियों में आए परिवर्तन के कारण उत्पन्न हुये हैं जैसा कि फीसिएसी समूह के लाइकेनो के बहुतायत में मिलने से लक्षित होता है जो कि नाइट्रोफिलस वातावरण को पसंद करते हैं।

जलवायु परिवर्तन के चलते तापमान वृद्धि एवं उच्च पराबैंगनी विकिरण के प्रति लाइकेनों की प्रतिक्रिया

12 पराबैंगनी रक्षक यौगिक (माइकोस्पोरिन जैसे अमीनो अम्ल MAAs) को पहली बार भारतीय लाइकेनों में अभिलक्षित किया गया। अत्यधिक ऊंचे स्थानों से प्राप्त नमूनों में पराबैंगनी रक्षक यौगिकों की अधिकतम सांद्रता प्रदर्शित हुई। एक चट्टान पर उगने वाले द्विरूपी लाईकेन *स्टीरियोकालान फोलियोलोसम* पर किए गए प्रदूषण संबंधी अध्ययनों में 3360 मी. तक धातु प्रदूषण का प्रभाव दिखा एवं 3400 मी. की ऊंचाई तक प्रदूषण भार में क्रमशः कमी देखी गई। तीन लाईकेन प्रजातियों में एट्रानोरिन एवं सालजीनिक अम्ल की मात्रात्मक प्रोफाइल पर आल्टीट्यूड ग्रेडिएंट के प्रभाव स्पष्ट संकेत देते हैं कि बढ़ती ऊंचाई के साथ विकिरण के प्रभाव एवं रासायनिक संगठन में महत्वपूर्ण परिवर्तन परिलक्षित होते हैं।

भारत के पश्चिमी घाटों की नीलगिरी पहाड़ियों में उष्ण कटिबंधीय वर्षा वनों की पर्यावरणीय निरंतरता हेतु लाइकेनों का आंकलन

नीलगिरी पहाड़ियों में वन परिस्थितियों के अध्ययन हेतु लाइकेनों के गुणात्मक, मात्रात्मक, सामाजिक व्यवहार, विशिष्ट आकारिकी-आंतरिक लक्षण एवं आवास प्राथमिकता को प्रयोग किया गया। मुख्य आवासीय वृक्षों की विविधता में कमी आने से लाईकेन प्रजातियों के दोहराव में एक निरंतरता देखी गई। नम स्थानों पर घरेलू उद्यानों, यूकेलिप्टस के घरों एवं सड़कों पर लगे वृक्षों, तनों के निचले हिस्सों एवं छाल पर लाईकेन प्रजातियों की व्यापक वृद्धि देखी गई। चाय बागानों, चरागाहों, लकड़ी, ईंधन एवं वन उत्पादों हेतु भूमि के निरंतर प्रयोग से नीलगिरी क्रमशः क्षय की प्रक्रिया में हैं जिसके फलस्वरूप सूक्ष्म-पर्यावरणीय स्तिथियों में आने वाले परिवर्तनों के चलते लाईकेन विविधता भी प्रभावित हो रही है।

हिमालयी लाइकेनों की बारकोडिंग, लाईकेन विविधता के अध्ययन एवं भारत में लाईकेन संरक्षण योजनाओं की स्थापना हेतु आधुनिकतम तरीका

nrDNA ITS सीक्वेंस डाटा एवं विस्तृत आकारिकी-वर्गिकी अध्ययनों से भारत में *सेट्रेलिया* की 10 प्रजातियों का पता चला है। *सेट्रेलिया चिसिटी* को पहली बार भारत से वर्णित किया गया है। आकारिकीय, जैव-रासायनिक एवं nrDNA ITS सीक्वेंस आंकलन के द्वारा *सेट्रेलिया चिसिटी* एवं निकट संबंधी प्रजाति *सेट्रेलिया सेट्रिओइडिस* के बीच भिन्नता सुनिश्चित की गई।

पूर्वी घाटों में ब्रायोफाइटों की विविधता का अध्ययन

तमिलनाडु के पूर्वी घाट क्षेत्रों के सर्वेक्षण में लगभग 515 नमूने एकत्र किए गए। इनके अध्ययन से मास के 10 वंशों के 40 टैक्सा एवं 4 वंशों के 14 टैक्सा का पता चला। *सिंट्राइकिया नार्वेजिका* वेब., *आलाइकोपाइलम ग्लाकम* विल्सन, *सोल्मिसयेल्ला बाइसेरियाटा* (आस्टिन) स्टीयर, *ग्रौटेलिया टोमेंटोसा* (ह र्न.) विज्क एवं मार्ग. को पूर्वी घाट के ब्राओफाइटों में नए सदस्य के रूप में चिन्हित किया गया।

चिन्हित संकटग्रस्त एवं क्षमतावान ब्रायोफाइटो की प्रजनन जैविकी एवं *एक्स-सीटू* संरक्षण का अध्ययन

एक लिवरवर्ट *मार्केन्शिया पालीमोर्फा* एवं एक मास *रोडोब्रायम रोसियम* की *इन-विट्रो* वर्धन के प्रयास किए गए। *मार्केन्शिया* में जेमी के प्रयोग से 45 दिनों में पूर्ण विकसित जेम्मा कप से युक्त स्वस्थ आबादी प्राप्त की गई। वहीं दूसरी ओर *रोडोब्रायम* में स्पोर के माध्यम से 90 दिनों में एक पूर्ण विकसित आबादी प्राप्त करने में सफलता पाप्त हुई।

उत्तर प्रदेश के दुधवा राष्ट्रीय पार्क एवं आस पास के क्षेत्रों में टेरिडोफाइट एवं ब्रायोफाइट की विविधता, वितरण एवं नृवनस्पतिविज्ञान

उत्तर पदेश के दुधवा राष्ट्रीय उद्यान, किशनपुर एवं कतर्नियाघाट वन्य जीव अभयारण्य में सर्वेक्षण के दौरान टेरिडोफाइट के 269 एवं ब्रायोफाइट के 119 नमूने एकत्र किए गए जिनका वर्गिकी अध्ययन चल रहा है। इस क्षेत्र से टेरिडोफाइट की 11 एवं ब्रायोफाइट की 10 प्रजातियाँ सर्वप्रथम बार वर्णित की गई हैं। एकत्रित वनस्पतियों की पारिस्थिक एवं नृवानस्पति जानकारी भी एकत्र की गई।

हिमालयी कुल *आक्सीट्रोपिस* (लेग्यूमीनोसी) की वर्गिकी एवं पारस्थितिकी

आक्सीट्रोपिस की 25 प्रजातियों की वर्गिकी अध्ययन की गई। *आ. टाटरीका* समूह, जिसमें 6 टैक्सा सम्मिलित हैं, का विस्तृत अध्ययन किया गया। चार प्रजातियों (*आ. गुंटेन्सिस, आ. हाइपोग्लोट्टोइडिस, आ. कांसुयानेंसिस* एवं *आ. मेलाइनोकैल्क्स*) को पहली बार भारत से वर्णित किया गया। तीन भिन्न ऊंचाइयों पर पादप-सामाजिकता का भी अध्ययन किया गया। बारंबारता, घनत्व, बहुलता एवं महत्व मूल्य सूचकांक का मात्रात्मक विश्लेषण किया गया।

उत्तर प्रदेश की वृक्ष वनस्पति का वर्गिकी अध्ययन

उत्तर प्रदेश में पूर्ण वन्य परिस्थितियों में पायी गई लेग्यूमीनोसी की 30 वृक्ष प्रजातियों का उनके वर्तमान नामकरण, लोकप्रिय नाम, वर्णन, फेनोलोजी, वितरण, वाउचर नमूने, रंगीन चित्रों आदि सहित विस्तृत वर्गिकी अध्ययन पूर्ण किया गया।

भारत में डेल्फीनी (रेननकुलोसी) ट्राइब का मोनोग्राफिक एवं फाइलोजेनेटिक अध्ययन

भारत में पायी जाने वाली डेल्फीनियम की प्रजातियों का विस्तृत अध्ययन किया गया। *डेल्फीनियम* की 10 एवं एकोनिटम की 2 प्रजातियों का अध्ययन पूर्ण हो चुका है। पूर्व एवं पश्चिम हिमालय से *डेल्फीनियम, कोंसोलिडा* एवं *एकोनिटम* की लगभग 20 प्रजातियों को एकत्र किया गया। *डेल्फीनियम* की 7 एवं एकोनिटम की 3 प्रजातियों का आणुविक अध्ययन किया गया। कोशिकीय अध्ययनों से पता चला कि *एकोनिटम* में द्विगुणित क्रोमोसोम संख्या 32 (n=16) एवं *डेल्फीनियम* में 16 (द=8) है। *डेल्फीनीयम विसकोसम, एकोनिटम हेटेरोफिल्लम* एवं *एकोनिटम वायोलेसियम* को पुनः अध्ययन किया गया एवं *डेल्फीनियम* एवं *एकोनिटम* में कई नए समूह प्रस्तावित किए गए। हिमाचल प्रदेश की लाहौल घाटी से एक नई प्रजाति *डेल्फीनियम लाहुलेन्सिस* अग्निहोत्री, हुसैन एवं हुसैन वर्णित की गई।

भारत की पादप विविधता का वर्गिकी अध्ययन एवं डिजीटाइजेशन

उत्तर प्रदेश के ऊपरी गांगेय मैदानों में शैवाल, लाईकेन, ब्रायोफाइट, टेरिडोफाइट, कुकुरबिट के वन्य संबंधियों, एवं वृक्ष लेग्यूम्स की वर्गिकी एवं पादप विविधता का आंकलन

उत्तर प्रदेश के ऊपरी गांगेय मैदानों के विभिन्न क्षेत्रों में किए गए सर्वेक्षणों में शैवालों के 6 वर्गों एवं 52 कुलों के 85 टैक्सा, 14 वंशों एवं 21 कुलों की 25 लाईकेन प्रजातियाँ, टेरिडोफाइट की 7 प्रजातियाँ एवं ब्रायोफाइट की 11 प्रजातियाँ पायी गईं। एक लाल शैवाल *थोरीया सियामेन्सिस* को प्रथम बार भारत से वर्णित किया गया।

कुकुरबिटों के वन्य संबंधियों में वर्गिकी एवं आनुवांशिक विविधता का आंकलन

लुफ्फा के 5 टैक्सा में आनुवांशिक विविधता एवं संबंध को ISSR-PCR एवं DAMD-PCR मार्करों से देखा गया जिस से सभी 5 टैक्सा के कुल 76 नमूनों में उच्च बहुरूपता (97.67%), औसत जीनिक दूरी (0. 04-0.75, औसत 0.49), निम्न हेटेरोजाइगोसीटी एवं शैनन सूचकांक मूल्य (H=0.131 एवं I=0.199) देखा गया।

ओनीकियम कंटीगम की प्रजनन जैविकी

ओनीकियम कंटीगम की प्रजनन जैविकी अध्ययन किए गए। अध्ययनों से प्रोटोएंडरस एवं चक्रीय गैमेटैनजिया एक्स्प्रेशन प्रदर्शित हुआ।

वुड्फोर्डिया फ्रूटीकोसा की प्रजनन जैविकी एवं पुनरुत्पादन क्षमता

ऊपरी गांगेय मैदानों में उगने वाली एक दुर्लभ औषधीय एवं रंग दायक पादप प्रजाति *वुड्फोर्डिया फ्रूटीकोसा* की परागण जैविकी, लैंगिक अनुकूलता, परागण माध्यम एवं पराग-वर्तिकाग्र सम्बन्धों का अध्ययन किया गया। अध्ययनों से अग्रिम प्रोटेण्ड्री तथा औसतन 91.28% जीवता का पता चला। पर परागण के साधन के रूप में पक्षी परागण को चिन्हित किया गया। सर्वाधिक विचरण करने वाली पक्षी के रूप में 'ओरिएंटल व्हाइट आई' (*जोस्टेरोप्स पल्पेब्रोसस*) पक्षी को देखा गया। अस्फुटित परागकोशों के भीतर परागकणों का अंकुरण भी देखा गया।

उत्तर प्रदेश की थारु जनजाति में विभिन्न बीमारियों एवं विकारों पर आधारित हर्बल क्रूड औषधियों हेतु संग्रहालय का विकास

आर्थिक एवं नृवानस्पतिक रूप से महत्वपूर्ण प्रजातियों के 9 पादप नमूनों को उत्तर प्रदेश के विभिन्न वन्य क्षेत्रों से एकत्र किया गया। इन पौधों की औषधीय क्षमता के उपयोगों को भी प्रलेखित किया गया।

सीएसआईआर-एनबीआरआई के पादपालय का डिजिटाइजेशन एवं संगठन (राष्ट्रीय सुविधा)

गोविंद वन्य जीव विहार एवं उत्तर प्रदेश के विभिन्न क्षेत्रों से एकत्र किए गए 20 शैवाल हरबेरियम शीट एवं 235 स्वच्छ जल के शैवाल के नमूने पहचानकर पादपालय में जमा किए गए। टेरिडोफाइटो के लगभग 209 नमूने एकत्र किए गए। दुधवा राष्ट्रीय उद्यान, लखीमपुर के ब्रायोफाइटों एवं टेरिडोफाइटो का आधार आंकड़ा तैयार किया गया। उत्तर प्रदेश के फर्न एवं फर्न-संबंधियों के चेक-लिस्ट भी तैयार की जा रही है।

पादपालय-राष्ट्रीय सुविधा

अंतर्राष्ट्रीय मानकों के अनुरूप पादपालय का विकास एवं देखरेख की जा रही है साथ ही भारत के विभिन्न भू-जैविक क्षेत्रों में पादप विविधता के आंकलन एवं मोनोग्राफिक रिवीजन अध्ययनों को भी किया जा रहा है। विभिन्न विद्यालयों, शोध संस्थाओं, एवं विश्व विद्यालयों के विद्यार्थियों एवं शोधार्थियों को पादप पहचान में तकनीकी सहायता भी प्रदान की जाती है। विभिन्न स्वदेशी एवं विदेशी पादपालयों से लोन एवं विनिमय के द्वारा एक क्रियात्मक लिंक भी स्थापित किया गया है। पादपालय में जम्मू और कश्मीर, हिमाचल प्रदेश, उत्तराखंड, सिक्किम, मध्य प्रदेश एवं उत्तर प्रदेश से नए पादप नमूनों के संग्रह को बढ़ाया गया है।

नए संग्रह में पुष्पीय पौधों की 223 प्रजातियाँ एवं अपुष्पी पौधों के 1167 नमूने सम्मिलित हैं। वर्तमान में संस्थान के पादपालय में 290 टाइप नमूनों एवं 895 टाइप फोटोग्राफ के अतिरिक्त कुल 2,90,966 नमूने संग्रहित हैं।

पादप पारिस्थितिकी एवं पर्यावरण विज्ञान

आर्सेनिक प्रदूषण का आंकलन एवं कृषि योग्य मृदा से आर्सेनिक संदूषण का जैव उपचार

उत्तर प्रदेश के पाँच जिलों एवं पश्चिम बंगाल के तीन जिलों में आर्सेनिक प्रदूषण हेतु मृदा (3-35 मिग्रा आर्सेनिक प्रति किलो), सिंचाई का भूमिगत जल (0-312 माइक्रोग्राम आर्सेनिक प्रति ली.) एवं फसल नमूनों (जड़ों में 4-16 मिग्रा. आर्सेनिक प्रति किग्रा तथा दानों में 0.179-0.932 मिग्रा आर्सेनिक प्रति किग्रा.) की जांच एवं आंकलन किया गया। पश्चिम बंगाल एवं उत्तर प्रदेश से धान के 200 जर्मप्लाज्म का आर्सेनिक सहनशीलता के लिए अध्ययन किया गया एवं आर्सेनिक संवेदनशील, मामूली सहनशील एवं आर्सेनिक सहनशील श्रेणियों में विभाजित किया गया। उत्तर प्रदेश एवं पश्चिम बंगाल के धान के खेतों की आर्सेनिक प्रदूषित मृदा से 69 फफूंदों के प्रभेदों को एकत्र किया गया एवं उनके आकारिकीय, सूक्ष्मदर्शिक एवं आण्विक लक्षणों के आधार पर पहचाना गया।

सबसे प्रभावी आर्सेनिक निष्कर्षण फफूंदों के प्रभेदों *ट्राइकोडर्मा* प्रजाति, *वेस्टर्डिकेल्ला* प्रजाति, *लाइसिओडिप्लोडिया* प्रजाति, *राइजोपस* प्रजाति, *एस्पर्जिलस ओराइजी*, *कीटोमियम* प्रजाति, *आथ्रीडर्मा बेन्हामी*, *ट्राइकोफाइटन वेरुकोसम*, *एस्पर्जिलस निडुलांस*, *राइजोम्यूकर वेरियाबिलिस*, *एमेरिसेल्ला* प्रजाति एवं *फ्यूसेरियम* प्रजाति द्वारा देखा गया। इन सभी प्रभेदों के एनसीबीआई जीनबैंक नमूना संख्या प्राप्त की गईं तथा इन प्रभेदों के नमूनों को एमटीसीसी एवं एनएफसीसीआई में संग्रहित कराया गया।

उत्तर प्रदेश के गांगेय मैदानों में कृषि एवं वन पारिस्थितिकी पर जलवायु परिवर्तन प्रभाव हेतु रणनीतिक ज्ञान

उष्ण कटिबंधीय शुष्क पर्णपाती वन (TDDFs) सर्वाधिक विस्तृत वन पारिस्थितिक तंत्रों में से एक हैं किन्तु वैज्ञानिक समुदाय इनकी ओर हाल ही में आकर्षित हुये हैं। इस परियोजना की शुरुआत उत्तर प्रदेश के गांगेय मैदानों के शुष्क पर्णपाती वनों की पादप विविधता एवं पारिस्थितिकी के आंकड़े एकत्र करने के लक्ष्य को ध्यान में रखकर की गई ताकि जलवायु परिवर्तन एवं वन पारिस्थितिक तंत्र प्रतिक्रिया हेतु पूर्वानुमान माडल बनाने हेतु डाटाबेस उपलब्ध हो सके। इस कार्य को दो भिन्न तरीकों से किया जा रहा है, पहला, उत्तर प्रदेश के सोनभद्र जिले के उष्ण कटिबंधीय शुष्क पर्णपाती वन में स्थापित किए गए स्थायी पारिस्थितिकी प्लाटों का दीर्घ अवधि अध्ययन एवं दूसरा, उष्ण कटिबंधीय शुष्क पर्णपाती वनों की प्रतिनिधि प्रजातियों का सीएसआईआर-एनबीआरआई, लखनऊ में स्थापित FACE (फ्री एयर CO_2 एनरिचमेंट) तंत्र में TDDFs का eCO_2 के प्रति प्रतिक्रिया का अध्ययन। जहां पहली पद्धति हमें पूर्वानुमान माडल हेतु डाटाबेस प्रदान करेगी वहीं दूसरी पद्धति उच्च CO_2 परिस्थितियों में वृक्षों की आकारिकी, शरीर-क्रिया, उत्पादकता, आदि में परिवर्तन/प्रतिक्रिया प्रदर्शित करेगी।

तीन वन समुदायों, साल मिश्रित वन, शुष्क विविध वन एवं *हार्डविकिया* मिश्रित वन में स्थापित किए गए 0.5 हेक्टेयर के 6 स्थायी प्लाटों को पारिस्थितिकीय, पादप-सामाजिकता आदि अध्ययन एवं कार्बन जब्ती आंकलन हेतु निर्धारित किया गया।

पादप विविधता

इस अवधि में अध्ययन क्षेत्र से 87 वंशों के 272 टैक्सा के 414 पादप नमूनों को संग्रहित किया गया। इनमें से 336 नमूनों (113 वृक्ष, 87 झाड़ियाँ, 69 शाक एवं 67 लताएँ) द्विबीजपत्री पौधों के एवं 78 नमूने एकबीजपत्री पौधों के हैं। पौधों को उनकी पुष्पन एवं/अथवा फलन स्तिथियों में GPS विवरण के साथ एकत्र किया गया। इस क्षेत्र में वृक्ष जैसे कि *लैजरेस्टोमिया पार्वीफोलिया, एनोजेसस लैटीफोलिया, अकेसिया कटेचू, हार्डविकिया बाइनाटा, सोंबिडा फेब्रीफ्यूगा, बाहुनिया रेसीमोसा, डायोस्पाइरोस मेलैनोसाइलान, ब्राइडेलिया रेट्यूसा, अल्बिजिया प्रजातियाँ, शोरिया रोबस्टा, मिलिऊसा टोमेंटोसा, हाल्दिना कार्डीफोलिया, निक्टैन्थस आर्बोर्ट्रिस्टिस, केसिया फिस्टुला, फ्लेकार्शिया इंडिका, जिजीफस ग्लैबेराइमा, टर्मिनेलिया एलिप्टिका* एवं *ब्यूटिया मोनोस्पर्मा* आदि बहुतायत में हैं। लताओं में *एम्पेलोसिसस लैटीफोलिया, क्रिप्टोलेपिस बुकनानाइ, मुकुना प्रूएंस* प्रमुख हैं। शाकों में *एलिफैण्टोपस स्केब, क्रोटालेरिया प्रोस्ट्रेटा, बटनेरिया हरबेसिया, ट्रिमफेट्टा पेंटेंडरा, हिपटिस स्वावियोलेन्स, यूरेरिया पिक्टा, टेफ्रोसिया स्ट्रीगोसा, इवाल्वुलस एक्सीनिओइडिस, बिडेंस बिटरनाटा* आदि प्रमुख प्रजातियाँ हैं। वन में अनेकों आर्थिक रूप से महत्वपूर्ण प्रजातियाँ भी पाई जाती हैं जैसे कि *शोरिया रोबस्टा, टर्मिनेलिया अलाटा, हाल्दिना कार्डीफोलिया, मैलोटस फिलीपेंसिस, टेक्टोना ग्रेंडिस, एहरेसिया लेविस, मित्रागाइना पार्वीफोलिया, बाहुनिया प्रजातियाँ, शाइजीगीयम कुमुनी, अकेसिया आरिकुलीफार्मिस, यूजीनिया ऊजेंसिस, मेलिया आजादीरख्ता* एवं *बुकनानिया लैंजेन* आदि।

स्थायी प्लाटों में पर्यावरणीय अध्ययन

3 मुख्य वन समुदायों (साल मिश्रित वन, शुष्क विविध वन एवं *हार्डविकिया* मिश्रित वन) प्रत्येक में 0.5 हेक्टेयर के 3 प्लाट स्थापित किए गए। सर्वाधिक वृक्ष विविधता साल मिश्रित वन में (30) पायी गई एवं शुष्क विविध वन व *हार्डविकिया* मिश्रित वन में क्रमशः 25 एवं 14 वृक्ष प्रजातियाँ प्राप्त हुईं।

जीवाणु समूहों द्वारा सरफेकटेंट के साथ बिना पाईरीन एवं फेनैन्थ्रीन का जैवउपचार

कम मात्रा में जल-घुलनशील पेट्रोलियम हाइड्रोकार्बन (PAH) विभिन्न यौगिकों के मृदा मिसेल्स द्वारा शोषण को बढ़ा देते हैं जिससे जैवअपघटक सूक्ष्मजीवों को उनकी प्राप्ति कम हो जाती हैं। अतः जीवाणुओं (*स्यूडोमोनास स्टुट्जेरी* BP10 एवं *आक्रोबैक्ट्रम इंटरमीडियम* P2) की उपस्थिति में मृदा में पालीएरोमैटिक हाइड्रोकार्बन के जैव-अपघटन में सरफेकटेंट की भूमिका को सुनिश्चित करने के लिए अध्ययन किया गया।

संदूषित क्षेत्रों में उगने वाले पौधों में एंडोसल्फान आइसोमर एवं इसके मेटाबोलाइट एंडोसल्फान सल्फेट का शोषण एवं संचयीकरण

पीड़कनाशी संदूषित क्षेत्रों में प्राकृतिक रूप से उगने वाले पौधों में एंडोसल्फान आइसोमर ($\alpha + \beta$) एवं इसके मुख्य मेटाबोलाइट एंडोसल्फान सल्फेट को आंकलित किया गया। उत्तर प्रदेश के गाजियाबाद में स्थित फ्लोरा केमिकल एंड फर्टिलाइजर्स लि. एवं इसके आस पास के इलाकों से मृदा एवं पौधों के नमूने एकत्र किए गए। मुख्य रूप से उगने वाले 7 पौधों (*सोंकस ओलेरेसियस, डिजिटेरिया लांगीफोलिया, पैनिकम पैलेण्डोसम, क्लोरिस वरगेटा, स्फेनोक्लिया जेलैनिका, सैकियोलेपिस इंटेरेप्टा, वेटिवर जीजीनोयडिस*) को दूषित क्षेत्र के विभिन्न स्थानों से एकत्र किया गया। पादप अंगों एवं मृदा से एंडोसल्फान अवशेषों को निष्कर्षित किया गया एवं गैस क्रोमैटोग्राफ के द्वारा सुनिश्चित किया गया। सभी मृदा एवं पादप नमूनों में एंडोसल्फान आइसोमर एवं इसके मेटाबोलाइट एंडोसल्फान सल्फेट की उपस्थिति देखी गई एवं इसकी सांद्रता पौधों एवं मृदा में क्रमशः 14-343 नैनोग्राम प्रति ग्राम एवं 13-938 नैनोग्राम प्रति ग्राम देखी गई। *वेटिवर जीजीनोयडिस* में सर्वाधिक एवं *स्फेनोक्लिया जेलैनिका* में न्यूनतम सान्द्रण पाया गया। अध्ययन से इन प्रजातियों द्वारा दूषित क्षेत्रों की जांच एवं जैव-उपचार में इनकी क्षमता का पता चलता है।

लेड (सीसा) प्रदूषित जल के जैव-उपचार हेतु हरित संश्लेषित जीरो-वैलेंट लौह नैनोकणों की क्षमता

एम्बलिका आफीसेनेलिस की पत्ती के अर्क को अपचयन एवं स्थिरीकारक एजेन्ट के रूप में एवं $FeCl_3$ को लौह स्रोत के रूप में प्रयोग करते हुये जीरो-वैलेंट लौह नैनोकणों को संश्लेषित करने हेतु एक बाटम-अप हरित संश्लेषण तरीके का प्रयोग किया गया। 20 मिली प्रति ली. सांद्रता के प्रयोग से हरित संश्लेषित जीरो-वैलेंट नैनोकण 24 घंटों के अंदर जलीय माध्यम से 10, 20, 50 एवं 100 पीपीएम सीसा के उपचार में अत्यधिक सफल रहे।

बीजी पौधों में अजैविक तनाव से पत्तियों, फलों एवं जड़ों के जैवभार निर्धारण में परिवर्तन

सूखा प्रतिरोधकता के आंकलन हेतु आप्टिकल गुणों का मार्कर उपकरणों के रूप में उपयोग

किसी भी अजैविक तनाव के प्रति सहिष्णुता एक जटिल लक्षण है जो तनाव कारकों एवं विभिन्न आण्विक, जैव-रासायनिक एवं कार्यिकी घटनाओं के मध्य आपसी संबंधों के चलते पादप वृद्धि एवं विकास को प्रभावित करता है। इस अध्ययन में पत्ती के परावर्तन गुणों एवं जल तनाव की स्थितियों में चक्रीय इलेक्ट्रान फ्लक्स को देखा गया।

पत्ती के परावर्तन गुणों के अध्ययन की शुरुआत पत्ती के सतह पर प्रकाश किरण पड़ने से होती है। यह प्रकाश तीन भागों में बंट जाता है। कुछ पत्ती से परावर्तित हो जाता है, कुछ इसके आर पार निकाल जाता है एवं कुछ पत्ती द्वारा अवशोषित हो जाता है जो प्रकाश-संश्लेषण एवं अन्य जैव क्रियाओं में काम आता है। परावर्तन गुण पत्ती की सतह के गुणों एवं पादप नमूने की आंतरिक संरचना द्वारा एवं साथ ही साथ जैव-रासायनिक यौगिकों की सांद्रता एवं वितरण पर निर्धारित होते हैं और इस प्रकार परावर्तित प्रकाश के अध्ययन से पौधे के कार्यिकी का आंकलन किया जा सकता है। इस क्रम में कपास की विभिन्न किस्मों के परावर्तन गुणों का अध्ययन किया गया ताकि एक नुकसान रहित तकनीक के रूप में प्रयोग कर इसके द्वारा कपास की विभिन्न चयनित किस्मों में सूखा सहनशीलता का अध्ययन किया जा सके।

कपास की पत्तियों का प्रोटियोमिक अध्ययन

सूखे की विभिन्न स्थितियों के दौरान विभिन्न पुष्पन स्थितियों पर प्रोटीनों के भिन्न भिन्न प्रदर्शनों के आंकलन हेतु कपास की दो प्रजातियों *गासीपियम हिर्सुटम* एवं *गासीपियम हरबेसियम* की प्रोटियोमिक अध्ययन किए जा रहे हैं।

आनुवंशिकी एवं आण्विक जैविकी

संकर बीज उत्पादन हेतु पौधों में एक नवीन नर बंध्य-प्रजनन क्षमता पुर्नस्थापना तंत्र

वैश्विक खाद्य सुरक्षा की मांग है कि बिना पानी एवं खाद का प्रयोग बढ़ाए निश्चित मात्रा की कृषि भूमि में फसल उत्पादन को बढ़ाने एवं सुरक्षित करने हेतु नई पद्धतियों का विकास किया जाय। पादप प्रजनन में हेटेरोसिस या संकर ओज ने वैश्विक फसल उत्पादन में असंख्य लाभ प्रदान किए हैं। किन्तु जैविक रूप से सुरक्षित तरीके से फसलों की विस्तृत उपयोग क्षमता वाले संकर बीजों के उत्पादन हेतु एक प्रभावी तरीके का विकास अभी भी शेष है। अतः पौधों में संकर प्रजनन हेतु एक नरबंध्य प्रजनन क्षमता पुर्नस्थापना तंत्र के विकास किया गया। इस तंत्र में निम्न अच्छाइयाँ हैं 1) पूर्ण नर-बंध्यता की प्राप्ति, 2) नर बंध्यता हेतु *एराबिडाप्सिस* BECLIN1 जीन का प्रयोग क्योकि यह एक पादप उत्पन्न जीन है एवं इसके कोई विषैले लक्षण ज्ञात नहीं हैं। 3) F1 संतति में पूर्ण नर-बंध्यता की पुनर्सृथापना काफी महत्वपूर्ण है जब आर्थिक उत्पाद बीज हो। 4) भविष्य में वाणिज्यिक उपयोग हेतु नर-बंध्य मादा लाइनों की देखभाल अति आवश्यक है। 5) प्रकृति में फसलों की व्यापक उपयोगिता एक आवश्यक तत्व है। संकर बीजों के वाणिज्यिक उत्पादन के दोहन हेतु इस तंत्र को फसली पौधों में स्थापित किए जाने की आवश्यकता है।

भारत में सजावट वाली बल्ब फसलों को संक्रमित करने वाले पोटीवाइरस के संभावित प्रबंधन हेतु उनकी आनुवांशिक विविधता का अध्ययन

क्राइनम एशियाटिकम अथवा स्पाइडर लिली, उष्ण एवं उपोष्ण कटिबंधीय देशों में विस्तृत रूप से उगाया जाने वाला एक सजावटी पौधा है जो अपनी पट्टी नुमा पत्तियों एवं गुच्छेदार सफेद फूलों के लिए उगाया जाता है। दिसंबर 2013 में एक सर्वे में दिल्ली एवं नोयडा के उद्यानों में स्पाइडर लिली के पौधों की पत्तियों पर मोसैक बीमारी के लक्षण पाये गए जो कि ब्राजील में स्पाइडर लिली पर देखे गए पोटीवाइरस के संक्रामण लक्षणों के समान थे। इलेक्ट्रान सूक्ष्मदर्शी अध्ययनों से लचीले, छड़ नुमा, लगभग 700x12 नैनो मी. के आकार के पोटीवाइरस के कणों की उपस्थिति की पुष्टि हुई। RT-PCR के माध्यम से प्राप्त एम्प्लीकान को क्लोन कर, सीक्वेंस कर सीक्वेंस आंकड़ों को जीनबैंक डाटाबेस में जमा कराया गया। ये आंकड़े न्यूजीलैंड, नीदरलैंड एवं अमेरिका से वर्णित नेरीन येलो मोजैक वाइरस (NeYSP) से मेल खाते हैं जो कि संभवतः भारत में इस वाइरस के वितरण की प्रथम सूचना है।

विथानिया सोमनीफेरा के स्टेरोल ग्लाइकोसिल ट्रांसफेरेस (SGT) जीन परिवार का mi-RNA तकनीक द्वारा क्रियात्मक आंकलन

विथानिया सोमनीफेरा के स्टेरोल ग्लाइकोसिल ट्रांसफेरेस जीन स्टेरोइडल हार्मोन्स के ग्लाइकोसिलेशन में महत्वपूर्ण भूमिका निभाते हैं जो पौधों के विकास एवं वृद्धि को नियंत्रित करते हैं। क्रियात्मक विश्लेषण हेतु इस परिवार के जींस को कृत्रिम amiRNA के द्वारा शांत किया गया। HPLC आंकलन द्वारा द्वीतीयक मेटाबोलाइटों के उत्पादन पर WsSGTL जीन परिवार के डाउन-रेगुलेटेड प्रभावों का अध्ययन किया गया। डाउन रेगुलेटेड लाइनों पर जैव तनाव का अध्ययन करने के लिए एक *विथनिया सोमनीफेरा* के एक सामान्य पर्ण-परजीवी फफूंद *आल्टर्नेरिया आल्टर्नेटा* को चयनित किया गया। यह देखा गया कि WsSGTL जीन परिवार पादप वृद्धि एवं विकास, मेटाबोलाइट बैलेंस एवं रक्षा तंत्र में महत्वपूर्ण भूमिका निभाते हैं।

अरबिडाप्सिस में MaSIN3 का क्रियात्मक विश्लेषण

SIN3 समूह एक उच्च संरक्षित बहु-इकाई समूह है जो जंतुओं, यीस्ट्स एवं पौधों में हिस्टोन डिएसीटिलेस के मध्यस्थ साइलेंसिंग के द्वारा जीन नियंत्रण में लिप्त रहते हैं किन्तु पौधों में इनकी भूमिका के बारे में अधिक जानकारी उपलब्ध नहीं है। अतः इस संदर्भ में केले के पौधे पर किए गए अध्ययनों से पता चला है कि केले का MaSIN3 जीन एक 1408 अमीनों अम्लों की प्रोटीन बनाता है जिसमें एन-टर्मिनल सिरे पर एक पीएएच डोमेन, मध्य में एक HDAC इंटेरेक्टिंग डोमेन एवं सी-टर्मिनल सिरे पर एक प्रोटीन-प्रोटीन संबंध डोमेन मौजूद होता है। *एराबिडाप्सिस* की MaSIN3 प्रदर्शन करने वाली ट्रांसजेनिक लाइनों में शीघ्र पुष्पन एवं पत्ती तथा पर्ण-वृंत की लंबाई में वृद्धि प्रदर्शित होने के साथ साथ अधिक किन्तु छोटे रंध्र प्रदर्शित हुये। इसके अतिरिक्त बीजों में ABA के प्रति संवेदनशीलता में सामान्य से कमी देखी गई तथा उनका अंकुरण भी शीघ्र हुआ। इन पौधों में ABA, लवण, मैनीटाल व ग्लूकोस युक्त मीडिया में जड़ की वृद्धि में ABA के प्रति संवेदना में कमी भी देखी गई। ये पौधे सूखे के प्रति अधिक संवेदी थे तथा सामनी से अधिक जल ह्रास प्रदर्शित हुई जो कि ABA के प्रति कम संवेदनशीलता का सूचक है।

धान में आर्सेनिक शोषण एवं चालन में mi-RNA की भूमिका

धान में आर्सेनिक का दूषण वैश्विक स्तर पर मानव स्वास्थ्य के लिए एक गंभीर खतरा है। धान में आर्सेनिक के शोषण, चालन एवं एकत्रीकरण से संबन्धित आण्विक प्रक्रिया की जानकारी इस समस्या के निदान में सहायक हो सकती है। miRNA छोटे आरएनए का एक समूह है जो विभिन्न जैविक क्रियाओं जैसे कि अंग ध्रुवण, मर्फोजेनेसिस, फ्लोरल ट्रांजीशन, हारमोन सिग्नेलिंग तथा पर्यावरण अनुकूलन में लिप्त रहते हैं। हालांकि आर्सेनिक तनाव में इनकी भूमिका के बारे में अधिक जानकारी नहीं है। इस संबंध में न AsIII एवं AsV तनाव के प्रति भिन्न भिन्न प्रतिक्रियाओं वाली धान की किस्मों में भिन्न भिन्न प्रदर्शनों वाले ज्ञात एवं नवीन miRNA की पहचान हेतु miRNA प्रोफाइलिंग एवं सीक्वेंसिंग की गई।

अलसी (*लाइनम यूसीटाईटीसिमम*) में आल्टर्नेरिया झुलसा प्रतिरोधी लोकाई की पहचान एवं मार्कर असिस्टेड बैक-क्रासिंग (MABC)

अलसी एक महत्वपूर्ण फसल है जो कि अनेकों जैविक तनावों जैसे ब्लाइट, रस्ट, विल्ट, मिलड्यू आदि के प्रति काफी संवेदनशील है और इस कारणवश इसे काफी नुकसान होता है। इस संबंध में झुलसा (ब्लाइट) प्रतिरोधी उच्च उत्पादक अलसी की किस्म उत्पादित करने के लिए मार्कर असिस्टेड प्रजनन की चेष्टा की गई। 715 SSRs के लिए प्राइमर संश्लेषित किए गए। पीसीआर एंप्लीफिकेशन किया गया तथा बहुरूपकता (पालीमोर्फिस्म) विश्लेषण से ज्ञान हुआ कि 500 SSR में से 31 या तो विफल हो गए या फिर उन्होने नान-स्पेसिफिक बैंड प्रदर्शित किए। शेष 469 में से 397 (85%) एकरूपक (मोनोमोर्फिक) एवं 72 (15%) बहुरूपक (पालीमार्फिक) पाये गए। 155 F2 मैपिंग आबादी से जीनोमिक DNA प्राप्त कर उसकी जीनोटाइपिंग की जा रही है।

अश्वगंधा (*विथानिया सोमनीफेरा*) से औषधि निर्माण एवं आनुवांशिक सुधार

अश्वगंधा द्वीतीयक मेटाबोलाइट्स का एक महत्वपूर्ण स्रोत है तथा इसके औषधीय गुण पौधों के अंगों में मौजूद मुख्य संघटकों विथानोलीड्स एवं उनके ग्लाइको-काञ्जुगेट के कारण होते हैं। अश्वगंधा के विभिन्न कीमोटाइपों को प्रयोग कर विथनोलीड्स के जैव-संश्लेषक पाथवे की पहचान की कोशिश की गई। इस प्रक्रिया में लिप्त जींस की पहचान के लिए 454 पाइरोसीक्वेंसिंग का प्रयोग करते हुये 3 भिन्न कीमोटाइपों (NMITLI-101, NMITLI-118 एवं NMITLI-135) की पत्तियों एवं जड़ों के ऊतकों की ट्रांस्क्रिप्टोम सीक्वेंसिंग की गई तथा पाथवे में लिप्त एंजाइमों के संश्लेषण से संबन्धित जींस को पहचाना गया। इस सूचना को डाटाबेस के रूप में संग्रहीत किया जा रहा है जो *विथानिया* के औषधीय गुणों के दोहन में सहायक होगा।

कीट प्रतिरोधकता हेतु पौधों में कीट प्रेरक मेथेनाल का उत्पादन

अधिकतम मेथेनाल उत्पादन एवं अधिक क्रियाशील PME जीन वाले विभिन्न पादप स्रोतों की जांच के बाद दो पीएमई (पेक्टिन मेथिल एस्टेरेज) WsPME एवं DS PME को चयनित किया गया। Muts प्रोटोकाल को प्रयोग करते हुये यीस्ट में WiPME के रीकाम्बिनेंट एक्स्प्रेशन के लिए *विथानिया सोमनीफेरा* के PME जीन को यीस्ट एक्स्प्रेशन वेक्टर (pPICZa) में क्लोन किया गया।

सजावटी पौधों में गंभीर बीमारियाँ उत्पन्न करने वाले पादप विषाणुओं के प्रबंधन हेतु आण्विक अध्ययन

हालीहाक येलो वेन मोजैक वाइरस के एक स्पष्ट प्रभेद एवं लुडविगिया लीफ डिस्टार्शन बीटासैटेलाइट का हालीहाक येलो वेन मोजैक के साथ संबंध

दिसंबर 2011 की शीत ऋतु में, लखनऊ के उद्यानों में हालीहाक के पौधों की पत्तियों पर येलो वेन मोजैक के लक्षण देखे गए। वाइरस की पहचान के लिए संक्रमित पत्तियों से डीएनए प्राप्त कर PCR आंकलन किया गया जिससे ज्ञात हुआ कि उक्त वाइरस जीनोम हालीहाक येलो वेन मोजैक वाइरस (HoYVMV) के एक विशिष्ट प्रभेद को प्रदर्शित करता है।

भारत में उगाई जाने वाली *जट्रोफा* की तीन सजावटी प्रजातियों की येलो मोजैक बीमारी से संबन्धित एक नवीन बेगोमोवाइरस का अभिलक्षणन

वर्ष 2013 में एक सर्वेक्षण के दौरान लखनऊ के उद्यानों में *जट्रोफा* की तीन सजावटी प्रजातियों *जट्रोफा इंटीग्राइमा, जट्रोफा पोडाग्रिका* एवं *जट्रोफा मल्टीफिडा* पर येलो मोजैक बीमारी के लक्षण देखे गए। इस बीमारी का कारक, सफेद मक्खी (*बेमीसिया टबाकी*) के द्वारा सफलतापूर्वक बीमार पौधों से स्वस्थ पौधों पर स्थानांतरित हुआ। प्राकृतिक रूप से संक्रमित पौधों में बेगोमोवाइरस का संक्रमण प्रारम्भ में PCR के माध्यम से बेगोमोवाइरस यूनीवर्सल प्राइमर के प्रयोग के द्वारा चिन्हित किया गया। अध्ययन किए गए आइसोलेट के 61% सीक्वेंस के आधार पर इसे एक नई बेगोमोवाइरस प्रजाति के रूप में पहचाना गया जिसे "जट्रोफा मोजैक लखनऊ वाइरस (JMLV)" नाम दिया गया। रीकांबिनेशन अध्ययनों से पता चला कि ये प्रजाति एक रीकाम्बिनेंट प्रजाति नहीं है एवं एक स्वतंत्र प्रजाति की तरह उत्पन्न हुई है। JMLV से संबन्धित जट्रोफा प्रजातियों की येलो मोजैक बीमारी का प्रथम बार अभिलक्षणन किया गया।

केना जैविकी

केना प्रजातियों का पुनरुत्पादन एवं आनुवांशिक रूपांतरण

केना (*केना इंडिका*) एक सजावटी पौधा है। देशी फसल होने के नाते इसे आनुवांशिक रूपान्तरण के लिए चुना गया। केना के सुनिश्चित आनुवांशिक रूपान्तरण हेतु कोई भी ऊतक संवर्धन प्रोटोकाल उपलब्ध नहीं है। अतः प्रथम बार केना के बीजों के प्रयोगशाला में अंकुरण हेतु प्रोटोकाल विकसित किया गया। बीजों को एक विसंक्रमित नेल क्लिपर से थोड़ा से काट कर 24-48 घंटे के लिए अथवा मूलांकुर के बाहर निकालने तक भिगोया जाना 100% अंकुरण में सहायक देखा गया। वृद्धि एवं विकास के लिए शीशे की गोलियों वाला जलीय मीडिया सर्वोत्तम सिद्ध हुआ। इस प्रकार उगाये गए पौधों में जड़ों की वृद्धि करा कर, अनुकूलित कर गमलों में स्थानांतरित किया गया जिनमें वे सामान्य रूप से विकसित हो रहे हैं।

पौधे के विभिन्न भागों को कैलस उत्प्रेरण हेतु प्रयोग किया गया। 2,4-D की उच्च मात्र में कैलस बनाने हेतु पुष्पक्रम वृंत सर्वोत्तम सिद्ध हुये। रूपान्तरण प्रोटोकाल स्थापित किए जाने के प्रयास किए जा रहे हैं।

केना में बीन येलो मोजैक वाइरस की आण्विक पहचान

अक्टूबर 2011 एवं जनवरी 2014 में वाइरल बीमारियों हेतु लखनऊ के उद्यानों में किए गए सर्वेक्षणों में बहुत सारे केना के पौधों में गंभीर मोजैक लक्षण देखे गए। इन्हें CMV अथवा पाटीवाइरस की उपस्थिति हेतु जांचा गया। एंटीसीरम का प्रयोग करते हुये ELISA जांच की गई सभी केना किस्मों के पर्ण-अर्क में पाटीवाइरस की उपस्थिति सुनिश्चित हुई।

आणुविक एवं परंपरागत तरीकों के माध्यम से पौधों में आनुवांशिक सुधार

ओपियम पोपी (*पैपावर सोमनीफेरम*)

पैपावरीन एवं थीबेन से भरपूर लाइनों को सर्वप्रथम विकसित किया गया। इन लक्षणों को उच्च उत्पादक किस्मों में समाहित करने हेतु प्रयास किए जा रहे हैं। कफ सिरपों में कोडीन एवं कैंसर के उपचार में नार्कोटीन के प्रयोग के कारण कोडीन एवं नार्कोटीन एलकेलोइड की मांग विश्व स्तर पर तेजी से बढ़ रही हैं अतः हम नार्कोटीन एवं कोडीन से भरपूर किस्मों को विकसित करने की दिशा में प्रयासरत हैं।

अलसी (*लाइनम यूसीटेटीसिमम*)

भारत में अलसी की फसल एक प्रमुख तेल उत्पादक फसल है जिसे इसके महत्वपूर्ण गुणों के कारण भविष्य में खाद्य तेल के रूप में भी प्रयोग किया जा सकता है। हालांकि इस तेल में लिनोलेनिक अम्ल की काफी अधिक मात्रा होने के कारण यह खाद्य तेल के रूप में प्रयुक्त नहीं हो सकता। अतः इस तेल को औद्योगिक तेल से खाद्य तेल में रूपांतरित करने हेतु इसमें मौजूद लिनोलेनिक अम्ल का स्तर 5% से कम किए जाने के प्रयास किए जा रहे हैं। इस दिशा में प्रयास जारी हैं कि निम्न लिनोलेनिक अम्ल लक्षण को 'लिनोला' (एक 5% से कम लिनोलेनिक अम्ल वाली लाइन) किस्म से उच्च उत्पादक किस्मों में स्थानांतरित किया जा सके।

वसा अम्लों की प्रोफाइलिंग के आधार पर अलसी का अभिलक्षण भी किया जा रहा है जिससे इससे उपलब्ध जर्मप्लाज्म के समुचित प्रयोग में सहायता मिल सके।

पादप सूक्ष्म जीव समन्वयन व भेषज विज्ञान

पादप सूक्ष्म जीव समन्वयन

अजैविक स्ट्रेस रोधी सूक्ष्मजीव आधारित बायोइनोकुलेन्ट का गुणवत्ता युक्त उत्पादन एवम उत्तर प्रदेश में स्वास्थ्य एवं फसल सुधार हेतु उनका लौकिकिकरण

सी.एस.आई.आर.-एन.बी.आर.आई., ने अजैविक रोधी जैव् संक्रमणकारी का मात्रसंवर्धन उपलब्ध कराया तथा गुणवत्ता युक्त जैव् संक्रमणकारी के व्यापक पैमाने पर उत्पादन हेतु उत्तर प्रदेश कृषि निदेशालय के 17 जैव उर्वरक प्रयोगशालाओं के कर्मचारियों को प्रशिक्षण, प्रदर्शन एवं तकनीकी सुझाव/सलाह प्रदान किया। उत्तर प्रदेश कृषि निदेशालय के अनुसंधान क्षेत्रों पर बहु-स्थानीय प्रमाणीकरण का कार्य निष्पादित किया गया एवं विभिन्न ऋतुओं एवं फसलों के जैव् संक्रमणकारी के प्रयोग को लोकप्रिय बनाने हेतु नौ कृषि जलवायुवीय क्षेत्रों में प्रशिक्षण एवं कार्यशालायें आयोजित की गईं।

कार्बनडाईआक्साइड के बढ़े हुए स्तर पर पौधों की प्रतिक्रिया तथा मृदा जड़ सूक्ष्मजीव क्रिया-प्रतिक्रिया पर इसके प्रभाव का अध्ययन

यह परियोजना मृदा सूक्ष्मजीव, कार्बन संचय के कार्यकारी विशेषताओं की जांच करने तथा खुली हवा एवं फेश सुविधा में *Tricoderma reesei* MTCC 5659 की उपस्थिति तथा अनुपस्थिति में धान का प्रयोग करके बढ़े हुए CO_2 दबाव को कम करने वाले जींस की पहचान करने हेतु प्रारम्भ किया गया था।

चने Chickpea (*Cicer arietinum*) में पादप वृद्धि नियामक Rhizobacteria के माध्यम से शुष्कता (सूखा) निवारण में miRNA का योगदान

पी.जी.पी.आर. मीडिएटेड सूखा स्ट्रेस रेस्पांस तथा अनुकूलन में उनका योगदान जानने के लिए चने की सूखारोधी प्रजाति BG-362 की जड़ों का नमूना जो की 20 प्रतिशत ईजी में 72 घंटे तक की प्युटिंग के उपिस्थिति या अनुपस्थिति में रखे गये थे miRNA प्रोफाइलिंग की गयी। कुल 41.8 मिलियन से अधिक सिक्वेंस रीड उत्पन्न हुए। चारों नमूनों से जिनकी 5.4-13.1 मिलियन प्रत्येक नमूने के लिए थी एडाप्टर व रिजेक्ट रीड्स हटाने के बाद, लगभग 13-65 युकिल्योटाइड छोटे स्तर के लिए लगभग 5.9 मिलियन विशिष्ट रीड्स प्राप्त हुए। 18 एन टी से <26 एन टी सिक्वेंस लेंथ से छानने के बाद तथा टी आर एन ए, आर आर एन ए, एस एन आर एन ए एवं अन्य को हटाने के बाद लगभग 2 मिलियन रीड्स चारों लाइब्रेरीज से प्राप्त हुए।

प्रमुख मिलेट्स की ट्रांसक्रिप्ट प्रोफाइलिंग तथा स्ट्रेस इन्दयूसिबल नियंत्रण ट्रांसक्रिप्शन कारकों की क्लोनल करेक्टराइजेशन

फाक्स्टेल मिलेट (*सितेरिया इटैलिका*) की जीनोम अध्ययन ने सिस्टमेटिक सिक्वेंस एनालिसिस द्वारा कुल 171 एपी 2/ इ आर एफ जींस की पहचान करने में सहायता मिली। जींस भौतिक रूप से नौ गुणसूत्रों पर मैप किये गए थे। जींस एस आई एपी 2/इ आर एफ -069, एस आई एपी 2/इ आर एफ - 103 एवं् एस आई एपी 2/इ आर एफ-120 की एक्सप्रेशन प्रोफाइलिंग द्वारा यह स्पष्ट हुआ की आगे इन जींस को वैलिडेशन एवं फसल सुधार में उपयोग किया जा सकता है।

पादप वृद्धि नियामक राइजोवैक्टीरिया द्वारा फसल उत्पादन का प्रबंधन

सी एस आई आर-एन बी आर आई सूक्ष्मजीव संग्रहालय से फास्फोरस घोलक, फास्फोरस संग्राहक व् फास्फेटेज क्रिया वाले जीवाणु स्ट्रेस को उनके स्ट्रेस टालरेंस के लिए स्क्रीन किया गया। सिलिकान डालने वाले जीवाणुओ की तीव्र स्क्रीनिंग के लिए एक मीडिया विकसित किया गया।

बायोकंट्रोल गुणवत्ता के लिए स्क्रीन किये गए सूक्ष्मजीवों को विभिन्न पादप वृद्धि नियामक गुणों के लिए चिन्हित किया गया। चयनित किये गए आठ जीवाणुओ में से पी पी बी 5, पी पी बी 3 एवं पी पी बी 6 के पर्याप्त मात्रा में काईटीनेज क्रिया पाई गई तथा उसमें वृहत् परास ओडी बायोकंट्रोल क्षमता फफूंद बीमारी कारकों के विरुद्ध पाई गई। ट्राईकोड्नी की बिभिन्न जातियों से स्वर्ण रजत नैनोकणों की जैव संशलेषण हेतु ट्राईकोड्नी के आइसोलेट टी पी 9 (*टी विरिडी* एन टी सी सी 5661) को स्क्रीन किया गया। स्वर्ण एवं रजत नैनोकणों की बाद में अन्य विधियों से पहचान की गयी। कवक नाशी कार्बोडाईजेम का क्षय परती खेत में उपजाऊ खेत की तुलना में कम पाया गया

इन विट्रो स्थिति में कई सूक्ष्म जीव स्ट्रेस की प्रोटियोज क्रिया विधि के साथ साथ सेलुलेज, ग्लुकेनेज एवं काइटिनेज क्रिया विधि की स्क्रीनिंग की गई। प्रोटियोज उत्पादक जैवनियंत्रक स्ट्रिंग में अधिक कवक विघटनकारी क्षमता पाई गई।

फ्यूजोरियम विल्ट काम्प्लेक्स कवक की उपस्थिति एवं अनुपस्थिति गाय के गोबर सप्लीमेंटेशन का प्रभाव देखने के लिए चने के राइजोस्फियर की सूक्ष्म जैविक मेटाबोलिक विविधता का अध्ययन किया गया। गाय का गोबर एवं फ्यूजेरियम संकलन में सूक्ष्मजीव विविधिता को बदल देने की क्षमता पाई गई।

भेषज विज्ञान

कुछ संकटग्रस्त औषधीय पौधों की सर्वोत्तम कीमोटाइप्स के माडीफाइड कल्टीवेशन तथा इन विट्रो उत्पादन तकनीकों द्वारा फाइटोकेमिकल्स का उत्पादन

भारत के विभिन्न पादप भू विविधता क्षेत्रों से एकत्रित किये हुए *ग्लोरिओसा सुवर्णा* एवं *कोलियस फोर्सकोहलाई* के टयूबर्स में काल्चीसीन व् फोर्सकोलिन की मात्रा के सम्बन्ध में कीमोटाईपिक विविधता का अध्ययन किया गया। 350 नैनोमीटर की रेसियो मीट्रिक स्कैनिंग के द्वारा *ग्लोरिओसा सुवर्णा* की 63 नमूनों में से काल्चीसीन की अधिकत्तम सांद्रता 3.212% एन बी जी (पश्चिमी घाटों) तथा न्यूनतम (0.02%) एन बी जी 20 (पूर्वी घाटों) में पाई गई। *कोलियस फोर्सकोहलाइ* की 52 नमूनों में से एन बी सी 02 (गंगा का मैदान) न्यूनतम (0.004%) तथा एन बी सी 46 (माला वार का पश्चिमी

किनारा) में फोर्सकोहलाइ की अधिकतम (1.153% क्) पाई गई। काल्वीसीन के अनुमान के लिए ओ पी एल सी द्वारा एक नई विधि विकसित की गई है

सक्षम फाइटोएकारीसाइड की कीमोप्रोफाइलिंग तथा प्रतिरोधी कैटिलिटिक्स के नियंत्रण के लिए उनकी पहचान

जैव सक्रिय यौगिक प्रिकोसीन 1 को क्वान्टीफाई करने के लिए भारत के 10 राज्यों से *एजेरेटम कोनीजोइंडिस्* की 37 नमूनों का एच पी टी एल सी प्रोफाइलिंग किया गया। अलग-अलग भौगोलिक क्षेत्रों से प्राप्त नमूनों में अलग-अलग सांद्रता पाई गई। पश्चिमी हिमालय से प्राप्त नमूनों में पिकोसीन अधिक मात्रा में था जबकि गंगा के मैदान व पश्चिमी घाट क्षेत्र से प्राप्त नमूनों में प्रिकोसीन कम मार्त्रा में था।

चयनित लघु मिलेट्स में पोषक तत्वों की प्रोफाइलिंग मुक्त रेडिकल स्कैवेंजिंग तथा एंटीआक्सीडेंट क्रियाएँ

चार लघु मिलेट्स की पोषक संरचना तथा एंटीआक्सीडेंट क्रिया विधि की खोज की गयी। सर्वाधिक रिड्यूसिंग शर्करा फिंगर मिलेट के आटे में थी उसके बाद क्रमश फिंगर मिलेट व फाक्स्टेल मिलेट में पायी गयी। सर्वाधिक जिंक एवं कापर फाक्सटेल मिलेट में पाए गए सर्वाधिक मैग्नीज फिंगर मिलेट के आटे में पाया गया। सर्वाधिक सम्पूर्ण पालीफिनाल (टी पी) तथा एंटीआक्सीडेंट क्रियाविधि एथेनालिक निष्कर्ष के बाद क्रमशः ब्यूटेनाल एवं एथेलेक्सीटेट एक्सट्रेक्ट में पायी गयी।

कम जाने हुए पौधों की पहचान व् मूलयांकन तथा कम लागत वाले हर्बल काम्बीनेशन का विकास

डी पी पी एच रेडिकल स्केवेजिंग तकनीक द्वारा *वाहिनिया प्रफ्युरिया, बेरीगेटा* तथा *आक्सैलिस कानीवुलेटा* के कुल फिनाल मात्रा कुल प्लेवेनायड मात्रा तथा कलियों तथा फूलों की एंटीआक्सीडेंट क्रिया विधि का पता लगाया गया।

औधोगिक महत्त्व के भारतीय औषधीय पौधों का गुणवत्ता मूल्याकन तथा वैज्ञानिक ज्ञान वैलिडेशन एवं परम्परागत ज्ञान पर आधारित हर्बल उत्पादों का विकास

परम्परागत ज्ञान पर आधारित हर्बल उत्पाद

गुणवत्ता मूल्यांकन तथा वैज्ञानिक वैलिडेशन हेतु निम्नांकित गतिविधियां चलाई गयी *क्लिटोरिया टेरनेटिया* के गुणवत्ता नियंत्रण मानकों का विकास आर्गेनोलेप्तिकगुणों: मैक्रो तथा माइक्रोस्कोपिक विवरण, फिजियोकेमिकल मानकों तथा टी एल सी फिंगरप्रिंट प्रोफाइल का प्रयोग करके सफेद तथा नीले फूलो वाले *सी. टेरनेटिया* की तुलनात्मक औषधीय मूल्यांकन किया गया। सूक्ष्मदर्शीय अध्ययन ने जड़ों में माडी पेरीसाइक्लिक धागों तथा जायलम वाहनियों तथा पिथ एवं पत्तियों की गुणात्मक मानकों को प्रदर्शित करता है।

कर्कस ल्यूकोट्राईकोफोरा एवं *कर्कस ग्लाका* की तुलनात्मक कीमोप्रोफाईलिंग

कर्कस ल्यूकोट्राईकोफोरा एवं *कर्कस ग्लाका* के छाल के मेथेनालिक निष्कर्षण रासायनिक मार्कर्स के साथ साथ का तुलनात्मक एच पी टी एल सी फिंगरप्रिंट विकसित किये गए।

शंखपुष्पी एवं इसके एडलट्रेन्ट्स की एंटीआक्सीडेंट क्षमता का अध्ययन

अधिकांश आर्युवेदिक लेखकों के विचार में *क्न्वोवुलस प्ल्युरिकालिस* (कुल क्न्वोवुलेसी) वास्तविक शंखपुष्पी का स्रोत है। अन्य जातियां जो कि शंखपुष्पी के रूप में जानी जाती है *इवोल्वुलस, एल्सीनोइड्स, ई मुमूलेरियस, टेफ्रोशिया, परफ्युरिया* एवं *क्लिटोरिया टरनेटिया* उपर्युक्त के बहुत से निष्कर्ष को अलग अलग विधियों से उनकी एंटीआक्सीडेंट क्षमता के लिए मूल्यांकन किया गया। *क्लिटोरिया टरनेटिया* के अतिरिक्त अन्य पांचो पौधों में अच्छी एंटीआक्सीडेंट क्षमता थी। सर्वाधिक क्रियाशील *कन्वोवुलस प्ल्यूरिकालिस* में थी तथा दूसरे स्थान पर *इवोल्वुलस एल्सीनोइड्स*। इन परिणामों ने इन पौधों की रसायन गुण को वैलिडेट किया गया।

टेफ्रोशिया, परफ्युरिया का मौसमी विविधता

टेफ्रोशिया परफ्युरिया एक महत्वपूर्ण औषधि है तथा इसका सामान्य नाम सरपुन्खा है *टेफ्रोशिया, परफ्युरिया* एल्कोहलयुक्त जलीय एल्कोहल एवं गर्म पानी निष्कर्ष तैयार किया गया ताकि ल्यूपियाल, रूटिन, रोटेनन व् बी-सिटोस्टोरोल की मात्रा का मौसमी बदलाव का अध्ययन किया जा सके।

हर्बल उत्पादों का निर्माण

हर्बल रंगो को प्रथक करके विभिन्न पदार्थों के साथ सयुंक्त करके टिकाऊ व् सस्ता हर्बल सिन्दूर बनाया गया

केनियासिस कि रोकथाम हेतु पादप निष्कर्ष (एन बी पी डी - 1) जेल आधारित उत्कृष्ट हर्बल फार्मूलेशन तैयार किया गया। सी एस आई आर-सीमैप के साथ सयुंक्त प्रयास द्वारा इसका सी एल्बिकेंस कवक परजीवी पर इसकी इन-वाइवो एवं इन-विट्रो अध्ययन किया गया द्य

राष्ट्रीय तकनीकी दिवस 13 मई, 2014 को मेसर्स एमिल फार्मास्युटिकल, नई दिल्ली को हर्बल तकनीकी NBRMAP DB जो कि एक सुरक्षित हाइपोग्लैसीमिक फार्मुलेशन है का हस्तान्तरण किया गया।

पादप रसायन

विभिन्न खाद्य मैट्रेसेज में न्यूट्रास्यूटिकल्स के वितरण हेतु निष्कर्षण एवं माइक्रोकैप्सुलेशन

17 पादप गम्स को खोजकर पृथक किया गया तथा न्यूट्रास्यूटिकल्स के कैप्सूली कारक हेतु उनकी क्षमता का अध्ययन किया गया। *करकुमिन बिकिसिन* ग्लूकोज बीटा कैरोटेंस आदि के मोनोकोर तथा मल्टीकोर माइक्रो कैप्सूल का विकास किया गया तथा इसका मानकों से तुलनात्मक मूल्यांकन किया गया।

अल्प ज्ञात प्राकृतिक गोद की पृथक्करण निष्कर्षण हेतु सस्ती कम लागत तकनीकी का विकास

शीत एवं ग्रीष्म निष्कर्षण तकनीकी से *अकेशिया मेंजियम, मधुका लोंगिफोलिया* फैटोकेमिक्ल्स की पोलैरिटी ग्रेडेंट का अध्ययन किया गया। भौतिक रसायन मानकों तथा विलयन गुणवत्ता का फार्मूलेशन कि दृष्टि से निर्धारण किया गया। गोंद के दस नमूनों के भारी धातुओं की गुणवत्ता मानकीकरण तथा मूल्य बर्धन का आकलन किया गया।

बायोप्रास्पेकशन के लिए *कामीफोरा वीटाई* (गुलगुल) का मेटाबोलिक प्रोफाइलिंग

गैस व् तरल क्रोमेटोग्राफी, मॉस स्पेक्ट्रोमेट्री तथा एन एस आर स्पेक्ट्रोस्कोपी द्वारा का वीटाई के जलीय व् जलरहित निष्कर्ष का विश्लेषण किया गया। *कामीफोरा वीटाई* के विभिन्न भागों के जलीय तथा जलरहित निष्कर्ष से 118 विविध रसायनों की मेटाबोलिक प्रोफाइलिंग की गई।

विभिन्न मेटाबोलिक क्रियाओं द्वारा बने विविध मेटाबोलिक पदार्थ यह सिद्ध करते है कि यह विभिन्न प्रकार की प्रतिकूल परिस्थितियों में उगने के लिए एक जटिल अनुकूलात्मक मेटाबोलिक सयोंग का धारक है सी वाई टाई में पहली बार क्विनिक अम्ल मायो-इनोसिताल प्रमुख मेटाबोलिक पदार्थ के रूप में चिन्हित किये गए सी एम एस का प्रयोग करके जलरहित निष्कर्ष से अन्य मेटाबोलिक पदार्थ जैसे ए-टोकोफेराल व् सिनामिक अम्ल चिन्हित किये गए इस प्रकार से मेटाबोलिक पदार्थ अब तक इस पादप में नही खोजे गए थे। कवक एन्डोकाईट (निग्रोस्प्योरा) का इस पादप से पृथक्करण प्रथम रिपोर्ट है।

औषधीय एवं संगध पौधों कि पादप रासायनिक अध्ययन

नौ औषधीय एवं संगध पौधों से निष्कर्षण, पृथक्करण तथा शुद्धीकरण का कार्य किया गया।

पादप गोंद की सुधार युक्त कार्यकारी गुणवत्ता के अध्ययन हेतु 10 से अधिक गोद गमफिल्म का प्रतिक्रिया डेरिवेटाईजेसन व् करेक्टराईजेसन का कार्य किया तथा उनसे किस्में भी विकसित की गई। दो अल्प ज्ञात बीजों का डेरिवेटाईजेसन व् तैलीय करेक्टराईजेसन क्रिया किया गया।

राष्ट्रीय वनस्पति अनुसंधान संस्थान के वनस्पति उद्यान में लगे हुए *बिक्सा, बीटेल, ट्राईगोनेला, मोरिंगा, एनसिफैलाइटोस, सिजीजियम* तथा कुछ अन्य प्रजातियों की एंटीआक्सीडेंट क्षमता का निर्धारण किया गया।

पौधों से व्युत्पन्न तीन गोंदों की जेलिंग गुणवत्ता का अध्ययन किया गया तथा हाइड्रोजन के फार्मूलेशन में प्रयोग होने वाले कामर्शियल जेलेंट्स से तुलनात्मक प्रास्पेक्सन भी किया गया। विभिन्न प्रकार की गुणवत्ता वाली जेल का निर्माण किया गया। पाँच से अधिक पादप गोंद को फार्मूलेशन एवं प्रभावशाली वितरण हेतु इक्सीपेंट्स के रूप में करेक्टराइज किया गया। तीन गोंदों को नई रोकने कि क्षमता का अध्ययन किया गया तथा ट्रांसडर्मल पैचेज में उनके संभावित उपयोग का आई आर द्वारा अध्ययन किया गया जिसकी प्रक्रिया मानकीकरण के आधीन है।

पाँच पादप गोंदों तथा स्रावों का प्रयोग करके लाल तथा पीले फूलों के रंगो के स्परीकरण की प्रक्रिया की गई। कुछ अधिक शक्ति तथा गुणनशीलता (लचीला) युक्त पालीमेरिक जैवविघटनकारी फिल्मे पादप गोंद स्रोतों (एन बी आर पी 1-11, एन बी आर पी 1-13, एन बी आर पी 1-23) से निर्मित की गई।

12 फिनालिक यौगिक उदाहरणतः गैलिक अम्ल, क्लोरोजेनिक अम्ल, केफिक अम्ल, रूटिन. सिनेपिक अम्ल, कौमेरिक अम्ल, फेरुलिक अम्ल, डाईडेजिन, क्योरसेटिन, जेनेस्टिन, कैमिफिरोल और बायोकेनिन- ए के एकल दौड़ एच बी एल सी द्वारा प्रथक्करण हेतु विश्लेषात्मक विधि का विकास किया गया।

दीमक रोधी क्रियाएँ

चार विभिन्न स्थानों से लिए गए *हेडीकियम स्पीकेटम* के राइजोम्स के एसेंसियल आयल निष्कर्स की विभिन्न सान्द्रताओं की दीमक रोधी क्रियाओं का *माइक्रोटर्मिस बीसोनी* के विरुद्ध परीक्षण किया गया सभी चार नमूनों में मृत्युदर तथा प्रतिकरशी गुणवत्ता का महत्वपूर्ण प्रदर्शन किया जो कि 20% कलोरपाईसीफास के समतुल्य है।

RESEARCH & DEVELOPMENT

SUPRA-INSTITUTIONAL NETWORK PROJECTS

1. Bioprospection of plant resources and other natural products (BioprosPR)

Nodal Scientist: DK Upreti

Scientists: P Agnihotri, AK Asthana, S Bag, Baleshwar, Soumit K Behera, LB Chaudhary, T Husain, PB Khare, S Khatoon, S Kumar, A Lehri, KN Nair, S Nayaka, SK Ojha, M Pal, A Prakash, TS Rana, ChV Rao, S Rastogi, AKS Rawat, S Roy, K Sahai, AP Singh, BN Singh, OP Sidhu, M Srivastava, SK Srivastava, MR Suseela, VV Wagh

Technical Staff: Sandeep K Behera, B Datt, KK Ingle, A Kumar, A Niranjan, MM Pandey, KK Rawat, V Sahu, S Verma

Objectives:

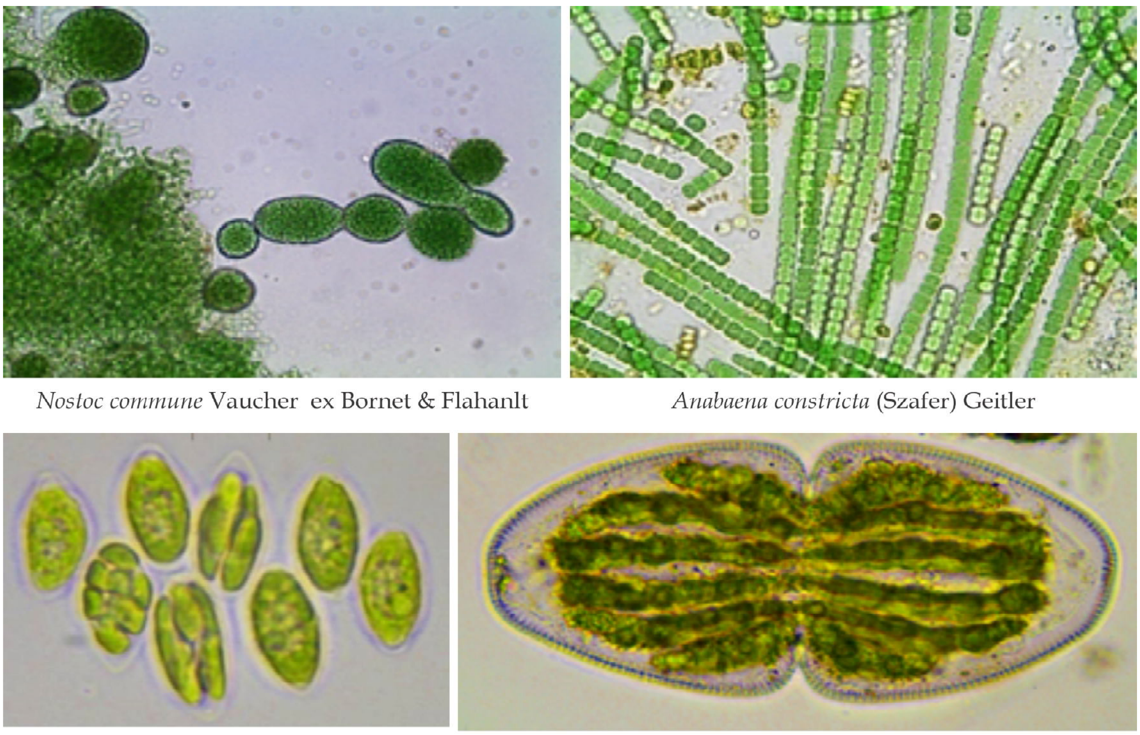
- Bioresource mapping, eco-geographic assessment, development of DNA bank and plant DNA barcode in selected study sites in the Himalayas and Western Ghats.
- Metabolic profiling of medicinally important plants for identification of commercially important chemotypes.
- Development of novel drug combinations using natural products to increase efficacy of known drugs.

Highlights

Bioresource mapping of Govind Wildlife Sanctuary

Bioresource mapping in Govind Wildlife Sanctuary (GWLS) in Uttarakhand was continued with the objective to systematically document and study the diversity in plant and lichen resources and identification of elite plants and lichen genotypes for bioprospecting for new phytomolecules and bioindicators for biomonitoring and bioremediation. During the current reporting period, more than 154 algal samples were collected from different altitude ranges between 1300 m to 4150 m. The identification of the samples resulted in 127 algal taxa, which is the first documentation of algae from GWLS. The algal flora in the sanctuary is dominated with species belonging to Chlorophyceae, Cyanophyceae, Bacillariophyceae and Euglenophyceae classes. Among various sites, Osla exhibited maximum algal diversity represented by 55 taxa, followed by 34 and 11 algal taxa in Har Ki Dun and Morinda Lake, respectively (Fig. 1).

A total of 98 species of lichens belonging to 43 genera and 18 families were enumerated from GWLS. The Parmeliaceae, Physciaceae and Pyrenulaceae were the dominant lichen families, while *Heterodermia* and



Nostoc commune Vaucher ex Bornet & Flahanlt

Anabaena constricta (Szafer) Geitler

Scenedesmus bijugatus (Turp.) Kutzing

Cosmarium sp.

Fig. 1. Some algal species recorded from GWLS

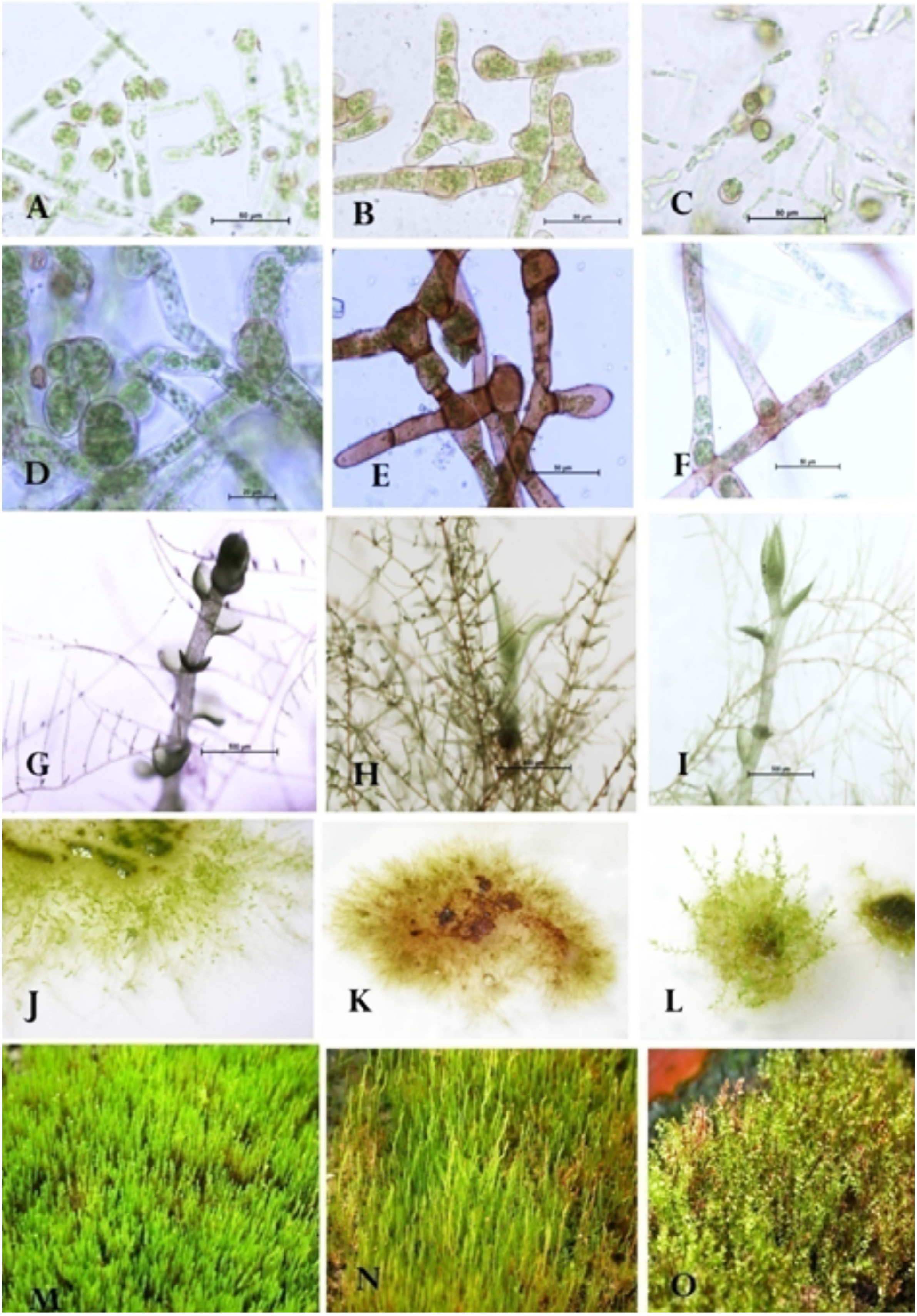


Fig. 2. *Bryum argenteum*: A. Germinating spores; D. Protonemal Stage; G. A young gametophore; J. *In vitro* raised plant population; M: Plants after transferring on soil in pots. *Bryum billarderi*: B. Germinating spores; E. Protonemal Stage; H. Young gametophores; K. *In vitro* raised plant population; N. Plants after transferring on soil in pots. *Bryum pallescens*; C. Germinating spores; F. Protonemal stage; I. A young gametophore; L. *In vitro* raised plant population; O. Plants after transferring on soil in pots.

Phaeophyscia were among the dominant genera recorded from various sites in GWLS. Bryophyte taxa recorded from GWLS included a total of 135 species belonging to 86 genera and 45 families, of which 84 species in 57 genera and 25 families were mosses; 49 species in 27 genera and 18 families were liverworts, and 2 species in 2 genera and 2 families were hornworts. The occurrence of the following six bryophyte species in GWLS constituted new regional records for Western Himalaya: *Solenostoma flagellaris* (Amak.) Vána & D.G. Long, *Aulacopilum glaucum* Wilson, *Tetralophozia filiformis* (Stephani.) Urmi, *Leptopterigynandrum decolor* (Mitt.) M. Fleisch., *Homalothecium neckeroides* (Griff.) Paris, *Microcampylopus khasianus* (Griffith) Giese & J. P. Frahm.

In order to establish protocols for *ex situ* regeneration of potential bryophyte taxa, *in vitro* propagation of three species of *Bryum* viz., *B. argenteum* Hedw., *B. billarderi* Schwagr. and *B. pallescens* Schleich. ex Schwagr. was carried out. *B. pallescens* and *B. argenteum* exhibited well grown plants as compared to *B. billardieri* (Fig. 2).

Taxonomic studies on about 85 specimens of pteridophytes collected from GWLS revealed the occurrence of 55 species under 26 genera and 15 families.

Reproductive performance of *Caltha palustris* at varying altitudes of Har Ki Doon in GWLS was studied and it was observed that reproductive phenology delayed at higher elevation. 'Syrphid flies' were common visitors at all elevations in spite of their low activity at higher elevation. Though *C. palustris* presented marked variation with elevation, reproductive success was equally hampered at all the elevations due to high (86%) post fertilization ovule abortion, possibly due to harsh environmental condition during seed development.

As part of ecogeographic mapping, tree phytosociological analysis in three altitudinal gradients (sub-tropical, temperate and sub-alpine) in GWLS by laying of 25 random quadrats of 20mX20m in each altitude was completed.

Genetic diversity assessment in West Himalayan populations of *Bergenia ciliata*

DAMD and ISSR markers were used to analyze genetic diversity and population structure in 74 accessions of eight populations of *B. ciliata*: Govind Wildlife Sanctuary (GWLS), Nainital (NTL), Ranikhet (RNKT), Binsar Wildlife Sanctuary (BWLS), Shimla (SHMA), Kufri (KFRI), Kullu (KULLU) and Pithoragarh (PTH). The study revealed low levels of genetic differentiation (G_{ST} = 0.33) and high genetic flow (Nm =1.02) between populations of *B. ciliata*. The data suggests that high genetic flow is one of the major factors responsible for low genetic differentiation. DAMD and ISSR profiles of *B. ciliata* provide the means of rapid characterization of accessions within the populations, and thus enable the selection of appropriate accessions for further utilization in conservation and prospection programmes of this important medicinal plant.

DNA Barcoding of selected medicinal plants of GWLS

Completed plant DNA barcode of 11 species and collected 180 accessions of *Bergenia* from J&K, HP, UK, Sikkim, Darjeeling (WB) for genotypic and chemotypic analysis.

***Ficus* L. (Moraceae) of the Gangetic plain in India**

About 115 species of *Ficus* L., have been reported from India, of which ca. 46 species are found in the Gangetic Plains, many of them in cultivation. Morphological diversity in some variable species of *Ficus* has been examined to understand the limit of the species and relationship with allied species. *Ficus krishnae* has been considered for diversity study and its relationship with *F. benghalensis*. Based on morphological, anatomical and cytological evidences *F. krishnae* is reinstated as a true species (Fig. 3).

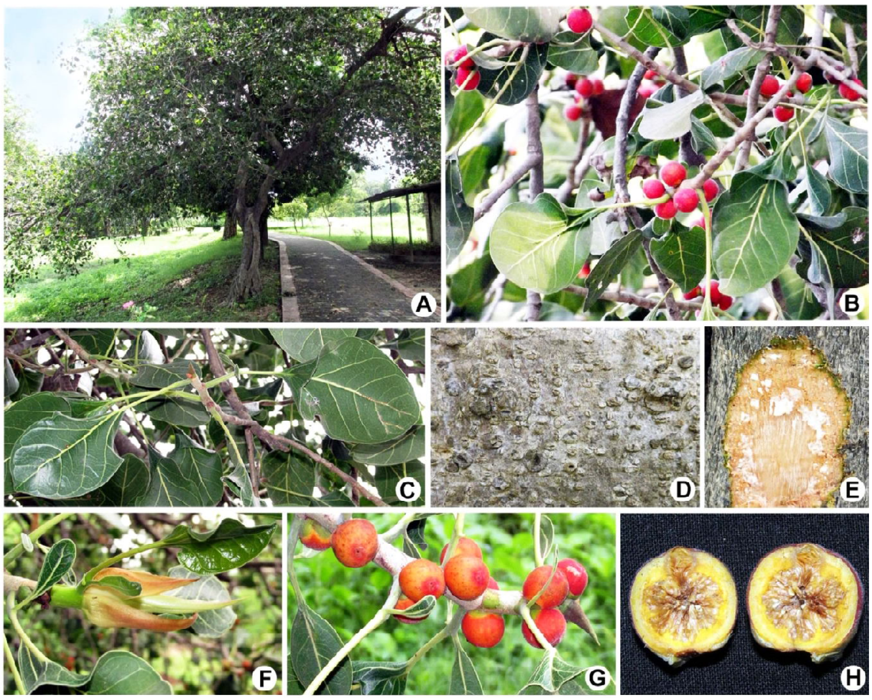


Fig. 3. *Ficus krishnae* : A. Habit; B. Close-up of habit with leaves and figs; C. Close-up of habit showing arrangement of leaves; D. Bark of stem; E. Blaze of the stem with latex; F. Stipules; G. Figs; H. Vertical section of a fig. (Source: *Phytotaxa* 192 (3): 169-180. 2015).

Nanoformualtion from a Lichen

A novel Swarna-based herbo-metallic colloidal nano-formulation as potent inhibitor of *Streptococcus mutant* quorum sensing was developed using bioactive metabolites of *Usnea longissima*, collected from GWLS.

Metabolite fingerprinting of potential anti-cancerous plants of GWLS

Potential cytotoxicity was observed in three extracts: 95% ethanolic extracts of NBC 11, NBC12 and NBC14. The 95% ethanolic extract of NBC 11 was further fractionated and its methanol fraction was found to be active. The methanol fraction was sub-fractionated using column chromatography with varying proportions of chloroform and methanol as solvent. The sub fractions were subsequently subjected to cytotoxic activity on cancer cell lines. The sub-fraction eluted at solvent ratio chloroform: methanol, 95:5, showed significant toxicity against colon and breast cancer cell lines. The LC-MS of active sub-fraction identified the presence of scopoletin and coptisine (Fig. 4) and an unknown compound which showed a higher Area % value, thus indicating high concentration. The unknown phyto-compound was run on preparative TLC in solvent system ethyl acetate: methanol:water (9:1:0.5). The band was scrapped and dissolved in methanol. It was further subjected to LC MS/MS and identified as ajmaline.

The 95% ethanolic extract of NBC-14 showed cytotoxicity against various cancer cell lines. The extract was subjected to successive fractionation with different solvents, including hexane, chloroform, ethyl acetate, and butanol which were further tested for their cytotoxicity. The hexane fraction was found to be most potential against lung (96.66%), breast (96.535%), colon (92.539), ovary (95.637) and head & neck (99.344%) cell lines. The cytotoxic activity of NBC 14 had not been reported so far, hence the plant has tremendous IPR value. The hexane fraction of NBC 14 is now under *in vivo* studies at CSIR-CDRI Lucknow.

Phytochemical profiling of potential medicinal plants

Phytochemical evaluation of *Betula utilis* barks (B1, B2), *Berginia ciliata* and *Hedychium spicatum* collected from different geographical zones in the Himalayas was carried out. Development of oil, sugar, acid and phenolic markers was done for identification and quantification of major/ minor known /unknown bioactive markers for metabolic profiling. Quantification of useful phytochemicals was done and antioxidant potential was determined. Determination of solution properties for prospect of its solution in development of some newer formulations to develop affordable health care and economical use. Investigation of the developed *Betula* bark markers is underway by extraction and isolation of bioactive fractions/isolates. Interaction with sugars/ additives and derivatization for development of novel drug combinations is initiated to increase activity and efficacy for its utilization in plant natural products/compounds.

Ethyl acetate extract (MBA-3) was column chromatographed over silica gel for isolation of potent anticancer molecule. Ten compounds have been isolated from ethylacetate fraction. Seven out of these 10 compounds

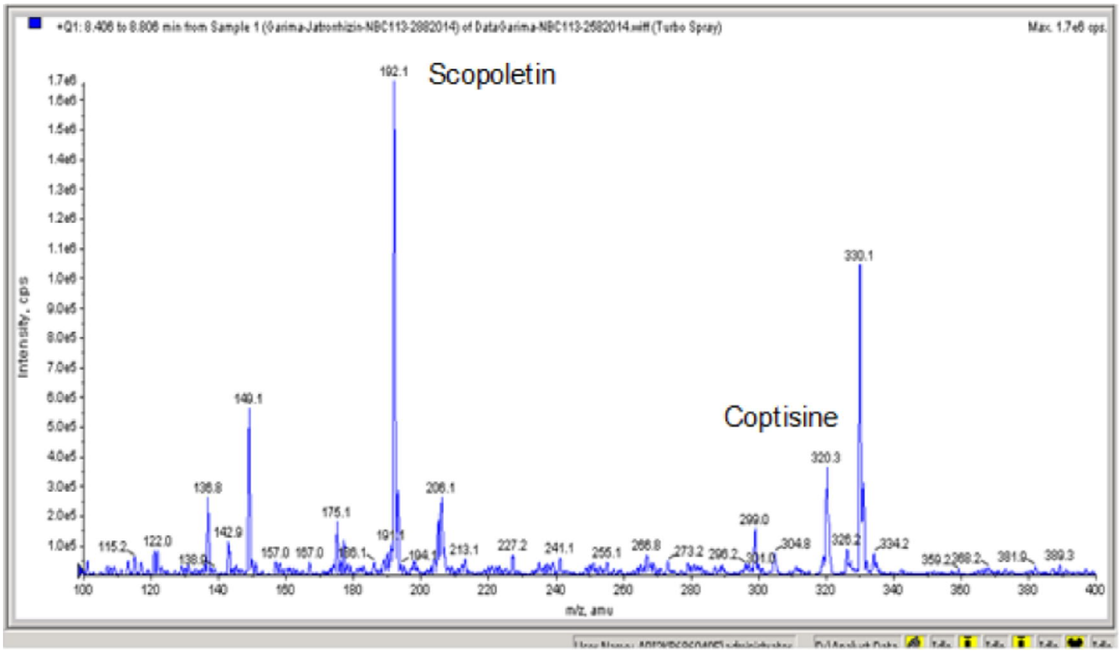


Fig. 4. LC-MS profile of NBC 11 column chromatography sub-fraction 95:5

has been identified as betulin, betulinic acid, Lupeol, oleanolic acid, beta-sitosterol, alpha amyrin and ursolic acid. Alpha amyrin and ursolic acid have been reported for the first time from *Betula utilis* bark**.** Identification of other three compounds is in progress. All the seven identified compounds are examined for anticancer activity at CSIR-CDRI, Lucknow.

Berginin content in 112 samples of *Bergenia ciliata* has been estimated. Extraction has been done for other thirty samples. Methanol extracts of 28 samples of *Betula utilis* bark from different geographic regions will be examined at CDRI, Lucknow for their markers quantification via mass spectrometry and anticancer activity.

Extraction of *Hedychium spicatum* rhizome has been done in methanol and further fractionated into different solvent systems such as hexane, ethyl acetate, chloroform, and water. Column chromatography of ethyl acetate fraction for isolation of bioactive compound is under process.

Four rhizome samples of *Hedychium spicatum* from four different geographical areas (MHS-1, MHS-2, MHS-3, and MHS-4) were hydro distilled for oil extraction. All the four samples were analyzed via GC-MS for their major component percentage variation (Fig. 5). Anticancer activity of the four oil samples has been tested. Percentage inhibition at 100 ìg/ml dose of essential oil samples were found to be active against human cancer cell lines like Lung (A549), Colon (DLD1), Breast (MCF7), Head and Neck (FaDu), Cervical (HELA), Breast (MDAMB-231) and Colon

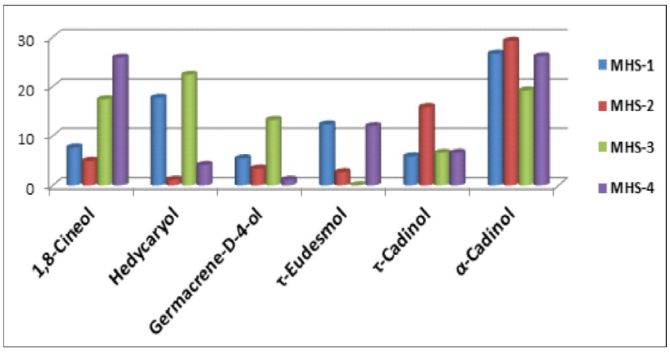


Fig. 5. Variation is major components of *Hedychium spicatum* rhizome oil

Table 1. IC_{50} (µg/ml) Values of different *Hedychium spicatum* oil samples against 7 cancer cell lines

Sample	IC_{50} Values against 7 Cancer Cell Lines						
	DLD-1	FADU	SW620	A549	HELA	MCF-7	MDAMB-231
MHS-1	41.86	33.35	73.18	32.08	44.16	90.5	75.9
MHS-2	**64.08**	**59.11**	**81.96**	**56.96**	**65.13**	**94.93**	**76.69**
MHS-3	45.16	35.74	69.35	35.5	42.54	80.51	66.4
MHS-4	42.87	26.77	74.79	32.65	43.55	56.7	69.9

(SW620) with IC_{50} value ranging from 26.77 to 94.33 µg/ml. Sample MHS-2 was significantly much active against most of the cell lines. Major component of MHS-2 is alpha-cadinol and beta-cadinene that may be responsible for its anti-cancerous activity (Table 1).

Publications

1. Asthana AK and Gupta S – Two mosses (Bryophyta) new to western Himalaya. *Indian J. For.*, 2014, **37**(2) : 189-92.
2. Asthana AK and Sahu V – New national and regional bryophyte records: *Homalothecium neckeroides* (Griff.) Paris; *Microcampylopus khasianus* (Griffith) Giese & J.-P. Frahm. *J. Bryol.*, 2014, **36** (4) : 311, 313.
3. Asthana AK and Sahu V – New national and regional bryophyte records : *Leptopterigynandrum decolor* (Mitt.) M. Fleisch. *J. Bryol.*, 2014, **36**(2) : 141-142.
4. Behera SK and Khare PB – First Report of Pteridophytes from Govind Wildlife Sanctuary, Uttarkashi, Uttarakhand, India. *Trop. Pl. Res.*, 2014, **1**(2) : 37-47.
5. Dixit P, Mishra T, Pal M, Rana TS and Upreti DK – *Polyalthia longifolia* and its pharmacological activities : Review. *Int. J. Scient. Innovative Res.*, 2014, **2**(1) : 17-25.
6. Dixit P, Pal M and Upreti DK – Comparative studies on the analytical and antioxidant activities of the medicinally important stem bark of *Holoptelea integrifolia* *J. Planar Chromatograp.*, 2014, **27**(3) : 162–165.
7. Eden H, Jones WC, Bajpai O, Chaudhary LB and Whittaker RJ – Isolated Ficus trees deliver dual conservation and develpoment benefits in a rural landscape. *Ambio,* 2015, **44**(7) : 678-684.
8. Karakoti N, Bajpai R, Upreti DK and Nayaka S – Lichen flora of Govind Wildlife Sanctuary in Uttarkashi district, Uttarakhand, India. *Geophytology*, 2014, **44**(1) : 41-48.
9. Mishra GK and Upreti DK – Altitudinal distribution of cetrarioid lichens in Govind Wildlife Sanctuary, Garhwal Himalaya, Uttarkhand, India. *Geophytology, ,* 2015, **45**(1) : 9-19.
10. Pal M, Mishra T, Kumar A, Baleshwar, Upreti DK and Rana TS – Characterization of fatty acids in the bark of *Betula utilis* growing in high altitudes of Himalaya. *Chem. Nat. Compounds,* 2015, **51**(2) : 326-327.
11. Sahu V and Asthana AK – Two moss species new to Govind Wild Life Sanctuary in Uttarkashi District, Uttarakhand, India. *Geophytology*, 2014, **44** (2) : 149-154.
12. Singh BN, Upreti DK, Singh BR, Pandey G, Verma S, Roy S, Naqvi AH and Rawat AKS - Quercetin sensitizes fluconazole -resistant candida albicans to induce apoptotic cell delta by modulating quorum sensing. *Antimicrob Agents Chemother.*, 2015, **59** (4) : 2153-2168.
13. Singh BN, Prateeksha, Pandey G, Jadaun V, Singh S, Bajpai R, Nayaka S, Naqvi AH, Rawat AKS, Upreti DK and Singh BR -- Development and characterization of a novel Swarna-based herbo-metallic colloidal nano-formulation – inhibitor of *Streptococcus mutans* quorum sensing. *RSC Advances*, 2015, **5**(8) : 5809-5822.
14. Tiwari R, Sudhakar JB, Chaudhary LB, Murthy GVS and Durgapal A – Revisit the taxanomy of *Ficus krishnae* (Moraceae). *Phytotaxa*, 2015, **193** (3) : 169-180.

2. Plant Diversity: Studying adaptation biology and understanding/exploiting medicinally important plants for useful bioactives (SIMPLE)

Nodal Scientist: Nandita Singh

Scientists: Soumit K Behera, LB Chaudhary, V Pandey, SA Ranade, S Roy, K Sahai, PA Shirke, OP Sidhu, PK Srivastava

Technical Staff: S Jamil, Anil Kumar, KK Rawat

Objectives:

- Understanding the possible role of chemicals (chemical ecology), genes (ecological genomics), proteins (ecological proteomics) and functioning (ecological physiology) in ecosystem.
- Species response to elevated CO_2 under Free Air Carbon dioxide Enhancement (FACE) System and field conditions in different ecosystem.

Highlights

Metabolite profiling of guggul and elucidation of biosynthetic pathway responsible for generation of major biologically active molecules.

Metabolites from three accessions of *Commiphora wightii* (guggul) collected from arid and semi-arid regions (Barmer, Jaisalmer and Jodhpur) of Rajasthan were extracted in different polarity solvents. Metabolite profiling of aqueous and non-aqueous extracts was carried out using GC-MS. Identified chemically diverse metabolites from aqueous and non-aqueous extracts of stem of different accessions of *C. wightii*. Variability was found in the concentration of metabolites in leaves of Barmer and Jaisalmer accessions (Fig. 1).

Altitudinal adaptation in *Arabidopsis thaliana*

Arabidopsis thaliana was collected from the western Himalayas at altitudes ranging from 700 m amsl to 3400 m amsl. The selected sites were Dehradun (Deh), Munasyari (Mun) and Chhitkul (Chit) at altitude 700, 1829 and 3453 m amsl, respectively. The representative sample pictures of *Arabidopsis thaliana* in the field are shown in Fig. 2. Leaves were collected from mid flowering stage from each site. Quality and quantity of total RNA samples were checked on agarose gel as well as using Bio-analyzer.

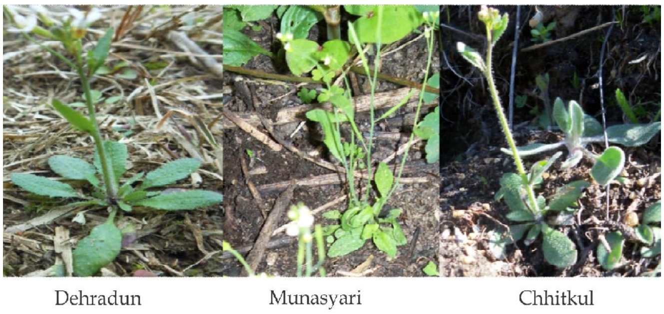


Fig. 2. *Arabidopsis thaliana* plants in natural habitats

Analysis of small RNA sequencing Data : Seven small RNA libraries were constructed, three from the field grown plants and four from in house grown plants including control (Col 0). After sequencing 17372730 reads from Deh field, 20658953 reads were obtained from Mun field and 24600818 reads from Chit field plants. Glass house grown plants generated 15067605 reads from Deh ,19971232 reads from Mun and 13888785 from Chit and 1144112 from Col 0. The reads length distribution of all the seven libraries show that majority of reads were 21 and 24 bp in length (Fig 3).

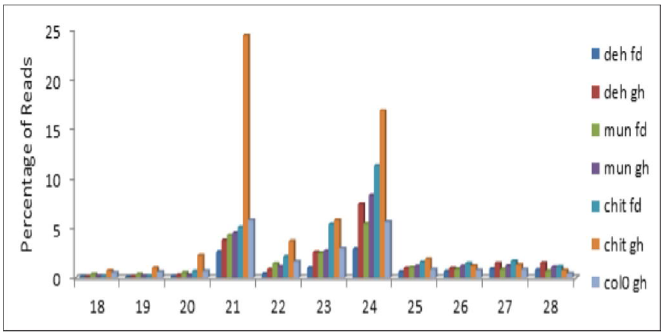


Fig. 3. Length distribution of small RNA population

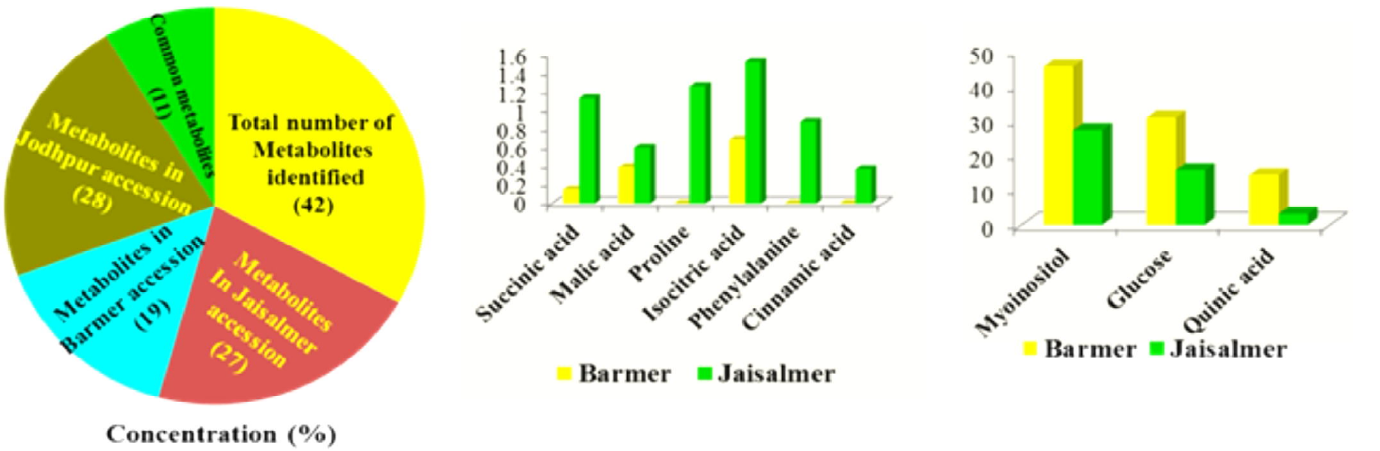


Fig. 1. Identified metabolites of *Commiphora wightii* from arid and semi-arid regions of Rajasthan

Target prediction and functional characterization: The biological role of miRNA is better understood by their target genes and their function. Therefore, a search was made for putative target genes by using a plant small RNA target analysis tool: psRNA-Target at default parameters setting. Role of miRNA Targets when compared with different accessions is given in Fig. 4.

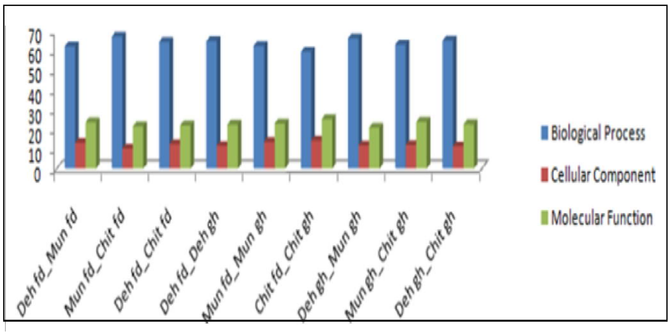


Fig. 4. Role of miRNA Targets

Further analyses and validation experiments of these miRNAs may provide cue to their role in adaptation of these plants which are exposed to extreme sets of climatic conditions including temperature, UV radiation and other abiotic stress across altitudinal gradient.

Adaptation of *Cyamopsis tetragonoloba* (Guar) to Arid/ Semi arid region

Diversity analysis among some of the *Cyamopsis tetragonoloba* (Guar) germplasm

The distribution of accessions in the UPGMA tree clusters obtained from RAPD and ISSR primers exhibiting greatest polymorphism is not correlated to their provenance. The collected germplasm includes at least five broad groups of accessions: (1) Accessions OG1 to 3 in red ovals are non-Guar legume taxa used as outgroup.(2)The Guar taxa are distributed in 5 major clusters A to E as shown in circles and that are indicative of as many genetic lineages (Fig 5).

Physiological performance of different Guar varieties

Twenty eight accessions of Guar were grown in the field, to study their performance under field conditions at Lucknow. The desiccation tolerance of these 28 accessions was studied by the "leaf drying method". Four accessions were selected for further physiological studies (2 tolerant and 2 sensitive). Gas-exchange and chlorophyll fluorescence to study Photosystem II and I were undertaken. The photosynthetic performance and efficiency of the selected 4 accessions was comparable

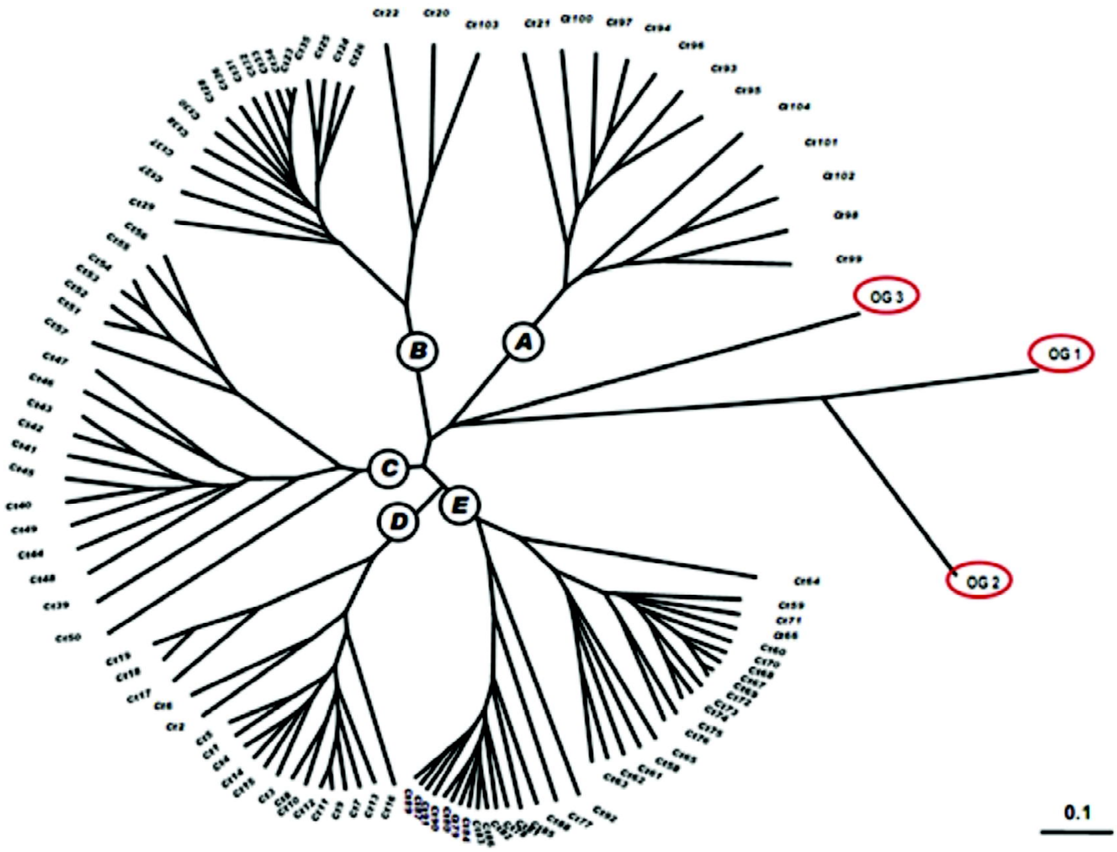


Fig 5. Radial UPGMA tree for the cumulative PCR profile data for RAPD + ISSR primers in case of Guar

under ambient conditions. Further, three week old plants of four varieties of guar plants, RGC-1066, RGC-1002 and RGC-936, RGC-1038 were subjected to water stress for 10 days and later allowed to recover. The relative water content (RWC) and photosynthetic rates were monitored throughout the experiment. RGC-1002 showed higher RWC, photosynthesis rates and better recovery. Under drought anthocyanin content showed maximum increase in RGC-1066 and least in RGC-1002. Total phenolic content showed maximum increase (46%) in RGC-1002 under drought while it was least in RGC-936 (22%). Proline content was maximum in RGC-936 and was minimum in RGC-1002 under drought. Our studies showed that the variety RGC-1002 was the most tolerant towards drought stress (Fig. 6).

Response of Guar and Teak to elevated CO_2 under FACE Conditions

Physiological study of Guar

Two varieties of Guar (RGC-1002 and RGC-1066) were grown under ambient and elevated conditions of CO_2 (480 µmol mol^{-1} air) during the summer season. Diurnal Photosynthesis parameters were studied. Maximum photosynthesis rates were comparable in the two varieties under ambient and elevated CO_2 conditions (Fig. 7). Carboxylation efficiency was higher and CO_2 compensation point was lower under CO_2 elevated conditions in both varieties. However, RGC-1002 showed better performance than RGC-1066. Electro transport Rate of PSII did not change significantly however, ETR(I) increased in both varieties under elevated CO_2 conditions.

Proteomics study of Guar

Leaf protein of Guar varieties RCG 1066 and RCG 1002 (for both ambient and elevated) was separated through 2-D. Isoelectric focusing analysis showed that out of 50 differentially expressed proteins, 23 were found to be upregulated and 27 downregulated in RCG 1066 under elevated CO_2. Whereas, in case of RCG 1002, out of 32 differentially expressed proteins 19 were found to be upregulated and 13 downregulated.

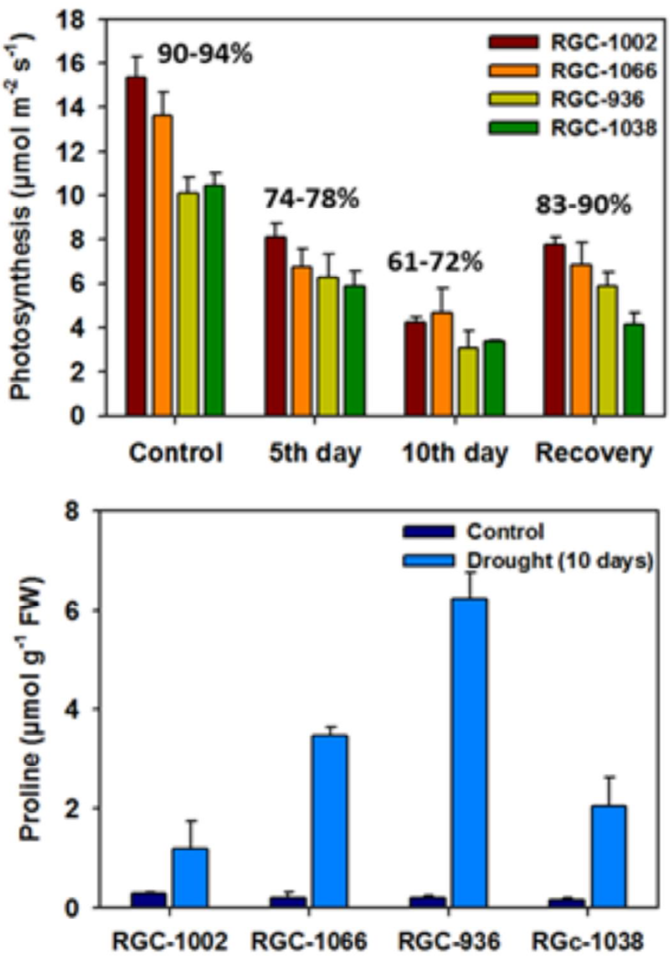


Fig. 6. Physiological performance in Guar varieties under drought stress

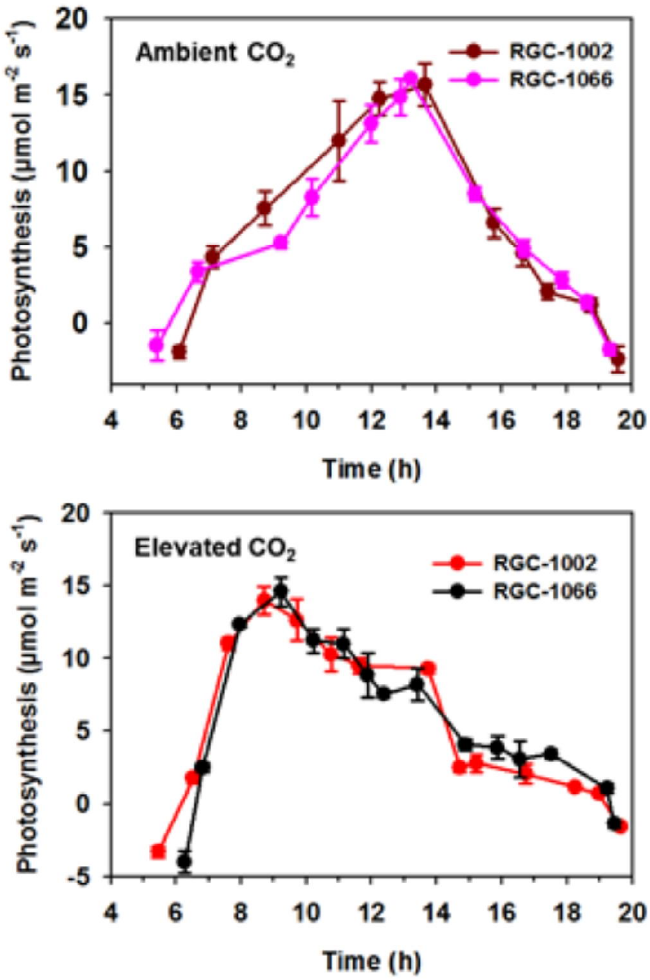


Fig. 7. Photosynthetic performance in Guar under Free-Air CO_2 Enrichment (FACE)

Physiological study of Teak

Teak trees leaf area index (LAI) was measured during monsoon season in both control and elevated FACE rings. Aboveground and below ground biomass were estimated in teak trees of approximately two years age in both control and elevated CO_2 rings by harvesting three trees in each ring. A higher LAI and higher aboveground and belowground biomass in teak tress in elevated CO_2 rings was observed as compared to control trees (Fig. 8).

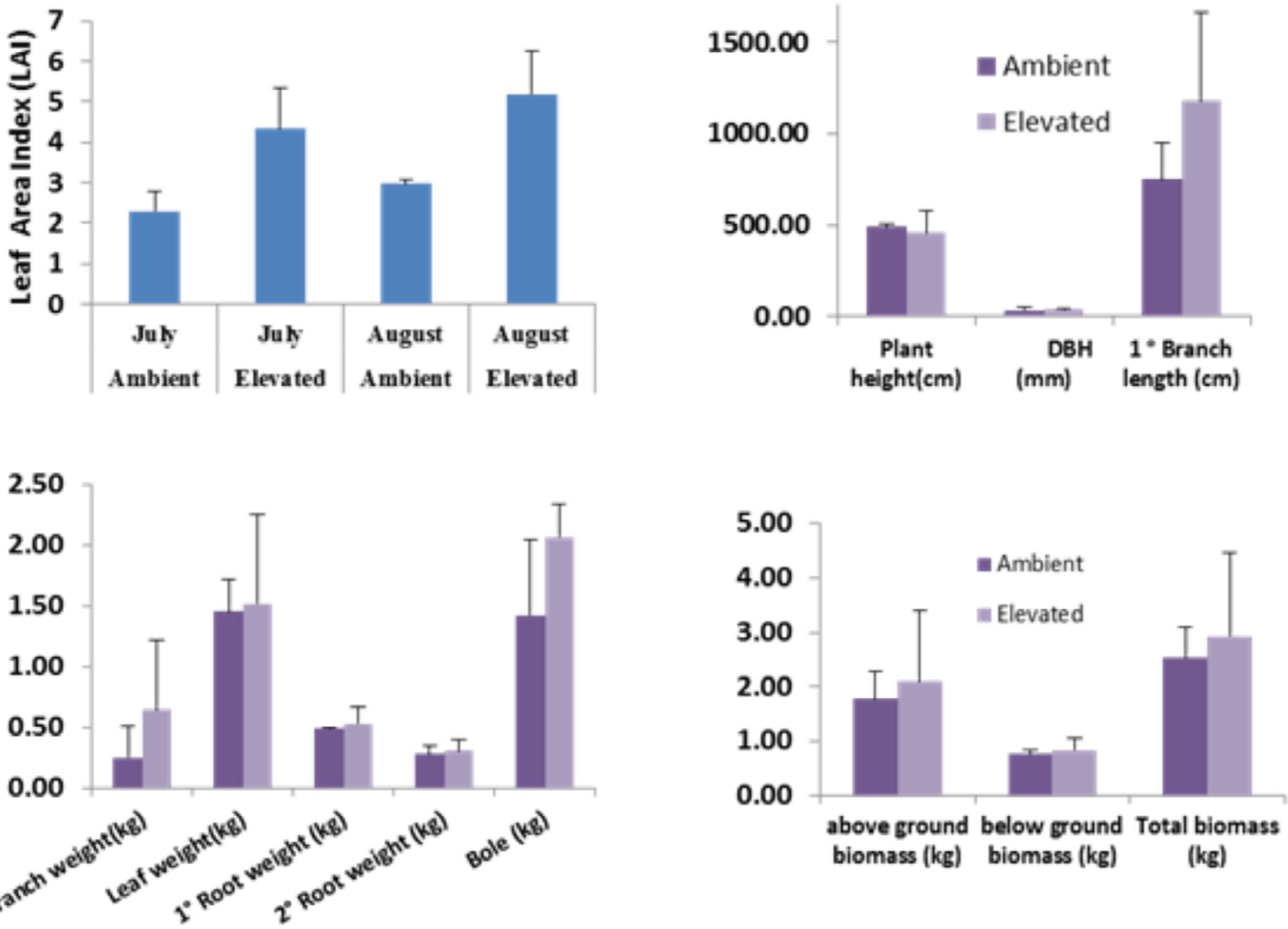


Fig. 8. Leaf area index, phenology and component wise biomass of 2 yr Teak trees under elevated CO_2 and control FACE rings

3. Integrated NextGen approaches in health, disease and environmental toxicity (INDEPTH)

Nodal Scientist: RD Tripathi

Scientists: D Chakrabarty, S Mallick, UN Rai, N Singh, PC Singh, SN Singh, PK Srivastava, Suchi Srivastava

Technical Staff: S Dwivedi, B Kumari

Objectives:

- Phytoextraction of arsenic and strategy for optimizing low grain arsenic in rice.
- Study of potential microbes involved in soil carbon sequestration through rice straw decomposition.
- Development of a microbe based strategy for faster degradation of petroleum hydrocarbons.

Highlights

Phytoextraction of arsenic and strategy for optimizing low grain arsenic in rice

Low grain arsenic (As) rice variety

Low grain arsenic rice variety CN1794-2–CSIR-NBRI (Fig. 1) was selected as best rice variety in terms of low grain As accumulation, higher productivity and rich in mineral nutrients after multilocational trials. It is scheduled to be released as safe arsenic variety by Govt. of West Bengal.

Fig. 1. New rice variety CN1794-2–CSIR-NBRI to be released for cultivation

Intervention of arsenic accumulation in rice by sulfur nutrition in rice

Sulfur supplementation resulted in decrease in As content during both arsenate and arsenite exposure in rice plant and resulted in toxicity reduction in rice (Fig 2).

Role of algae in mitigating arsenic in rice plants

Inoculation of algae *Chlorella vulgaris* and *Nannochloropsis* sp. greatly influenced As concentration in rice and achieved a larger biomass, reduced uptake of As in shoot and cellular toxicity as compared to uninoculated rice and thus mitigate the acute toxicity of As in rice. Further, rice inoculated with *Nannochloropsis* sp. showed better antioxidant enzymatic responses against As stress.

Isolation of arsenic tolerant novel bacterial strains from rhizospheric regions of rice roots from arsenic contaminated areas of Uttar Pradesh

Isolated arsenic tolerant bacteria from rhizospheric regions of rice roots from arsenic contaminated areas of Uttar Pradesh. 24 bacterial strains were screened for their abilities to tolerate high level of Arsenic. Out of these five bacterial strains (NBRI-011, -012, -013, -014 -015) showed good growth in culture plates containing concentration of As (V) ranging from 100 to 40,000 mg l^{-1} . All five isolates showed Plant Growth Promoting Response (PGPR) activity. On the basis of 16s rDNA analysis and morphological, biochemical and physiological characteristics, the hypertolerant three bacterial strains have been identified as NBRI-011 (*Bacillus aryabhattai*), NBRI-012 (*Brivundimonas diminuta*) and NBRI-013 (*Virgibacillus proomii*) and the identification of two is in progress.

Phytoextraction and arsenic stabilization of bacterial strains

The Five isolated strains were inoculated in arsenic treated (50 µg g^{-1}) rice root zone. The application of bacterial strains (NBRI-011, NBRI-012 and NBRI-013) decreased arsenic uptake in upper plant parts and increased stabilization of arsenic in root zone of rice plant, which leads to improved plant tolerance to arsenic and as well as enhanced plant growth promotion. Whereas, application of bacterial strain (NBRI-014 and NBRI-015) enhanced arsenic uptake in root and shoot part of rice plant which

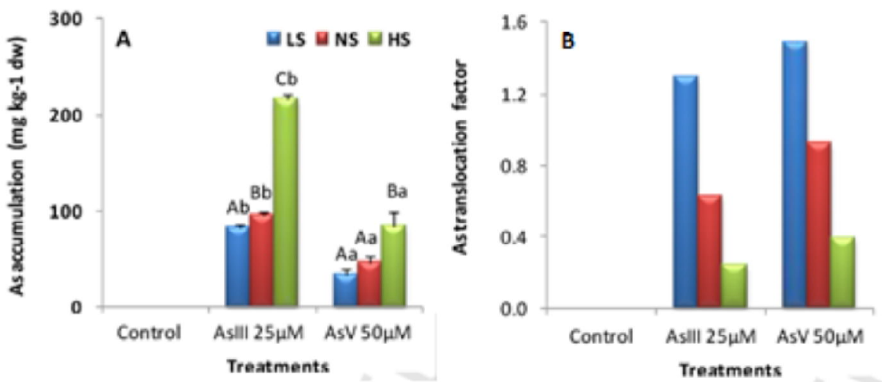


Fig. 2. Effect of sulfur supplementation on As accumulation in rice plant

might help to improve phytoextraction efficiency of plant. Overall 30-40% reduction of the total As uptake after applying the strains as compare to As treated plant (Fig. 3).

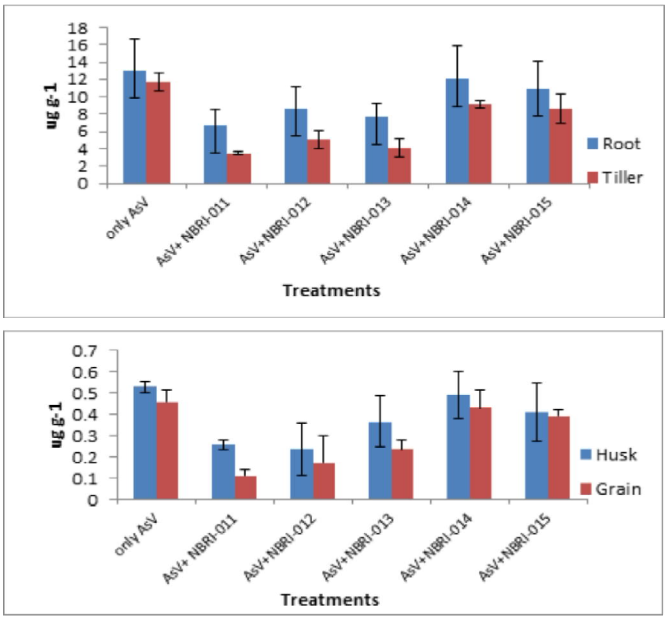


Fig. 3. Total As uptake after applying the bacterial strains

Evaluation of the effect of identified Arsenic accumulators grown along with crop plants

Contamination of soil is of major concern as it not only affects the plant growth and yield but also has impact on human health. In India rice and wheat are the major staple crops but are grown in those areas where soil is contaminated with arsenic. So the major concern here is to use the phytoremediation technology in such a way that the crops grown have safe level or nil concentration of arsenic in grains. Keeping in view the above said hypothesis an experiment was designed in which hyperaccumulators/accumulators were grown along with the crops.

Table 1. Percentage reduction of Arsenic in soil when rice and wheat were grown with Accumulator plants

Cultivar	% Arsenic Reduction in soil	Cultivar	% Arsenic Reduction in soil
R as	31.36	Wt as	27.16
R+Pt as	58.91	Wt+Pt as	59.83
R+Vt as	63.65	Wt+ Vt as	49.61
R+Ph as	63.45	Wt+ Ph as	56.08

Table 2. Percentage reduction of grain yield when rice and wheat were grown with Accumulator plants

Cultivar	% Reduction in Grain yield	Cultivar	% Reduction in Grain Yield
R as	31.82	Wt as	30
R+Pt as	9.09	Wt+Pt as	10
R+Vt as	8.18	Wt+ Vt as	14
R+Ph as	10	Wt+ Ph as	12

Three known hyperaccumulators viz. *Pteris vittata, Phragmites* and *Vetiveria* were planted along with rice and wheat in the plots having As (50 mg kg^{-1}) contaminated soil. The soil arsenic was reduced when accumulators were grown with rice. The reduction was 56 to 63% (Table 1). Whereas, the grain yield which had decreased around 30 % after As treatment was reduced to 6-14% in a growth period (Table 2).

Microbes for soil carbon sequestration through rice straw decomposition

After rigorous screening of bacterial and *Trichoderma* strains for production of cell wall degrading enzymes, microbes were further characterized for faster decomposition of rice straw using *in vitro* and *in vivo* microcosm study. Best microbial consortia were selected

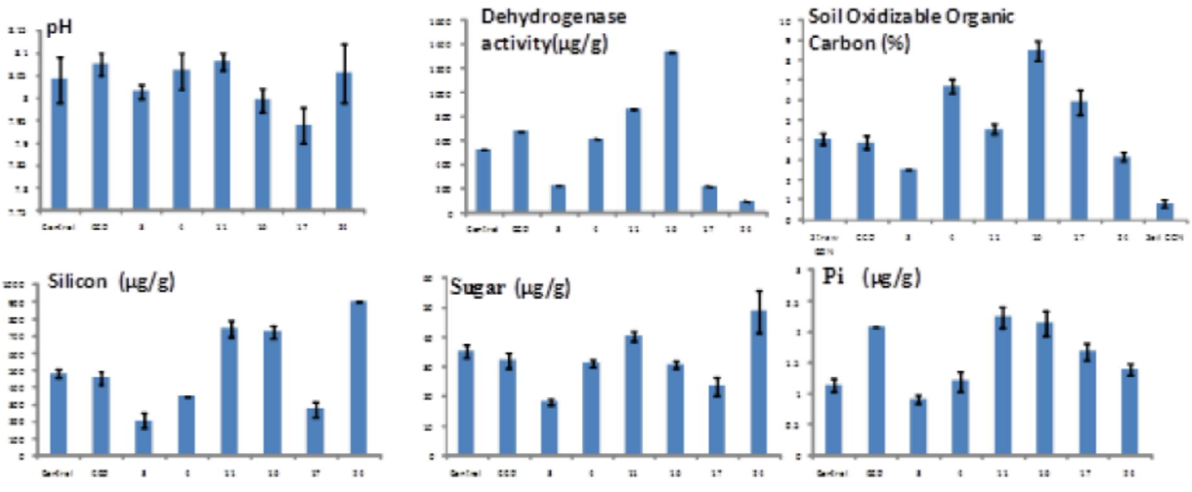


Fig. 4. Enhancement of soil nutrient pool after 60 days of rice straw decomposition

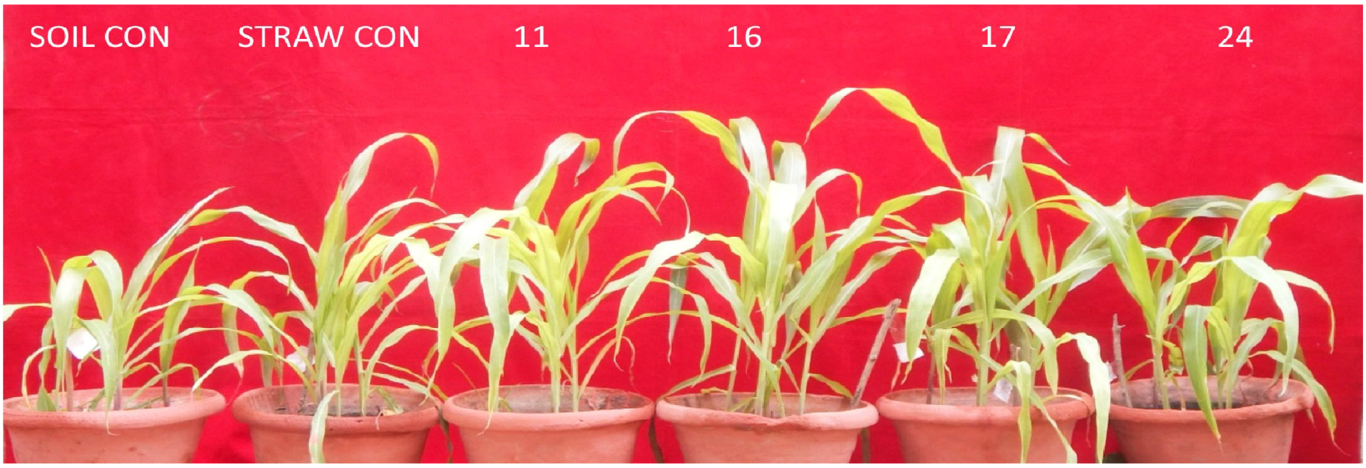


Fig. 5. Plant growth promotion of selected microbial consortia using maize as host plant.(decomposed straw and soil were mixed in 1:1 ratio before seeding)

by heaping and burying of rice straw using selected microbes in different combinations. Further only six microbial consortia, comprising species of *Trichoderma*, *Bacillus* and *Phanerochaete* were selected for future study. These combinations were found to increase soil nutrient pool after 60 days of decomposition (Fig 4). Selected consortia were used for up-scaling the decomposition experiment in pits of 48x28cm dimensions under shed conditions and consortia of *Trichoderma harzianum, T. asperellum*, *Bacillus pumilus* and *Phanerochaete chrysosporium* were found as efficient decomposers. Better plant growth promotion was also observed in maize (host plant) with the selected microbial consortia (Fig. 5).

Microbe based strategy for faster degradation of petroleum hydrocarbons

Biodegradation of Hexacosane

In-vitro degradation of hexacosane ($C_{26}H_{54}$), a HMW n-alkane, was studied in MSM by two bacterial strains i.e., *Pseudomonas* sp. BP10 and *Stenotrophomonas nitritireducens* E9, isolated from petroleum sludge, in isolation and combination. The result revealed that *Pseudomonas* sp. BP10 and *Stenotrophomonas nitritireducens* E9 could degrade 83% of hexacosane (50 ppm) in isolation while 98% in combination (Fig. 6).

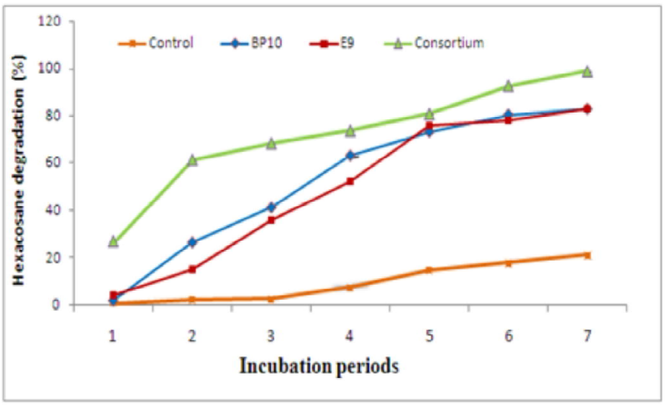


Fig. 6. Hexacosane degradation by bacterial strains in isolation and combination

Activity of alkane hydroxylase continued to increase with incubation during degradation of hexacosane degradation. The peak activities of this enzyme were recorded as high as 607 nmol mg^{-1} protein in consortium followed by 563 n mol mg^{-1} protein in E9 and least 527 n mol mg^{-1} proteins was observed in BP10. While, the peak activity of alcohol dehydrogenase enzyme was recorded as high as 2311 n mol mg^{-1} protein in consortium, followed by E9 (1494 µ mol mg^{-1} protein) and the least (802 n mol mg^{-1} protein) was recorded in BP10.

Publications

1. Jauhari N, Mishra S, Kumari B and Singh SN – Bacteria-mediated aerobic degradation of hexacosane in vitro conditions. *Bioresource Technol.*, 2014, **170** : 62–68.
2. Kumari B, Rajput S, Gaur P, Singh SN and Singh DP – Biodegradation of pyrene and phenanthrene by bacteiral consortium and evaluation of role of surfactant. *Cell Mol. Biol.*, 2014, **60**(5) : 22-28.
3. Mishra S, Singh SN and Pande V – Bacteria induced degradation of fluoranthene in minimal salt medium mediated by catabolic enzymes *in vitro* condition. *Bioresource Technol.*, 2014, **164** : 299-308.
4. Srivastava PK, Singh M, Gupta M, Singh N and Kharwar RN, Tripathi RD and Nautiyal CS – Mapping of arsenic pollution with reference to paddy cultivation in the middle Indo-Gangetic Plains. *Environ. Monitor. Assessment*, 2015, **187**(4) : 198.
5. Srivastava S and Singh N – Mitigation approach of arsenic toxicity in chickpea grown in arsenic amended soil with arsenic tolerant plant growth promoting *Acinetobacter* sp. *Ecological Engin.*, 2014, **70** : 146-153.

4. Genomics of medicinal plants and agronomically important traits (PlaGen)

Nodal Scientist: PK Trivedi

Scientists: MH Asif, S Bag, D Chakrabarty, SN Jena, CS Mohanty, SA Ranade, AP Sane, VA Sane, SV Sawant, S Shukla, PK Singh, PC Verma, HK Yadav

Objectives:

- Developing conceptual framework and specific resources for accelerating progress in the area of functional genomics related to plant development and stress response.
- Understanding and elucidating various biological processes and pathways involved in secondary plant product biosynthesis as well as proper growth, development and stress response of the plant.
- Utilization of the information generated for translational research for human health.
- Commercial utilization for better plant varieties for improved productivity and stress tolerance.

Highlights

In an attempt to elucidate papaverine biosynthesis, full-length cDNA of genes putatively involved in uncharacterized steps were cloned. Various constructs were developed and used for Virus Induced Gene Silencing (VIGS) and study of modulation in metabolite content.

Developed flavonoid-rich tomato transgenic lines expressing *AtMYB12* transcription factor of Arabidopsis. Transgenic lines exhibited enhanced accumulation of flavonols and chlorogenic acid (CGA) in leaf and fruit accompanied with elevated expression of phenylpropanoid pathway genes involved in flavonol biosynthesis (Fig. 1). In addition, global gene expression analysis in leaf and fruit suggested that AtMYB12 modulates number of molecular processes including aromatic amino acid biosynthesis, phytohormone signaling and stress responses.

To unravel complex gene regulation during fruit ripening and flower petal abscission transcriptome sequences of banana, mango fruits and rose petal were established and analyzed in detail. Comparative analysis of ripe and un-ripe banana fruit transcriptome suggest differential expression of genes related to fruit softening, arome production, and ethylene biosynthesis as well as perception during banana fruit ripening (Fig. 2).

In the area of molecular basis of gender distinction in a dioecious medicinal plant (*Tinospora cordifolia*), studies have been carried out to establish morphological and anatomical features of gender distinction as well as

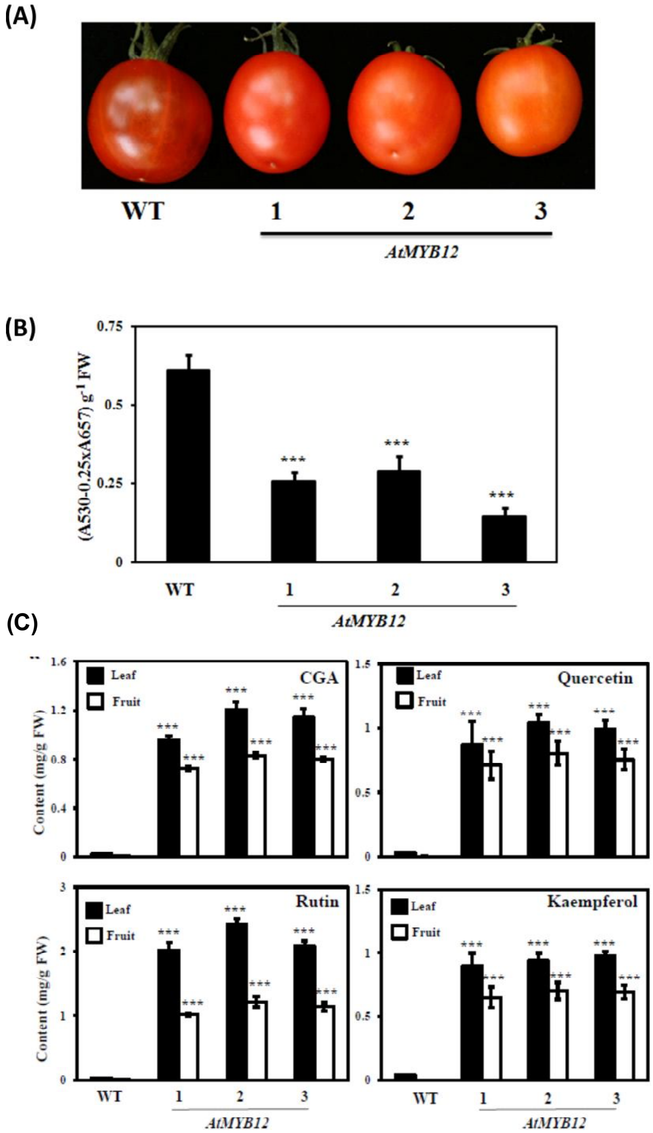


Fig. 1. *AtMYB12*-expressing tomato transgenic lines: (A) Mature wild type (WT) and transgenic lines (1, 2 and 3) of tomato fruits; (B) Total anthocyanin content in leaves of WT and *AtMYB12*-expressing transgenic tomato lines; (C) Quantification of various flavonoids in WT and transgenic lines using HPLC. (1, 2 and 3 represents transgenic lines line 1, line 2 and line 3 respectively; CGA and rutin were quantified by separating non-hydrolyzed methanolic extracts).

determination of gender-specific PCR profiles for use as a marker.

In the area of cotton genomics with the aim to identify and characterize regulators of cotton fiber quality, team has developed NBRI-Comprehensive Cotton Genomic Database (www.ncgd.nbri.res.in) and identified transcription factors and genes related to epigenetic modulation. Exploration of the effect of epigenetic modifiers on cotton fiber development by *in vitro* ovule culture assay revealed that anacardic acid can enhance yield of the cotton fiber through histone modifications. These results have been validated in field and use of anacardic acid as non-GM technology for improvement of fiber yield and

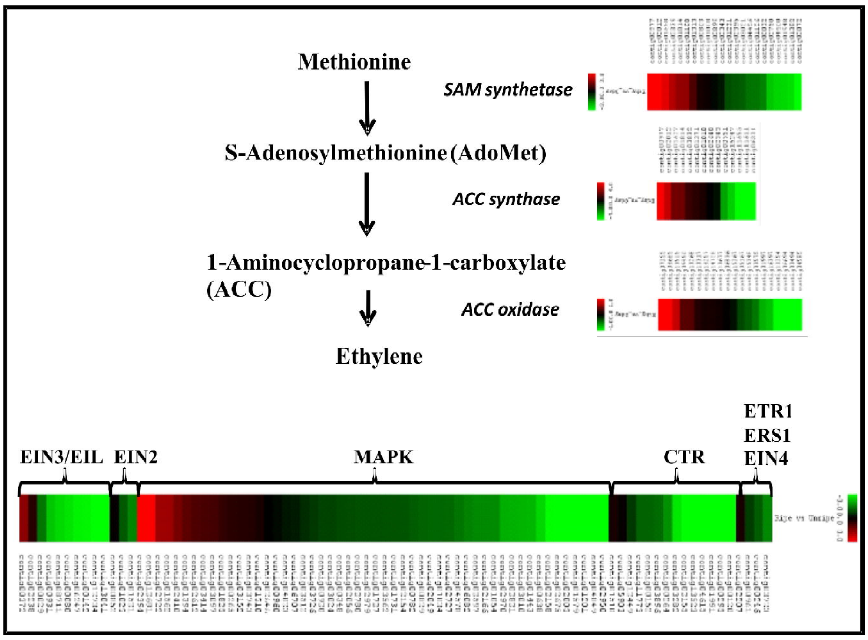


Fig. 2. Members of gene families involved in ethylene biosynthesis and perception and their differential expression during banana fruit ripening. The color scale (representing log fold change values) is shown.

quality has been proposed (Fig. 3). Results also suggest that the SQUAMOSA Promoter binding Like 5D (GhSPL5D) transcription factor and epigenetic modifier GhJmj12 regulate fiber initiation and development in cotton. In addition, EMS induced tilling population of cotton have been developed and more than 7,500 M_2 plants (3 plants per M_2 Lines) are being grown in field at Aurangabad. This population is being analyzed for various phenotypic traits.

To elucidate genetic changes regulating differential somatic embryo development in Japonica and Indica Rice varieties, genome-wide expression analysis of different stages of rice callus and regeneration has been carried out. Detailed analysis of expression profiles has identified number of regulatory genes which can putatively be involved in regulating differential embryogenesis in Indica and Japonica rice varieties.

Number of genes and promoters has been functionally characterized for their involvement in abiotic stress response including heavy metal stress tolerance and accumulation.

In the area of characterization of a novel early acting wound inducible promoter, one promoter from rose has been characterized in detail. The early wound responsive behavior of this promoter has been demonstrated in various plant systems and during insect infection. Group has also demonstrated efficacy of cryIAc under this promoter in transgenic Arabidopsis and tomato against *Helicoverpa armigera*.

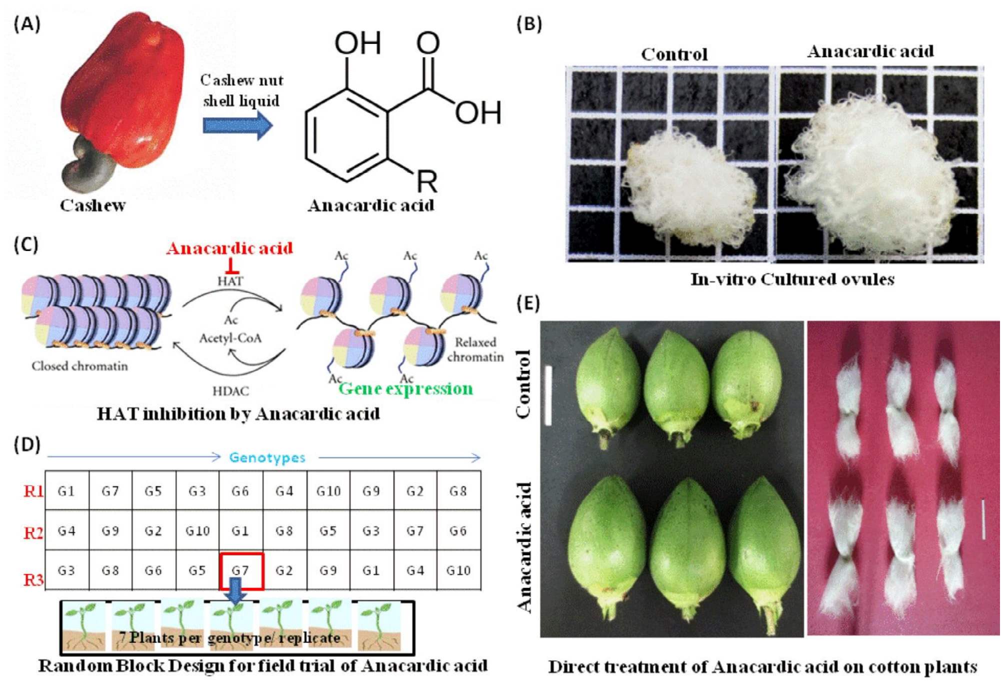


Fig. 3. Non-GM technology for improvement of fiber yield and quality; (A) structure and (B) effect of anacardic acid on cotton fiber development by in-vitro ovule culture assay; (C) Proposed molecular mechanism for anacardic acid on histone modification; (D) Random field design to validate effect of anacardic acid; (E) enhanced yield of cotton ball and fiber due to anacardic acid spray. Patent for this technology has been filed (Patent Appl. # 0231/DEL/2015).

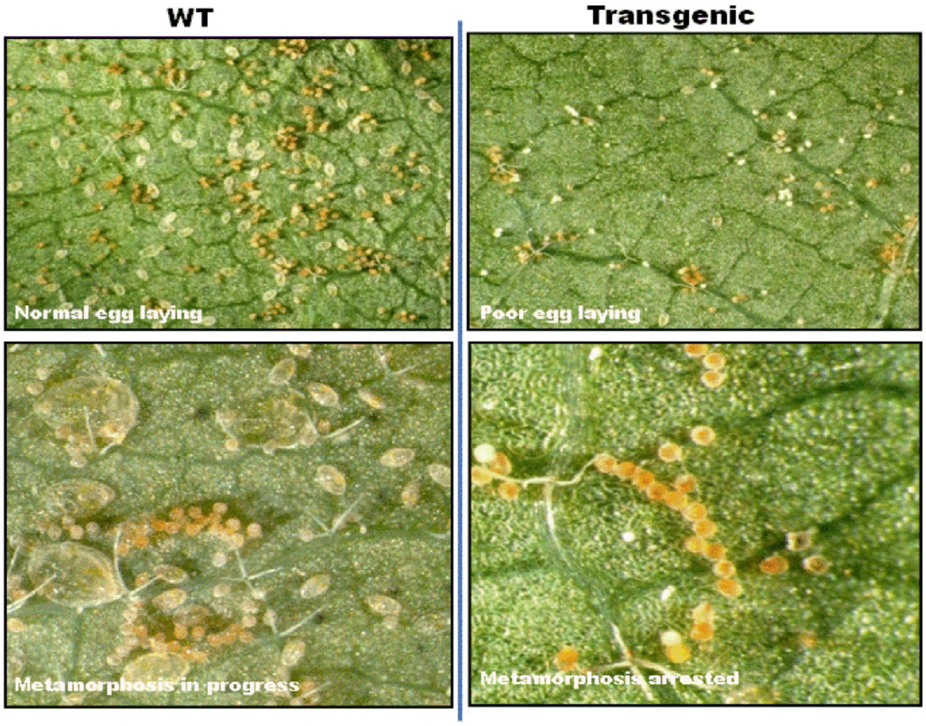


Fig. 4. Mechanism of whitefly resistance in transgenic cotton plants. Transgenic cotton exhibits resistance through interference in the life cycle of whitefly. Eggs are scanty and mostly sterile.

CSIR-NBRI has developed cotton transgenic lines using gene encoding Tma12 protein. Developed transgenic events show high tolerance to whitefly infestation through interference in the life cycle in contained field trials (Fig. 4). The toxicity studies suggest that protein does not produce any symptomatic changes in rats subjected to acute and sub-chronic exposures. Pepsin digestibility and absence of putative allergenic domains indicate possibility of safe use of the protein in biotech crops. Whitefly resistant cotton plants developed also show significant protection against cotton leaf curl disease. The technology has potential to offer protection to crops against whitefly and associated diseases.

Publications

1. Asif MH, Lakhwani D, Pathak S, Gupta P, Bag SK, Nath P and Trivedi PK – Transcriptome analysis of ripe and unripe fruit tissue of banana identifies major metabolic networks involved in fruit ripening process. *BMC Pl. Biol.* 2014, **14**: 316.
2. Dubey S, Shri M, Misra P, Lakhwani D, Bag SK, Asif MH, Trivedi PK, Tripathi RD and Chakrabarty D – Heavy metals induce oxidative stress and genome-wide modulation in transcriptome of rice root. *Func. Int. Genomics*, 2014, 14 : 401–417
3. Kumar S, Dubey RS, Tripathi RD, Chakrabarty D and Trivedi PK – Omics and biotechnology of arsenic stress and detoxification in plants: Current updates and prospective. *Environ. Int.*, 2015, **74** : 221-230.
4. Pandey A, Misra P, Bhambhani S, Chitra B and Trivedi PK – Expression of Arabidopsis MYB transcription factor, AtMYB111, in tobacco requires light to modulate flavonol content. *Scientific Reports,* 2014, **4** : 5018
5. Sharma D, Tiwari M, Lakhwani D, Tripathi RD and Trivedi PK – Differential expression of microRNAs by arsenate and arsenite stress in natural accessions of rice. *Metallomics*, 2015, **7**: 174-187
6. Shri M, Dave R, Diwedi S, Shukla D, Kesari R, Tripathi RD, Trivedi PK and Chakrabarty D – Heterologous expression of Ceratophyllum demersum phytochelatin synthase, CdPCS1, in rice leads to lower arsenic accumulation in grain *Scientific reports,* 2014, **4**(5-6) : 5784.
7. Tiwari M, Sharma D and Trivedi PK – Artificial microRNA mediated gene silencing in plants: progress and perspectives. *Pl. Molecular Biol.*, 2014, **86**:1-18.

5. S&T Interventions to combat malnutrition in women and children

Nodal Scientists: C S Nautiyal and AKS Rawat

Scientists: S Khatoon, SK Ojha, Ch V Rao, S Rastogi, Sharad Srivastava, SK Tewari

Technical Staff: MM Pandey

Objectives:

- CSIR-NBRI product (Nutri-jam) having high nutrient value particularly micronutrients, vitamins and minerals will be taken to the selected Tech-villages and villages.
- Distribution of the product (Nutri-Jam) in selected villages among women & children's suffering from malnutrition and monitoring for the improvement in health.
- Dissemination of knowledge about the use of local/ traditional fruits, vegetables, cereals to combat malnutrition through imparting training, publishing manuals, leaf lets and posters.
- Preparation, Quality control and scientific evaluation studies of the CSIR-NBRI products will be continued to maintain batch to batch consistency of the products on pilot scale.

Highlights

Two Tech-villages – Dua (Unnao) and Dafedar Ka Purva (Barabanki) have been selected and targeted for intervention through S&T to combat malnutrition with the developed product Nutri-Jam of CSIR-NBRI. Procured the ingredients for the preparation of product in bulk. SOPs to prepare the final products at industrial level have been finalized. Initially prepared 250 (500g) packed bottles for distribution among the targeted population of Tech-villages.

Surveyed both the villages several time for collection of data, nutritional status, food and drinking water status of the individuals. Posters on various aspects related to the importance of vegetables, fruits, cereals and medicinal plants etc were prepared and displayed in the class rooms of Primary School of Daun village for creating health awareness among the rural masses. Educated the school children about nutritional value and importance of vegetables, fruits etc and about common medicinal plants and their uses.

During this year, participated in Two Health Camps organized by CSIR-CIMAP on 14th Aug 2014 at Dau village and on 10th Jan 2015 at Lucknow. During Dau Health camp exhibited the Institute's products and posters related to nutrition .The CSIR-NBRI scientists also interacted with the villagers and provided the information on the use of nutritional fruits, vegetables and cereals .A team of doctors (Drs. Sanjeev Ojha, D. Mani and VK Agarwal) collected the data regarding health status of about 500 children, young girls, women and men for the selection of individuals under this program by providing nutritional products to combat the malnutrition. During Lucknow Health camp organized at CIMAP dispensary and health check-up of 40 selected individuals of Dau, Unnao, village was done. Blood samples were collected from the aforesaid people for the selection of individuals to whom the nutritional products will be distributed to combat the malnutrition. Approval of the Institutions and Human Ethic Committee has been taken for the distribution of the "Nutri Jam" among the selected individuals of the villages.

Output

- Selection of individuals based on BMI from three biovillages for the distribution of product (Nutri Jam).
- Selected School (Dafedar ka Purva, Deva) under the project and Glimpse of Health Mela organized at Dau (Unnao) to combat the malnutrition.
- Spread awareness about the use of local fruits, vegetables, cereals etc. for health benefits among the selected schools and villages.

Distribution of Nutri-Jam in Dafedar ka Purwa, Deva and Views of health camp at Dau Village, Lucknow

6. Probing the changing atmosphere and its impacts in Indo-Gangetic Plains and Himalayan Region (AIM-IGPHim)

Nodal Scientist: V Pandey

Scientists: CS Nautiyal, A Mishra, PA Shirke, OP Sidhu

Technical Staff: R Kanaujia

Objectives:

- Impact of Green House Gases (CO_2 and O_3) on crops of Indo-Gangetic plains.
- Identification of soil microbes related to carbon sequestration.

Highlights

Impact of elevated CO_2 on wheat (variety Kundan)

Bread wheat (*Triticum aestivum* L.) is the most important staple crop in the world, providing on average 20% of the total calories and 22% of the total protein in the human diet.

Wheat plants were grown in Free Air Concentration Enrichment (FACE) rings. Three rings were supplied with elevated CO_2 while other 3 rings served as control (supplied with air). Plant biomass and yield, photosynthesis and stomatal conductance and proteomics studies were carried out. During the study period ambient temperature, relative humidity, light and CO_2 concentrations were monitored. CO_2 enrichment was started after seed germination and continued untill final harvest. The targeted CO_2 concentration was reached to about 470 ppm (8 AM to 5 PM). Higher photosynthetic rate (*A*) rate was observed at vegetative stage (Fig 1A) than at flowering stage (Fig. 1B) and *A* was more in eCO2 at both the stages. Similar responses were found in stomatal conductance (Figs 1 C, D). A/Ci curve indicated that photosynthetic acclimation was almost similar at both the stages in both the treatments. (Fig. 1E, F).

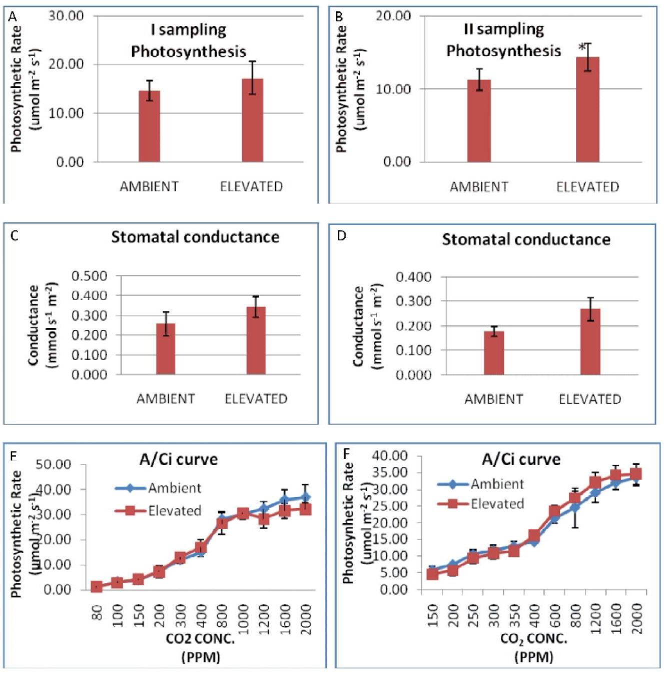


Fig. 1. Impact of elevated CO on photosynthesis (A, B), stomatal conductance (C, D) and A/Ci curve (E, F) in wheat plants at vegetative and flowering stages.

Increased shoot biomass was found in plants grown under eCO_2 (Fig 2A). All the yield parameters also showed upward trend under eCO_2, including grain wt/plant, 1000 grain wt. (Fig 2 B, C) and Harvest Index (Fig 2 D).

The average yield of Kundan variety has been reported to be 40-45 Q/hectare. We found that in control plants, estimated yield was 44.48 Q/hectare while in eCO_2, it was 56.3 Q/hectare.

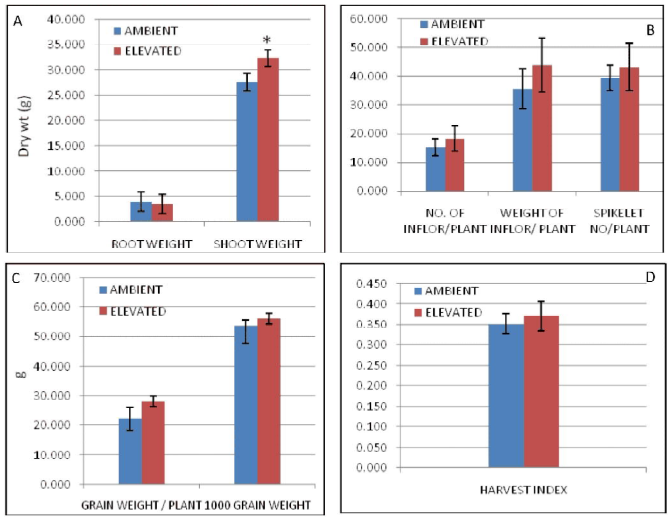


Fig. 2. Impact of elevated CO_2 on dry weight (A) and other yield parameters (B,C,D)

Wheat leaf proteomics

In wheat leaves, 50 proteins were differentially expressed out of which 20 were up-regulated while 30 were down-regulated (Fig 3). Thirty two proteins were identified by MALDI TOF TOF. Up-regulated proteins were related to defense (SOD, germin, peroxidase, thioredoxin),

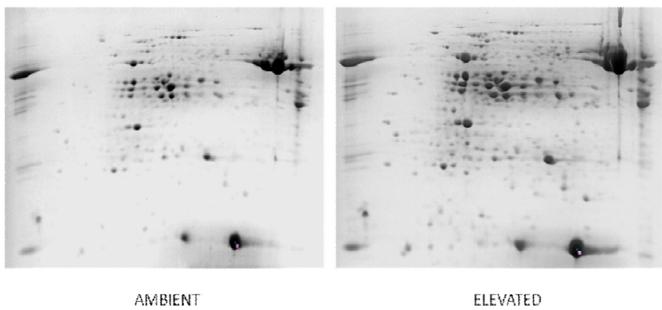


Fig. 3. Representative gels of whole leaf protein of wheat plants grown at ambient and elevated CO_2. Proteins were separated through 2-D PAGE. Isoelectric focusing done on IPG strips of pH 4-7 with 120 µg protein loading and second dimension through 12% SDS-PAGE.

photosynthesis (Rubisco large subunit, oxygen evolving enhancer, carbonic anhydrase), energy metabolism (ATP synthase) etc. While down-regulated proteins were a Chl a/b binding protein, many Rubisco proteins and proteins involved in glycolysis and gluconeogenesis.

Wheat Grain Proteomics

In our study, differential expression protein profiling showed that out of 49 differentially expressed proteins, 24 were upregulated and 25 were downregulated in wheat grains under eCO2 condition. Through Mass Spectrometry 33 proteins were identified and functionally characterized. They were found to be involved mainly in carbon metabolism, storage, defence and proteolysis (Fig 4).

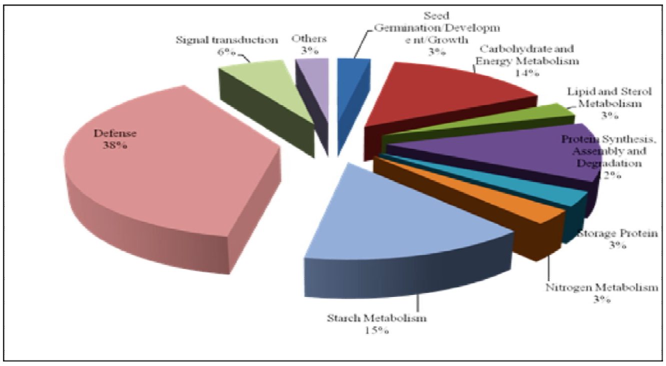


Fig 4. Functional categorization of identified wheat grain proteins

Gluten proteins

Gluten proteins are normally associated with superior end quality, especially dough strength and elasticity. There was more expression of high molecular wt. glutenin (HMW) and low molecular weight (LMW) glutenin proteins in eCO_2 wheat grains (Fig 5). Differences in glutenin ratio in wheat grains might have an adverse impact on bread dough end-product quality.

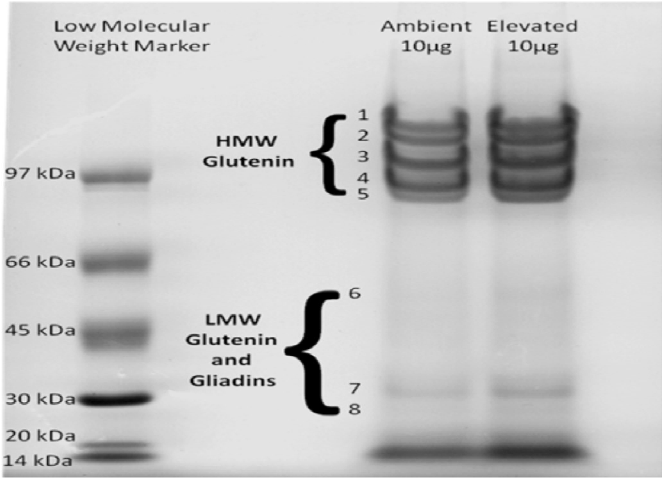
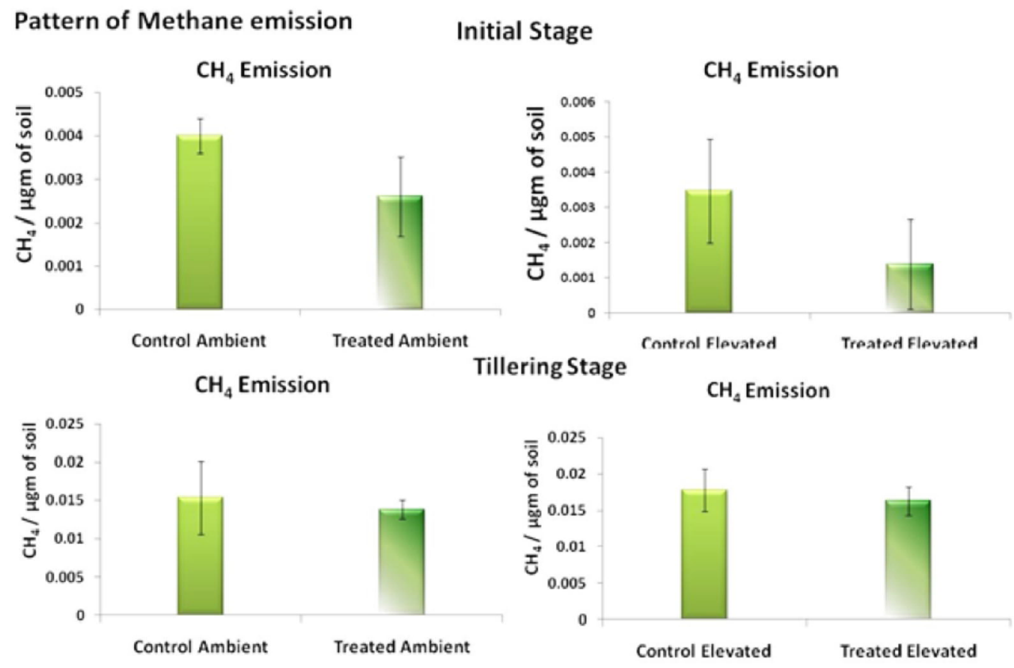


Fig. 5. SDS PAGE showing various high and low molecular weight glutenin proteins in wheat grains

Soil microbiological studies

Soil samples were taken from ambient and elevated conditions of FACE and were compared for CH_4 emission and microbial dynamics. Microbial population was affected in higher concentration of CO_2 where the microbial population of *Trichoderma* was unaffected in elevated CO_2 stress condition. Bacteria and fungi were screened and selected for abiotic stress tolerant from both soil samples. *Trichoderma* played potential role to maintain soil microflora. Microbial activity was suppressed in



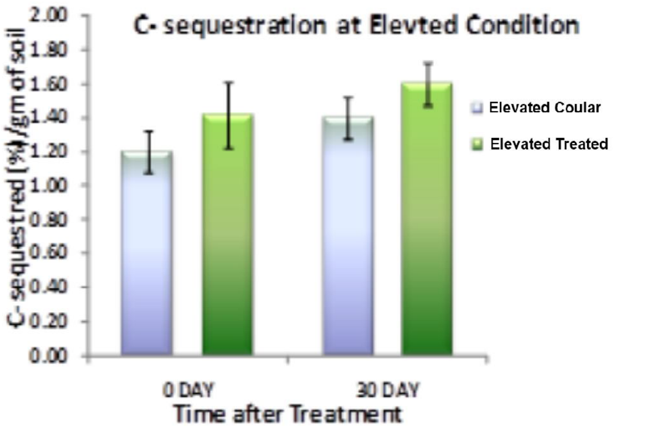
In situ methane measurement

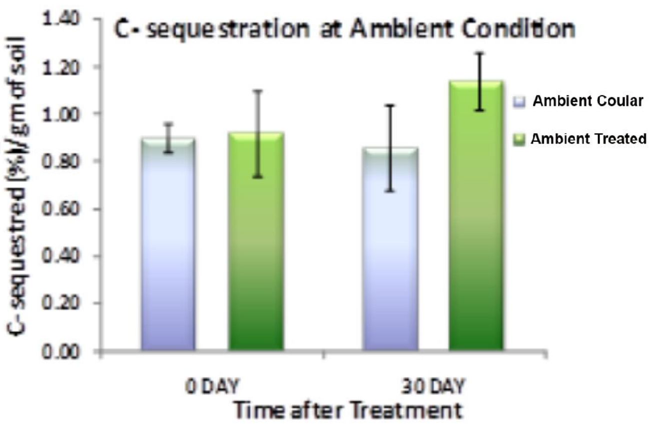
higher CO_2 concentration condition without *Trichoderma* treatment.

In relation to green-house gases emission from incubation of ambient and elevated soil, the CH_4 emission gradually increased according to incubation period (0.0530 µmol/gm soil). CO_2 emission increased due to induced microbial activity (28.68 µ mol/gm/soil) after 3 day and gradually decreased according to incubation period.

Isolation and Screening of abiotic stress tolerant microbes from high CO_2 elevated condition

Soil sampling was done from elevated and ambient CO_2 rings. 150 bacterial strains and 90 fungal isolates were screened for abiotic stress (pH, salt, drought and temperature) tolerance.





For bacterial strains pH tolerance- Among all 12 screened strains from elevated CO_2 soil, 2 isolate (PPFIEB-3, PPFHEB-2) tolerant up to 10.5 pH while 2 isolates (PPFHEB-3, PPFHEB-4) were tolerant even up to pH 11.

Among all 12 screened isolates from elevated CO_2 soil, 2 isolates (PPFIEB-2, PPFHEB-2) were found tolerant up to 1M NaCl and 3 isolates (PPFIEB-4, PPFHEB-1,PPFHEB-2) were found tolerant up to 1.5M NaCl.

8 bacterial strains were selected for drought tolerance- 3 strains (PPFIEB-1, PPFIEB-2 & PPFHEB-1) were able to tolerate 35%, 4 strains (PPFIEB-3, PPFIEB-4, PPFHEB-2 & PPFHEB-4) were tolerant to 40% drought.

Impact of *Trichoderma* on C- sequestration of FACE soil under elevated and ambient condition of CO_2

C- sequestration in soil: C- sequestration (Total organic carbon) was estimated and it was observed that there was significant increment of C-sequestration after the treatment of *Trichoderma* under both condition (Elevated and Ambient condition of CO_2). *Trichoderma* was able to ameliorate the sequestration of carbon under both conditions.

Effect of *Trichoderma* on microbial population under elevated and ambient condition of CO_2

Overall microbial population (Bacterial, Trichodermal and Fungal) was found to be maximum in potent *Trichoderma* treated soil after 90 days of incubation under both Elevated and ambient conditions.

Carbon Sources utilization pattern of CO_2 enriched and ambient soil

Selected carbon sources:

Urea, Lignin, Pectin, Cellulose, Phytic Acid, Chitin, Para Nitro Phenol, Silicic Acid, Ferrulic Acid, Cassin, Gelatin, Glucose, Benzoic Acid & Cinnamic Acid.

Findings:

Glucose, Gelatin, Pectin were maximally utilized in ambient condition, utilization was less in high CO_2 condition.

Lignin, Cellulose, Phytic acid, Chitin were maximally utilized in elevated CO_2 condition, utilization was less in ambient CO_2 condition.

Ferrulic acid, Cassin and Benzoic acid were uniformly utilized in both ambient and elevated CO_2 conditions.

Urea, PNP, Silicic acid and Cinnamic acid were negligibly utilized in all condition.

7. Plant microbe and soil interactions (PMSI)

Nodal Scientist: CS Nautiyal

Scientists: PS Chauhan, Manoj Kumar, Charu Lata, Aradhana Mishra, SK Raj

Objectives:

- Isolation of ACC deaminase producing PGPR from different stressed soils in India.
- Expression and characterization of ACC deaminase genes from PGPR.
- Evaluation of ACC deaminase producing PGPR for plant growth promotion under stressed environments in control and field conditions.
- Characterizing plant interactions with PGPR and viruses.

Molecular characterization of *Cucumber mosaic virus* (CMV) from gerbera

During a survey, chlorotic mosaic disease was observed on a number of gerbera (*Gerbera jamesonii*) plants of two cultivars (Zingaro and Silvester) growing in a polyhouse at CSIR-NBRI, Lucknow. The diseased plants exhibited severe chlorotic mosaic, floret and flower deformations along with color breaking symptoms as compared to healthy one suspecting to be a viral disease. The infection of CMV was detected by Western blot immunoassay using CMV-antibodies and confirmed by RT-PCR using CMV coat protein gene specific primers. Further, the complete RNA3 genome of three isolates of CMV was amplified by RT-PCR from the total RNA isolated from three infected gerbera leaf samples. The amplicons obtained were cloned, sequenced and deposited in GenBank under the accessions JN692495, JX913531 (from cv. Zingaro) and JX888093 (from cv. Silvester). These isolates were found to be of 2219 nucleotides translating two open reading frames (ORFs): movement protein gene of 229 amino acids and coat protein gene of 218 amino acid residues. Both the ORFs were separated by 300 nucleotide long intergenic region and flanked by 5'un-translated region (UTR) and 3'UTR of 122 and 302 nucleotides, respectively. These isolates shared 98–99 % identities to each other and with a strain of CMV-Banana reported from India, and 90–95 % identities with various strains of CMV reported worldwide. Phylogenetic analysis revealed their closest affinity with CMV-Banana strain, and close relationships with several other strains of CMV of subgroup IB. This study provides evidence of subgroup IB CMV causing severe chlorotic mosaic and flower deformation in two cultivars (Zingaro and Silvester) of *G. jamesonii* in India.

Development of virus-free gerbera plants

CMV is considered to be the most important because it caused severe flower deformation leading to decline in the market value of gerbera flowers. Therefore, elimination of CMV was attempted through *in vitro* chemotherapy (using 30 mg/l virazole) of ~4x8 mm^2 capitulum explants of infected gerbera cv. Zingaro for its quality improvement. A total of 38 plants were developed from 57 explants on Murashige and Skoog (MS) medium supplemented with 1 mg/l 6-benzylaminopurine (BAP), 0.5 mg/l indole-3-acetic acid (IAA) and 0.5 mg/l adenine sulphate (Fig. 1). The developed plants showed absence of CMV in 81.6% (31/38) plants when screened by RT-PCR using coat protein specific primers of CMV (Fig. 2).

The CMV-free plants showed better plant growth: increase of 53.7% in length of leaf lamina and 59.2% in leaf width as well as better blooming performance: increase of 62.6% in flower size (diameter in cm) and 69.1% in number of flowers per pot having intense red flower colour as compared to the control ones. Elimination of CMV by *in vitro* chemotherapy (using virazole) of capitulum explants of gerbera cv. Zingaro is being reported for the first time from India.

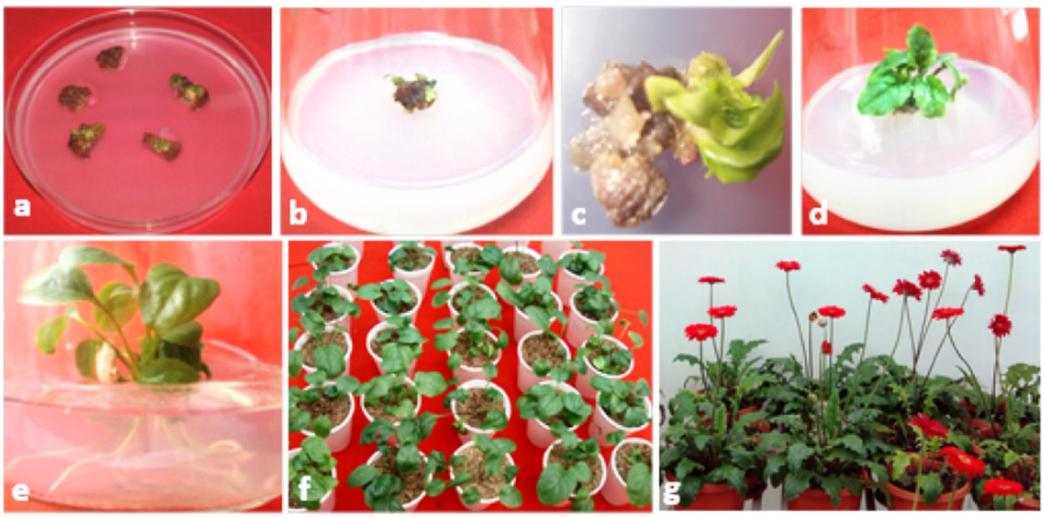


Fig. 1. Different stages in the development of virus-free plants from infected floral bud explants of Gerbera cv. Zingaro

Cloning and sequencing of the complete genome of *Bean yellow mosaic potyvirus* isolate infecting Gladiolus

The ~9.5 kb complete genome of an isolate of BYMV infecting *Gladiolus*

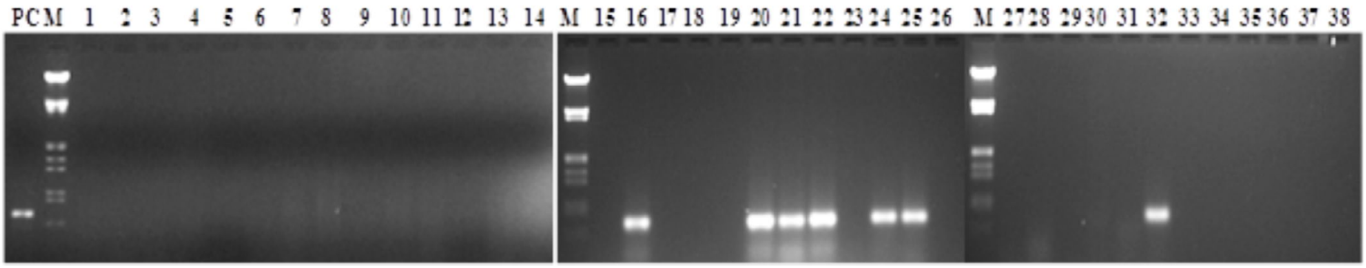


Fig. 2. Screening of 38 regenerated gerbera plants by RT-PCR using CMV-CP gene specific primers. ~650 bp amplicons in only 7 samples confirm them as CMV-free.

(cv Sylvia) has been amplified and sequenced in 4 independent attempts. The sequence data were aligned and assembled by removing overlapping data and the resulted 9532 nucleotide long RNA genome was submitted in GenBank under the accession number (KM114059). The complete genome comprises the 5′ UTR, P1, HC-Pro, P3, CI, Vpg, Pro, Nib, coat protein and 3′ UTR regions. BLASTn analysis of complete genome sequence revealed highest identity with BYMV (D83749) isolate reported from Japan. The pairwise sequence analysis also revealed the highest 94% identity of isolate under study with the BYMV isolate (D83749) and 90-94% identities with BYMV isolates of phylogenetic group IV. During phylogenetic analysis the virus isolate under study clustered with other isolates of BYMV phylogenetic group IV. Based on high identities and close phylogenetic relationships, the potyvirus under study was identified as BYMV of Phylogenetic group IV.

Publication

1. Gautam KK, Raj R, Kumar S, Raj SK, Roy RK and Katiyar R – Complete sequence of RNA3 of Cucumber mosaic virus isolates infecting *Gerbera jamesonii* suggest its grouping under IB subgroup. *Virus Disease*, 2014, **25** : 398-401.

8. Root biology and its correlation to sustainable plant development and soil fertility (RootSF)

Nodal Scientist: CS Nautiyal

Scientists: MH Asif, S Bag, D Chakrabarty, PS Chauhan, A Lehri, A Mishra, RC Nainwal, V Pandey, AP Sane, VA Sane, I Sanyal, SV Sawant, PA Shirke, OP Sidhu, Devendra Singh, PC Singh, Suchi Srivastava, SK Tewari, RD Tripathi

Objectives:

- Generation of soil metagenomic map of agricultural area of the state of Uttar Pradesh for improving soil productivity under normal and abiotic stressed conditions.
- Study of developmental changes in root system architecture (RSA), morphology and physiology of rice and chickpea roots growing under normal and stressed (less water for rice and drought for chickpea) soil conditions.
- Study of the effect of plant growth promoting bacteria on rice and chickpea root development and its mechanism of action under normal and stressed (drought) soil conditions.
- Understanding signaling cross-talk during root development.

Highlights

Metabolite profiling reveals abiotic stress tolerance in Tn5 mutant of *Pseudomonas putida*

Growth and crop productivity is limited by drought and temperature in arid and semi-arid regions. The stress also affects the effectiveness of many efficient PGPRs. *Pseudomonas* is an efficient plant growth–promoting rhizobacteria (PGPR); however, intolerance to drought and high temperature limit its application in agriculture as a bioinoculant. A mutant NBRI1108T, generated from *Pseudomonas putida* NBRI1108 was selected after screening of nearly 10,000 transconjugants. It confirmed to harbour a single Tn5 insertion using southern hybridization analysis and exhibited significant tolerance towards high temperature and drought. Insertion of Tn5 influenced the metabolic profile of NBRI1108 and NBRI1108T examined using 1H, 31P nuclear magnetic resonance (NMR) spectroscopy and gas chromatography-mass spectrometry (GC-MS). Application of multivariate principal component analysis (PCA) on the quantified metabolites revealed clear variations in NBRI1108 and NBRI1108T in polar and non-polar metabolites (Fig.1). Thirty six chemically diverse metabolites were identified and quantified which included significantly higher concentration of aspartic acid, glutamic acid (34%), glycinebetaine (95%), glycerophosphatidylcholine (GPC) (100%) and putrescine in NBRI1108T as compared to that in NBRI1108. Results indicate that biosynthesis of GPE may have taken place via the methylation pathway of phospholipid biosynthesis. However, high GPC and low GPE concentration in NBRI1108T suggest that methylation pathway and phosphatidylcholine synthase (PCS)

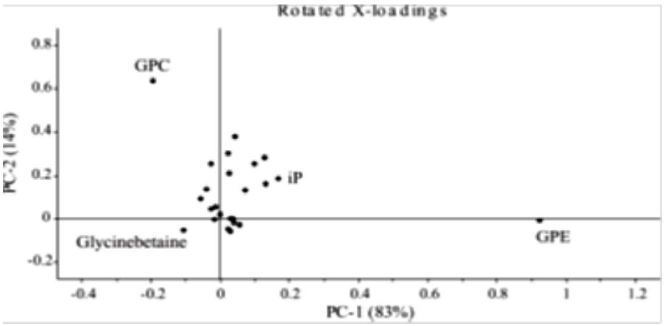


Fig. 1. Principal component analysis of quantified polar and nonpolar metabolites of *P. putida* NBRI1108 and NBRI1108T

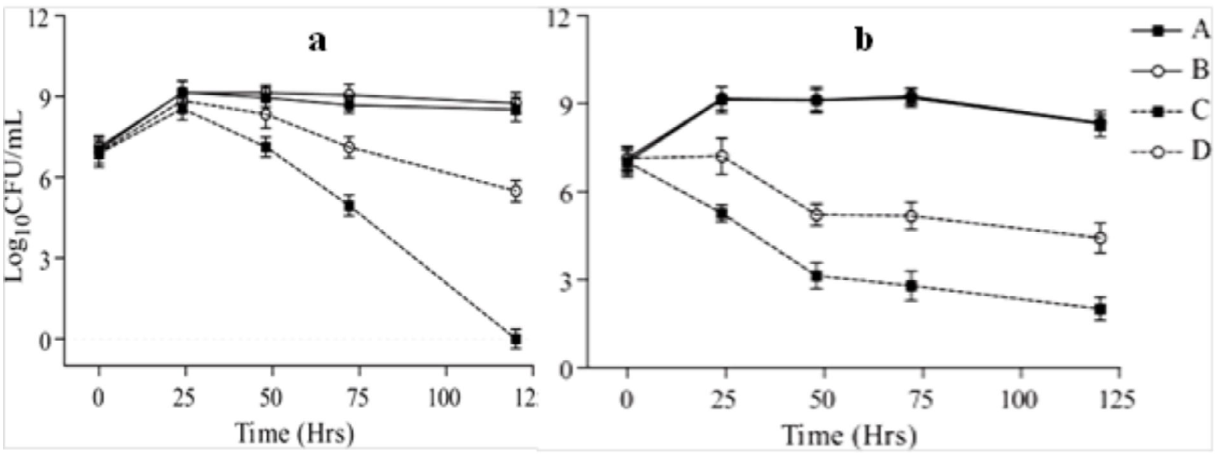


Fig. 2. (a): Effect of temperature on the survival of *P. putida* NBRI1108 and NBRI1108T. Treatments are designated as (A) NBRI1108 at 28 ± 2°C, (B) NBRI1108T at 28 ± 2°C, (C) NBRI1108 at 40°C and (D) NBRI1108T at 40°C. Values are the mean ± SE of three samples. (b): Effect of drought on the survival of *P. putida* NBRI1108 and NBRI1108T. Treatments are designated as (A) NBRI1108 without PEG6000, (B) NBRI1108T without PEG6000, (C) NBRI1108 with 45% PEG6000 and (D) NBRI1108T with 45% PEG6000. Values are the mean ± SE of three samples.

pathway of phospholipid biosynthesis are being followed in the NBRI1108T. Increase in betaine and GPC levels consequently led NBRI1108T to tolerate drought and temperature to a greater extent. Figure 2 shows effect of temperature (Fig.2a) and drought (Fig 2b) on the survival of *P. putida* NBRI1108 and NBRI1108T. Tolerance to drought was further confirmed in greenhouse experiments with maize as host plant, where NBRI1108T showed relatively high biomass under drought conditions. Drought and temperature stress tolerance conferred by NBRI1108T in *P. putida* represents a novel, compelling approach towards improving plant productivity with mutant symbiont. The study suggests that the Tn5 generated mutant NBRI1108T can efficiently be used in drought stress condition for higher productivity.

Biocatalytic and antimicrobial activities of gold nanoparticles synthesized by *Trichoderma* sp.

Gold nanoparticles have attracted significant scientific interest as a new generation of antimicrobial agents because of increasing resistance of bacteria toward antibiotics. Though several chemical and physical approaches are available for synthesis of gold nanoparticles, focus has now been shifted toward greener approach because of ease of biosynthesis and elimination of harsh chemical procedures. *Trichoderma*, a plant growth promoter and biocontrol agent was used for green synthesis of gold nanoparticles. In the present study *Trichoderma viride* and *Hypocrea lixii* were used for very rapid biosynthesis of gold nanoparticles which took 10 min respectively at 30 ºC and 100 ºC when their cell-free extracts were used. Biomolecules present in cell free extracts of both fungi were capable to synthesize and stabilize the formed particles. Synthesis procedure was very quick and environment friendly and did not require subsequent processing. The biosynthesized nanoparticles served as an efficient biocatalyst which reduced 4-nitrophenol to 4-aminophenol in the presence of $NaBH_4$ and had antimicrobial activity against pathogenic bacteria (Fig. 3). Fig. 4 dipicts a general graphical representation showing biosynthesis and activity of gold nanoparticles. To the best of our knowledge, this is the first report of such rapid biosynthesis of gold nanoparticles within 10 min by *Trichoderma* having plant growth promoting and plant pathogen control abilities, which served both, as an efficient biocatalyst, and a potent antimicrobial agent.

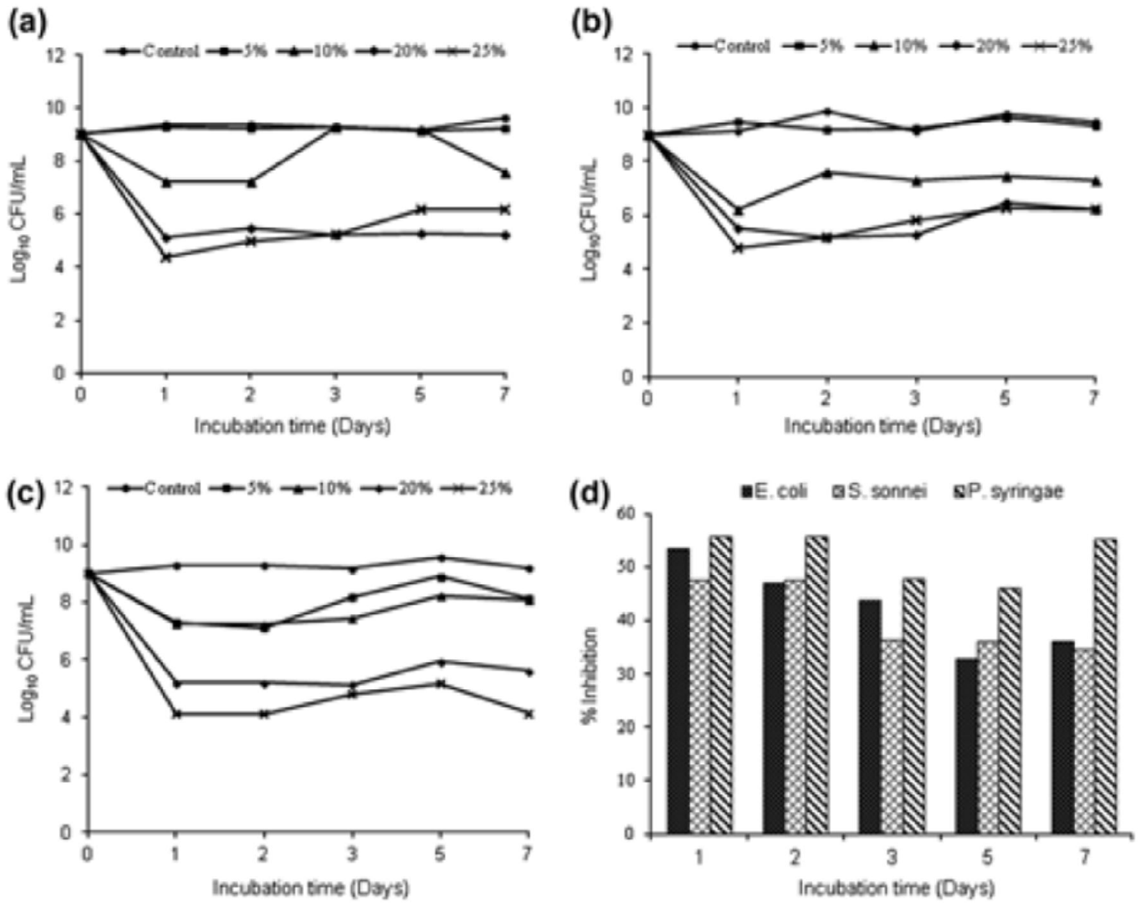


Fig. 3. Reduction in CFU count of (a) *E. coli*, (b) *S. sonnei* and (c) *P. syringae* after addition of 5%, 10%, 20%, and 25% of biosynthesized gold nanoparticles for a time period of seven days; (d) Percent inhibition of pathogenic bacteria after addition of 25% of gold nanoparticles to media over a time period of seven days.

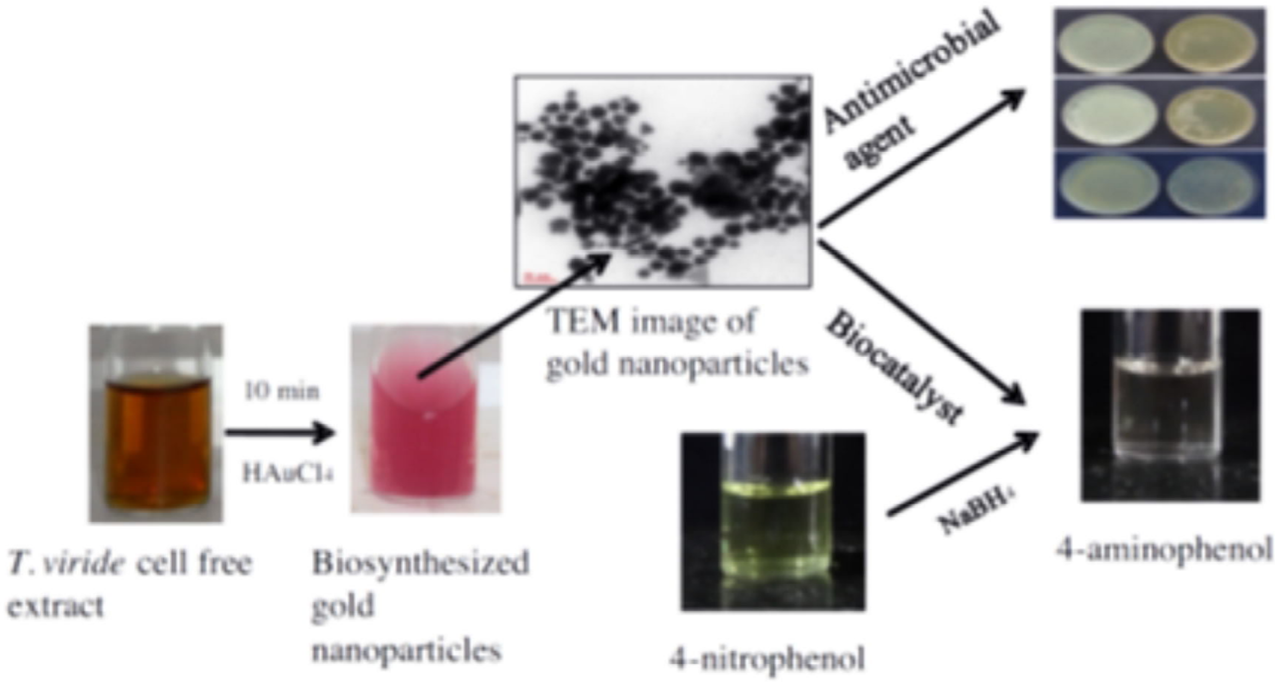


Fig. 4. Graphical representation showing biosynthesis and activity of gold nanoparticles. (Source : Mishra A, *et al.*, *Bioresour. Technol.*, 2014, **166**: 235-242).

Publications:

1. Chaudhry V, Bhatia A, Bharti SK, Mishra SK, Chauhan PS, Mishra A, Sidhu OP and Nautiyal CS – Metabolite profiling reveals abiotic stress tolerance in Tn5 mutant of *Pseudomonas putida*. *PLOS ONE*, 2015, **10**(1) : e0113487
2. Koul B, Amla DV, Sanyal I and Singh R – Analysis of response to water deficit in three Indian varieties of chickpea (*Cicer arietinum* L.) for drought tolerance. *Int. J. Agron. Agricult. Res.*, 2014, **4**(3) : 35-48.
3. Tripathi RD, Tripathi P, Dwivedi S, Kumar A, Mishra A, Chauhan PS, Norton GJ and Nautiyal CS – Roles for root iron plaque in sequestration and uptake of heavy metals and metalloids in aquatic and wetland plants. *Metallomics* 2014, **6** : 1789-1800

9. Genomics and informatics solutions for integrating biology (Genesis)

Nodal Scientist: S Kumar

Scientist: SN Singh

Bioinformatics of legumes: Digitization of DUS characters and collection, compilation and curation of genomic information for identification of useful gene responsible for medicinal properties and food value.

Legumes are treated as economically most important group of plants. Pulse crops of legumes constitute the most important group of food plants in India. Presently India produces around 15-16 million tons of total pulses. To feed the growing population, the total requirement of pulses would be around 30 million tons by 2020 AD. Pulses contain 18-27% protein. The present project has focus on various aspects viz., I- Develop DUS character database of varieties of pulses, II- Develop software tool for collection compilation, curation of georeference data, genomic information, etc., III- Develop software tool for integrating legume data on map layers, IV- Collect and compile data, using GPS in 100 botanic gardens for medicinal and RET legumes species, and add satellite images in back drop of vector map layers, V- Undertake analysis of genomic information to extract the useful gene responsible for medicinal properties, and VI- Analysis of geospatial data to study the impact of climate change, etc.

Objectives:

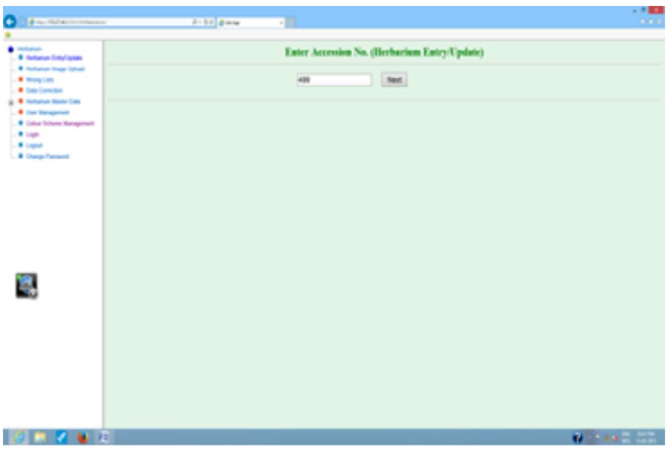
- Design and development of OS independent software tools capable of real time collection, compilation, curation, retrieval of both primary and secondary data on descriptions, geospatial data map layers, genomic information on medicinal and food value legumes.
- Development of an on-line query system for analyzing the genomic information to extract the useful gene responsible for medicinal properties and food value of legumes.
- Development of unique geolocation of medicinal and RET legumes in wild and cultivated (in botanical gardens of India) using GPS data and Geospatial analysis and study the impact of climate change.
- Establishment of link with global databases like Encyclopedia of Life (EOL), the Consortium for the Barcode of Life (CBOL) and the Catalogue of Life (COL), etc.
- Organising training courses/workshops for help in preparing base line data for on DUS characters. Barcodes of medicinal legumes of India to help / achieve India's obligation in global treaties / conventions like CBD, GEF, WTO, WIPO-IGC, CIPGR, UPOV, UNCTAD, GSPC, GBIF, CITES, GTI, etc.
- Facilitating the work of authority like PPV& FRA, NBA, etc.

Highlights

- Completed characterisation of 200 species of legumes of food & medicinal and gene value.
- Developed a new software using PHP and My SQL for entry of specimen lable data and upgraded taxonomic data, GIS data, Image data, Videos and genomic data.

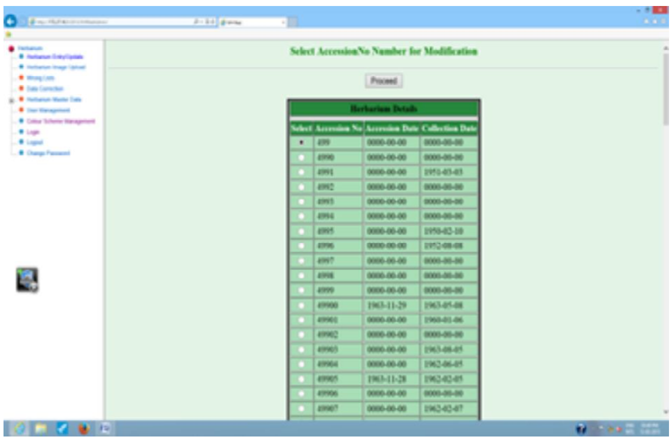
Entry inputs screens

Enter Accession No.



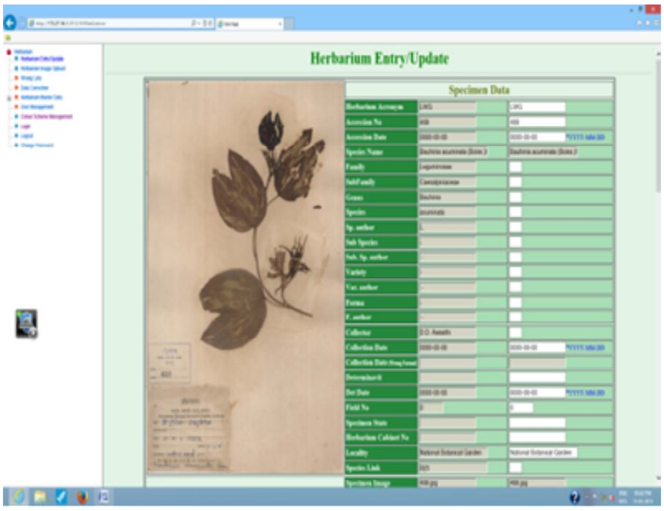
1

List of accession nos. is displayed through pull down menu



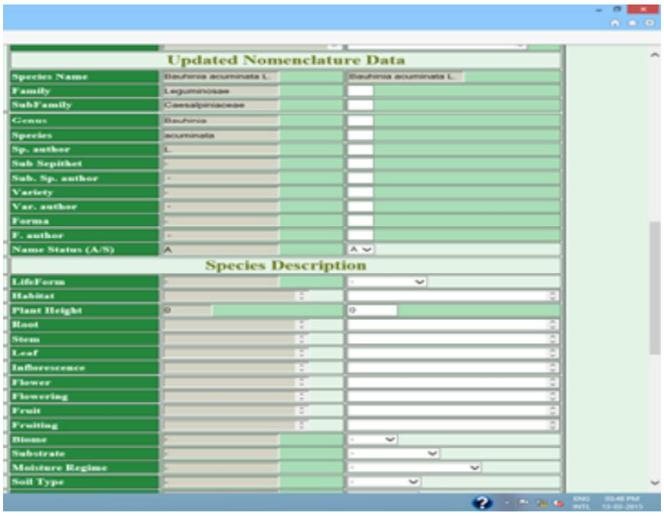
2

After selecting a particular accession, specimen label data is displayed and user can enter/edit data after using Zoom in Zoom out facility



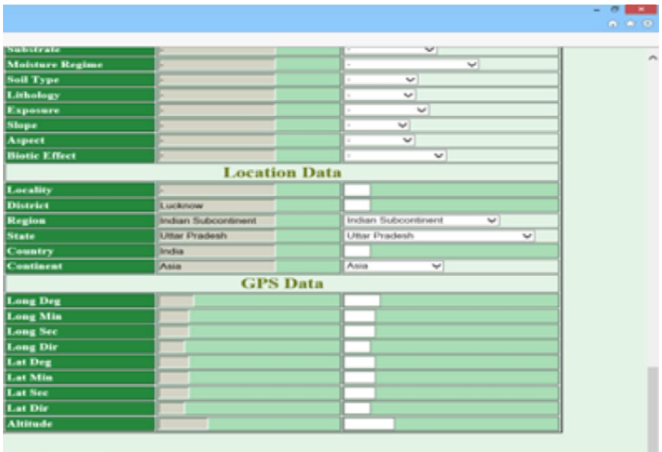
3

After editing/entering of label data software allows entry of updated nomenclature and description data



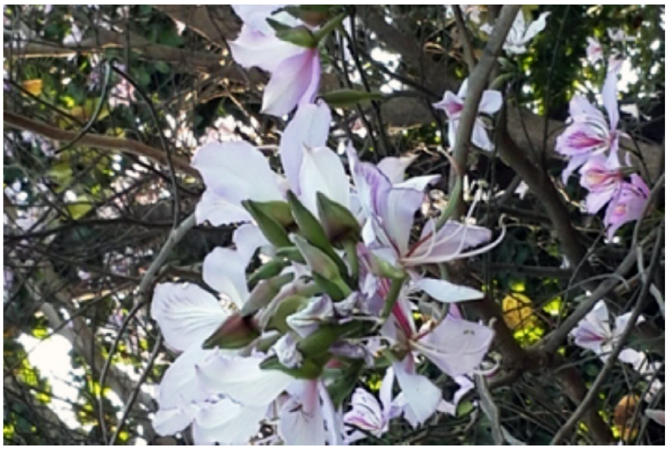
4

After entry of descriptors data software allows entry of GPS & Location data



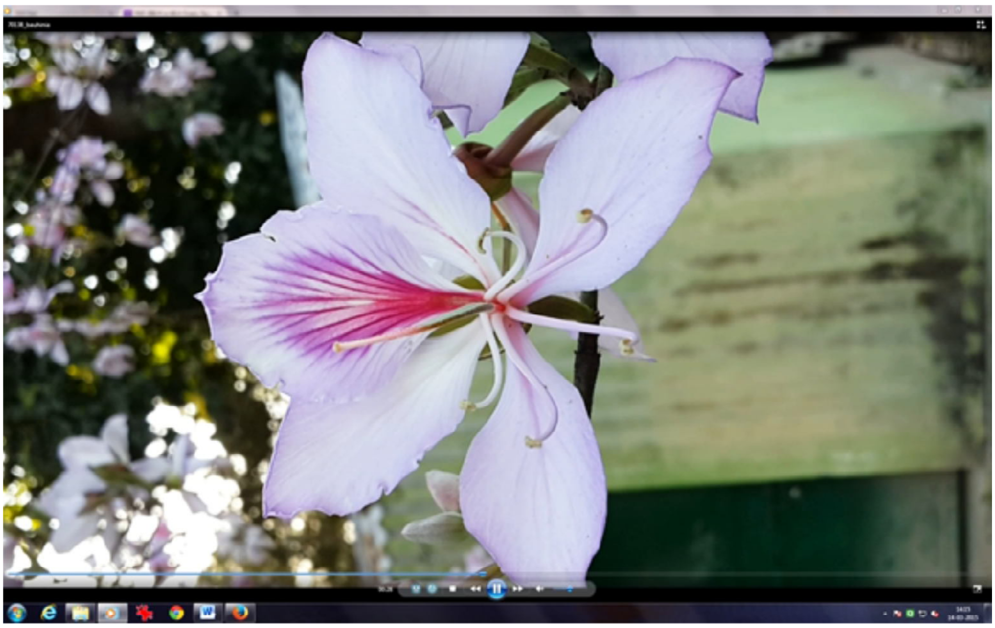
5

Live Image



6

Video of the plant



10. Introduction, domestication, improvement and cultivation of economically important plants (AGTEC)

Nodal Scientists: AK Goel, RK Roy

Scientists: RS Katiyar, RC Nainwal, TS Rana, Devendra Singh, PC Singh, SK Tewari

Objectives:

- Development of improved varieties of *Canna*, *Gladiolus*, Rose and bulbous crops.
- Introduction of selected novel floricultural and economic crops in the hills and plains.
- Evaluation of *Bixa* & *Curcuma* germplasm collection for plant improvement.
- Evaluation of Damask Rose for sodic soils.
- Evaluation of performance of biofertilizers and biopesticides on plants.

Evaluation of *Bixa* and *Curcuma* germplasm collection for plant improvement

***Curcuma* (Turmeric)**

Thirty four accessions of *Curcuma longa,* collected from various biogeographical regions are being conserved at Banthra Research Station. Biochemical analysis (total curcuminoids, total phenolic contents, antioxidant activity) of 24 accessions has been done.

To evaluate the effect of sodicity and normal soil on *Curcuma* growth, yield and quality, three accessions of *C. longa* (NBH-3, NBH-10 and NBH-18-2) were cultivated in garden soil and partially reclaimed sodic soil to select superior genotype for better yield and quality to broaden its cultivation base to northern India, basically sodic wastelands. The results reveal that total phenolic content, curcumin, demethoxycurcumin and bis-demethoxy curcumin, leaf and rhizome essential oil contents were higher in rhizomes from sodic soil. Antioxidant activity was studied from rhizomes in terms of IC_{50} DPPH and the rhizome from moderate sodic soil showed more antioxidant capacity than garden soil. α-phellandrene, α-terpinolene and p-cymene were the major components of leaf oil obtained from hydrodistillation, while β-tumerone, Ar-tumerone and p-cymen were the major compounds in rhizome oil. NBH-10 produced the highest rhizome yield in sodic soil and NBH-18 yielded maximum in garden soil.

Rhizomes of NBH-2, NBH-3, NBH-8 NBH-10, NBH-12, NBH-17, NBH-18 and Prabha, were subjected to induce physical mutation (control, 2.5 Gy, 5.0 Gy, 7.5 Gy, 1.0 Gy and 2.0 Gy) in 2011. These accessions were selected on the basis of their superior and inferior quality in terms of curcuminoids and yield content. Eight mutants have been identified on the basis of leaf abnormality, stunted and vigorous growth and chlorophyll mutation. Its heritability, genotypic coeffeicient, phenotypic coefficient, genetic advancement have also been studied in M_{1V2}. Total curcuminoid content was estimated by HPLC and the results showed the increase of curcuminoids in two mutants. Decrease in total curcuminoids was also observed in two mutants.

DAMD and ISSR methods were used to estimate the genetic variability in 29 genotypes of indigenous turmeric germplasm. Cumulative data analysis revealed 82% polymorphism across the turmeric genotypes. Wide range of pairwise genetic distances (0.03-0.59) between the genotypes revealed that these genotypes are genetically quite diverse. The results further demonstrated the efficiency and reliabilityof DAMD and ISSR markers in determining the genetic diversity and relationships among the idigenous turmeric germplasm.

***Bixa orellana* (Annatto)**

Bixa orellana is cultivated commercially to extract Annato colour from seeds. Besides some medicinal uses in the indigenous system of medicine, the commercial product is Annato dye which is used mostly in the dairy industry for colouring butter, cheese, ghee, chocolate, ice cream, in dyeing cotton, silk clothes and leather, colouration of medicines and making boot polishes. The colour is also used in making bindi or kumkum. By and large, it is a multipurpose species whose bark, leaves, roots and seeds are used for medicinal, pharmaceutical, cosmetics and edible colouring purposes.

Seventeen accessions of *Bixa orellana* collected from different bio-geographical regions are being evaluated for growth, yield and quality at Banthra, having pH ranging from 8.7 to 9.2. The plants have shown variations in morphological characters (leaf shape, flower colour, capsule shape, size and colour, etc.), yield (number of capsule per plant, number and weight of seeds per capsule) and quality (Bixin content). Based on morphological characterization, total collection has been arranged into seven groups. These groups have also been sampled for molecular characterization. The initial results are promising for utilization of sodic soils for *Bixa* plantation. The seeds of best five *Bixa* accessions along with brief write-up about the technical details have been sent to CSIR-CIMAP, CSIR-IHBT and CSIR-NEIST for the multi-location trials.

Evaluation of Damask Rose in Sodic Soils

Screening of different varieties of Damask Rose in sodic soils was carried out. Nutrient management practices for growth and yield of Damask Rose were performed. Biofertilizer response for growth and yield of Damask Rose was studied.

Performance and evaluation of elite plant material and/ or cultivars through multi-locational coordinated trials

Multilocational trials of mandate crops

Corms of four Gladiolus cvs. Neelima, Roshni, Usha, and Amethyst, and rhizomes of two Canna cultivars: Raktima and Agnishikha along with guidelines for Gladiolus and Canna cultivation were provided to CSIR-IHBT, Palampur and CSIR-IIIM, Jammu. Seeds of five accessions of *Bixa* with experimental plan for their performance evaluation were also provided to CSIR-IHBT and and CSIR-IIIM. The field trials are in progress.

CSIR-IHBT, Palampur has provided corms of six cvs. of Gladiolus (Palampur Pride, Palampur Delight, Palampur Queen, Tushar Mouli, The Saint and Selection No. 30). The performance of Palampur Delight is best followed by Tushar Mouli and Selection No. 30.

Publications

1. Singh S, Kumar S, Prasad R, Roy RK, Kumar S and Goel AK –Comparative analysis of growth and flowering characteristics of Canna cultivars in agro-climatic condition of Lucknow, Uttar Pradesh, India. *Pl. Archives,* 2014 **14** (2): 935-938.
2. Verma S, Singh S, Sharma S, Tewari SK, Roy RK, Goel AK and Rana TS – Assessment of genetic diversity in indigenous turmeric (*Curcuma longa*) germplasm from India using molecular markers. *Physiol. Mol. Biol. Plants*, 2015, **21**(2) : 233-242.

BOTANIC GARDEN AND DISTANT RESEARCH CENTRES

Scientists: L Bahadur, AK Dwivedi, AK Goel, Arvind Jain, RS Katiyar, RC Nainwal, TS Rahi, RK Roy, D Singh, SK Tewari

Technical Staff: A Batra, B Das, Alok Kumar, Rajeev Kumar, Satish Kumar, G Sharma, SK Sharma, Shweta Singh, RK Tripathi, SS Tripathi, Shankar Verma, Saurabh Verma

Grant-in-Aid Projects

Genetic improvement of bougainvillea through induced mutation, preparation of descriptors of the cultivars and development of germplasm collection centre

Bougainvillea is an important ornamental plant in floriculture and landscaping. Colourful bracts of Bougainvilleas appear in various shades of red, magenta, purple, mauve, orange, yellow, white, bi-coloured and also multi-coloured forms. Many of them have variegated foliage with attractive patterns. In this project, selected varieties of *Bougainvillea* have been treated with different doses of gamma rays and planted in experimental plots for assessing their performance and detection of mutants (Fig. 1). The main target is developing genetically dwarf and thorn less varieties suitable for pot culture. New mutants with desirable phenotypic characters will be identified and isolated in pure form. After multiplication the new mutant will be developed as new variety.

For proper identification of the varieties, morphological characters were documented and descriptors developed for each available variety. The morphological characters documented are - stem, leaves, thorns, bracts, flowers as per international standards. Further, for the development of 'National Germplasm Collection Centre' at the CSIR-NBRI, all the available varieties have been planted in a separate enclosure with proper label and lay out plan.

Establishment of a DUS test centre at CSIR-NBRI, Lucknow for bougainvillea, canna and gladiolus crops

Bougainvillea

A germplasm collection of 200 varieties is being maintained in the DUS test centre at the Botanic Garden, CSIR-NBRI, Lucknow. The varieties belong to four different species- *Bougainvillea spectabilis, B. glabra, B. peruviana* and *B.×buttiana.* Enrichment of germplasm collection was made by acquiring new varieties from various authentic sources: AHSI, Kolkata and other nurseries (Mrs. Eva Light Purple Variegata, Double Delight, L.N. Birla, Refulgens).

Characterization by recording morphological characters, both vegetative and floral, has been done keeping in view the key and diagnostic characters, which would be helpful to ascertain authenticity of the variety.

DUS guidelines have been prepared and approved by PPV & FRA. Registration of new varieties is ongoing.

Canna

A germplasm collection of 50 varieties is being maintained in the DUS test centre at the Botanic Garden, CSIR-NBRI, Lucknow. The varieties belong to six species - *Canna indica, C. generalis, C. flaccida, C. latifolia, C. edulis* and *C.warscwiczii.*

Morphological characterization has been done by recording key and diagnostic characters of each variety.

DUS guidelines prepared and approved by PPV & FRA. Registration of new varieties is ongoing.

Fig.1. Treated Bougainvillea cuttings in pots and Bougainvillea germplasm in the field

Evaluation of medicinal plants for cultivation in sodic wasteland of Uttar Pradesh

Soil sodicity is a major problem in arid and semiarid regions of India as it affects plant growth, development and productivity. As per the data published by Wasteland Atlas of India- 2011, saline and sodic land area in the country is about 6.81 lakh ha and Uttar Pradesh is the largest state that alone contributes 2.55 lakh ha (37.51 %) of the total sodic land in India. Salt tolerant varieties of some non-traditional crops, which can produce the valuable products under salt stress conditions, are being evaluated for economic utilization of sodic lands.

(a) Ashwagandha (*Withania somnifera* (L.) Dunal)

Ashwagandha plants were re-evaluated under pot and field experiments during this year for refinement and reconfirmation of previous results. In pot experiment, the sodicity levels were 10.0, 13.0, 17.5, 25.0, 30.0 and 35.0 ESP. Results indicated that increasing ESP levels did not affect the plant growth parameters up to 30 ESP. However, at 35.0 ESP plants were unable to produce the economic yield of the root (Fig.2).

(b) Kalmegh (*Andrographis paniculata* (Burm. f.) Nees)

Andrographis paniculata plants were grown in 8, 12, 16, 20, 24, 32 ESP soils. The result indicated that plants were unable to produce the economic yield above 16 ESP, indicating the critical limit for cultivation of kalmegh at 16 ESP under sodic soil condition (Fig. 3).

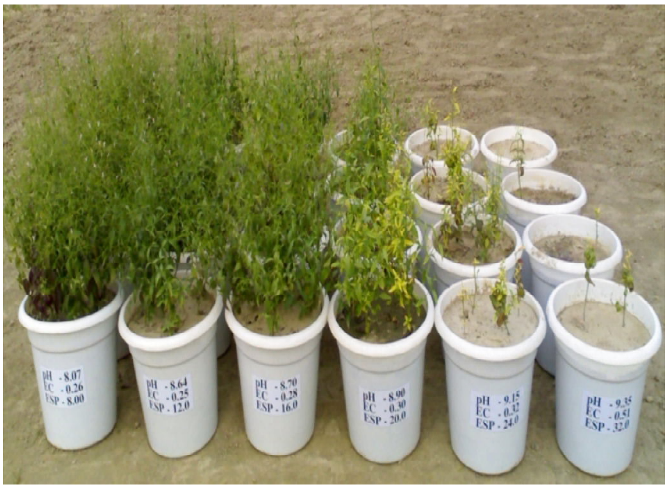


Fig. 3. Sodicity evaluation of *Andrographis paniculata* at 8, 12, 16, 20, 24, 32 ESP levels

Study on the effect of different sources and levels of organic matter on biomass yield and quality of Kalmegh

This project has been taken up to study the effects of different levels of organic manures like FYM, Pressmud and Vermi-compost and standardize their optimum doses for organic cultivation of Kalmegh.

The experiment involved application of FYM 0 - 30 t

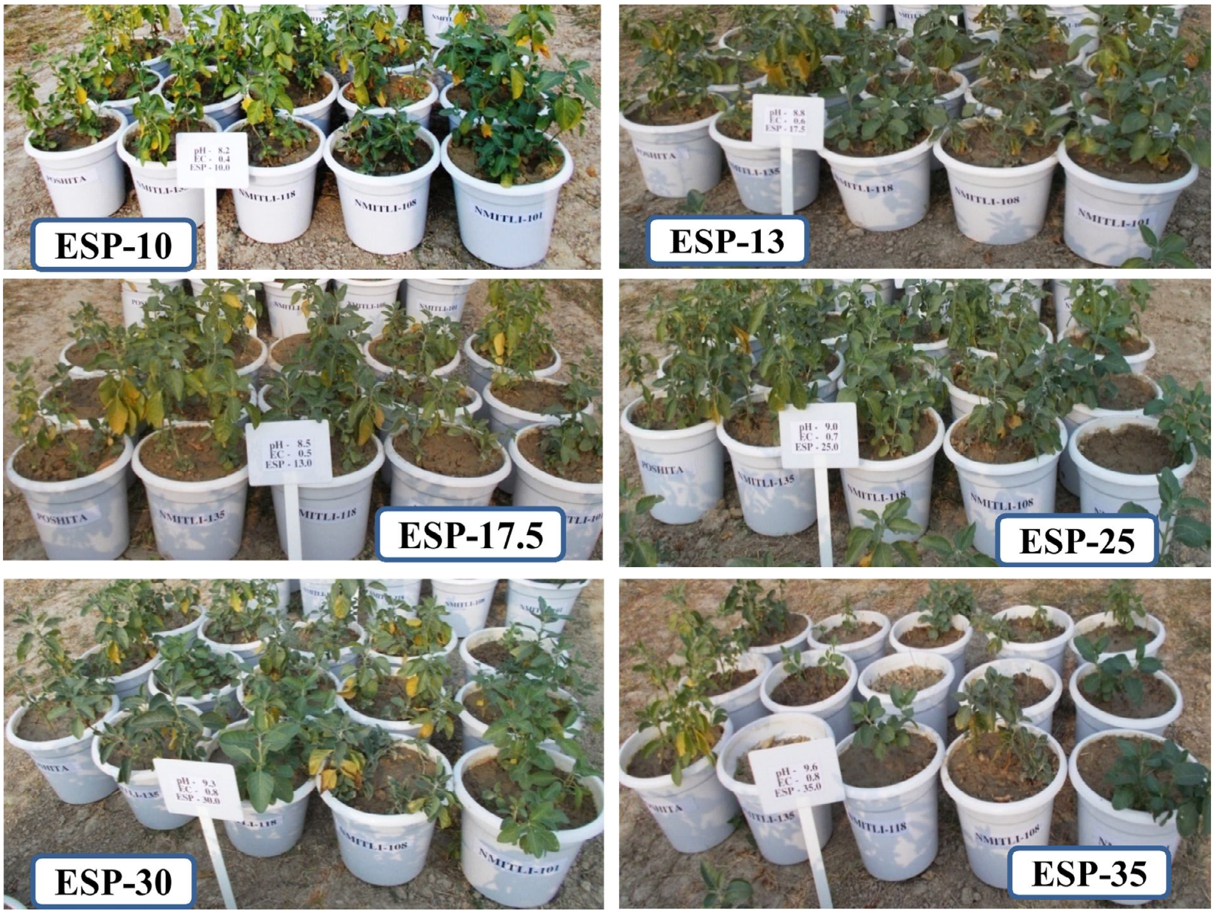


Fig. 2. Sodicity evaluation of ashwagandha at different ESP levels

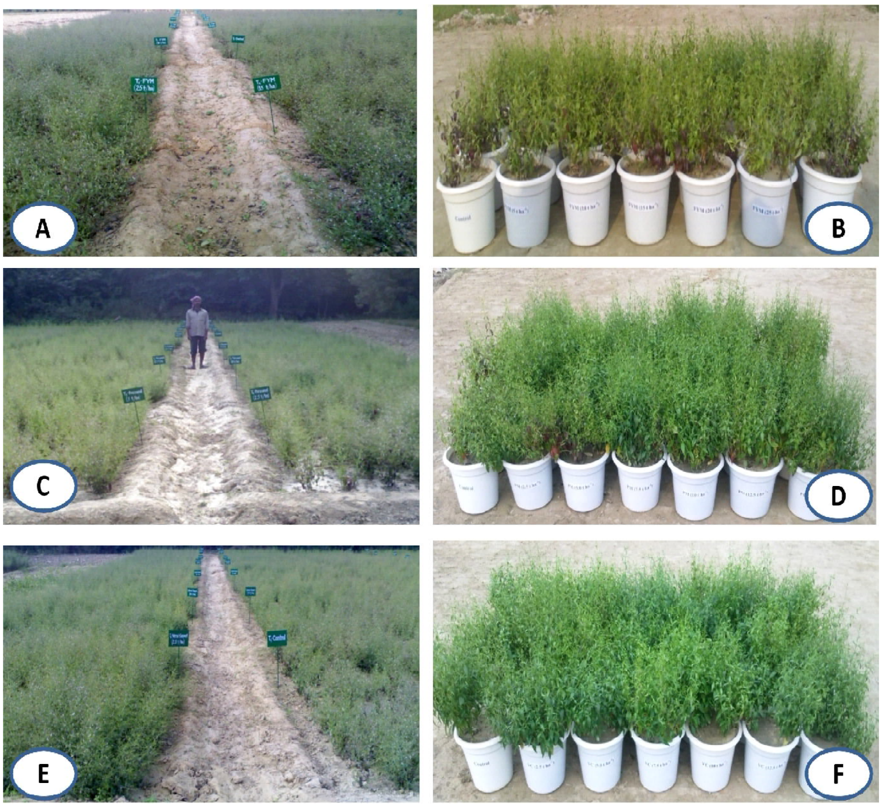


Fig. 4. (A-F). Field and pot experiments on the effect of organic manures on Kalmegh: A & B. FYM Field & Pot experiments; C& D. Pressmud Field & Pot experiments; E& F. Vermicompost Field & Pot experiments.

ha^{-1}, pressmud (up to 15 t ha^{-1}) and vermi-compost (up to 15 t ha^{-1}). The results indicated that plant height, number of branches, stem diameter, plant spread and plant biomass increased significantly with increasing doses of FYM up to 20 t ha^{-1}, and pressmud and vermi-compost up to 10 t ha^{-1} (Fig. 4A-F). In all the three trials, the growth of aerobic microbes increased with increasing doses of the manures resulting in decomposition, nutrient mineralization and an increased soil enzyme activity. Similar results were also recorded in the case of pot experiments involving the application of FYM, pressmud and vermi-compost.

Standardization of protocols and promotion of organic cultivation for Turmeric (*Curcuma longa*) in Uttar Pradesh

Considering the increasing demand for organically grown turmeric for commercial utilization, organic cultivation protocols were standardized using the following experimental designs:

Experiment-1 : (Standardization of integrated organic farming approach to achieve optimum yield and quality), consisting 11 treatments, viz. T_1 - 100 % RDF (NPK+ Zink), T_2 - Vermicompost 20 tonnes/ha, T_3 - Coir compost (@ 5 t/ha), T_4- 75 % Coir compost + 25 % Vermicompost, T_5- 75 % Vermicompost + 25% coir compost, T_6 - 50% Coir compost + 50 % Vermicompost, T_7 - 100 % Vermicompost + PSB, T_8- 100 % Coir compost + PSB, T_9 - 75 % Coir compost + 25 % Vermicompost + PSB, T_{10} - 75 % Vermicompost + 25% Coir compost + PSB, T_{11} - 50% Coir compost + *Azospirillum* + PSB.

Experiment-2 (Organic inputs for disease control and standardization of the proper remediation for disease and insect management), consisting 09 treatments, viz. T_1 – Control, T_2 - Mancozeb seed treatment, T_3 - Neem cake soil treatment, T_4 - *Trichoderma viride* seed treatment, T_5 - *Pochonia chlamydosporia* Bioagents, T_6 - Bordeaux mixture 1% spray, T_7 - Neem oil (0.5%) spray, T_8 - *Bacillus subtilis* seed treatment, T_9 - Neemgold (0.5%) spray. Both experiments were carried out in randomized block design, with three replications.

Fig. 5a- Field view of organic nutrient management; 5b- Field view of organic disease management.

In the experiment-1, different treatments significantly affected the growth attributing characters and yield of turmeric in comparison to control (Fig. 5a). Yield attributing characters like fresh weight of rhizomes, weight of mother rhizomes, weight of primary rhizomes per plants and total yield of rhizomes per hectare basis were also significantly affected corresponding to the treatments with maximum in T_7 - 100 % Vermicompost + PSB seed as compared to other nutritional treatments.

In the experiment-2, all the treatments of organic input significantly affected the yield and growth attributing characteristics of turmeric in comparison to control (Fig. 5b). However, *Trichoderma viride* seed treatment was found more effective in comparison to all other treatments. In case of disease incidence of leaf spot disease,seed treatment with *Trichoderma viride* was found more effective in comparison to all other treatments. Among the various bio control treatments, seed treatment with *Trichoderma viride*(T_4) showed higher fresh weight of rhizomes (101.78 g), mother rhizomes (33.80 g), primary rhizomes (67.98 g) and total yield (131.67 q ha^{-1}).

Utilization of industrial wastes for cultivation of medicinal and aromatic plants in sodic soil

Rehabilitation of degraded waste lands and sustainable utilization of industrial wastes require sustainable development of natural resources. For this, an experiment is being conducted at Distant Research Centre, CSIR-NBRI, Lucknow to assess the possibility of utilizing fly ash and press mud for cultivation of medicinal and aromatic plants in sodic soil.

Seven treatments i.e. T1-Control, T2- Press mud @ 20t ha^{-1}, T3- Fly ash @ 20t ha^{-1}, T4- Fly ash @ 2.5t ha^{-1} + Press mud @ 20t/ha, T5- Fly ash @ 5t/ha + Press mud @ 15t/ha, T6- Fly ash @ 7.5t/ha + Press mud @ 10t/ha, T7- Fly ash @ 10t/ha + Press mud @ 5t/ha and four medicinal and aromatic plants namely *Vetiveria zizanioides* (L.) Nash (Vetivar), *Cymbopogon flexuosus* Steud Wats (Jarankush), *Andrographis paniculata* (Brum f.) Wall ex Nees (Kalmegh) and *Plantago ovata* Forsk. (Isabgol) were grown in 2 X 2 m size plots. Significant increase in the growth and herbage yield of medicinal and aromatic plants had been observed by application of press mud and fly ash combinations in the waste sodic land having pH 9.57. Application of 15 t ha^{-1} press mud + 5 t ha^{-1} fly ash and 10 t h^{-1} press mud + 7.5 t ha^{-1} fly ash increased the yield significantly in *Andrographis paniculata*, whereas significant increase in growth parameters and fresh herbage yield in *Cymbopogon flexuosus*, *Vetiveria zizanioides* and *Plantago ovata* has been observed by application of 20 t ha^{-1} press mud + 2.5 tha^{-1} fly ash and 15 t ha^{-1} press mud + 5 t/h fly ash. Result of experiment shows that combination of industrial wastes like press mud and fly ash can be successfully used for cultivation of medicinal and aromatic plants in sodic soil. Safety evaluation (estimation of heavy metal content) in various plant products is under process.

In-House Projects

Enrichment and maintenance of the germplasms collection of diversified groups of plants and selected ornamental crops for conservation, education and bio-aesthetics

New Introduction

The Botanic Garden of CSIR-NBRI is known for the conservation and maintenance of germplasm collection of diverse groups of plants of botanical, horticultural and other economic interests. Exchange of plants of interests with other botanic gardens in India and abroad has been one of the major activities of NBRI Botanic Garden.

Seeds of *Erythrina crista-galli* were received from the Botanic Garden & Arboretum, Linz (Germany) in August, 2001. Seedlings of this plant were raised and their performance was closely monitored. The plantlets were matured in to small trees and they flowered for the first time during late April, 2014 (Fig. 6). A brief description *E. crista-galli* with other details is given below:

***Erythrina crista-galli* L. (Family: Fabaceae)**; Common Name: 'Cockspur Coral Tree', 'Cry-baby-tree'; Origin: Native to South America; National tree of Argentina; National flower of Argentina and Uruguay.

A tall shrub up to 3-4 m high; bark rough, grey; leaves pinnately trifoliate; leaf rachis 7-12 cm long, swollen at base; stipule small; leaflets ovate-lanceolate, margin entire, apex ovate, base truncate-round, glabrescent; two smaller leaflets opposite to each other (5.8-9 cm × 3-4 cm), the

Fig. 6. *Erythrina crista-galli* in blooms in NBRI Botanic Garden

third one terminal, larger (6.8-11 cm × 3.7-4.7 cm) with up to 1 cm long petioles, the stipels biglandular; inflorescence racemose, bilateral symmetric, 30 cm long; flowers pinkish red, corolla 2 lipped, 3-5 cm long, vexillium 2-3 cm broad, keel 3-4 cm long, wings minute hidden within the spathaceous calyx; stamens 10, diadelphous (9 fused in filaments, 1 free); style inflexed, 3.4 cm long; stigma small, terminal. Flowering: In late April.

Fig. 7. *Vernonia amygdalina* in vegetative and flowering stage

Vernonia amygdalina Delile (Asteraceae)

Vernonia amygdalina, an interesting medicinal plant species, has been introduced in the Botanic Garden. The rooted plants were collected from Mokakchung in Nagaland during a plant collection tour in August, 2008 and the stem cuttings were also procured from Supaul, Bihar in 2011. The performance of the plants was under consistent observation in the Botanic Garden. This species started flowering since 2012 (Fig. 7).

A native of tropical Africa, *Vernonia amygdalina* is locally called in Bihar as 'Insulin Plant' or 'Somnath'. Its common name in English is 'Bitter Leaf' as its leaves have a very bitter taste. In Bihar the leaves of this plant are used for controlling blood sugar levels, and also as wormicide, in malarial fevers, constipation and liver ailments. In Nagaland, the leaves are used for controlling persistent high fevers. Brief description of plant is as under:

A large shrub up to 3.5 m high with rough stem bark. Leaves petiolate, glabrous, elliptic, 5.0 - 22.5 x 1.5- 8.5 cm in size,dark green above, light green below, with a characteristic smell, light tomentose on mid-vein and lateral nerves, margins entire or finely toothed; petioles 1.0-6.0 cm long. Flowers creamy white in terminal corymbose panicles. Capitula up to 15.0 cm long, occasionally tinged with mauve, sweet scented attracting the honey bees. The plants are under constant observation and can be rapidly regenerated through the stem cuttings. Flowering: January - March in Lucknow.

New introduction to the Fern House

Helminthostachys zeylanica (Fig. 8 A) collected from Dudhwa National Park in Lakhimpur Kheri and *Asplenium nidus* (Fig. 8B & C) raised at culture room were introduced to enrich the fern house of CSIR-NBRI.

Conservation and Mass Propagation

Mass propagation (approximately 750 replicates) of nine ornamental fern species (*Adiantum capillus-veneris, Colysis elliptica, Microsorum alternifolium, M. punctatum, Nephrolepis biserrata, N. cordifolia, N. exaltata, N. tuberosa, Pteris vittata*), and Sanjeevani Booti (*Selaginella bryopteris*) was carried out for conservation and for exchange and sale. *In-vitro* regeneration and multiplication of *Adiantum peruvianum, Anemia rotundifolia, Athyrium pectinatum, Asplenium nidus, Microsorum scolopendrium* and *Lepisorus* sp. were also undertaken.

Renovation of Conservatory in Botanic Garden

The conservatory is the oldest Plant House of the Botanic Garden covering an area of 1370 sq. m. This was designed by Late S. Percy Lancaster, the famous British-Indian horticulturist, who worked in the Botanic Garden during 1953-59. The house has beds in informal design containing about 350 different plant species/ varieties representing about 80 countries.

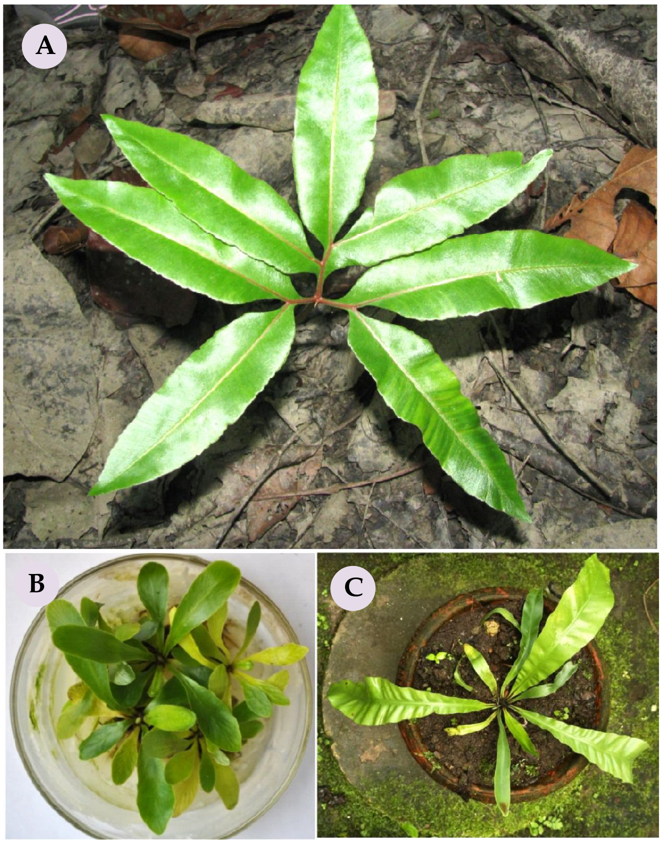


Fig. 8.(A-C). Ferns introduced in fern house of CSIR-NBRI: A. *Helminthostachys zeylanica;* B. & C *Asplenium nidus*

Fig.9. Newly renovated thematic beds in Conservatory

Over the years, the conservatory has become little out of date and necessitated renovation in order to make it modern, educative and more purposeful for the visitors. Keeping intact the basic layout, the renovation work has been taken up by relaying some selected beds that have been planted family-wise with representative plant species. The families included are: Bromeliaceae, Zingiberaceae, Acanthaceae, etc. Some beds have been planted genus-wise, such as *Aglaonema*, *Alocasia*, *Anthurium*, *Dieffenbachia*, *Draceana*, *Heliconia*, etc. All the plants were relabeled in accordance with widely accepted taxonomic disposition and latest botanical nomenclature (Fig. 9). Plant labels for threatened plant species were prepared, based on the latest IUCN Red List.

A new demonstration facility in the form of a glass house has been created and named as 'The World of House Plants'. Altogether eight display boards on various groups of house plants viz. flowering type, foliage type, bromeliads, bulbous, rhizomatous, tuberous plants, ferns, palms and different styles of vertical gardening have been installed. Selected house plants on different themes have also been displayed in an aesthetic manner (Fig. 10). The facility therefore, showcases the diversity of house plants and their use in various ways in a systematic and thematic manner for interior plantscaping purposes.

Fig.10. Interior view of the new facility- 'The World of House plants'

New varieties released

Chrysanthemum

A new variety of Chrysanthemum - '**NBRI-Kesar**' was released during the Rose and Gladiolus Flower Show held at NBRI Botanic Garden on January 18-19, 2015.

***Pedigree*:** Gamma irradiation mutant developed from *Chrysanthemum morifolium* 'Puja'.

Description

The new mutant variety bears medium-sized, 'Decorative'- type, bi- coloured flower heads which bloom during late chrysanthemum season (late December to mid January). Due to the effect of gamma-ray mutation, the colour of the upper surface of florets developed yellow pigment (RHS Colour Chart; Yellow Group 9B; FAN-1) instead of pink (in parent 'Puja'; RHS Colour Chart; Purple Group 77C; FAN-2), while the colour of the lower surface did not change and remained light pink. The colour contrast between upper & lower surfaces of florets is visible due to spatulate-tubular (partially open or semi-quilled) nature of the florets. The variety name 'NBRI-Kesar' is chosen to represent this new ornamental effect produced by the yellow-pink, spatulate-tubular ray florets of the capitulum (flower-head). The plant attains average height up to 50 cm and produces up to 50 flower-heads. Average size of the capitulum (across) and floret length at its full bloom is 7.7 cm & 4.3 cm, respectively (Fig. 11).

Speciality

The novelty of the new variety lies in its 'Yellow-pink' bi-coloured florets and larger capitulum size (~10% larger). It is a new ornamental addition to the late-blooming section of our *Chrysanthemum morifolium* germplasm which can be used in beds, as potted plants and for cut- flower purposes.

Fig.11. Chrysanthemum 'NBRI-Kesar'

Gladiolus

A new variety of Gladious - '**NBRI-Lalima**' was released on February 9, 2015.

***Pedigree*:** 'Jester' × 'Fedelio'

Description

A hybrid seedling; plant height 75-90 cm; spike length 70-85 cm; florets 15-16 per spike; florets compactly arranged in two rows; flower heads horizontal, 10-12 x11-12 cm in size, uniform pinkish-red in colour from tip to the middle and gradually fading to the bottom, mature florets are pinkish-red (Fan-1, Red Group 50A); throat and inner two tepals of the floret have a purplish-red blotch (Fan-2, Red-purple Group 60B) at the base and also an yellow coloured stripe; purplish splashes on the tip of the tepals; highly frilled (Fig. 12).

Fig.12. Gladiolus 'NBRI-Lalima'

Speciality

Floret colour is unique in pinkish-red combination with purplish splashes on the tip. The florets are highly frilled. It is a late blooming variety, ideal for vase decoration and as cut-flowers.

Distant Research Centres (Banthra Research Station)

The Distant Research Centre (Banthra Research Station) comprises the experimental field units of CSIR-NBRI, developed on sodic land. These field units were rehabilitated under diverse land use systems, including floriculture, herbiculture, moriculture, energy plantations, field gene bank, poplars, bambusetum, and a semi-natural forest. The centre is also working on germplasms conservation of economically important plants such as exotic and indigenous poplar clones, varieties of Chrysanthemum, HT rose, *Canna* and ~200 species of medicinal and aromatic plants. R&D experiments are carried out for standardization of agro-technology on degraded sites. In this attempt greater emphasis is laid on non-traditional crop plants, including floriculture and medicinal and aromatic plants.

Identification of sodicity tolerant varieties of Gladiolus and integrated nutrient management

An experiment was conducted at Gehru Centre, comprising three different nutritional management practices as main factor and twelve gladiolus varieties as sub factor for evaluating the growth and performance and selection of the most promising gladiolus variety suitable for cultivation in degraded sodic land. It was concluded that the field provided with well decomposed organic manure, and corms treated with phosphorus solubilising bacteria (PSB) and *Trichoderma* showed significantly higher growth and flowering with more number of spikes bearing florets per plant. Among the varieties, 'Tiger Flame' and 'Big Time Supreme' showed significantly better growth performance in terms of plant height at 90 DAS, spike length and florets/spike. However, significantly higher corm yield per plant was obtained from 'Big Time Supreme', indicating ultimately better peroformance of Big time supreme, among the all varieties evaluated under sodic land condition (Fig. 13).

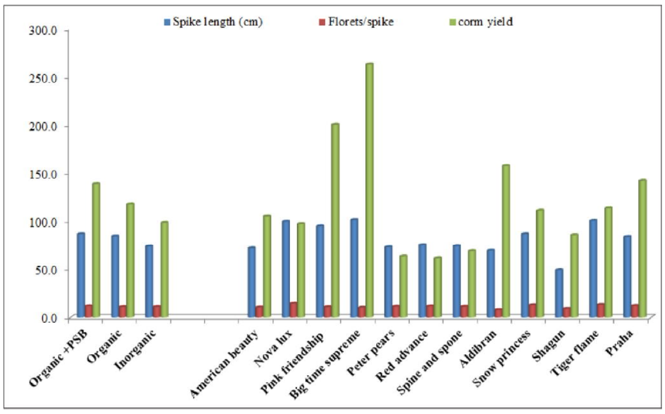


Fig. 13. Performance of growth and yield in 12 variieites of Gladiolus under three nutritional management regime under sodic land conditions

Evaluation of *Canna* sp. in sodic soils

The growth performance of *Canna* 'Red Dazzler' was evaluated under three different fertilization trials: (i) sole application of chemical fertilizers, (ii) FYM + PSB, + *Trichoderma*), and (iii) PSB + *Trichoderma*. The response of biofertilizers on the growth of Canna was not significant at the initial stage of investigation. However, response of FYM supplemented with PSB and *Trichoderma* and combination of both (PSB+*Trichoderma*) were found better than application of chemical fertilizers. The *Canna* varieties in CSIR-NBRI collections were screened to identify the best suited cultivars for sodic soil. Five varieties 'Caltolen', 'Pink Sunrise', 'Facceda', 'Black Night' and 'Bengal Tiger' were found as suitable for sodic lands. Significant variation was recorded in terms of their growth performance, although significant higher plant height was recorded in 'Black Night' throughout the year. This was followed by 'Bengal Tiger' and 'Caltolen', which were at par with 'Pink Sunrise'. However, number of tillers per plant was significantly higher in later stage of growth at 300 DAP (days of planting). The varietal evaluation was further extended by adding three species and 24 varieties (Fig.14 A & B).

Screening of drought tolerance in rice varieties

Field experiments were conducted with two rice varieties- Heena and Kiran, transplanted at different water stress levels, including no irrigation (control), one irrigation at maximum tillering stage (I0), two irrigations- one at maximum tillering stage and other at flowering stage (I1), irrigation at interval of 4-5 days to maintain the field at saturation level (I2). Heena performed well during different water stress levels. Variation in plant height among the genotypes indicated that different genotypes had different water requirement. Heena responded well by showing more fertility in water stress levels. In both Heena and Kiran, moisture stress reduced the seed test weight significantly, although the degree of reduction in 1000 seed weight was different in the two genotypes. Different soil moisture levels and rice genotypes interacted significantly for grain yield. Water stress at flowering stage reduced the grain yield than water stress at other growth stages. Another field experiment was conducted for screening the drought tolerant cultivar of rice and response of PGPRs for its growth and yield under rainfed condition. The results showed that PGPR colonization significantly enhanced rice growth under rainfed conditions. Among the rice cultivars, ND 359 produced significantly higher grain yield followed by 'Sushk Samrat', due to comparatively higher harvest index.

Conservation and propagation

Different tree species (80), shrubs/ herbs (30) including 30 RET species are maintained in Field Gene Bank in 2 ha area. During the reporting year, five new species were added to the Field Gene Bank. Natural regeneration of 30 species was observed in the conservation garden. Three species of aquatic plants (*Nelumbo nucifera,*

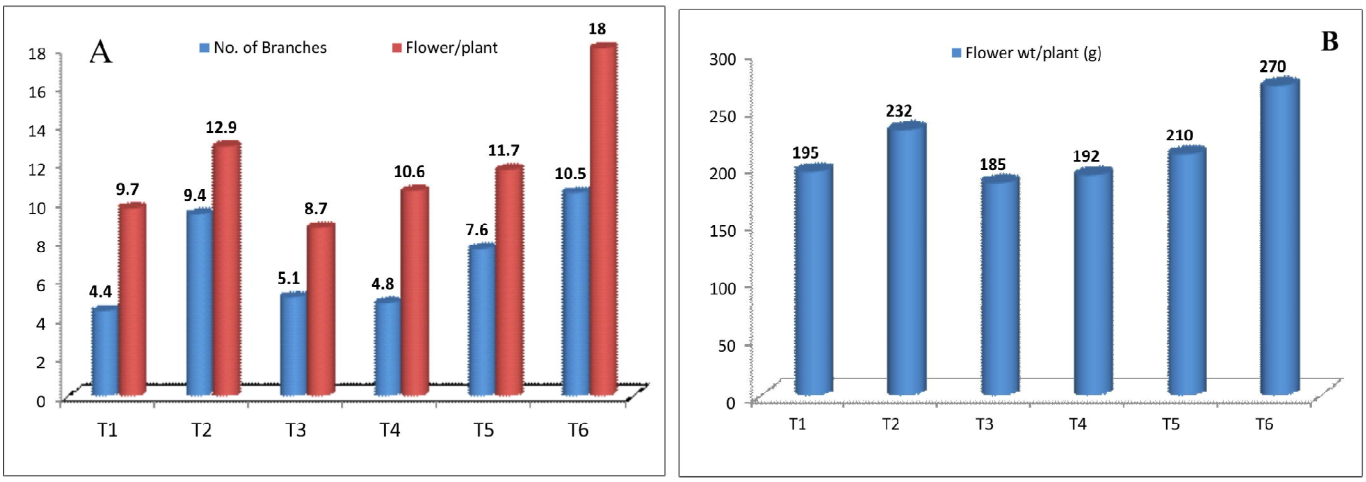


Fig. 14 (A–B). Evaluation of five Canna varieties for their growth performance under sodic soils: (A) number of branches and flowers per plant; (B) flower weight per plant.

Nymphaea stellata, and *Euryale ferox*) are being maintained. *Nymphaea* collection was enriched with addition and large scale multiplication of *Nymphaea stellata*. Vegetative propagation of different horticulture crops including ornamental, house plant, medicinal and aromatic plants was also done for R&D and sale purposes.

Evaluation of ashwagandha (*Withania somnifera* (L.) Dunal} and kalmegh (*Andrographis paniculata* (Burm. f.) Nees) with different organic carbon levels

The levels of soil organic carbon are directly related to the yield and quality of the plant. For optimization of the organic carbon levels for optimum yield and quality of Ashwagandha and Kalmegh, the experiments were conducted with different organic carbon (OC) levels.

Ashwagandha and Kalmegh were evaluated with various levels of OC (0.5% - 3.5% in Ashwagandha and 0.5-4.0% in Kalmegh) as a residual effect of added organic manures in the previous year. Results indicated that plant height, root and shoot length, root and shoot weight in both the plants increased with increasing organic carbon. Analysis of the root, stem and leaf for quality parameters is in progress.

Collection, acclimatization, multiplication and establishment of germplasm bank of *Aloe* spp. in sodic soil

Utilization of degraded sodic wastelands with adaptable plants of industrial importance is the aim of this project. *Aloe* is a potential candidate that can be exploited scientifically for sodic land reclamation. Twenty six species of *Aloe* have been collected, acclimatized, multiplied, and established as a germplasm bank for gradual sodicity screening and cultivation.

Assessment of growth and gel yield in *Aloe* spp. at various levels of sodicity

Achieving high growth and yield of any plant species in sodic stress environment is directly related to proper remediation and utilization of such soil. With this view three highly marketed *Aloe* spp. as per taste of gel, viz. *Aloe vera* (normally bitter), *A. ferox* (extremely bitter), and *A. maculata* (non- bitter), were examined for their growth parameters and gel yield production at four levels of naturally existing soil pH as 8.0 (control), 8.50, 9.10 and 9.65 at Distant Research Centre (DBC) Banthra (Fig. 15).

The plant growth in all three *Aloe* species increased

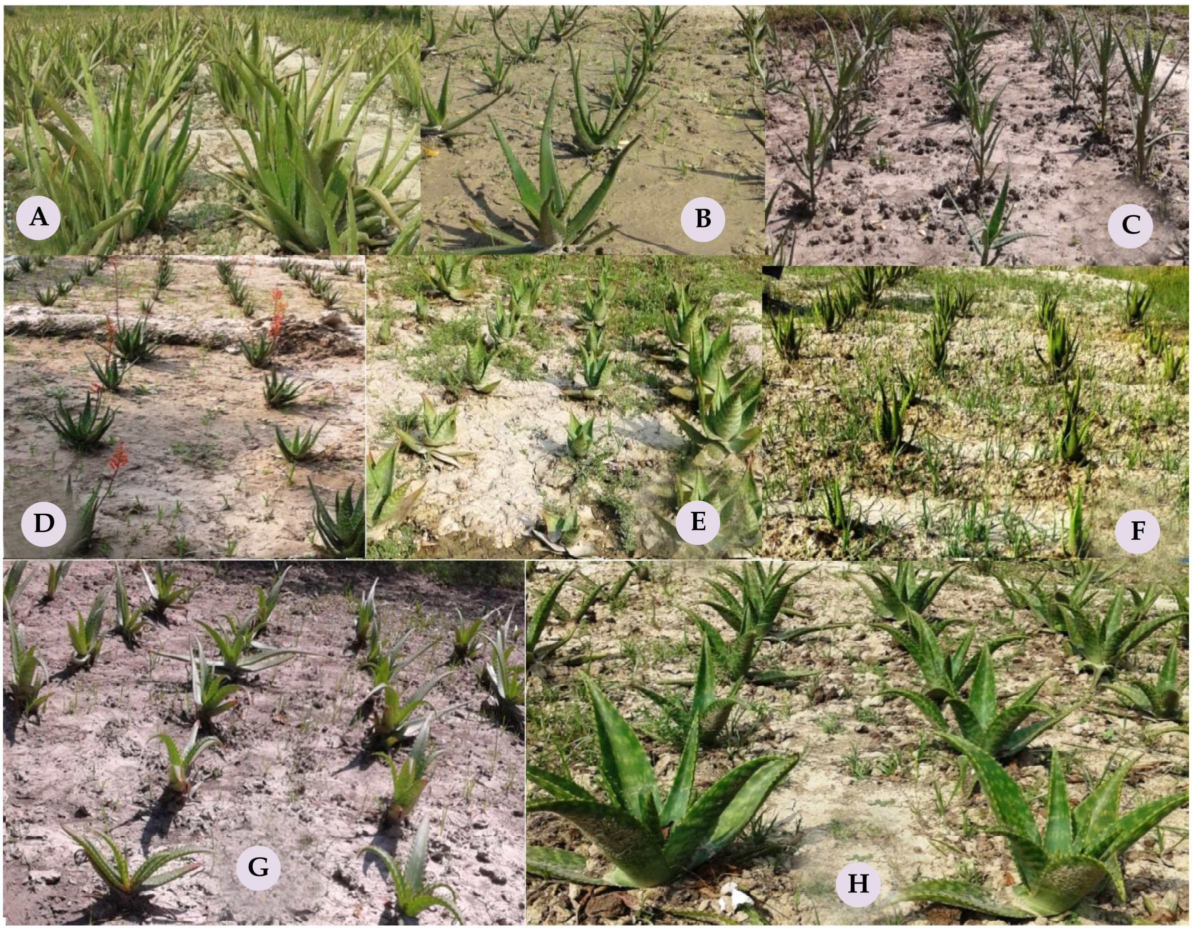


Fig. 15 (A-H). *Aloe* species in germplasm bank at DRC Banthra: A. *Aloe vera*; B. *A.spicata*; C. *A.aageodon*; D. *A.×nobilis*; E. *A.maculata*; F. *A.ferox*; G. *A.greatheadii*;H. *A.gariepensis*

Table 1. Effect of sodicity on growth performance of different *Aloe* spp. grown at various sodicity levels at DRC Banthra

Growth Character Observations	Sodicity (pH) levels	*Aloe* species			Mean	LSD at 0.05
		Aloe vera	*Aloe maculata*	*Aloe ferox*		
Plant height (cm)	(Control) 8.0	22.20	17.00	16.00	**18.40**	1.80
	8.5	31.00	22.00	21.00	**24.67**	
	9.1	37.00	30.00	27.00	**31.33**	
	9.65	22.00	16.60	16.00	**18.20**	
	Mean	**28.05**	**21.40**	**20.00**		
	LSD at 0.05		**2.072**			
Number of leaves	(Control) 8.0	22.00	14.00	13.00	**16.33**	3.68
	8.5	28.00	18.00	16.00	**20.67**	
	9.1	40.00	24.00	20.00	**28.00**	
	9.65	21.60	13.60	12.80	**16.00**	
	Mean	**27.90**	**17.40**	**15.45**		
	LSD at 0.05		**4.24**			
Width of leaves (cm)	(Control) 8.0	4.28	5.34	2.18	**3.93**	1.03
	8.5	4.66	5.84	2.40	**4.30**	
	9.1	5.00	7.40	3.20	**5.20**	
	9.65	4.10	4.98	2.00	**3.69**	
	Mean	**4.51**	**5.89**	**2.45**		
	LSD at 0.05		**1.19**			
Thickness of Leaves (cm)	(Control) 8.0	1.16	0.83	0.70	**0.90**	0.089
	8.5	1.22	0.90	0.80	**0.97**	
	9.1	1.60	1.17	0.85	**1.21**	
	9.65	1.14	0.82	0.68	**0.88**	
	Mean	**1.28**	**0.93**	**0.76**		
	LSD at 0.05		**0.103**			

significantly with increasing pH levels up to pH 9.1 and decreased at pH 9.65 at par to that of control soil pH (8.0). The plant growth was considerably greatest in *A. vera* followed by *A. maculata* and comparatively slow in *A. ferox* in control to highest sodic soil pH (9.65) level (Table 1). The gel yield followed the same trend as in case of growth pattern of all three species.

Flowering phenology in *Aloe* spp. under sodicity

The flowering behaviour, ie. time of floral bud initiation, duration of blooming and senescence in seven species of *Aloe* (*Aloe ferox, A. greatheadii, A. harlana, A.* × *nobilis, A. ortholopha, A. spicata* and *A. vera*) was studied under sodicity stress (Fig. 16).

In most of the *Aloe* species examined the flowering occurred in one year old plants and its season started generally from October and remained till April. The flowering in *Aloe* ×*nobilis* starts in August and remains till April. The flowering in *Aloe spicata* occurs in two year old plants and the duration of flowering was same as in other species. The flower colour is red in *Aloe ferox, A. ortholopha, A.* × *nobilis* and *A. vera* whereas it is light maroon in *A. greatheadii* and yellow in *A. spicata* till senescence.

Fig. 16 (A-I). Early stages and full blooming in *Aloe* species : A-C, Early and full blooms in *Aloe spicata*; D. *A. ferox*; E. *A.* ×*noblis*; F. *A. greatheadii*; G. *A. harlana*; H. *A. vera*; I. *A. ortholopha*

Seed germination in *Aloe vera*

Seeds of *Aloe vera* were sown and observed for viability, germination time, germination %, mortality and growth behaviour. Out of 80 seeds sown, only 45 seeds germinated. Of these, 10 germinated seeds did not grow further while the remaining 35 germinated seeds are in the seedling stage with 3 or 4 small leaves and with a well developed root system.

Bacterial and fungal diseases in *Aloe* spp. under sodic soil conditions

Aloe species are known to be affected with several bacterial and fungal diseases. Aloe products must be prepared from disease free Aloe leaves. Considering this, a study was conducted to examine the bacterial and fungal disease infected plants of different *Aloe* species growing in sodic soil environment at DRC Banthra. The study revealed that fungal diseases occur mostly in susceptible *Aloe species* in summer and bacterial diseases in rainy season. *Aloe greatheadii* and *A.* ×*nobilis* have been observed with bacterial infection, while *Aloe maculata* and *A. spicata* with fungal infection.

Publications

1. Akansha, R, Kumar S, Singh S, Rastogi RR and Roy RK – Studies on reproductive parts of flower and palynology of *Gladiolu*s (*Gladiolus* L.) varieties. *Int. J. Curr. Microbiol. Appl. Sci*., 2014, **3**(10) : 823-829.
2. Bahadur L and Tiwari DD – Nutrient management in mung bean (*Vigna radiata* L.) through sulphur and biofertilizers. *Legume Res*., 2014, **37**(2) : 180-87.
3. Goel AK and Roy RK – Conservation and popularization of Cycads in India - At CSIR-NBRI Botanic Garden, *Encephalartos*, *Int. J. Cycad Soc. South Africa*, 2014, **116** : 9-12.
4. Jha V, Jha JK and Goel AK – *Calotropis procera* based 'Aartak Paat' cottage industry related with 'Chhath' festival in North Bihar. *Ethnobotany*, 2014, **25**(1-2) : 166-68.
5. Katiyar RS, Nainwal RC, Singh D, Chaturvedi V and Tewari SK. — Effect of spacing and varieties on growth and yield of Coriander (*Coriandrum sativum* L.) on reclaimed sodic waste soil. *Progressive Res. 2014*, **9** : 811-814.
6. Kumar S, Kumari B and Goel AK – Study of leafy vegetables supplemental to malnutrition among tribals in Jharkhand. *Ethnobotany*, 2014, **25**(1-2) : 135-38.
7. Kumar S, Roy RK, Goel AK and Tewari SK – Comparative studies on growth and cut flowers production of Gerbera under naturally ventilated polyhouse and low cost greenhouse in north eastern plains of Uttar Pradesh. *Indian J. Hort*., 2014, **17**(4) : 531-535.
8. Nainwal RC, Singh D, Katiyar RS, Sharma L and Tewari SK – Response of garlic to integrated nutrient management practices in a sodic soil of Uttar Pradesh. *J. Spices Aromatic Crops*. 2015, **24**(1) : 33-36.
9. Roy RK and Singh S – Urban landscape and amelioration of environment by trees : Methods and approaches. *Int. J. Latest Res. Sci. Technol*., 2014, **3**(3) : 98-104.
10. Sahoo AK, Pal DC and Goel AK – A glimpse of the tribal and ethnobotanical diversity in India. *Ethnobotany*, 2014, **25**(1-2) : 47-55.
11. Singh D, Nainwal RC, Katiyar RS and Tewari SK – Influence of integrated management of growth and yield of garlic (*Allium sativum* L.) under partially reclaimed sodic soil. *Progressive Res*. 2014, **9** : 783-788.
12. Singh S, Kumar S, Prasad R, Roy RK, Kumar S and Goel AK –Comparative analysis of growth and flowering characteristics of Canna cultivars in agro-climatic condition of Lucknow, Uttar Pradesh, India. *Pl. Archives*, 2014, **14** (2): 935-938.

PLANT DIVERSITY, SYSTEMATICS AND HERBARIUM

Scientists: P Agnihotri, AK Asthana, Baleshwar, LB Chaudhary, T Husain, PB Khare, Sudarshan Kumar, KN Nair, S Nayaka, Anand Prakash, TS Rana, Kanak Sahai, AP Singh, MR Suseela, DK Upreti, VV Wagh

Technical Staff : Sandeep K Behra, B Dutt, KK Ingle, KK Rawat, V Sahu, K Toppo, Sushma Verma

Grant-in-Aid Projects

Studies on algal blooms, their characterization and the factors influencing bloom formation

Mass culture of algae: Six algal strains were isolated from different localities of Uttar Pradesh, of which four strains of *Chlamydomonas* sp. (NBRI 077), *Nannochloropsis* sp. (NBRI 078), *Chlorella* sp. (NBRI 079) and *Scenedesmus* sp. (NBRI 080) were grown in two different culture media (TAP and BG11) for studies on their growth curve and biomass productivity. The algal strains showed better biomass production in TAP media than BG11. Lipid and protein estimates showed *Nannochloropsis* sp. with maximum lipid and *Chlorella* sp. with maximum protein content.

Mass culturing of selected algal strains was carried in open system in CSIR-NBRI's fish pond and other ponds in Institute's Botanic Garden. The culture conditions were optimized initially for culturing the natural algal bloom of *Golenkenia* sp. present in the fish pond. Two more strains- *Neochloris* sp. (NBRI 081) and *Nannochloropsis* sp. (NBRI 082) were cultured in two open ponds. Density polythene containers (photobioreactors) were designed and 15 L cultures were grown in each photobioreactor. Low cost agriculture fertilizer urea (100 mg/L) and single super phosphate (SSP- 50 mg/L) were added in tap water along with 15% inoculums while other culture conditions were kept constant. In late log phase the cultures were transferred to open ponds having 2500 L of media and the volume of the cultures was further scaled up to 30000 L by addition of media. The growth rate of algae in open ponds was also determined by measuring the O.D. at 680 nm.

Optimization of culture condition for enhanced biomass and lipid: To enhance the biomass and lipid production the culture conditions were optimized. The *Scenedesmus* sp. (NBRI 080) was grown in three different trophic conditions viz. Autotrophic, Heterotrophic and Mixotrophic. Various sources of organic carbon, such as acetic acid, glucose, sucrose and glycerol were used for the mixotrophic culture conditions. The pH (5, 6, 7, 8 and 9) and light intensity (3000, 4000, 5000 and 6000 Lux) were also optimized by culturing the algal strain. Maximum biomass was found at 5000 Lux light intensity and pH 7, while lipid percentage was found maximum at pH 5 and 4000 Lux light intensity. Optimization of nitrogen source was done by cultivating the algal strain using different nitrogen sources such as urea, KNO_3, NH_4Cl, and $NaNO_3$. The biomass yield and lipid content were found maximum when NH_4Cl was used as the nitrogen source.

Wastewater cultivation of algal species: *Scenedesmus* sp. (NBRI 080) was collected from wastewater at a local beverage industry in Barabanki. Different ratio of waste water and TAP media i.e, 1:3, 1:1, 3:1 and 1:0 were used to get various concentrations (25%, 50%, 75% and 100%) of media for cultivation of the algal strain. A combination of 50% wastewater and 50% TAP media produced the maximum biomass and lipid content.

Amelioration of bio-hydrogen generation by genetic modification and process optimization from microorganisms

Six microalgal isolates (*Chlamydomonas* sp., *Chlorella* sp., *Scenedesmus* sp., *Chlorococcum* sp., *Nanochloropsis* sp., *Phormidium* sp.) were screened for biomolecules by Fourier Transform Infrared Spectroscopic (FTIR) analysis. The isolates were compared for biomass, carbohydrate and lipid content in three different culture media, viz. BG11, BBM and TAP. Higher biomass, carbohydrate and lipid content were observed in the TAP medium. Higher biomass yield (252.23 ± 15.4 mg/L/d) and lipid productivity (56.5 ± 1.9 mg/L/d) were obtained in *Chlorella* sp. (NBRI029) followed by *Scenedesmus* sp. (NBRI012) with 202.37±10.2 mg/L/d biomass and 37.6 ± 1.2 mg/L/d lipid content.

H_2 production was measured for these isolates by using H_2 sensor fitted to fabricated photobioreactor in anaerobic condition. *Scenedesmus* sp. (NBRI012) showed maximum percentage of H_2 (17.72 %) of the total evolved gases in head space of the photobioreactor on the sixth day of the fermentation, whereas *Chlorella* sp. (NBRI029) evolved H_2 up to 9.56 % on the 4^{th} day of fermentation. On subjecting to sulfur depletion, there was an initial increase in the dissolved O_2 as well as pH of the growth medium. The dissolved O_2 concentration began to drop rapidly within one day and the culture became anoxic, and as a result, the pH began to decline from 7.9 to 7.1. It was inferred that sulfur deprivation during H_2 production increased the lipid content of the residual biomass (lipid content prior S deprivation, 244.44 mg/L and after S deprivation, 410.03 mg/L). The S deprived biomass is expected to be a good source of lipid. The biodiesel quality of the fatty acids of residual biomass of *Scenedesmus* sp. (NBRI012) was found to be in accordance with international standards (IS 15607, ANP255, EN14214, and ASTM D6751).

Characterization of cyanotoxins (microcystins) and quantification of their potential utilization

Water sampling was done from Dal lake (Jammu), Shardha River (Unnao), Ganga Ghat, Sewage treatment plant water (Jajmau, Kanpur), Sai and Gomti River (Lucknow) and local water bodies of Lucknow for isolation of toxic microalgae. The physico-chemical parameters, i.e. pH, Dissolved Oxygen, conductivity, phosphate, nitrate, sulphate, iron, chromium and chlorine were estimated. Algal growth in the water bodies was evident during the months November to February. The most prominent algal forms observed belonged to the genera: *Sceendesmus*, *Chlorella, Microcystis, Oscillatoria*, *Phormidium, Anabaena, Nostoc, Aphanothece, Aphanocapsa, Chroococcus* and *Lyngbya*.

The microalgal forms were isolated, purified, grown and maintained in BG11 media in standard growth conditions in the culture room. Toxicity of microalgae was checked by antibacterial and anticancerous assay. The microorganisms *Staphylococus aureus, Bacillus subtilis, Pseudomonas aeruginosa* and *Klebsiella pneumonia* were obtained from CSIR-IMTECH, Chandigarh for antibacterial assay while cancer cell lines were cultured at CSIR-CDRI, Lucknow. Algal cultures were harvested, freeze dried and extracted in various solvents for the preparation of extract. The extract was used for bioassay and for purification of the active component. *Scenedesmus* sp., *Oscillatoria* sp. and *Phormidium* sp. extract was found to be toxic and showed prominent antibacterial and anticancerous activity. The active component was detected by HPTLC and HPLC analysis. *Oscillatoria tenuis* obtained from Ganga River in Kanpur showed microcystin concentration well above the permissible limit of WHO. *Oscillatoria tenuis* was selected for further study of abiotic stress on the biomass and total protein content of the cyanobacterium.

Screening of potential algal species for bio fuel production and optimization of growth condition for high lipid accumulation

To overcome the problem of global energy crises researchers are now focusing on alternative sources of energy. Microalgae with their potential to produce high biomass and lipid content have been identified as one of the alternatives for fossil fuels. Keeping this in mind a large number of fresh water green microalgae were screened, of which *Scenedesmus abundans* was found to be a good feedstock for biodiesel production. Optimal nitrogen content in culture media was determined in order to enhance the overall lipid content. Best lipid extraction as well as trans-esterification process and optimal pH condition were also worked out. The pH is one of the important factors that regulate the lipid producing machinery by regulating the expression of key lipid biosynthesis gene - Acetyl-CoA carboxylase (ACCase). Other culture conditions such as, optimal light intensity as well as the concentration of phosphate in the culture media were also studied for higher production of biomass as well as lipid content.

Characterization of microalgae from carpet industry effluent to assess their potential for antimicrobial and biofuel

Algal samples collected from carpet industry effluent of Bhadohi district were isolated and purified using standard methods. The algae were identified based on microphotographs and using manuals. The prominent algal forms belonged to *Chlorella*, *Oscillatoria*, *Nannocloropsis*, *Phormidium*, *Scenedesmus*, *Clamydomonas* and *Nostoc.* The algal cultures are maintained in BG11 liquid growth medium and agar slants. Collected algal samples were deposited in CSIR-NBRI (LWG) herbarium. Water samples of industrial effluent were regularly monitored for physico-chemical characteristics such as pH, temperature, ion conductivity, dissolved oxygen, concentrations of nitrite, nitrate, phosphorus, sulphate, chromium, copper and iron. Algal cultures were harvested, freeze dried and extracted in various solvent for the preparation of extract. The extract was used for antibacterial assay and lipid estimation. *Bacillus subtilis, Klebsiella pneumonia*, *Pseudomonas aeruginosa* and *Staphylococus aureus*, obtained from CSIR-IMTECH, were used for antibacterial assay. *Nostoc* sp. and *Oscillatoria* sp. extract showed prominent antibacterial activity. Maximum lipid content in *Scenedesmus* sp. was 28% of dry weight, while in optimized condition lipid content increased to 48% of dry weight.

Isolation, screening and nutritional profiling of promising microalgal strains

The biomass of naturally growing green alga *Golenkinia radiata* Chodat (Fig. 1), was collected from water bodies in Uttar Pradesh and its proximate compositions like carbohydrate, protein, lipid and also the pigments (chlorophyll and carotenoids) were analyzed. This is the first report of nutritional analysis of Indian species of *Golenkinia*. The nutrient profile of the *G. radiata* included carbohydrate (40.39%), protein (13.3%), lipid (12.9%), 64.9 mg total lipid per 500 mg biomass, and energy 1385.24 kJ per 100 gm biomass. The biomass was rich in carbohydrate content which may have influenced the fish growth in the ponds from where the microalga was collected.

Alpine ecosystem dynamics and impact of climate change in Indian Himalaya

Under long term monitoring programme of Indian Space Research Organization (ISRO), the Highest Summit Point (HSP) in East Sikkim and Aparwat area in Jammu & Kashmir were explored for their lichen diversity within 3m, 5m and 10 m Submit Area Sections (SAS). Spectral analyses were completed for seven lichen species.

Lichenometric studies were carried out in Kupup and Thangu areas of Eastern Himalaya in Sikkim and Thajiwas Glacier in Ganderbal district of Jammu & Kashmir by estimating diameter of a common crustose lichen (*Rhizocarpon geographicum*) growing luxuriantly on exposed boulders. It was estimated that the rate of glacier retreat is faster in Eastern Himalaya as compared to the North Western Himalayan regions in India.

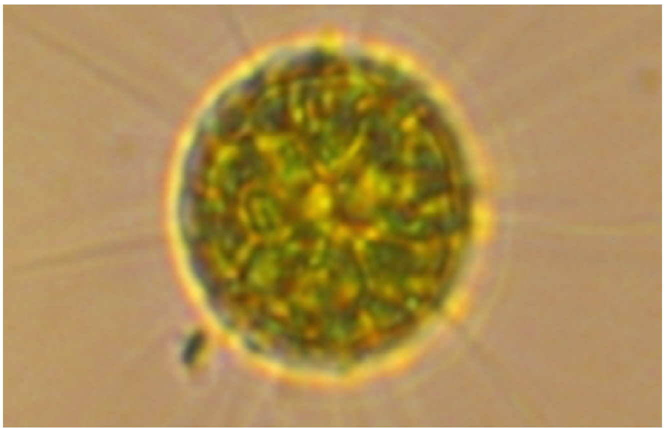


Fig.1. *Golenkinia radiata* Chodat

Lichen exploration in protected areas of Uttar Pradesh and sensitizing stakeholders for conservation

The project aims to explore lichens from protected areas of Uttar Pradesh and also to conduct biodiversity awareness workshops for students, local people and foresters. A field trip to Hastinapur Wildlife Sanctuary, Soor Sarovar Wildlife Sanctuary, National Chambal Sanctuary and few western districts of Uttar Pradesh (Agra, Bijnore, Lakhimpur, Moradabad, Muzaffarnagar, Pilibhit, Rampur, Saharanpur and Shahjahanpur) resulted in collection of 200 lichen specimens belonging to 33 species in 21 genera and 14 families. Seven lichen species were encountered as new records to the state of Uttar Pradesh: *Arthothelium chiodectoides* (Nyl.) Zahlbr., *Diorygma soozanum* (Zahlbr.) M. Nakan. & Kashiw., *Graphis pyrrhocheiloides* Zahlbr., *Opegrapha microspora* Müll. Arg., *Porina internigrans* (Nyl.) Müll. Arg., *Pyrenula leucotrypa* (Nyl.) Upreti, and *Pyxine reticulata* (Vain.) Vain. Among all the districts, Pilibhit represented a maximum number of 19 lichen species, while Muzaffarnagar and Shahjahanpur districts showed poor growth of lichens represented by 5 species each.

Three one day 'Biodiversity Awareness Workshops' were conducted at Dudhwa Tiger Reserve, Dudhwa for foresters, Mewalal Ram Dulari Vidhya Mandir Inter College, Majhagain, Kheri for school children and at Department of Botany, University of Allahabad for M.Sc. students. An introduction to biodiversity and its importance was explained to the audience. Special emphasis was given to lichens, their diversity and importance to nature and mankind.

Assessing the diversity of mangrove lichens in Gujarat State, India

The principal aim of the project is to document the lichen flora of mangrove forests of Gujarat and its comparison to lichen diversity in inland vegetation. Exploration in Kutch, Surat, Bharuch, Navsari, Valsad, Ahmedabad, Gandhinagar districts and Gir National Park (Junagadh) and Purna Wildlife Sanctuary (Dang) resulted in collection of 150 lichen samples of 30 species. The Kutch district has scarce mangrove vegetation with poor growth of lichens. The lichens were mostly collected from inland vegetation and rocks near the sea shore. The lichen flora was dominated by crustose lichens mostly belonging to Roccellaceae group, of which 7 species were new addition to the lichen flora of Gujarat State.

National Network program on lichens: Bioprospection its secondary compounds and establishing cultures and collections

Mycobiont Culture: Mass culture of 15 medicinally potential lichen species was established through mycobiont culture. The dried mycobionts harvested were provided to M. S. Swaminathan Research Foundation (MSSRF), Chennai for screening for secondary metabolites.

Paracetamol-induced hepatoprotective and antioxidant activities in Lichens: Paracetamol, a widely used over the counter analgesic (pain reliever) and antipyretic (fever reduce) drug, is commonly used in relieving of fever, headaches, etc. These measures lead to the disruption of calcium homeostasis, mitochondrial dysfunction, and oxidative stress and may eventually culminate in cellular damage and death. An obvious sign of hepatic injury is the leaking of cellular enzymes into the plasma due to disturbance caused in the transport functions of hepatocytes. When liver cell plasma is damaged, a variety of enzymes located normally in cytosol are released into the blood, thereby causing increased enzyme levels in the serum. Reinforcing the above known mechanisms, the extracts and fractions of selected lichens viz *Usnea longissima, Cladonia furcata, Parmotrema reticulatum, Sticta weigelii* at dose levels of 200 and 400 mg/kg showed a significant reduction in the elevated levels of SGOT, SGPT, total bilirubin, direct bilirubin and total cholesterol comparable to silymarin. However, usnic acid is the normal component of lichen cells and is one of the most common and abundant lichen metabolites.

A suitable combination of bioactive fractions of lichens fractions with or without lichen metabolite was tested on drug induced liver toxicity. The novel bioactive fractions with standardized content of usinic acid reduced the elevated liver biochemical markers and stabilized the ATPase activity. In continuation the hydro-ethanolic extract of *Cladonia furcata* showed suppressive effect on gastric acid secretion by opposition to the action of histamine and blocking of H+-K+-ATPase. A significant increase in plasma histamine concentration was observed after development of gastroesophageal reflux disease (GERD). The high level of H+K+ATPase stimulates parietal cells to hypersecretion of acid, which in turn causes the GERD and is selectively blocked by the action of omperazole, an acid blocker used to treat gastric ulcer.

Our observation indicated that treatment with lichen extract caused the reduction in histamine and H+K+ATPase in GERD models, indicating the gastric defensive effect. It has also been found that oxygen-derived free radicals are implicated in the mechanism of GERD and scavenging these free radicals can play a pivotal role in the GERD treatment. The antioxidant properties of the *Cladonia furcata* extract has beneficial effect in the gastroesophageal reflux disease treatment.

Phytochemical assays: Extracts obtained from *Cladonia furcata (L3), Parmotrema nilgherense (L4), Everniastrum cirrhtum (L5), Lobaria retigera (L6), Flavoparmelia caparata (L7)* were characterized for qualitative and quantitative assays and detection of secondary compounds. Secondary markers of fatty acids, flavanoids, sugars, cartetenoids, terpenoids and anthraquinones, depsones, depsides & lichen acids/ were identified through TLC and some identified known lichen acids were isolated using P-TLC & Column chromatography.

Genetic diversity in *Everniastrum cirrhatum*: Genetic variability in *Everniastrum cirrhatum*, a medicinally important lichen, has been evaluated using ISSR-PCR and DAMD-PCR markers. Fourteen primers (10 ISSR and 4 DAMD) were used to estimate the genetic diversity in 45 accessions of *E. cirrhatum*. These primers have resulted in 152 fragments, of which 144 fragments were polymorphic, accounting for 94.95% polymorphism in *E. cirrhatum* accessions. The mean Polymorphic Information Content (PIC) value recorded for 14 cumulative primers (ISSR+DAMD) was 0.40. The cumulative genetic distance between pairs of accessions ranged from 0.19 - 0.85 with an average value of 0.65 among all the accessions. The UPGMA dendrogram revealed that the clustering pattern of *E. cirrhatum* accessions was in congruence with their geographical affiliations. The UPGMA dendrogram and PCA plot did not show any altitudinal specific preferences in *E. cirrhatum* accessions.

Develop a system to monitor climate change with lichens in India

The change in diversity of lichens and its correlation with climate change in some selected regions of India was initiated. The study sites (Darjeeling: West Bengal and Mount Abu: Rajasthan) were selected based on previous records of lichen taxa available in NBRI herbarium (LWG). A list of lichen specimens housed in LWG, representing collections made in the year 1970 from Darjeeling and Mount Abu, was prepared. The 1970 collections of lichens from 13 localities in Darjeeling district showed the occurrence of 125 species belonging to 57 genera. When the same localities were revisited in 2014 a total of 251 records of lichens were made, of which 100 species were new additions while 26 species were common in both past and present collections.

After more than 40 years the area showed distinct change in the lichen flora as members of the lichen family Physciaceae dominate over the Parmeliaceae. The change in lichen flora may be correlated to the changes in environmental conditions as indicated by the presence of members of Physciaceae which prefer nitrophilous environment. The dominance of crust forming lichens in the area further indicates the changes in the present environmental conditions. A total of 10 elements (Cu, Co, Mn, Ni, Fe, Se, Zn, Cr, As and Pb) together with C, N and S content were analysed in both the samples (recorded earlier and freshly collected) from nine localities of the area along with meteorological data such as temperature, RH, precipitation, wind direction and speed. Similar studies are in progress in Mount Abu to monitor the change in lichen community composition in arid region of India.

Lichens response to rising temperature and high ultraviolet radiance due to on-going climate change

The project aims to explore the utility of lichens as an indicator of on-going climate change by monitoring the change in lichen diversity and explore putative role of secondary metabolites as an adaptive mechanism to combat rising temperature and increasing incident of UV radiation in high altitude ecosystem of the Garhwal Himalayas.

Twelve UV protecting compounds (Mycosporine like Amino Acids -MAAs) were characterized for the first time in Indian lichens. The samples from higher exposed altitudes exhibit higher concentration of UV protecting compounds. The metal pollution studied in *Stereocaulon foliolosum*, a dimorphic rock inhabiting lichen, showed impact of metal pollution up to an altitude of 3360 m and the pollution load declined up to a greater extent at an altitude of 3400 m. Comparing the metal profile and lichen diversity since 1994 revealed that temporal decline in the lichen diversity is clearly apparent with the constant increase in the metal profiles in the past nineteen years.

The assemblage of both pollution tolerant and sensitive species in distinct altitudinal ranges clearly indicates the role of secondary metabolites present in lichen species in determining their specific habitats in different environmental conditions. The influence of aspect and altitudinal gradient on the quantitative profile of atranorin and salazinic acid in three lichen species distinctly indicates the influence of incident radiation and significant variation in the chemical content with the rising altitude.

Lichen analysis for ecological continuity of tropical rain forests in Nilgiri Hills of Western Ghats, India

Quantitative, qualitative, social behaviour, peculiar morpho-anatomical characters and habitat preferences of lichens are utilized to study the forest condition in Nilgiri Hills. The selective removal of phorophytes resulted in scanty appearance of species that were commonly observed in the past. A continuous trend of species repetition was also observed due to decline in host tree diversity. At present natural biota seems to be restricted to protected forests, and many lichen species that were previously easily available have now been shifted mostly to managed forests.

Home gardens, cultivated and avenue trees of

Eucalyptus sp., and basal trunk and exfoliated bark of trees in wet and moist places exhibit luxuriant growth of lichen species and thus help in conservation of many rare lichen species. Due to continuous use of land for tea gardens, grazing, and for timber, fuel wood and forest products, the Nilgiris are in a process of gradual degradation, which also leads to the consequent change in lichen diversity due to changes in micro-climatic conditions.

Barcoding Himalayan Lichens - cutting edge approaches to study lichen biodiversity and setting lichen conservation strategies in India

Detailed morpho-taxonomic studies supplemented with nrDNA ITS sequence data revealed the occurrence of 10 species of *Cetrelia* in India. *Cetrelia chicitae* (W.L. Culb.) W.L. Culb. & C.F. Culb. was reported as a new record for Indian lichen biota. The taxonomic distinction between *Cetrelia chicitae* and the closely allied *C. cetrarioides* was established through morphological, phytochemical and nrDNA ITS sequence analysis.

Study of Bryophyte diversity in the Eastern Ghats

Exploration in Yercaud (Kiliyur falls, Rose garden), Kalrayan Forest Reserve, Giant Orchard, Bodamalai Forest Reserve, Javadi Hills, Sirumalai hills, Kolli hills and Malai Mahadeshwara Wild Life Sanctuary of Eastern Ghats areas in Tamil Nadu resulted in collection of about 515 bryophyte specimens. Critical studies on these revealed the occurrence of 40 taxa of mosses belonging to 19 families, and 14 taxa of liverworts belonging to four families. Four bryophyte species (*Syntrichia norvegica* Web, *Aulacopilum glaucum* Wilson *Solmsiella biseriata* (Austin) Steere, *Groutiella tomentosa* (Hornsch) Wijk & Marg) were recorded as new addition to the bryoflora of the Eastern Ghats.

Studies on morphogenesis, reproductive biology and *ex situ* conservation of selected endangered, threatened and potential bryophytes

In vitro propagation of two bryophytes, a liverwort (*Marchantia polymorpha* L.) and a moss (*Rhodobryum roseum* (Hedw.) Limpr.), has been initiated to study their morphogenesis and reproductive biology, besides standardizing protocol for multiplication of their germplasm. In case of *M. polymorpha* gemmae were used as explant and a population of healthy plants could be grown in 45 days with well developed gemma cups. On the other hand spores were used as explants for *R. roseum* and a good population was developed in 90 days (Fig.2). Using this protocol, germplasm of these potential taxa can be successfully propagated in bulk.

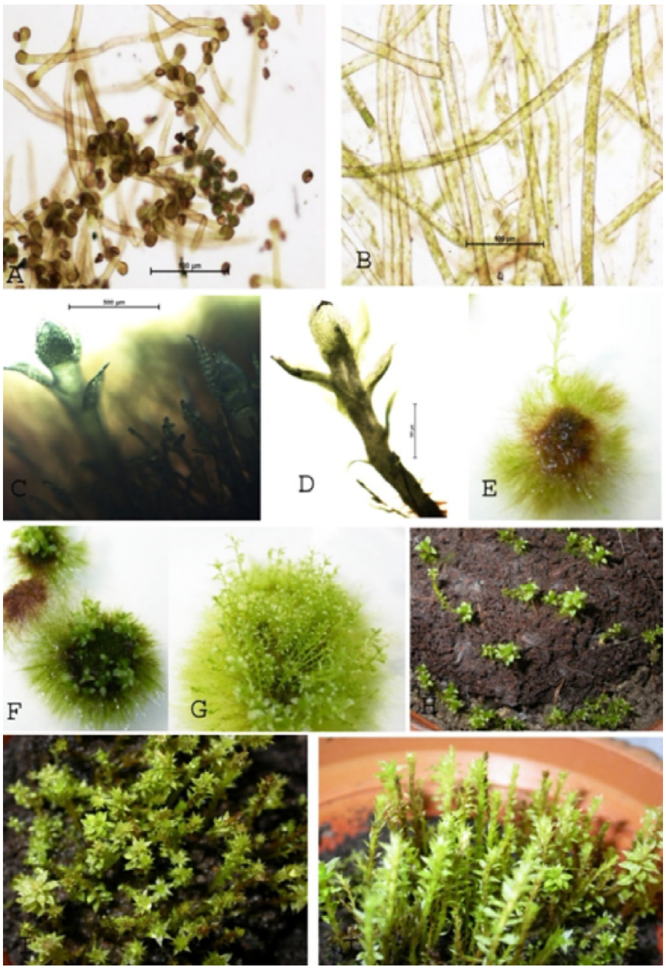


Fig. 2 (A-J). *Rhodobryum roseum*: A, B. Germinating spores, developing protonema in culture medium; C. Developing young gametophore bud; D. A young gametophores; E. Colony of protonema with gametophores; F, G. Population of young gametophores; H. Young plants transferred to soil in pots; I. Population of young plants on soil; J. Mature plants growing on soil in pot.

Diversity, Distribution and Ethnobotany of Pteridophytes and Bryophytes in Dudhwa National Park in Uttar Pradesh and bordering regions

Survey and collection of pteridophytes and bryophytes from different localities of Dudhwa National Park and Kishanpur Wildlife Sanctuary in Lakhimpur Kheri, and Katarniaghat Wildlife Sanctuary in Bahraich were made for assessment of diversity, distribution and enrichment of the NBRI herbarium.

About 269 specimens of pteridophytes and 119 specimens of bryophytes were collected from above areas along with records of their habitat, associated plant species and ecological data. Taxonomic identification of the collected materials is in progress. Out of 21 species of pteridophytes identified so far, the following 11 species were new records to the study area: *Azolla pinnata*, *Christella appendiculata*, *C. dentata*, *Diplazium esculentum*, *Dryopteris cochleata*, *Equisetum diffusum*, *Lygodium japonicum*, *Marsilea minuta*, *Microlepia speluncae*, *Pteris biaurita*, *P. vittata*. A comparative study on distribution pattern of pteridophytes across the geographical regions revealed that *Adiantum philippense*, *Ampelopteris prolifera*, *Christella dentata*, *Diplazium esculentum*, *Lygodium flexuosa* and *Ophioglossum reticulatum* were dominant species, whereas *Azolla pinnata*, *Ceratopteris thallictroides*, *Chelianthus tenuifolia*, *Christella appendiculata*, *C. parasitica*, *Dryopteris cochleata*, *Equisetum ramosissimum*, *E. diffusum*, *Helminthostachys zeylanica*, *Lygodium japonicum*, *Marsilea minuta*, *Microlepia speluncae*, *Pteris biaurita* and *P. vittata*, showed rare distribution.

Studies on 56 specimens of bryophytes revealed the identity of 21 species, out of which 10 species, viz. *Asterella pathankotensis*, *Reboulia hemispherica*, *Riccia fluitans*, *R. cavernosa* (Hepaticae); *Phaeoceros carolinnianus* (hornwort); *Anisothecium molliculum*, *Brachythecium* sp., *Physcomitrium eurystomum*, *Taxithelium nepalense*, *Thuidium* sp. (Mosses) were new records to the study area.

Taxonomy and ecology of the Himalayan genus *Oxytropis* DC. (Leguminosae) in India

The purpose of study was to prepare an updated comprehensive taxonomic account of *Oxytropis* by using morphological and ecological attributes. Based on field studies, literature survey and examination of previous collections housed at different Indian herbaria, 25 species of *Oxytropis* were recorded from India. Systematic account on each species has been prepared with correct nomenclature, description, phenology, distribution, habitat/ecology, conservation status, etc. The detailed infraspecific studies of *O. tatarica* complex which includes about six taxa have also been made. Four species (i. e. *O. guntensis, O. hypoglottoides, O. kansuanesis* and *O. melanocalyx*) have been reported for the first time for India. *Oxytropis shivai, O. rauti* and *O. thomsonii* have been treated as synonyms while *O. microphylla* and *O. chiliophylla* have been treated separately contrary to the earlier works. The phytosociology at three altitudinal gradients was also studied by laying 60 random quadrates of 1m × 1 m area. Quantitative analysis of frequency, density, and dominance and importance value index was done. This is the first study made on taxonomy of *Oxytropis* in India after JD Hooker's Flora of British India in 1876.

Taxonomic Study of Tree Flora of Uttar Pradesh

The work was carried out to provide the current taxonomic account of the tree species of Uttar Pradesh. Based on our several field surveys and examination of herbarium specimens housed at different herbaria, about 389 tree species have been recorded from Uttar Pradesh, of which about 172 species are found in wild, 81 in semi-wild and 136 only in cultivation. The top five families with larger representation of tree species in UP are the Leguminosae (ca. 70 spp.), Moraceae (24 spp.), Bignoniaceae (17 spp.), Euphorbiaceae (16 spp.) and Rubiaceae (15 spp.). During the reporting period detailed taxonomic account of 30 tree species of Leguminosae found in pure wild condition has been prepared with their current nomenclature, vernacular names, description, phenology, distribution, voucher specimens, colour images, etc. This will be the first taxonomic account on trees of whole Uttar Pradesh after the work of J. F. Duthie published in 1903 in 'The Flora of Upper Gangetic Plains'.

Monographic and phylogenetic studies in the tribe *Delphineae* (Ranunculaceae) from India

The tribe *Delphineae* comprises of three genera: *Delphinium, Aconitum* and *Consolida*. Critical micro-morphological, ecological, cyto-taxonomical and molecular phylogenetic studies have been initiated so as to achieve a better understanding of the gross-morphological evolution, and delimitation of the genera, subgenera and species complexes in Indian Delphineae.

As part of the systematic study on Indian Delphineae, a taxonomic enumeration and phytogeographic analysis of Indian species of *Delphinium* was made. Out of *ca.* 50 Indian species of *Delphinium*, *Consolida* and *Aconitum*, critical studies on 10 species of *Delphinium* and two species of *Aconitum* were completed. *Aconitum* shows high level of endemism. Out of 27 species of *Aconitum* in India, 11 are endemic to the Western Himalaya while 16 are confined only to the Eastern Himalaya. Interestingly, there is no overlap of *Aconitum* species in both the West and East Himalayas.

About 20 species of *Delphinium*, *Consolida* and *Aconitum* were collected from different localities in the western and eastern Himalayas. Molecular analyses of seven species of *Delphinium* and three species of *Aconitum* were carried out.

Cytological studies showed the diploid chromosome number in *Aconitum* as 32 (n=16) and 16 (n=8) in *Delphinium*. Meiotic divisions in *Delphinium vestitum* were not normal and various type of meiotic anomalies such as bridge in telophase, micronuclei, C-metaphase and clumped anaphase were observed.

A new species *Delphinium lahulensis* Agnihotri, Husain & Husain was described from Lahul valley of Himachal Pradesh.

In-House Projects

Taxonomic studies and digitization of plant diversity of India

Taxonomy and assessment of plant diversity of Algae, Lichens, Bryophytes, Pteridophytes, wild relatives of Cucurbits and Tree Legumes in the Upper Gangetic Plains (UGP) of Uttar Pradesh

Algae

Algal samples were collected from three different zones of UGP of Uttar Pradesh, namely Western, Mid-western and Central Plains, which included nine districts (Saharanpur, Pilibhit, Rampur, Lucknow, Kanpur, Kanpur Dehat, Raebareli, Allahabad and Lakhimpur Kheri). The identification of the samples resulted in total of 85 algal taxa in 52 genera and six classes. *Thorea siamensis* Kumano & Traichaiyaporn, a red alga was reported for the first time from India, while *Compsopogon coeruleus* (Balbis) Montagne, a rare red alga was reported for the second time from Uttar Pradesh. The class Chlorophyceae showed the maximum diversity with 29 taxa under 21 genera, followed by Cyanophyceae (31 taxa, 17 genera), Bacillariophyceae (15 taxa, 12 genera), and Euglenophyceae (7 taxa, 3 genera). The classes Rhodophyceae (2 taxa, 2 genera) and Chrysophyceae (1 taxon, 1 genus) poorly represented in the studied area. The genera represented under each class are:

Class	Genera
Cyanophyceae	*Anabaena, Nostoc, Oscillatoria, Phormidium, Lyngbya, Chroococcus, Scytonema, Cylindrospermum, Aphanothece, Aphanocapsa, Gloeothece, Schizothrix, Synechococcus, Plectonema, Microcoleus, Gloeocapsa, Microcystis*
Chlorophyceae	*Spirogyra, Rhizoclonium, Scenedesmus, Chlorella, Chlamydomonas, Oedogonium, Pithophora, Golenkenia, Chlorococcum, Sphaerocystis, Pandorina, Pithophora, Crucigenia, Sphaeroplea, Oocystis, Stigeoclonium, Haematococcus, Closterium, Cosmarium, Ulothrix, Eremosphaera*
Bacillariophyceae	*Fragillaria, Pinnularia, Penium, Nitzschia, Cocconeis, Cymbella, Navicula, Stauroneis, Surirella,Craticula, Gyrosigma, Cyclotella*
Euglenophyceae	*Euglena, Phacus, Trachelomonas*
Rhodophyceae	*Thorea, Compsopogon*
Chrysophyceae	*Mallomonas*

Lichens

About 1000 specimens of lichens were collected from Lakhimpur, Pilibhit Tiger Reserve, and other localities in Uttar Pradesh. The collections represented 25 species belonging to 21 genera and 14 families.

Bryophytes & Pteridophytes

Soor Sarovar Wildlife Sanctuary and National Chambal Wildlife Sanctuary in Agra, Hastinapur Wildlife Sanctuary in Meerut were explored for systematic documentation of pteridophytes and bryophytes. In total 42 specimens of seven species of pteridophytes and 30 specimens of 11 bryophyte species were collected from the above sanctuaries. All the seven pteridophytes (*Azolla pinnata, Marsilea minuta, Adiantum philippense, Adiantum incisum, Ampelopteris prolifera, Equisetum ramosissimum* ssp. *ramosissimum* and *E. ramosissimum* ssp. *debile*), and seven bryophytes (*Riccia fluitans, R. cavernosa, R. crystalina, Marchantia linearis, Bryum* sp., *Semibarbula* sp., *Physcomitrium* sp.) were the first records from the sanctuaries.

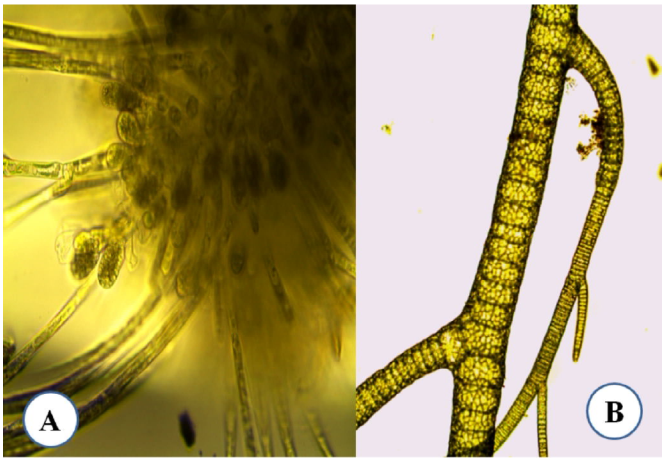


Fig. 3. A. *Thorea siamensis* Kumano; B. *Compsopogon coeruleus* (Balbis) Montagne.

Systematics and genetic diversity assessment in wild relatives of cucurbits

The genus *Luffa* in UGP comprises five species: three cultivated (The Ridge Gourd- *L. acutangula* (L.) Roxb.; The Smooth Gourd- *L. aegyptiaca* Mill.; The Hermaphrodite Luffa- *L. hermaphrodita* Singh & Bhandari), and two wild species (*L. graveolens* Roxb.; *L. echinata* Roxb.). The study under report was carried out to estimate the genetic diversity and relationships among the five taxa of *Luffa* using ISSR-PCR and DAMD-PCR markers.

A cumulative analysis of the combined marker data (15 ISSR + 7 DAMD) revealed high percentage polymorphism (97.67%), moderate genetic distance (0.04-0.75; avg. 0.49), low heterozygosity and Shannon index values (H= 0.131 and I= 0.199) across all the 76 accessions of the five taxa of *Luffa*. Cluster analysis using UPGMA method grouped the five species of *Luffa* in two main clusters with high bootstrap support. Cluster I included *Luffa echinata, L. acutangula* and *L. hermaphrodita*; cluster II comprised *L. graveolens* and *L. aegyptiaca*. Principal coordinate Analysis (PcoA) also showed a similar grouping. The clustering pattern indicated the probable origin of the cultivated ridge gourd (*L. acutangula*) from its wild progenitor- *L. echinata* and the widely cultivated and feral forms of the smooth gourd (*L. aegyptiaca*) from the wild progenitor- *L. graveolens*.

Interestingly, the hermaphrodite Luffa was found nested within the ridge gourd group, indicating the closer affinities among the two. Despite its morphological distinction as the only species of *Luffa* with bisexual flowers, the molecular analyses, however, support the treatment of *L. hermaphrodita* as a cultivated variety within *L. acutangula*.

Reproductive Biology of Adiantum peruvianum and Onychium contiguum

Studies on reproductive behaviour in *Adiantum peruvianum* Klotzsch were carried out in order to understand the reproductive bottlenecks in the species. The gametophytes in *A. peruvianum* were monoecious but found functionally dioecious with the archegonia appearing first followed by the antheridia with a periodical gap. Sporophyte production in composite culture of gametophytes (heterozygous) was moderate (36.43%), favouring less genetic load and reduced lethality (63.57%) in a genetically different gametophyte. On the other hand the sporophyte production in isolate and extended isolated culture of gametophyte was nil, which supports the postulate of maximum genetic load and highest lethality (100%) in homozygous gametophytes. Each regenerate from extended isolate cultures was dioecious, bearing only archegonia or antheridia. Inbreeding depression in isolate gametophytes and in extended isolate cultures of gametophytes was high. The study confirmed inter-gametophytic selfing as the means of sporophyte production in heterozygotic gametophytes of *A. peruvianum* (Fig. 4 A-L, Fig. 5A-L).

Reproductive biological studies in *Onychium contiguum* Wall ex Hope. showed four month viability of spore, 82% spore germination, sexual expression (male and female) on 60th and 68th day, respectively, and sporophyte development on 117th day. About 256 gametophytes were developed from the spores, which produced 135 individual sporophytes. These in-vitro propagated gametophytes/sporophytes are under observation for acclimatization and introduction in the fernery of NBRI. The study revealed protandrous and cyclic gametangia expression in *O. contiguum*. The gametophytes exhibit protandrous tendency at spatulate stage and archegonia appears little late at the stage of cordate gametophyte. This process of cyclic gametangia expression (male followed by female) could be the cause for their poor colonization (Fig. 6A-P).

Reproductive biology and regeneration potential of Woodfordia fruticosa

Pollination biology, including sexual compatibility of the plant, mode of pollination and pollen-stigma interaction was studied in *Woodfordia fruticosa* (L.) Kurz. – a rare medicinal and dye yielding plant species growing in UGP. Flower showed copious amount of nectar in the range of 0.5-24 µl with 4-24% sugar concentration. Average of anther per flower and pollen per anther ranged from 9 to 12 and 59375 to 146875, respectively. The study revealed advanced protandry. Pollen became fully mature much before stigma receptivity with an average 91.28% viability. Germinated pollen grains were regularly observed inside un-dehisced anther lobes while stigma was in its initial young stage below the level of stamens. This is an unusual event not reported so far in *W. fruticosa*. Pollen and stigma showed asynchronous relationship regarding their viability/ receptivity, which showed their maximum reliability towards out-crossing. Ornithophily (bird pollination) was the mode of cross pollination. The most common visiting bird was identified as 'Oriental White eye' (*Zosterops palpebrosus*) bird (Fig.7).

This is the first evidence in the pollen study of *W. fruticosa*, where pollen germination was observed inside the un-dehisced anther lobe. Though flowering, fruiting and regeneration potential was good in

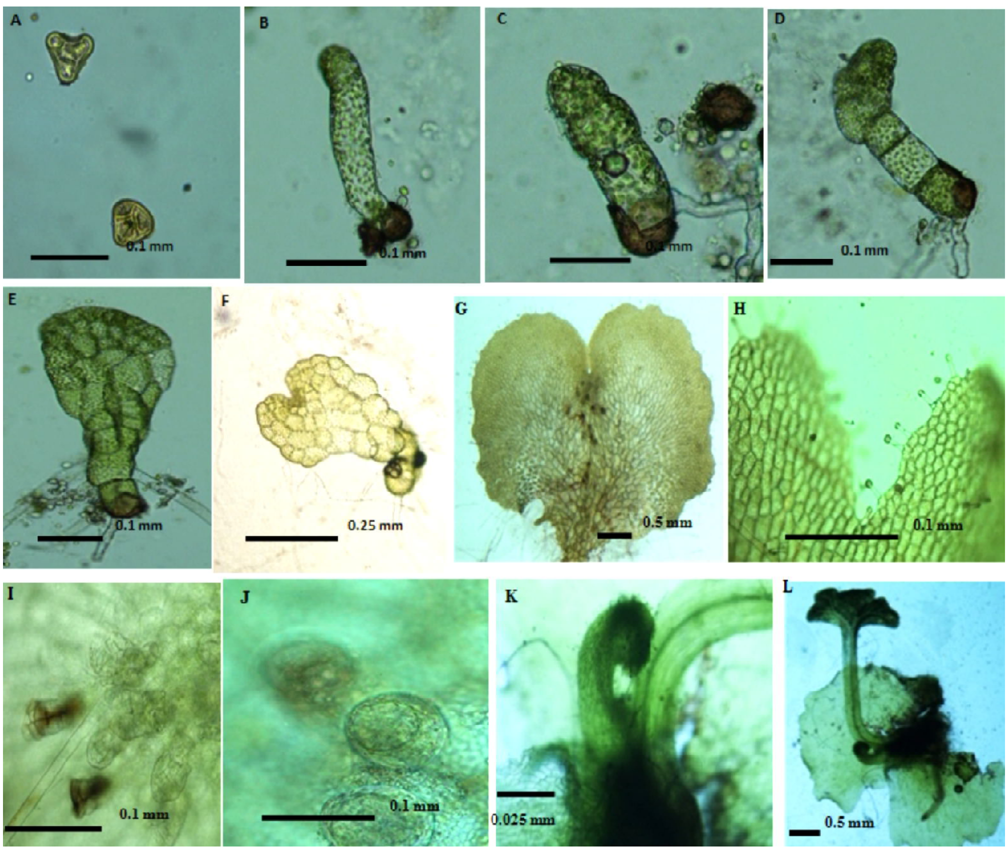


Fig. 4 (A-L). Spores of *Adiantum peruvianum* Klotzsch sown on composite culture

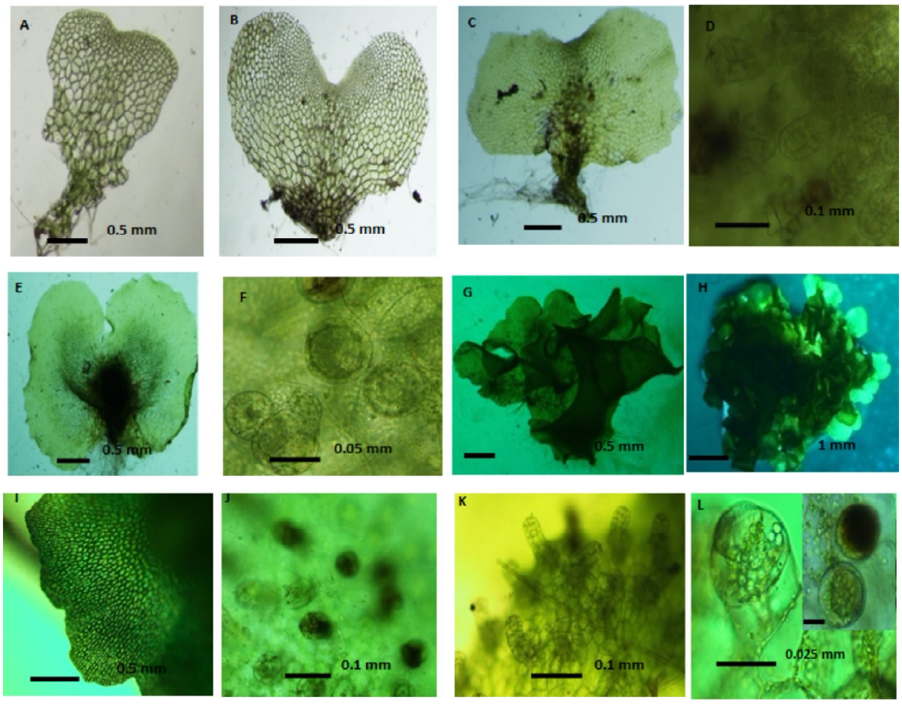


Fig. 5 (A-L). Gametophytes of *Adiantum peruvianum* growing in isolate and extended isolate culture

Woodfordia fruticosa, survival beyond its natural environment was unsuccessful so far.

Development of Repository of Herbal Crude Drugs based on various Diseases and Disorders among the Tharu tribals in Uttar Pradesh

Plant samples of *Aegle marmelos, Capparis zeylanica, Carissa opaca, Chlorophytum tuberosum, Cordia dichotoma, Holarrhena pubescens, Pithecellobium dulce, Terminalia bellirica* and *Xeromphis uliginosa* were collected from different forest areas in Uttar Pradesh. The potential uses of these plants in medicine were also documented.

Digitization and organization of CSIR-NBRI Herbarium (National Facility)

A total of 20 algal herbarium sheets and 235 fresh water algal samples collected from Govind Wildlife Sanctuary and different parts of Uttar Pradesh were identified and deposited in LWG.

About 209 herbarium specimens of pteridophytes were accessioned. A baseline data on pteridophytes and bryophytes of Dudhwa National Park, Lakhimpur was prepared. A checklist (partial) of Ferns and Fern-allies (Pteridophytes) of Uttar Pradesh was also prepared.

Herbarium – A National Facility

Herbarium development and maintenance as per international standard was carried out, besides undertaking monographic and revisionary studies, and floral diversity assessment in different phytogeographic zones of India. Technical assistance was rendered to visiting students and researchers from various Research Institutes/ Universities/Colleges, etc., particularly in connection with identification of plants. Active link has been maintained through loan and exchange with other recognised herbaria of the country and abroad. The herbarium was enriched by incorporating fresh voucher specimens, from Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Madhya Pradesh and Uttar Pradesh.

The new additions included 223 specimens of flowering plants and 1167 specimens of cryptogrammic plants (Pteridophytes-257, Bryophytes-734, Lichens-150, Algae-187). At present, herbarium of CSIR-NBRI possesses a total collection of 2, 90,966 specimens, besides 290 type specimens and 895 type photographs.

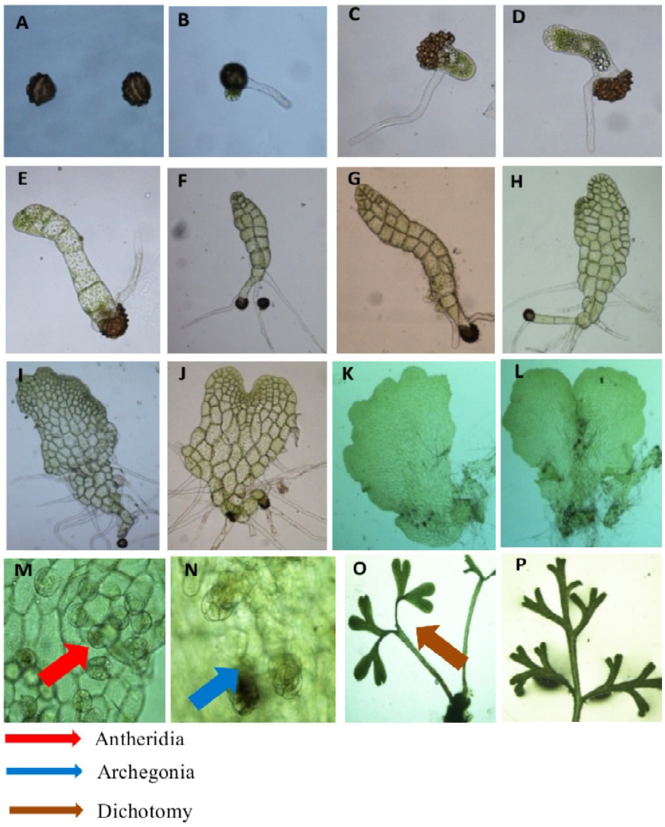


Fig. 6 (A-P). Developmental stages of *Onychium contiguum*

Fig. 7. 'Oriental White Eye' (*Zosterops palpebrosus*) bird visiting flowers of *Woodfordia fruticosa*

HERBARIUM HOLDINGS

HERBARIUM HOLDINGS	
Angiosperms & Gymnosperms	1,01,200
Pteridophytes	5,607
Bryophytes	15,972
Lichens	1,49,650
Algae	2,537
Carpological collections	16,000
TOTAL	**2,90,966**

Publications

1. Agnihotri P, Dixit V and Husain T – Conspectus of the genus *Veronica* Linnaeus (Plantaginaceae) in India. *Pleione*, 2014, **8**(1) : 9-16.
2. Agnihotri P, Husain D and Husain T – A new species of the genus *Delphinium* (Ranunculaceae) from Lahul Valley of Himachal Pradesh, India. *Phytotaxa*, 2014, **186** : 287-291.
3. Agnihotri P, Jena SN, Husain D and Husain T – Perspective of the genus *Delphinium* Linnaeus (Ranunculaceae) in India. *Pleione*, 2014, **8**(2) : 344-352.
4. Agnihotri P, Singh H, Husain D and Dixit V – Notes on the ethnobotanically important genus *Geranium* Linnaeus (Geraniaceae) in India. *Pleione*, 2014, **8**(2) : 396-407.
5. Asthana AK and Gupta S – Two mosses (Bryophyta) new to western Himalaya. *Indian J. For.*, 2014, **37**(2) : 189-92.
6. Asthana AK and Srivastava A – In new national and regional records: *Fissidens pellucidus* Hornsch; *Neckeropsis andamana* (Mull. Hal.) M. Fleisch. *J. Bryol.*, 2014, **36**(3) : 228, 231.
7. Bajpai R, Shukla V, Singh N, Upreti DK and Rana TS – Investigation of biochemical and genotypic changes in toxitolerant lichen species, *Pyxine cocoes* towards chromium (+VI) stress. *Envir. Sci. Pollut. Res.*, 2015, **22** : 3727-3738.
8. Bajpai R, Shukla V, Upreti DK and Semwal M – Selection of suitable lichen bioindicator species for monitoring climatic variability in the Himalaya. *Envir. Sci. Pollut. Res.*, 2014, **21** : 11380-11394.
9. Bhat M, Shukla V, Upreti DK, Verma S, Sharma G and Anand R – Assessment of air quality of Rajouri town, Jammu & Kashmir using lichen transplant technique. *Sci. Technol. J.*, 2014, **2**(1) : 15-19.
10. Bhat M, Verma S and Upreti DK – Lichens for sustinable environment. *Int. J. envir. Res. Development*, 2014, **4**(4) : 325-328.
11. Biju H, Bagool RG, Nayaka S – Diversity of lichens in Idukki district with new records to flora of Kerala. *Indian J. Forestry, 2014,* **37**(3) : 333-340.
12. Biju H, Bagool RG, Nayaka S – New records of Graphidaceous lichens from Western Ghats, India. *Indian J. Forestry, 2014,* **37**(4) : 477-481.
13. Dasgupta CN, Suseela MR, Mandotra SK, Kumar P, Pandey M K, Toppo K, Lone JA – Dual uses of microalgal biomass : An integrative approachfor biohydrogen and biodiesel production. *Applied Energy*, 2015, **146** : 202–208.
14. Datt B, Meena B, Rana TS. – *Artemisia santolinifolia* Turcz. ex Besser (Asteraceae) - An overlooked species in the Indian flora. *JBNH*, 2014, **111** (1) : 67-68.
15. Dixit V, Verma P, Agnihotri P, Paliwal AK, Rao CV and Husain T – Antimicrobial, antioxidant and wound healing properties of *Leucas lanata* Wall. ex Benth. *J. Phytopharmaco.*, 2014, **4**(1) : 9-16.
16. Gupta R, Nath V and Asthana AK – New national and regional bryophyte records : *Lejeunea wightii* Lindenb. In Gott., Lindenb. & Nees, *Phaeoceros udarii* Asthana & Nath. *J. Bryol.*, 2014, **36**(2) : 141, 143.
17. Gupta R, Nath V and Asthana AK – New national and regional bryophyte records: *Bryum porphyroneuron* var. *erythrinum* (Mitt.) and *Ptychostomum pseudotriquetrum* (Hedw.) J.R. Spence & H.P. Ramsay M. Fleisch. *J. Bryol.*, 2015, **37**(1) : 70,77.
18. Ingle KK, Nayaka S, Bajpai R, Rawal JR, Upreti DK and Trivedi S – An account of lichen diversity in Island of Marine protected area, Jamnagar, Gujarat. *Uttar Pradesh State Biodiversity Bull.*, 2014, **4** : 23-30.
19. Jena SN, Verma S, Mishra S, Srivastva AK, Nair KN, Rana TS – Genetic diversity and population structure of the mangrove lime (*Merope angulata*) in India revealed by AFLP and ISSR markers. *Aquatic Bot.*, 2014, **120** : 260-267.
20. Joshi Y, Tripathi M, Bisht K, Upreti DK – Current distributional status of *Remototrachyna adducta* (Nyl.) Divakar and A. Crespo, in India. *National Academy Sci. Letters,* 2014, **37**(4) : 397-399.
21. Krishan Lal, Kushwaha AK and Chaudhary LB – Taxonomic notes on *Hedysarum astragaloides* Benth. ex Baker (Fabaceae). *J. Jpn. Bot.*, 2014, **89**(4) : 230-235.
22. Kumar J, Dhar P, Tayade AB, Gupta D, Chaurasia OP, Upreti DK, Arora R and Srivastava RB – Antioxidant capacities, phenolic profile and cytotoxic effects of saxicolous lichens from Trans-Himalayan Cold Desert of Ladakh. *PLoS One*, 2014, **9**(6) : e98696.
23. Kumar J, Dhar P, Tayade AB, Gupta D, Chaurasia OP, Upreti DK, Toppo K, Arora R, Suseela MR, Srivastava RB Chemical Composition and Biological Activities of Trans-Himalayan Alga *Spirogyra porticalis* (Muell.) Cleve. PLoS ONE, 2015, **10**(2): e0118255.
24. Logesh AR, Upadhyay AK, Joshi S, Kalaiselvam M, Upreti

DK and Shukla AC – Lichen as indiactor of metal pollution in the vicinity of SIPCOT industries in Cuddalore southeast coast of India. *Mycosphere*, 2014, **5**(5) : 681-687.

25. Mishra GK and Upreti DK – Accumulation of heavy metals in foliose lichens growing in industrial area of Udham Singh Nagar, Uttarakhand. *Int. J. Curr. Res. Acad. Rev.*, 2014, **2**(10) : 48-54.
26. Mishra GK and Upreti DK – An enumeration of lichens from the Bageshwar district of Kumaun Himalaya, Uttarakhand, India. *Int. J. Curr. Microbiol. Appl. Sci.*, 2014, **3**(11) : 420-435.
27. Mohabe S, Reddy AM, Devi AB, Nayaka S and Shankar PC – Further new additions to the lichen mycota of Andhra Pradesh, India. *J. Threatened Taxa*, 2014, **6**(8) : 6122-6126.
28. Nayaka S, Saxena P – Physiological responses and ecological success of lichen *Stereocaulon foliolosum* and moss *Racomitrium subsecundum* growing in same habitat in Himalaya. *Indian J. Fund. Appl. Life Sci.*, 2014, **4**(3) : 167-179.
29. Nayaka S, Upreti DK and Tandon J – Heavy metal accumulation in *Pyxine cocoes* (Sw.) Nyl. transplanted at Kolkata city, West Bengal, India. *G-J. Envir. Sci. Technol.*, 2014, **2**(1) : 1-5.
30. Rawat KK and Verma PK – On a collection of liverworts from Tawang, Arunachal Pradesh, India with *Frullania rhystocolea* Herzog, new to India. *Frahmia*, 2014, **8** : 1-7.
31. Rawat S, Upreti DK and Singh RP – Five new lichen records from India. *Geophytology*, 2014, **44**(1) : 77-80.
32. Sahai K and Rawat KK – Degrading population of *Cajanus lineatus* (Wight et Arn.) Maesen, in parts of the Western Ghats, India. *Genetic Resour. Crop Evol.*, 2015, **62** : 515-523.
33. Sahu N, Alam A, Rawat KK, and Verma PK – Spore morphology of some South Indian species of *Asterella* P. Beauv. (Marchantiophyta). *J. Am. Sci.*, 2014, **10**(4) : 18-24.
34. Sahu V and Asthana AK – Diversity of liverworts and hornworts in Pithoragarh and its neighbouring areas, western Himalaya of India. *Indian Forester*, 2014, **40**(4) : 389-394.
35. Sahu V and Asthana AK – *Pogonatum perichaetiale* subsp. *thomsonii* (Mitt.) Hyvönen - An uncommon species from western Himalaya. *Tropical Pl. Res.*, 2014, **1**(3) : 13 –15.
36. Sahu V, Niranjan A and Asthana AK – *In-vitro* propagation and identification of phenol compounds of potential medicinal value in the moss *Oxystegus stenophyllus* (Mitt.) Gangulee. *J. Bryol.*, 2014, **36** (4) : 325-327.
37. Shukla P, Upreti DK and Tewari LM – Lichen genus *Usnea* (Parmeliaceae, Ascomycetes) in Uttarakhand, India. *Curr. Res. Envir. Appl. Mycol.*, 2014, **4**(2) : 188-201.
38. Shukla P, Upreti DK and Tewari LM – Secondary metabolite variability in lichen genus Usnea in India: A potential source for bioprospection. *G-J. Environ. Sci. Technol.*, 2015, **2**(3) : 29-40.
39. Shukla P, Upreti DK and Tiwari P – Assessment of dye yielding potential of Indian lichens. *Indian J. Pl. Sci.*, 2014, **3**(1) : 57-63.
40. Singh H, Husain T, Agnihotri P, Pande PC and Khatoon S – An ethnobotanical study of medicinal plants used in sacred groves of Kumaon Himalaya, Uttarakhand, India. *J. Ethnopharmacol.*, 2014, **154** : 98-108.
41. Singh N, Bajpai R, Mahar KS, Tiwari V, Upreti DK and Rana TS – ISSR and DAMD markers revealed high genetic variability within *Flavoparmelia caperata* in western Himalaya (India), *Physiol. Mol. Biol. Pl.*, 2014, **20**(4) : 501-508.
42. Singh S, Upreti DK, Lehri A, Paliwal AK – Quantification of lichens commercially used in traditional perfumery industries of Uttar Pradesh, India. *Indian J. Pl. Sci.*, 2015, **4**(1) : 29-33.
43. Srivastava N, Suseela MR and Toppo K – Fresh water cyanobacteria of Sai River near Lucknow, Uttar Pradesh. *Tropical Pl. Res.*, 2014, **1**(2) : 11-16.
44. Tiwari R, Sudhakar JV, Srivastava AK, Chaudhary LB, Murthy GVS and Durgapal A – Taxonomy, distribution and diversity assessment within *Ficus palmata* Forssk ssp. *virgata* (Roxb.) Browicz (Moraceae) in India. *J. Threatened Taxa*, 2014, **6**(9) : 6172- 6185.
45. Verma PK and Rawat KK – Present status of genus *Rectolejeunea* A. Evans (Marchantiophyta) in India. *J. Bryol.*, 2014, **36**(2) : 160-162.
46. Verma PK, Rawat KK and Yadav A – A note on *Plagiochila furcifolia* Mitt. (Marchantiophyta: Plagiochilaceae) from India. *Geophytology*, 2014, **44**(1) : 85-88.
47. Wagh VV and Jain AK – Ethnomedicinal uses of underground plant parts in Jhabua district of Madhya Pradesh, India. *Adv. Biol.. Res.*, 2014, **8**(4) : 151-56.
48. Wagh VV, Datt B and Husain T-An assessment of diversity of genus *Geranium* L. (Geraniaceae) in India with special emphasis on Indian Himalaya region. *J. Biodivers. Manage. Forestry*, 2015, **5**:2.
49. Wagh VV and Jain AK – Inventory of ethnobotanical and other systematic produces for regional conservation of medicinal and sacred plants. *Envir. Sys. Decis.*, 2015, **35** : 143-156.

PLANT ECOLOGY AND ENVIRONMENTAL SCIENCES

Scientists: Soumit Kumar Behera, S Mallick, V Pandey, UN Rai, PA Shirke, N Singh, SN Singh, PK Srivastava, RD Tripathi

Technical Staff: S Dwivedi, Sarah Jamil, Babita Kumari, MK Shukla, GG Sinam

Grant-in-Aid Projects

Assessment of arsenic pollution & bioremediation of arsenic contamination from agricultural soils

The assessment and monitoring of arsenic pollution in five districts of Uttar Pradesh and three districts of West Bengal were performed on soil (3 – 35 mg As kg^{-1}), irrigation groundwater (0 – 312 µg As L^{-1}) and crop samples (4 – 16 mg As kg^{-1} in the roots and 0.179 – 0.932 mg As kg^{-1} in the grains). Over 200 rice germplasm from West Bengal and Uttar Pradesh were studied for arsenic tolerance, and screened categorically into arsenic sensitive, moderately tolerant and arsenic tolerant varieties. A total of 69 fungal strains were isolated from arsenic contaminated paddy soils from the states of West Bengal and Uttar Pradesh and identified according to their phenotypic, microscopic and molecular (ITS) characters. During arsenic tolerance experiments, all the 69 soil fungal strains were cultivated in medium supplemented with 10, 100, 1000, 5000 and 10,000 ppm of arsenate. Their radial growth was determined and compared to the control (without arsenate). Amongst dominant (frequently encountered) soil fungal isolates, *Trichoderma* spp., *Aspergillus* spp. survived up to 10,000 ppm of arsenate. The strains belonging to *Rhizopus, Westerdykella, Lasiodiplodia*, *Microdochium*, *Chaetomium*, *Myrothecium*, *Stachybotrys*, *Rhizomucor* and *Fusarium* also showed tolerance up to 10000 ppm of arsenate. The arsenic removal efficacy of 25 fungal strains, tolerant to 5000 ppm of arsenate, was also assayed under laboratory conditions for 21 days. All these 25 fungal strains were cultivated individually on mycological broth initially enriched with 10 mg L^{-1} of arsenic. Fungal biomass of these strains removed arsenic biologically from the medium which ranged from 10.92 to 65.81%, depending on fungal strain. The flux of biovolatilized arsenic was determined directly by estimating the arsenic content in a silver nitrate impregnated filter paper gauge. The mean percent removal (as flux of bio-volatilized arsenic) ranged from 3.71 t o 29.86%. Most effective removal of arsenic was done by the fungal strains *Trichoderma* sp., *Westerdykella* sp., *Lasiodiplodia* sp., and *Rhizopus* sp., *Aspergillus oryzae*, *Chaetomium* sp., *Arthroderma benhamiae*, *Trichophyton verrucosum*, *Aspergillus nidulans*, *Rhizomucor variabilis*, *Emericella* sp. and *Fusarium* sp. The NCBI Genbank accession numbers of these strains have been obtained and their cultures have been deposited at the MTCC and the NFCCI, India.

The novel arsenite methyltransferase (arsM) genes were cloned and characterized in some novel native arsenic-tolerant soil fungi : partial arsM genes from *Aspergillus niger* FNBR_FA-12 (NCBI gb# arsM partial: KJ682649), *Westerdykella aurantiaca* FNBR_FA-03 (NCBI gb#arsM partial: KJ682647), *Trichoderma longibrachiatum* FNBR_FA6 (NCBI gb# arsM partial: KJ682648), *Lasiodiplodia* sp. FNBR_FA13 (NCBI gb# arsM partial: KJ682650), along with and a full length arsM gene (876 bp) from *Westerdykella aurantiaca* (NCBI gb# JN118571). Lead soil fungal strains were tested for their plant growth promoting abilities and they did not exhibit any pathogenic symptoms to test crops. These fungal strains can be effectively used for the arsenic bioremediation in arsenic-contaminated agricultural soils.

Strategic knowledge for climate change on agriculture and forest ecosystem in Indo-gangetic plains (IGP) of UP

Tropical dry deciduous forests (TDDFs) are one of the most extended tropical forest ecosystems, but they have received attention of the scientific community only recently. This project has been initiated with the main objective to compile data on the plant diversity and ecology of the dry deciduous forests of IGP of UP, to generate database for developing and parameterizing the predictive models for climate change and forest ecosystem responses. The work has been undertaken through two separate approaches. First, by long term monitoring at permanent ecological plots established in tropical dry deciduous forest at Sonebhadra, UP. Second, by studying the response of representative tree species of TDDFs to elevated CO_2 under FACE (Free Air CO_2 Enrichment) system at CSIR-NBRI, Lucknow. While the first approach will give us the database for predictive models, the second approach will express the changes/responses in tree morphology, phenology, physiology, productivity and nutrient dynamics under scenario of elevated CO_2.

Six Permanent plots of 0.5 ha were marked in three forest communities, i.e. sal mixed forest, dry miscellaneous forest and Hardwickia mixed forest for ecological, phenological, phytosociological studies and carbon sequestration assessment.

Forest Microclimate: Data on five microclimate variables-photosynthetically active radiation (PAR), air temperature

(^{0}C), soil temperature (^{0}C), atmospheric ambient CO_2 concentrationand air absolute humidity (mmol mol^{-1}) were collected in dry miscellaneous and sal mixed forest communities in Renokoot district of UP.

Plant Diversity: During the reporting period ca. 414 plant specimens belonging to 272 taxa and 87 families were collected from the study site. Out of which, 336 specimens (113 trees, 87 shrubs, 69 herbs and 67 climbers) belong to dicotyledons and ca. 78 specimens to monocotyledons. The plants were collected with GPS information either in flowering or fruiting condition. The area is chiefly dominated by trees like *Lagerstroemia parviflora*, *Anogeissus latifolia*, *Acacia catechu*, *Hardwickia binata*, *Soymida febrifuga*, *Bauhinia racemosa*, *Diospyros melanoxylon*, *Bridelia retusa*, *Albizia* spp.,*Shorea robusta*, *Miliusa tomentosa*, *Haldina cordifolia*, *Nyctanthes arbortritis*, *Cassia fistula*, *Flacourtia indica*, *Ziziphus glaberrima*, *Terminalia elliptica* and *Butea monosperma*. The conspicuous climbers are *Ampelocissus latifolia*, *Cryptolepis buchananii* and *Mucuna pruiens*. Under herbaceous elements, *Elephantopus scabe*, *Crotalaria prostrata*, *Buettneria herbacea*, *Triumfetta pentandra*, *Hyptis suaveolens*, *Uraria picta*, *Tephrosia strigosa*, *Evolvulus alsinoides*, *Bidens biternata*, etc. are some of the common species. Many economically important species are also found in the forest, *e. g.*: *Shorea robusta*, *Terminalia alata*, *Haldina cordifolia*, *Mallotus philippensis*, *Tectona grandis*, *Ehretia laevis*, *Mitragyna parvifolia*, *Bauhinia* spp., *Syzygium cumini*, *Acacia auriculiformis*, *Ougenia oogensis*, *Melia azadirachta* and *Buchanania lanzan*.

Phytosociological analysis in Random Plots: Phytosociological attributes of each tree species in both the forest communities were studied by laying of 50 and 30 random quadrates of 20 m X 20 m in dry miscellaneous and sal mixed forests, respectively. The Shannon-Wiener's diversity index was 2.68 and 1.65 in dry miscellaneous and sal mixed forests, respectively. The highest diversity index (H$'$) was recorded in dry miscellaneous forest, showing it as more species diversity rich and more heterogeneous community in comparison to sal mixed forests. Concentration of dominance (C) was 0.063 and 0.259 in dry miscellaneous and sal mixed forests, respectively (Table 1).

Ecological studies in Permanent Plots: Three 0.5 hectare permanent plots each were established in three major community/ forest types (triplicate 0.5 ha area permanent plot each in sal mixed forest, dry miscellaneous forest and Hardwickia mixed forest). Maximum tree diversity was found in sal mixed forest (30) followed by dry miscellaneous forest (25). Least tree species diversity was observed in Hardwickia mixed forest (14). The tree basal cover was maximum (20.05 m^2/ha) in sal mixed forest followed by dry miscellaneous forest (13.01 m^2/ha) and

Table 1. Phytosociological analysis of Dry miscellaneous, (DMF) Sal mixed (SMF) and Hardwickia forests

SNo.	Forest Attributes	DMF	SMF	Hardwickia
1	Plant Species richness	25	30	14
2	Genera	25	30	14
3	Family	20	23	12
4	Density	802.87	1009	748
5	Basal cover (m^2/ha)	13.016	16.428	10.035
6	Simpson Index	0.10	0.09	0.16
7	Shannon Weiner Index	2.27	2.47	1.86
8	Hill diversity			
	N0	25	30	14
	N1	10.1	11.7	6.1139074
	N2	9.7	11.8	6.3983765

was lowest in Hardwickia mixed forest (10.03 m^2/ha^{-1}). The maximum basal cover in sal mixed forest community was occupied due to higher density of sal trees per hectare. Sal mixed forest observed maximum tree density (1009 stems/ha^{-1}) followed by dry miscellaneous forest (803 stems/ha^{-1}) and Hardwickia mixed forest (748 stems/ha^{-1}). The rich understory layer with high density and good tree regeneration results in higher tree density in sal mixed forest. Simpson index was maximum in Hardwickia forest (0.16) followed by dry miscellaneous forest (0.10) and sal mixed forest (0.09). The highest Simpson index showed complete dominance of Hardwickia tree in Hardwickia forest community. The Shannon diversity index ranged from 2.47 to 1.86 among the three forest communities. Sal mixed forest showed maximum Shannon diversity index of 2.47 followed by dry miscellaneous forest (2.27) and Hardwickia forest (1.86).

In-House Projects

Biodegradation of pyrene and phenanthrene by bacterial consortium with/without surfactant

The low water-solubility of petroleum hydrocarbon (PAH) increases sorption of compound to soil micelle and limits their availability to biodegrading microorganisms. Hence, the present study was performed to determine the role of surfactant in biodegradation of Polyaromatic hydrocarbons (pyrene and phenantherene) in soil in presence of bacterial consortium (*Pseudomonas stutzeri* BP10 and *Ochrobactrum intermedium* P2). Among the four non-ionic surfactants, i.e. Triton X-100, Tween 80, Brij 35 and Tergitol-7, Tween 80 was found less toxic to these selected bacterial strains. Maximum reduction in surface tension of media by Tween 80 was recorded at the concentration of 200 µg ml^{-1}.

When two bacterial strains were incubated in soil spiked with two PAHs (pyrene and phenanthrene, 100 ppm each) for 14 days, LMW PAH, i.e. phenanthrene was

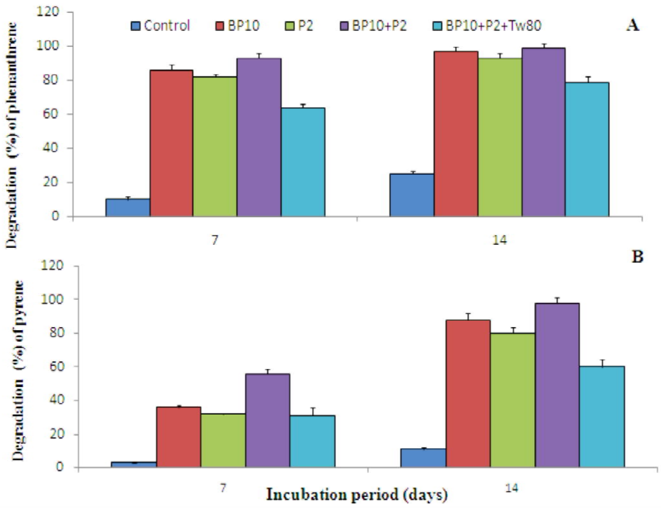


Fig. 1. Degradation of Phenantherene (A) and pyrene (B) by bacterial strains i. e. BP10 and P2 in isolation and combination with or without surfactant.

degraded at higher rate than pyrene as high molecular weight compounds are more recalcitrant than low molecular weight PAHs. Phenanthrene degradation was more than 80% by individual bacterial strains, whereas their combination enhanced the degradation up to 93% within 7 days of incubation (Fig 1A). After 14 days of incubation, bacterial consortium degraded 99% of phenanthrene in absence of surfactant, where as presence of surfactant degradation efficiency was reduced by about 20%. In case of pyrene, bacterial combination boosted the degradation up to 98% as compared to degradation by individual bacterial strains, i. e. BP10 (88%) and P2 (80%), while application of exogenous surfactant reduced the degradation rate up to 60% after 14 days of incubation (Fig. 1B).

Reduction in degradation of PAHs may directly be correlated with the induction of dioxygenase activity of microbe as presence of surfactant reduced the induction of dioxygenase enzymes in soil (Table 2).

Among the two bacterial strains, BP10 showed higher degradation efficiency. It may be due to the higher cell surface activity of BP10 (82 ± 0.8%) than P2 (75 ± 1.1%) for aromatic compound like benzene. Besides, isolated biosurfactant from BP10 showed higher desorption of phenantherene and pyrene (32% and 27%, respectively) than P2 (12 and 29%, respectively).

Uptake and accumulation of endosulfan isomers and its metabolite endosulfan sulfate in naturally growing plants of contaminated area

Endosulfan isomers (α + β) and its main metabolite, endosulfan-sulfate were analyzed in naturally growing vegetation of pesticide contaminated area. The plant and soil samples were collected from the campus and nearby areas of Flora Chemical and Fertilizers Limited, Ghaziabad, Uttar Pradesh. Seven species of dominating plants (*Sonchus olerceous, Digitaria longifolia, Panicum palndosom, Chloris virgata, Sphenoclea zeylanica, Sacciolepis interrupta, Vetiver zizanioides*) were collected at different locations within the contaminated area. Endosulfan residues from plant parts and soil were extracted and determined by a gas chromatograph equipped with 63Ni electron capture detector (GC-ECD). Endosulfan isomers and endosulfan-sulfate were present in almost all soil and plant samples (Figs. 2 and 3). The concentration of total endosulfan in plant and soil samples analyzed ranged from 14 to 343 ng g^{-1} and 13 to 938 ng g^{-1}, respectively. Out of seven plant species studied, *Vetiveria zizanioides* (Khus Khus) and *Sphenoclea zeylanica* (Chiken spike) showed the highest and lowest accumulation, respectively, with a significant difference at $p<0.01$ level. *Vetiveria zizanioides* and *Digitaria longiflora* (Crab grass) could accumulate

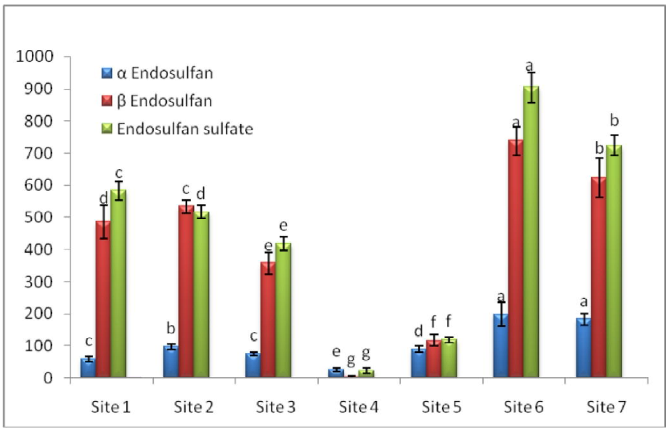


Fig. 2. Concentration of endosulfan isomers and its metabolite endosulfan sulfate in the soil of the study area (ng g^{-1})

Table 2. Catechol dioxygenase activities (μ mol mg^{-1} of protein) in different treatments

Treatments	Incubation period					
	0 day		7th day		14th day	
	C12O	C23O	C12O	C23O	C12O	C23O
Control	18.2 ± 1.4	10.2 ± 0.8	110.1 ± 5.8	23.6 ± 0.7	135.1 ± 3.4	32.7 ± 2.5
BP10	25.4 ± 0.5	9.8 ± 0.6	453.2 ± 2.3	47.2 ± 2.3	372.7 ± 2.8	44.2 ± 1.9
P2	21.2 ± 1.1	11.6 ± 0.7	379.3±11.2	29.8 ± 1.7	323.6 ± 4.2	32.6 ± 0.5
BP10+P2	25.4 ± 1.3	12.3 ± 0.6	653.5 ± 6.7	37.5 ± 2.9	530.4 ± 9.8	57.8 ± 0.8
BP10 +P2+Tw80	25.1 ± 0.9	11.9 ± 0.4	250.2 ± 4.7	21.6 ± 1.6	270.6± 19.4	31.2 ± 1.1

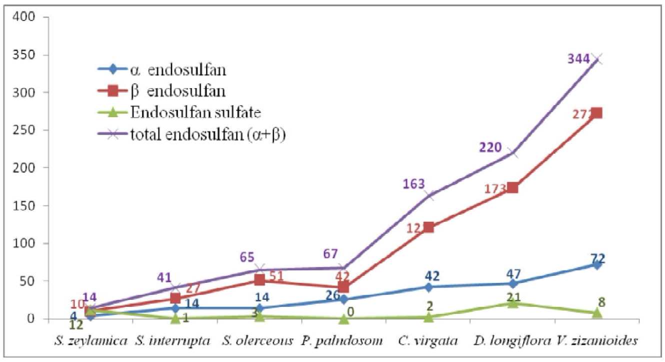


Fig. 3. Concentration of endosulfan isomers and metabolite endosulfan sulfate in tested species (ng g^{-1})

considerable levels of endosulfan isomers (α+β) (343 and 163 ng g^{-1}, respectively) and endosulfan-sulfate (21and 2 ng g^{-1}, respectively). The outcomes of the study reflect the value of test species in monitoring purposes and their potential for remediation of contaminated sites (Fig. 2 and 3).

Potential of green synthesized zero-valent iron nanoparticles for remediation of lead-contaminated water

A bottom-up green synthesis method has been used to synthesize zero-valent iron nanoparticles taking *Emblica officinalis* leaf extract as reducing and stabilizing agent at ambient temperature and using $FeCl_3$ solution as a source of iron to be reduced. UV–Vis spectroscopy, scanning electron microscopy, transmission electron microscopy, Fourier Transform Infrared Spectroscopy and X-ray diffraction have confirmed the fabrication of green synthesized zero-valent iron nanoparticles. In the UV–Vis spectrum, there was a shift in absorption peak ranging between 350 and 600 nm wavelengths. Nearly, spherical zero-valent iron nanoparticles having average size of 22.6 nm were obtained through this method. Fourier transform infrared spectrum reveals that the biomolecules are responsible for the synthesis and stabilization of the green synthesized zero-valent iron nanoparticles. Diffraction peak at 2δθ of 44.9° in X-ray powder diffraction spectrum illustrates the presence of pure metallic α -Fe nanoparticles with zetapotential value -26.7 mv. With the application of 20 ml l^{-1} concentration, green synthesized zero-valent iron nanoparticles were found very efficient for the remediation of 10, 20, 50 and 100 ppm of lead from aqueous medium within 24 h and the efficiency was positively correlated with the application time period and concentration of GZVINPs.

Phytodiversity on fly ash deposits: evaluation of naturally colonized species for sustainable phytorestoration

Proliferation of fly ash (FA) deposits and its toxicity have become a global concern. In this regard, identification of potential plant species for restoration of FA deposits is the main concern. Keeping this view in mind, the present study was conducted to identify potential plant species naturally growing on FA deposits for the restoration purposes. Six intensive surveys were made during 2010–2014 to collect naturally growing plant species during different seasons from two FA deposits in Unchahar of Raebareli district, Uttar Pradesh, India. The plant species having potential for FA deposits' restoration were identified on the basis of their ecological importance, dominance at the study sites and socio-economic importance for rural livelihoods. *Typha latifolia* L., *Cynodon dactylon* (L.) Pers., *Saccharum spontaneum* L., *S. bengalense* Retz. (syn. *S. munja*), *Prosopis juliflora* (Sw.) DC., *Ipomoea carnea* Jacq. and *Acacia nelotica* L. were identified as potential plant species for FA deposits' restoration. Furthermore, the characteristics of naturally colonized species can be used for the phytorestoration during a revegetation plan of new FA deposits for multiple benefits.

The field results also revealed that the *Saccharum spontaneum* is a suitable candidate for green capping of coal FA basins because of its higher survivability and abundan growth. The establishment of *S. spontaneum* on the fresh coal FA basins and significant change in chemical properties, microbial biomass carbon and enzymatic activities between non-rhizospheric and rhizospheric soil were studied. Besides green capping of coal FA basins, it provides other hidden benefits such as substrate quality enhancement, aesthetically pleasant landscape and carbon sequestration.

Changes in Biomass Allocation to Leaves, Stems, Fruits and Roots Under Abiotic Stress in Seed Plants

Optical Properties and Cyclic Electron Transport as Marker Tools for Assessing Drought Stress

Drought is a meteorological term and is commonly defined as a period without significant rainfall. Generally drought stress occurs when the available water in the soil is reduced and atmospheric conditions cause continuous loss of water by transpiration or evaporation. Tolerance to abiotic stresses is very complex, due to the intricate interactions between stress factors and various molecular, biochemical and physiological phenomena affecting plant growth and development. Knowledge generation about drought tolerance and selection of marker and varieties for drought tolerance has always been higher priority. In continuation with our drought tolerance work in cotton varieties, the reflectance properties of leaf and cyclic electron flux under water stressed conditions was studied.

Study of leaf optical properties (reflectance spectroscopy) begins with falling of light rays on leaf surface. Incident light is divided into three parts one which is reflected from the surface, second which is transmitted through the leaf. Third one is most important because it is absorbed into the leaves and participates in photosynthesis, fluorescence and heat dissipation. The property of reflectance is governed by the surface properties and internal structure of the plant sample, as well as by the concentration and distribution of biochemical components, and thus analysis of reflected light can be used to assess the physiological status of a plant.

The reflectance properties of different varieties of cotton were studied so as to assess drought tolerance and to use this technique as non destructive to select tolerant varieties of cotton.

Drought induced degradation of pigments, specially chlorophyll results in change in reflectance spectra in the red spectral region. The main reflectance changes observed in chl *a* and carotenoids absorption were maximum 440 and 678 nm respectively. In cotton leaves under drought, light reflectance in the photosynthetically active region (PAR) region (400-700nm) increased to overcome the light stress (Fig. 4). The increase in reflectance observed is due to change in water balance and pigmentation of the leaf. The reflectance and scattering coefficient spectrum with the increasing water stress increased between 600-750 nm. The absorbance coefficient and remission functions spectra become narrower and decreased with increasing drought (Fig. 4).

In recent years, the importance of alternative routes for electron transport in protecting the photosynthetic apparatus from stress has been subject of considerable debate and cyclic electron flux has been considered as protecting mechanism for photosynthetic apparatus (Fig. 5). The formation of pH in chloroplast is mainly induced by linear electron flow (ETRII) and cyclic electron flow (CEF) around the PSI. CEF is essential for protecting PSII against excess excitation pressure because CEF dependent building-up of pH across thylakoid membrane helps the activation of non-photochemical quenching (NPQ) and stabilization of oxygen-evolving complexes.

In cotton leaves cyclic electron flow (CEF) increases in moderate drought, however, further continuation of

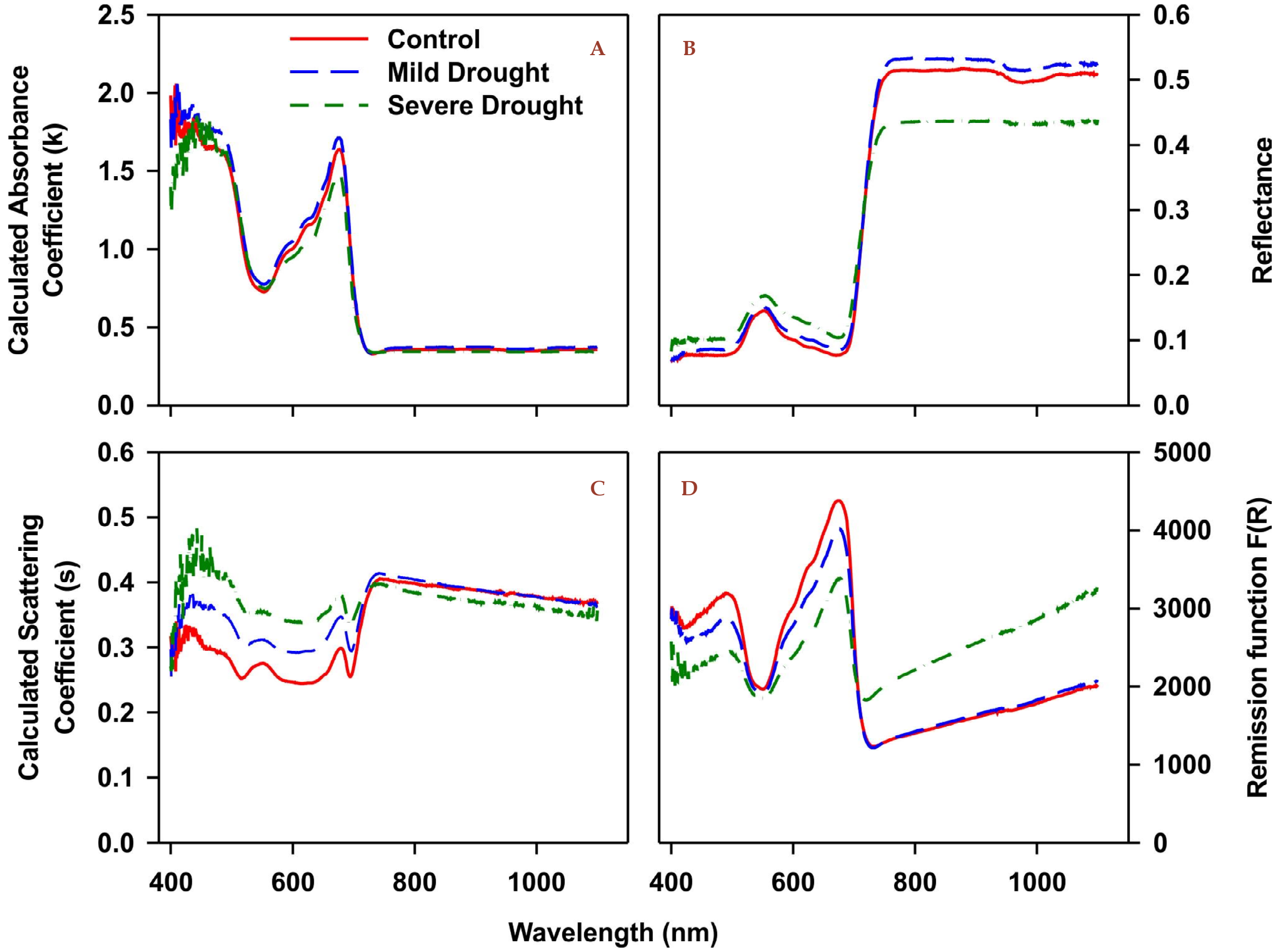


Fig. 4. Variation in absorption coefficient, k (A), Reflectance (B), Changes in Scattering coefficient, s (C), Remission function F(R) (D) during drought for adaxial surface of cotton leaf. As water content decreased during drought absorption coefficient and reflectance spectra became broader while reemission function also decreased so that fluorescence of a leaf decreased. Scattering coefficient spectra also became broader during drought.

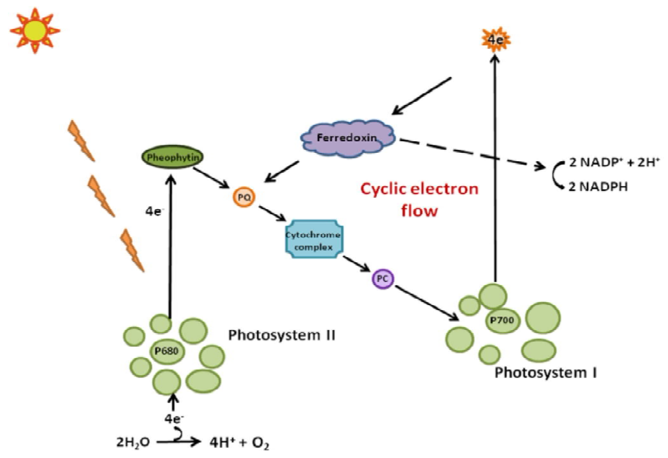


Fig. 5. A schenatic representation of cyclic electron flux (Source : Singh R *et al.*, *Photochem. Photo Biol.* 2014, **90**: 544-555)

drought stress resulted in decrease in CEF. In cotton leaves without water stress, the CEF/ETR(II) ratio was lower than 1, while it was 2.5 in leaves subjected to drought stress (Fig. 6). CEF has been documented as a crucial mechanism for protection against high-temperature stress, chilling, drought and high light. It was also hypothesized that CEF plays an important role in protecting PSI and PSII against drought stress for resurrection plants. Photochemical quantum yield of PSI and PSII and electron transport flow decreased during drought. With the onset of drought stress, the maximum photochemical quantum yield,Y(I), Y(II) and ETR(I), ETR(II) decreased initially and remained constant during the moderate water stress. However, under extreme drought stage, Y(II) and ETR decreased significantly. The fraction of energy dissipated as heat via the regulated non-photochemical quenching mechanism, Y(NPQ) strongly increased under mild drought. While under severe drought Y(NPQ) decreased significantly, this may be due to degradation of the chlorophyll and reduction in PQ pool size.

Proteomic analysis of cotton leaves : Proteomic analysis of two species of cotton namely *Gossypium hirsutum* and *G. herbaceum* have been undertaken in order to analyse the differential expression of proteins on their respective flowering phases during different regimes of drought. Two regimes of drought stress, i.e. at 75% RWC (D1) and 50% RWC (D2) and a rehydration (Rh) regime have been undertaken.

Two-dimensional gel electrophoresis coupled with mass spectrometry revealed eleven common functional categories among 42 and 102 proteins identified in *G. hirsutum* (JFL) and *G. herbaceum* (RFL) leaves, respectively during different stress (D1 and D2) and Rh in flowering phase. Six categories were found to be common between JFL and RFL of which major proteins fell in the category of photosynthesis which consisted of 42 proteins including JFL that contributed 20 proteins while remaining 22 proteins were from RFL (Fig. 7).

The second largest category was stress and defence which shared maximum number of proteins from RFL (22 protein) while remaining 2 proteins were from JFL. Protein metabolism category consisted of 7 proteins of which 4 were from RFL and 3 from JFL. Carbohydrate and energy metabolism category shared two proteins each between JFL and RFL. Carbon and nitrogen metabolism constituted 4 proteins of which 3 were from RFL and remaining one protein was from JFL. Cytoskeleton shared 2 proteins from RFL and 1 protein JFL. Four categories were found in RFL namely, cell wall composition, cell redox homeostasis, signal transduction and nucleotide metabolism which contributed 1 and 2 proteins, respectively in each category. While one category namely transcriptional control belongs to JFL that constituted 2 proteins (Fig. 7).

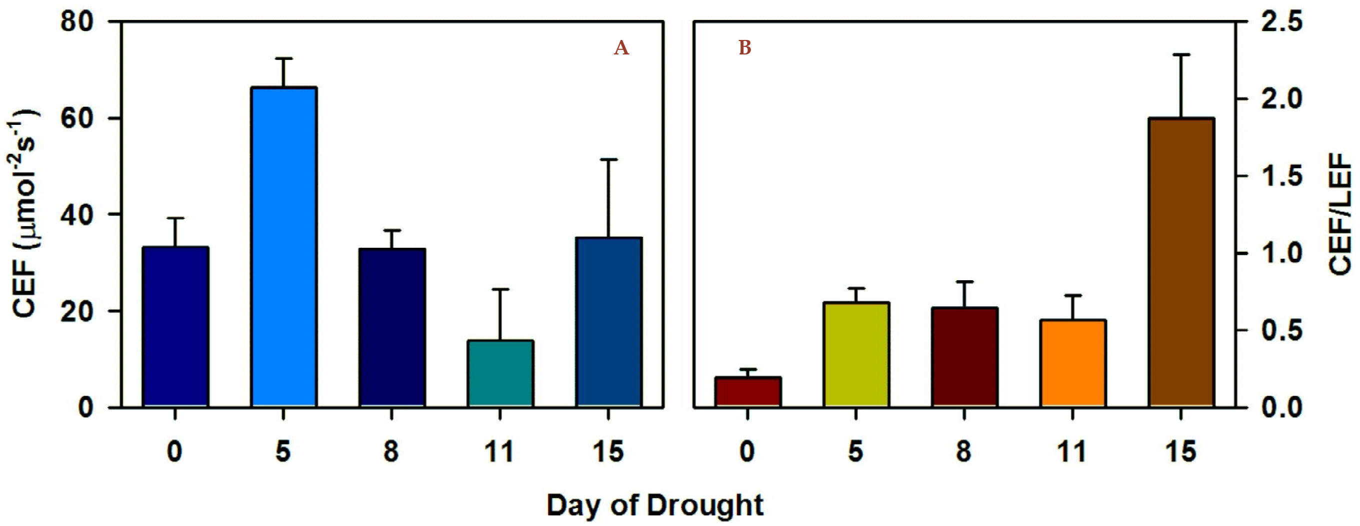


Fig. 6. Drought response changes in cyclic electron flow, CEF (A) and ratio between cyclic and linear electron flow, CEF/ETR(II) (B).

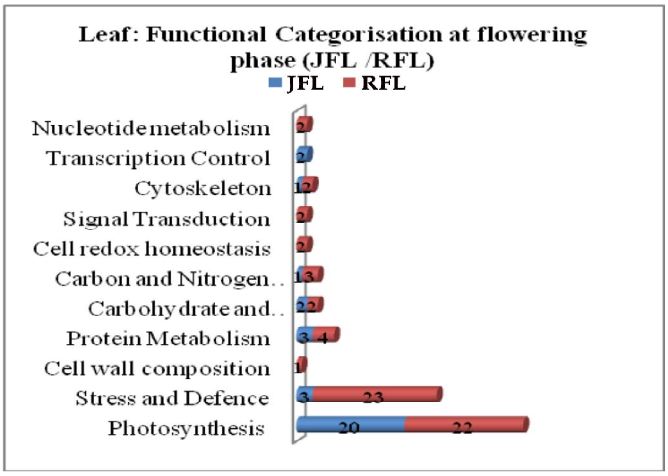


Fig. 7. Graph showing different functional categories among the identified proteins in leaves (L) of *G. hirsutum* (J) and *G. herbaceum* (R) at different drought stages (75% RWC-D1 and 50% RWC- D2) and rehydration (Rh) at flowering (F) phase. Values inside the bar represent the number of proteins falling in their respective categories. Note: *G. hirsutum* leaf at flowering phase is represented as JFL while *G. herbaceum* as RFL

G. hirsutum **(JKC-770) leaves:** There were 875 spots matched to all the treatment gels, out of which 77 were found to be differentially expressed in *G. hirsutum* (JKC-770) leaves during different treatment of drought (D1 and D2) and on recovery in flowering phase gels (Fig. 8). Out of 77 spots, 45 were significantly identified in MALDI/TOF-TOF. During different stress treatments, more than 65% proteins were down regulated while only 30% proteins were up-regulated in the leaves of JKC-770 during flowering phase.

Up-regulated proteins involved the categories of cellular stress and defence (superoxide dismutase; ascorbate oxidase; methyltetrahy dropteroyltriglutamate-homocysteine methyltransferase; glutathione-S-transferase), cytoskeleton (alpha tubulin), photosynthesis (RuBisCO LSU; chlorophyll a/b binding protein), etc.

Down-regulated proteins involved the categories of photosynthesis (RuBisCO LSU; chlorophyll a/b binding protein; photosystem II 23 kDa polypeptide; carbonic anhydrase), protein folding and assembly (HSPs 70), energy metabolism (ATP synthase alpha subunit), protein degradation (cysteine proteases), etc.

G. herbaceum (RAHS-187) Leaves: flowering phase

There were 948 spots found in each set of treatment in the leaves of *G. herbaceum* (RAHS-187) during flowering phase, out of which 907 spots were matched to all the treatment gels (D1, D2 and Rh) as compared to control. Out of 126 differentially expressed protein spots, 111 spots were identified in MALDI/TOF-TOF (Fig. 9).

More than 60% proteins were up-regulated over different drought stress and recovery stages. Some of the up-regulated proteins exhibited higher expression during D1 that included DNA repair protein, NBS LRR Like proteins, glutamine synthase, ferredoxin—NADP reductase, leaf isozyme, chloroplastic, haloacid dehalogenase-like hydrolase domain-containing protein; while some of them were observed up-regulated during D2 that included the proteins under the categories of protein folding (HSPs), photosynthesis (RuBisCO LSU, Phosphoribulokinase, NADH dehydrogenase), protein degradation (presequence protease, Serine type peptidase, Cysteine proteases) and the proteins of detoxification CuZn SOD, Cys Peroxiredoxins, ascorbate peroxidase.

Remaining 40% of down regulated proteins involved major categories of photosynthesis (ferredoxin—NADP reductase; plastid fructose 1,6 bisphosphate aldolase class 1; ribulose-1,5-bisphosphate carboxylase/oxygenase large subunit; ribose 5-phosphate isomerase A photosystem II oxygen-evolving complex protein 2; photosystem II 23 kDa polypeptide; Ferredoxin, chloroplastic; cytochrome b6-f complex iron-sulfur subunit); protein folding and assembly (molecular chaperone Hsp90-2; heat shock protein 70 and 9; chaperonin), carbohydrate and energy metabolism (Phosphoglycerate kinase; Thiazole biosynthetic enzyme; chloroplast transketolase precursor; triosephosphate isomerase); defence (lipoxygenase ribulose-1,5-bisphosphate carboxylase/oxygenase activase 1; cysteine synthase; Epoxide hydrolase; chloroplast drought-induced stress protein; disease resistance protein; peroxiredoxin); Photorespiration (mitochondrial glycine decorboxylase complex P protein), transport (H+ transporting ATP synthase) etc.

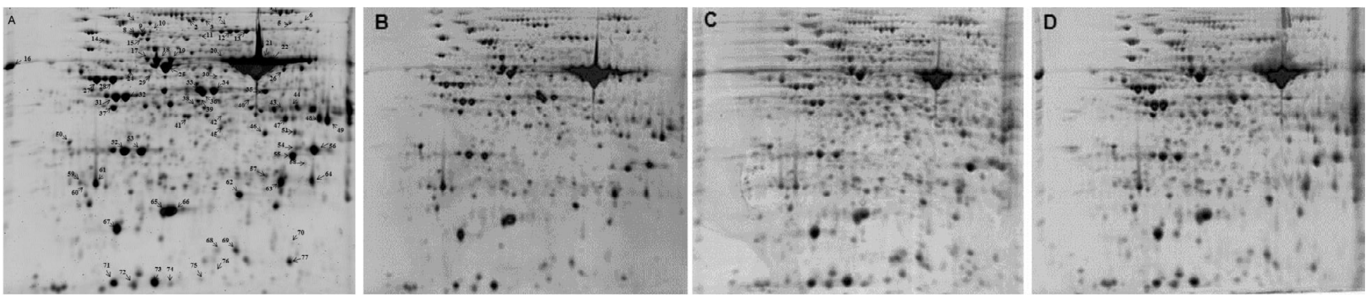


Fig. 8. Sypro ruby stained gels of *G. hirsutum* leaves at (A) Control, showing differentially expressed protein spots during (B) 75% RWC, (C) 50% RWC, (D) rehydration (Rh) stages at flowering phase.

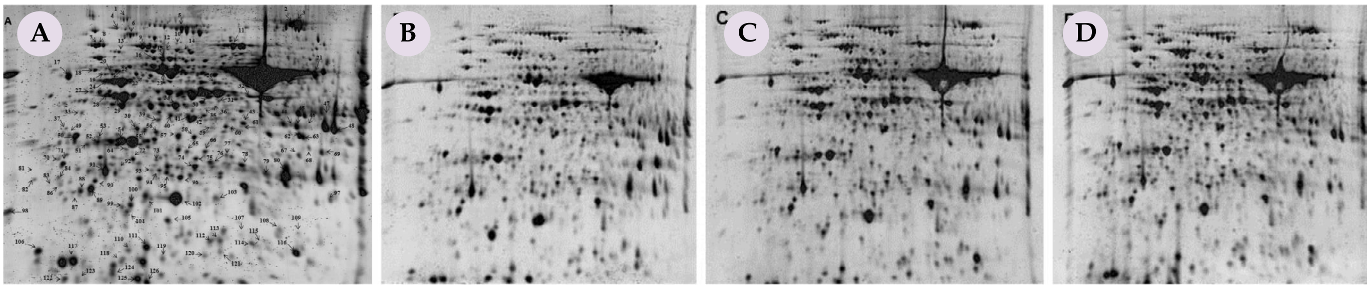


Fig. 9. Sypro ruby stained gels of *G. herbaceum* leaves at (A) Control, showing differentially expressed protein spots during (B) 75% RWC, (C) 50%, (D) rehydration (Rh) stages at flowering phase.

Publications

1. Dubey RK, Tripathi V, Singh N and Abhilash PC – Phytoextraction and dissipation of lindane by *Spinacia oleracea* L. *Ecotoxicol. Envir. Safety*, 2014. **109** : 22-26.
2. Edrisi SA, Dubey RK, Tripathi V, Bakshi M, Srivastava P, Jamil S, Singh HB, Singh N and Abhilash PC – *Jatropha curcas* L. : A crucified plant waiting for resurgence. *Renewable Sustainable Energy Rev.*, 2015, **41**: 855-862.
3. Mallick S, Kumar N, Sinha S, Dubey AK, Tripathi RD, Srivastav V - H_2O_2 pretreated rice seedlings specifically reduces arsenate not arsenite: difference in nutrient uptake and antioxidant defense response in a contrasting pair of rice cultivars. Physiol. Mol Biol P, 2014, **20** (4): 435-447.
4. Mishra S, Singh SN - Biodegradation of benzo(a)pyrene mediated by catabolic enzymes of bacteria. *In. J. Environ. Sci. Tech.*, 2014, **11** (6): 1571-1580.
5. Pandey AK, Majumder B, Keski-Saari S, Kontunen-Soppela S, Pandey V and Oksanen E – Differences in responses of two mustard cultivars to ethylenediurea (EDU) at high ambient ozone concentrations in India. *Agriculture, Ecosystem Envir.*, 2014, **196** : 158-166.
6. Pandey VC and Singh N – Fast green capping on coal fly ash basins through ecological engineering. *Ecological Engin.*, 2014, **73** : 671-675
7. Pandey VC, Bajpai O, Pandey DN, Singh N - *Saccharum spontaneum*: an underutilized tall grass for revegetation and restoration programs. *Genet. Resour. Crop Evol.*, 2015, **62** (3): 443-450.
8. Pandey VC, P Prakash, Bajpai O, Kumar A and Singh N – Phytodiversity on fly ash deposits: evaluation of naturally colonized species for sustainable phytorestoration. *Environ. Sci. Pollui. Res.*, 2015, **22** : 2776–2787.
9. Pandey VC, Pandey DN and Singh N – Sustainable phytoremediation based on naturally colonizing and economically valuable plants. *J. Cleaner Production.*, 2014, **86** : 37-39.
10. Pandey VC, Singh N, Singh RP and Singh DP – Rhizoremediation potential of spontaneously grown *Typha latifolia* on fly ash basins : Study from the field. *Ecological Engin.*, 2014, **71** : 722–727.
11. Raj A, Jamil S, Srivastava PK, Tripathi RD, Sharma YK, Singh N - Feasibility study of *Phragmites karka* and *Christella dentate* grown in West Bengal as arsenic accumulator. *Int. J. Phytoremediat.*, 2015, **17** (9): 869-878.
12. Raj A and Singh N – Phytoremediation of Arsenic Contaminated Soil by Arsenic Accumulators: A Three Year Study. *Bull. Environ. Contam. Toxicol.*, 2015, **94** : 308-313.
13. Ranjan S., Singh R., Singh M., Pathre U.V., Shirke PA - Characterizing Photoinhibition and Photosynthesis in Juvenile-red Versus Mature-green Leaves of Jatropha curcas L. *Plant Physiol. Biochem.*, 2014, **78**: 48-59.
14. Singh M, Rai UN, Nadeem U and David AA – Role of *Potamogeton pectinatus* in phytoremediation of metals. *Chem. Sci. Rev. Lett.*, 2014, **3**(11S) : 123-129.
15. Singh M, Ranjan S, Verma KK, Pathre UV, Shirke PA – Photosynthetic characteristics of red and green leaves in growing seedlings of *Jatropha curcas*. *Turkish J. Biol.*, 2014, **38 :** 457- 468.
16. Singh R, Naskar J, Pathre U V., Shirke PA - Reflectance and Cyclic Electron Flow as an indicator of drought stress in Cotton (*Gossypium hirsutum*). *Photochem. Photobiol.*, 2014, **90** (3): 544-551.
17. Singh R, Pandey N, Naskar J, Shirke PA – Physiological performance and differential expression profiling of genes associated with drought tolerance in contrasting varieties of two Gossypium species. *Protoplasma*, 2015, **252 :** 423-438.
18. Srivastava P, Sharma YK and Singh N – Soil carbon sequestration potential of *Jatropha curcas* L. growing in varying soil conditions. *Ecological Engin.*, 2014, **68** : 155-166.
19. Tiwari S, Singh SN and Garg SK – Bacterial reduction of Cr (VI) and Fe (III) *in vitro* conditions. *Biorem. J.*, 2014, **18**(2) : 158-168.
20. Tripathi RD, Singh R, Tripathi P, Dwivedi S, Chauhan R, Adhikari B and Trivedi PK – Arsenic accumulation and tolerance in rootless macrophyte *Najas indica* are mediated through antioxidants, amino acids and phytochelatins. *Aquatic Toxicol.*, 2014, **157** : 70-80.
21. Tripathi V, Dubey RK, Edrisi SA, Narain K, Singh HB, Singh N and Abhilash PC – Towards the ecological profiling of a pesticide contaminated soil site for remediation and management. *Ecological Engin.*, 2014, **71** : 318-325.
22. Tripathi V, Dubey RK, Singh HB, Singh N, Abhilash PC, Is *Vigna radiate* (L.) R. Wilczek a suitable crop for Lindane contaminated soil? *Ecol. Eng*, 2014, **73**: 219-223.
23. Upadhyay AK, Singh NK and Rai UN – Comparative metal accumulation potential of *Potamogeton pectinatus* L. and *Potamogeton crispus* L. : Role of enzymatic and non-enzymatic antioxidants in tolerance and detoxification of metals. *Aquatic Bot.*, 2014, **117** : 27–32.

GENETICS AND MOLECULAR BIOLOGY

Scientists: MH Asif , SK Bag, D Chakrabarty, SN Jena, P Misra , CS Mohanty, SK Raj, SA Ranade, S Roy, AP Sane, VA Sane, I Sanyal, SV Sawant, S Shukla, PK Singh, PK Trivedi, PC Verma, HK Yadav

Technical Staff: A Kumar, KN Maurya, DK Purshottam, SK Snehi, DD Toppo

Grant-in-Aid Projects

A novel male sterility-fertility restoration system in plants for hybrid seed production

Global food security demands the development of new technologies to increase and secure crop production on finite arable land without increasing water and fertilizer use. The use of heterosis or hybrid vigor in plant breeding has produced tremendous economic benefits in worldwide crop production. The development of an efficient method of hybrid seed production with broad applicability to crops in a biological safe manner is still a need. Here, we report a male sterility–fertility restoration system by engineering the inner-most nutritive anther wall layer tapetum of female and male parents to facilitate the hybrid seed production at commercial scale.

The experimental strategy and underlying hypothesis

Two tapetum-specific expression cassettes were developed:

1. **Female expression cassette (male-sterility module/ 1371);** It works on functional complementation of mutated TATA-box (TGTA) and TATA-binding protein mutant 3 (TBPm3) resulting high-level expression of *BECLIN1* gene specific to tapetum. *BECLIN1* expression interferes with natural programme of tapetal degeneration resulting in pollen abortion or male sterility (Fig. 1-a).
2. **Male expression cassette (Restorer-module/1373);** Constitutive photo-morphogenesis1 (COP1) gene expressed specific to tapetum, using A9 promoter (Figure1-b).

The crosses between above systems resulted F1 hybrids harbouring both expression cassettes in the same tapetal cell. Here, COP1 protein physically interacts with $HFR1^{NT131}$ fragment of conjugated protein $HFR1^{NT131}$-TBPm3 leading to their proteosomal degradation. Therefore, transcription of *BECLIN1* gene was abolished due to unavailability of TBPm3 to TGTA-mutated promoter TA29. *BECLIN1* expression abolition leads to normal tapetal degeneration programme and restored pollen fertility (Figure 1-c).

Male-sterility and fertility restoration system in plants

The transgenic expressing *BECLIN1* gene using the female expression cassette showed no morphological anomaly, with normal growth and development comparable to wild plants except male sterility (Fig 2a-b). The pollen viability, pollen morphology, and in-vitro pollen germination assay showed complete male sterility plants with nil seed settings (Figure 2-d, 2-f and 2-g) when compared with control (Figure 2-c, 2-f and 2-g). The F1 obtained by crossing female line (male sterile) and male line (male fertile) showed restored pollen viability and seed setting comparable with control (Figure 2-e, 2-f and 2-g) as the BECLIN1 expression was abolished.

The *BECLIN1* expression in tapetum caused the tapetal developmental defects like delayed degeneration and abnormal growth that resulted in abortive pollen formation (Figure 3a-b). In F1 the *BECLIN1* expression was abolished, therefore, normal tapetal degeneration was achieved producing fertile pollens (Fig. 3-c).

In this study, we have developed a male sterility–fertility restoration system for heterosis breeding in plants. The system has following advances, 1) achievement of complete male sterility; 2) use of Arabidopsis *BECLIN1* gene for the male-sterility as the gene is of plant origin with no reported toxic effects; 3) 100% fertility restoration of F1 which is very important when commercial product is seed and 4) maintaining the male-sterile female lines; a prerequisite for future commercial application. Linking the herbicide resistance gene in the construct 1371 will enable the selection of male-sterile female parents after crossing the heterozygous male-sterile female parent (BECLIN1/-) with its wild type (-/-) followed in ~50% of the male-sterile progeny; the system has broad applicability to crops due to its generic nature.

Studies on genetic diversity of potyviruses infecting bulbous ornamental crops in India for development of their possible management

Association of nerine yellow stripe virus with mosaic disease of *Crinum asiaticum*

Crinum asiaticum, commonly known as spider lily, is widely grown ornamental plant in gardens of tropical and subtropical countries for its long strap-like green leaves and clustered white flowers. During a survey in December, 2013, severe mosaic symptoms were observed on a number

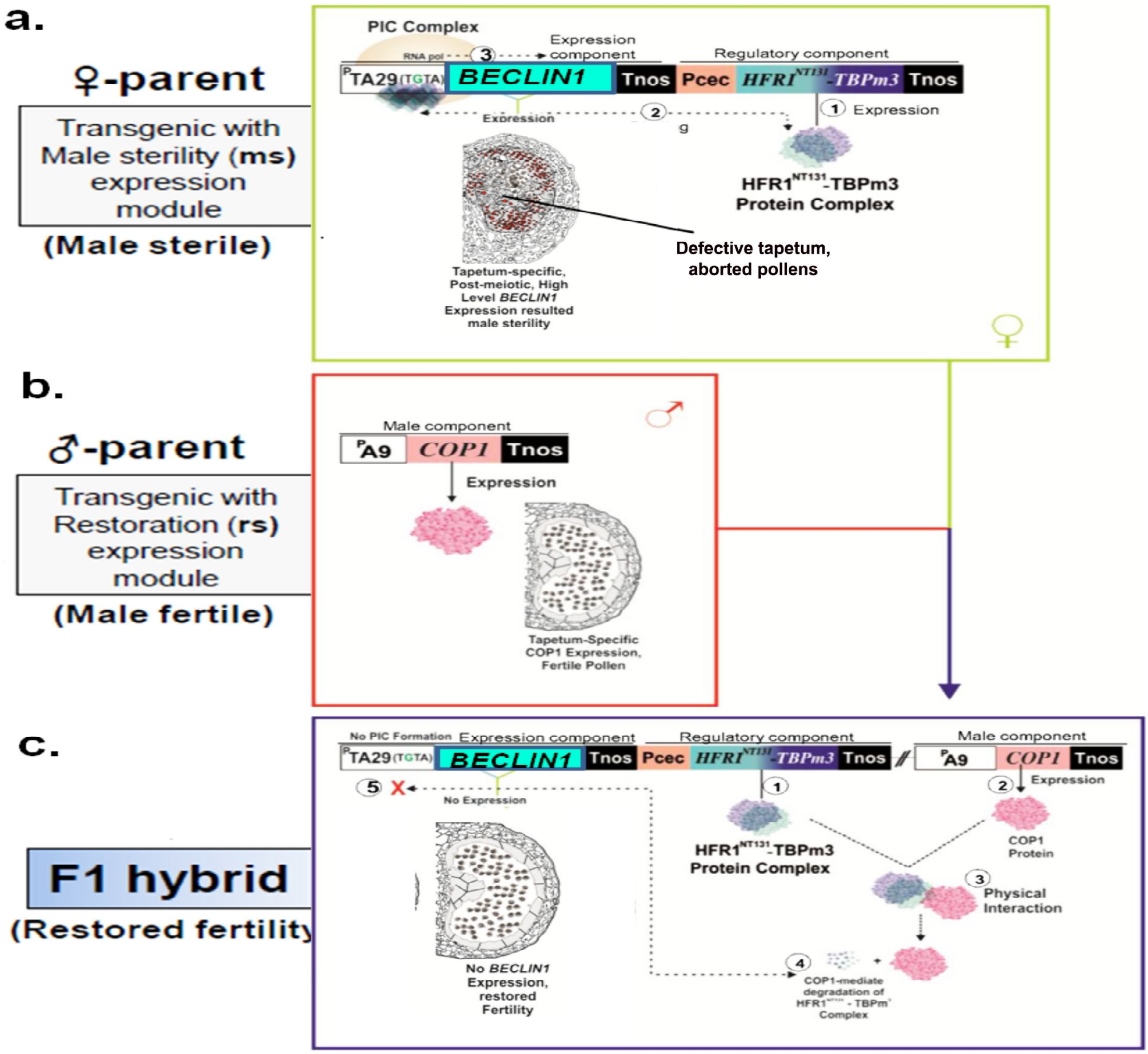


Fig. 1. Experimental design and underlying mechanism of the male sterility–fertility restoration system in plants for hybrid seed production: **(a)**. The female expression cassette contains two transcriptional units: expression component (^{P}TA29$_{(TGTA)}$-*BECLIN1*-Tnos) and the regulatory component (^{P}Pcec-*HFR1^{NT131}-TBPm3*-Tnos). The regulatory component express conjugated protein HFR1^{NT131}-TBPm3, which binds to TATA-box mutated promoter (^{P}TA29$_{(TGTA)}$) of expression component, and resulted transcriptional pre-initiation complex (PIC) formation b$. The high-level and tapetum-specific expression of *BECLIN1* was achieved, as TGTA-mutated promoter was functionally complemented by TBPm3 (or HFR1^{NT131}-TBPm3) pool. This expression cassette is useful in achieving tapetum-specific, high-level expression of the male-sterility gene (we expressed *BECLIN1*); **(b)** The male expression cassette expresses COP1 (or COP1^{L105A}) by using the tapetum-specific promoter A9, thus giving normal male-fertile plants; **(c) Fertility restoration mechanism of F1.** F1 is obtained by crossing with plants expressing female (male-sterile) and male (male-fertile) expression cassettes. Regulatory component express HFR1^{NT131}-TBPm3 and male-component express COP1 (or COP1^{L105A}) proteins in the F1-tapetal cell. The COP1 physically interact with the HFR1^{NT131} fragment of the conjugated protein (HFR1^{NT131}-TBPm3) and, sequentially degrades it, resulting in the unavailability of TBPm3, hence no PIC formation on the TGTA-mutated TA29 promoter, leading to expression abolition of *BECLIN1* (male sterility gene). *BECLIN1* abolition resulted normal degeneration program and restored fertility of F1-progeny. [TA$_{29(TGTA)}$ = Tapetum-specific promoter from tobacco with mutated TATA box to TGTA, *gusA*= b-glucuronidase, Pcec= artificial promoter[48], *HFR1^{NT131}* = N-terminus 131 amino acid fragment of Long **h**ypocotyle in **f**ar **r**ed **1** (HFR1), *TBPm3* = TATA-binding protein with three amino acid substitution (Ile$_{152}$ to Phe$_{152}$, Val$_{161}$ to Thr$_{161,}$ and Leu$_{163}$ to Val$_{163}$), Tnos= transcriptional terminator, A9= tapetum-specific promoter from *Arabidopsis*, COP1= **Co**nstitutive **p**hotomorphogenic**1**, COP1^{L105A}= COP1-mutant with increased nuclear localization].

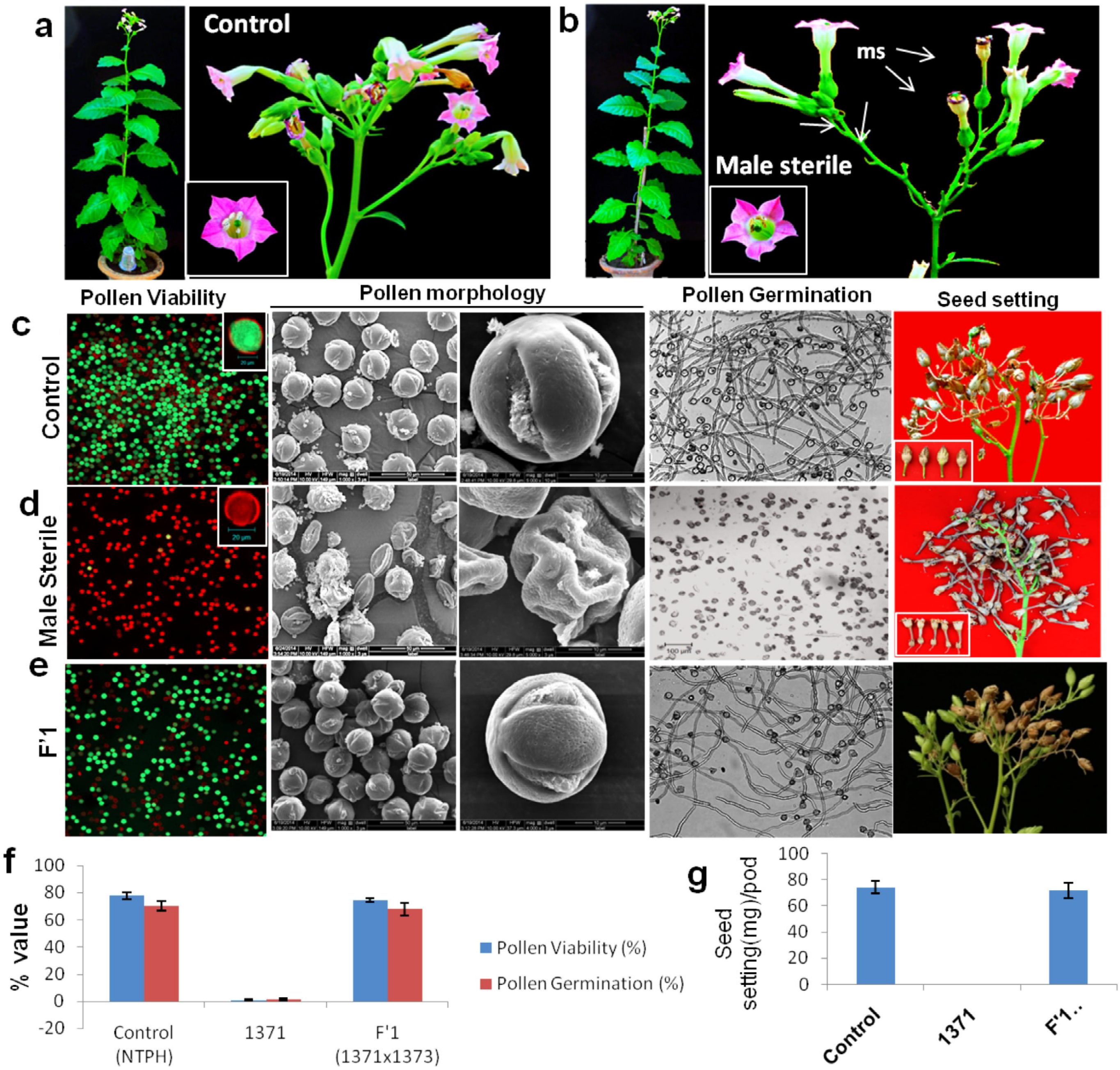


Fig. 2. Transgenic male-sterility and fertility-restoration in tobacco: (a-b) The control and BECLIN1 transgenic plants showed normal growth and development except male sterility in 1371 transgenic (arrows indicate the dying and detachment of flower that are unsuccessful in fertilization due to male sterility). **[c-e]** Pollen viability assay using FDA-PI method, Scanning electron microscopic (SEM) analysis, In-vitro pollen germination assay and Seed setting in control **(c)**, BECLIN1-transgenic **(d)**, and F1 **(e)**. **[f]** Quantitative analysis (in %) of pollen viability and in-vitro pollen germination in control, BECLIN1- transgenic, and F1 hybrid lines. Error bar represents SD of n=10 lines.**[g]** Quantitative analysis (in mg/pod) of seed setting in control, BECLIN1-transgenic, and F1 hybrid lines.

of *C. asiaticum* plants growing in gardens at Noida and New Delhi, India. The symptoms, similar to that of a potyvirus infected *Crinum* sp. symptoms described earlier from Brazil, suggested, potyvirus infection. Electron microscopic studies, revealed flexuous rod shaped virus particles of ~700x 12 nm size, while RT-PCR using potyvirus degenerate primers. RT-PCR resulted in the expected size (~1.5 kb) amplicon in all symptomatic samples. The amplicons were cloned, sequenced and sequence data was deposited in GenBank database under accession numbers: KJ886933 (Nod-1), KM066970 (Nod-2), KM066968 (Nod-3), KJ886934 (Del-1), KM066971 (Del-2) and KM066969 (Del-3) isolates. The isolates shared 98-99% sequence identity together and 78-99% identities with *Nerine yellow stripe virus* (NeYSV) isolates (FJ618537, DQ407932, EF362621, EF362622, EU042758 and JX865782) reported from New Zealand, The Netherlands and USA. Phylogenetic analysis reveled that he isolates under study clustered together and showed close relationships with NeYSV isolates. To best of our

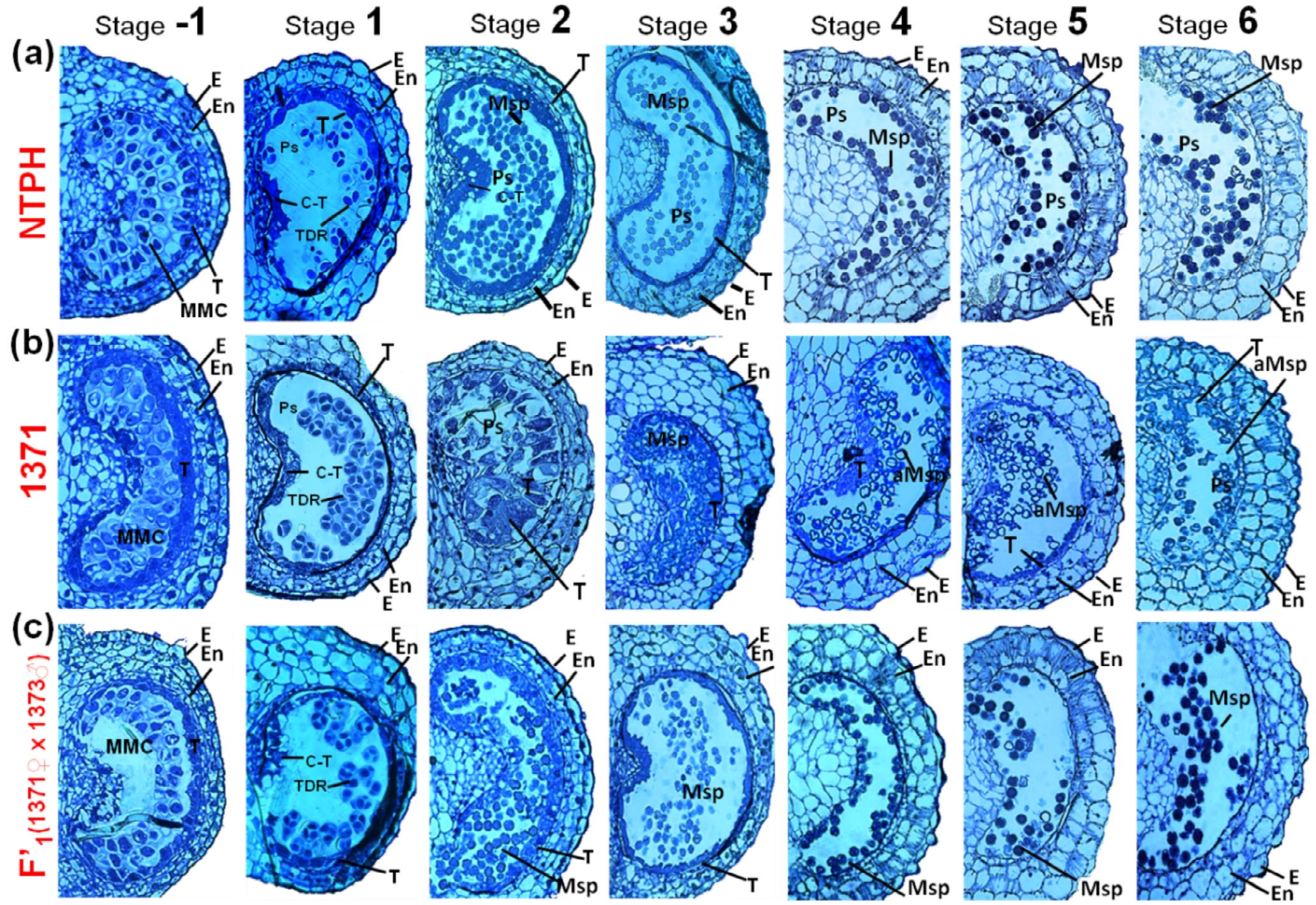


Fig. 3. Transverse anatomical comparison of anther development in wild type (NTPH), BECLIN1 transgenic (1371) and F'1
Semi-thin cross sections of control (a), BECLIN1-transgenic (1371) (b), and F1 (c) at anther stages from -1 to stage 6. E, epidermis; En, endothecium; ML, middle layer; T, tapetum; TDR, tetrads; Msp, microspore; Ps, pollen sac; C-T, connective tapetum, MMC, microspore mother cell; aMsp, aborted microspore. Bars= 100 µm.

knowledge, this is the first report of natural occurrence of NeYSV on *C. asiaticum* in India.

Functional analysis of sterol glycosyl transferase (SGT) gene family of *Withania somnifera* using mi-RNA technology

The *SGT* gene family plays animportant role in *Withania somnifera* in the glycosylation of steroidal hormone, which modulates growth and development of plants.These glycosylated secondary metabolites help in the plant defense. For functional analysis,the family was silenced by transforming the plant with artificial miRNA (amiRNA) gene construct in VIGS plasmid. The down-regulation effect of *WsSGTL* gene family on secondary metabolite production in transgenic lines was checked by HPLC analysis. To study the effect of biotic stress on down-regulated lines, a fungal pathogen *Alternaria alternata,*a common foliar pathogen of *W.somnifera,* was selected.

miRNA159a of *Arabidopsis thaliana*was used as backbone for the preparation of artificial miRNA(amiRNA) against *SGT* gene family of *W.somnifera*. We have replaced 21 bp stem region from precursor miRNA159a with selected different 21 bp conserved region of *WsSGTL* gene and designed three different amiRNA named as, 2mi*sgt*, 4mi*sgt* and 6mi*sgt*.

An efficient protocol for the VIGS analysis of *W. somnifera* was developed by using phytoenedesaturase (*PDS*) gene as reporter gene. After down-regulation of *PDS*gene, bleaching of chlorophyll started and the leaves of the plants became white (Fig. 4).

The two most efficient amiRNA i.e., 2mi*sgt* and 4mi*sgt* were further utilized to clone into VIGS vector for the preparation of aMIR-VIGS construct and transformed into *W. somnifera*. The transcript abundance of *SGTLs* gene decreased in the transgenic lines as compared to control (empty vector) (Fig. 5A). This was further checked by total SGT enzymatic analysis in control and transgenic plants and observed that in transgenic lines, the total SGTs activity was less than in control plants (Fig. 5B). After one month of transformation, the height and leaf area of

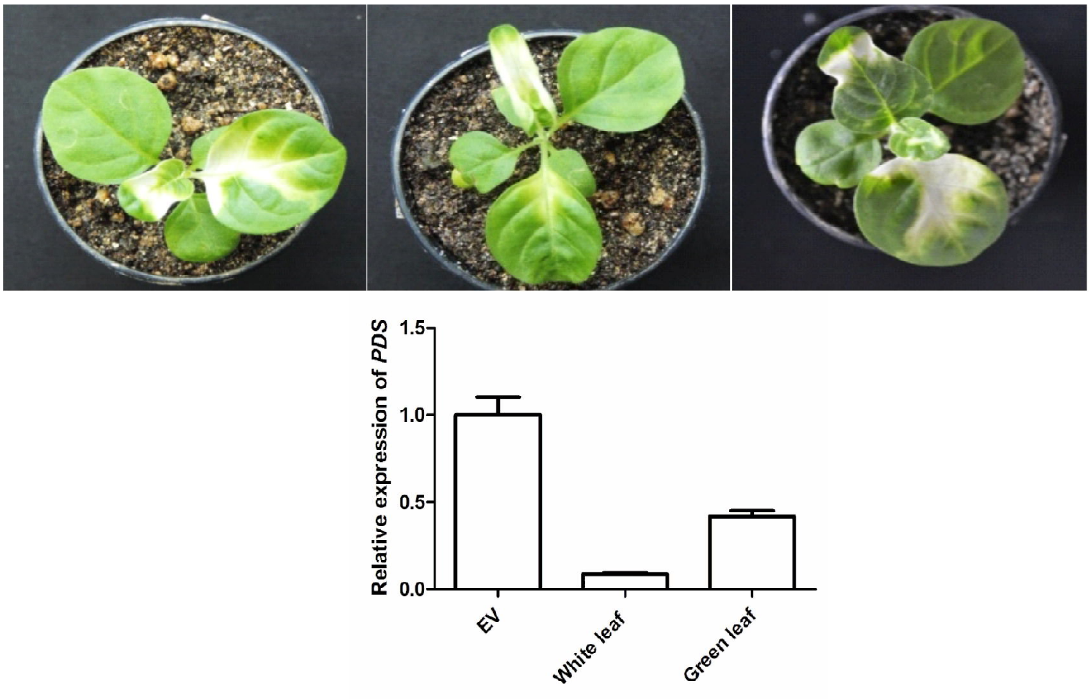


Fig. 4. MIR-VIGS mediated *PDS* gene silencing of *W. somnifera*

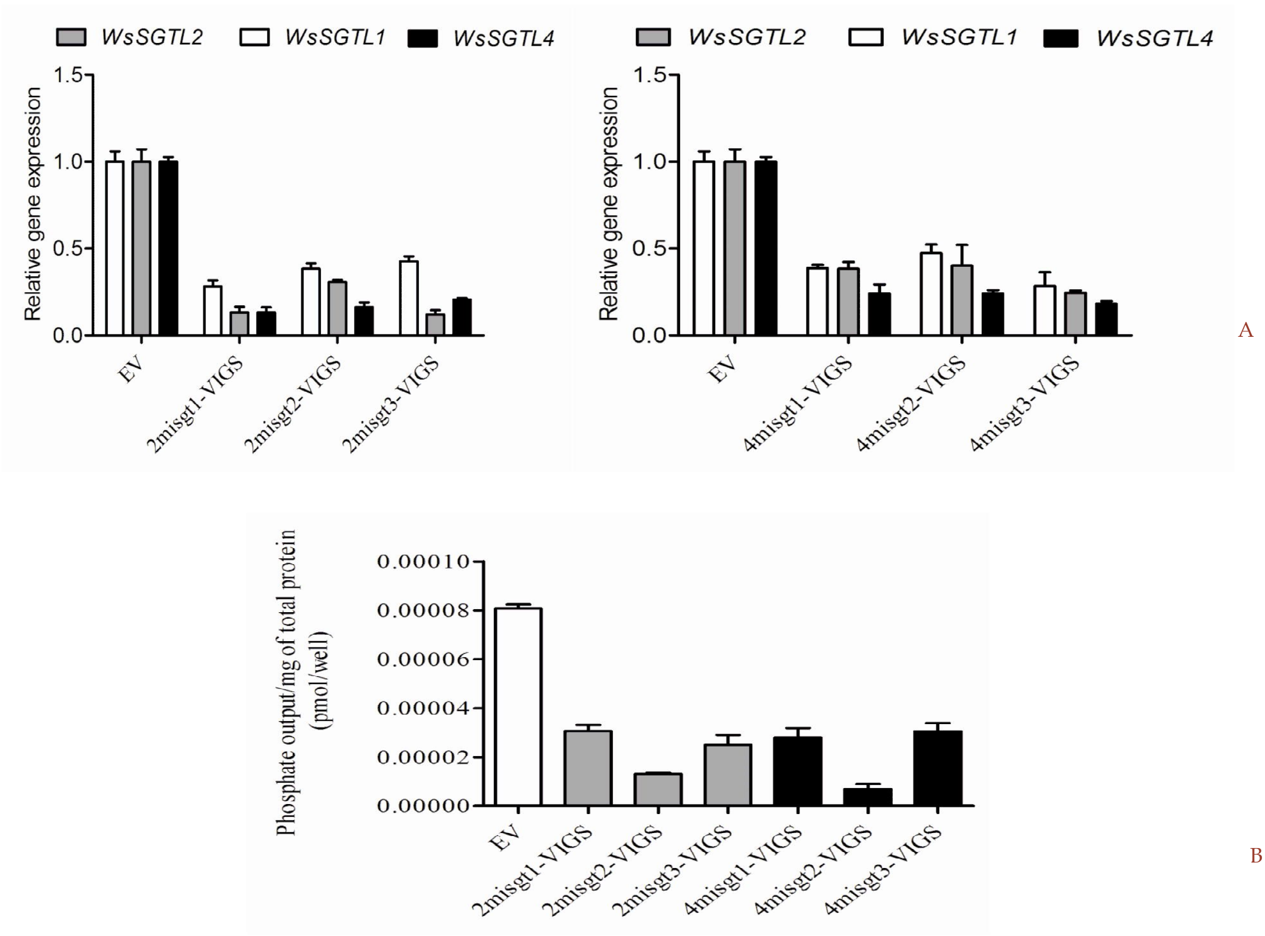


Fig. 5. *WsSGTLs* down-regulation by aMIR-VIGS system: (A) qRT-PCR showing the relative expression level; (B) The relative *WsSGTLs* enzyme activity from the total protein of transgenic lines.

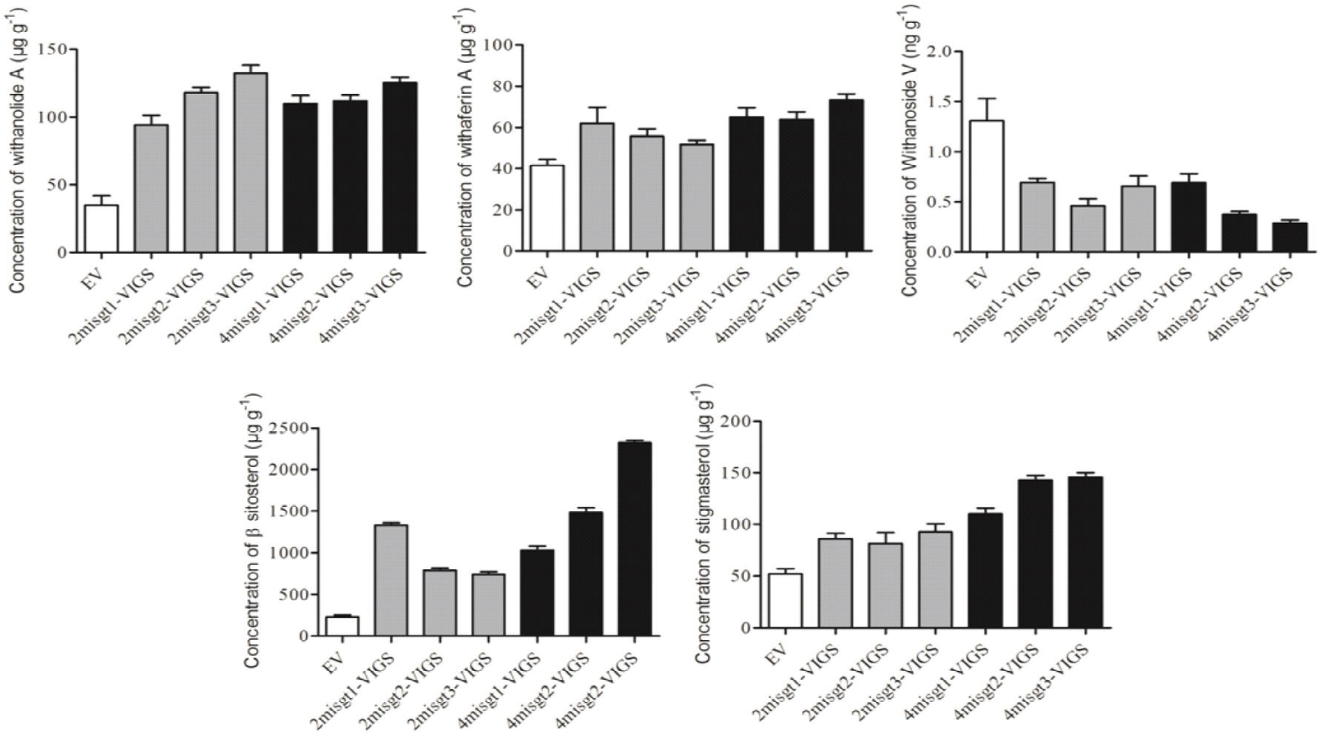


Fig. 6. Relative quantification of HPLC analysis of withanolide A, withanoside V, withaferin A, sitosterol and stigmasterol

transgenic lines was significantly less as compared to control plants.

After down regulation of *WsSGT* gene family, the glycowithanolids (withanoside V) levels decreased in the transgenic lines while free withanolides such as withanolide A and withaferrin A were increased in the transgenic lines. Higher levels of free sterols such as stigmasterol and sitosterol werefound in transgenic lines (Fig. 6). This was further confirmed by qRT-PCR of intermediate genes of MVA pathway which showed increase in their expression level.

The role of *WsSGTL* gene against biotic stress was checked by infecting the transgenic plants with *Alternaria alternata,* a foliar fungal pathogen of *W. somnifera*. After down-regulation of *WsSGTL* gene family, the plant became susceptible to fungal pathogen (Fig. 7A). This was checked by total spore count (cfu mL^{-1}) in the leaves of the silenced lines and analysed that in the down-regulated lines total cfu count was higher than the control plants (Fig. 7B).

After pathogen attack these intermediate phenolics, salicylic acid, level of reactive oxygen species and H_2O_2 have significantly increased in down-regulated lines as compared to control plants.The expression of defense related gene *WsPR1, WsDFS, WsSPI* and *WsPR10,* increased with the infection time shows that the defense system of the plant turn on the SAR mediated pathway against the fungal stress.

This is the first study of artificial miRNA based gene silencing of SGTs for their functional analysis in plant system.From our results, we have concluded that *WsSGTL* gene family plays a very significant role in the growth and development, metabolic balance and defense mechanism of the plant system. After fungal infection, the level of SA, SOD, callose deposition and H_2O_2content increased in the transgenic lines.

Functional analysis of MaSIN3 in Arabidopsis

The SIN3 complex is a highly conserved multi-subunit complex involved in gene regulation through histone deacetylase mediated silencing in animals, yeasts and plants but with limited information about function in plants. The main aim of this study was to understand the role of SIN3 in plants.

The *MaSIN3* gene (from banana) encoded a protein of 1408 amino acids with three PAH domains at the N-terminal end, an HDAC interacting domain in the centre and a conserved protein-protein interaction domain at the C-terminal end. It was localized to the nucleus. Transgenic lines expressing *MaSIN3* in Arabidopsis showed early flowering and increased leaf and petiole length and smaller but more stomata. Several ABA mediated responses were affected in *MaSin3FL* over-expressing lines. Seeds of transgenic lines showed reduced sensitivity to ABA and germinated earlier as compared to control on ABA and other abiotic stress supplemented media.

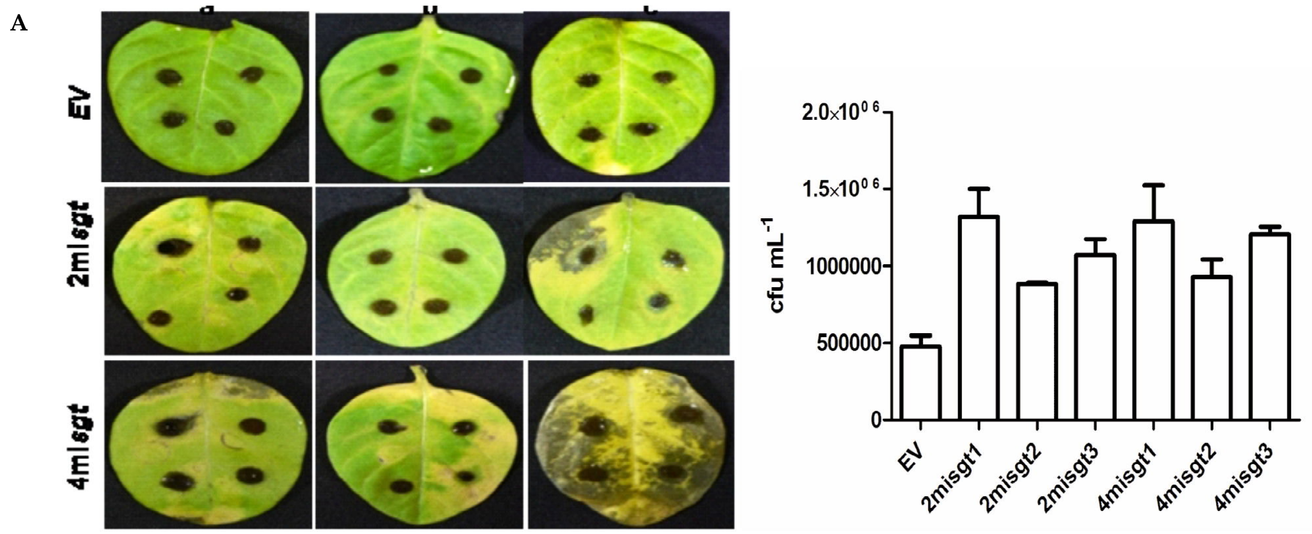


Fig. 7. A&B Down-regulation of members of *SGTLs* increases disease susceptibility of *W. somnifera*

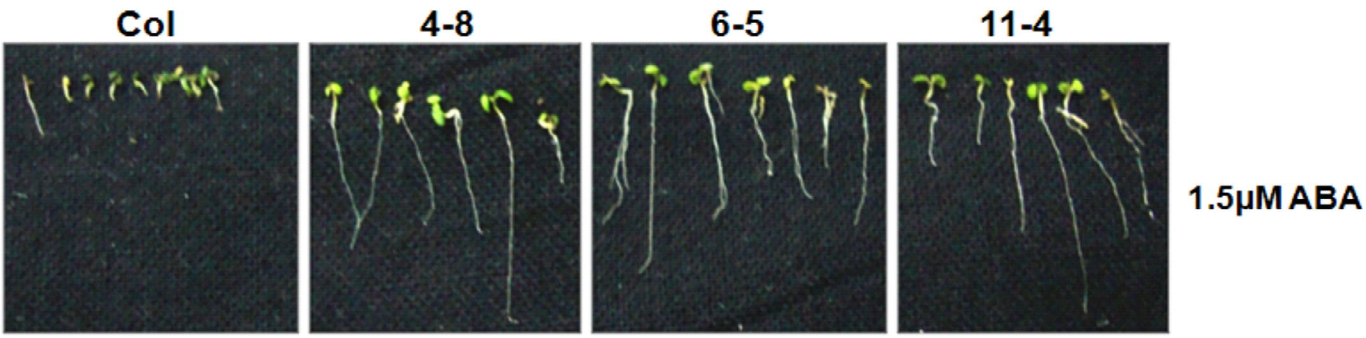


Fig. 8. Reduced ABA sensitivity of root growth of various transgenic MaSIN3 expressing Arabidopsis lines (4-8, 6-5, 11-4) on 1.5 μM ABA

MaSin3FL over-expressing plants also showed ABA hyposensitivity in root growth of seedlings on ABA (Fig. 8), salt, mannitol and glucose containing media. *MaSin3FL* plants were more sensitive to drought stress and had greater water loss rates compared to control indicating reduced ABA sensitivity. *Reduced ABA respo*nses were not due to reduced ABA levels but due to a reduction or delay in the expression of *ABI3, ABI5, AREB1, AREB2, AREB3, ABF1, MYC2 and MYB2* and their targets such as *RD29B, RD22, RaB18, ERD10, KIN1* and *CoR15a* (Fig. 9).

MaSin3 seems to function as negative regulator of most ABA responses by targeting a general component of the ABA response machinery

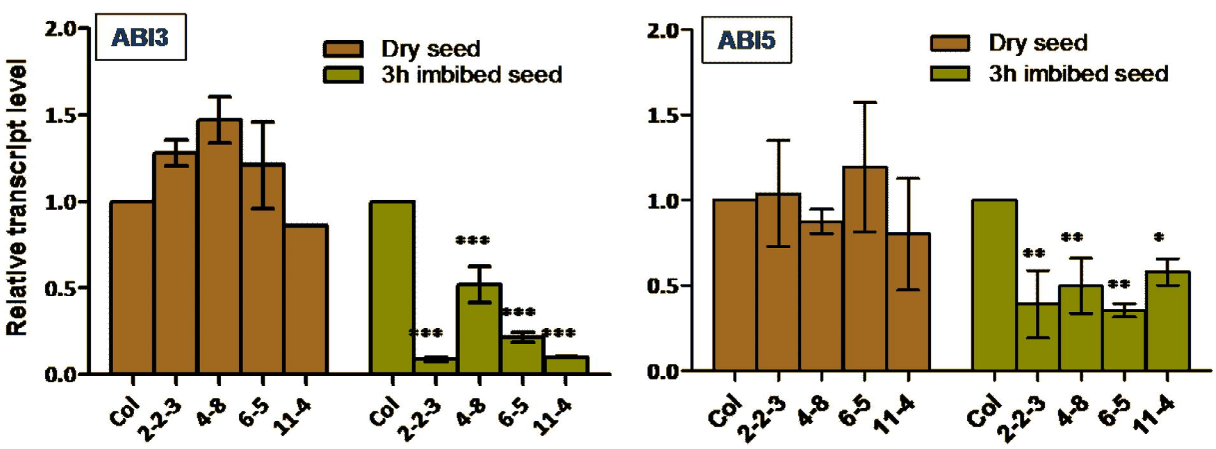


Fig. 9. Reduced transcript levels of ABI3 and ABI5 upon water imbibition in seeds of various transgenic *MaSIN3* expressing Arabidopsis lines (Col–wild type Columbia ecotype; Lines 2-2-3, 4-8, 6-5 and 11-4 represent transgenic lines expressing *MaSIN3* under the CaMV35S promoter

Role of mi-RNAs in arsenic uptake and transport in rice

Arsenic (As) contamination of rice (*Oryza sativa*) imposes serious threat to human health worldwide. Understanding the molecular mechanisms of As transport and accumulation in rice may provide promising solutions to the problem. MicroRNAs (miRNAs) are novel class of short, endogenous, non-coding small RNAs involved in wide variety of biological processes such as organ polarity, morphogenesis, floral transition, hormone signalling and adaptation to environment. However, their role in As stress has not been studied in detail. In this project, we have carried out miRNAs profiling as well as small RNA sequencing in contrasting As accumulating rice accessions to identify known and novel miRNAs with differential expression in rice varieties with differential response to AsIII and AsV stress. Our analysis led to identification of differentially expressed miRNAs in contrasting As accumulating rice cultivars in response to AsIII (25 µM) and AsV (50 µM) stress. The differentially expressed miRNAs were subjected to validation of expression and bioinformatic analyses to predict and categorise the key miRNAs and their target genes involved in As stress. Analysis suggests As-species and rice accession specific miRNA might be responsible for the differential response of contrasting rice accessions towards AsIII and AsV stress. Study of proximal promoter sequences of the As-responsive miRNAs suggests that these identified miRNAs contain metal-responsive *cis*-acting motif and other elicitor and hormonal related motifs.

Tagging *Alternaria* blight resistance loci and marker assisted backcrossing (MABC) in linseed (*Linum usitatissimum* L.)

Linseed is an important oil seed crop having >65% omega-3- fatty acid (highest among the plants) and ~20% omega-6-fatty acid. This crop is prone to various biotic stresses such as blight, rust, wilt and mildew and among which blight causes major loss. No systematic efforts have been made till date to develop blight resistant high yielding linseed varieties. Therefore, the project started to develop blight resistant high yield linseed variety through marker assisted breeding.

Primers for 715 SSRs have been synthesized. PCR amplification was done with DNA of parental lines (JRF4 and Chambal) with 500 SSRs. The polymorphism analysis (carried out with ABI3730xl DNA analyzer) showed that out of 500 SSR, 31 SSRs were either failed or gave non specific bands. Out of remaining, 469 SSRs, 397 (85%) were found to be monomorphic and 72 (15%) were polymorphic among the parental lines. Genomic DNA from 155 F_2 mapping population (derived from JRF4 × Chambal) have been isolated and genotyping is in progress.

NMITLI Project

Leads based drug development and genetic improvement of ashwagandha (*Withania somnifera*)

Withania somnifera is very rich repository of secondary metabolites, which include several bioactive alkaloids and steroidal lactone based phytochemicals. The medicinal properties of *W. somnifera* are attributed to active key constituents named withanolides and their glyco-conjugates (glycowithanolides) present in different plant parts. In this project different chemotypes of Withania have been used to elucidate biosynthetic pathway for withanolides.

To identify genes involved in withanolide biosynthesis as well as to develop understanding related to differential biosynthesis of withanolides in different chemotypes, transcriptome sequencing of leaf and root tissues of three distinct chemotypes (NMITLI-101, NMITLI-118 and NMITLI-135) was carried out using 454 pyrosequencing. Through transcriptome analysis, genes encoding enzymes involved in each step for biosynthesis of the withanolides have been identified.

The information generated has been compiled in the form of database (Withanome) (Fig. 10). This database has comprehensive information about Withania in terms of medicinal properties, withanolides, different chemotypes, transcriptome datasets and proposed pathway for biosynthesis of specific withanolides. Information about group involved in the NMITLI project has also been included in the database. Monitoring committee of the NMITLI project has recommended launch of this databases as soon as possible.

EMPOWER Project

Insect inducible methanol production in plants for insect resistance

Two PMEs (Pectin methyl esterase) WsPME and DS PME were selected after screening of different plant sources with maximum methanol production and highly active PME gene. PME gene of *Withania somnifera* (WsPME) was cloned in Yeast expression vector (pPICZá) for recombinant expression of WiPME in Yeast using Mut^s protocol. Optimization of expression condition is under progress for further characterization. Simultaneous cloning of WsPME in plant expression vector is also in progress.

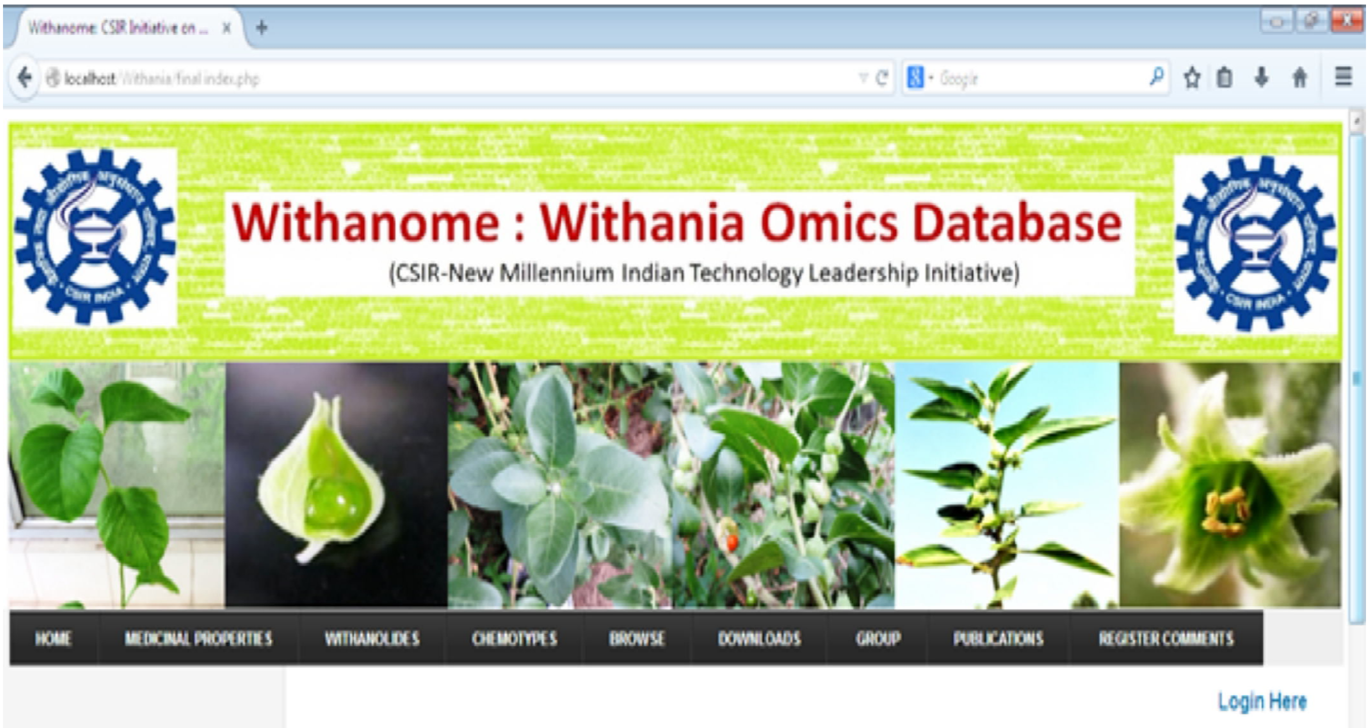


Fig. 10. Withanome: Withania Omics Database
Withania somnifera (L.) Dunel (Family Solanaceae), commonly known as Ashwagandha is one of the most valuable medicinal plants used in Indian medicinal system since ancient times. It is also known as 'winter cherry' or 'Indian ginseng' for its restorative benefits. *W. somnifera* is characterized by small, usually erect, branched shrubs attaining the height of 70-150 cm. Leaves are simple, petiolate with the leaf blade varying in shape from elliptic-ovate to broadly ovate, entire along a margins, acute to obtuse at apex, cuneate or oblique at base. Leaves on vegetative shoots are alternate and large and those on floral branches are opposite, arranged somewhat laterally in pairs of one large and one small leaf, bearing in their axil a cymose cluster of 5-25 inconspicuous pale green flowers. Barries are red, smooth containing yellow seeds with oily texture.

In-House Projects

Molecular studies for management of plant viruses causing severe diseases in ornamental plants

Association of a distinct strain of Hollyhock yellow vein mosaic virus and Ludwigia leaf distortion betasatellite with yellow vein mosaic disease of hollyhock:

During winter of 2011, a number of hollyhock plants growing in gardens at Lucknow were observed showing yellow vein mosaic symptoms on leaves. The possibility of infection with a begomovirus (genus *Begomovirus*, family *Geminiviridae*) was suspected due to typical yellow mosaic symptoms. For detection of infecting virus, total DNA was extracted from symptomatic leaf samples and PCR was performed using begomovirus DNA-A and beta-01/beta-02 betasatellite specific primers, which resulted in ~1.2 kb and ~1.3 kb amplicons respectively. For molecular identification, Phi-29 DNA polymerase based rolling circle amplification (RCA) was performed, followed by digestions with *Hind*III restriction endonuclease. The fragments of ~2.7 kb and ~1.3 kb were cloned and sequenced (JQ911766 for DNA genome and JQ408216 for betasatellite). Both BLASTn and Clustal-V pairwise identity analyses indicated that the virus genome from hollyhock represents a distinct strain of hollyhock yellow vein mosaic virus (HoYVMV) based on ICTV guidelines. Agroinfiltration of HoYVMV and LuLDB induced yellow vein mosaic symptoms on hollyhock, thereby demonstrating causality of the disease.

Characterization of a novel begomovirus associated with yellow mosaic disease of three ornamental species of Jatropha grown in India:

Severe yellow mosaic disease was observed in three ornamental species of *Jatropha*: *J. integerrima*, *J. podagrica* and *J. multifida* grown in gardens at Lucknow, India, during a survey in 2013. The causal pathogen was successfully transmitted from diseased to healthy plants of these species by whitefly (*Bemisia tabaci*). The infection of begomovirus was initially detected in naturally infected plant samples by PCR using begomovirus universal primers. The begomovirus was characterized having a monopartite genome based on sequence analyses of the cloned <"2.9kb DNA-A genome amplified by RCA using Phi-29 DNA polymerase. The genome contained 2844 nucleotides that could be translated into seven potential open reading frames. The nucleotide sequences of DNA-A genome of the begomovirus isolates: JI (KC513823), JP (KF652078) and JM (KF652077) shared 94-95% identities together and 93-95% identities with an uncharacterized begomovirus isolated from *J. curcas* (the only sequences available in GenBank database as GU451249 and EU798996 under the name jatropha leaf curl virus). These shared highest identity of 61% and highly distant phylogenetic relationships with other begomoviruses reported worldwide. Based on 61% sequence identities (much less than 89%, the species demarcation criteria for a new begomovirus) the isolates under study were identified as members of a new Begomovirus species for which the name was proposed as "Jatropha mosaic Lucknow virus (JMLV)" (Fig. 11). The recombination analysis also suggested that JMLV was not a recombinant species and evolved as an independent species, hence considered as unidentified *Begomovirus* species. Koch's postulates were also established by agroinfiltration assay of agroinfectious clone of JMLV. Characterization of JMLV associated with yellow mosaic disease of *J. integerrima*, *J. podagrica* and *J. multifida* is being reported for the first time.

Canna Biology

Regeneration and genetic transformation of canna spp.

Canna (*Canna indica* L.) is an ornamental landscape plant. Being an indigenous crop, it was selected for genetic improvement. For genetic improvement of canna, a foolproof tissue culture protocol is not available in the literature.

In the present report, *in vitro* seed germination protocol of canna has been optimized for the first time (Fig. 12). Chipping off seeds with a sterilized nail clipper and soaking for 24-48 h or till radical emergence was a prerequisite for obtaining 100% seed germination in all the 10 cvs. Liquid media with glass beads proved best for multiplication and growth of the shoots. The regenerated shoots were rooted, acclimatized and transferred to the pots, where they grew normally.

Different plant parts were used for callus induction. Inflorescence stalk proved as the best explants to initiate

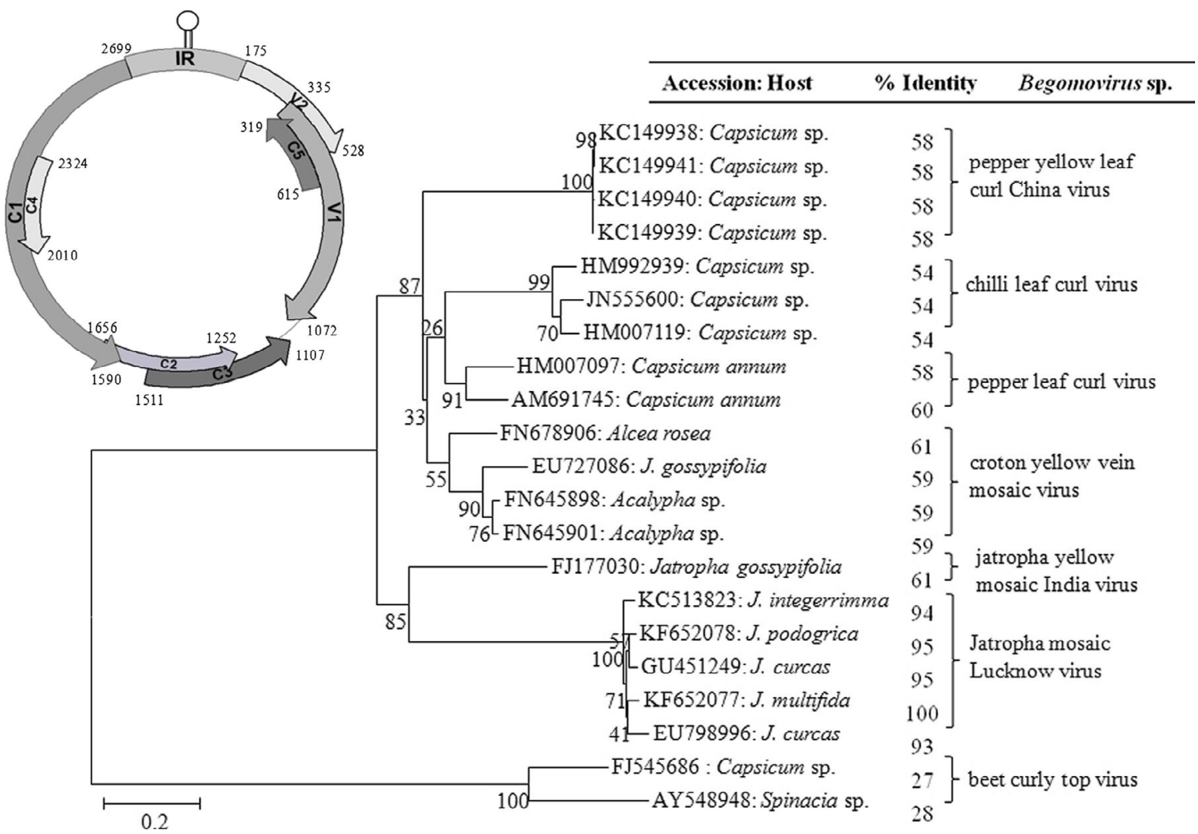


Fig. 11. Genome organization, sequence identities and phylogenetic relationships of the begomovirus infecting three species of ornamental Jatropha

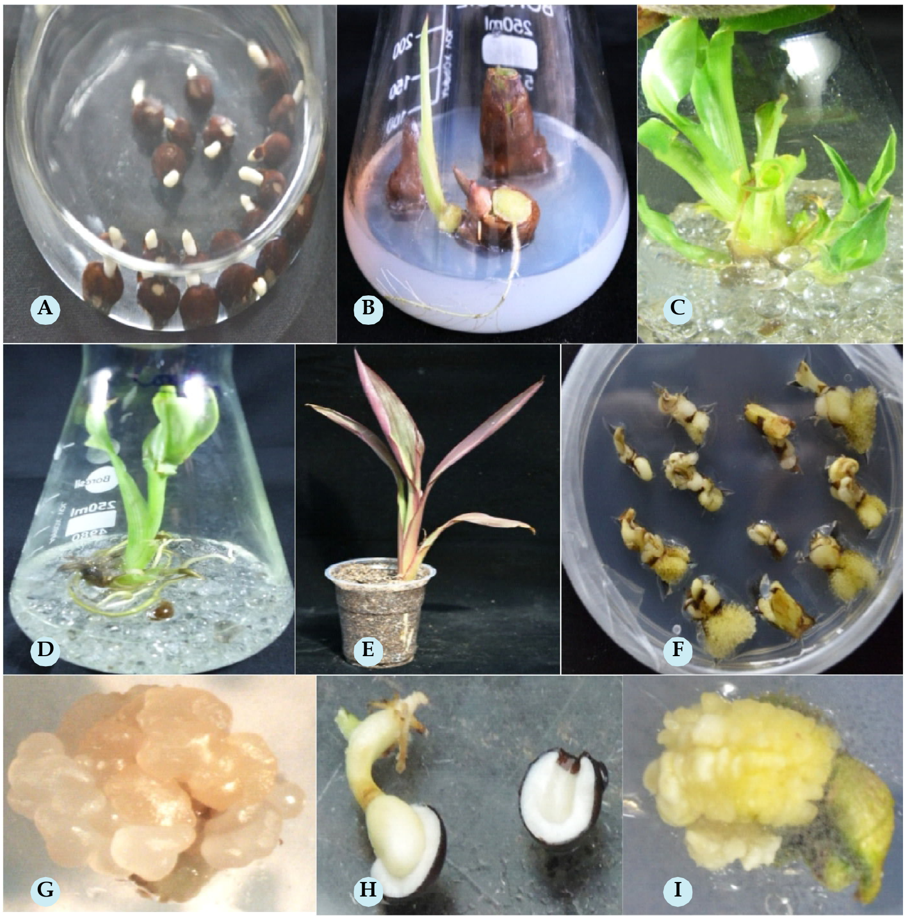


Fig. 12. Regeneration and transformation in Canna : A. 100% seed germination in liquid medium; B. Shoot regeneration from rhizome axillary bud; C. Multiplication of seeds; D. Rooting of isolated shoot and in-vitro raised potted plant; E. tissue raised plant growing in pot; F. Callus induction from inflorescence stalk used for transformation; G. Differentiating inflorescence stalk calus; H. Germinating seed for excision of embryoonal axis; I. Callus induction from embryonal axis used for transformation.

callus in the presence of high concentration of 2,4-D. The callus thus induced was being used for transformation purposes. Attempts are being made to optimize transformation protocol.

Molecular identification of *Bean yellow mosaic virus* in canna

Several canna plants exhibiting severe mosaic symptom were observed in the commercial gardens in Lucknow, India during two surveys for viral diseases in October 2011 and January 2014. We tested for the presence of a potyvirus or CMV. ELISA was performed using antiserum that detects most potyvirus and CMV. Potyvirus infection was confirmed in the leaf extracts of all four canna cultivar sampled but CMV not detected from any of these samples. RT-PCRs were performed using potyvirus and CMV-specific primers. Amplicon of expected size (~1.5 kb) was obtained in all four samples tested with potyvirus primers but not with CMV primers. The amplicons were cloned, sequenced and deposited in GenBank under accession numbers: JQ178366 (*C. flaccida* cv. Flaccida), JQ012792 (*C. generalis* cv. Black Knight), KJ561634 (*C. generalis* cv. Golden yellow Lucifer) and KJ781366 (*C. generalis* cv. Pink rose) as CJ-1, CJ-2, AK-1 and AK-2 isolates, respectively. Sequence comparisons showed that the cloned RT-PCR product corresponded to partial nuclear inclusion b, complete coat protein and the 3'UTR regions. The isolate CJ-1 shared 97% sequence identity with CJ-2 and 87% with both AK-1 and AK-2 isolates. It also showed 77-97% identities with various strains of *Bean yellow mosaic virus* (BYMV, EF592169, EF592168, DQ060521, EU144223, HG970869, HG970865, JX173278, HG970860, KF632713 and FJ492961) reported worldwide. The isolate CJ-1 also shared 71-97% amino acid identities with BYMV strains. The infection of BYMV was further confirmed by western immunoblot assay using polyclonal antibodies of BYMV which resulted in positive reaction with the 35 kDa coat protein subunits in all four canna samples, confirming BYMV infection. Mechanical inoculations of infected canna sap to canna and *Nicotiana benthamiana* were also done which resulted in mild mosaic symptoms on both species and they were found positive for BYMV when tested by RT-PCR. To best of our knowledge, this is the first natural occurrence of BYMV on canna in India.

Genetic improvement of plants through the intervention of molecular and conventional methods

Opium Poppy (*Papaver somniferum* L.)

Papaverine and Thebaine rich lines were developed for the first time. Introgression of these traits in high yielding varieties is in progress. The demand of codeine and narcotine alkaloids is increasing globally due to use of codeine in cough syrups and narcotine in the treatments of cancers. So, we are trying to develop lines rich in narcotine and codeine.

The recurrent and pedigree selections in selected high narcotine, codeine and total alkaloid containing lines were done. BC_2F_1 seeds and transgressive segregants for recurrent selection of the crosses between high yielding varieties (NBRI-5 and NBRI-2) and high thebaine lines (NBIHT-1 and NBIHT-3) were obtained. BC_1F_1 and F_2 seeds for further back crossing and selection of transgressive segregants from the F_1 population of the cross between high yielding variety (NBRI-5 and NBRI-2) and papaverine line were obtained. The selected transgressive segregants from F_2 population of the cross between high yielding variety (NBRI-2) and papaverine line were subjected to recurrent selection. Pattern of quantitative inheritance of yield and component traits in opium poppy was studied.

Linseed (*Linum usitatissimum* L.)

In India vegetable oils are main source of edible oils. Despite considerable R&D in these oilseeds, the commercial recovery of oils is unable to meet the actual demands of the consumers. In this context, linseed can be a future edible oil seed crop as it has similar physical, chemical and processing properties of edible oil. Howver, the high level of linolenic acid in the oil makes it unsuitable for edible purposes. So, to convert linseed oil from industrial to edible purposes, it is necessary to reduce the level of linolenic acid to < 5%. Hence, efforts are being done to introgress low linolenic acid trait from the variety 'Linola' (a low linolenic acid <5% line) to high yielding varieties through backcrossing programme. The characterization of linseed is also taken up on the basis of fatty acids profiling as it can facilitate proper utilization of available germplasm.

Fatty acid analysis: The fatty acid analysis of 175 germplasm lines of linseed was accomplished through GC to find out the chemotypic diversity. BC_5F_1 seeds were obtained by back crossing with recipient parents of the crosses between Ajgan, Shweta and Surabhi with Linola (low linolenic acid). Transgressive segregants from F_2 population of the crosses between high yielding varieties rich in linolenic acid (EC-110288, EC-112689, Mukta, A-993 and Ex-3-3) were isolated for further recurrent selection. Characterization of linseed based on fatty acids profiling alongwith morphological traits was done. Crosses between low linoleic acid and highy yielding yielding lines were made in six paprameter model to study the gene actions for low linoeleic acid.

QTL analysis: A study has also been initiated to tag QTLs (quantitative trait loci) for linolenic acid (omega-3-fatty acid) by using SSR makers and their application for marker assisted breeding to develop high omega -3- fatty acid Indian linseed variety. So far, more than 2500 SSR primers have been designed from whole genome sequence of linseed. PCR amplification with 500 SSRs was carried out with parental lines i.e. 'Neelum' (low linolenic acid) and 'LINOLA' (high linolenic acid), and 75 polymorphic SSRs (16.8%) were identified. DNA from 200 F_2 mapping population have been isolated and genotyping with polymorphic SSRs is in progress.

Publications

1. Chandrawati, Maurya R, Singh PK, Ranade SA and Yadav HK – Diversity analysis in Indian genotypes of linseed (*Linum usitatissimum* L.) using AFLP markers. *Gene*, 2014, **549** : 171-178.
2. Chatterjee A, Shukla S, Rastogi A, Mishra BK and Singh SP – Comparative study of mutagen effectiveness for elite lines with enhanced Thebaine in commercial Poppy (*Papaver somniferum* L.). *Adv. Appl. Agric. Sci.*, 2014, **2**(12) : 11-26.
3. Jha S, Sanyal I and Amla DV – High-level expression and purification of a therapeutic recombinant serine protease inhibitor from transgenic tomato plants. *Int. J. Adv. Res. Sci. Engin.*, 2014, **4**(1) : 1158-1176.
4. Kaur C, Raj R, Kumar S and Raj SK – First report of Bean yellow mosaic virus on cape gooseberry in India. *New Dis. Rep.*, 2014, **29** : 17.
5. Khan MS, Tiwari AK, Raj SK, Srivastava A, Ji SH and Chun SC — Molecular epidemiology of begomoviruses occurring on some vegetables, grain legume and weed species in the Terai belt of north India. *J. Pl. Dis. Protec.*, 2014, **121** (2): 53-57.
6. Khedgikar V, Ahmad N, Kushwaha P, Gautam J, Nagar GK, Singh D, Trivedi PK, Mishra PR, Sangwan NS and Trivedi R – Preventive effects of withaferin A isolated from the leaves of an Indian medicinal plant *Withania somnifera* L. comparisons with 17-â-estradiol and alendronate. *Nutrition*, 2015, **31**: 205-213.
7. Koul B, Amla DV and Sanyal I – Expression of insecticidal toxin coded by modified full-length and truncated Bt-*cry1Ac* gene in transgenic tomato for assessment of their stability and efficacy against target insects. *Int. Archives Sci. Technol.*, 2014., **14**(1) : 1-8.
8. Koul B, Srivastava S, Amla DV and Sanyal I – Establishment and optimization of *Agrobacterium*-mediated transformation and regeneration of tomato (*Solanum lycopersicum* L.). *Int J. Biosci.*, 2014, **4**(10) : 51-69.
9. Kumar A, Dwivedi S, Singh RP, Chakrabarty D, Mallick S, Trivedi PK, Adhikari B and Tripathi RD – Evaluation of amino acid profile in contrasting arsenic accumulating rice (*Oryza sativa* L.) genotypes under arsenic stress grown in hydroponic condition. *Biol. Plantarum*, 2014, **58**(4) : 733-742.
10. Kumar A, Singh RP, Singh PK, Awasthi S, Chakrabarty D, Trivedi PK and Tripathi RD – Selenium ameliorates arsenic induced oxidative stress through modulation of antioxidant enzymes and thiols in rice (*Oryza sativa* L.) *Ecotoxicology*, 2014, **23**(7) : 1153-1163.
11. Kumar S, Asif MH, Chakrabarty D, Tripathi RD, Dubey RS and Trivedi PK – Comprehensive analysis of regulatory elements of the promoters of rice sulphate transporter gene family and functional characterisation of OsSul1; 1 promoter under different metal stress. *Pl. Signaling Behavior*, 2015, **10**(4) : e990843
12. Kumari A, Kaur C, Kumar S, Raj SK, Roy, RK and

Nautiyal CS – First report of Bean yellow mosaic virus causing a mosaic disease of *Canna* sp. in India. *Plant Disease*. 2015 **99**(6) : 897.

13. Maurya KN, Shukla S and Asthana G – Pattern of quantitative inheritance of yield and component traits in opium poppy (*Papaver somniferum* L.). *Genetika,* 2014, **46**(2) : 569-578.
14. Maurya R, Gupta A, Singh SK, Rai KM, Chandrawati, Katiyar R, Sawant SV and Yadav HK – Genomic-derived microsatellite markers for diversity analysis in *Jatropha curcas*. *Trees*, 2015, **29**(3) : 849-858
15. Maurya R, Kumar U, Katiyar R and Yadav HK – Correlation and path coefficient analysis in *Jatropha curcas* L. *Genetika*, 2015, **47**(1) : 63-70.
16. Mishra BK, Rastogi A, Verma N, Shukla S, Prasad B, Parmar D and Sharma NC – Effect of genotype, environment and their interaction on seed and opium yield in opium poppy (*Papaver somniferum* L.) and comparison of different stability models for GEI. *Acta Hortic.*, 2014, **1036** : 163-68.
17. Pandey V, Dhar YV, Gupta P, Bag SK,, Atri N, Asif MH, Trivedi PK and Misra P – Comparative interactions of withanolides and sterols with two members of sterol glycosyltransferases from *Withania somnifera*. *BMC Bioinformatics*, 2015, **16**:120.
18. Pandey V, Niranjan A, Atri N, Chandrashekhar K, Mishra MK, Trivedi PK and Misra P – *WsSGTL1* gene from *Withania somnifera*, modulates glycosylation profile, antioxidant system and confers biotic and salt stress tolerance in transgenic tobacco. *Planta,* 2014, **239**(6) : 1217-1231.
19. Pattanayak R, Misra, Omkar, Chanotiya CS, Rout PK and Mohanty CS– Does the volatile Hydrocarbon profile differ between the sexes : A case study on five Aphidophagous lady birds. *Arch. Insect Biochem Physiol,* 2014, **87** (3) : 105-125.
20. Rai A, Bhardwaj A, Misra P, Bag SK, Adhikari B, Tripathi RD, Trivedi PK and Chakrabarty D – Comparative transcriptional profiling of contrasting rice genotypes shows expression differences during Arsenic Stress *Pl. Genome,* 2015, **8**(2) : 1-14.
21. Ranade SA and Yadav HK – Universal molecular markers for plant breeding and genetics analysis. *J. Pl. Biochem. Physiol.*, 2014, **2** : e121.
22. Rastogi A, Mishra BK, Singh M, Mishra R and Shukla S – Role of micronutrients on quantitative traits and prospects of its accumulation in linseed (*Linum usitatissimum* L.). *Archives Agron. Soil Sci.,* 2014, **60**(10) :1389–1409.
23. Siddiqui A and Shukla S – Conservation of plant genetic resources and their utilisation in global perspective. *Int. J. Life Sci.*, 2015, 4(1) : 46-61.
24. Singh M, Bag S, Bhardwaj A, Ranjan A, Mantri S, Nigam D, Sharma Y and Sawant SV – Global nucleosome positioning regulates salicylic acid mediated transcription in *Arabidopsis thaliana*. *BMC Plant Biol.*, 2015, **15** :13.
25. Srivastava A, Jaidi M, Kumar S and Raj SK – Molecular identification of a new begomovirus associated with leaf crumple disease of *Jatropha curcas* L. in India. *Arch. Virol.*, 2015, **160**(2) : 617-619.
26. Srivastava A, Jaidi M, Kumar S, Raj SK and Shukla S – Association of papaya leaf curl virus with the leaf curl disease of grain amaranth (*Amaranthus cruentus* L.) in India. *Phytoparasitica*, 2014, **43**(1) : 97-101.
27. Srivastava A, Kumar S, and Raj SK – First report of *Ageratum enation virus*, betasatellite and alphasatellite causing leaf curl and enation disease of *Amaranthus hypochondriacus* in India. *Plant Dis*., 2014, **98**(9) : 1285.
28. Srivastava A, Kumar S, Jaidi M and Raj SK – Characterization of a novel begomovirus associated with yellow mosaic disease of three ornamental species of *Jatropha* grown in India. *Virus Res.*, 2015, **201** : 41-49.
29. Srivastava A, Kumar S, Jaidi M and Raj SK – Molecular characterization of new begomovirus associated with leaf yellow mosaic disease of *Jatropha curcas* in India. *Arch. Virol.,* 2015, **160**(5) : 1359-1362.
30. Srivastava A, Kumar S, Raj SK and Pande SS – Association of a distinct strain of Hollyhock yellow vein mosaic virus and Ludwigia leaf distortion betasatellite with yellow vein mosaic disease of hollyhock (*Alcea rosea*) in India. *Arch. Virol.*, 2014, **159**(10) : 2711-2715.
31. Srivastava A, Kumar S, Raj SK, Association of *Pedilanthus leaf curl virus*with yellow mottling and leaf curl symptoms in two jasmine species grown in India. *J. Gen. Plant Path.*, 2014, **80** (4): 370-373.
32. Upadhyay RK, Gupta A, Ranjan S, Singh R, Pathre UV, Nath P and Sane AP – The EAR motif controls the early flowering and senescence phenotype mediated by over-expression of SlERF36 and is partly responsible for changes in stomatal density and photosynthesis. *PLoS ONE,* 2014, **9**(7) : e101995.

PLANT MICROBE INTERACTION AND PHARMACOGNOSY

PLANT MICROBE INTERACTION

Scientists: CS Nautiyal, PS Chauhan, S Khatoon , Manoj Kumar, A Lehri, Charu Lata, Aradhana Mishra, SK Ojha, M Pal, Ch. V Rao , S Rastogi, AKS Rawat, OP Sidhu, BN Singh, PC Singh, M Srivastava, Sharad Srivastava, Suchi Srivastava

Technical Staff: Anil Kumar, SK Mishra, A Niranjan, MM Pandey, Sumit Yadav

Grant-in-Aid Projects

Quality production of abiotic stress tolerant microbes-based bioinoculants and their popularization for improving health and sustained crop production in UP

The main objectives/activities of this project included providing mother culture, developed and maintained at CSIR-NBRI, to 17 biofertilizer labs of Agriculture Departments in Uttar Pradesh for various crops and seasons; training, demonstration and technical advice to the staff of 17 Biofertilizer labs of UP Directorate of Agriculture for mass production of quality bio-inoculants; multi-locational field demonstrations for assessing the impact of technology on soil health and viability of bioinoculants at research farms of UP Directorate of Agriculture; large scale production of phosphate solubilizing bacteria (PSB) based biofertilizer packets at CSIR-NBRI for distribution to the beneficiaries; popularizing the application of bioinoculants in different seasons and crops through intensive trainings and demonstrations in nine agro-climatic zones; and popularizing the production of microbe enriched manure from agricultural residues as an additional livelihood tool for rural youth (Fig. 1a-f).

Fig. 1 (a-d). a) Training Program for officers of 17 Biofertilizer production labs, Department of Agriculture, UP on September 20, 2014; b) Farmers Interaction Meet at DRC (CSIR-NBRI), Banthara on November 14, 2014; c) Farmers Training program at Mauranipur, Jhansi on February 22, 2015; d) Farmers Training program at Farrukhabad on February 28, 2015.

Fig. 1 (e-f). e) Farmers Training program at Rudramuli, Agra on March 1, 2015; f) Farmers Training program at Varanasi on March 22, 2015

Describing plant responses to elevated carbon dioxide and its implication for root-soil-microbe interactions

Not much is known about the performance of paddy crop treated with *Trichoderma* sp. under elevated atmospheric CO_2. This project, initiated in 2014, will examine the functional characteristics of the soil microbial community so as to elucidate the ecological strategy of the soil microbial community and soil organic carbon pools, using paddy in presence and absence of *Trichoderma reesei* MTCC5659, grown under fully open air conditions at the Free Air CO_2 Enrichment (FACE) facility at CSIR-NBRI. Comparative analysis of roots of paddy grown under elevated CO_2 condition with or without *T. reesei* MTCC5659 will also be conducted to decipher differentially expressed genes and to identify plant gene(s) involved in amelioration of elevated CO_2 stress. The proposed work will thus enable us to provide new and much needed insight into the nature of the plant and microbial response to increased atmospheric CO_2.

A study on the role of miRNA(S) in plant growth promoting rhizobacteria mediated drought stress alleviation in chickpea (*Cicer arietinum* L.)

Small RNA sequencing and data analysis: MicroRNAs (miRNAs) are a class of small non-coding RNAs that are involved in post-transcriptional control of gene expression, either through degradation or translational inhibition of target mRNAs. In order to understand their role in PGPR-mediated drought stress response and adaptation, miRNA profiling was carried out in a drought tolerant chickpea cultivar (BG-362) root samples which were subjected to 20% PEG stress for 72 h in presence or absence of *Pseudomonas putida RAR*. A total of more than 41.8 million sequence reads were generated from all the four samples namely control, drought, RAR and drought+ RAR, in the range 5.4–13.1 million for individual sample. After 3′ adaptor and redundant reads removal, a total of approximately 5.9 million unique reads for 16-35 nucleotide small RNA sequences were obtained. After filtering by sequence length of >18nt to <26nt, and removal of tRNA, rRNA, snRNA and others, approximately 2 million reads were obtained in total from all four libraries. Details of the miRNA statistics is given below:

Properties	Control	Drought	RAR	Drought + RAR
Total Number of Reads	5404469	13110618	12091808	11223229
Distinct reads	579083	1302735	899336	1433797
Reads After 3'Adapter removal	1806489	3458037	675471	2662393
Distinct reads after Adapter removal	264376	544998	162473	526864
Input reads (16 nt to 35 nt)	1068810	2449400	600034	1773927
Filter by sequence length (>18nt to <26nt)	471783	793906	136472	598459
After removal of tRNA, rRNA, snRNA	471391	793280	136358	598019

Transcript profiling of major millet crops under drought stress and cloning-characterization of stress-inducible transcription factors

The APETALA2/ethylene-responsive element binding factor (AP2/ERF) family is one of the largest transcription factor (TF) families in plants that includes four major sub-families, namely AP2, DREB (dehydration responsive element binding), ERF (ethylene responsive factors) and RAV (Related to ABI3/VP). AP2/ERFs are known to play significant roles in various plant processes including growth and development and biotic and abiotic stress responses. Considering this, a comprehensive genome-wide study was conducted in foxtail millet (*Setaria italica* L.). A total of 171 AP2/ERF genes were identified by systematic sequence analysis and were physically mapped onto nine chromosomes. Expression profiling of candidate AP2/ERF genes against drought, salt and phytohormones revealed insights into their precise and/or overlapping expression patterns which could be responsible for their functional divergence in foxtail millet (Fig. 2). The study showed that the genes SiAP2/ERF-069, SiAP2/ERF-103 and SiAP2/ERF-120 may be considered as potential candidate genes for further functional validation as well for utilization in crop improvement programs for stress

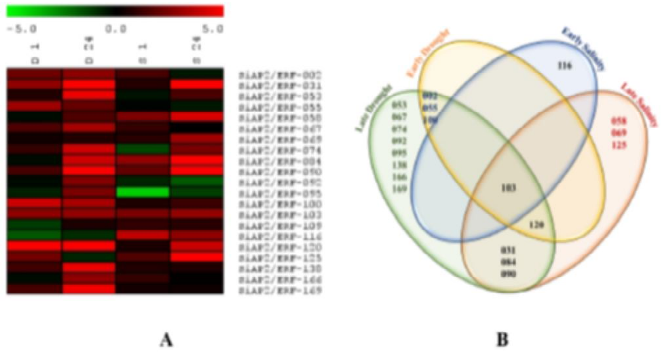


Fig. 2. Expression profile 21 *SiAP2/ERF* genes under drought and salinity stresses

resistance since these genes were up-regulated under drought and salinity stresses in ABA dependent manner. Altogether the present study provides new insights into evolution, divergence and systematic functional analysis of AP2/ERF gene family at genome level in foxtail millet which may be utilized for improving stress adaptation and tolerance in millets, cereals and bioenergy grasses.

In-House Project

Plant growth promoting rhizobacteria mediated stress management for increasing crop productivity

Screening and characterization of stress tolerant microbes with plant growth promoting abilities and understanding the role of stress tolerant plant growth promoting microbes in abiotic and biotic stress management are the main objectives of this project. The following are the main results achieved during the reporting period:

Bacterial strains from our lab repository were screened for P solubilization, P accumulation and phosphatase activity for their correlation with stress tolerance. Plant growth promotional activity of the screened strains under drought and P stress conditions was performed. A defined media for quick screening of silicon solubilizing microbes has been developed. The defined media can be used for qualitative and quantitative screening of silicon solubilizing microbes and further elucidation of their role in abiotic and biotic stress tolerance.

Microbes screened for biocontrol properties were also characterized for different plant growth promoting traits such as chatecholate and hydroxamate type of siderophore, IAA and gibbrellic acid production and P solubilization production. Among the eight selected microbes, PPB5, PPB3 and PPB6 were found to produce significant amount of chitinase acivity and have broad range OD biocontrol efficacy against fungal phytopathogens *Sclerotium rolfsii*, *Rhizoctonia solani*, *Fusarium oxysporum* and *Alternaria solani*.

Trichoderma isolate TP9 (*T. viride*, MTCC 5661) was screened out for biosynthesis of gold and silver nanoparticles from the diverse population of *Trichoderma* spp. Gold and silver nanoparticles biosynthesized by *T. viride* were further characterized by zeta size, UV-vis spectroscopy, transmission electron microscopy (TEM), selected area electron diffraction (SAED), energy dispersive X ray analysis (EDAX), X ray analysis (XRD) and fourier transform infrared spectroscopy (FTIR).

Carbendazim has been used frequently in agricultural fields as fungicide and its degradation in the soil has been studied in fallow and cultivated conditions. Results demonstrated that its degradation is less in fallow fields as compared to the cultivated land which is in correlation with functional microbial diversity.

Effect of phytoplasma infection on rhizospheric microbial diversity was assessed in *Cactharnthes roseus* plant rhizosphere. Narrowness of the microbial diversity in *C. roseus* phytoplasma-infected roots as compared to control rhizosphere emphasizes that many species/strains of microorganisms could not grow in association with phytoplasma-infected *C. roseus* roots.

Proteases are involved in various processes. Therefore, a number of strains has been screened for protease activity. These protease producing microbes were also characterized for their biocontrol efficacy and production of cellulase, glucanase and chitinase activity under *in vitro* conditions. Protease producing biocontrol strain was found to have higher mycolytic activities.

Microbial metabolic diversity of chickpea rhizosphere was studied in order to see the effect of cowdung supplementation in presence and absence of *Fusarium* wilt complex fungi. Cowdung supplementation and *Fusarium* infection was found to change the microbial diversity.

PHARMACOGNOSY

Grant-in-Aid Projects

Production of phytochemicals from best chemotypes of some threatened medicinal plants through modified cultivation and *in vitro* production technologies

In this study chemotypic variability in *Gloriosa superba* and *Coleus forskohlii* with respect to colchicine and forskolin content, respectively, in plant samples (tubers) collected from different phytogeographic zones of India was done. The principal aim of the study is to identify the best germplasms/chemotypes and establish correlation of secondary metabolite in relation to their ecogeography. The elite germplasm/chemotypes and the ecological conditions along with the associated species were documented for future strategic planning for cultivation

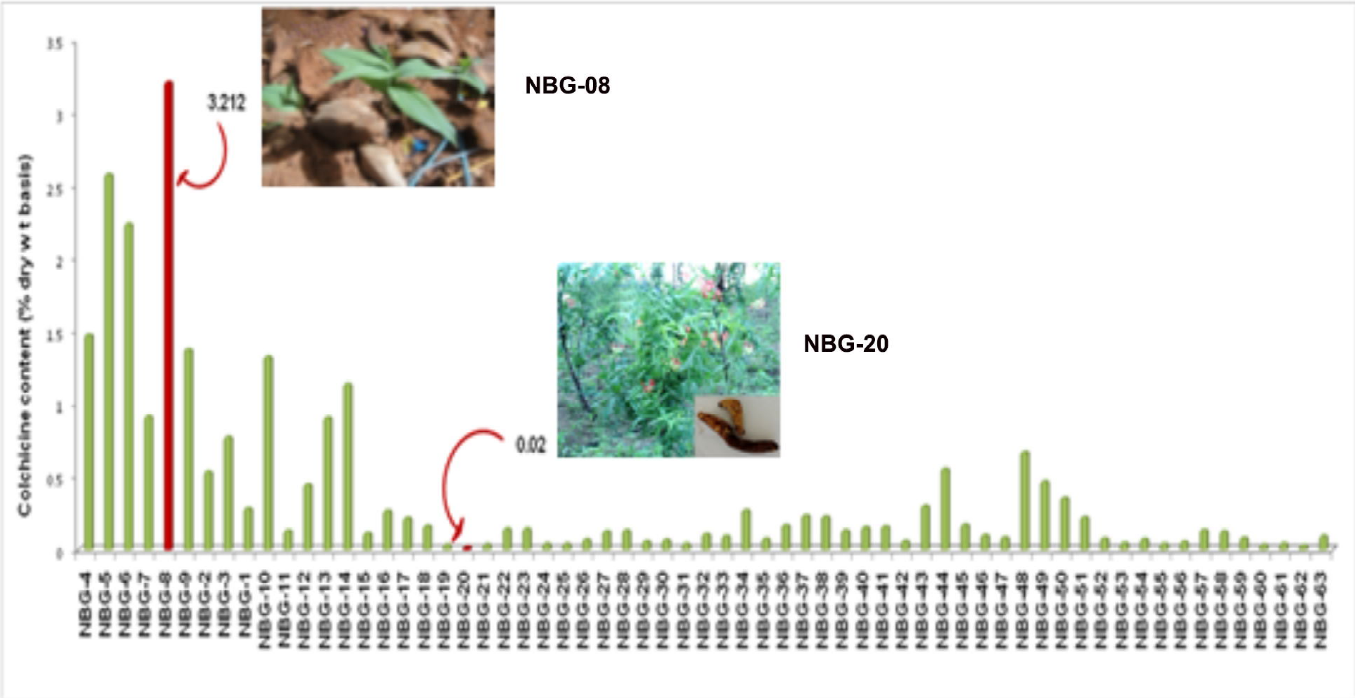


Fig. 3. Colchicine content in *G. superba* samples collected from various phytogeographical zones of India

of these species in different regions of the country. Following are the key findings:

Among the total 63 samples of *Gloriosa superba*, densiometric scanning at 350 nm revealed maximum concentration of Colchicine i.e. 3.212 % of dry weight (tuber) in NBG-08 (Western Ghats) and minimum concentration (0.02 %) in NBG-20 (Eastern Ghats) (Fig. 3).

Among the collected 52 samples of *Coleus forskohlii* NBC-02 (Gangetic Plains) contains minimum (0.004% dw) and NBC-46 (Western coast of Malabar) contains maximum concentration (1.153 % dw) of forskolin (Fig. 4).

A new method for estimation of Colchicine through OPLC has also been developed, validated (Fig. 5).

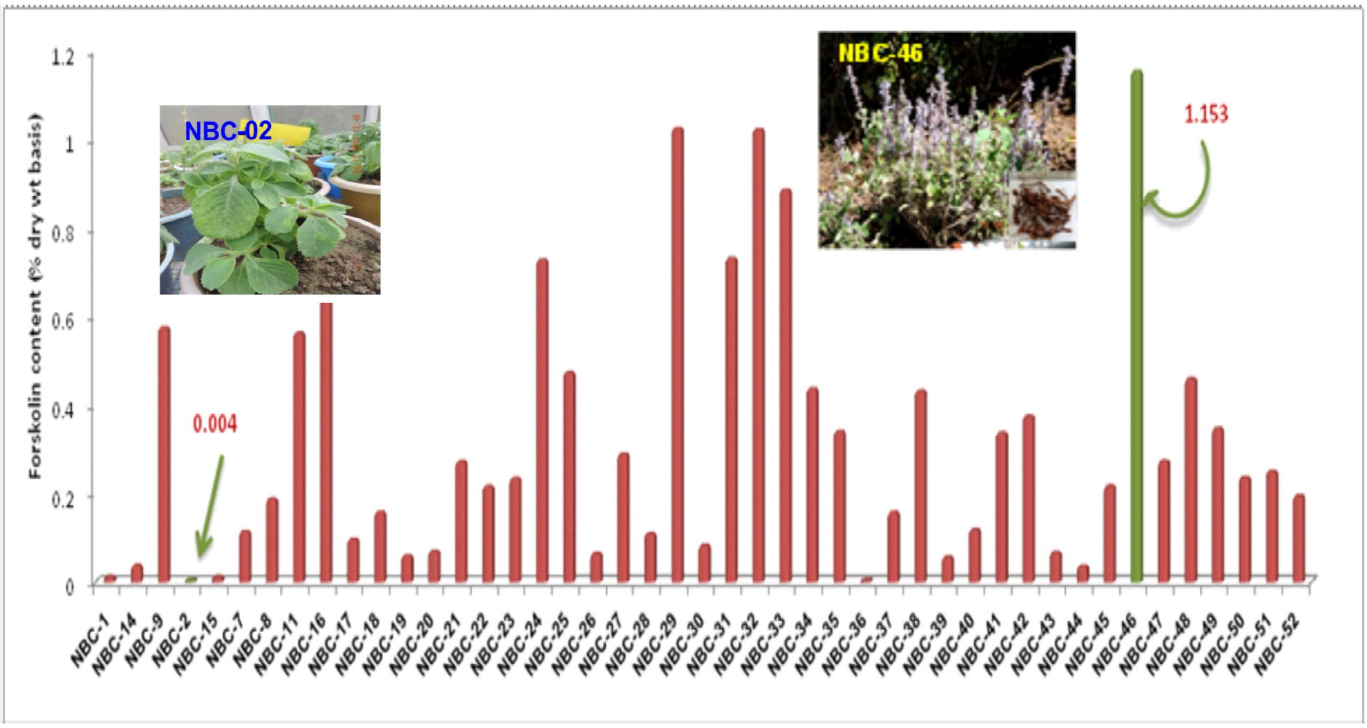


Fig. 4. Forskolin content in *C. forskohlii* samples collected from various phytogeographical zones of India

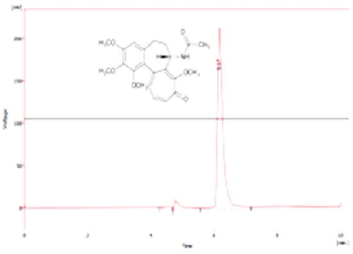


Table: Validation parameters.

Slope	23 370.53
Intercept	310.06
Regression coefficient (r^2)	0.9991
Linearity (mg/ml)	50–250
LOD (mg ml)	0.261
LOQ (mg/ml)	0.790
Rt (min)	6.17
RSD (%)	0.031

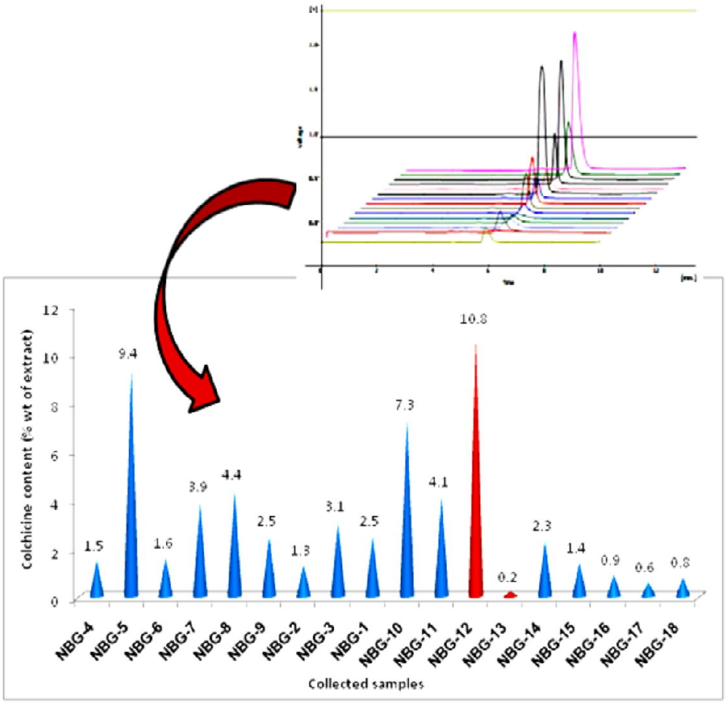


Fig. 5. Quantification of Colchicine through validated OPLC Method

Chemoprofiling of potential phytoacaricides and their functional characterization for controlling resistant cattle ticks

In the present study, germplasm of the targeted species i.e., *Ageratum conyzoides* L. were collected from 37 places covering 10 states (Uttar Pradesh, Bihar, Jharkhand, Haryana, Himachal Pradesh, West Bengal, Sikkim, Tamil Nadu, Kerala, Andhra Pradesh). Passport data of each sample was prepared with information about the altitude, latitude, longitude, phyto-geographical zones etc. of collection sites.

HPTLC profiling of the samples were done to quantify the bioactive marker compound Precocene I. The solvent system used was Hexane: Chloroform (7:3) for resolving the extract. Quantification data suggests that there are variations in the concentration of marker compound in germplasms of different geographical conditions. Variations also occur within the samples of same phyto-geographical zone. However, on the basis of the samples analyzed through HPTLC, it can be said on an average, that the samples collected from the Western Himalaya region contain relatively higher Precocene I while germplasms collected from some parts of Gangetic Plains and Southern Western Ghat region contain lesser Precocene I. Highest amount of Precocene I (0.110 %) was found in the germplasm collected from Algarh, West Bengal (NAC-44), while least concentration (0.003 %) was found in samples from Thrissur, Kerala (NAC-63) and Ramachandrapuram, Andhra Pradesh (NAC-66).

Each collected sample was coarsely powdered and subjected to 95% ethanolic extraction. 100 gm of powdered raw drug was extracted repeatedly up to complete extraction. Physicochemical parameters viz., water soluble extractive, alcohol soluble extractive, total ash and acid insoluble ash were studied for the standardization purposes (Fig. 6).

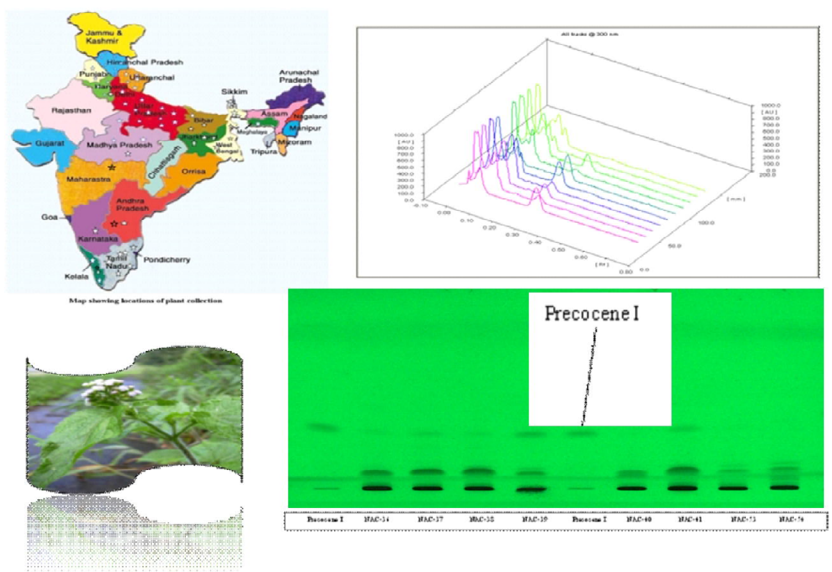


Fig. 6. HPTLC profiling of germplasm of *Ageratum conyzoides* collected from 10 states

Nutritional profiling, free radical scavenging and antioxidant activities of selected small millets

Four small millets *viz.* foxtail millet, finger millet, prosomillet and khodo millet were investigated for their nutritional profiling and antioxidant activity. Flour of finger millet showed maximum reducing sugar and solution protein contents, followed by whole grain of finger millet and foxtail millet flour. Maximum levels of zinc and copper were estimated in bran and whole grain of foxtail, respectively. While highest manganese was found in whole grain of finger millet. Highest total polyphenol (TP) contents as well as antioxidant activity were examined in ethanolic extract, followed by butanol and ethyl acetate extracts. However, the hexane extract exhibited the lowest TP and antioxidant activity. TP content showed higher relation with radical scavenging activity and reducing power. We have also established that the strong antioxidant activity of finger millet bran is attributed to the presence of polyphenolic compounds, examined by HPLC and MS/MS analysis. Our results also demonstrated that the mechanism of antioxidant action of finger millet extracts was free radical scavenging and reducing of oxidized intermediates. Polyphenolic compounds played a significant role on the antioxidant activity via reducing mechanisms. The study indicates that finger millet bran can be used as a rich source of natural antioxidants.

Identification and evaluation of some lesser known plants for malnutrition and development of a low cost herbal combination thereof

Total phenolic content, total flavonoid content and antioxidant activity of *Bauhinia purpurea* buds, *Bauhinia purpurea* flower, *Bauhinia variegata* buds and flowers and *Oxalis corniculata* was performed by DPPH Free Radical Scavenging Activity, Reducing power assay, β-Carotene linoleic acid assay. Further, elemental analysis for the estimation of micronutrients of aforesaid samples using ICPMS was also performed.

In-House Project

Quality evaluation and scientific validation of indigenous Indian medicinal plants having industrial application (pharmaceutical, nutraceutical, cosmaceutical) and development of herbal product(s) based on traditional knowledge

Herbal Product(s) Based On Traditional Knowledge

The herbal medicines market has increased dramatically in recent years, as consumers became more health conscious. Herbal medicines are considered to be safe by consumers. This over increasing demand led to adulteration or substitution in the herbal drug market. Therefore, there is an urgent need to develop quality assurance parameters for single raw drug and formulations. The development of authentic analytical methods which can reliably profile the phytochemical composition, including quantitative analyses of marker/ bioactive compounds and other major constituents, is a major challenge to scientists. Standardization is an important step for the establishment of a consistent biological activity, a consistent chemical profile, or simply a quality assurance program for production and manufacturing of herbal drugs. The following activities were undertaken for quality evaluation and scientific validation of medicinal plants-

Development of Quality control parameters of *Clitoria ternatea* L.

Clitoria ternatea belongs to the family Fabaceae and has two varieties, i.e. white flowered and blue flowered (Fig. 7). The white-flowered one is found to be therapeutically more active and has been accepted as 'Shankhpushpi' by most of the South Indian Vaidyas. Comparative pharmacognostic evaluation of both the varieties of *C. ternatea* was carried out using organoleptic characters, macro and microscopic details, physicochemical parameters and TLC fingerprint profiles. The microscopy showed more starch grains in root, variations in pericyclic fibers, xylem vessels and pith in stem, and quantitative parameters of leaf. Some variations were also observed in physicochemical parameters. However, TLC fingerprint profiling represented the characteristic bands e.g. blue fluorescent band at Rf 0.38 under UV 366 nm and greyish blue band at Rf 0.58 , after derivatization under visible light, were observed only in white variety.

Fig. 7. White and Blue colored *Clitoria ternatea*

Comparative chemoprofiling of *Quercus leucotrichophora* and *Q. glauca.*

Quercus leucotrichophora and *Q. glauca* (Family-Fagaceae), commonly known as Oak, are traditionally used as astringent, remedy for hemorrhoids, dyspepsia, eczema, skin and eye disorders. Comparative HPTLC fingerprints of the methanolic extract of stem bark of the above two species along with the chemical markers viz. β-sitosterol, lupeol, ursolic acid, gallic acid, catechin and quercetin were developed. Chemical variations were observed in both the species (Fig. 8).

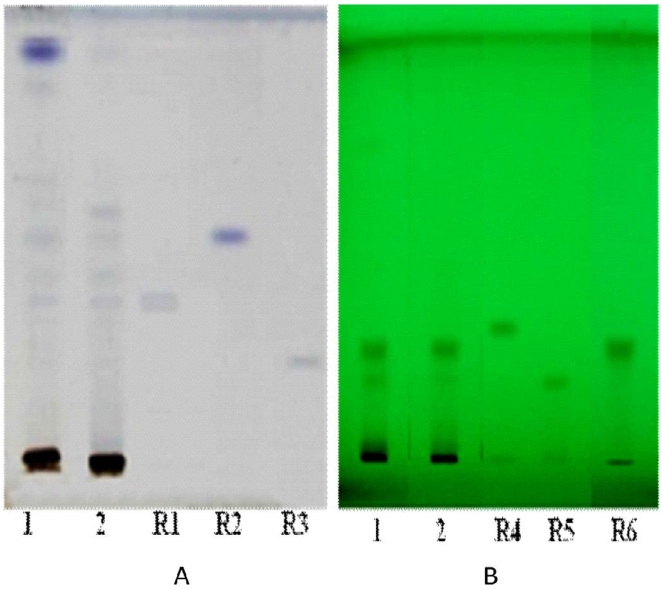


Fig. 8. Comparative HPTLC finger print profiling of *Quercus leucotrichophora* and *Q. glauca*: A. Under visible light after spraying with detecting reagent and heating at 120°C for 10 minutes; B. Under UV 254 nm; Samples- 1. *Quercus leucotrichophora*, 2. *Q. glauca*, R1. â-sitosterol, R2. Lupeol, R3. Ursolic acid, R4. Gallic acid, R5. Catechin, R6. Quercetin

Antioxidant potential of Shankhpushpi & its Adulterants/ Substitutes

The Sanskrit word 'Sankhapushpi' literally means that the flowers of which are in the shape of a conch or Sankha which is considered to be auspicious. In Ayurvedic texts, it is included in Rasayanas and has been categorized as Medhya – intellect promoting i.e. a rejuvenative to nervous tissue. Most of the authors of Ayurvedic texts are of the opinion that *Convolvulus pluricaulis* Choisy. (Fam., Convolvulaceae) is a real source of '*Shankhpushpi*'. Other species also reported as 'Sankhapushpi' are *Evolvulus alsinoides, E. nummularius, Tephrosia purpurea and Clitoria ternacea.*

Antioxidants are vital substances which possess the ability to protect the body from damage caused by free radical induced oxidative stress. Several assays have been frequently used to estimate antioxidant activity of medicinal plants to evaluate their potential medicinal properties. Various extracts of aforesaid plant species were evaluated for their antioxidant potential using DPPH radical scavenging assay, β carotene bleaching assay, hydroxyl radical scavenging assay, anti-lipid peroxidation assay of goat liver model, ABTS radical scavenging assay, NOS and ROS assays. All the five plants showed good antioxidant potential except *Clitoria ternacea. Convolvulus pluricaulis* showed best activity followed by *Evolvulus alsinoides*. These results validated the Rasayana property of aforesaid plants.

Seasonal variation studies on plant *Tephrosia purpurea*

Season has its impact on quantity and quality of active principles and secondary metabolites of medicinal plants. *Tephrosia purpurea* (L.) Pers (Family-Fabaceae), is an important Ayurvedic drug, commonly known as 'Sarapunkha'. The plant material was collected in early summer, winter and rainy seasons. The alcohol, aqueous alcohol and hot water extracts were prepared for seasonal variation studies and quantification of lupeol, rutin, rotenone and â-sitosterol. The quantity of these chemical markers varies from season to season. Rutin was maximum in early summer season i.e. 2076 µg/g and minimum in winter season i.e. 1169 µg/g while β-sitosterol was maximum in rainy season. However, lupeol and rotenone were found maximum in winter season, i.e. 326 µg/g and 2482 µg/g, respectively. The effect of *Tephrosia purpurea* extracts was also observed on the activities of liver marker enzymes on CCL4-induced liver toxicity in rats. Silymarine was used as a control (Fig. 9).

Development of herbal products

Herbal colours were isolated and combined with various base materials and the protocols developed for stable and economic herbal Sindoor.

A novel herbal gel-based formulation containing 2% plant extract (NBPD-1) has been developed for the management of Candidiasis. The bio-efficacy of this formulation has been tested under *in vitro* and *in vivo* models systems against human pathogenic fungal pathogen- *C. albicans*, in collaboration with CSIR-CIMAP, Lucknow.

Herbal technology 'NBRMAP-DB, a safe hypoglycaemic herbal formulation' was transferred to M/ S Aimil Pharmaceuticals, New Delhi on occasion of National Technology Day, May 13, 2014. This novel formulation for the management of diabetes was jointly developed by CSIR-NBRI and CSIR-CIMAP, Lucknow.

PHYTOCHEMISTRY

Grant-in-Aid Projects

Extraction and microencapsulation of nutraceuticals for effective delivery into different food matrices

Seventeen plant gum sources were investigated to separate, extract and isolate gums and assess their suitability as potential encapsulants of nutraceuticals. Physicochemical, chemical and mechanical characterization of the encapsulants was done. Different methods for microencapsulations (solvent evaporation-emulsification, lyophilization, pancoating method, ionotropicgelation method, concervation phase separation

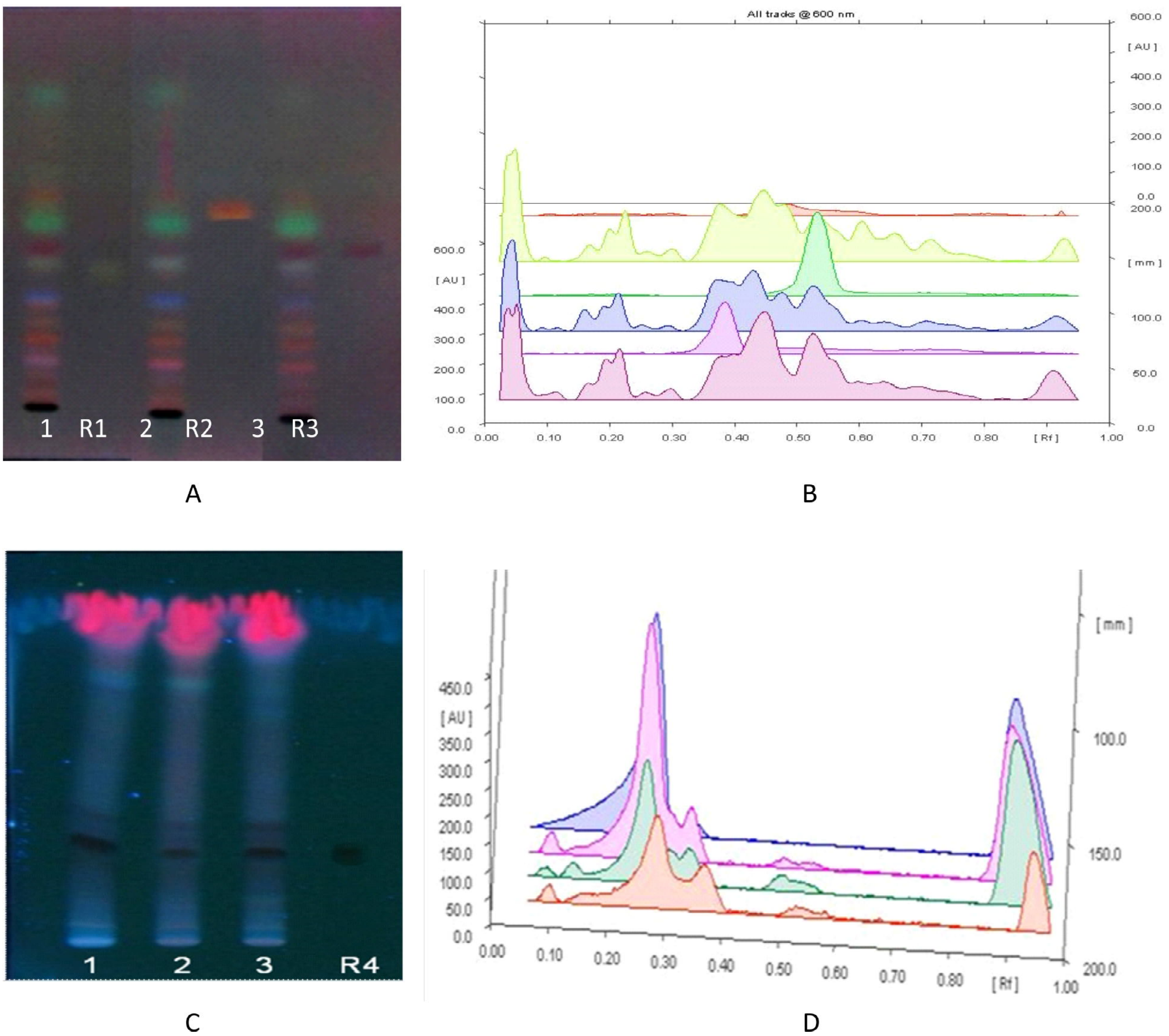


Fig. 9. HPTLC finger print profiling of *Tephrosia purpurea:* A. Under UV 366 nm after spraying with detecting reagent and heating at 120°C for 10 minutes; B. Densitometric scanning at 600nm; C. Under UV 366nm; D. Densitometric scanning at 360nm. Samples- 1: Winter; 2: Rainy; 3: Early summer, R1. β-sitosterol, R2. Lupeol, R3. Rotenone, R4. Rutin

non- solvent addition) were tried to encapsulate some nutraceutically and pharmaceutically important oils such as castor oil, olive oil and fish oil, colour/pigments using four plant gums encapsulants in different concentrations, and a method (sodium alginate-calcium chloride complexation) was modified for improving encapsulation process. Development of monocore and multicore microcapsules of curcumin, bixin, glucose, beta carotenes, vitamin E were done and its evaluation was compared with reference standards.

Development of low cost technology for extraction/ isolation of some lesser know natural gums and value addition thereof

Ten gum yielding plant species (*Buchanania* sp., Dhawda, Jigand, *Mangifera indica*, *Azadirecta indica*, *Butea monosperma*; *Sesamum* sp., *Acacia mangiun, A. auriculiformis, Delbergia sisso*) were collected from from tribal areas of various villages of Sonbhadra District of Uttar Pradesh.

Cold and Successive soxhlet hot extraction of *Acacia mangium*, *Madhuca longifolia* (Mahua) and *Buchanania* sp was carried out to obtain polarity gradient extracts in different solvents for their phytochemical studies. Qualitative and quantitative analysis of Babool species, *Acacia. nilotica, A. mangiun, Prosopis juliflora, Luceana luococephala* for carbohydrate, protein, alkaloids, terpenoids, tannin, phenolics, flavonoids, fiber and identification of sugar, phenolics and flavonoids by TLC.

Determination of physicochemical parameters and solution properties such as pH, TDS, conductivity, refractive index, colour, viscosity, etc. in seed gums viz *Mangifera indica, Azadirecta indica, Butea monosperma* was accomplished for formulation prospects. Heavy metals were estimated in 10 different gum samples for its quality assessment standardization and value addition.

Survey of some villages and tribal areas of Lucknow, Sultanpur, ,Jaunpur, Varanasi and Sonebhadra district of Uttar Pradesh for extensive awareness programmes and identifying groups of beneficiaries specifically women's/ tribals for value addition and income generations using gums/gum technologies.

Non-targeted metabolic profiling of *Commiphora wightii* (guggul) for bioprospection

Commiphora wightii (Arn.) Bhandari (syn. *Commiphora mukul*), commonly known as guggul, is one of the most valued medicinal plants having several pharmaceutical applications and is an article of commerce in India. Gum resin and its constituents have been used to treat a variety of ailments. The medicinal importance of *C. wightii* resin is because of the presence of guggulsterone-Z and guggulsterone-E present in gum-resin of this plant. Analysis of metabolites of *C. wightii* is limited to guggulsterones content. The aim of this study was to investigate the entire metabolic signature of *C. wightii* as the plant is in great demand for healthcare and nutraceutical products. To accomplish this objective, aqueous and non-aqueous extracts from leaves, stem, roots, latex and fruits were analyzed using gas and liquid chromatography, mass spectrometry and NMR spectroscopy. *C. wightii* has not been reported to associate with secondary metabolites producing endophytic fungi. Additionally, various metabolites including biologically active secondary metabolites of medicinal importance were characterized from the endophytic fungus, *Nigrospora* sps.

Comprehensive metabolic profiling of *Commiphora wightii* using ^{1}NMR spectroscopy and chromatography (HPLC and GCMS) techniques identified 118 chemically diverse metabolites including amino acids, fatty acids, organic acids, phenolic acids, pregnane-derivatives, steroids, sterols, sugars, sugar alcohol, terpenoids, and others (tocopherol, lactam derivative (NMP), alkaloid (trigonelline), guanidine and nucleoside) from aqueous and non-aqueous extracts of leaves, stem, roots, latex and fruits (Fig. 10).

Detection of chemically diverse metabolites of diverse metabolic pathways (carbohydrate metabolism, glycolysis, TCA cycle, DOXP/MVA, Shikimate and Phenylpropanoid pathways) suggests a complex adaptive metabolic combination towards abiotic and biotic stresses as it grows under harsh environmental conditions where it survives at very high temperature during hot summer and for months with no rain (Fig. 11).

For the first time quinic acid and myo-inositol were identified as the major metabolites in *C. wightii*. Very high concentration of quinic acid was found in fruits (553.5 mg

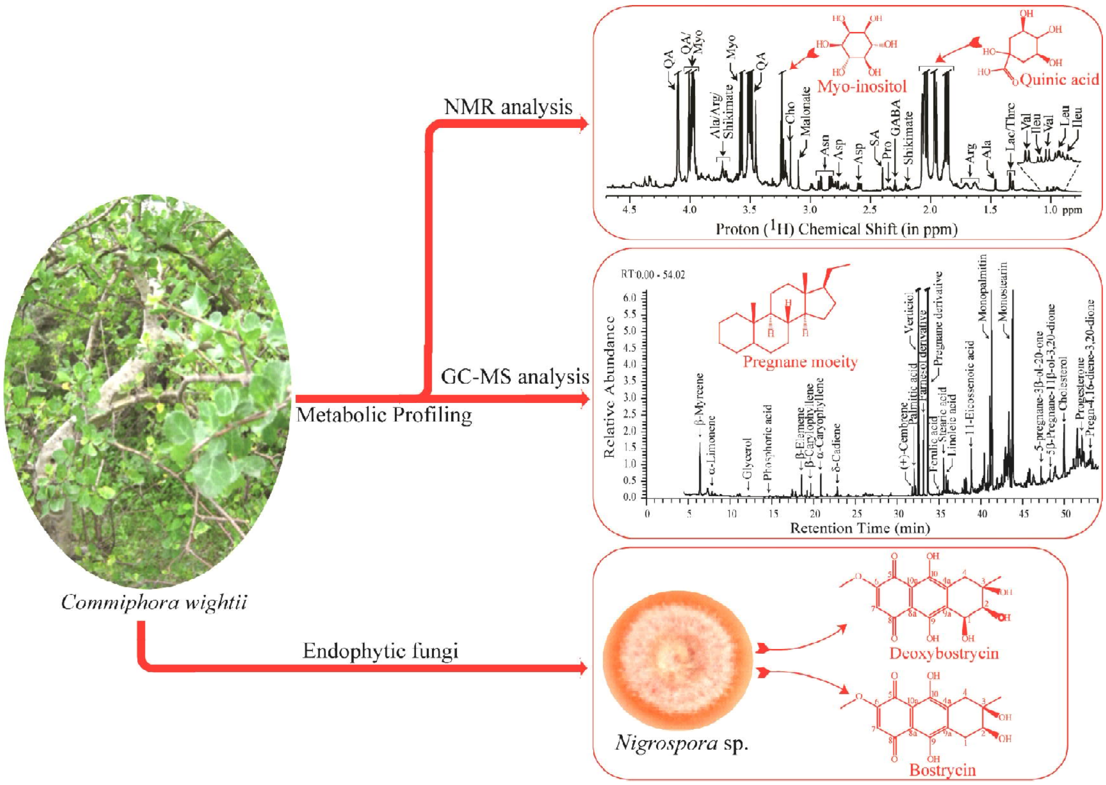


Fig. 10. Comprehensive metabolite profiling of *C. wightii*

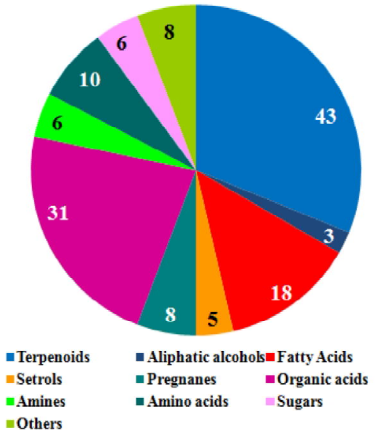


Fig. 11. Aqueous and non-aqueous metabolites from different parts of *C. wightii*

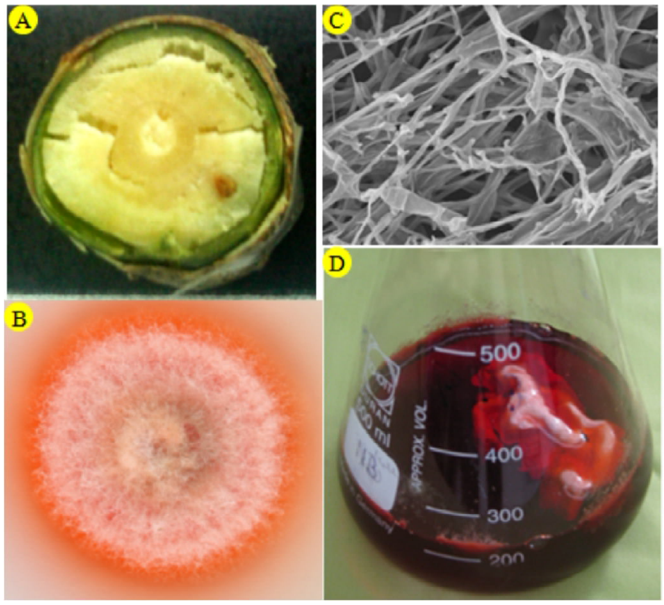


Fig. 12. Healthy stem of *C. wightii* (A); Isolated endophytic fungi from stem (B); SEM of endophytic fungi (C); Showing secondary metabolites produced by endophytic fungi in potato dextrose broth (D).

g^{-1} dry wt.) and leaves (212.9 mg g^{-1} dry wt.). Similarly, high concentration of myo-inositol (168.8 mg g^{-1} dry wt.) was observed from fruits.

The other metabolites of cosmeceutical, medicinal, nutraceutical and industrial significance such as a-tocopherol, n-methylpyrrolidone (NMP), trans-farnesol, prostaglandin F2, protocatechuic, gallic and cinnamic acids were identified from non-aqueous extracts using GC–MS. These important metabolites have thus far not been reported from this plant.

Isolation of a fungal endophyte, (*Nigrospora* sp.) from this plant is the first report. The fungal endophyte produced a substantial quantity of bostrycin and deoxybostrycin known for their antitumor properties (Fig. 12, 13). Very high concentrations of quinic acid and myo-inositol in leaves and fruits; a substantial quantity of a-tocopherol and NMP in leaves, trans-farnesol in fruits, bostrycin and deoxybostrycin from its endophyte makes the taxa distinct, since these metabolites with medicinal properties find immense applications as dietary supplements and nutraceuticals.

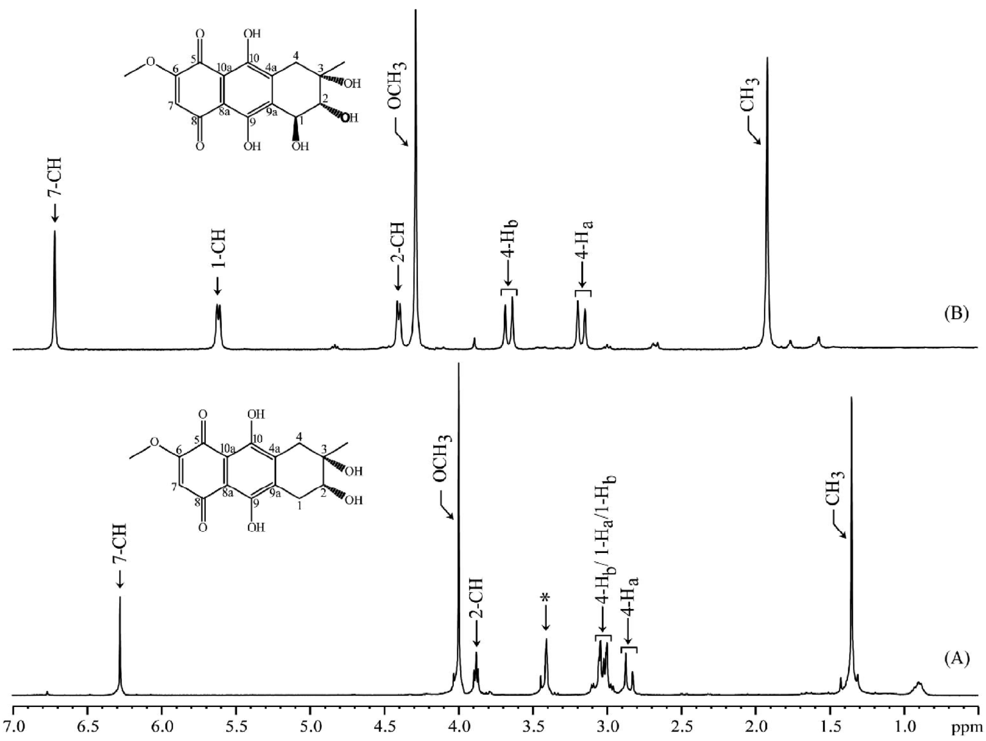


Fig. 13. ^{1}H NMR spectra of bostrycin (A) and deoxybostrycin (B) isolated from *Nigrospora* sp. grown potato dextrose broth

In-House Project

Phytochemical studies of medicinal & aromatic plants

Extraction, isolation and purification of some medicinal and aromatic plant were carried out for development of economically useful phyto-chemicals, secondary metabolites, natural additives, formulations and products, viz. *Ficus carica* and *Ficus racemosa* (leaf & bark), *Piper betel*, *Bixa orellana*, *Moringa oleifera*, *Sesamum indicum* , *Sterculia* sp., *Sesbania* sp. and *Mucuna* sp.

Fresh rhizome of *Hedychium spicatum* collected from four different locations crushed and hydrodistilled for extraction of essential oil. Essential oil tested for antitermite activity at different doses (0.2%, 0.4%, 0.6%, 0.8%, and 1% v/V) against *Microcerotermes beesoni* termite species. Essential oil samples were tested for termite mortality and repellency. All the four oil samples showed significant mortality and repellency at 1% v/V dose which is equivalently effective as market available 20 % chlorpyriphos (Fig. 14).

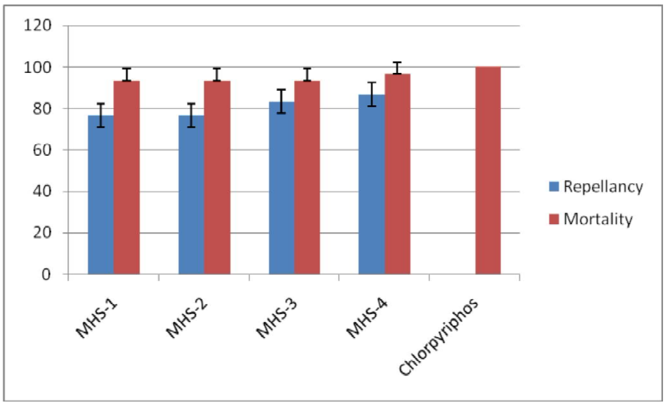


Fig. 14. Comparative antitermite activity among four samples of essential oil from *Hedychium spicatum* and commercially available chlorpyriphos against the termite species *Microtermis beesoni*

Antioxidant potential was determined in speices of *Bixa*, *Betel*, *Trigonella*, *Moringa*, *Encephalartos*, *Syzigium* and some commonly known flowers grown in the NBRI Botanic Garden. and compared with standards viz. Gallic acid, Ascorbic acid, Rutin and quercitin. MIC values in different flowers ranged from 0.120 to 0.326 µg/ml.

Developed analytical method for the separation of 12 phenolic compounds in single run using HPLC namely (1) gallic acid, (2) chlorogenic acid, (3) caffeic acid, (4) rutin, (5) sinapic acid, (6) coumaric acid, (7) ferulic acid, (8) diadzein, (9) quercetin, (10) genestein, (11) kaempferol and (12) biochanin A.

Extraction, isolation and phytochemical studies of medicinal, aromatic plants for economically important gums (seeds/ exudates), lipids, essential oils and other secondary metabolites of therapeutic and commercial significance

Interaction, derivatization and characterization of more than 10 gums/ gumfilms for improved functional properties of plant gums and developed films there from. Derivatization and oil characterization of two lesser known seeds was done and evaluation and formulation of seed flour for high protein and fiber rich food supplement is under process.

Gelling properties of three plant derived gums (NBRgl-16, NBRgl-22 & NBRgl-23,) were studied and compared with commercial gellants for prospection of plant gums to be utilized in formulation of hydrogels. Various types of gel formulations with varying ranges of viscosity, stability and other characteristics were prepared. These functional properties of the materials may be tailored for many fold applications to be explored as potential additives, hydrogels, effective deliveries and encapsulants. (Fig. 15) More than five plant gums were characterized as excipients for formulations and effective deliveries. Moisture retaining capacity of three gums was studied and their functional properties analysed through IR for possible utilization in transdermal patches, which is under process of standardization.

A gum source has been explored as a natural pigment clarifying agent.Some polymeric biodegarable films with plant gum sources (NBRPl-11, NBRPl-13, NBRPl-23) were prepared with improved strength and plasticity through modification and interaction. Formulation studies are under process with sources (NBRFc-13, NBRFc-15, NBRFc-17, NBRFc-21) for development of biodegradable films with foaming and cleaning property. Development and utilization of plastic and glassy films for coating and lamination of leaves and flowers for value added technology.

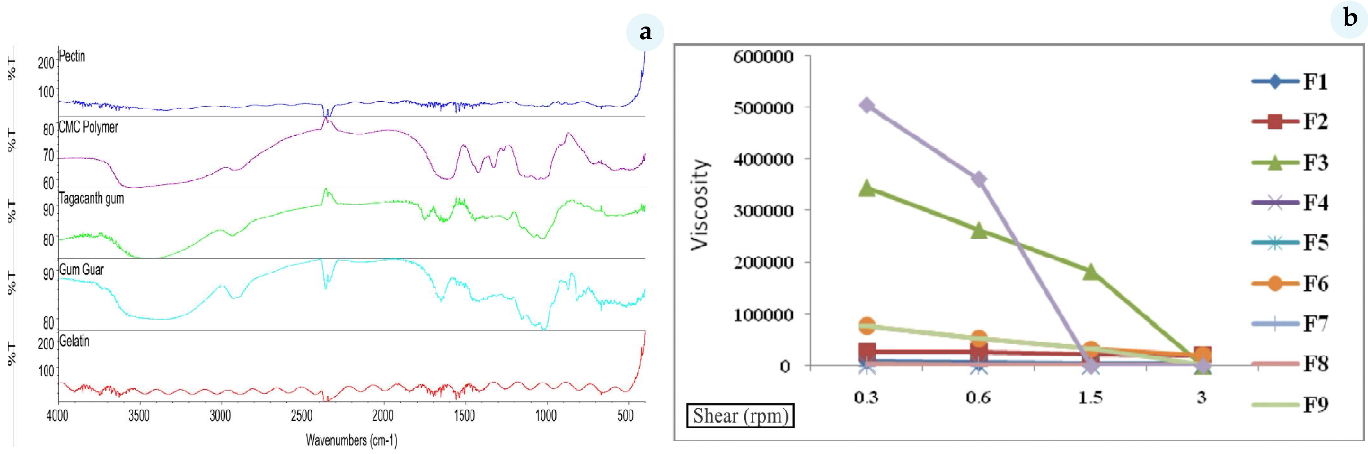


Fig. 15. (a) Identification of functional properties of gel formulation through IR; (b) Representation of the viscosity (CPS)

Publications

1. Aeron A, Chauhan PS, Dubey RC, Maheshwari DK, Bajpai VK - Root nodule bacteria from *Clitoria ternatea* L. are putative invasive nonrhizobial endophytes. *Can. J. Microbiol.*, 2015, 61: 131-142.
2. Agarwal M, Rai V, Khatoon S and Mehrotra S – Effect of microbial load on therapeutically active constituent glycyrrhizin of *Glycyrrhiza glabra* L. *Indian J. Trad. Knowledge,* 2014, **13**(2) : 319-324.
3. Bhatia A, Bharti SK, Tripathi T, Mishra A, Sidhu OP, Roy R, Nautiyal CS, Metabolic profiling of *Commiphora wightii* (guggul) reveals a potential source for pharmaceuticals. *Phytochemistry*, 2015, **110** : 29-36.
4. Brind L, Misra A and Srivastava S – Evaluation of central nervous system stimulating and analgesic activity of *Murraya koenigii* leaves. *J. Acute Med.*, 2014, **4** (2): 81-85.
5. Chen XQ, Shao LD, Pal M, Shen Y, Cheng X, Xu G, Peng LY, Wang K, Pan Z. H, Li MM, Leng Y, He J, and Zhao QS – Hupehenols A E, selective 11b-Hydroxysteroid Dehydrogenase type 1 (11b-HSD1) inhibitors from *Viburnum hupehense* *J. Nat. Prod.*, 2015, **78** : 330-334.
6. Choudhary N, Siddiqui MB and Khatoon S – Pharmacognostic evaluation of *Tinospora cordifolia* (Willd.) Miers and identification of biomarkers. *Indian J. Trad. Knowledge*, 2014, **13**(3) : 543-540.
7. Choudhary N, Siddiqui MB, Bi S and Khatoon S – Effect of seasonality and time after anthesis on the viability and longevity of *Cannabis sativa* pollen. *Palynology*, 2014, **38** (2): 235-241.
8. Choudhary N, Singh S, Siddiqui MB and Khatoon S – Impact of seasons and dioecy on therapeutic phytoconstituents of *Tinospora cordifolia*, a Rasayana Drug. *Biomed. Res. Int.*, 2014, Article ID 902138.
9. Dasgupta GM, George BS, Bhatia A, Sidhu OP - Characterization of Withania somnifera Leaf Transcriptome and Expression Analysis of Pathogenesis – Related Genes during Salicylic Acid Signaling. *PLoS ONE*, 2014, 9(4): e94803.
10. Gupta A, Verma S, Kushwaha P, Srivastava S and Rawat AKS – Phytochemical and antioxidant studies of *Salvadora persica* L. stem and twig. *Indian J. Pharmaceut. Education Res.*, 2015, **49**(1) : 71-75.
11. Gupta A, Verma S, Kushwaha PS, Srivastava S and Rawat AKS – Estimation of Asiatic acid, Asiaticoside & Madecassoside in two accessions of *Centella asiatica* (L.) Urban for morpho-chemotypic variation. *Indian J. Pharmaceut. Education Res.* , 2014, **48**(2) : 65-69.
12. Gupta PC, Rao ChV - Gastroprotective effect of standardized leaf extract from *Careya arborea* on experimental gastric ulcers in rats. *Pharm. Biol.*, 2014; 52(8): 1003-1008.
13. Gupta SS, Kumar GR, Sharma M, Pandey G, Mohapatra PK and Rao ChV – Effects of flavonoids from *Morus alba* leaves extract on experimentally induced gastroesophageal reflux disease (GERD) in Rats. *Res. J. Pharmaceutical, Biol. Chem. Sci.*, 2014, **5**(1) : 1021-1030.
14. Gupta SS, Lubna A, Shukla I, Verma P, Mohapatra PK and Rao ChV — Structural and functional characterization of flavonoid ingredient of *Andrographis setpyllifolia* leaves extract against experimentally induced gastroesophageal reflux disease. *Inter. J. Indigenous Medicinal Pl.*, 2015, **48**(1) : 1803-1810.
15. Gupta SS, Sharma J and Rao ChV – Effects of flavonoids from *Andrographis serpyllifolia* leaves extract on carbon tetrachloride-induced hepatotoxicity in wistar rats. *Indian J. Appli. Res.*, 2014, **4**(5) : 534-537.
16. Khatoon S, Singh H, Rathi A, Ojha SK and Rawat AKS – Standardization of an Ayurvedic formulation - Kalyanavleha and estimantion of Curcumin using HPTLC. *Indian J. Trad. Knowledge,* 2014, **13**(3) : 535-542.
17. Kumar PS, Verma P, Yadav MS, Debjit B, Gupta SS, Lubna A, Shukla I, Rao BK and Rao ChV – Advance Technique In Ocular Drug Delivery System. *World J. Pharmacy Pharmaceutical Sci.*, 2015, **4**(5) : 346-365.
18. Kumar PV, Maiti A, Gupta SS, Shukla I and Rao ChV – Effect of the Standardized Extract of *Holarrhena Antidysenterica* seeds against Steptozotocin-Induced Diabetes in Rats. *Inter. J. Pharma Res. Review.* 2015, **4**(4) : 1-6.
19. Mishra A, Kumari M, Pandey S, Chaudhry V, Gupta KC and Nautiyal CS – Biocatalytic and antimicrobial activities of gold nanoparticles synthesized by *Trichoderma* sp. *Bioresour. Technol.*, 2014, **166** : 235-242.
20. Mishra S, Srivastava S and Nautiyal CS –. Differential gene expression profile in *Pseudomonas putida* NBRIC19-treated wheat (*Triticum aestivum*) plants subjected to biotic stress of *Parthenium hysterophorus. Mol. Biol. Rep.*, 2014, **41**(3) : 1385-1399.
21. Misra A, Srivastava S and Srivastava M – Phytochemical and anti diarrheal potential of *Moringa oleifera* (Lam.) leaves. *J. Pharmacog. Phytochem.*, 2014, **2**(5) : 43-46.
22. Misra A, Srivastava S, Rawat AKS and Kaveri SV – *Moringa oleifera* (Lam.) - A tree with miraculous medicinal, nutritional and socio-economical benefits. *La Phytotherapie Europeenne*, 2015, **84** : 22-26.
23. Misra A, Tandon N, Srivastava M, and Srivastava S – Evaluation of *in-vitro* anti oxidant potential of *Acacia tortilis* seed endosperm *J. Free Radicals Antioxidants*, 2014, **140 :** 332-338.
24. Negi KS, Koranga SS, Ojha SN, Rawat AKS and Srivastava S – NKO-24 (IC0573223; INGR13069), a Spiked Zinger Lily (*Hedychium spicatum*) germplasm with bold seed, early emergence and late senescence. *Ind. J. Plant Genet. Resour.*, 2014, **27**(1), 81- 84.
25. Niranjan A, Tewari SK, Lehri A and Amla DV – Extraction of polyphenols from *Trewia nudiflora* and its antioxidant activity. *Medicinal Pl.*, 2015, **7**(1) : 9-19.
26. Pandey AK, Bajpai AK, Kumar A, Pal M, Baboo V and Dwivedi A – Isolation, identification, molecular and electronic structure, vibrational spectroscopic investigation, and Anti-HIV-1 activity of Karanjin using density functional Theory, *J. Theor. Chem.*, 2014, **14** : 1-13.

27. Pandey G, Chaudhary V, Yadav S, Chauhan PS, Gupta SS, Mishra A, Rawat AKS and Rao ChV – Wound healing activity of *Premna latifolia* Roxb. *Brit. J. Pharmaceut. Res.*, 2014, **4**(8) : 929-942.

28. Pandey G, Gupta SS, Ojha SK and Rao ChV – Wound repair and anti-inflammatory potential of *Fumaria indica* in excision wound-induced rats. *Brit. J. Pharmaceut. Res.*, 2014, **4**(2) : 257-266.

29. Pandey G, Rao ChV, Gupta SS, Verma KK and Singh M – Antioxidant and antibacterial activities of leaf extract of *Achyranthes aspera* Linn. (Prickly Chaff Flower). *European J. Med. Pl,*. 2015, **4**(6) : 695-708.

30. Parmar N, Virdi AS, Singh N, Kaur A, Bajaj R, Rana JC, Agrawal L and Nautiyal CS–Evaluation of physiochemical, textural, mineral and protein characteristics of kidney bean grown at Himalayan region. *Food Res. Int,* 2014, **66** : 45-57**.**

31. Patel S, Shende S, Arora, RRB Singh, Rastogi S, Rawat AKS - Antioxidant potential of herbs and spices during deep frying of ghee. *Int. J. Dairy Techol.*, 2014, 67(3): 365-372.

32. Rao ChV, Lubna A and Gupta SS – Phytochemical and pharmacological review on *Andrographis serpyllifolia*: Potential herbal cure-All. *Mintage J. Pharmaceutical Medical Sci.*, 2014, **3**(3) : 1-3.

33. Rastogi S, Pandey MM and Rawat AKS – Medicinal plants of genus *Betula*-Traditional uses and a phytochemical-pharmacological review. *J. Ethnopharmacol.*, 2015, **159** : 62-83.

34. Singh A, Kumar G R, Gupta SS, Singh S, Rawat AKS and Rao ChV – Hepatoprotective Potential of *Ziziphus oenoplia* (L.) Mill roots against Paracetamol induced hepatotoxicity in rats. *Am. J. Phytomedicine Clinical Therapeutics*, 2015, **3**(1) : 64-78.

35. Singh BN, Rawat AKS, Khan W, Naqvi AH and Singh BR – Biosynthesis of stable antioxidant ZnO nanoparticles by *Pseudomonas aeruginosa* Rhamnolipids. *PLoS ONE*, 2014, e106937

36. Srivastava A, Singh BN, Deepak D, Rawat AKS and Singh BR – Colostrum hexasaccharide, a novel Staphylococcus aureus quorum sensing inhibitor. *Antimicrob. Agents Chemother.*, 2014, **59**(3) : 2169-2178.

37. Srivastava M, Kumar G, R Mohan and S Malhotra – Phytochemical studies and antimicrobial activity of babool seeds *J. Scientific Ind. Res.*, 2014, **73** : 724-728.

38. Srivastava N, Srivastava A, Srivastava S, Rawat AKS and Khan AR– HPTLC-densitometric determination and kinetic studies on antioxidant potential of monomeric phenolic acids (MPAs) from *Bergenia* species. *RSC Adv.*, 2015, 4 : 52647–52657.

39. Srivastava N, Srivastava S, Verma S, Khan AR and Rawat AKS –. Evaluation of quantitative variation of secondary metabolites in *Bergenia ciliata* (Haw.) using high performance thin layer chromatography. *J. Biomed. Res.* ,2014, **28**(4) : 328–331.

40. Srivastava RK, Singh A, Srivastava GP, Lehri A, Niranjan A, Tewari SK, Kumar K and Kumar S – Chemical Constituents and biological activities of promising aromatic plant Nagarmotha (*Cyperus scariosus* R.Br.): A Review, *Proc Indian Nat. Sci. Acad* ., 2014, **80** : 525-536.

41. Srivastava S and Rawat AKS – Quantification of Berberine in different *Berberis* species and their commercial samples from herbal drug markets of India through HPTLC. *J. Adv. Chem.*, 2014, **8**(3) : 1700-1706.

42. Srivastava S, Pandey R, Kumar S and Nautiyal CS – Correspondence between flowers and leaves in terpenoid indole alkaloid metabolism of the phytoplasma-infected *Catharanthus roseus* plants. *Protoplasma,* 2014, **251** : 1307-1320.

43. Srivastava S, Srivastava M, Misra A, Pandey G and Rawat AKS – A review on biological and chemical diversity in *Berberis* (Berberidaceae). *EXCLI J.*, 2015, **14** : 247-267.

44. Srivastava S, Verma D, Srivastava A, Tiwari SS, Dixit B, Singh RS and Rawat AKS – Phytochemical and nutritional evaluation of *Amorphophallus campanulatus* (Roxb.) Blume corm. *J. Nutrition Food Sci.*, 2014, **4** (3): 274.

45. Srivastava S, Verma S, Gupta A, Rajan S and Rawat AKS – Studies on chemotypic variation in *Centella asiatica* (L) Urban from Nilgiri range of India. *J. Planar Chromatography*, 2014, **27**(6): 454-459.

46. Tripathi P, Singh PC, Mishra A, Tripathi RD and Nautiyal CS –. *Trichoderma* inoculation augments grain amino acids and mineral nutrients by modulating arsenic speciation and accumulation in chickpea (*Cicer arietinum* L.). E*cotoxicol. Environ. Safety*, 2015, **117** : 72–80.

47. Veena N, Arora S, Kapila S, Singh RRB, Katara A, Pandey MM, Rastogi S and Rawat AKS – Immunomodulatory and antioxidative potential of milk fortified with *Asparagus racemosus* (shatavari). *J. Medicinal Pl. Studies*, 2014, **2**(6) : 13-19.

48. Veena N, Arora S, Singh RRB, Katara A, Rastogi S, Rawat AKS - Effect of Asparagus racemosus (shatavari) extract on physicochemical and functional properties of milk and its interaction with milk proteins. *J. Food Sci. Technol.*, 2015, **52**(2):1176–1181.

49. Verma P, Singh SP, Vind SK, Kumar GR and Rao ChV – Protective effect of *Acacia nilotica* (bark) against anti tubercular drug induced hepatic damage—An experimental study. *Inter. J. Pharmacy Pharmaceutical Sci.*, 2014, **6**(9) : 75-79.

50. Watal G, Dhar P, Srivastava SK and Sharma B– Herbal medicine as an alternative medicine for treating diabetes: The Global Burden. *Evid. Based Complementary Alterna. Med.*, 2014, (e-CAM), Article ID 5996071.

S & T SUPPORT

S & T SUPPORT SERVICES

INFORMATION, PUBLICATION & LIBRARY (IPL)

IPL functions as one of the core S&T support systems of the Institute. It primarily caters to the information needs of scientists, researchers, students, industrialists, planners, administrators, and people from other walks of life on various aspects of plant sciences and related research disciplines. With its three constituent functional units, IPL serves as a gateway for science dissemination and as a knowledge resource centre for the benefit of a wide user groups. The main functions of IPL include collection, collation, publication and effective dissemination of the S&T information resources generated by the Institute through different communication tools, including print and electronic media.

It serves as the principal communication link between the Institute and its stakeholder groups. It organizes scientific events, press meets, celebration of national and international days of scientific, technological and strategic importance to the Institute and our nation, besides showcasing the Institute's publication and other R& D outputs to the science community and the public through different media and means.

Its primary function is publication of the research and development outcomes and outputs of the Institute in the form of *NBRI News Letter* (a quarterly in-house publication), *Annual Report*, and other science and popular books, bulletins and calendars on different themes of topical interests on plants, environment, biotechnology, agro-technology, ornamental horticulture, etc.

Publications : It is one of the major activities of the division. Following publications were brought out during 2014-2015 :

i) *CSIR-NBRI Newsletter*, 2014, Vol. **41**, Nos. 2-4 and 2015, Vol. **42,** No. 1.

ii) Schedule of Chrysanthemum & Coleus Flower Show, December 2014.

iii) Schedule of Rose & Gladiolus Flower Show, January 2015.

iv) Educational Material for the year 2015 was designed and produced, depicting coloured photographs.

v) CSIR-NBRI Annual Report **:** Annual Report 2013-2014 was compiled and brought out. It was released on the occasion of Annual Day of the Institute on October 25, 2014 by Prof. Deepak Pental, Director, Centre for Genetic Manipulation of Crop Plants, University of Delhi South Campus, New Delhi.

vi) CSIR Annual Report **:** Progress report on important R&D projects was compiled with respect to CSIR-NBRI, which covered significant contributions of CSIR-NBRI in the areas of Science & Technology, HRD activities, Awards and Distinctions, Patents Filed & Granted and sent to CSIR HQ for inclusion in the CSIR Annual Report 2013-2014.

Sale of Publications : **₹ 10, 280/-**

Parliament Questions : Ten parliament questions received from CSIR HQ were attended.

KNOWLEDGE RESOURCE CENTRE (KRC)

The library is the designated Knowledge Resource Centre of the Institute and provides services and facilities to meet the S&T knowledge requirement of the R& D Groups of the Institute and other user groups as well. The KRC repository at NBRI includes: Books (29186); Periodicals – Bound Volumes (31529), Currently subscribed periodicals (Indian + Foreign) - including print only (82), Print + online (32), Online only subscribed through NBRI (KRC) (26), Online periodicals subscribed through CSIR-Consortium (472), Complimentary periodicals (27); Online/CD- ROM Databases; OPAC (Online Public Access Catalogue); Biological Abstracts on CD-ROM from 1995 to 2005; ASTM standards on CD-ROM; ISI WEB OF KNOWLDEGE (Web of Science); QPAT patent database.

At present KRC (Library) is using LIBSYS Software and all operations of KRC are fully automated. OPAC (Online Public Access Catalogue) is available to the users on their desks. The KRC operates with the following objectives :

- To support the learning process of the students through provision of knowledge/Information.
- To meet knowledge/information needs of the scientists and research students to support their research activities.
- To respond effectively, where possible, to the knowledge/information needs of the Institute's clientele.

PLANNING, MONITORING AND EVALUATION

The Planning, Monitoring and Evaluation Division of the Institute primarily coordinates, monitors and facilitates the functioning of all the R&D projects undertaken by various R&D groups of the Institute. The Division strives to spearhead the programmes and projects of various divisions of the institute from the stage of planning to outputs of value to diverse stakeholders. It acts as a link between the institute and CSIR with respect

LIBRARY HOLDINGS (As on 31.3.2015)

Books & Journals **1. Number of books and journals added during 2014-2015**	
(i) Books Purchased	76
(ii) Books received on gratis/ exchange	28
(iii) FAO's Books received	38
(iv) Bound Journals	1576
Total number of books added during 2014-15	**142**
2. Number of books and bound journals as on 31.3.2015	60715
Current Periodicals	
(i) Print only	82
(ii) Print + Online	32
(iii) Online only	26
(iv) Complimentary/Exchange	27
Total number of Periodicals (titles) received during 2014-2016	**167**
Reprography Service Total number of photocopies of documents and scientific publications provided to the scientists of the Institute during 2014-2015	8300

to Five Year Plans, Annual Plans and their operationalization and developmental activities of institute. The activities of the division include scrutiny and coordinating the evaluation of new research proposals, allotment of project numbers, monitoring the progress of research projects, maintenance of repository of R&D projects in the both physical documents and as well as electronic databases.

During 2014-15, 22 Grant-in-Aid/Consultancy/ Network/Technical Support Projects were populated in the R&D module as a part of ERP solutions for quick online accessibility and usability of complete accurate information. Newly joined employees were mapped for the new projects commenced during the period under report. The primary and secondary roles of all the permanent staff of the institute, joined during the period under report were assigned and mapped to establish correspondence between employee ID and responsibilities of the employee concerned, enabling the employee the privileges for the different relevant modules in the ERP implementation, including project, finance and HR modules. The necessary project receipts of the FY 2014-15 of ongoing projects were processed in the Centralized Valuable Receipt (CVR).

CSIR-NBRI 12th Five Year Plan Achievement Document (April 1, 2012-May 31, 2014): The document detailing achievements in terms of most significant technologies; societal intervention; patents, publications, networking & linkages, HR development, ECF generated; international collaborations; details in reference to mapping to national priorities was prepared and sent to CSIR HQ, New Delhi.

Mid-Term Appraisal of Twelfth Five Year Plan (2012-13 and 2013-14 and till September 2014): Mid-Term Appraisal of 12th Five Year Plan document highlighting overall positioning of the laboratory in the socio-economic sector served; project-wise information on major targets and achievements of the laboratory; financial performance for all approved projects, etc was prepared and sent to CSIR HQ, New Delhi.

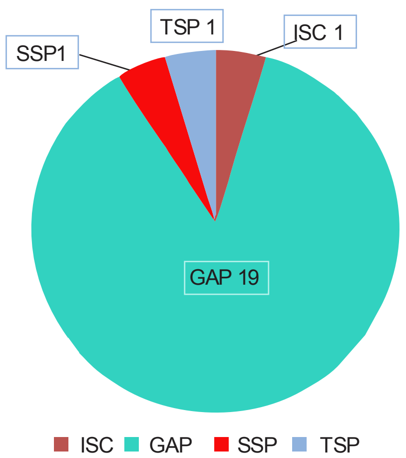
The major activities carried out during the year were:

- Preparation of plan documents
- Database maintenance for R&D projects (in-house, sponsored, collaborative, Grant-in-aid, Consultancy, NMITLI, Plan Projects & Network Projects)
- Scrutiny & evaluation of new research proposals
- Project number allotment and maintenance of records of R&D project
- Technical manpower planning and human resource development
- Organization of 43rd Research Council (RC) meetings held during December 12-13, 2014
- Interface with auditors : the division interacted and provided supporting information for submission of internal and external audit parties of CSIR in the auditing of R&D projects
- Coordination between various agencies with respect to R&D activities
- Examination, evaluation and processing of indents
- To facilitate distribution of money realized from license fee/royalty/consultancy
- Preparation of Research Utilization Data (RUD)
- Processing of foreign deputation cases of researchers for various R&D purposes

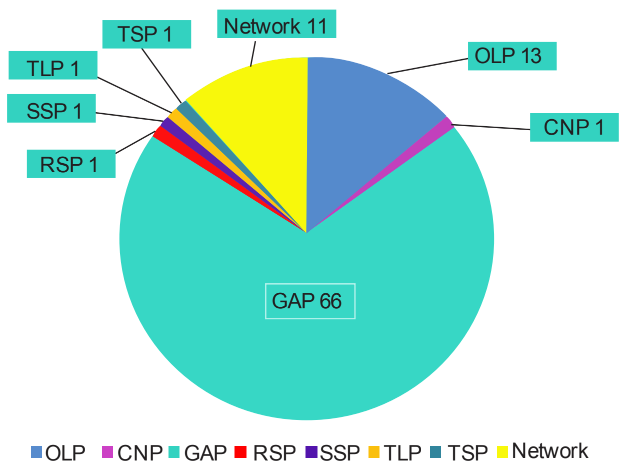
Projects Initiated during 2014-15

Sl. No.	Project	Project title	Funding Agency	Project Co-ordinator/ Project Investigator	Duration
1.	ISC 0102	CSIR knowledge gateway and open source private cloud infrastructure (KNOWGATE)	CSIR	Dr. Sudarshan Kumar	36 months w.e.f. 01-Apr-14
2.	SSP 2903	Study of impact on Arsenic contamination in rice using ortho sillicic acid formulation	Privi Life Sciences Pvt. Ltd., Mumbai	Dr. R.D. Tripathi	12 months w.e.f. 28-Oct-14
3.	GAP 3336	Identification and characterization of arsenite oxidase genes in fungi isolated from arsenic contaminated soils	DST, New Delhi	Dr. Pankaj Srivastava/ Dr. Virendra Kumar Jaiswal	36 months w.e.f. 27-May-14
4.	GAP 3337	Taxonomic study of the tree flora of Uttar Pradesh	UPSBB, Lucknow	Dr. L.B. Chaudhary	24 months w.e.f. 24-Jun-14
5.	GAP 3338	A study on the role of miRNA(s) in plant growth promoting *Rhizobacteria* mediated drought stress alleviation in chickpea (*Cicer arietinum* L.)	DST, New Delhi	Dr. Charu Lata	36 months w.e.f. 03-Jul-14
6.	GAP 3339	Promoting gugulsterone production in *Commiphora wightii* : Metabolite profiling of contrasting chemotypes and identifying precursors of guggulsterones	DBT, New Delhi	Dr. O.P. Sidhu	36 months w.e.f. 05-Aug-14
7.	GAP 3340	To study the effect of different sources and levels of organic matter on biomass yield and quality of Kalmegh	UPCAR, Lucknow	Dr. Lal Bahadur	36 months w.e.f. 02-Sep-14
8.	GAP 3341	Standardization of protocols for organic seed production of turmeric (*Curcuma longa*) in Uttar Pradesh	UPCAR, Lucknow	Dr. Devendra Singh	24 months w.e.f. 02-Sep-14
9.	GAP 3342	Role of micro-climate in soil carbon sequestration in two pulses in Indo-Gangetic plains of Uttar Pradesh	UPCAR, Lucknow	Mr. Soumit K. Behera	36 months w.e.f. 02-Sep-14
10.	GAP 3343	Tagging *Alternaria* blight resistance loci and marker assisted back-crossing (MABC) in linseed (*Linum ussitatisimum* L.)	UPCAR, Lucknow	Dr. Hemant Kumar Yadav	36 months w.e.f. 10-Sep-14
11.	GAP 3344	Development of transgenic cotton lines for resistance against whitefly (*Bemisia tabaci*)	DST, New Delhi	Dr. P.K. Singh/Ms. Alka Mishra	36 months w.e.f. 18-Sep-14
12.	GAP 3345	Standardization and validation of lichen species *Usnea longissima* and *Cladonia furcata* used in peptic ulcer.	DST, New Delhi	Dr. Ch. V. Rao	36 months w.e.f. 10-Nov-14
13.	GAP 3346	Screening of rice (*Oryza sativa* L.) varieties for tolerance to arsenic: investigation of rhizospheric and in planta chemistry of arsenic and biochemical responses of tolerant and sensitive varieties	DST, New Delhi	Dr. R.D. Tripathi/ Dr. Seema Mishra	36 months w.e.f. 13-Oct-14
14.	GAP 3347	Evaluation of floral bio-diversity and microbial biomass in sodic lands of Uttar Pradesh under the sodic land reclamation (Project Phase-III)	RSAC, U.P.	Dr. S.K. Tewari	12 months w.e.f. 27-Nov-14
15.	GAP 3348	Transcript profiling of major millet crops under drought stress and cloning-characterization of stress-inducible transcription factors	DST, New Delhi	Dr. Charu Lata	36 months w.e.f. 19-Nov-14
16.	GAP 3349	Deciphering plant responses to elevated carbon dioxide and its implication for Root-Soil-Microbe Interactions	DST, New Delhi	Dr. Aradhana Mishra	36 months w.e.f. 01-Dec-14
17.	GAP 3350	Utilization of natural gums as low cost material for development of sanitary napkins and awareness on health & menstrual hygiene issues in rural area	NASI, Allahabad	Dr. Manjoosha Srivastava/Ms. Akanksha Srivastava	12 months w.e.f. 02-Jan-15

Sl. No.	Project	Project title	Funding Agency	Project Co-ordinator/ Project Investigator	Duration
18.	GAP 3351	Tomato Ripening Network: Targeted manipulation of SIERF6 and SIERF8 in tomato: their role in regulating fruit ripening and productivity	DBT, New Delhi	Dr. A.P. Sane	60 months w.e.f. 14-Jan-15
19.	GAP 3352	Prospects of gum rich plant for technological intervention and societal benefits	NASI, Allahabad	Dr. Manjoosha Srivastava/Ms. Kamini	12 months w.e.f. 02-Mar-15
20.	GAP 3353	Genome wide identification and functional characterization of dehydrin gene families in rice and analysis of their responsiveness to drought and other abiotic stresses	DST, New Delhi	Dr. Debasis Chakrabarty / Dr. Giti Verma	36 months w.e.f. 25-Mar-15
21.	GAP 3354	Development of F_1-Hybrid cotton using novel reversible male sterility system	DBT, New Delhi	Dr. Samir V. Sawant	36 months w.e.f. 25-Mar-15
22.	TSP 0002	Training to Nepalese scientists in the area of plant molecular biology	Development of Plant Resources, Govt. of Nepal	Dr. S.K.S. Rathore	3 months w.e.f. 23-Jun-14



New projects initiated during 2014-15



Projects in operation (2014-15)

DEPUTATION OF NBRI SCIENTISTS/FELLOWS ABROAD

Sl. No.	Name of Scientist (s)	Country visited	Date of visit	Purpose of visit
1.	Dr. Vivek Pandey	Beijing, China	May 18-23, 2014	To attend the International Conference on "Ozone and Plants"
2.	Dr. A.K. S. Rawat	Kunming, China	July 27-30, 2014	To attend the brain storming session on "Traditional knowledge and medicine" as a member of Indian delegation
3.	Dr. Sunil Kumar Snehi	San Antonio, USA	October 06-11, 2014	To participate in 4th world congress on Virology
4.	Dr. S.A. Ranade	Lumbini, Nepal	November 01-03, 2014	To participate in the Asian Plant Sciences Conference
5.	Dr. Poonam Singh	Lumbini, Nepal	November 01-03, 2014	To participate in the Asian Plant Sciences Conference
6.	Dr. Aradhana Mishra	Lumbini, Nepal	November 01-03, 2014	To participate in the Asian Plant Sciences Conference
7.	Dr. T.S. Rana	Kuwait Institute for Scientific Research (KISR), Kuwait	November 10-13, 2014	To attend the joint meeting for scientific co-operation between Kuwait Institute for Scientific Research (KISR) and CSIR, New Delhi
8.	Dr. Samir V. Sawant	Bangkok , Thailand	November 26-28, 2014	To participate in the 6th ASIAHORC Symposium on "The impact of climate change to food and health"

TECHNOLOGY TRANSFER AND BUSINESS DEVELOPMENT, PATENT, RTI AND TRAINING CELL

Technology Transfer & Business Development (TTBD) division continued its efforts to increase the business development opportunities for the Institute. The major activities of the division are:

- Interaction with industries, agencies for increasing business possibilities for the Institute.
- Preparation of agreements (MoU, MoA, Secrecy Agreement, Technology Transfer Agreement) for smooth business activities of the Institute.
- Negotiations with various stakeholders in the R&D activities of the Institute for exploring business opportunities.
- Information dissemination about the technologies of the Institute for publicity and attracting potential clients.
- Participation in displaying technologies/know-how of the Institute through exhibitions.
- Management of short term (3-6 months) training / project work of PG students of various Universities from all over the country, so as to develop trained manpower in research activities leading to capacity building.
- IP protection by identification of patentable invention, patent application filing and prosecution of application of the institute, patent analysis, prior art search and co-ordinates with IPU division, CSIR HQ, New Delhi, for patent related matters.

TECHNOLOGY TRANSFERRED

Details	Client	Date
Herbal Formulation for Diabetes (NBRMAP-DB) technology / knowledge base	M/s Aimil Pharmaceuticals Ltd., New Delhi	May 12, 2014

MoUs/MoAs/MTAs SIGNED

Sl.No.	Details	Client	Date
1.	Agreement for Technology Marketing	CSIR-TECH Private Ltd., 100 NCL Innovation Park, Dr. Homi Bhabha Road, Pune – 411008	16.04.2014
2.	MoA for Taxonomic Study of Tree Flora of Uttar Pradesh	Uttar Pradesh State Biodiversity Board (UPSBB), Lucknow	01.05.2014
3.	MTA for Transgenic Cotton	Central Institute of Cotton Research (CICR), Nagpur	02.06.2014
4.	Agreement for Research Work for Sodic Land Reclamation	Remote Sensing Application Centre (RSAC), Sector G, Jankipuram, Lucknow	23.07.2014
5.	MoU for Project on Study of Quality of Kalmegh	U.P. Council of Agricultural Research (UPCAR), Lucknow	30.07.2014
6.	MoU for Project on Standardization of Protocols for Organic Seed Production of Turmeric in U.P.	U.P. Council of Agricultural Research (UPCAR), Lucknow	30.07.2014
7.	MoU for Project on Role of Micro-Climate in Soil Carbon Sequestration in two Pulses in Indo-Gangetic Plans of U.P.	U.P. Council of Agricultural Research (UPCAR), Lucknow	30.07.2014
8.	MoU for Project on Tagging *Alternaria blight* Resistance Loci and Marker Assisted Backcrossing in Linseed	U.P. Council Of Agricultural Research (UPCAR), Lucknow	30.07.2014
9.	Agreement for Sponsored Research for Project Entitled "Impact on Arsenic Contamination in Rice Using Ortho Silicic Acid Formulation"	Privi Life Sciences Pvt. Ltd., Navi Mumbai	28.10.2014
10.	MTA Signed for Chickpea Variety	Indian Institute of Pulses Research (IIPR), Kanpur U.P	11.12.2014
11.	MTA for "The Germplasm of Following Crops : *Lepidium sativum, Limonia acidissima, Aegle marmelos, Vitex negundo*"	Central Institute of Medicinal and Aromatic Plants (CIMAP), Lucknow – 226015	05.01.2015
12.	MTA for "Procurement of Vector (Plasmid) for Research Work"	Max Planck Institute, Germany	09.01.2015

EXPOSITION

The maintenance and developmental works of the exposition were regularly undertaken. More than 1000 dignitaries from various scientific and non-scientific organizations including common public, school children, college and university students, teachers, scientists, researchers and other academicians of the country and abroad have visited the institute's exposition. On the 'Open Days' of the institute the exposition was also kept open for the public and common people. The visitors got acquainted with the research activities and other programmes carried out by the the institute through displays of the exposition. To inspire and influence the visitors day-to-day thoughts and inspiring phrases were regularly displayed by the group.

CENTRAL INSTRUMENTATION FACILITY (CIF)

Technical Services provided and Achievement

Central Instrumentation Facility of the institute, maintaining all the equipments (HPLC, HPTLC, LC/MS, GLC, AAS, Flash Chromatography, Microwave Digestion system, Stereo Microscope, Refractometer, Tintometer, and SCFE etc.) has provided analytical services to various industries/organization/entrepreneurs/individuals (External samples) and various scientists/staff of the institute (Internal samples). The details of external and internal samples analyzed are given below:

External samples analyzed

No. of samples analyzed	:	63
Revenue earned	:	Rs. 154395.00
No. of new industries/organizations/ Entrepreneurs/individuals benefitted	:	27

Internal samples analyzed

No. of samples analyzed	:	11280

at CIF for Scientists / Staff of the institute

(LCMS/MS, GCMS, IRMS, HPLC, HPTLC, AAS. GLC, UV etc.)

Continuation of NABL – Accreditation

NABL-New Delhi after reassessment audit in May 2014, recommended for continuation of NABL-Accreditation of the institute for another two years, i.e. up to 20.7.2016.

Participation in International and National PT/ILC programme	:	4

INFORMATION & COMMUNICATION TECHNOLOGY (ICT)

CSIR-NBRI Sub-DIC

CSIR-NBRI SubDIC, established in 1999-2000, is a collaboration between DBT (Department of Biotechnology) and CSIR. This is one of the major S&T support Systems in the Institute that provides the following services and functions:

(i) Facilitating bioinformatics research by establishing state-of-the-art Ethernet switch based network in CSIR-NBRI, (ii) maintainence of the Institute website (www.nbri.res.in), (iii) collection, compilation and curation of database of legumes of South Asia under the aegis of the International Legume Database and Information Service (ILDIS), U.K, (iv) undertaking bioinformatics research through database standards, software development, and digitization of plant diversity information, including digitization of the NBRI herbarium specimen information, and (v) maintainence of scientifically validated comprehensive database of Indian plants to facilitate the study and conservation of Indian biodiversity.

Salient achievements

- The NBRI Sub-DIC operates through Ethernet Switch based NBRI-LAN (1.0gbps) and consists of about 600 nodes in the institute and also hosts the institute Website (www.nbri.res.in).
- Development and updating database of 2030 legumes of eight South Asian Countries (www.ildis.org).
- Development and updating of 'Plants of India' database for 19000 taxa, containing information on species nomenclature (scientific names and common names), geographical distribution, descriptors, uses, and genomic information, where avaible.
- Development of database on nomenclature and uses of 2600 species identified by CSIR TKDL.
- Development of "Indian Microbial Diversity Information System" for developing a database on microbial diversity. Using this model compiled and curated a database of 1100 fungal species of Uttar Pradesh with information on species name, host name, district of occurrences, and genomic information.
- Updated taxonomic data for 93349 specimens of herbarium of CSIR-NBRI (LWG) through development of new softwares .
- DUS center for three crops, viz. *Canna, Bougainvillea*, and *Gladiolus* and finalization of DUS character guidelines for the three crops.

OTHER PUBLICATIONS

General Articles

1. Nair KN, Mishra A, Suseela MR, Trivedi PK, Sawant SV and Nautiyal CS – Transforming plant biology to translational research applications- National Botanical Research Institute. *Curr. Sci.*, 2015, **108** : 1066-1071.

2. Singh PC - Global collaboration, *Science*, 2014, **62** : 47-49.

Monograph/Books

1. Kumar A, Tewari DD and Tewari SK – Ethnobotanial Healthcare Management Practices in Uttar Pradesh: Ethnophytotherapeutics and Crude Drug Formulations of Tharu Tribal Community. *Lambert Academic Publishing*, Germany. 2014. ISBN: 978-3-659-60881-0.

2. Roy RK – Ornamental Trees of India, *Pointer Publishers*, Jaipur, 2015 : pp. 452.

3. Singh D, Yadav R and Singh RA – Impact of non-monetary inputs in cultivation of late sown wheat (*Triticum aestivum*). *Lambert Academic Publishing*, Germany, 2015 : pp. 100. ISBN 978-3-659-67586-7.

4. Upreti DK, Divakar PK, Shukla V, and Bajpai R (Eds.) – Recent Advances in Lichenology Volume 1 : Modern Methods & Approaches in Lichen Biomonitoring & Bioprospection. *Springer*, New York, 2015 : pp. 265 .ISBN 978-81-322-2180-7.

5. Upreti DK, Divakar PK, Shukla V, and Bajpai R (Eds.) – Recent Advances in Lichenology Volume 2 : Modern Methods & Approaches in Lichen Systematics & Culture Techniques. *Springer*, New York, 2015 : pp. 232 . ISBN 978-81-322-2234-7.

6. तिवारी एस के एवं नौटियाल सी एस – ग्रामीण विकास हेतु हरित प्रौद्योगिकियाँ। *सीएसआईआर-राष्ट्रीय वनस्पति अनुसन्धान संस्थान*, लखनऊ, 2014 : पृ. 116.

7. राय यू एन, सिंह एस एन, त्रिपाठी आर डी, सिंह एन के, उपाध्याय ए के, वर्मा एस एवं प्रसाद डी – पादप परिवेषोद्वार : गंगा नदी प्रदूषण का प्रबन्धन। सूचना एवम प्रकाशन, *सीएसआईआर-राष्ट्रीय वनस्पति अनुसन्धान संस्थान*, लखनऊ, 2014 : पृ. 44.

Chapters in Books/Proceedings

1. Bajpai R, Upreti DK and Nayaka S – Lichen diversity of Govind Wildlife Sanctuary, Uttarakhand : A potential plant resource for bioprospectional and biotechnological studies. *In* : Geology, Biodiversity and Natural Resources of Himalaya and their Intellectual Property Law (Ed. RA Singh). *Pratyush Publications*, Delhi. 2014 : 262-273.

2. Devi AB, Mohabe S, Reddy MA, Nayaka S, Ponmurugan P, Ayyappadasan G – Antimicrobial activity of lichen *Roccella montagnei* Bél. obtained from Horsley Hills, Andhra Pradesh, India. *In* : Bioactives from Natural Products (Ed. J. Madhusudana Rao). Proc. A.P. Akademi of Sciences (PAPAS) Special Issue, 2014, **16**(1) : 13-19.

3. Elluru S, Srivastava S, Pamonsinlapatham P, Rawat AKS and Kaveri SV – Anti-tumoral mechanisms underlying immunomodulatory effects of *Viscum album* preparations. *In* : Natural Products : Recent Advances (Eds. AK Chauhan, P Pushpangadan and V George). *Write and Print Publications*, New Delhi, 2014 : 93–103.

4. Mishra BK, Rastogi A, Siddiqui A, Srivastava M, Verma N, Pandey R, Sharma NC and Shukla S – Opium poppy : Genetic upgradation through intervention of plant breeding techniques. *In* : Plant Breeding from Laboratories to Fields (Ed. Andersen SB). *InTech Publishers*, Croatia. 2013 : 209-38.

5. Nayaka S, Asthana S – Diversity and distribution of lichens in India *vis a vis* its lichenogeographic regions. *In* : Biodiversity Conservation, Status, Future and Way Forward (Eds. T Marimuthu, P Ponmurugan, M Subramanian, N Mathivanan and S Anita). *National Academy Biolo. Sci.*, Chennai, 2015 : 79-96.

6. Rathore SKS, Tewari SK, Srivastava V, Sharma S and Verma S. – Enhancement of entrepreneureship through herbal technologies. *In* : Technologies for Sustainable Rural Development having Potential for Socio-economic Upliftment- TSRD-2014. (Ed. JP Shukla). *Allied Publishers* Pvt Ltd., New Delhi, 2014 : 69-74.

7. Seth MK, Negi HC and Goel AK – Some significant ethnobotanical plants from Kinnaur district in alpine region of Himachal Pradesh, India. *In* : Diversity and Conservation of Plants and Traditional Knowledge (Eds. S Panda and G Chandra). *Bishan Singh Mahendra Pal Singh*, Dehradun, 2014 : 377-88.

8. Shukla P and Upreti DK – Lichen dyes : Current scenario and future prospects. *In* : Recent Advances in Lichenolgy Volume 2 : Modern Methods & Approaches in Lichen Systematics & Culture Techniques (Upreti DK, Divakar PK, Shukla V and Bajpai R (Eds.)). *Springer*, New York, 2015 : 209-229.

9. Singh N, Srivastava PK, Tripathi RD, Srivastava S and Vaish A – Microbial in-situ mitigation of arsenic contamination in plants and soils. *In* : *In-Situ* Remediation of Arsenic-Contaminated Sites. (Eds J Bundschuh, H. M. Holländer and LQ Ma) . *CRC Press, Taylor & Francis Group*, LLC, 2014 : 115–143.

10. Singh Vand Mohanty CS – Effort towards reducing the antuinutrients in the legume through the application of genomic technologies. *IN* : Biotechnology Vol.5 Gene and Protein Engineering. *Stadium Press* LLC, USA, 2014 : 403-423.

11. Srivastava S, Verma S, Gupta A, Kushwaha P and Rawat AKS – Chemotaxonomic studies of forskolin in *Coleus forskohlii* Briq. from different phyto-geographical zones of India. *In* : Traditional Medicine and Globalization : The Future of Ancient Systems of Medicine (Ed. Mukherjee PK). *Maven Publishers*, Kolkatta, 2014 : 322-30.

12. Verma N and Shukla, S – Prospects of plant biotechnology for crop improvement in modern era. *In* : New Approaches for Fast Forward Agricultural Production (Eds. CP Malik, Hi Bhati–Kushwaha and R Kaur). *Agrobios (India*), Agro House, Jodhpur, 2015 : 1-24.

Popular Articles

1. Ali A and Rai UN – Role of Prokaryotes for Arsenic Reduction and Detoxification in rice. *Environews*, 2015, **21** : 06-07.

2. Batra A and Dwivedi AK – Research – Blooming garden with mini Chrysanthemum. *Floriculture Today*, 2014, **19**(4) : 30-32

3. Rastogi RR, Singh S, Sharma G and Roy RK – Splash colour in the landscape by Bougainvilleas. *Indian Bougainvillea Annual*, 2015, **26** :23-26.

4. Roy RK, Rastogi RR, Singh S and Goel AK – Some outstanding Bougainvillea varieties with leaf variegation for ornamental gardens. *Floriculture Today*, 2014, **19**(2) : 22-24.

5. Roy RK – New Gladiolus Varieties from CSIR-NBRI for Commercial Floriculture. *Floriculture Today*, 2014, **19**(12): 20-22.

6. Roy RK, Rastogi RR, Singh S and Prasad R – Urban green spaces and landscapes : Key to clean and healthy environment. *Environews*, 2014, **20**(3) : 6-7.

7. Roy RK, Singh S, Rastogi RR and Verma S – Development of new varieties of Bougainvillea : The contribution of CSIR-NBRI. *Indian Bougainvillea Annual*, 2015, **26** :11-15.

8. Verma PK, Schlauer J, Rawat KK and Giri K – Status of insectivorous plants in northeast India. *Carnivorous Pl. Newsletter*, 2014, **43** : 49-58.

9. उस्मानी एम ए, सुशीला एम आर टोप्पो के एवं शेख एस - शैवाल आहार भी हैं। *पर्यावरण चेतना*, 2015 : 24-25.

10. गोयल ए के, रॉय आर के, कुमार एस और तिवारी एस के-सी. एस.आई.आर.-राष्ट्रीय वनस्पति अनुसंधान संस्थान का वनस्पति उद्यान शिक्षा, अनुसंधान और उपयोग के लिए एक राष्ट्रीय सुविधा। विज्ञान प्रगति, 2015 : 9-17.

11. टोप्पो के, बाजपेयी आर, उस्मानी एम ए एवं सुशीला एम आर - कैंसर इलाज के अनुसंधान में नील हरित शैवाल। *ज्ञान-विज्ञान*, 2014 : 49-50.

12. टोप्पो के, उस्मानी एम ए, बाजपेयी आर एव सुशीला एम आर - कैंसर में कारगर शैवाल। *पर्यावरण चेतना*, 2015 : 24-25.

13. दयाशंकर, शर्मा जी, निषाद आर सी और रॉय आर के - छत उद्यानिकीः एक अलेंत बागवानी तकनीकी. प्रादेशिक फल, *शाकभाजी एवं पुष्प प्रदर्शनी*, राजभवन फरवरी 21-22, 2015.

14. दयाशंकर, शर्मा जी, निषाद आर सी और रॉय आर के - छत उद्यानिकीः एक अलेंत बागवानी तकनीकी. *प्रादेशिक फल, शाकभाजी एवं पुष्प प्रदर्शनी*, राजभवन फरवरी 21-22, 2015.

15. बत्रा ए एवं द्विवेदी ए के - "फूलों की रानी गुलदाउदी", *कृषक श्रंखला*, 2014, अंक 7, पृष्ठ 37-39.

16. बत्रा ए एवं द्विवेदी ए के - "फूलों की रानी गुलदाउदी". *कृषक श्रंखला*, 2014, अंक 7 : 37-39.

17. राय, यू एन- तीन-चौथाई सीवेज बिना उपचार के जा रहा है गंगा में। *पर्यावरण चेतना* (मासिक हिन्दी) आरएनआई नं०- 58573/94] 21(5), पृष्ठ 19-22.

18. राय यू एन - तीन-चौथाई सीवेज बिना उपचार के जा रहा है गंगा में। *पर्यावरण चेताना*, 2014, 21(5) : 19-22.

19. वर्मा, एस., चौधरी, आर.के., रॉय, आर.के. और गोयल ए.के. - वर्टीकल उद्यान गृह सज्जा की नई तकनीकीद्य प्रादेशिक फल, *शाकभाजी एवं पुष्प प्रदर्शनी*, राजभवन फरवरी 21-22, 2015 :46-47.

20. वर्मा एस, चौधरी आर के, रॉय आर के और गोयल ए के - वर्टीकल उद्यान गृह सज्जा की नई तकनीकी. प्रादेशिक फल, *शाकभाजी एवं पुष्प प्रदर्शनी*, राजभवन फरवरी 21-22, 2015.

21. सिंह पी के, तिवारी ए के, ओझा एस के एवं तिवारी एस के - वचा (एकोरस कैलेमस) - वाणी और बुद्धि वर्धक। *अनुसन्धान विज्ञान शोध पत्रिका*, 2014, 2(1) : 38-47.

22. श्रीवास्तव एन, सुशीला एम आर एव रूबीना एल - सूक्ष्मशैवाल एवं नील हरित शैवालों की सूक्ष्मजीवीरोधी गतिविधियां। *पर्यावरण चेतना*, 2014 : 36-38.

23. सुशीला एम आर, टोप्पो के एवं उस्मानी एम ए - शैवाल से आऐगा जैव ईधन *पर्यावरण चेतना*, 2015 : 27.

विज्ञानवाणी 2014, अंक 20

1. अस्थाना ए के एवं गुप्ता आर - भारतीय हॉनवर्ट पादपों की विविधता एवं जातिवृत्तीय महत्व का संक्षिप्त परिदृश्य : 70-73.
2. ओझा एस के - वार्षिक प्रतिवेदन 2013-14 राजभाषा कार्यान्वयन समिति : 108-109.
3. इरशाद एस, रावत ए के एस एवं खातून एस - *कोनवोलब्युलस प्लयुरिकॉलिस* ंखपुष्पी मस्तिष्क के लिए वरदान औषधीय पादप का वानस्पतिक एवं भौतिक-रासायनिक विवरण : 47-50.
4. उस्मानी एम ए, सुशीला एम आर एवं शेष एस - 'हरित स्वर्ण' शैवाल से उत्पादित बहुआयामी बायोएक्टिव घटकः 24-28.
5. उस्मानी एम ए, सुशीला एम आर, टोप्यो के एवं शेख एस - हरी शैवाला गोलन-कीनिया रैडिएट के पोषक तत्वों की रूप रेखा : 29-31.
6. कुमार ए, चतुर्वेदी वी, सिंह डी, शर्मा एस एवं तिवारी एस के - ऊसर भूमि में ईसबगोल की खेती : 62-65.
7. कुमार ए, शर्मा एल के, नैनवाल आर सी, सिंह एस, कटियार आर एस एवं तिवारी एस के - व्यक्तिगत स्वास्थ्य सुधार हेतु गुणकारी आँवला : 66-69.
8. गुप्ता एस एस, राव सी एच वी एवं ओझा एस के - एंडोग्राफीस सरपैलीफोलिया की पत्तियों से निकले फ्लेबोनायिड्स का कार्बन टेट्रोक्लोराइड से प्रेरित हेपटोटोक्सिसिटी पर प्रभाव : 32-35.
9. गोयल ए के एवं कुमार एस-वानस्पति उद्यान - जैव विविधता संरक्षण एवं उद्यान की का विशिष्ट केन्द्र : 14-16.
10. जौहरी जे के - पादप वृद्धि हेतु माइकोराइजा की उपयोगिता : 77-79.
11. टंडन ए, चौहान पी एस एवं नौटियाल सी एस - शैक (लाइकेन) अध्ययन में डी.एन.ए. बारकोडिंग का महत्व : 12-16.
12. तिवारी आर, दुर्गापाल ए एवं चौधरी एल बी - फाइकस कृष्णाई सी. डीसी. (मोरेसी) एक बहुचर्चित अनोखा वृक्ष : 44-46.
13. दास बी - कुचला : 51-52.
14. निरंजन ए, कुमार ए, जयन्त एवं लहरी ए - सुगन्धित तेलों की गुणत्ता परीक्षण : 36-38.
15. प्रकाश ए, रावत के के एवं वर्मा पी सी - उत्तर प्रदेश का मूल सीमित देशज, एक मातृ प्रजातीय, विलुप्त प्राय संकटग्रस्त, संरक्षण अपेक्षी पादप, हाथी पउला, इन्डोपिप्टा-डेनिया अवधेसिसः 39-43.
16. बत्रा ए एवं द्विवेदी ए के - कोलियस एक शोभाकारी पौधा : 53-55.
17. मिश्र जी के एवं उप्रेती डी के - शैक (लाइकेन) अध्ययन में डी.एन.ए. बारकोडिंग का महत्व : 12-13.
18. मोतीलाल एवं राही टी एस - ऊसर भूमि सुधार द्वारा कृषि उत्पादन में वृद्धि : 56-61.
19. रावत पी एवं पाल एम - फाइकस रेसिमोसा से 9-एमारिन एसिटेट के निष्कर्षण की नवीन विधि : 20-23.
20. शुक्ला आर पी, सिंह वी एवं मोहन्ती सी एस-बहुपयोगी एवं बहुगुणकारी चौकोरी सेम : 74-76.
21. सिंह बी एन एवं रावत ए के एस - पारम्परिक लघु धान्य अनाजों का वैज्ञानिक अवलोकन एवं इनका मानव स्वास्थ्य में महत्व : 80-82.
22. श्रीवास्तव वी, गौनियाल ए के एवं राय ए के - उच्च शिक्षा सेवा सम्बन्धित क्षेत्र में गुणवत्ता : एक समीक्षा : 83-86
23. श्रीवास्तव एम, आरिफ मो एवं उप्रेती डी के - अस्निक अम्ल की जैविक एवं औद्योगिक उपयोगिताएं : 17-19

PATENTS GRANTED / FILED

PATENTS GRANTED

Sl. No.	Title	Inventors	Complete Filing date	Country & Grant date	Patent No.
1.	A gene for inducing male sterility in plants	Sawant SV, Tuli R and Singh SP	10/08/2011	US/29/04/2014	8710301

PATENTS FILED

Sl. No.	Title	Inventors	Country	Filling Date/Application No.
1.	Herbal composition for the management of diabetes	Nautiyal CS, Rao ChV, Ojha SK, Rawat AKS, Mani D, Pal A and Kumar D	India	12/06/2014/1591DEL2014
2.	A synergistic pharmaceutical composition for gastrointestinal disorders	Pandey G, Rao ChV, Sidhu OP, Rawat AKS and Nautiyal CS	India USA	25/06/2014/1698DEL2014 19/11/2014/14/547296
3.	A novel insecticidal protein toxic to whiteflies and lepidopteran caterpillars, toxin encoding gene and its application thereof	Singh PK, Singh R, Chandrashekar K, Rai P, Saurabh S, Upadhyay SK, Singh H, Mishra M, Singh AP, Verma PC, Nair KN and Tuli R	India	12/11/2014/3265DEL2014
4.	A wound inducible expression construct sand a method of its preparation	Sane AP, Pandey RA, Saurabh P and Singh AP	India	23/12/2014/3865DEL2014
5.	A novel formulation for improving the yield and quality of fiber in cotton plants	Sawant SV, Singh SK, Singh B and Bhattacharya P	India	28/01/2015/0231DEL2015
6.	Blood detoxifying composition used in liver disorders	Upreti DK, Rao ChV, Rana TS, Nayaka S, Rawat AKS, Hariharan GSN, Bajpai R and Sharma J	India	11/03/2015/0660DEL2015
7.	A process for preparation of a novel insecticidal chitinase toxic against whiteflies, its encoding nucleotides and application thereof	Singh PK, Upadhyay SK, Chandrashekar K, Saurabh S, Singh R, Rai P, Singh H, Mishra M, Singh AP, Verma PC, Nair KN and Tuli R	Europe South Africa Canada Australia Brazil USA Mexico	17/06/2014/12824781.4 24/06/2014/2014/04656 25/06/2014 25/06/2014/ 2012360018 26/06/2014/BR1120140159300 27/06/2014/14/369610 27/07/2014/ MX/A/2014/007944
8.	*Allium fistulosum* leaf agglutinin protein, its encoding gene, primer and process for prepation thereof	Singh PK, Rai P, Singh R , Upadhyay SK, Saurabh S, Singh H, Verma PC, Chandrashekar K and Tuli R	BR CN US CA	30/06/2014/ BR1120140162549 28/08/2014/201280070840.4 24/06/2014/14/368443 25/06/2014/2861158
9.	A novel formulation for polyherbal masticatory product useful for tobacco de-addiction and health rejuvenation	Nautiyal CS, Kumar D, Rawat AKS, Agarwal S, Mani D, Ojha SK, Pal A, Rao ChV, Darokar MP and Kalra A	WO	04/07/2014/PCT/IN2014/000446
10.	A method for production of transgenic cotton plant	Sawant SV, Tripathi RK and Aasif I	WO	13/10/2014/ PCT/IN2014/000651

HUMAN RESOURCE DEVELOPMENT

TRAININGS/WORKSHOPS/EXHIBITIONS ATTENDED

Sl. No.	Name of Scientist(s)	Subject of Training Course/Workshop	Places/Organizers	Date/Period
1.	Dr. Lal Bahadur	a) Improving agricultural productivity in the backdrop of depleting natural resources and changing climate conditions	U.P. Council of Agricultural Research, Lucknow	May 06, 2014
		b) Integrating extension agencies for improving the impact of agricultural extension		May 08, 2014
		c) Augmentation of soil and crop productivity through organic	G. B. Pant University of Agriculture & Technology, Pantnagar	September 26 to October16, 2014
		d) Climate Change Vulnerabilities and Adaptation Strategies	Indian Council of Forestry Research and Education, Dehrudun	February 2-6, 2015
2.	Dr. D Singh	a) Improving agricultural productivity in the backdrop of depleting natural resources and changing climate conditions	U.P. Council of Agricultural Research, Lucknow	May 06, 2014
		b) Integrating extension agencies for improving the impact of agricultural extension		May 08, 2014
3.	BL Meena	a) Patent Information	CSIR-CDRI, Lucknow	March 19, 2015
4.	V Srivastava	a) Indian Industries Association b) Patent Information	Lucknow CSIR-CDRI, Lucknow	February 18, 2015 March 19, 2015

TRAINING IMPARTED

a) Group Trainings/Workshops

A summary of extension activities, organized during the year, under CSIR-800 and other projects is provided in the following table :

Sl. No.	Number of participants	Subject of the Training Course/Workshop	Sponsoring Agency	Date/Period
1.	300 farmers	Biofertilizer & MAPs programme	CSIR & RKVY	Apr 01, 2014
2.	12 teachers 200 students	Workshop on Dehydrated Floral Craft	CSIR	Sept 12, 2014
3.	40 Officers of Biofertilizers	Training program organized for Officers of Biofertilizer companies	RKVY	Sept 20, 2014
4.	25 Teachers	Faculty Motivation and Teacher's Training Programme	CSIR	Oct 30-31, 2014
5.	70 farmers	Farmers Interaction Meet	RKVY	Nov 14, 2014
6.	40 teachers 150 students	Workshop on Dehydrated Floral Crafts	CSIR	Nov 29, 2014
7.	580 farmers	Participated in Kisan Mela, organized by CSIR- Central Institute of Medicinal and Aromatic Plants (CSIR-CIMAP), Lucknow	RKVY	Jan 31, 2015
8.	08 teachers 60 students	Workshop on "Health through Herbs" in rural school	CSIR	Feb 07, 2015
9.	280 farmers	Biofertilizer Training Programme	RKVY	Feb 22, 2015
10.	260 farmers	Biofertilizer Training Programme	RKVY	Feb 28, 2015
11.	290 farmers	Biofertilizer Training Programme	RKVY	Mar 01, 2015
12.	33 farmers	Demo of Improved Betelvine Production System	CSIR	Mar 13, 2015
13.	242 farmers	Kisan Mela	CSIR	Mar 20, 2015

b) Individual Trainings

1. Fifty-three post-graduate students of different universities/institutes were imparted training on various topics of their interest, during April 2014 to March 2015. A sum of ₹ 7,30,000.00 was realized from them as training fee.

HONOURS/AWARDS/DISTINCTIONS

Honours/Awards/Recognitions

Dr. CS Nautiyal Honoured with J. C. Bose National Fellowship

Dr. CS Nautiyal, Director, CSIR-NBRI has been awarded the prestigious 'J. C. BOSE NATIONAL FELLOWSHIP' by the Department of Science and Technology (DST), Ministry of Science and Technology, Government of India. The fellowship is meant to recognize active scientists and engineers for their outstanding performance and contributions.

This Fellowship is conferred to Dr. Nautiyal for his eminence and contributions in the field of exploring ecosystem friendly approaches to unravel the science behind plant-microbe interactions that he has constantly pursued for three decades. Dr. Nautiyal has developed novel technologies that have enabled rapid screening and selection of useful plant growth promoting microbes that impart plant tolerance to salt, drought, and pathogenic microorganisms. Major spin-off of his contributions has been several patents, publications and utilization of these technologies by several biotechnology companies nationally and internationally.

The J. C. Bose National Fellowship carries an honorarium of Rs. 25,000/- per month in addition to regular salary. A contingency of Rs.10 lakhs per annum is provided towards conference participation and other expenses.

Sl. No.	Scientist(s)	Award(s)
1.	Agnihotri P	**Dr. A.P. Das Biodiversity Medal 2014 by the East Himalayan Society for Spermatophyte Taxonomy (EHSST)**
2.	Chauhan PS	**Innovative Young Scientist Award** by Asian PGPR Society for Sustainable Agriculture, Hyderabad, for contributions in the field of Agricultural Microbiology
3.	Goel AK	**B. A. Razi Medal - 2014** by the Association for Plant Taxonomy
4.	Husain T	**B. A. Razi Medal - 2014** by the Association for Plant Taxonomy
5.	Khare PB	**S S Bir Medal – 2014** by the Association for Plant Taxonomy
6.	Little AC	For outstanding contributions in the field of World Photography Day on August 19, 2014 by Meerut Camera Club, Meerut
7.	Pandey G, Chauhan PS, Rao ChV and Rawat AKS	**Best Research Paper Poster Award** in International Conference on Medicinal Plants: Resource for Affordable New Generation Healthcare, held at Indira Gandhi Pratishthan, Lucknow, India, organized by CSIR-CIMAP, Lucknow on 20-22 March, 2015
8.	Pandey MM, Rastogi S and Rawat AKS	**Best Research Paper Poster Award** in International Conference on Medicinal Plants: Resource for Affordable New Generation Healthcare, held at Indira Gandhi Pratishthan, Lucknow, India, organized by CSIR-CIMAP, Lucknow on 20-22 March, 2015
9.	Rawat AKS	SFE-ZANDU Award-2015 for the best research on "Plant Drugs" , by Society For Ethnopharmacology (SFE-INDIA)
10.	Shukla MK	**Lab to Land Award (2014)** by NCSTC, DST, Govt. of India and Marshal Art Society for conducting Science programmes in rural area
11.	Singh D	**Young Scientist Award** by Astha Foundation, Meerut (UP)

Member/Editor, Referee, Expert, Reviewer, Judge, etc. (selected, recognized, enrolled, empanelled, nominated)

1.	Agnihotri P	i) Fellow of the Society of Ethnobotanists for the year 2014 ii) Fellow of Association for Plant Taxonomy for the year 2014
2.	Asthana AK	Reviewer for the *J. National Academy Sci. Letters,* Taiwania
3.	Khatoon S	Reviewer of Asian Journal of Plant Sciences, International Journal of Botany, Research Journal of Medicinal Plant Research, Reviewer for various scientific journals viz., Journal of AOAC International, JPC-Planar Chromatography, Journal of Ethnopharmacology, Indian Journal of Traditional Knowledge, Ethnobotany and Pharmaceutical Biology; Secretary, Society of Ethnobotanists
4.	Nayaka S	I) Life Member of National Academy of Biological Sciences (NABS), Chennai II) Life Member of Mycological Society of India (MSI), Chennai III) Life Member of International Association for Lichenology (IAL), UK

5.	Rahi TS	Life member of Indian Society of Soil Science
6.	Rai UN	i) Life member of Society of Tropical Plant Research, India
7.	Raj SK	ii) Editor in Chief of *Asian Journal of Plant Pathology* iii) Reviewer of *Current Sciences, Journal of Biosciences, Indian Journal of Virology, Phytoparasitica, Journal of Phytopathology, Acta Physiologiae Plantarum, African Journal of Biotechnology* and *Phytoparasitica*
8.	Rao ChV	Member, Indian Pharmacy Graduates Association (IPGA) Reviewer of *Journal of Food Chemistry, Journal of Ethnopharmacology, Journal of Experimental Biology*
9.	Rastogi S	Life Member of Society for Ethno-Pharmacology
10.	Rawat KK	Fellow of Association for Plant Taxonomy (FAPT)
11.	Roy RK	Reviewer for Indian Journal of Experimental Biology
12.	Rawat AKS	Reviewer for various national & international scientific journals viz. Journal of Ethnopharmacology, Pharmaceutical Biology, JPC-Planar Chromatography
13.	Singh BN	Life Member of Society for Ethno-pharmacology
14.	Shirke PA	Life Member of the International Society Environmental Botanists
15.	Singh AP	Life Member of The Society of Plant Reproductive Biologists, The International Journal of Plant Reproductive Biology and The Palaeobotanical Society and Geophytology
16.	Trivedi PK	i) Fellow of National Academy of Sciences, India (FNASc)-2014 ii) Academic Editor, *PLoS One* iii) Editorial Board Member, *Scientific Reports*
17.	Yadav HK	Life member of UP Academy of Agricultural Sciences (UPAAS), Lucknow

Recognition as Guides/Co-ordinators/Examiners, etc.

Sl. No.	Scientist(s)	Universities/Institutions
1.	Rao ChV	Recognised as Ph. D Guide of Ravenshaw University, Cuttack; Lucknow University, Lucknow; Amity University, Lucknow

Ph.D. Awarded

1. Ms. Anshita Raj

Approaches/ Strategies for the Phytoremediation of Arsenic from Polluted Environment Soil/Water

Supervisors : Dr. Nandita Singh, Principal Scientist, CSIR-NBRI, Lucknow and **Prof. YK Sharma**, University of Lucknow

University : University of Lucknow

2. Ms. Arti Rai

Genomics of arsenic stress in arsenic accumulating contrasting rice genotypes

Supervisor : Dr. Debasis Chakrabarty, Scientist, CSIR-NBRI, Lucknow

University : AcSIR, New Delhi

3. Ms. Babita Kumari

Investigations on bioremediation of petroleum crude oil contaminated soils

Supervisors: **Dr. SN Singh**, Chief Scientist, CSIR-NBRI, Lucknow and **Prof. DP Singh**, Babasaheb Bhimrao Ambedkar University, Lucknow

University : Babasaheb Bhimrao Ambedkar University, Lucknow

4. Mr. Karmveer Kumar Gautam

Molecular detection and characterization of strains of *Cucumber mosaic virus* infecting *Petunia* and *Gerbera* and their disease management

Supervisors: Dr SK Raj, Chief Scientist, CSIR-NBRI, Lucknow and **Dr. Ratna Katiyar,** Associate Professor, Department of Botany, University of Lucknow, Lucknow

University: University of Lucknow

5. Mr. Manish Tiwari

Functional characterization of genes encoding arsenic responsive transporters from rice (*Oryza sativa*)

Supervisors: Dr. Prabodh Kumar Trivedi, Scientist, CSIR-NBRI, Lucknow and **Dr. M Singh,** Lucknow University

University: University of Lucknow

6. Ms. Manju Shri

Development of transgenic rice for low grain arsenic

Supervisor : **Dr. Debasis Chakrabarty**, Scientist, CSIR-NBRI, Lucknow

University : AcSIR, New Delhi

7. Ms. Namrta Choudhary

Seasonal variation in some important herbal drugs used in Indian pharmaceutical industries

Supervisor : Dr. Sayyada Khatoon, Scientist, CSIR-NBRI, Lucknow

University : Aligarh Muslim University, Aligarh

8. Ms. Sonali Dubey

Genome-wide modulation in rice root transcriptome during different heavy metal stress

Supervisors : **Dr.D. Chakrabarty,** Scientist, CSIR-NBRI, Lucknow and **Dr. Prabodh Kumar Trivedi,** AcSIR, CSIR-NBRI, Lucknow

University : AcSIR, New Delhi

9. Ms. Pooja Bansal

Morphotaxonomic studies on the genus *Bryum* Hedw. (Moss) in India

Supervisors : Dr. V Nath, Emeritus Scientist, CSIR-NBRI, Lucknow and **Prof. Neerja Pande**, Kumaun University, Nainital.

University : Kumaun University, Nainital

10. Mrs. Priya Srivastava

Screening of antimicrobial properties of some Indian lichens against human pathogens

Supervisors : Dr. DK Upreti, Chief Scientist, CSIR-NBRI, Lucknow

University : Dr. RML Avadh University, Faizabad

11. Ms. Sadhna Tiwari

Bioremediation of toxic metals from fly ash by plants coupled with microbial augmentation

Supervisor : Dr. SN Singh, Chief Scientist, CSIR-NBRI, Lucknow and **Prof. SK Garg**, RML Avadh University, Faizabad

University : Dr. RML Avadh University, Faizabad

12. Mr. Smita Kumar

Functional genomics of members of sulphate transporter and glutathione S-transferase gene families involved in arsenic stress in rice

Supervisors : Dr. Prabodh Kumar Trivedi, Scientist, CSIR-NBRI, Lucknow and **Dr. RS Dubey,** BHU, Varanasi

University: Banaras Hindu Varanasi

13. Mr.Sumya Pathak

Elucidation of papaverine biosynthesis pathway by comparative transcriptome analysis of contrasting *Papaver somniferum* L. germplasm lines

Supervisors : Dr. Prabodh Kumar Trivedi, Scientist, CSIR-NBRI, Lucknow and **Prof. V.K. Joshi** Banaras Hindu University, Varanasi

University: Banaras Hindu University, Varanasi

14. Mrs. Parul Gupta

Comparative transcriptome analysis of different chemotypes of *Withania somnifera*

Supervisors : Dr Prabodh Kumar Trivedi, Scientist, CSIR-NBRI, Lucknow and **Prof. SP Singh,** Banaras Hindu University, Varanasi

University: Banaras Hindu University, Varanasi

15. Ms. Reesa Gupta

Assessment of Bryodiversity of Pachmarhi Biospehere Reserve

Supervisors : Dr. V Nath, Emeritus Scientist, CSIR-NBRI, Lucknow and **Prof. Neerja Pande**, Kumaun University, Nainital.

University: Kumaun University, Nainital

16. Ms. Vandana Singh

Bioremediation of endosulfan contaminated soils by using selected plant species and rhizospheric microbial strains

Supervisor : Dr. N Singh, Principal Scientist, CSIR-NBRI, Lucknow

University : AcSIR, New Delhi

Ph.D. Theses Submitted

1. Mr. Ashish Srivastava

Molecular characterization and identification of begomovirus/es affecting Amaranth and Poppy grown in India.

Supervisors : Dr SK Raj, Chief Scientist, CSIR-NBRI, Lucknow and **Dr. S S Pande**, Director, RGBC, RTM Nagpur University, Nagpur

University : Rashtrasant Tukadoji Maharaj Nagpur University, Nagpur

2. Mr. Krishna Mohan Rai

Exploring the role of JMJC domain containing histone demethylases in epigenetetic regulation of cotton fiber development

Supervisors : Dr. SV. Sawant, Principal Scientist, CSIR-NBRI, Lucknow and **Dr. Veena Pande** and **Dr. KK Pande**, Kumaun University, Nainital

University : Kumaun University, Nainital

3. Ms. Manjul Gupta

Development of vermicompost based soil formulation and evaluation of its potential for crop production in sodic soil

Supervisors : Dr. SK Tewari, Sr. Principal Scientist, CSIR-NBRI, Lucknow and **Dr. Shikha,** Babasaheb Bhimrao Ambedkar University, Lucknow

University : Babasaheb Bhimrao Ambedkar University, Lucknow

4. Mr. Manoj Kumar Mishra

Functional genomics of sterol glycosyltransferase gene (SGT) family members of *Withania somnifera* using SGT knockout mutant of *Arabidopsis thaliana*

Supervisors : Dr. Pratibha Misra, Sr. Principal Scientist, CSIR-NBRI, Lucknow and **Dr. Nishi Kumari,** Banaras Hindu University

University : , Banaras Hindu University, Varanasi

5. Ms. Neha Karakoti

Ecophysiological attributes of selected lichen species of Garhwal Himalayas along an altitudinal gradient

Supervisor : Dr. DK Upreti, Chief Scientist, CSIR-NBRI, Lucknow

University : Kumaun University, Nainital

6. Ms. Neha Pandey

The functional characterization of Calmodulin binding transcription activator (CAMTA) in response to drought stress in plant

Supervisors : Dr. SV Sawant, Principal Scientist, CSIR-NBRI, Lucknow and **Dr. HP Pandey,** Banaras Hindu University, Varanasi

University : Banaras Hindu University, Varanasi

7. Ms. Pratibha Tripathi

Studies on characterisation stress tolerate *Trichoderma* isolate for application in arsenic contaminated soils

Guides : Dr. CS Nautiyal and Dr. RD Tripathi, Chief Scientist, CSIR-NBRI, Lucknow and Dr. RT Bais, Barkatullah University, Bhopal, M.P.

University : Barkatullah University, Bhopal

8. Ms. Priya Gupta

Genetic diversity analysis of *Jatropha curcas* L. using Single Nucleotide Polymorphism (SNP)

Supervisors : Drs. SV Sawant, Principal Scientist and **CS Mohanty**, Sr. Scientist, CSIR-NBRI, Lucknow

University : AcSIR, New Delhi

9. Mr. Rajeev Tripathi

Functional validation of *SQUAMOSA* promoter binding like (SPL) transcription factor in cotton fiber development

Supervisors : Dr. SV. Sawant, Principal Scientist , CSIR-NBRI, Lucknow and **Dr. Veena Pande** and **Dr. KK Pande**, Kumaun University, Nainital

University : Kumaun University, Nainital

10. Ms Rajluxmi

Role of SIN3, a global transcriptional regulator, in plant growth and development

Supervisors : Dr AP Sane, Principal Scientist, CSIR-NBRI, Lucknow

University : AcSIR, New Delhi

11. Mr. Ramanuj Maurya

Development and application of microsatellite markers for diversity analysis in *Jatropha curcas* L.

Supervisor: Dr. HK Yadav, Senior Scientist, CSIR-NBRI, Lucknow and **Dr. Ratna Katiyar**, Lucknow University

University: University of Lucknow

12. Ms.Vibha Pandey

Functional analysis of sterol glycosyltransferase gene family members of *Withania somnifera*

Supervisor: Dr. P Misra, Principal Scientist, CSIR-NBRI, Lucknow and **Dr. Neelam Atri**, Banaras Hindu University

University: Banaras Hindu University, Varanasi

DATELINE

Sl. No.	Date	Salient details
1.	April 29, 2014	A Task Force Meeting was organized at the Institute to discuss and finalize the DUS Test Guidelines for the two mandate crops *viz. Canna* and *Gladiolus*. Dr. G Kalloo, Ex. DDG (Hort. & CS), ICAR Hq., New Delhi, was the Chairman of the Task Force Committee. The members of the Committee visited all conservatories as well as the germplasm collection of DUS Test Crops *viz. Bougainvillea, Canna* and *Gladiolus* in the Botanic Garden. Dr. G Kalloo, Chairman, in his opening remarks briefed about the 1st Task Force Meeting held at PPV & FRA, New Delhi on February 4, 2014 and lauded CSIR-NBRI for efforts made for the maintenance of mandate crops in the Botanic Garden. Dr. RC Agarwal, Registrar General, PPV & FRA, explained his observations on mandate crops as per the DUS Test Guidelines. Drs. AK Goel and S Kumar, Scientists, made detailed presentations on *Canna* and *Gladiolus* crops. The members of the task force comprising Drs. UG Nalavadi, RL Mishra and Tejbir Singh, deliberated in the discussions to finalize the DUS test guidelines for *Canna* and *Gladiolus*.
2.	May 13, 2014	CSIR-NBRI celebrated **National Technology Day** on May 13, 2014. The day was observed as 'Open Day' and its various laboratories, *viz.*, Exposition, Herbarium, Library, Botanic Garden, various R&D Laboratories were visited by a large number of students drawn from various local schools and colleges. On this occasion, Prof. Ravi Kant, a renowned surgeon and Vice Chancellor, King George's Medical University, Lucknow, was the Chief Guest of the function and delivered the National Technology Day Lecture. Distinguished guests, scientists and staff of CSIR-NBRI, researchers and a number of students were present on the occasion. On this occasion, technology for 'NBRMAP-DB, a safe hypoglycaemic herbal formulation', was for transferred to M/s Aimil Pharmaceuticals, New Delhi. This novel formulation for the management of diabetes was jointly developed by CSIR-NBRI and CSIR-CIMAP, Lucknow.
3.	May 21, 2014	**Anti-terrorism Day**
4.	May 30, 2014	A garden competition (**Dil Bag-Bag Ho Jaye**) for the home gardens in Lucknow city was organized jointly by CSIR-NBRI and Dainik Jagran, Lucknow, during February, 2014. It had two catagories *viz.,* Garden Area less than 50 sq.m and Garden Area more than 50 sq.m. The judges visited the shortlisted gardens after the preliminary screening and in each category, three prizes were awarded. The prize distribution function was held at the Institute on May 30, 2014. Dr. CS Nautiyal, Director, CSIR-NBRI, was the Chief Guest of the function and gave away the prizes to the winners.
5.	June 5, 2014	The '**World Environment Day**' was observed on June 5, 2014. The theme of this year was 'Raise your voice, not the sea level'. A 'Quiz Competition' was organized for 25 students of XII+ (science background) from National Post Graduate College, Lucknow.
6	August 14, 2014	CSIR-NBRI participated in a health camp organized by CSIR-CIMAP at Dau village in Unnao district of Uttar Pradesh on 14th August, 2014 under the project on 'S&T Interventions to Combat Malnutrition in Women and Children'. CSIR-NBRI products and posters were exhibited at the health camp and scientists interacted with the participants. Data regarding health status of about 500 children, young girls, women and men, were collected for the selection of persons to whom the nutritional products be distributed to combat malnutrition. Nutri-Jam, a nutraceutical product of CSIR-NBRI, was distributed to selected beneficiaries.
7.	August 15, 2014	**Independence Day**
8.	August 20, 2014	**Sadbhavna Diwas**
9.	September 12, 2014	The training-cum workshop programme on **dehydrated floral craft technology** of CSIR-NBRI was organized for teachers and students of Mahila Degree College, Aminabad, Lucknow under the CSIR Faculty Training Programme on Motivation and Adoption of Schools and Colleges. The workshop was attended by about a dozen teachers and 200 students. Dr. SK Tewari, Senior Principal Scientist explained the details of dehydrated floral crafts. The students participated in the workshop in five groups and made beautiful greeting cards and wall hangings from dry flowers.

Sl. No.	Date	Salient details
10.	सितम्बर 1-15, 2014	सीएसआईआर–राष्ट्रीय वनस्पति अनुसंधान संस्थान, लखनऊ द्वारा सितम्बर 1–15, 2014 के मध्य हिन्द पखवाड़ा का आयोजन किया गया। जिसके अंतर्गत अधिकारियों व कर्मचारियों के लिए विभिन्न हिन्दी प्रतियोगिताओं व कार्यशाला का आयोजन किया गया। 02 सितम्बर, 2014, प्रथम कार्यशाला आयोजित की गई जिसमें डॉ. विजय नारायण तिवारी, वरिष्ठ हिन्दी अधिकारी, सीएसआईआर–सीडीआरआई, लखनऊ ने "तनाव प्रबन्धन" पर अपना व्याख्यान दिया। हिन्दी पखवाड़े का समापन सितम्बर 15, 2014 को हिन्दी दिवस समारोह के रूप में मनाया गया। इस समारोह के मुख्य अतिथि सुप्रसिद्ध अवधविद डा. योगेश प्रवीन थे। संस्थान पुस्तकालय में आयोजित हिन्दी पुस्तकों की प्रदर्शनी का उद्घाटन डा. योगेश प्रवीन एवं डॉ. चन्द्रशेखर नौटियाल, निदेशक द्वारा किया गया।
11.	September 26, 2014	CSIR-NBRI observed "Open Day" on September 26, 2014 to commemorate the **Foundation Day** of the Council of Scientific & Industrial Research. On this occasion, Laboratories, Botanic Garden, Herbarium, Exposition, Library and Banthra Research Station of the Institute remained open to public from 11.00 am to 4.00 pm. A large number of students, researchers and general public visited the Institute's laboratories and other facilities. Prof. Akhilesh Kumar Tyagi, Director, National Institute of Plant Genome Research (NIPGR), New Delhi, graced the occasion as Chief Guest and delivered the Foundation Day Lecture on the topic "Seeds of Dialogue". Prof. Akhilesh K Tyagi, distributed certificates and mementoes to 21 employees who have completed 25 years of CSIR service and 27 employees who retired in 2013. Prof. Tyagi also distributed prizes and certificates to those children of staff who participated and won in the Science Essay competition organized by the Institute.
12.	September 27, 2014	The ENVIS unit of CSIR-NBRI initiated a **cleanliness campaign** on September 27, 2014. Dr. N Singh, Principal Scientist, along with her team organized lectures for a group of vegetable vendors in Lucknow and made them aware of cleanliness and how they could contribute towards it through simple efforts. Dr. Pankaj Srivastava, Scientist, apprised the research scholors of CSIR-NBRI about the importance of vermicompost and demonstrated the formation of manure from degradable waste. The ENVIS staff made a door to door campaign on 'Clean India' mission. A school cleaniless drive along with the school staff and students was undertaken at Saraswati Prathmic Vidyalaya, Lucknow.
13.	October 2, 2014	A cleanliness campaign was initiated by Dr. CS Nautiyal, Director, CSIR-National Botanical Research Institute, Lucknow, along with scientists and other staff members to support the Prime Minister's call for **"Swachh Bharat Mission".** A 'Swachhta Shapath' (pledge) was administered to all the staff members by Dr. Nautiyal on October 2, 2014. Marathon sweeping and cleaning steps were taken by the Director and staff at the KN Kaul Block Lawn of the Institute and at the botanic garden campus and laboratories afterwards. Dr. CS Nautiyal specially mentioned that it was a regular practice of the institute that the leaf waste generated by the cleaning was transformed to compost/ vermi-compost by the scientists and field workers. It is used in the experimental fields and pots as per their requirements. Dr. Nautiyal also planted a sapling of *Plumeria* 'Blue' on this occasion.
14.	October 25, 2014	The Institute celebrated its **Annual Day** on October 25, 2014. Renowned plant geneticist of international repute, Prof. Deepak Pental, Director, Centre for Genetic Manipulation of Crop Plants (CGMCP), University of Delhi South Campus, New Delhi, was the Chief Guest and Shri Rajan Shukla, IAS, Principal Secretary, Coordination, Govt. of UP, Lucknow, presided over the function. Dr. CS Nautiyal, Director, CSIR-NBRI welcomed the dignitaries and guests and presented the Annual Report of the Institute, summarizing various activities undertaken and the major achievements made by the Institute in the past one year. The Annual Report 2013-14 was released by Prof. Deepak Pental, the Chief Guest of the function. Prof. Pental delivered the Annual Day lecture titled 'Polyploidy and Angiosperm Evolution'. Shri Rajan Shukla, released the Hindi Magazine 'Vigyan Vani'. Shri Shukla felicitated the scientists/ research scholars who published high impact research papers in different decision units of NBRI.
15.	October 30-31, 2014	A faculty training under motivation and adaptation of schools and colleges programme was organized during 30-31 October, 2014 at CSIR- NBRI, Lucknow. A number of teachers from degree colleges of Lucknow and Barabanki districts participated in the training programme to get an exposure to the advanced research and technological developments in the area of botanical research. In his inaugural address, Dr CS Nautiyal, Director, appreciated the important role the teachers play in spreading knowledge and wisdom in the society. He encouraged them for disseminating knowledge to enlighten the society.
16.	October 27 to November 1, 2014	The Institute celebrated Vigilance Awareness Week from October 27 to November 1, 2014. Dr. CS Nautiyal, Director, administered the pledge on October 27, 2014. The posters and banners were placed at various places in the Institute. Besides this, Mr. Bhanu Pratap Singh. IPS, ADG (Vigilance), U. P. Police, delivered a lecture titled, 'Combating Corruption–Technology as an enabler'.

Sl. No.	Date	Salient details
17.	November 7, 2014	A demonstration on use of PSB was conducted in Gladiolus planted at CSIR-NBRI Techvil-Dafedar ka Purwa with three varieties (American Beauty, Nova Lux and White Prosperity). Approximately 2000 treated and untreated corms of each variety were planted.
18.	November 19, 2014	**National Integration Day**
19.	November 29, 2014	A one day training-cum-demonstration workshop on **CSIR-NBRI's Dehydrated Floral Crafts",** was organized at S. N. Sen B.V. Degree College, Kanpur under the Faculty Motivation programme. Teachers and students from seven degree colleges from Kanpur participated in the workshop. The participants were imparted hand on training on techniques of various floral crafts.
20.	December 13-14, 2014	A two-day Annual Chrysanthemum and Coleus Show was organized by CSIR-NBRI, at the Botanic Garden on 13th & 14th December, 2014. At NBRI Central Lawn, the fresh and dainty Coleus, after the dew bath overnight, displayed multi coloured foliage. Besides this, cut flowers and special flower arrangements were also organized in a huge enclosure. The elegance and beauty of different varieties of flowers and foliage elated the visitors from every age group. The prize distribution function was organized at the open-air theater of the Institute, amidst the swing blooms of vast array of Chrysanthemum and splendid varieties of Coleus scattering colour and joy in the atmosphere. Honourable Shri Ram Naik, Governor of Uttar Pradesh was the Chief Guest at the closing ceremony of the flower show and Ms. Juthika Patankar, Principal Secretary to Governor, was the Guest of Honour.
21.	January 10, 2015,	A **health camp** was organised at CSIR- CIMAP, on January 10, 2015, where health checkup and malnutition status was assessed. Drs AKS Rawat, SK Ojha, MM Pandey from CSIR-NBRI partipated in the camp. Dr SK Ojha alongwith the medical team, Dr VK Agrawal and Dr Dayanandan Mani, examined the women and children suffering from malnutrition.
22.	January 17-18, 2015	CSIR-NBRI organized the **Annual Rose and Gladiolus Show** at the Botanic Garden on January 17-18, 2015. On the final day of the Show 25 running challenge cups, shields and trophies, besides 284 other prizes were awarded to the winners. Shri JS Mishra, Founder Chairman, Gomti Action Parivar, Rishikesh, was the Chief Guest and Shri Rajan Shukla, IAS, Principal Secretary, UPDASP, Gomti Nagar, Lucknow, was the Guest of Honour of the prize distribution ceremony. On this occasion 'KESAR', a new variety of Chrysanthemum developed by CSIR-NBRI, was released by the Chief Guest.
23.	January 26, 2015	**Republic Day**
24.	March 02, 2015	The **National Science Day** was celebrated by the CSIR-NBRI on March 02, 2015. The day was observed as 'Open Day' when its various laboratories, viz., Exposition, Herbarium, Library, Botanic Garden, various R&D Laboratories were visited by a large number of students from various local schools and colleges. Padma Shri Prof. R.C. Sobti, Vice Chancellor, Baba Saheb Bheemrao Ambedkar University, Lucknow, India, was the Chief Guest of the function and delivered the National Science Day Lecture. Scientists, researchers and students were present on the occasion.
25.	March 02, 2015	A programme was organized on March 02, 2015 at Distant Research Centre, Banthra, Lucknow for about 50 betelvine farmers from Lucknow, Unnao, Sitapur and Raibareilly districts. Dr R S Katiyar described the modern systems of betelvine cultivation and appraised that these techniques and improvisation of bareja are helpful for early production and protection of betelvine from excess heat in summer and frost during winter. The planting material of betelvine was also distributed to the farmers.
26.	March 4, 2015	**National Safety Day**
27.	March 20, 2015	Under the Rural Development Programme of CSIR, the Farmers' Interaction Day (Kisan Mela) and Biofertilizer Training was organized on March 20, 2015 at Banthra Research Station (BRS) of CSIR-NBRI for 200 selected farmers of Ramchaura, Kurauni, Banthra, Aurawan, Mirzapur Benti, Garhi chunauti and Newa villages, adjoining to Banthra of Lucknow district. Besides farmers, 15 post graduate students of the Deparment of Horticulture, BBAU and 27 students of Lucknow Model Public School, Banthra also visited the Mela. The programme was meant for disseminating the NBRI Green Technologies among the farmers. The full day programme was inaugurated by Dr. CS Nautiyal, Director, CSIR-NBRI.
28.	March 18-20, 2015	A training programme on Bonsai Technique was organized at CSIR-NBRI Botanic Garden on March 18-20, 2015 for the garden lovers, hobbyists, housewives and unemployed persons. The main purpose was to make them learn the techniques of Bonsai preparations so that the same could be an avenue for recreation as well as income. The training programme was inaugurated by Dr. CS Nautiyal, Director, CSIR-NBRI in presence of other senior scientists. Altogether 26 trainees took part in the programme. This is part of fulfillment of CSIR-NBRI's societal commitment and promotion of horticulture as a profession and entrepreneurship.

Glimpses of CSIR-NBRI Events

Prize Distribution for Garden Competition in collaboration with Jagaran

National Technology Day

World Environment Day

हिन्दी पखवाड़ा : पुस्तक प्रदर्शनी का उद्घाट्न

हिन्दी पखवाड़ा : कार्यशाला एवं हिन्दी दिवस समारोह

Glimpses of CSIR-NBRI Events

CSIR Foundation Day

स्वच्छता अभियान एवं पौध रोपण

Faculty Motivation Programme

Glimpses of CSIR-NBRI Events

CSIR-NBRI Annual Day Celebration

Annual Chrysanthemum & Coleus Show

Glimpses of CSIR-NBRI Events

Annual Rose and Gladiolus Show

National Science Day

Farmers' Training Programme

ACADEMY OF SCIENTIFIC AND INNOVATIVE RESEARCH (AcSIR)

(http://www.nbri.res.in/acsir.php)

The **Academy of Scientific and Innovative Research** or **AcSIR** is an Indian institute of national importance, currently head quartered in CSIR Campus, Taramani, Chennai. The Academy was established for the purpose of granting doctoral and post-doctoral degrees, through a centralized institution to manage research and development in CSIR laboratories. It was established in 2010 (Government of India resolution of June 17, 2010 and the Academy of Scientific and Innovative Research Act, 2011 notified on April 3, 2012), as an 'Institution of National Importance', with an aim of furtherance of advancement of learning and research in the field of Science & Technology and their interfaces in association with Council of Scientific and Industrial Research (CSIR), India.

The mission of the Academy is to create highest quality personnel with cross- disciplinary knowledge, aiming to provide leaders in the field of science and technology. The Academy shall primarily focus on research and imparting instructions in such a manner that the methodology is novel and off the beaten track. Further, the Academy aims to:

- nurture a research-propelled, technology-enabled, industry-linked, socially conscious higher education platform.
- achieve a seamless integration of intellectual strengths with current market needs with a people centric focus.
- develop niche capability required to bolster research efforts in futuristic science. Provide the opportunity to work on the frontier and contemporaneously challenging areas for nurturing innovation.

It is one of its kind meta-University in India with study centers in 37 laboratories and 6 units of CSIR, spread across 23 cities of India.

At present the Academy has about 2200 full-time faculty members from CSIR Laboratories, over 2000 students enrolled in various programmes and 7 non-academic staff members.

National Research Professor Prof. RA Mashelkar took charge as the first Chairperson of AcSIR, from Prof. SK Brahmachari (former Acting Chairperson of interim AcSIR) and Director General, CSIR. The Academy has received recognition from Department of Scientific and Industrial Research (DSIR), Ministry of Science & Technology, as a Scientific and Industrial Research Organization (SIRO).

AcSIR Course work option for CSIR-NBRI students

Sl. No.	Course Name	Course Number
1.	Biostatistics (Compulsory)	1-001
2.	Computation/bioinformatics (Compulsory)	1-002
3.	Basic Chemistry (Compulsory)	1-003
4.	Research Methodology, Communication/ethics/safety (Compulsory)	1-004
5.	Biotechniques and Instrumentation (Compulsory)	2-001
6.	Biology of Inheritance	2-003
7.	Genomics: Information flow in Biological System	2-005
8.	Plant Microbe Interaction	2-009
9.	Plant Environment Interaction	2-010
10.	Cell Signalling	2-012
11.	Developmental Biology-Plants	2-016
12.	Epigenetics and Chromatin Organization	2-017
13.	Homeostasis and feedback in biological systems	2-018
14.	Molecular Breeding of Plants	2-021
15.	Biodiversity	2-025
16.	Plant morphogenesis and regeneration	2-486
17.	Seminar Course (Compulsory)	3-001
18.	Cell and Tissue Engineering	3-003
19.	Climate change and Plants	3-486
20.	Bioremediation	3-487
21.	Environmental Biochemistry and Biotechnology	3-488
22.	Taxonomy and speciation	3-489
23.	Plant conservation and reproductive biology	3-490
24.	Economic Plants and Pharmacology	3-491
25.	Floriculture and Agronomy	3-492
26.	Phylogenomics – An interdisciplinary course	3-493
27.	Biofuels – An interdisciplinary course	3-494
28.	Knowledgebase Research Management and it's utilization	3-495

Students Enrolled in CSIR-NBRI AcSIR Course during 2014-15

August 2014 Batch

Sl. No.	Enrollment No.	Name of Student	Name of Supervisor
1.	10BB14A25001	Shipra Pandey	Dr. Aradhana Mishra
2.	10BB14A25002	Sonal Srivastava	Dr. Suchi Srivastava
3.	10BB14A25003	Vinay Kumar	Dr. SA Ranade
4.	10BB14A25004	Rashmi Raj	Dr. SK Raj
5.	10BB14A25005	Veenita Tomar	Dr. Manjoosha Srivastava
6.	10BB14A25006	Raghvendra Dubey	Dr. PA Shirke
7.	10BB14A25008	Rajni Gautam	Dr. SA Ranade

January 2015 Batch

Sl. No.	Enrollment No.	Name of Student	Name of Supervisor
1.	10BB15J25001	Nitanshi Jauhari	Dr. SN Singh
2.	10BB15J25004	Pooja Singh Sikarwar	Dr. SA Ranade
3.	10BB15J25007	Umesh Kumar	Dr. Hemant K Yadav
4.	10BB15J25005	Annu Lata	Dr. SA Ranade
5.	10BB15J25008	Narender Kumar	Dr. TS Rana
6.	10BB15J25003	Ram Jatan	Dr. Charulata
7.	10BB15J25002	Nishtha Mishra	Dr. Aradhana Mishra
8.	10BB15J25006	Sudhanshu Sharma	Dr. Samir V Sawant

राजभाषा यूनिट

संस्थान की राजभाषा कार्यान्वयन समिति के तत्वाधान में निम्नलिखित हिन्दी के प्रगामी प्रयोग को बढ़ावा देने से संबंधित गतिविधियाँ वर्ष 2014-15 में सफलतापूर्वक की गयी।

1. संस्थान में राजभाषा विभाग, गृह मंत्रालय, भारत सरकार द्वारा जारी दिशानिर्देशों के अनुसार समय में तिमाही बैठकों का आयोजन किया गया।
2. संस्थान के अधिकारियों तथा कर्मचारियों के लिए हिन्दी के प्रगामी प्रयोग में और भी अधिक वृद्धि लाने हेतु संस्थान के निदेशक महोदय द्वारा व्यक्तिशः आदेश जारी किए गये।
3. समय-समय पर कार्यालय ज्ञापन व सूचनायें जारी की गई जिससे संस्थान के अधिकारियों व कर्मचारियों द्वारा कार्यालयी कार्य हिन्दी में करने में वृद्धि हुई।
4. संस्थान में हिन्दी के प्रगामी प्रयोग संबंधी त्रैमासिक व छमाही रिपोर्ट तैयार कर सीएसआईआर मुख्यालय, नई दिल्ली तथा सचिव नराकास, एचएएल, लखनऊ को समय से प्रेषित की गयी जिन्हें मुख्यालय व नराकास द्वारा प्रशंसनीय कहा गया।
5. संस्थान में हिन्दी के प्रयोग में और भी अधिक वृद्धि लाने हेतु संस्थान से राजभाषा पत्रिका "विज्ञानवाणी" का प्रकाशन किया गया जिसे पिछले कई वर्षों से लखनऊ में स्थित 169 केन्द्रीय सरकार के कार्यालय में प्रकाशित पत्रिकाओं में से प्रथम स्थान प्राप्त होता रहा है जो संस्थान के लिए बहुत बड़ी उपलब्धित रही है।
6. संस्थान में हिन्दी के प्रयोग करने हेतु राजभाषा विभाग, गृहमंत्रालय द्वारा जारी दिशानिर्देशों के अनुसार संस्थान के अधिकारियों व कर्मचारियों के लिए वर्ष में चार हिन्दी कार्यशालाओं का आयोजन किया गया।
7. महाविद्यालयों से आये छात्र-छात्राओं को राजभाषा नीति, नियम अधिनियम आदि की जानकारी दी गई।
8. इसके अतिरिक्त 1 से 15 सितम्बर 2014 के बीच हिन्दी पखवाड़े का आयोजन किया गया, जिसमें विभिन्न प्रतियोगिताओं द्वारा हिन्दी में दक्षता को बढ़ाने का प्रयास किया गया इसके अलावा हिन्दी में कार्य करने वाले कर्मचारियों को प्रोत्साहन देने का भी गत वर्ष की भाँति निर्णय किया गया जिसके विजेताओं को प्रोत्साहन राशि के अलावा इसी कार्यक्रम में प्रमाण पत्र भी वितरित किए गये।

हिंदी पखवाड़े का आयोजन

सीएसआईआर-राष्ट्रीय वनस्पति अनुसंधान संस्थान लखनऊ में 1 से 15 सितंबर तक हिंदी पखवाड़ा मनाया गया। इसके अंतर्गत अधिकारियों व कर्मचारियों के लिए विभिन्न हिंदी प्रतियोगिताओं व कार्यशाला का आयोजन किया गया। दो सितंबर को प्रथम कार्यशाला में डॉ विजय नारायण तिवारी, वरिष्ठ हिंदी अधिकारी, सीएसआईआर-सीडीआरआई, लखनऊ ने तनाव प्रबंधन पर अपना व्याख्यान दिया। लगभग 140 से अधिक कर्मचारी अधिकारी व वैज्ञानिकों ने इसमें सहभागिता की। एक अन्य कार्यशाला 10 सितंबर को हुई, जिसमें उत्तर प्रदेश सचिव, सचिवालय प्रशासन विभाग श्री अंजनी कुमार वर्मा ने प्रशासनिक कर्मचारी एवं अधिकारी हिंदी टिप्पणी आलेखन तथा पत्राचार कैसे करें, विषय पर अपना व्याख्यान दिया। इसमें 50 से अधिक कर्मचारियों एवं अधिकारियों ने सहभागिता की। विभिन्न हिंदी प्रतियोगिताओं में सभी वर्ग के लोगों के लिए हिंदी ज्ञान प्रतियोगिता व वर्ग पहेली प्रतियोगिता तथा कर्मचारियों के बच्चों के लिए निबंध प्रतियोगिता आयोजित की गई।

15 सितंबर 2014 को हिंदी दिवस समारोह के पूर्व पुस्तकालय में आयोजित हिंदी पुस्तकों की प्रदर्शनी का उद्घाटन निदेशक डॉ. चंद्रशेखर नौटियाल व सुप्रसिद्ध अवधविद् डॉ. योगेश प्रवीन ने किया। हिंदी दिवस व्याख्यान मुख्य अतिथि डॉ. योगेश प्रवीन ने दिया। निदेशक डॉ. चंद्रशेखर नौटियाल ने मुख्य अतिथि का स्वागत करते हुए डॉ. योगेश प्रवीन को अंग वस्त्र और स्मृति चिन्ह प्रदान किया। संस्थान में हिंदी भाषा के ज्ञान व प्रयोग को बढ़ावा देने हेतु निदेशक डॉ चंद्रशेखर नौटियाल ने कर्मचारियों व अधिकारियों को प्रोत्साहन देने पर विशष रूप से निर्देशित किया। डॉ योगेश प्रवीन ने हिंदी और उर्दू को सगी बहन बताते हुए हिंदी भाषा की खूबियों पर प्रकाश डाला। उन्होंने लखनऊ के गली-कूचों के बारे में व लखनऊ की शायरी तथा लखनऊ के नवाबों, बेगमातों ऐतिहासिक इमारातें, लड़ाइयों का हाल बयां किया। इसके अलावा हिंदी में कार्य करने वाले कर्मचारियों को मुख्य अतिथि डॉ योगेश प्रवीन ने प्रमाण-पत्र भी वितरित किए। धन्यवाद ज्ञापन उपाध्यक्ष डॉ अनिल कुमार गोयल ने किया। कार्यक्रम का संचालन डॉ संजीव ओझा ने किया। हिंदी समारोह में बड़ी संख्या में कर्मचारियों की सहभागिता रही।

राजभाषा पत्रिका विज्ञानवाणी का विमोचन

संस्थान के वार्षिक दिवस समरोह पर राजभाषा कार्यान्वयन समिति के द्वारा प्रकाशित राजभाषा पत्रिका विज्ञानवाणी का विमोचन 25 अक्टूबर 2014 को श्री राजन शुक्ल, आई ए एस तथा ख्याति प्राप्त पादप आनुवांशिकी प्रोफेसर दीपक पेंटल, निदेशक, सेंटर फार जेनिटिक मनीपुलेशन ऑफ क्रॉप प्लांट्स (CGMCP) व डॉ चंद्रशेखर नौटियाल निदेशक, सीएसआईआर-एनबीआरआई की गरिमामयी उपस्थिति में हुआं इस अवसर पर प्रमुख वैज्ञानिक डॉ एस के राज भी उपस्थित थे।

हिन्दी कार्यशाला

संस्थान की राजभाषा कार्यान्वयन समिति के तत्वाधान में दिनांक 11.03.2015 को संस्थान के अधिकारियों व कर्मचारियों के लिए कंप्यूटर पर हिन्दी में कार्य कैसे करे विषयक हिन्दी कार्यशाला का आयोजन किया गया। इस कार्यशाला में डॉ. विजय नारायण तिवारी, वरिष्ठ हिन्दी अधिकारी सी.एस.आई.आर.-सी.डी.आर.आई., लखनऊ ने अपना व्याख्यान प्रस्तुत किया। कार्यशाला की अध्यक्षता वरिष्ठतम वैज्ञानिक डॉ. डी.के. उप्रेती ने की। इस अवसर पर डॉ. विजय नारायण तिवारी ने बताया कि यूनिकोड द्वारा राजभाषा का प्रयोग अत्यन्त संरल है। माइक्रोसाफ्ट हिन्दी टूल को डाऊनलोड करके कंप्यूटर पर सरला से हिन्दी भाषा में कार्य किया जा सकता है। मंच का संचालन सचिव रा.का.स. डॉ. संजीव कुमार ओझा ने कराते हुये निदेशक महोदय का आभार व्यक्त किया। धन्यवाद प्रस्ताव उपाध्यक्ष रा.का.स. डॉ. ए.के.एस. रावत ने दिया। इस कार्यशाला में संस्थान के 100 से अधिक अधिकारियों व कर्मचारियों ने भाग लिया।

RESEARCH COUNCIL

Prof. SK Sopory Vice Chancellor Jawaharlal Nehru University **NEW DELHI – 110 067**	Chairman	**Dr. Ehrlich Desa** CSIR Distinguished Scientist CSIR-4 PI, NAL Belur Campus **BENGALURU-560 037**	Member
Prof. R Uma Shankar Professor & Head Crop Physiology University of Agricultural Sciences GKVK **BENGALURU-560 065**	Member	**Dr. KC Gupta** Director CSIR- Indian Institute of Toxicology Research M G Marg, P. B. No. 80 **LUCKNOW – 226 001**	Member
Prof. PK Gupta Hon. Emeritus Professor & NASI Senior Scientist Department of Genetics & Plant Breeding, Ch. Charan Singh University **MEERUT – 2500 04**	Member	**Dr. PS Ahuja** Director CSIR-Institute of Himalayan Bioresource Technology Palampur (Holta), Distt. Kangara **PALAMPUR - 176 061**	Member
Prof. JS Singh Professor Emeritus Department of Botany Banaras Hindu University **VARANASI-221 005**	Member	**Dr. CS Nautiyal** Director CSIR-National Botanical Research Institute Rana Pratap Marg **LUCKNOW – 226 001**	Member
Prof. JP Khurana Coordinator and Head Department of Plant Molecular Biology University of Delhi, South Campus Benito Juraj Marg **NEW DELHI-110021**	Member	**Dr. Sudeep Kumar** Head or his Nominee Planning & Performance Division, CSIR Anusandhan Bhawan, 2, Rafi Marg **NEW DELHI – 110001**	Member
Prof. Sunil Kumar Mukherjee NASI-Sr. Scientist Platinum Jubilee Fellow Genetics Department University of Delhi, South Campus Benito Juraj Marg **NEW DELHI-110021**	Member	**Prof. V Verma** Dean Faculty of Engineering, Director School of Biotechnology Shri Mata Vaishno Devi University **JAMMU**	Member
Dr. Paramjit Singh Director Botanical Survey of India CGO Complex Salt Lake City **KOLKATA – 700 064**	Member	**Dr. SK Tewari** Senior Principal Scientist CSIR-National Botanical Research Institute Rana Pratap Marg **LUCKNOW – 226 001**	Member-Secretary

MANAGEMENT COUNCIL

Dr. CS Nautiyal Director CSIR-National Botanical Research Institute **LUCKNOW - 226 001**	Chairman
Dr. Ram Rajsekharan Director CSIR-Central Food Technological Research Institute **MYSORE**	Member
Dr. DK Upreti Chief Scientist CSIR-National Botanical Research Institute **LUCKNOW - 226 001**	Member
Dr. AK Gauniyal Senior Principal Scientist CSIR-National Botanical Research Institute **LUCKNOW - 226 001**	Member
Dr. ChV Rao Principal Scientist CSIR-National Botanical Research Institute **LUCKNOW - 226 001**	Member
Mr. Vivek Srivastava Senior Scientist CSIR-National Botanical Research Institute **LUCKNOW - 226 001**	Member
Dr. P Agnihotri Scientist CSIR-National Botanical Research Institute **LUCKNOW - 226 001**	Member
Shri AA Malick Senior S E CSIR-National Botanical Research Institute **LUCKNOW - 226 001**	Member
Mr. Sanjeev Shekhar Finanace & Accounts Officer CSIR-National Botanical Research Institute **LUCKNOW - 226 001**	Member
Mr. Rajeev Kumar Verma Administrative Officer CSIR-National Botanical Research Institute **LUCKNOW - 226 001**	Member Secretary

EXPENDITURE AND EARNINGS 2014-15

		Figure in Lakhs of Rupees
	I. EXPENDITURE	
A.	**Revenue**	
1.	Salary & Sal. Linked Allowances	2590.753
2.	Other Allowances	
	a. Re-imburs. of Med.Exp./CGHS/Med.charges	60.000
	b. Overtime Allowance	2.010
	c. Honorarium	1.004
	d. Leave Travel Concession	30.000
	e. T.A. (India)	3.922
	f. T.A. (Foreign)	
	g. Professional Update Allowance	12.483
	h. Total Other Allowances (a to g)	109.419
3.	Total Salaries (1+2h)	2700.172
4.	P-04 Contingencies	391.688
5.	P-05 H.R.D.	
6.	P-06 Lab. Maintenance	170.024
7.	P-701 Staff Qrs. Maintenance	50.000
8.	P07 Chemical/Consum.& Other Res.Exp.	579.940
9.	Total Revenue (3 to 8)	3891.824
B.	**Capital**	
a)	P-50 Land Cost	
a)	P-50 Land Cost	
b)	(i) P-50 Works & Services/Elec. Installations (Lumpsum)	150.022
b)	(ii) P-50 Works & Services/Elec. Installations (Other)	
c)	P-50 App. & Equip./Computer Equipments	454.207
d)	P-50 Workshop Machinery	
e)	P-50 Office Equipments	
f)	P-50 Furniture & Fittings	
g)	P-50 Library	
	i) Books	
	ii) Journals	
	iii) e-Journal	90.030
h)	P-50 Model & Exhibits	
i)	P-50 Vehicles	
j)	P-50 Tools & Plants	
k)	P-50 Software development/procurement/LAN/WAN	
l)	P-26 -ICT	
m)	(i) P-702 Staff Qrs.(Construction) (Lumpsum)	50.000
m)	(ii) P-702 Staff Qrs.(Construction) (Other)	
	Total Capital (a to m)	744.259
	Total A+B	4636.083
C.	**Special Proj. SIP/NWP/FAC/IAP/RSP/HCP/12th Plan Proj.**	
1.	Revenue	
	(i) T. A. (India)	15.794
	(ii) T.A. (Foreign)	

		Figure in Lakhs of Rupees
(iii)	Contingencies	216.536
(iv)	Maintenance	58.550
(v)	Chemical, Consum.& Other Res.Exp.	918.649
	Total Rev. (C1)	1209.529
2.	Capital	
(i)	Work's & Services	50.000
(ii)	Apparatus & Equipment	205.750
(iii)	Other Capitals	
	Total Capital (C2)	255.750
	Total allocation SIP/NWP/FAC/IAP/RSP/HCP/12th Plan (C1+C2)	1465.279
	Total National Labs. (A+B+C)	6101.362
D.	**Central Administration**	
	P-804 Pension & Other retirement benefits	1710.524
	P-801 and P-62 ISTADS	
	P-803 PPD/TNBD	
	P-805 HRD	
	P-80508 RAB	
	P-807 Publicity & Exhibition	
	P80804 Grant to other Sci. Organisations	
	P80805 CSIR Guest Houses (Science Centre)	
	P80806 Celebrations	
	P906- Advance	
(i)	Conveyance/Computer Advance	3.000
(ii)	House Building Advance	
(iii)	Others	
	Total Central Admin.	1713.524
	II. EARNINGS	
	RECEIPTS	
	R04 DONATION	
	R05 CONTRIBUTION	
	R06 MISC RECEIPTS	34.530
	R906 RECOV. OF ADV.	11.116
	TOTAL R06+R906	**45.646**
	R071 LAB RESERVE	
a)	Royality Premia	
b)	Testing & Analytical Charges	0.789
c)	Other Technical Service	
d)	Job Work	15.468
e)	Rest of R 071 heads	44.334
	Total Lab Reserve (R-071)	**60.591**
	R909 EXTERNAL CASH FLOW	
	a) Govt deptt./PSU's	527.124
	b) Private agencies	4.000
	c) Foreign govt/agencies	12.335
	TOTAL ECF (a+b+c)	**543.459**
	Royalty & Premia for distribution (R907)	**20.430**

PERSONNEL (As on 31.03.2015)

Director
C S Nautiyal

Chief Scientists
S K Raj
P B Khare
R D Tripathi
D K Upreti
S A Ranade

Sr. Principal Scientists
Kanak Sahai
RS Katiyar
A K Dwivedi
Tariq Husain
A K S Rawat
U N Rai
R K Roy
P A Shirke
S K Tewari
T S Rana
A K Gauniyal
K N Nair

Principal Scientists
Sudarshan Kumar
Anand Prakash
Sudhir Shukla
Talewar Singh
Nandita Singh
P K Trivedi
L B Chaudhary
Vivek Pandey
Samir V Sawant
A P Sane
Pratibha Misra
V A Sane
Alok Lehri
Ch. V Rao
Kamla Kulshreshtha
Sayyada Khatoon
Mahesh Pal
Sharad Srivastava
Sanjeeva Nayaka
Ashish K Asthana

Senior Scientists
P K Singh
Arvind Jain
S K Ojha
O P Sidhu
Indraneel Sanyal
Vivek Srivastava
Shubha Rastogi
C S Mohanty
H K Yadav
Aradhana Mishra
P S Chauhan

Scientists
Shekhar Mallick
Pankaj K Srivastava
Poonam C Singh
S K Behra
Suchi Srivastava
P C Verma
S N Jena
M H Asif
A P Singh
Manjoosha Srivastava
S K Bagh
Debasis Chakrabarty
Sribash Roy
Baleshwar
Lal Bahadur
Devendra Singh
Priyanka Agnihotri
RC Nainwal
Brahmanand Singh
Manoj Kumar
V V Wagh
Charu Lata

Pr. Technical Officers
A A Malick
S S Tripathi
Yogendra Nath
M L Kain

Sr. Tech. Officers (3)
Bhaskar Dutt
Yogendra Misra
V D Tripathi
A C Little
R K Tripathi
D K Purshottam

Sr. Tech. Officers (2)
Alok Kumar
Shankar Verma
Lalit K Srivastava
Anil Kumar
Daya Shanker
Sanjay Dwivedi
Abhishek Niranjan

Sr. Tech. Officers (1)
Bhagwan Das
R N Gupta
Atul Batra
Sushma Verma
Rajeev Kumar
G Sharma
Harendra Pal
M Raju
SK Behera
Vinay Sahu
Anil Kumar

Technical Officers
MK Shukla
Kiran Toppo
MM Pandey
VL Agarwal
Surjit Kumar
Swati Sharma
Sara Jamil
Leena Wahi Gupta
SK Sharma
KN Maurya
Babita Kumari
GG Sinam
Sumit Yadav
KK Rawat
DD Toppo
Somanath Swain

Technical Assistants
Satish Kumar
Saurabh Verma
Prashant Srivastava
Jai Chand
Shweta Singh
Rameshwar Prasad
Rekha Kannaujaia
Shashank K Mishra
Komal K Ingle
Bharat Lal Meena
Vivek Kumar Gupta

Administration
Pankaj Bahadur, AO
(Relieved on 31.3.2015)
Sanjeev Shekhar, F&AO
Sachin Mehrotra, SO
Prasoon Misra, SO
Ishwar Nath Jha, SO
Shiva Kant Mishra, SO
Surya Kant Singh, SO
KC Lohani, SO
KK Singh, SO
BP Pande, PS
Mohd. Aslam, PS
Shashi Kant Pandey, Security Officer

WHERE PLANT-BASED RESEARCH TOUCHES LIFE THROUGH INNOVATION

CSIR NBRI

Estd. 1953

CSIR-NBRI

CSIR-National Botanical Research Institute
(Council of Scientific & Industrial Research, New Delhi)
Rana Pratap Marg, Lucknow - 226 001, U.P., India

Phones : 0522-2205848, 0522-2297802 **Fax :** 0522-2205839
E-mail : director@nbri.res.in **Website:** http://www.nbri.res.in

army printing press
www.armyprintingpress.com
Lucknow (0522) 5565333