75 Years of
CSIR Touching Lives

वार्षिक प्रतिवेदन
Annual Report
2016-2017

CSIR NBRI Estd. 1953
WHERE PLANT-BASED RESEARCH TOUCHES LIFE THROUGH INNOVATION

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

Published by
Director
CSIR - National Botanical Research Institute
Rana Pratap Marg, Lucknow -226 001

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

Front Cover **: New plant varieties, and herbal product developed by CSIR-NBRI**
1. A view of Gladiolus field at CSIR-NBRI Botanic Garden
2. Chrysanthemum 'NBRI-Asha-Kiran' - A new variety with tubular florets and large capitulum
3. Chrysanthemum 'NBRI-CSIR75' - A new variety commemorating platinum jubilee of CSIR
4. Herbal Hand Sanitizer - An alcohol free hand sanitizer

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With best compliments from :

Director
CSIR-NBRI
Lucknow

सीएसआईआर–राष्ट्रीय वनस्पति अनुसंधान संस्थान
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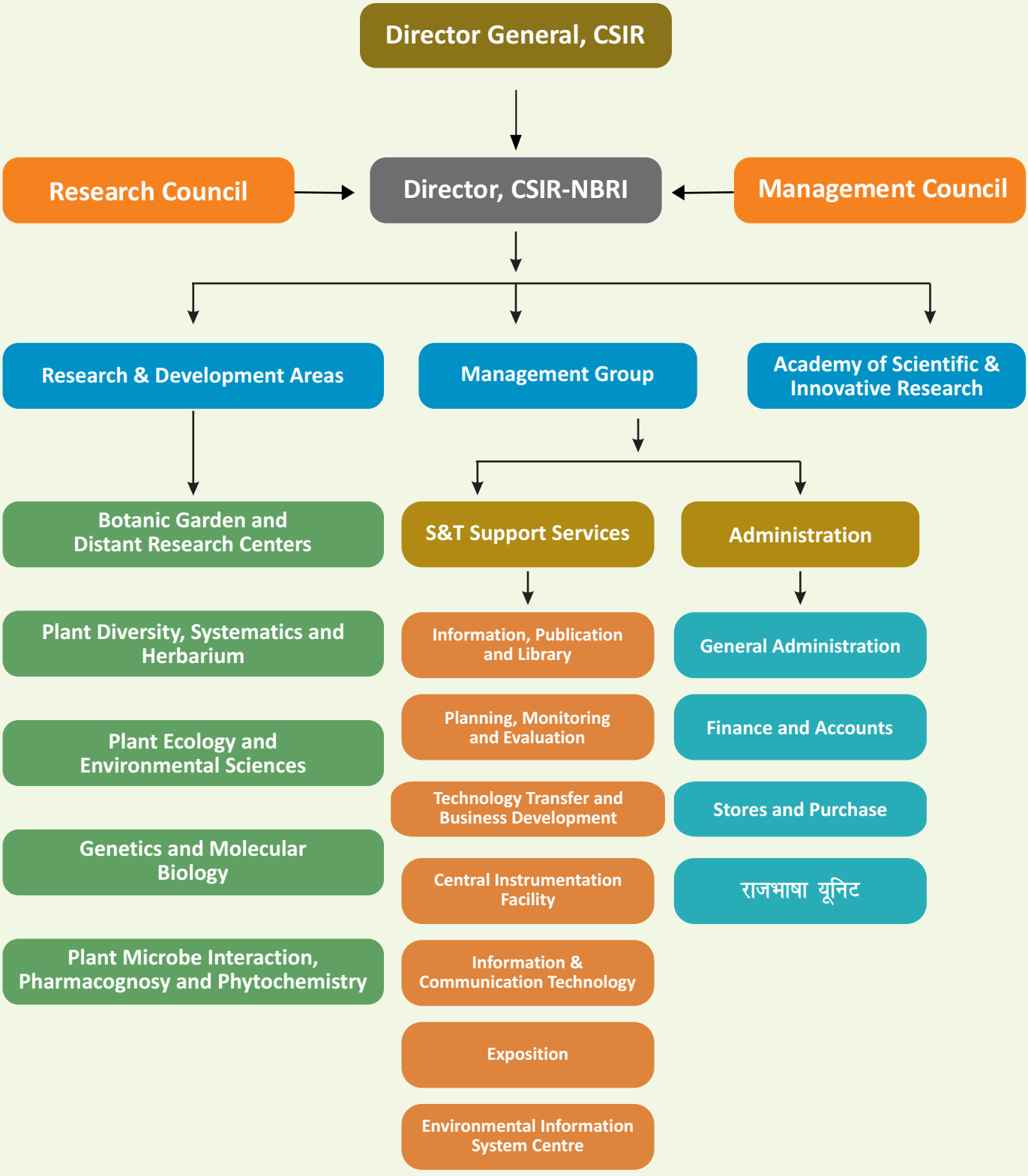
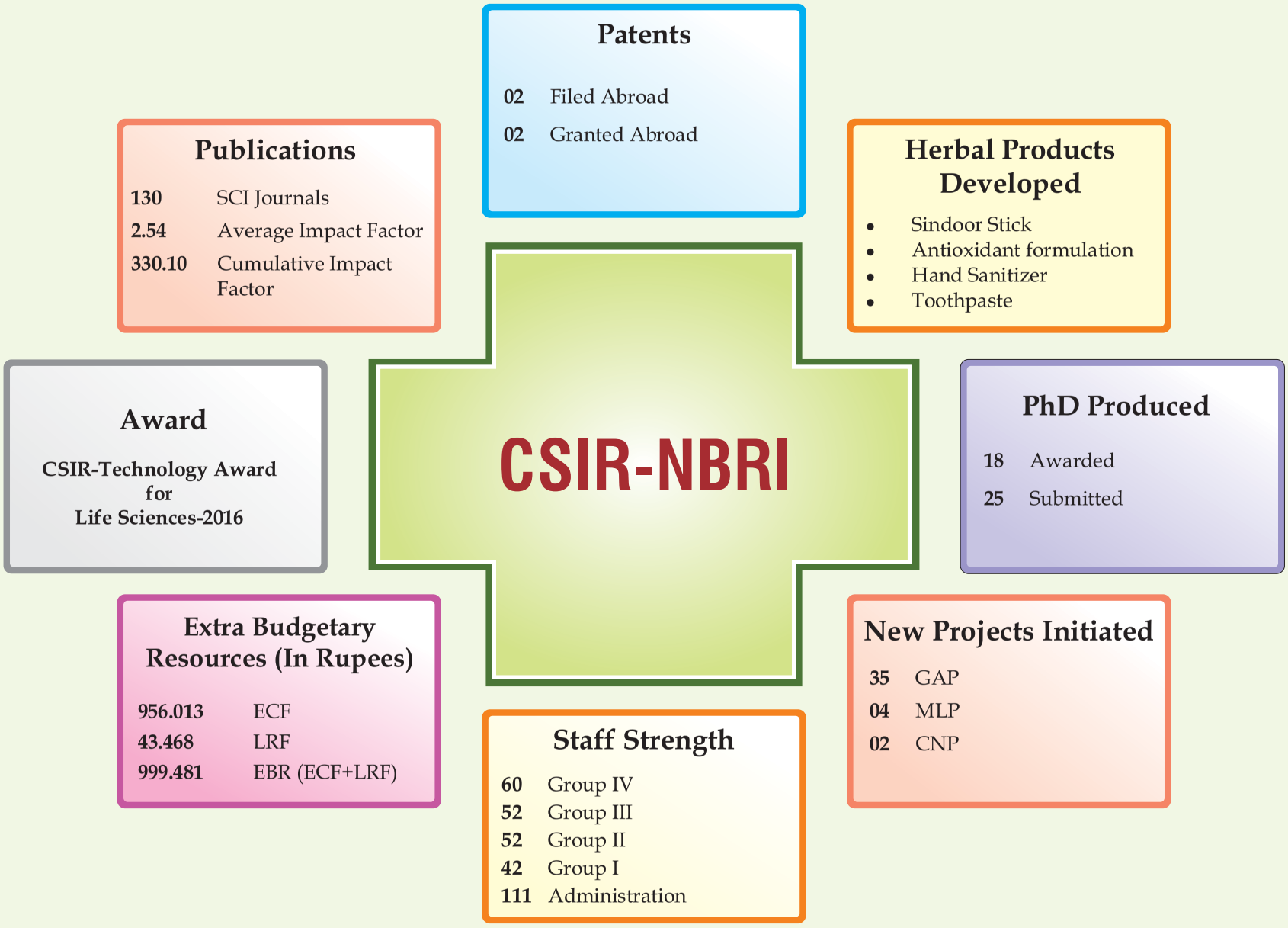
Organizational Set-Up



Contents

Annual Progress At A Glance



निदेशक की कलम से.....

सीएसआईआर-राष्ट्रीय वनस्पति अनुसंधान संस्थान, लखनऊ के लिए वर्ष 2016-17 कई मायनों में यादगार रहेगा। इस वर्ष के दौरान संस्थान ने विज्ञान और प्रौद्योगिकी के क्षेत्र में पूरे विश्व में सवर्प्रथम सफेद मक्खी प्रतिरोधी कपास की किस्म को विकसित करके एक नया मुकाम हासिल किया। इस शोध को प्रतिष्ठित जर्नल *नेचर बायोटेक्नोलॉजी* (इम्पैक्ट फैक्टर 41.667) में प्रकाशित किया गया।

12 वीं पंचवर्षीय योजना के पूरा होने के साथ-साथ विभिन्न मेगा नेटवर्क परियोजनाओं से कई नए नतीजे प्राप्त हुये जो नई प्रौद्योगिकियों और उत्पादों में रूपांतरण हेतु तैयार हुए। इनमें से कुछ महत्वपूर्ण शोध नतीजे निम्न है। कपास की पैदावार और रेशों की गुणवत्ता में बढ़ोत्तरी हेतु ऐनाकार्डिक अम्ल आधारित फोर्मुलेशन, नैनो एमल्सन-आधारित एंटीमाइक्रोबियल उत्पाद, विविध फसलों में *फ्यूजेरियम* के नियंत्रण हेतु माइक्रोबियल प्रभेद, एवं दानों में अल्प आर्सेनिक वाली चावल की किस्म। मानव स्वास्थ्य देखभाल हेतु उच्च क्षमता युक्त 22 यौगिकों की *बेटुला युटैलिस* की छाल से, 29 यौगिकों की *हेडेकियम स्पिटकेटम* के कंद से एवं 20 यौगिकों की *जस्टिसिया अधैतोडा* से पहचान की गयी। चार कैंसर सेल लाइनों जैसे स्तन, बृहदान्त्र, सिर और गर्दन, और सामान्य उपकला कोशिकाओं के विरुद्ध *इन-विट्रो* कोशिकीय विषाक्तता गतिविधि के लिए एक ब्रायोफाईइट *मार्केन्शिया पालीमोर्फा* का मूल्यांकन किया गया। एक रोगाणुरोधी बायो-नैनो जेल (एनबीसी-099) को विकसित किया गया एवं *इन-विट्रो* और *इन-विवो* मॉडल सिस्टम के तहत इसकी घाव भरने की क्षमता हेतु परीक्षण किया गया। *कॉमिफोरा एगेलोचा* से एक नए चिकित्सीय यौगिक की पहचान की गई, जिसने TNF-α सहित सूजन के लिए जिम्मेदार मध्यस्थों को रोक कर महत्वपूर्ण एंटी इंफ्लेमेटरी एवं एंटी ओर्थीराइटिक गुणों का प्रदर्शन किया । इसी पौधे के लेटेक्स से एक दूसरे यौगिक, 2,4 डाईटरब्युटाइल फिनोल, जो एक शक्तिशाली एंटीऑक्सीडेंट है, को अलग कर के, शोधन कर पहचाना गया। *एजेरेटम कोनीजॉयडेस* नामक खर-पतवार से एक रसायनिक यौगिक की पहचान की गयी जिसने मवेशियों की किलनियों को नियंत्रित करने में आशाजनक नतीजे प्रदर्शित किए। संजीवनी पौधे *सेलाजिनेला ब्रायोपटेरिस* पौधे से पृथक किए गए पॉलीफेनॉल्स ने चूहों में तनाव जनित कॉर्टिसोल के स्तर एवं रक्त शर्करा के स्तर में महत्वपूर्ण कमी प्रदर्शित की। शैकों *अस्निया लोंगिसिमा* तथा *क्लैडोनिया फर्केटा* ने चूहों में पेप्टिक अल्सर और ईसोफेगल रिफ्लेक्स रोगों के विरुद्ध संभावित क्षमताएँ प्रदर्शित की।

द्वितीयक पादप उत्पाद जैवसंश्लेषण में miRNA की भागीदारी स्थापित करने के लिए एरेबिडोप्सिस miR858a का विस्तृत कार्यात्मक लक्षण वर्णन किया गया। कपास में, फाइबर विकास से संबंधित हिस्टोन संशोधनों में शामिल जीन परिवारों की पहचान की गयी एवं लक्षण वर्णन किया गया। *tma12* जीन (एक फर्न से पृथक किया गया कीटनाशक जीन) और Tma12 प्रोटीन को कपास ट्रांसजेनिक लाइनों में अभिव्यक्त कराते हुये विस्तृत वर्णनीकरण किया गया । चावल की किस्मों 'इंडिका' और 'जपोनिका' के कैलस संवर्धन की विभिन्न विकासात्मक अवस्थाओं से ट्रांसक्रिप्टोम की स्थापना और उनका विश्लेषण किया गया। *सोलेनम खासियानम* के कांटा रहित एवं कांटा युक्त प्रभेदों के बाह्यत्वचीय ऊतकों से प्राप्त आरएनए की डिफ्रेंसियल mRNA सिक्वेंसिंग द्वारा कांटा निर्माण की गतिविधि को समझने के लिए एक सफल प्रयास किया गया। यह प्रदर्शित किया जा चुका है कि *एराबिडोप्सिस थैलियाना* एवं *एस्पर्जिलस नाइजर* से अलग किए गए पेक्टिन मेथिलईस्टेरेज का उच्च प्रदर्शन मेथेनोल उत्पादन के द्वारा कीटों के वृहद समूह के प्रति प्रतिरोधकता प्रदान करता है। कीट प्रतिरोधकता हेतु मेथेनोल उत्पादन के लिए इस जीन को कपास में डालने के प्रयास किए जा रहे हैं। *एराबिडोप्सिस थैलियाना* की भारतीय आबादियों में डीएनए मेथिलीकरण पैटर्न में भिन्नता के अध्ययन के द्वारा आणुविक स्तर पर अनुकूलन तंत्र को जानने का प्रयास किया जा रहा है।

संस्थान द्वारा विकसित उच्च थीबेन युक्त ओपियम पॉपी की लाइन्स के ब्रीडर बीजों को व्यवसायिक उपयोग हेतु संस्थान में पृथक-भूखंडो पर वंशवृद्धि हेतु उगाया जा रहा है। इन लाइन्स के प्रदर्शन परीक्षण राजस्थान एवं मध्य प्रदेश के गाँवों में किये जा चुके है।

देश के विभिन्न हिस्सों में शैवाल, शैकों, ब्रायोफाईइट्स, टेरीडोफाईट्स, कुकरबिट्स एवं फलीदार वृक्षों की विविधिता का अध्ययन जारी रखा गया। संस्थान द्वारा मोनोग्राफिक एवं वंशावली अध्ययन से भारत में *डेलफेनी* ट्राइब (रैननकुलेसी) की 46 प्रजातियों एवं 6 इंट्रास्पेसिफिक टैक्सा की उपलब्धता की पुष्टि हुई जो तीन जेनेरा *एकोनिटम, डेलफिनियम* एवं *कंसोलिडा* में वितरित हैं। भारत में *डीडमोकार्पस-हेन्केलिया* जेनेरिक समूह (जेस्नेरिएसी) के आणुविक वर्गिकी अध्ययन में *हेन्केलिया* की 26 प्रजातियों एवं *डीडमोकार्पस* की 17 प्रजातियों की आकारिकी-वर्गिकी जानकारी का संकलन किया गया।

पादपलय के संगठन एवं रखरखाव की गतिविधि के अंतर्गत बीजी पौधों के लगभग 1036 नमूनों, अबीजी पौधों के 2311 नमूनों (टेरीडोफाईइट्स-280, ब्रायोफाईइट्स- 836, शैवाल-45) एवं शैको के 1150 नमूनों को संग्राहलय में जोड़ा गया जिससे पादपलय के संग्रह की कुल संख्या 2,96,317 पहुँच गई है।

कृषि और वन पारिस्थितिकी प्रणालियों पर जलवायु परिवर्तन के प्रभावों और कार्बनिक एवं गैर-कार्बनिक प्रदूषकों के जैव-उपचार पर किए जा रहे कार्य प्रशंसनीय रहे हैं। तीन जीवाणु प्रभेदों, *कोरीनेबैक्टीरियम* प्रजाति PSM 10, *स्यूडोमोनस एरुजिनोसा* PSA 5 और *रोडोडोकस* प्रजाति NJ 2 द्वारा एन्थ्रेसिन के जैव-अपघटन को जांचा गया जिन्होंने अच्छे नतीजे प्रदर्शित किए। फॉस्फेट घोलक जीवाणुओं पर आधारित एक फार्मूलेशन को विकसित किया गया जिसने ग्लेडियोलस में पादप वृद्धि क्षमताएँ प्रदर्शित कीं एवं इसके अनेकों अन्य पुष्पीय फसलों में संभावित अनुप्रयोग है। खेतों में चावल की भूसी का अपघटन तेजी से करने हेतु तीन *ट्राईकोडर्मा* प्रभेदो एवं एक *बेसिलस* प्रभेद को मिला कर एक फार्मूलेशन को विकसित किया गया।

पौधों के विविध समूहों एवं सजावटी पौधों के जननद्रव्य के शामिल करने, संवर्धन और रखरखाव के लिए प्रतिबद्ध सीएसआईआर-एनबीआरआई के वनस्पति उद्यान ने उद्यान में इस वर्ष कई विलुप्त प्रजातियों के जननद्रव्य को शामिल किया है। इस वर्ष के दौरान, गुलदाउदी की विलंबित पुष्पन वाली दो नयी किस्मो 'एनबीआरआई-आशा किरण' एवं सीएसआईआर की प्लेटिनम जयंती के उपलक्ष्य में 'एनबीआरआई-सीएसआईआर 75' को जारी किया गया। वनस्पति उद्यान में एक अधिपादप *डिसकेडिया मेजर* एवं अन्य तीक्ष्ण सुगंध वाले पौधे *होया पैरासिटिका* को लाया गया। नोंग नूच वनस्पति उद्यान, थाईलैंड ने साईंकेड की सात संकटग्रस्त प्रजातियों के 70 बीज दान करके साईंकेड संरक्षण केंद्र को समृद्ध करने में मदद की। डॉ. गिरीश साहनी, महानिदेशक, सीएसआईआर और सचिव, डीएसआईआर, न्यू दिल्ली ने वनस्पति उद्यान में एक अ र्किड गृह का उदघाटन किया जिसमे लगभग 80 विभिन्न प्रजातियों के ऑर्किड्स को संगृहित किया गया है।

संस्थान के दूरस्थ अनुसंधान केंद्रों ने आर्थिक रूप से महत्वपूर्ण पौधों के संरक्षण के लिए कार्य किए। अवक्रमित मृदा हेतु अनेकों आर्थिक रूप से महत्वपूर्ण पौधों की कृषि-तकनीकी का मानकीकरण किया गया। हल्दी की चार प्रजातियों *कर्कुमा लोंगा, क. सेसिया, क. जिओडेओरिया* एवं *क. एमाडा* का उनकी उपज, गुणवत्ता एवं रासायनिक विशेषताओ के लिए मूल्यांकन किया गया।

संस्थान ने इस वर्ष में अनेकों समूह प्रशिक्षणों, कार्यशालाओं एवं किसान संवाद कार्यक्रमों का आयोजन किया । विभिन्न हितधारकों को विभिन्न विषयों जैसे वर्गिकी, बागबानी, पुष्पीय, कृषि प्रौद्योगिकी, जैव-उर्वरक, पुष्प निर्जलीकरण एवं पुष्प कला, पान की खेती, औषधीय एवं सगंध पौधों की खेती आदि पर प्रशिक्षण प्रदान किया गया। विभिन्न विश्वविद्यालयों/संस्थानों के परास्नातक विद्यार्थीयों को भी पादप विद्यार्थियो विज्ञान के विभिन्न विषयों जैसे आणुविक जैविकी, सूक्ष्म जीव विज्ञान, भेषज विज्ञान एवं जैव-प्रौद्योगिकी पर प्रशिक्षण प्रदान किया गया।

संस्थान ने इस वर्ष आंतरिक, उच्च संस्थागत, निमिटिली एवं अन्य संस्थानों से प्रायोजित 120 शोध एवं विकास परियोजनाओं के माध्यम से अपनी शोध गतिविधियों को जारी रखा। इन अनुसंधानों से विभिन्न राष्ट्रीय एवं अंतर्राष्ट्रीय विज्ञान जर्नल्स में 202 शोध पत्र प्रकाशित हुए। इस वर्ष कुल 130 शोध पत्र एससीआई पत्रिकाओं में प्रकाशित हुए जिनका कुल इम्पैक्ट फैक्टर 330.102 एवं औसत इम्पैक्ट फैक्टर 2.54 प्रति शोध पत्र था। मात्र 60 वैज्ञानिकों के संस्थान के लिए यह एक उल्लेखनीय उपलब्धि है। इस वर्ष 18 विद्यार्थियों को पीएचडी डिग्री प्रदान की गई एवं 25 ने अपने पीएचडी शोध प्रबंध जमा किए। इस वर्ष 2 पेटेंट का अनुमोदन प्राप्त हुआ एवं तीन अन्य दाखिल किए गए, 20 समझौतों पर हस्ताक्षर हुए एवं 41 नई परियोजनाएं प्रारम्भ की गईं।

संस्थान को इस वर्ष जीवन विज्ञान में सीएसआईआर प्रौद्योगिकी पुरस्कार 2016 प्रदान किया गया जो सीएसआईआर-एनबीआरआई एवं सीएसआईआर-सीमैप को संयुक्त रूप से टाइप II मधुमेह के प्रबंधन हेतु एक हर्बल संयोजन (NBRMAP-DB) के विकास के लिए प्रदान किया गया। तनाव एवं कैंसर पीड़ितों की कीमोथेरेपी के दौरान लाभदायक हर्बल एंटीऑक्सीडेंट फॉर्मूलेशन एवं ज्ञात आयुर्वेदिक पौधों से प्राप्त पॉलीहर्बल

फॉर्मूलेशन युक्त हर्बल टूथपेस्ट की तकनीकों को विकसित किया गया जो वाणिज्यिकरण हेतु तैयार हैं। अल्कोहल मुक्त हैंड सैनीटाइजर की एक तकनीक तैयार की गई जिसका लाइसेंस हाल ही में मेसर्स सतगुरु बायोलोजिकल्स, बाराबंकी, उत्तर प्रदेश को प्रदान किया गया।

वर्ष 2016-17 में डॉ. हर्षवर्धन, केंद्रीय मंत्री, विज्ञान एवं प्रौद्योगिकी एवं पृथ्वी विज्ञान, भारत सरकार ने संस्थान का भ्रमण किया एवं इसके कार्यों की सराहना की। डॉ. गिरीश साहनी, महानिदेशक, सीएसआईआर एवं सचिव, डीएसआईआर, नई दिल्ली एवं महामहिम प्रो. अमीना गुरिब-फकीम, राष्ट्रपति, मॉरीशस ने भी संस्थान का भ्रमण किया एवं वैज्ञानिकों के साथ अपने विचार साझा किए।

मैं संस्थान को एक जीवंत एवं उत्पादक संगठन बनाने के लिए ईमानदारी से प्रयास करने के लिए सीएसआईआर-एनबीआरआई के सभी वैज्ञानिक, तकनीकी एवं प्रशासनिक साथियों बधाई देता हूँ। जहाँ हमें अपनी समग्र उपलब्धियों पर गर्व है वहीं हमें आगे की चुनौतियों के लिए खुद को तैयार रखना चाहिए। जैसा कि हमारे माननीय प्रधानमंत्री श्री नरेंद्र मोदी एवं माननीय केंद्रीय मंत्री, विज्ञान एवं प्रौद्योगिकी, डॉ. हर्ष वर्धन जी द्वारा बार बार जोर दिया गया है, सभी सीएसआईआर संस्थानों को उपयुक्त प्रौद्योगिकियों के विकास के माध्यम से देश की चिन्हित समस्याओं को हल करने की आवश्यकता है। देश को उम्मीद है कि वैज्ञानिक शोध में अपनी वैश्विक नेतृत्व की स्थिति को बनाए रखते हुए सीएसआईआर के वैज्ञानिक ऐसे उत्पादों को विकसित करें जो जो हमारे समाज के बड़े हिस्से के लिए उपयोगी हों। सीएसआईआर के वैज्ञानकों को आम आदमी की समस्याओं को हल करने एवं हमारे किसानों के लिए बेहतर खाद्य उत्पादन में सहायक नई प्रौद्योगिकियां विकसित करने की आवश्यकता है। देश के 'कौशल विकास मिशन' के अंतर्गत हमारे शिक्षित बेरोजगार युवाओं के लिए अलग अलग व्यवसायों में कौशल विकसित करने में सीएसआईआर को महत्वपूर्ण भूमिका निभानी होगी एवं हमारे वैज्ञानिकों को 'जिज्ञासा' कार्यक्रम के माध्यम से युवा स्कूली बच्चों को विज्ञान को एक कैरियर के रूप में लेने एवं उनमें वैज्ञानिक स्वभाव विकसित करने के लिए उत्साहित करना चाहिए। एक पादप आधारित शोध संगठन होने के नाते सीएसआईआर-एनबीआरआई में देश को नवीन प्रजातियों, जैव-अणु एवं जींस तथा नवीन पादप-आधारित प्रौद्योगिकियाँ एवं उत्पाद उपलब्ध करा कर देश की अनेकों गंभीर समस्याओं को हल करने की क्षमता है। बुनियादी विज्ञान अनुसंधान में उत्कृष्टता हासिल करते हुए हमें अनुवादित अनुसंधान पर समान जोर देने की आवश्यकता है। हमें हमारे कार्यों में अधिक तालमेल एवं ध्यान देने की, अधिक अभिनव होने की, एवं चिन्हित लक्ष्यों को हासिल करने के लिए गुणवत्तायुक्त समय प्रदान करने की आवश्यकता है। मुझे पूरा भरोसा है कि सभी सदस्यों की बढ़ी हुई प्रतिबद्धता और कड़ी मेहनत के साथ सीएसआईआर- एनबीआरआई जल्दी ही एक नई ऊंचाई हासिल कर सकेगा। सीएसआईआर परिवार के एक नव प्रवेशी होने (3 नवंबर 2017 से) के नाते इस महान संस्था का नेतृत्व करने में मुझे गर्व की अनुभूति हो रही है एवं मुझे विश्वास है कि एक साथ हम अपने अभिनव विज्ञान एवं अनुवादपरक अनुसंधान के माध्यम से राष्ट्र की उम्मीदों को पूरा करने में सक्षम होंगे।

मैं संस्थान के सफल वैज्ञानिक एवं तकनीकी प्रबंधन के लिए समर्थन, मार्गदर्शन एवं सलाह हेतु डॉ. गिरीश साहनी, महानिदेशक, सीएसआईआर का आभारी हूँ। हम संस्थान के शोध एवं विकास कार्यक्रमों के सफल क्रियान्वयन में दिशा निर्देशन हेतु प्रो. एस के सोपोरी, अध्यक्ष, शोध परिषद, एवं शोध परिषद तथा प्रबंध परिषद के सभी सम्मानित सदस्यों के आभारी हैं। हम अपनी शोध एवं विकास तथा आउटरीच गतिविधियों के सफलतापूर्वक प्रदर्शन में अपने सहयोगियों, शुभचिंतकों एवं समर्थकों से मिली सहायता एवं सहयोग के आभारी हैं। हम अपने भविष्य के प्रयासों में आपके निरंतर मार्गदर्शन, सलाह एवं समर्थन के आकांक्षी हैं।

सरोज बारिक

सरोज के बारिक
निदेशक

From the Director's Desk .....

The year 2016-17 is memorable for CSIR-National Botanical Research Institute (CSIR-NBRI), Lucknow in many ways. The institute achieved a major break-through in science and technology during the year in the form of development of white fly- resistant transgenic cotton lines for the first time in the world. This research was published in the journal *Nature Biotechnology* with an impact factor of 41.667.

With the completion of 12th Five Year Plan, several new leads from different mega network projects got matured and were ready to translate them into new technologies and products. To mention a few, anacardic acid-based formulation to enhance cotton yield and fibre quality, nano emulsion-based antimicrobial products, microbial strains for control of *Fusarium* in diverse crops, and development of low arsenic grain rice variety. Twenty two compounds from *Betula utilis* bark, 29 compounds from *Hedychium spicatum* rhizome and 20 compounds from *Justicia adhatoda* were identified with high potential for human health care. *Marchantia polymorpha,* a bryophyte was evaluated for *in vitro* cytotoxic activity against four cancer cell lines viz., Breast, Colon, Head & Neck, and normal epithelial cells. An antimicrobial BIONANO gel (NBC-099) was developed and tested for its wound healing potential under *in-vitro* and *in-vivo* model systems. A novel therapeutic compound from *Commiphora agallocha* was identified, which showed significant anti-inflammatory and arthritic properties by inhibiting the mediators responsible for inflammation including TNF-α. A second compound, 2, 4 ditertbutyl phenol, a potent antioxidant was isolated, purified and identified from the latex of *C. agallocha*. A chemical compound was identified from the weed, *Ageratum conyzoides*, which showed promising results in controlling cattle ticks. Polyphenols isolated from the resurrection plant, *Selaginella bryopteris* showed significant decrease in stress induced elevated levels of Cortisol and blood glucose levels in rats. The lichens, *Usnea longissima* and *Cladonia furcata*, showed potential against peptic ulcer and oesophageal refluxes disease in rats.

A detailed functional characterization of Arabidopsis miR858a was carried out to establish involvement of miRNAs in secondary plant product biosynthesis. In cotton, gene families involved in histone modifications related to fibre development were identified and characterized. Detailed characterization of cotton transgenic lines expressing *tma12* (an insecticidal gene isolated from a fern) and Tma12 protein was carried out. Transcriptome of callus culture from different developmental stages of Indica and Japonica rice was established and analyzed. A successful effort has been made to decipher the mechanism of prickle formation in *Solanum khasianum*, using RNA isolated from the epidermal tissues from the stem of prickly and prickleless strains by differential mRNA-sequencing. It has been demonstrated that the over-expression of Pectin methylesterase (PME) isolated from *Arabidopsis thaliana* and *Aspergillus niger* provides resistance against broad spectrum of insects by producing methanol. It is being tried to introduce this gene in cotton for methanol production for insect resistance. The adaptation mechanism at the molecular level is being tried to unravel in *Arabidopsis thaliana* by studying the variation in DNA methylation pattern in Indian populations.

Breeder seeds of high thebaine lines of opium poppy developed by the institute are being multiplied in isolation plots at CSIR-NBRI campus for commercialization, and the performance trials of these thebaine lines were conducted at various villages of Rajasthan and Madhya Pradesh.

The taxonomy and assessment of diversity of Algae, Lichens, Bryophytes, Pteridophytes, wild relatives of Cucurbits and Tree Legumes in different parts of the country was continued. The monographic and phylogenetic studies in the Tribe *Delphineae* (Ranunculaceae) confirmed that, in India the tribe Delphineae is represented by 46 species and six infraspecific taxa distributed in three genera namely, *Aconitum, Delphinium* and *Consolida*. In the study of molecular systematics of the *Didymocarpus- Henckelia* generic complex (Gesneriaceae) in India, morphotaxonomic data on 26 species of *Henckelia* and 17 species of *Didymocarpus* were compiled.

As a part of organization and maintenance activity of Herbarium, about 1,036 specimens of seed plants and 2311 specimens of cryptogamic plants (Pteridophytes-280, Bryophytes-836 and Algae-45), and 1150 specimens of Lichens were added to the Herbarium taking the collection to 2,96,317.

The works on impact of climate change on agriculture and forest ecosystems and bioremediation of organic and non-organic pollutants have been appreciable. Biodegradation of anthracene was investigated using three bacterial strains, namely *Corynebacterium* sp. PSM10, *Pseudomonas aeruginosa* PSA5 and *Rhodococcus* sp. NJ2 which showed promising results. A Phosphate solubilizing bacteria (PSB) based formulation was developed that showed plant growth promoting attributes in *Gladiolus* and has potential application in several other floriculture crops. A microbial formulation consisting of three *Trichoderma* and one *Bacillus* strain was formulated for fast degradation of rice straw in the field.

The Botanic Garden of CSIR-NBRI, which is committed to introduction, enrichment and maintenance of germplasms of diversified groups of plants and ornamentals, enriched its collection by introducing several threatened species. During the year under report, two new late blooming varieties of Chrysanthemum, 'NBRI-CSIR75', commemorating the platinum jubilee of CSIR, and 'NBRI-Asha Kiran' were released. The Botanic Garden was enriched with *Dischidia major*, an epiphyte species, *Hoya parasitica*, a plant with strong sweet fragrance. The Nong Nooch Botanical Garden, Thailand extended help in enriching the Cycad Conservation Centre by donating 70 seeds of seven threatened cycads. An Orchidarium, which houses about 80 different species of orchids, was inaugurated by Dr. Girish Sahni, DG, CSIR and Secretary, DSIR, New Delhi.

The Distant Research Centres worked on conservation of economically important species. It standardized agro-technologies for several economically important plants on degraded sites. Four species of *Curcuma* viz. *C. longa. C. caesia, C. zeodoaria* and *C. amada* were grown for evaluating their yield, quality and biochemical properties.

The Institute during the year conducted a number of training programmes, workshops and Farmer's Interaction programmes. Training was imparted to various stakeholders on different subjects, including taxonomy, gardening, floriculture, agrotechniques, biofertilizers, dehydration of flowers and floral crafts, betelvine cultivation, and cultivation of medicinal and aromatic plants. Post-graduate students of different universities/institutes were also imparted training on various aspects of plant sciences, including molecular biology, microbiology, pharmacology, and biotechnology.

The institute during the year carried out its research activities through 120 Research and Development projects under in-house, network, supra-institutional, NMITLI and other externally funded projects. These R&D activities led to 202 publications in peer reviewed national and international journals. One hundred and thirty papers were published in SCI journals with a cumulative impact factor of 330.102 and an average impact factor of 2.54 per paper. This was a commendable achievement for the institute with only 60 scientists. Eighteen students were awarded Ph.D. degree and 25 students submitted their Ph.D. theses. Two patents were granted and three were filed. Twenty MoUs/ Agreements were signed and 41 new projects were initiated.

The institute was the recipient of the CSIR TECHNOLOGY AWARD FOR LIFE SCIENCE 2016 which was conferred jointly to CSIR-NBRI and CSIR-CIMAP, for the development of Herbal Composition (NBRMAP-DB) for management of Diabetes Type II. Technologies for a herbal antioxidant formulation useful during stress and chemotherapy of cancer patient, and a herbal toothpaste containing polyherbal formulation from known Ayurvedic

medicinal plants have been developed and are ready for commercialization. A technology for alcohol free Herbal Hand Sanitizer was made ready and recently licensed to M/s. Satguru Biologicals, Barabanki, Uttar Pradesh.

During the year, Dr. Harsh Vardhan, Union Minister for Science & Technology and Earth Sciences, Govt. of India visited the Institute and appreciated its work. Dr. Girish Sahni, DG, CSIR and Secretary, DSIR, New Delhi, and Her Excellency Prof. Ameenah Gurib-Fakim, President of Mauritius also visited the Institute and shared their visions with the scientists of CSIR-NBRI.

I congratulate all the scientific, technical and administrative staff of CSIR-NBRI for their sincere efforts to make the institute a vibrant and productive scientific organization. While we take pride in our overall achievements, we must prepare ourselves for the challenges ahead. As has been repeatedly emphasized by our Hon'ble Prime Minister Shri Narendra Modi and Hon'ble Minister, Science and Technology, Dr. Harsh Vardhan, all the CSIR institutions need to solve country's identified problems through developing appropriate technologies. While maintaining its global leadership position in scientific research, the country expects CSIR scientists to develop products which are useful for the large section of our society. CSIR scientists need to solve the problems of common man and develop new technologies to help enhanced food production for our farmers. CSIR has to play a pivotal role in developing skill in different vocations for our educated unemployed youth under country's "Skill development Mission" and also our scientists need to enthuse young school children to take science as a career and develop scientific temper among them through "Jigyasa" programme. Being a plant-based research organization, CSIR-NBRI has the ability to solve several of the country's acute problems by providing the nation several novel species, biomolecules and genes, and novel plant-based technologies and products. While continuing to excel in basic science research, we need to put equal emphasis on translational research. We need more synergy and focus in our actions, need to be more innovative, and provide quality time to achieve the identified goals. I am confident that, with enhanced commitment and hardwork of all the members, CSIR-NBRI would attain a new height very soon. As a new entrant to CSIR family (since 3rd November, 2017), I feel privileged to lead this great institution, and I am sure, together we shall be able to meet the expectation of the nation through our innovative science and translational research approach.

I take this opportunity to place on record my sincere gratitude to Dr. Girish Sahni, the Director General of CSIR, for his support, guidance and advice for the successful S&T management of the Institute. We sincerely thank Prof. SK Sopory, Chairman, Research Council and all the honourable members of the Research Council as well as of the Management Council for their guidance in successful implementation of the research and development programs of the Institute. We acknowledge the help and cooperation received from our peers, well-wishers and supporters in performing our R&D and outreach activities successfully. We look forward to your continued guidance, advice and support in all our future endeavours.

SK Barik
Director

EXECUTIVE SUMMARY

The Council of Scientific and Industrial Research - National Botanical Research Institute (CSIR-NBRI), Lucknow, established in the year 1953, is one of the 38 constituent laboratories of CSIR, Department of Scientific and Industrial Research, Ministry of Science and Technology, Government of India. The institution has been in the forefront of plant sciences research in the country for the past six decades and is an institution of national importance. As a globally recognized advanced centre of botanical research, the institute carries out multidisciplinary R&D programmes in almost all fields of plant sciences. The mandate of the institute is to undertake basic and applied research on various aspects of plant science, including conservation, systematics, documentation, prospection and genetic improvement with particular emphasis on under-exploited, non-traditional and wild plant genetic resources of the country for the sustainable development and human welfare. The institute has core strength in the following areas:

- Plant diversity, systematics and databases for lower and higher plant groups.
- Bioprospection and development of nutraceutical, cosmaceutical and health care products.
- Botanic garden, plant conservation and development of new varieties of floricultural plants.
- Microbes for enhanced plant productivity.
- Pollution remediation through plants and microbes.
- Climate change adaptation studies and carbon sequestration.
- Plant improvement through conventional and molecular breeding, and genetic engineering.
- Agro-technologies for sustainable development of sodic land and other wastelands.
- Societal development activities through outreach programmes.

The Institute is surging ahead with its envisioned goals of exploring the untapped potentials of the underexplored and unexplored plant diversity of the country for generating new knowledge, and affordable technologies for human health care, agriculture, and environmental protection. The year 2016-17 witnessed several significant achievements in the scientific, technological and outreach activities of CSIR-NBRI, a summary of which is given below:

Plant diversity documentation and conservation

The institute continued its sustained efforts to carry out systematic documentation, characterization, evaluation and conservation of plant and lichen resources of India. The floristic account of Govind Wildlife Sanctuary was completed. A total of 637 species of angiosperms, 352 lichens, 381 bryophytes, 391 taxa of algae and 88 species of pteridophytes, and additionally 25 ethnobotanically important plants were documented from the sanctuary. Taxonomic studies on various groups such as Thelotrematoid (121 spp.), Cetrarioid lichens, (47 spp.) *Corydalis* (23 spp.) and *Ficus* (40 spp.) were completed. Molecular systematic studies of the genera *Bergenia* (Saxifragaceae) and *Luffa* (Cucurbitaceae) in India were completed, while a new study on molecular systematics of the *Didymocarpus-Henckelia* generic complex (Gesneriaceae) in India has been initiated.

In the area of molecular characterization of plant genetic resources, analysis of genetic variability and population genetic structure was carried out in 11 populations of *Ephedra foliata* collected from its distributional range in arid and semi-arid regions of north western India. Additionally, sequence-characterized amplified region (SCAR) markers from the RAPD and ISSR fragments were developed for the identification and authentication of *Gladiolus* germplasm.

The monographic and phylogenetic studies in the Tribe *Delphineae* (Ranunculaceae) confirmed that, in India the tribe Delphineae is represented by 46 species and six infraspecific taxa distributed in three genera, viz., *Aconitum, Delphinium* and *Consolida*.

Mapping the floristic diversity and conservation studies on plant resources of Kishanpur Wildlife Sanctuary (KWS) continued for better understanding of

the plant diversity of the protected area. A total of 215 plant species were collected from KWS and deposited in the herbarium of the institute (LWG) for future reference. A diversity assessment of angiospermic flora has been initiated to provide a taxonomic account of angiosperms of Sonbhadra district in the Vindhyan region of Uttar Pradesh. The extensive survey of the area over the years, critical examination of previous collections housed at various herbaria, and review of published literature revealed that a total of 705 species belonging to 459 genera under 110 families are present in Sonbhadra district. This year, a new study on the plant diversity assessment in Dima Hasao, a hilly region of Assam, was initiated and about 150 species were collected from the area.

Lichens were recorded from 18 sites of Nilgiris in Western Ghats, which clearly differentiated the diverse micro and macroclimatic conditions of the area. A total of 223 species belonging to 80 genera and 33 families were recorded from these study sites.

A survey of bryophytes was carried out in Darjeeling hills to study the species composition along the altitudinal gradients. The primary data indicated that over the decades, the species richness index fluctuated at Tiger Hill and it had a steady increase at Llyod Botanical Garden (LBG). These differences could be due to the fact that Tiger hill is a site with greater tourist influx as compared to the LBG which has limited anthropogenic activities.

Exploration of bryophyte rich localities in the Eastern Ghats of Odisha was undertaken. About 321 specimens were collected, and an illustrated account of the studied taxa with descriptions along with their distribution data is in the final stage. Similarly, a study on the bryophytes from Terai region of Uttar Pradesh has revealed the occurrence of 29 species of bryophytes: 21 species belonging to 16 genera of 11 Families of Mosses; 6 species belonging to 3 genera of 3 families of Liverworts; and 2 species belonging to 1 genus of 1 family of Hornworts.

From the water samples collected from different parts of Lucknow, 12 algal taxa under 11 genera and 2 classes were described. Algal studies for harnessing its potential as a source of biofuel were continued.

Under the National Mission for clean Ganga project, algae were collected from eleven defined sites and the study revealed the occurrence of 37 species belonging to 24 genera. The diversity and distribution pattern of pteridophytes from Haridwar and Ganga Sagar showed a record of 17 species which belonged to 12 genera under 9 families.

Six species of bryophytes were introduced to the collection in the Moss House of the institute. Plants of *Nephrolepis hirsutula* collected from Andaman Islands were introduced in the fern house of the institute. Mass multiplication of 13 ornamental species of pteridophytes was undertaken for conservation, and experimental studies.

About 1,036 specimens of seed plants and 2311 specimens of cryptogamic plants (Pteridophytes-280, Bryophytes-836, Algae-45), and 1150 specimens of Lichens were added to the Herbarium (LWG), making the total collection to 2,96,317.

The Botanic Garden of CSIR-NBRI continued its activities through introduction, enrichment and maintenance of germplasms of diversified groups of plants and ornamentals. It also serves as a National Repository of Indian and exotic germplasm including threatened plant species. During the year under report, two new late blooming varieties of Chrysanthemum, 'NBRI-CSIR75', commemorating the platinum jubilee of CSIR, and 'NBRI-Asha Kiran' were released. The Botanic Garden was enriched with *Dischidia major*, an epiphyte species, and *Hoya parasitica,* a plant with strong sweet fragrance. The Nong Nooch Botanical Garden, Thailand extended help in enriching the Cycad Conservation Centre by donating 70 seeds of seven threatened cycads. Four species of succulents were introduced in the Cactus and Succulent House. A new "Indoor and Plants of Ancient Times" Conservation House was conceptualized to add more educative values to the idea of conserving plant diversity of different ages at one place. Adding plants of ancient times such as *Gingko biloba, Cycas* sp., *Zamia* sp., *Dioon* sp. and ferns was highlight of plant propagation centres during 2016-17. An Orchidarium, which houses about 80 different species of orchids, was inaugurated by Dr. Girish Sahni, DG, CSIR and Secretary, DSIR, New Delhi.

The Distant Research Centres accelerated their working on conservation of economically important plant species, and standardization of agro-technologies for economically important plants on degraded sites. Four species of *Curcuma* viz. *C. longa. C. caesia, C. zeodoaria*

and *C. amada* were grown for evaluating their yield, quality and biochemical properties. The turmeric variety 'Kesari', released last year, was further evaluated for performance, yield and for comparison with locally grown varieties. Matricaria *(Chamomilla recutita*) was evaluated for its oil content and quality at different soil pH. *Bixa orellana,* a dye yielding shrub and one of the most widely used food colouring substances of the food industry, was studied for pruning effects on growth and productivity. Aloe and *Andrographis paniculata* were studied for their sustainable cultivation on sodic wastelands.

A Phosphate solubilizing bacteria (PSB)- based formulation has been developed which shows potential for plant growth promoting attributes on Gladiolus and can be taken up for large scale production for utilization in floriculture crops.

Climate change monitoring using plants and lichens

Long-term climate change monitoring studies were undertaken in three highest summit point (HSP) in the Indian Himalayan region. The sites were surveyed for lichens, and lichenometry analysis in and around Kabi and Tingda area of north Sikkim was undertaken. A total of 52 species of lichens belonging to 27 genera and 16 families were recorded from three summit points. The bryophytic diversity was marked with dominance of mosses, followed by liverworts. The bryo-diversity of these areas mostly consisted of populations of temperate-subalpine bryo-flora, while typical alpine-subalpine elements were observed in lesser quantity. Studies regarding changes in atmospheric deposition during the last half century and its impact on lichen community structure were carried out in Darjeeling and Tawang area of the Eastern Himalayas, Pindar valley in Western Himalayas and Mount Abu in North-western India. The research demonstrated the potential use of herbarium specimens for mapping lichen diversity which can help as a tool for the assessment of environmental stress on toxitolerant lichens in the study area. Studies on secondary metabolites and amino acids of lichens along with the diversity of lichens were used to assess the response of rising temperature and ultra-radiance in Indian Himalayan region.

In order to study the dynamics of forest ecosystems in relation to climate responses, above ground biomass assessment in tropical deciduous forest at Katerniaghat Wildlife Sanctuary (KWLS) of Uttar Pradesh was undertaken in three forest communities, viz. dry mixed, sal mixed and teak forests.

In another study, response of three wheat varieties to elevated carbon dioxide and ethylene diurea (EDU) treatment was assessed under Free Air CO_2 Enrichment (FACE) facility.

Environmental Biotechnology and Bioremediation

Studies on impact of climate change on agriculture and forest ecosystems resulted in several significant leads in terms of identifying potential plant and microbes for bioremediation of arsenic, and organic and non-organic pollutants such as anthracene and total petroleum hydrocarbons.

The impact of Ortho Silicic Acid, the bioavailable form of silicon, in reducing arsenic accumulation in rice grains was analysed. Application of Silicon enhanced the growth and yield of plants under arsenic stress by stimulating synthesis of thiols and activities of antioxidant enzymes, and greatly reduced grain arsenic accumulation. Results confirmed that application of Ortho Silicic Acid reduces negative impacts of arsenic, not only in terms of economic yield but also the quality of grains. Rice seedlings supplemented with Selenium mitigated Arsenic toxicity by reducing arsenic uptake and ameliorating amino acid content.

A rice variety CN-1794-2-CSIR-NBRI (Muktashree) exhibiting low grain As accumulation developed by CSIR-NBRI in collaboration with West Bengal Government is being approved for cultivation in arsenic affected areas following successful multi-locational field trials.

A consortium of four fungal strains were identified, studied and confirmed for their superior performance in arsenic removal and was developed as a bio-augment formulation for remediating arsenic contamination in paddy crop.

Biodegradation of anthracene was investigated using three bacterial strains viz., *Corynebacterium* sp. PSM10, *Pseudomonas aeruginosa* PSA5 and *Rhodococcus* sp. NJ2. All the three strains showed promising results. A microbial consortium of selected bacterial and fungal

strains degraded 49% of total petroleum hydrocarbons after one month of incubation, when grown in 30% crude oil spiked soil.

A microbial formulation consisting of three *Trichoderma* and one *Bacillus* strain was formulated for *in situ* application in the fields having remains of rice stubble. Application of the formulation resulted in faster degradation of rice straw in the field. The technology has great promise to substitute the on-going practice of burning the field after crop harvest.

Genetic improvement of plants through conventional and molecular interventions

Anacardic acid was identified as an important candidate molecule for the improvement of yield and fibre quality in cotton. The same was used for multi-location field trials in Bhatinda, Maharashtra and Telangana.

In cotton, gene families involved in histone modifications related to fiber development were identified and characterized. Development of a commercially viable F1-Hybrid Cotton using Novel Reversible Male Sterility System is in progress.

Detailed characterization of cotton transgenic lines expressing *tma12* (an insecticidal gene isolated from a fern) and Tma12 protein was carried out.

Molecular genetics of guar (*Cyamopsis tetragonoloba*) was studied using more than 200 accessions collected from different parts of the country using SNP marker approach, and tagging *Alternaria* blight resistance loci, and marker assisted backcrossing (MABC) were carried out in linseed (*Linum ussitatisimum* L.).

Breeder seeds of high thebaine lines of opium poppy, developed by the institute are being multiplied in isolation plots at CSIR-NBRI campus for commercialization, and performance trials of these thebaine lines were conducted at various villages of Rajasthan and Madhya Pradesh.

Full-length cDNAs of putative genes involved in uncharacterized steps of Papaverine biosynthesis were identified and functionally characterized.

The analysis of sterol glycosyltransferase (*sgt*) gene family of *Withania somnifera* using artificial miRNA technology in the glycosylation of secondary metabolite revealed that sterol glycosyltransferase enzyme activity of *W. somnifera* provides tolerance against high temperature.

Transcriptome and small RNA sequencing of ripe and unripe stages of banana completed, and detailed analysis of various gene and miRNA families carried out.

To obtain insights into the molecular changes that occur during the ripening, an Illumina-based transcriptome analysis of inner and outer zones of *Dashehari* mango was carried out. Prominent genes of the ethylene pathway, cell wall softening, and other major ripening related pathways that included the aroma genes and carotenoids were identified.

Transcriptome analysis of a fragrant variety of rose, *R. bourboniana* (commonly known as Desi Gulab), which is also sensitive to endogenous and exogenous ethylene with petal fall within hours of exposure to ethylene, is under progress.

Transcriptome of callus culture from different developmental stages of Indica and Japonica rice was established and analysed.

To establish involvement of miRNAs in secondary plant product biosynthesis, a detailed functional characterization of Arabidopsis miR858a was carried out.

The mechanism of prickle formation in *Solanum khasianum* was understood using RNA isolated from the epidermal tissues from the stem of prickly and prickleless strains by differential mRNA-sequencing.

Targeted manipulation of SlERF6 and SlERF8 in tomato and deciphering their role in regulating fruit ripening and productivity, and *in silico* identification of SNP diversity in cultivated and wild tomato species are in progress.

The role of Nonexpressor of pathogenesis-related gene, NPR1 in the Nucleosome remodelling in *Arabidopsis thaliana* was unravelled. Over-expression of Pectin methylesterase (PME) isolated from *Arabidopsis thaliana* and *Aspergillus niger* showed resistance against broad spectrum of insects by producing methanol. Efforts are continued to introduce this gene in cotton for methanol production for insect resistance.

The adaptation mechanism at the molecular level was examined in *Arabidopsis thaliana* by studying the variation in DNA methylation pattern in Indian populations.

Study on the role of miRNA(s) in plant growth promoting rhizobacteria *Pseudomonas putida* RAR mediated drought stress alleviation in chickpea (*Cicer arietinum* L.), indicated that RAR inoculation alters miRNA and target gene expression resulting in ameliorating drought stress response in drought tolerant chickpea cultivar.

Transcript profiling of major millet crops under drought stress and cloning-characterization of stress-inducible transcription factors showed that a zinc finger protein coding gene (*PgZnF*) was found to be up-regulated under late drought stress.

The *GheCAMTA* and *NAC*-2 genes in chickpea were functionally validated in response to water stress. The aim was to develop drought-tolerant chickpea.

One of abiotic stress related genes, *OsASR6* was found to be up-regulated by PGPR treatment in rice roots. Transgenic lines with *Arabidopsis thaliana* were developed.

Physiological studies were carried out in *Gossypium* species to decipher the alteration in the metabolic pathways during drought stress in the leaf tissues. The accumulation of more sugars, sugar alcohols, amino acids and increase in fatty acid content provided enhanced osmo-protection under drought stress.

Soybean plants treated with salicylic acid through seeds pretreatment, under drought regimes showed that the proteins involved in photosynthesis and carbon metabolism were major proteins upregulated which contributed towards increased productivity and seed yield.

Molecular virological studies revealed association of *Cotton leaf curl Multan virus* in *Hibiscus rosa-sinensis*. Molecular characterization of a begomovirus associated with diseases of *Parthenium hysterophorus* and wild sunflower (*Helianthus* sp.) was undertaken. Coexistence of three virus genera viz., *Badnavirus, Potyvirus* and *Cucumovirus* in *Canna* species was reported.

Bioprospection of plant resources and natural product development

The institute during the year under report developed the following scientifically validated herbal products from indigenous plants and associated indigenous knowledge systems of India. These include: (i) Sindoor stick with herbal colours with vegetable oil aroma and bees wax as base material, (ii) a herbal antioxidant formulation useful during stress and chemotherapy of cancer patient, and (iii) a herbal toothpaste containing polyherbal formulation from known Ayurvedic medicinal plants. The technologies for all these products have been transferred to industry. A technology for alcohol free Herbal Hand Sanitizer was made ready, and recently licensed to M/s. Satguru Biologicals, Barabanki, Uttar Pradesh.

A CSIR-NBRI formulation is being developed from *Artemisia nilagirica* plants which have shown significant termite mortality rate as compared to that of synthetic pesticides.

The bioprospecting R&D at the institute has also generated the following promising leads with potentials of translating them into products and technologies for the herbal, cosmetic and nutraceutical industries.

Twenty two compounds from *Betula utilis* bark, 29 compounds from *Hedychium spicatum* rhizome and 20 compounds from *Justicia adhatoda* have been identified which would be of human health interest. *Marchantia polymorpha,* a bryophyte has been evaluated for *in vitro* cytotoxic activity against four cancer cell lines of Breast, Colon, Head & Neck, and normal epithelial cells. An antimicrobial BIONANO gel (NBC-099) has been developed and tested for its wound healing potential under *in-vitro* and *in-vivo* model systems.

A novel therapeutic compound from *Commiphora agallocha* was identified, which showed significant anti-inflammatory and arthritic properties by inhibiting the mediators responsible for inflammation including tumor necrosis factor alpha (TNF-α). A second compound, 2,4 ditertbutyl phenol, a potent antioxidant was isolated, and purified from the latex of *C. agallocha*.

A chemical compound has been identified from *Ageratum conyzoides* which shows promising results in controlling cattle ticks.

Polyphenols isolated from the resurrection plant *Selaginella bryopteris*, showed significant decrease in stress induced elevated levels of Cortisol and blood glucose levels in rats.

The lichens, *Usnea longissima* and *Cladonia furcata,* have shown potential against peptic ulcer and oesophagal refluxes disease in rats.

A marker metabolite, quinic acid, was identified in leaves of *Commiphora wightii* which may be used as a marker metabolite for identifying the commercially/ medicinally important high guggulsterone yielding elite chemotypes.

A method was standardized to develop squalene enriched fraction from amaranth grain oil. This can be used for development of cosmaceutical and nutraceutical products.

Fifteen gum bearing plants were identified to explore the potential of the plant gums as natural binders and stabilizer of food, colour, and for development as a natural additive or nutritional food supplement.

Training, Extension and Outreach

The Institute during the year conducted a number group trainings, workshops and Farmer's Interaction programme. Training was imparted to various stakeholders on different subjects including taxonomy, gardening, floriculture, agrotechniques, biofertilizers, dehydration of flowers and floral crafts, betelvine cultivation, cultivation of medicinal and aromatic plants. The beneficiaries of these training programmes were farmers, teachers, students, housewives, entrepreneurs and officers of Biofertilzer units. Post-graduate students of different universities/institutes were also imparted training on various topics in plant sciences, including molecular biology, microbiology, pharmacology, and biotechnology.

Projects, Publications and Awards

During the year under report, 120 R&D projects were implemented by the institute, 202 papers were published with cumulative impact factor of 330 (IF 2.54 per paper), and 18 students were awarded Ph. D. degree. The Institute jointly with CSIR-CIMAP won CSIR Technology Award for Life sciences - 2016 for the anti-diabetic (Type II) formulation-NBRMAP-DB.

CSIR-NBRI Success Story : Development of Whitefly Resistant Cotton

CSIR-NBRI, Lucknow becomes the First Institute in the World to develop a technology for resistance against whitefly

Whitefly (*Bemisia tabaci*)

- Highly invasive pest on several field crops.
- Most affected countries are India, Pakistan, Israel, Brazil, Argentina, USA, China and Australia
- Major affected crops are cotton, tomato, brinjal, capsicum, chilli, cucumber, other vegetables

Loss Value

In 2015 outbreak of whitefly caused widespread devastation of cotton crop, grown in 1.5 million hectare land in Punjab, Haryana and Rajasthan.

In terms of productivity, the revenue loss was estimated at INR 10,000 Crores, despite the use of pesticides worth INR 500 Crores.

Infection Mode

Whitefly damages the crops by sucking phloem sap; causing fungal infection and spreading plant viruses.

Damage Value

Routinely, it leads to average loss of 10-30% in crop productivity, which may exceed to 100% in severe cases.

CSIR-NBRI Counter Measure Efforts

- A team of scientists and students, led by Dr. PK Singh has isolated a novel anti-whitefly gene (designated as *tma12*) from a fern (*Tectaria macrodonta*). This fern has been maintained in the fernery at CSIR-NBRI Botanic Garden.
- The anti-whitefly gene was introduced in cotton. The fern gene has made GM cotton resistant to whitefly infestations. It controls the whitefly population by inhibiting its reproduction and hampering colonization.
- Whitefly resistance in GM cotton has been consistent for generations. Whitefly is also a vector of plant viruses. Restriction on whitefly population also controls whitefly spread viral diseases.
- Whitefly resistant GM cotton does not cause any harmful effect on beneficial insect like Ladybird beetle.

About the Ethics

The source plant of the gene is a fern, *Tectaria macrodonta*. This fern is eaten as salad and vegetable. Its concoction is used in medical remedies.

Rodents fed with very high dose of the Tma12 protein for two weeks, did not show any negative effect in animals. This indicates that the use of *tma12* gene in cotton and other crops will be safe to non-target animals and to the environment.

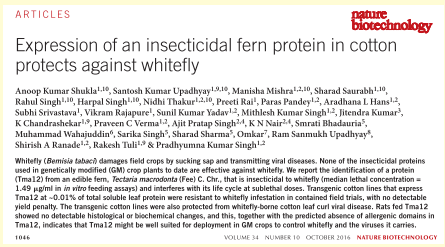
This is for the first time a novel insecticidal protein was discovered from an untapped plant resource. The *tma12* gene can be deployed in more than 30 crops to protect the yield without application of hazardous pesticides.

Worth Notable

It is notable that no GM technology is available for the control of whitefly in world. It is still an unmet need.

Brought Glory

The above work has been published in one of the Top Nature Group journals – **Nature Biotechnology** having an Impact Factor of 41.667


ARTICLES

nature biotechnology

Expression of an insecticidal fern protein in cotton protects against whitefly

Anoop Kumar Shukla[1,10], Santosh Kumar Upadhyay[1,9,10], Manisha Mishra[1,2,10], Sharad Saurabh[1,10], Rahul Singh[1,10], Harpal Singh[1,10], Nidhi Thakur[1,2,10], Preeti Rai[1], Paras Pandey[1,2], Aradhana L Hans[1,2], Subhi Srivastava[1], Vikram Rajapure[1], Sunil Kumar Yadav[1,2], Mithlesh Kumar Singh[1,2], Jitendra Kumar[3], K Chandrashekar[3,8], Praveen C Verma[1,2], Ajit Pratap Singh[3,4], K N Nair[3,4], Smrati Bhadauria[5], Muhammad Wahajuddin[6], Sarika Singh[6], Sharad Sharma[7], Omkar[7], Ram Sanmukh Upadhyay[8], Shirish A Ranade[1,2], Rakesh Tuli[1,9] & Pradhyumna Kumar Singh[1,2]

Whitefly (*Bemisia tabaci*) damages field crops by sucking sap and transmitting viral diseases. None of the insecticidal proteins used in genetically modified (GM) crop plants to date are effective against whitefly. We report the identification of a protein (Tma12) from an edible fern, *Tectaria macrodonta* (Fee) C. Chr., that is insecticidal to whitefly (median lethal concentration = 1.49 μg/ml in *in vitro* feeding assays) and interferes with its life cycle at sublethal doses. Transgenic cotton lines that express Tma12 at ~0.01% of total soluble leaf protein were resistant to whitefly infestation in contained field trials, with no detectable yield penalty. The transgenic cotton lines were also protected from whitefly-borne cotton leaf curl viral disease. Rats fed Tma12 showed no detectable histological or biochemical changes, and this, together with the predicted absence of allergenic domains in Tma12, indicates that Tma12 might be well suited for deployment in GM crops to control whitefly and the viruses it carries.

1046 VOLUME 34 NUMBER 10 OCTOBER 2016 NATURE BIOTECHNOLOGY

Distinguished Visitors

Visit of Dr. Harsh Vardhan, Hon'ble Union Minister, Ministry of Science & Technology and Ministry of Earth Sciences, Government of India

on April 20, 2016











Distinguished Visitors

Visit of Her Excellency Prof. Ameenah Gurib Fakim, President of Mauritius

on November 25, 2016

Distinguished Visitors

Visit of Dr. Girish Sahni, Director General, CSIR & Secretary, DSIR, Government of India, New Delhi

on December 10, 2016

अनुसंधान एवं विकास

संस्थान का अधिदेश

वै.औ.अ.प. राष्ट्रीय वनस्पति अनुसंधान संस्थान, लखनऊ वर्ष 1953 में स्थापित, वैज्ञानिक एवं औद्योगिक अनुसन्धान परिषद्, वैज्ञानिक तथा औद्योगिक अनुसंधान विभाग, विज्ञान एवं प्रौद्योगिकी मंत्रालय, भारत सरकार के 38 संस्थानों में से एक अंशभूत संस्थान है।

संस्थान पिछले छह दशकों राष्ट्रीय प्रतिष्ठा के रूप में पादप अनुसंधान के क्षेत्र में पूरे देश में अग्रणी रहा है। वानस्पतिक अनुसंधान के क्षेत्र में विश्व प्रख्यात केंद्र के रूप से प्रसिद्ध यह संस्थान पादप अनुसंधान के लगभग सभी अग्रणी बहु-विषयक क्षेत्रो में अनुसंधान व विकास पर कार्यरत है। संस्थान का मुख्य उद्देश्य मूल रूप से पादप तथा पादप अनुप्रयुक्त अनुसंधानों के विभिन्न पहलुओं जैसे संरक्षण, वर्गिकी, प्रलेखन, पूर्वक्षेपण एवं आनुवांशिक सुधार के साथ गैर-पारंपरिक, अल्प-शोषित व प्रतिशत पौध संसाधनों के सतत् विकास में कार्य करना है जिसे मानव कल्याण हेतु उपयोग किया जा सके।

संस्थान की मुख्य सामर्थ्य निम्न लिखित विशेषज्ञता के क्षेत्रो में हैं।

- पादप विविधिता, वर्गिकी एवं न्यून व उच्चतम पौधों के लिए डाटाबेस
- पूर्वक्षेपण एवं पौष्टिक-औषधीय, औषधीय-प्रसाधन एवं स्वास्थ्य कल्याण हेतु उत्पाद विकास
- वनस्पति उद्यान, पादप संरक्षण एवं पुष्पीय पौधों की नई किस्मों का विकास
- उच्च पादप उत्पादकता हेतु सूक्ष्मजीवी
- पौधों एवं सूक्ष्मजीवी द्वारा प्रदूषण उपचार
- जलवायु परिवर्तन अनुकूलन अध्ययन एवं कार्बन जब्ती अध्ययन
- पारंपरिक व आणुविक प्रजनन एवं आनुवंशिक अभियांत्रिकी द्वारा पादप सुधार
- सोडिक व बंजर भूमि के सतत् सुधार हेतु कृषि-तकनीकियाँ
- आउटरीच कार्यक्रमों के द्वारा समाज कल्याण हेतु गतिविधियाँ

संस्थान मानव कल्याण, कृषि एवं पर्यावरण बचाव हेतु पादप अनुसंधान के लिए अध्ययनरत् ज्ञात व अज्ञात क्षेत्रों में अपने अप्रयुक्त क्षमता के साथ नव-ज्ञान सृजन एवं किफायती तकनीक विकास में आगे बढ़ने के लिए हमेशा प्रतिबद्ध है।

वानस्पतिक उद्यान एवं दूरस्थ अनुसंधान केंद्र

अनुदान प्राप्त परियोजनाएं

उत्तर प्रदेश में हल्दी के जैविक बीज उत्पादन का मानकीकरण एवं प्रचार

हल्दी के जैविक बीज उत्पादन के लिए औराँवा अनुसंधान केन्द्र, राष्ट्रीय वनस्पति अनुसंधान संस्थान, लखनऊ में निम्नलिखित दो प्रयोग किये गये-

(i) एकीकृत जैविक खेती के अंतर्गत अनुकूल गुणवत्ता एवं उपज के लिए हल्दी की खेती का मानकीकरण

(ii) एकीकृत जैविक खेती के अंतर्गत रोग और कीट प्रबंधन

मानकीकरण के अंतर्गत उपचारों के साथ परीक्षण किया गया और पाया गया कि नाइट्रोजन, फास्फोरस एवं पोटाश के साथ जिंक की 100% मात्रा द्वारा पौधों की लंबाई, पत्तियों की लंबाई एवं चौड़ाई, प्रकंद के ताजा भार एवं कुल उपज में अन्य उपचारों की तुलना में सार्थक वृद्धि पाई गयी किन्तु केंचुआ खाद के साथ जीवाणु द्वारा बीज उपचार अत्यधिक प्रभावी पाया गया, हालांकि इस मामले में पत्तियों की संख्या में सार्थक अंतर नहीं पाया गया। हल्दी पाउडर एवं तेल में पाए जाने वाले कुरकुमिनोइड आदि में भी सार्थक अंतर नहीं देखा गया। नतीजों में विभिन्न जैव नियंत्रण उपचारों के प्रयोग से हल्दी की फसल में बीमारियों के प्रति सार्थक प्रतिरोध भी देखा गया।

कालमेघ की उपज एवं गुणवत्ता पर जैविक पदार्थों के विभिन्न स्रोतों एवं स्तरों के प्रभाव का अध्ययन

अध्ययन में यह देखा गया कि किसान 15 टन प्रति हेक्टेयर की दर से FYM का प्रयोग करके रु. 56,280 की लागत पर रु. 1,70,860 का लाभ प्राप्त कर सकते हैं, इसी प्रकार प्रेसमड के 7.5 टन प्रति हेक्टेयर के प्रयोग से रु. 47,040 की लागत पर रु. 1,70,860 का लाभ तथा वर्मीकंपोस्ट के 5 टन प्रति हेक्टेयर के उपयोग से रु. 90,720 की लागत पर रु. 84,780 का लाभ प्राप्त कर सकते हैं। इस प्रकार प्रेसमॅड का प्रयोग अधिक लाभकारी पाया गया। कालमेघ के पौधों में नाइट्रोजन, फोस्फोरस एवं पोटेशियम का सर्वाधिक ग्रहण भी प्रेसमड में देखा गया। हालांकि मैंगनीज का ग्रहण FYM या वर्मीकंपोस्ट की मात्रा बढ़ने के साथ बढ़ी लेकिन प्रेसमड की मात्रा बढ़ाने पर कमी देखी गई।

उत्तर प्रदेश की सोडिक बंजर भूमि पर खेती हेतु किसानो को प्रशिक्षण एवं प्रचार-प्रसार हेतु *एलो* प्रजातियों की कृषि प्रौद्योगिकी विकास

एलो वेरा, एलो वेरा एक्सेशन एवं *एलो मैकुलाटा* के पौधों को विभिन्न pH स्तरों में उगाया गया। विभिन्न मानकों का अध्ययन करने से ज्ञात हुआ कि *एलो वेरा एक्सेशन* उच्च सोडिक मृदा में खेती हेतु उकृष्ट है।

घरेलू परियोजनाएं

संरक्षण, शिक्षा एवं जैव-सुंदरीकरण हेतु चुनिन्दा सजावटी फसलों एवं विभिन्न समूहों के पौधों का संग्रहण एवं जननद्रव्य संग्रह की देखभाल

संस्थान द्वारा विकसित नई किस्में

गुलदाउदी

जनवरी 2017 में गुलदाउदी की दो नई किस्मों 'एनबीआरआई-सीएसआईआर 75' (सीएसआईआर के प्लेटिनम जुबली समारोह के उपलक्ष्य में) एवं 'एनबीआरआई-आशा किरण' को जारी किया गया।

उद्यान में नवीन पौधे

डिस्कीडिया मेजर

असम से इस अधिपादप प्रजाति के पौधे का एक नमूना संग्रहित किया गया। विशेष रूप से रूपांतरित पत्तियों में चीटियों के घर बनाने के कारण इस पौधे को सामान्य रूप से 'चींटी पौधा' के रूप में जाना जाता है।

होया पैरासिटीका

असम-मेघालय के सीमा क्षेत्र से एकत्र किए गए इस मीठी सुगंध वाली प्रजाति के पाँच पौधों को उद्यान में लगाया गया है जिनमें से एक पौधे में फूल लगने भी आरंभ हो गए हैं।

जननद्रव्य संग्रहण

नोंग नूच वानस्पतिक उद्यान, थाईलैंड से संस्थान को सात दुर्लभ एवं संकटग्रस्त साइकेड्स के 70 बीज प्राप्त हुए हैं। उद्यान के साथ संरक्षण एवं वर्गिकी के क्षेत्रों में भविष्य में सहयोग हेतु प्रयास किए जा रहे हैं। कैक्टस एवं सैकुलेंट गृह में भी चार प्रजातियों को लगाया गया।

वानस्पतिक उद्यान का जैव विविधता प्रलेखन

उद्यान में कुल 103 इवेसिव प्रजातियाँ देखी गईं। इनके अतिरिक्त बेलों की 45 प्रजातियाँ भी देखी गईं। उद्यान में झाड़ियों, तितलियों, मकड़ियों एवं वृक्षों कि पुनर्गणना का कार्य भी किया जा रहा है।

जनन द्रव्य संग्रहण

छह संकटग्रस्त प्रजातियों एवं दो सैकुलेंट प्रजातियों को उद्यान में लगाया गया। इसके अतिरिक्त सुंदरनाथ कॉलेज, कोलकाता एवं ब्रह्मानन्द कॉलेज, कानपुर से जर्मप्लाज्म एक्सचेंज कार्यक्रम की शुरुआत की गई।

नवीन सुविधा-घरेलू पौधों एवं प्राचीन पौधों का संरक्षण केंद्र

इस केंद्र के पाँच मुख्य आकर्षण हैं अ) संरक्षणगृह, ब) विकास उद्यान, स) साइकेड कार्नर, द) एडेनसोनिया कॉर्नर एवं ई) आर्किड अनुकूलन केंद्र।

इनके अतिरिक्त यहाँ दो आकर्षक जल निकाय भी हैं। विभिन्न सुविधाओं को आपस में रास्तों के द्वारा जोड़ा गया है।

ओर्किडेरियम

इसका शुभारंभ सीएसआईआर के महानिदेशक डॉ गिरीश साहनी द्वारा दिसंबर 2016 में किया गया। यहाँ ओर्किड की 80 विभिन्न प्रजातियाँ संरक्षित हैं। इनमें से कुछ आर्थिक रूप से महत्वपूर्ण हैं वहीं कुछ संकट ग्रस्त हैं। इस प्रकार से यह गृह ओर्किड्स के वानस्पतिक अध्ययन एवं शोध के अतिरिक्त इनके संरक्षण केंद्र के रूप में भी कार्य करेगा।

दूरस्थ शोध केंद्र (बंथरा शोध केंद्र)

आंशिक रूप से कृषि हेतु बनाई गई सोडिक मृदा हेतु हल्दी की प्रजातियों का विश्लेषण

हल्दी (कर्कुमा लांगा) की 36 प्रजातियों को विभिन्न जैव भौगोलिक क्षेत्रों से एकत्र कर संस्थान के बायोमास शोध केंद्र में जून 2015 में ऊसर भूमि में मूल्यांकन हेतु लगाया गया। वर्ष 2016 में औरावां शोध केंद्र में हल्दी के दो सेटो में 34 जर्मप्लास्म लगाए गए एवं फरवरी में उनकी खुदाई की गई। प्रजाति NB 2017 में सबसे अधिक पैदावार पाई गई जिसका गुणात्मक मूल्यांकन किया जा रहा है। गुणवत्ता मूल्यांकन हेतु हल्दी की चार प्रजातियों *कर्कुमा लोंगा, कर्कुमा सेसिया, कर्कुमा जिओडोरिया* एवं *कर्कुमा अमाडा* का जैव रासायनिक विश्लेषण भी किया गया।

विभिन्न pH पर तेल की मात्रा एवं गुणवत्ता हेतु कैमोमाइल का विश्लेषण

कैमोमिला रेकुटिटा (*Chamomilla recutita*) की पौध को विभिन्न पीएच (7.8, 8.5, 9.43, 9.8 और 10.1) के स्थानों पर लगाया गया। इस प्रयोग का उद्देश्य कैमोमाइल की पौध पर, उसके तेल की मात्रा तथा तेल के यौगिक पर विभिन्न पीएच का असर जांचना तथा उसर भूमि में उगाने से मृदा में सुधार देखना है। इस से प्राप्त तेल के जीसीएमएस विश्लेषण में β-Farnesene, Caryophyllene oxide, α-Bisabolol oxide-β, Chamazulene और α-Bisabolol जैसे प्रमुख यौगिक पाये गये हैं। मिट्टी की pH, OC, Na and K की जाँच बोवाई से पहले और फसल कटाई के बाद की गई। कैमोमाइल कटाई के बाद मिट्टी की pH, Na और K की मात्रा घटी हुई पाई गयी जोकि संभवतः पौधों द्वारा Na और K के अवशोषण के कारण, कम पीएच और अधिक जैविक कार्बन को दर्शाता है।

बिक्सा ओरेलाना पर छंटाई के प्रभाव का अध्ययन

सिंदूरी (*बिक्सा ओरेलाना*) का रंगीन खाद्य पदार्थ रूप में खाद्य उद्योग में सर्वाधिक व्यापक रूप में इस्तेमाल किया जाता है। वर्तमान अध्ययन में 17 भौगोलिक क्षेत्रों से एकत्रित सिंदूरी के विभिन्न नमूनों का उपज और गुणवत्ता के लिए मूल्यांकन किया जा रहा है। कुल संग्रह को सात समूहों में व्यवस्थित किया गया है। पौधों की बेहतर उपज, कमजोर पौधों को हटाने के लिए और पौधों के आकार को संतुलित करने के लिए शाखाओं की कटाई छँटाई (प्रूनिंग) की जाती है। बिक्सा के 110 पौधों में ये प्रूनिंग वर्ष 2016 के अप्रैल माह में एक मीटर की ऊंचाई से की गई जिसके प्रतिकूल प्रभाव देखने को मिले। कुछ पौधों में कम फूल खिले एवं कम फल (कैप्सूल) बने। एच-1 टाइप में हल्का प्रभाव दिखा एवं उपज में मामूली कमी देखी गई जबकि ई-1 टाइप बुरी तरह प्रभावित हुआ एवं उपज में 85% की कमी देखी गई।

जल तनाव का सामना करने में जैव उर्वरकों का प्रदर्शन

सिंचाई के पानी की कमी में चने की पैदावार पर संस्थान द्वारा विकसित जैव उर्वरकों की भूमिका को परखने की उद्देश्य चने की दो किस्मों पूसा 362 (देशी) एवं पूसा 1003 (काबुली) पर परीक्षण किए गए जिसमें दोनों किस्मों को सिंचाई की भिन्न अवस्थाओं में उगाया गया। जांच के दौरान पूसा काबुली में विभिन्न प्रयोगों में जैव उर्वरकों की मदद से बेहतर प्रदर्शन किया।

उत्तर प्रदेश की प्रमुख धान किस्मों की वृद्धि एवं उपज पर सूक्ष्म जीवाणुओं की भागीदारी का विश्लेषण

इस अध्ययन हेतु धान की चार किस्मों इंद्रासन, सरजू 52, संभा मंसूरी एवं NDR-359 पर परीक्षण किए गए। इन किस्मों की वृद्धि एवं उपज पर विभिन्न जीवाणुओं एवं कवकों की भागीदारी का प्रभाव देखा गया। प्राप्त नतीजों को दूसरे वर्ष में पुनः जांच के द्वारा सुनिश्चित किया जाएगा।

सोडिक मृदा में *एलो* प्रजातियों का संग्रह, अनुकूलन एवं जननद्रव्य बैंक की स्थापना

एलो सोडिक मृदा के सुधार क्षमता युक्त एक महत्वपूर्ण प्रजाति हैं। संस्थान के बंथरा शोध केंद्र पर इसकी प्रजातियों के जननद्रव्य के संग्रह हेतु एक बैंक की स्थापना की गयी जहाँ देश के विभिन्न इलाको से एकत्रित 5 प्रजातियों/नमूनों को संग्रह कर स्थापित किया गया।

पादप विविधता, वर्गिकी एवं पादपालय

अनुदान प्राप्त परियोजनाएं

अत्याधुनिक बायो-जेट ईंधन प्रौद्योगिकी हेतु अंतर्राष्ट्रीय कंशोर्शियम

सीएसआईआर-एनबीआरआई की शैवाल प्रयोगशाला में उपलब्ध 70 शैवाल प्रभेदों में लिपिड की मात्रा का डेटा एकत्रित किया गया। ये शैवालीय प्रभेद 14 कुलों के हैं जिन्हें भारत के विभिन्न स्थानों से एकत्र किया गया है। उच्च लिपिड की मात्रा एवं आसानी से उपलब्धता के आधार पर दो प्रजातियों *नैनोक्लोरोप्सिस* प्रजाति (95.77 ±1.7 मिग्रा/ली), एवं *सेनेडेस्मस* प्रजाति (222.08 ± 8.1 मिग्रा/ली) का जैवभार उत्पादन हेतु चयन किया गया। नैनोक्लोरोप्सिस प्रजाति को इस कार्य हेतु विशेष रूप से निर्मित जलाशयों में सीवेज जल में उगाया गया। इस जलाशय से 40 दिनों बाद *नैनोक्लोरोप्सिस* प्रजाति का 7.5 किग्रा शुष्क जैवभार प्राप्त हुआ जिसमें 8% लिपिड की मात्रा थी। इन दिनों में सीवेज जल की गुणवत्ता में भी सुधार देखा गया। इसी प्रकार एक अन्य जलाशय में सामान्य जल में 1.5 ग्रा/ली यूरिया एवं 0.04 ग्रा/ली सुपर फॉस्फेट को पोषक तत्वों के रूप में मिलाकर *सेनेडेस्मस* प्रजाति को उगाया गया जिससे 30 दिनों में 9% लिपिड की मात्रा युक्त 4.7 किग्रा जैवभार प्राप्त हुआ।

सूक्ष्म शैवाल से सतत जैव ऊर्जा एवं मूल्य वर्धित उत्पादों के उत्पादन हेतु आणुविक दृष्टिकोण

सेनेडेस्मस क्वाड्रीक्रडा के जैव भार एवं लिपिड उत्पादकता की विभिन्न स्थानों से पृथक्कृत किए गए अन्य सूक्ष्म शैवालों से तुलना की गई। इन पृथक्कृत किए गए सूक्ष्म शैवालों में *नैनोक्लोरोप्सिस ओकुलेटा, क्लोरेल्ला वल्गेरिस* एवं *किरचनेरिएलिया ओबेसा* अधिक तेल की मात्रा युक्त सबसे अधिक तेजी से उगाने वाले शैवाल पाए गए। विभिन्न मीडिया पर उगाने पर TAP मीडिया में सर्वाधिक जैव भार *सेनेडेस्मस क्वाड्रीकाडा* का पाया गया। इसी प्रकार TAP मीडिया में *सेनेडेस्मस क्वाड्रीकाडा* के दोनों प्रभेदों की लिपिड की मात्रा भी काफी अधिक पाई गई। इन प्रभेदों की जैव-प्रौद्योगिकीय क्षमताओं का आंकलन करने हेतु जीनोम सीक्वेंसिंग की गई एवं इनकी वंशावली का अध्ययन किया गया। *सेनेडेस्मस क्वाड्रीकाडा* के प्रभेद NBRI012 में *एग्रोबैक्टीरियम* आधारित रूपान्तरण भी किया गया जिसका प्रयोग आने वाले समय में इस प्रजाति में लिपिड उत्पादन में सुधार हेतु आनुवांशिक एवं उपापचयी रूपान्तरण करने में किया जाएगा।

आशाप्रद सूक्ष्मशैवालीय प्रभेदों का पृथक्कीकरण, छंटनी एवं पोषण संबंधी रूपरेखा

पाँच शैवाल प्रजातियों (*स्फेरोसिस्टिस श्रोटेराई, क्लोरेल्ला वल्गेरिस, क्रूकोकस माइनर, हीमैटोकोकस प्लुविएलिस* एवं *गोलेंकीनिया रेडिएटा*) के अर्कों उनकी कुल फेनोलिक मात्रा, लेवोनोइड्स, फ्री रेडिकल सफाई क्रिया, एंटीऑक्सीडेंट क्षमता आदि का विश्लेषण किया गया सर्वाधिक कुल फेनोलिक मात्रा, कुल लेवोनोइड मात्रा, रिड्यूसिंग क्षमता एवं कुल एंटी ऑक्सीडेंट क्षमता *क्लोरेल्ला वल्गेरिस* में देखी गई। रिड्यूसिंग क्षमता सर्वाधिक *क्लोरेल्ला वल्गेरिस* में जबकि सबसे कम *क्रूकोकस माइनर* में देखी गई।

सभी पाँच प्रभेदों ने अर्कों की सांद्रता बढ़ने की साथ साथ फ्री रेडिकल सफाई क्रिया में वृद्धि प्रदर्शित की। इसमें भी कम सांद्रता पर *क्लोरेल्ला वल्गेरिस* जबकि अधिक सांद्रता पर गोलेंकीनिया रेडिएटा ने सर्वाधिक क्रिया प्रदर्शित की। इससे यह सिद्ध हुआ कि *क्लोरेल्ला वल्गेरिस* फ्री रेडिकल सफाई क्रिया में एक बेहतर प्रजाति है। सर्वाधिक IC50 मात्रा भी क्लोरेल्ला वल्गेरिस में पाई गई।

कालीन उद्योग अपशिष्ट से प्राप्त सूक्ष्म शैवाल का सूक्ष्मजीवरोधी एवं जैव-ईंधन क्षमताओं हेतु निरूपण

आकारकीय एवं आणुविक लक्षणों के आधार पर कुल 22 शैवाल प्रजातियों को पहचाना गया। क्लोरोफाइसी सदस्यों के छोटी सबयूनिट के 18S rRNA जीन का सीक्वेंस NCBI जीन बैंक में संग्रहित कराया गया जिनके एक्सेसन नंबर हैं: *क्लोरेल्ला* प्रजाति- KY407757; *क्लोरेल्ला सोरोकिनियाना* KY285080; *क्लोरेल्ला थर्मोफिला* KY317933; एवं *क्लोरेल्ला वल्गेरिस* KY407756।

सभी शैवाल नमूनों से फोल्च विधि से लिपिड निष्कर्षित किया गया एवं जैव-ईंधन क्षमताओं का अध्ययन किया गया।

भारतीय हिमालय में एल्पाइन पारिस्थितिक तंत्र गतिकी एवं जलवायु परिवर्तन का प्रभाव

दीर्घावधि जलवायु परिवर्तन अध्ययन हेतु लाईकेन एवं लाइकेनोमेट्री विश्लेषण करने के लिए भारतीय हिमालय क्षेत्र में उत्तर सिक्किम के काबी एवं टिंगड़ा क्षेत्र में तीन उच्चतम शिखर बिन्दुओं को चुना गया। इन तीन शिखरों से 16 वंशों के 27 जीनस की 52 प्रजातियों को संग्रहित किया गया। लाईकेन वंश पारमेलियेसी का इस क्षेत्र में सर्वाधिक प्रभुत्व है। *अस्निया* जीनस इस क्षेत्र में 13 प्रजातियों के साथ सबसे अधिक विस्तृत है जबकि *राइजोकार्पोन, एकैरोस्पोरा, लेकानोरा* आदि इस क्षेत्र में बिल्कुल भी नहीं पाए गए।

इस क्षेत्र में ब्रायोफाइट्स में सबसे ज्यादा विविधता मॉस पौधों की देखने मिली। *ब्रूटेलिया डाइक्रेनेशिया* इस क्षेत्र में सर्वाधिक पाया जाने वाला मॉस है। यहाँ पर की शीतोष्ण-सबएल्पाइन पौधों की मिश्रित आबादी देखी गई जबकि विशिष्ट एल्पाईन-सबएल्पाईन पौधे कम मात्रा में देखने को मिले हालांकि यहाँ देखे गए कुछ लिवरवर्ट्स जैसे *एनास्ट्रेपटा* एवं *एपोमोर्सुपेल्ला* विशेष रूप से एल्पाईन-सबएल्पाईन क्षेत्र के पौधे हैं जिनका दीर्घावधि निगरानी हेतु बॉयो-सूचक के रूप में प्रयोग किया जा सकता है।

शिमला जिले के रोहरु क्षेत्र में चांशल पास के तीन उच्चतम शिखर बिंदुओं पर लाईकेन पौधों की 51 प्रजातियाँ देखी गईं। यहाँ भी पारमेलीयेसी वंश के पौधे बहुतायत में पाए गए। लाइकेनोमेट्रिक अध्ययन हेतु लाईकेन प्रजाति *राइजोकार्पोन जियोग्राफिकम* की वृद्धि का अध्ययन किया गया।

शैकों (लाईकेन) पर राष्ट्रीय कार्यक्रमः इनके द्वितीयक मेटाबोलाइटों का जैव-पूर्वेक्षण तथा संवर्धनों एवं संग्रहों की स्थापना

भेषज अध्ययन

अस्निक अम्ल, लाइकेस्टेरिनिक अम्ल एवं अन्य द्वितीयक मेटाबोलाइट युक्त शैकों (लाईकेन) का उनकी हिपैटोप्रोटेक्टिव क्षमता हेतु अध्ययन किया गया। लाईकेन अर्कों (NBRI/L10/Ha1, NBRI/L8A/Ha1and NBRI/L5A/Ha1) ने चूहों में कार्बन टेट्राक्लोराईड प्रेरित विषाक्तता के विरुद्ध प्रभावी प्रतिक्रिया प्रदर्शित की।

पादप-रासायनिक अध्ययन

प्रमुख केंद्रों द्वारा प्राप्त स्पष्ट एंटी-ट्यूबरकुलोसिस क्रिया युक्त 5 प्रभावी अर्कों के प्रोटोकॉल का मानकीकरण किया गया। विशिष्ट कीमोमार्कर्रों की पहचान एवं निष्कर्षण के लिए उचित तंत्र विकसित करने हेतु पाँच भिन्न विलायक तंत्रों का प्रयोग किया गया। चार शैकों का HPLC एवं LC-MS का प्रयोग करते हुए शुद्धिकरण एवं रासायनिक निरूपण किया गया।

HPLC एवं LC-MS के द्वारा दो शैकों NBRI-LS6 एवं NBRI-LS7 में छह ज्ञात लाईकेन अम्लों की पहचान एवं निरूपण किया गया। इसी प्रकार दो शैकों NBRI-LS8 एवं NBRI-LS9 के एसीटोन अर्कों में लाईकेन अम्लों/यौगिकों को पृथक्कृत कर पहचाना गया।

MSSRF, ARI एवं NBRI केंद्रों से प्राप्त 26 कोडेड अर्कों में कीमोमार्करों का पृथक्कीकरण एवं पहचान की गई एवं पाँच चयनित अर्कों को यौगिकों के निष्कर्षण हेतु आगे की प्रक्रिया से गुजारा गया। सर्वाधिक एंटी ट्यूबर्कुलोसिस क्रिया युक्त पाँच अर्क क्रमशः ARI/L7/Ha1, ARI/L7/Se1, ARI/L8/Ha1, ARI/L8/Se1 एवं MSSRF/TE/04 देखे गए एवं इन्हें पाँच विभिन्न विलायक तंत्रों में पृथक किया गया ताकि कीमोमार्करों/लाईकेन अम्लों के पृथक्कीकरण एवं पहचान हेतु सर्वश्रेष्ठ विलायक तंत्र की पहचान की जा सके।

विश्लेषण तकनीक के द्वारा PTLC कॉलम क्रोमैटोग्राफी का प्रयोग करते हुए कुल 12 शुद्ध यौगिकों को निष्कर्षित किया गया, पृथक किया गया, शुद्ध किया गया एवं निरूपित किया गया। लाईकेन यौगिकों की लाइब्रेरी विकसित करने की दिशा में प्राप्त किए गए रासायनिक आंकड़ों को व्यवस्थित करने का कार्य किया जा रहा है।

भारत में शैकों का प्रयोग करते हुए जलवायु परिवर्तन निगरानी हेतु तंत्र का विकास

पूर्वी हिमालय के दार्जिलिंग एवं तवांग क्षेत्र, पश्चिमी हिमालय की पिंडर घाटी एवं उत्तर पश्चिम भारत के माउंट आबू में पिछले आधी सदी के दौरान वायुमंडलीय निक्षेप एवं शैक समुदायों के संगठन पर इसके प्रभावों से संबंधित अध्ययन किए गए। इन अध्ययनों से इन क्षेत्रों में शहरीकरण की बहुत तीव्र दर प्रदर्शित हुई। इस अध्ययन ने वायुमंडलीय निक्षेप के एतिहासिक रूझानों को पुनर्गठन करने में एवं वैश्विक जलवायु अथवा स्थानीय सूक्ष्म-जलवायुवीय परिवर्तनों के संदर्भ में शैकों के सामुदायिक संगठन में भिन्नता के अध्ययन में पादपालय नमूनों के महत्व को भी इंगित किया। फ्रूटीकोस शैक समुदाय प्रदूषण के प्रति सर्वाधिक संवेदनशील पाए गए। इस संदर्भ में दार्जिलिंग क्षेत्र में सर्वाधिक प्रदूषण देखा गया इसी क्रम में घटते क्रम में क्रमशः माउंट आबू, पिंडर घाटी एवं तवांग क्षेत्र रहे।

जलवायु परिवर्तनों के कारण बढ़ते तापमान एवम उच्च पराबैंगनी विकिरण के प्रति शैकों की प्रतिक्रिया

इस अध्ययन में शैकों के द्वितीयक मेटाबोलाइट्स, अमीनो अम्लों एवं शैकों की विविधता के प्रयोग के द्वारा भारतीय हिमालयी क्षेत्र में बढ़ते तापमान एवं पराबैंगनी विकिरण के प्रभावों का अध्ययन किया गया। 3200 मी से अधिक की ऊंचाई पर शैक विविधता में रंजक युक्त शैक, मुख्यतः *साइनोबैक्टीरिया* युक्त शैक बहुतायत में देखे गए। यह संकेत करता है कि इस तरह की शैक विविधता एवं सौर विकिरण में कुछ संबंध है जिसकी आगे किए गए प्रयोगो से पुष्टि हुई। इसके अतिरिक्त अन्य ऊंचाई वाले स्थानों पर भी सौर विकिरण को रोकने में सक्षम शैकों की बहुलता वाली विविधता देखने को मिली। *हेटेरोडर्मेटा डाईडिमेटा* में वसीय अम्लों को जैव-मार्करों के रूप में प्रयोग कर शैक समुदाय पर तापमान के प्रभाव को आँका गआ। भारतीय हिमालय के सूदूर दुर्गम क्षेत्रों में कार्बनिक प्रदूषकों के पाए जाने से स्थानीय एवं लंबी दूरी के प्रदूषक स्रोतों मे अंतर स्पष्ट हुआ।PAHs एवं PCBs लंबी दूरी के स्रोतों से उत्पन्न होने एवं NAPH तथा धातुओं के स्थानीय श्रोतों से उत्पन्न होने के संकेत मिले।

भारत के पश्चिमी घाट की नीलगिरी पहाड़ियों के उष्ण कटिबंधीय वर्षा वनों की पारिस्थितिक निरंतरता हेतु शैकों का विश्लेषण

नीलगिरी पहाड़ियों के 18 स्थानों से 223 प्रजातियाँ देखी गई। सर्वाधिक प्रचुर शैकों में *ग्रैफिस* कुल की 25 प्रजातियाँ, अस्निया की 15 तथा *हेटेरोडर्मिया* की 11 प्रजातियाँ देखी गईं। अपने घने वनों के कारण साइलेंट वैली राष्ट्रीय उद्यान की शैक विविधता नीलगिरी की शैक विविधता से काफी अलग देखी गई। पूर्व में देखी गई अनेकों प्रजातियाँ वर्तमान में नहीं पाई गईं जो जंगलों के कटने के चलते विशेष आवासों (विशेष वृक्षों) के नष्ट हो जाने के कारण संभव है। ऊंचे स्थानों पर निचले स्थानों की तुलना में अधिक शैक विविधता देखी गई। नीलगिरी के जंगलों में *ग्रैफिडेसी* शैकों के मिलने से संकेत मिलते हैं कि यह वन पादप-अनुक्रमण की चरम अवस्था में हैं।

हिमालयी शैकों की बारकोडिंगः शैक विविधता अध्ययन एवं भारत में शैक संरक्षण रणनीतियाँ बनाने हेतु अत्याधुनिक दृष्टिकोण

हिमालयी क्षेत्रों के शैक कुल अस्निया एवं सेट्रेरियोइड समूह के शैकों को डीएनए बारकोडिंग अध्ययनों के लिए चुना गया। सेट्रेरियोइड समूह के कुल 75 नमूनों को ITS के द्वारा विश्लेषित किया गया। पीसीआर एवं सीक्वेंसिंग सफलता का प्रतिशत क्रमशः 75% एवं 80% पाया गया। आंकड़ों के माध्यम से यह भी देखा गया कि भारत में अस्निया समूह के शैकों को आसानी से न्यूक्लियर राइबोसोमल आई टीएस के माध्यम से अलग किया जा सकता है।

जैव-प्रौद्योगिकी उद्देश्यों के लिए टीलोशिस्टेसी समूह के दक्षिण एशियाई शैकों का वंशानुक्रम समूहीकरण

भारत के टीलोशिस्टेसी समूह के शैकों पर अध्ययन से स्सवस्किया की दो नई प्रजातियों की खोज हुई एवं एक प्रजाति को पहली बार भारत में देखा गया। इसी के साथ पाँच शैक कवकों को भी भारत में पहली बार देखा गया।

स्वच्छ गंगा हेतु राष्ट्रीय मिशन के अंतर्गत गोमुख से हुगली तक जल की गुणवत्ता की निगरानी

इस अध्ययन के दौरान 11 स्थानों से एकत्र नमूनों से 34 प्रजातियों की जानकारी प्राप्त हुई। इन सभी स्थानों पर क्लोरोफाइसी, सायनोफाइसी एवं बैसिलेरियोफाइसी के सदस्यों की व्यापक उपस्थिती से फास्फोरस एवं नाइट्रोजन जैसे पोषक तत्वों की उच्च मात्रा के मौजूद होने के संकेत प्राप्त हुए। बलिया, पटना एवं भागलपुर जैसे स्थानों पर नदी के किनारे बहुत कम मात्रा में शैवाल मिले जो नदी के किनारे के खेतों में रासायनिक उर्वरक और कीटनाशकों के प्रयोग का संकेत करता है। वाराणसी, हुगली, कानपुर, नरोरा आदि स्थानों पर सीवेज जल की अधिकता के कारण सायनोफाइसी शैवालों की बहुतायत देखने को मिली। वहीं, फरक्का क्षेत्र में संभवतः घने वनाच्छादन एवं बहते जल के कारण कम शैवाल देखने को मिले।

गंगा नदी के किनारे गोमुख से लेकर गंगासागर तक गंगा नदी के किनारे टेरिडोफाइट्स की विविधता एवं वितरण को समझने के लिए एक अध्ययन किया गया जिसमें 215 नमूनों के अध्ययन से 17 प्रजातियों के होने का पता चला।

दार्जिलिंग की पहाड़ियों में जलवायु परिवर्तन एवं संरक्षण रणनीतियों के संदर्भ में ब्रायोफाइट्स की विविधता, प्रजाति प्रचुरता का आंकलन

पादपालय में उपलब्ध ब्रायोफाइट्स नमूनों को पहचाना गया एवं 1000 मी से 2500 मी के बीच अलग-अलग ऊंचाई पर 6 आवास स्थानों क्रमशः मृदा, गीली चट्टानें, सूखी चट्टानें, मृदा आच्छादित चट्टानें, पथरीली दीवारों एवं अधिपादप में वितरण के आधार पर आंकलन किया गया। प्राथमिक आंकड़ों के तीन सेटों क्रमशः सेट 1(1965), सेट 2 (1981, 1983) एवं सेट 3 (2002, 2003) के विश्लेषण के आधार पर 316 प्रजातियों को अभिलेखित किया गया। प्रजाति प्रचुरता के आंकड़ों से यह संकेत मिले कि टाइगर हिल जैसे स्थानों पर पर्यटकों की मानवीय गतिविधियों के चलते प्रजाति प्रचुरता के आंकड़ों में काफी अव्यवस्थता दिखी जबकि लायड वनस्पति उद्यान में कम गतिविधियों एवं प्राकृतिक आवासों की आसानी से उपलब्धता के कारण आंकड़ों में निरंतरता देखी गई।

बीजाणुओं से संवर्धित किए जा सकने वाले *स्फेग्नम खासियानम* को दैहिक ऊतकों से संवर्धन में उगाने में सफलता प्राप्त की गई। इसी प्रकार एक महत्वपूर्ण एशियाई प्रजाति *सोलेनोस्टोमा शाऊलियानम* के संवर्धन में सफलता प्राप्त हुई।

पश्चिमी घाट में ब्रायोफाइट विविधता का अध्ययन

ओडिशा की कई महत्वपूर्ण ब्रायोफाइट प्रचुर स्थानों जैसे सिमलीपाल बाघ एवं बायोस्फीयर रिजर्व, मयूरभंज जिले, महेन्द्रगिरी पर्वत, गजपति जिले आदि का सर्वेक्षण किया गया एवं लगभग 321 नमूने एकत्र किए गए जिनसे 75 प्रजातियों की जानकारी प्राप्त हुई। 12 प्रजातियाँ दक्षिण भारत में पहली बार देखी गईं जबकि 15 प्रजातियाँ पश्चिमी घाट क्षेत्र से पहली बार अभिलेखित की गईं।

चुनिन्दा संकटग्रस्त एवं संभावना युक्त ब्रायोफाइट्स की आकारिकी, प्रजनन जैविकी एवं एक्स-सीटू संरक्षण का अध्ययन

तीन संकटग्रस्त एवं 2 संभावना युक्त लिवरवर्ट्स एवं 1 मॉस का अध्ययन पूर्ण किया गया। संकटग्रस्त प्रजाति *स्टीफेंसोनियेल्ला ब्रेवीपेडंकुलेटा* के ट्यूबर से उत्पन्न संवर्धन को स्थापित करने के प्रयास किए गए। यह देखा गया कि इस प्रजाति को होगलैंड मीडियम एवं हाफ स्ट्रेंथ नॉप + विटामिन मीडियम में प्रयोगशाला स्थितियों में बेहतर तरीके से संवर्धित किया जा सकता है।

भारत में *डेल्फीनी* (रेननकुलेसी) ट्राइब का मोनोग्राफिक एवं वंशानुक्रम अध्ययन

भारत में डेल्फीनी ट्राइब की 46 प्रजातियों एवं 6 अन्य निम्न टैक्सा की उपस्थिति का पता चला जो मुख्यतः 3 कुलों *एकोनिटम, डेल्फीनियम* एवं *कोंसोलिडा* की हैं। मुख्यतः हिमालय के शीतोष्ण कटिबंधीय क्षेत्रों से लेकर अल्पाइन इलाकों में मिलने वाले कुल एकोनिटम की एक नई प्रजाति *एकोनिटम अरुणाई* अग्निहोत्री एवं अन्य को सिक्किम से खोजा गया। यह भी देखा गया कि *डेल्फीनियम* की प्रजातियाँ *एकोनिटम* की तुलना में अधिक दुर्लभ हैं।

आणुविक वंशानुक्रम अध्ययनों में *एकोनिटम* एवं *डेल्फीनियम* के दो भिन्न एवं स्पष्ट क्लेड प्राप्त हुए। अध्ययन ने *एकोनिटम* के एकल वंशक्रम को स्पष्ट रूप से प्रदर्शित किया किन्तु बहुवर्षीय प्रजाति *ए. लैवी, एकोनिटम* की किसी भी अन्य प्रजाति के साथ समूहबद्ध नहीं हुई।

इस समूह की वर्गिकी को बेहतर रूप में समझने के लिए कोशिकावर्गिकी अध्ययनों के अंतर्गत *डेल्फीनियम, एकोनिटम* एवं *कोंसोलिडा* की भिन्न आबादियों के सूत्री एवं अर्धसूत्री विभाजनों का भी अध्ययन किया गया।

एकोनिटम के 4 टैक्सा के लेक्टोटाइप भी निर्धारित किए गए।

किशनपुर वन्य जीव अभयारण्य की वन्य विविधता का मापन एवं पादप संसाधनों का संरक्षण अध्ययन

उत्तर प्रदेश के तराई क्षेत्र में स्थित किशनपुर वन्य जीव अभयारण्य के सर्वेक्षण के दौरान 215 पादप प्रजातियों के नमूने प्राप्त किए गए जिनकी पहचान की गई एवं नमूनों को पादपालय में संग्रहीत किया गया। कुछ लता प्रजातियों का पारिस्थितिक अध्ययन भी किया गया।

उत्तर प्रदेश के सोनभद्र जिले के पुष्पीय पौधों का विविधता आंकलन

सर्वेक्षण एवं पूर्व जानकारी के आधार पर क्षेत्र में 705 प्रजातियों का पता लगाया गया जिनमें से 541 प्रजातियाँ द्विबीजपत्री पौधों की एवं 164 एकबीजपत्री पौधों की हैं। 10 प्रजातियों के साथ फैबेसी परिवार सबसे अधिक प्रचुर समूह है जबकि 14 प्रजातियों के साथ *साइप्रेरस जीनस* सबसे बड़ा है। पूरे वन में मुख्यतः *एकेशिया कटेचू, बोस्वेलिया सेरेटा, ब्यूटिया मोनोस्पर्मा, हार्डविकिया बाइनाटा* एवं *शोरिया रोबस्टा* पौधों की बहुलता है।

उत्तर प्रदेश में लखनऊ के नवाब वाजिद अली शाह प्राणी उद्यान की पादप विविधता का अभिलेखन

स्थानीय पादप विविधता को जानने के उद्देश्य से लखनऊ के नवाब वाजिद अली शाह प्राणी उद्यान में निरंतर सर्वेक्षणों के आधार पर 75 वृक्ष प्रजातियों को पहचाना गया।

असम के दीमा हासो जिले में पादप विविधता आंकलन

असम के दीमा हासो जिले की पादप विविधता आंकलन के लिए क्षेत्र में दो सर्वे किए गए जिनके माध्यम से अब तक150 प्रजातियों को अभिलेखित किया जा चुका है।

भारत में *डिडिमोकार्पस-हेंकेलिया* जेनेरिक समूह की आणुविक वर्गिकी अध्ययन

भारत के 10 एवं 5 विदेशी पादपालयों में उपलब्ध नमूनों के अध्ययनों के माध्यम से *हेंकेलिया* की 26 एवं *डिडिमोकार्पस* की 17 प्रजातियों के प्राथमिक वर्गिकी अध्ययन के आंकड़ों को एकत्र किया जा चुका है। दक्षिणी पश्चिमी घाट (केरल एवं तमिल नाडु), पश्चिम (उत्तराखंड) एवं पूर्वी हिमालय (सिक्किम) के 18 स्थानों पर किए गए सर्वेक्षणों से *हेंकेलिया* की 12 प्रजातियों के 66 नमूने एवं *डिडिमोकार्पस* की 5 प्रजातियों के 41 नमूने प्राप्त किए गए। डीएनए निष्कर्षण हेतु इनकी पत्तियों के 88 नमूनों को एकत्र किया गया। 52 नमूनों को पीसीआर द्वारा प्रवर्धित किया गया। विस्तृत पीसीआर सीक्वेंसिंग प्रक्रिया चल रही है।

घरेलू परियोजनाएं

वर्गिकी अध्ययन एवं भारत की पादप विविधता का डीजिटलीकरण

उत्तर प्रदेश के ऊपरी गांगेय मैदानों में शैवाल, शैक, ब्रायोफाइट्स, टेरिडोफाइट्स, कुकुरबिट्स के वन्य संबंधी एवं फलीदार वृक्षों का वर्गिकी एवं विविधता का अध्ययन

शैवाल

लखनऊ से 7 ताजे जल के शैवाल नमूने एकत्र किए गए जिनमें 12 शैवाल टैक्सा की उपस्थिति देखी गई। क्लोरोफाइसी के सर्वाधिक 5 जीनस की उपस्थिति देखी गई। साथ ही सात शैवाल प्रभेदों को एनसीबीआई जीन बैंक में जमा किया गया।

शैक

गंगा के बाढ़ क्षेत्र में हरिद्वार एवं भीमगोड़ा स्थानों से शैकों के 100 नमूने एकत्र किए गए जिनसे 32 प्रजातियों की उपस्थिति का पता चला। इन क्षेत्रों में इन स्थानों में क्रस्टोज शैकों की बहुलता भी देखने को मिली।

ब्रायोफाइट्स

उत्तर प्रदेश के तराई क्षेत्र के सर्वेक्षण में ब्रायोफाइट्स की 29 प्रजातियों का पता चला जिनमें 7 प्रजातियाँ उत्तर प्रदेश में पहली बार देखी गईं।

पचमढ़ी बायो स्फीयर रिजर्व में विभिन्न आवासों एवं भिन्न भिन्न ऊंचाइयों पर विविधता के आदार पर किए गए अध्ययन में कुल 41 लीवरवर्ट प्रजातियों का पता चला जिनमें से 17 निचले स्थानों (400-800 मी.) जबकि 12 अधिक ऊंचाई वाले स्थानों (1001-1400 मी.) पर पाए गए। किन्तु सर्वाधिक टैक्सा माध्यम ऊंचाई वाले स्थानों में पाए गए।

एक अन्य लीवरवर्ट *कुर्जिया ट्राइकोक्लैडोस* (के. मुलर) ग्रोल्ले को पहली बार भारत में देखा गया। यह पौधा एक असंबद्ध वितरण प्रदर्शित करता है और इससे पूर्व यूरोप, उत्तरी अमेरिका एवं दक्षिण पूर्वी एशिया से ज्ञात था। वर्तमान अध्ययन से दक्षिण एशिया में इस पौधे के वितरण क्षेत्र में विस्तार का पता चला है।

मेघालय के मॉस पौधों के अध्ययन से *एंटोडोन* जीनस के 6 टैक्सा का पता चला जिसमें से *ए. कोन्निसनस* (डे नॉट) पेर. उपप्रजाति *कैलिजीनोसस* (मिट्ट.) मिजुशिमा पूर्वी हिमालय के लिए एक नई खोज है जबकि *ए. स्कैरियोसस* मेघालय के लिए एक नई खोज है।

राष्ट्रीय वनस्पति अनुसंधान संस्थान के मॉस गृह में लाए गए पौधे

1) *ब्रायम कोरोनेटम* स्वईगर
2) *यूनेरिया हाइग्रोमेट्रीका* हेडविग
3) *कोनोसेफेलम कोनिकम* (ली.) लिंडेंब.
4) *रिबोलिया हेमीस्फेरिका* (ली.) रैड़ाई
5) *विसनेरेल्ला डेनूडेटा* (मिट्ट.) स्टेफानी
6) *मार्केन्शिया पोलीमोर्फा* ली.

टेरिडोफाइट्स

उत्तर प्रदेश के टेरिडोफाइट्स की एक चेकलिस्ट तैयार की गई है। 151 टेरिडोफाइट्स नमूनों को अध्ययन किया गया, एवं इनके नमूनों को पादपालय में संग्रहीत किया गया।

राष्ट्रीय वनस्पति अनुसंधान संस्थान के फर्न गृह में लाए गए नए पौधे

अंडमान द्वीप समूह से एकत्रित *नेरोलेपिस हिर्सुटेटा* (जी. फोर्स्ट.) सी. प्रेस्ल को फर्न गृह में लगाया गया।

वृहद उत्पादन एवं संरक्षणः

13 सजावटी प्रजातियों के 1200 पौधों का संरक्षण एवं प्रायोगिक अध्ययनों हेतु वृहद उत्पादन किया गया।

भारतीय *लुफा ली.* (कुकुबिटेसी) की वन्य एवं खेती की जाने वाली प्रजातियों का आणुविक वर्गिकी अध्ययन

क्लोरोप्लास्ट डीएनए के trnL-F क्षेत्रों के विश्लेषण के द्वारा लुफा के 5 टैक्सा के आणुविक वंशानुक्रम अध्ययन किए गए। कुल 35 नमूनों का आंकलन किया गया। वंशानुक्रम आंकड़ों के अनुसार लुफा के सभी नमूने मुख्यतः दो समूहों में विभक्त हुएरू समूह 1 में *लु. हर्मारोडिटा* एवं *लु. अक्यूटेंगुला* के सभी नमूने एवं समूह 2 में 2 उप-समूह देखे गए। उपसमूह 2a में *लु. एचिनेटा* के सभी नमूने जबकि उपसमूह2b में पुनः अन्य प्रजातियों में विभेदन देखा गया। प्राप्त आंकड़ों के आधार पर *लु. हर्मारोडिटा* प्रजाति *लु. अक्यूटेंगुला* के अंतर्गत ही समूह बनाती देखी गई। साथ ही *लु. ट्यूबेरोसा* का मोमोर्डीका में समाहित होने को भी सही साबित किया।

भारत में *इफेड्रा* जीनस की वर्गिकी एवं विविधता

भारत के शुष्क एवं अर्ध शुष्क क्षेत्रों में वितरित *इफेड्रा फोलिएटा* की 11 आबादियों से प्राप्त नमूनो के आधार पर आनुवांशिक विभिन्नता एवं आबादी की आनुवांशिक संरचना पर अध्ययन किया गया। इन आंकड़ों ने सभी प्राकृतिक आबादियों को दो समूहों में विभक्त किया जिससे दो आनुवांशिक रूप से भिन्न आबादियों का पता चला जिनका स्वरूप भौगोलिक वितरण के आधार पर देखा गया।

सीएसआईआर-एनबीआरआई पादपालय (राष्ट्रीय सुविधा) का डिजिटलीकरण एवं संगठन

संस्थान के पादपालय के संगठन एवं देखभाल की प्रक्रिया के अंतर्गत देश भर के विभिन्न स्थानों से लगभग 836 ब्रायोफाइट नमूने एकत्र कर संग्रहीत किए गए। गोविंद वन्य जीव अभयारण्य (उत्तराखंड), पश्चिमी घाट (तमिल नाडु) एवं खासी पहाड़ियों (मेघालय) के 800 नमूनों को पहचाना एवं संग्रहीत करने का काम पूरा हो चुका है।

पादपालय-एक राष्ट्रीय सुविधा

सामान्य पादपालय गतिविधियों के अतिरिक्त अन्य गतिविधिया भी सम्पन्न की गईं। देश भर के शोध संस्थानों/विश्वविद्यालयों/ कॉलेजों आदि के विभिन्न विद्यार्थियों एवं शोधार्थियों को पौधों की पहचान हेतु तकनीकी सहायता प्रदान की गई। देश एवं विदेश के अन्य पादपलयों से पादप नमूनों के हस्तांतरण आदि के लिए संबंध स्थापित किए गए। देश के विभिन्न हिस्सों जैसे कि जम्मू एवं कश्मीर, हिमाचल प्रदेश, ओडिशा, सिक्किम, तमिलनाडु, उत्तराखंड, उत्तर प्रदेश एवं पश्चिम बंगाल आदि से एकत्र नमूनों को पादपालय में संग्रह कर इसे प्रचुर किया गया।

नए संग्रहों में बीजी पौधों के 1,036 नमूने एवं अबीजी पौधों के 2311 नमूने सम्मिलित हैं (टेरिडोफाइट्स -280, ब्रायोफाइट्स -836, लाईकेन -1150, शैवाल -45)।

पादपालय संग्रह

उच्च पौधे (एंजियोस्पर्म्स एवं जिम्नोस्पर्म्स)	1,02,862
टेरिडोफाइट्स	6138
ब्रायोफाइट्स	17,142
लाईकेन	1,51, 500
शैवाल	2675
बीज संग्रह	16,000
कुल पादपालय संग्रह	2,96,317

पादप पारिस्थितिकी एवं पर्यावरण विज्ञान

अनुदान प्राप्त परियोजनाएं

आर्थो-सिलिसिक अम्ल के प्रयोग से धान में आर्सेनिक संदूषण के प्रभावों का अध्ययन

धान के दानों में आर्सेनिक संग्रहण को कम करने में आर्थो सिलिसिक अम्ल के वाणिज्यिक फोर्मुलेशन की भूमिका का अध्ययन किया गया। आर्सेनेट (As^{V}, 10 एवं 50 मिग्रा प्रति ली.) एवं आर्सेनाइट (As^{III}, 10 एवं 25 मिग्रा प्रति ली.) के प्रयोग ने पौधों की वृद्धि को डोज निर्धारित रूप में प्रभावित किया। नतीजों से पता चला कि As^{III} 25 मिग्रा प्रति ली. एवं As^{V} 50 मिग्रा प्रति ली. ने पादप वृद्धि एवं उपज को निश्चित रूप से कम किया।

पौधों को आर्सेनिक देने से अन्य सूक्ष्म अवयवों के संग्रहण को भी प्रभावित किया। आर्सेनिक उपचारित पौधों के दानों में नियंत्रित नमूने की तुलना में जिंक एवं कोबाल्ट की मात्रा काफी कम पाई गई जबकि कॉपर, मैंगनीज तथा सेलेनियम की मात्रा में बढ़त देखी गयी।

भूमि में उपचार करने की तुलना में पत्तियों पर सिलिक्रॉन का उपचार करने से दानों में आर्सेनिक की मात्रा सबसे कम देखी गई। नतीजों ने सुनिश्चित किया किया कि आर्थो सिलिसिक अम्ल आर्सेनिक के बुरे प्रभावों में कमी लाता है जिससे न सिर्फ उपज में बढ़त प्राप्त होती है अपितु दानों की गुणवत्ता में भी सुधार प्राप्त होता है।

आर्सेनिक सहनशीलता हेतु धान की किस्मों की छंटनी: सहिष्णु एवं संवेदनशील किस्मों की जैव रासायनिक प्रतिक्रियाएँ

विभिन्न आर्सेनिक किस्मों के उपापचय को समझने के लिए धान की जड़ों एवं तनों में अकार्बनिक (As^{V}) एवं मेथिलेटेड (MA^{V}, DMA^{V}) आर्सेनिक के संग्रहण, परिवहन आदि का अध्ययन किया गया। मेथिलेटेड आर्सेनिक की तुलना में As^{V} से उपचारित किस्मों में जड़ों में आर्सेनिक का संग्रहण अधिक रहा। As^{V} से उपचारित पौधों में अधिकांश आर्सेनिक जड़ों में ही संचित हुआ एवं मात्र 4% ही तनों में गया। जबकि MA^{V} एवं DMA^{V} से उपचारित पौधों में तनों में क्रमशः 15% एवं 81% आर्सेनिक पहुंचा।

धान की फसल में आर्सेनिक संदूषण के उपचार हेतु जैव आवर्धन आधारित सुरक्षित कृषि पद्धति का विकास

अप्रैल-मई 2016 में पश्चिम बंगाल की आर्सेनिक से बुरी तरह प्रभावित जगहों का सर्वे किया गया ताकि इन स्थानों पर कृषि भूमि में आर्सेनिक की मात्रा का पता लगाया जा सके इस सर्वे में पश्चिम बंगाल के 5 जिलों के 9 ब्लॉकों के अंतर्गत 10 गांवों के 33 खेतों को शामिल किया गया और धान के खेतों से मिट्टी के नमूने लिए गए। आर्सेनिक की उच्च मात्रा होने के आधार पर जुलाई 2016 में नादिया जिले के चकदाह ब्लॉक के गोटेरा एवं घेतुगाची गांवों एवं उत्तर 24 परगना के गाइघाटा ब्लॉक के पिपली गाँव का पुनः सर्वे किया गया। प्रत्येक गाँव से 5 धान के खेतों से मिट्टी के नमूने लिए गए। तीन गावों के 15 खेतों से लिए गए नमूनों में देखा गया कि मिट्टी में मौजूद कुल आर्सेनिक में जैव-उपलब्ध आर्सेनिक की मात्रा 15-25% थी। इन तीनों गांवों के 15 खेतों में से एक को क्षेत्र परीक्षणों के लिए चुना गया। इन परीक्षणों के लिए एक स्थानीय निकाय 'नादिया जिल्ला किसान विकास संगठन' के साथ सहयोग स्थापित किया गया। इन्हीं गांवों में जैव-सुधार हेतु बोरो-धान के सीजन में 4 आर्सेनिक संग्राहक किस्मों क्रमशः आईआर-36, त्रिगुणा, ललाट एवं क्षितिज पर कवक उपचार के प्रयोग भी किए गए।

इसके अतिरिक्त 4 कवक प्रभेदों क्रमशः *वेसटरडाइकेल्ला औरेन्शियाका, ट्राइकोडर्मा लोंगीब्रैशीएटम, लेसियोडिप्लोडिया* प्रजाति, *राइजोपस डेलमर* को उनकी आर्सेनिक निष्कर्षण की क्षमता के लिए अध्ययन किया जा रहा है।

रसायनों के विशेष संदर्भ में जोखिम आंकलन के लिए पादप-पर्यावरण संबंधों की मॉडलिंग

पौधों के पर्यावरणीय संदूषण के जैव-निरीक्षकों की भांति प्रयोग एवं जैव-सुधार प्रयासों हेतु पौधों में रसायनों के ग्रहण की सीमा को समझना महत्वपूर्ण है। 63 वाष्पशील कार्बनिक रसायनों (VOCs) के जल-पादप क्यूटिकल पार्टीशन कोफिशिएंट के आंकड़ों को एकतर किया गया एवं क्यूएसपीआर आधारित मॉडलिंग के लिए चुना गया। सभी रसायनों के लिए एक एवं दो विमीय आणुविक डिसक्रप्टर्स (n=3839) का आंकलन किया गया। इस मॉडल ने कम लागत एवं कम समय के प्रयोग से अनुमान लगाने में बढ़िया क्षमताएँ प्रदर्शित की हैं जिनका प्रयोग संरचानात्मक रूप से काफी भिन्न रसायनों के जल-पादप क्यूटिकल पार्टीशन कोफिशिएंट (log KMXw) के आंकलन में हो सकता है।

घरेलू परियोजनाएं

धान में आर्सेनाइट विषाक्तता का सेलेनेट से उपचार

सेलेनेट से उपचारित धान ने आर्सेनाइट विषाक्तता के प्रति सहिष्णुता प्रदर्शित की एवं आवश्यक अमीनो अम्लों की गुणवत्ता बढ़ाई।

कपास की प्रजातियों के पर्ण ऊतकों में सूखा तनाव के दौरान उपापचयी पाथवे में बदलाव

सूखा तनाव की स्थितियों में सूखा प्रतिरोधी किस्मों JKC-770 एवं JKC-717 ने संवेदी किस्मों KC-2 की RAHS-187 की अपेक्षा अधिक शर्करा एकत्र की जबकि संवेदी किस्मों की शर्करा स्तर में खास अंतर नहीं दिखा। इसी प्रकार γ-अमीनो ब्यूटाइरिक अम्ल एवं प्रोलीन भी प्रतिरोधी किस्मों में एकत्र हुआ एवं वसीय अम्ल की मात्रा में वृद्धि देखी गई।

सूखा तनाव में सोयाबीन में सैलिसिलिक अम्ल की भूमिका

सोयाबीन के पौधों को बीजों के माध्यम से सैलिसिलिक अम्ल (0.5 उड़) से उपचारित कर सूखे से तनाव की स्थितियों में रखा गया एवं दैहिक एवं पुष्पन की स्थितियों में परीक्षण किए गए। अधिक तनाव की स्थिति में दैहिक एवं पुष्पन दोनों ही स्थितियों में एस्कोर्बेट पराक्सीडेज क्रिया स्पष्ट रूप से अधिक देखी गई। साथ ही ग्लूटाथीयोन रिड्क्टेस एवं कैटालेस क्रियाओं में भी माध्य तनाव की स्थिति में वृद्धि देखी गई। सैलिसिलिक अम्ल से उपज लक्षणों में भी स्पष्ट प्रभाव देखा गया।

आनुवंशिकी एवं आणुविक जैविकी

अनुदान प्राप्त परियोजनाएं

सोलेनम खासियानम में काँटों के निर्माण में भाग लेने वाले ट्रांस्क्रिप्शन नियंत्रकों की खोज

सोलेनम खासियानम में काँटों के विकास से संबन्धित कोशिकीय लक्षपन कार्य पूर्ण कर लिया गया है। हमने काँटों की आकारिकीय एवं विकास अवस्थाओं को पहचान लिया है। यह पाया गया कि काँटों का विकास ग्रंथीय रेशों के आधार पर प्रारंभ होता है। इस प्रकार के रेशे तने की सतह पर प्रचुर मात्रा में पाए गए। कांटा युक्त एवं कांटा रहित प्रभेदों के तने के बाह्य त्वचा ऊतकों से ड़िफ्रेंसियल mRNA-सीक्वेंसिंग हेतु आरएनए को निकाला गया ताकि काँटों के विकास एवं उनके कार्यविधि से संबन्धित ट्रांसक्रिप्शन नियंत्रकों को प्राप्त किया जा सके।

एसएनपी मार्करों के प्रयोग से ग्वार की आणुविक आनुवंशिकी

इस अध्ययन के दो मुख्य उद्देश्य हैं- पहला उद्देश्य ग्वार के प्रमुख कृषि लक्षणों का लक्षणन एवं जननद्रव्य का संग्रहण जबकि दूसरा उद्देश्य एसएनपी खोज हेतु जननद्रव्य लाइनों की सीक्वेंसिंग के द्वारा जीनोटाइपिंग एवं उपलब्ध जननद्रव्य का विविधता आंकलन

200 से अधिक नमूनों से जीनोमिक डीएनए को अलग किया गया, मात्रात्मक विश्लेषण किया गया एवं एग्रोज जेल पर गुणात्मक जांच की गई। आरएडी लाइब्रेरी का निर्माण एवं जीबीएस के द्वारा एसएनपी खोज का कार्य चल रहा है।

अलसी में *आल्टर्नेरिया ब्लाइट* प्रतिरोधी लोसाइ की टैगिंग एवं मार्कर के माध्यम से बैकक्रॉसिंग

इस अध्ययन को निम्न उद्देश्यों के हेतु किया गया।

- *आल्टर्नेरिया ब्लाइट* प्रतिरोधी लोसाइ का लिंकेज आंकलन एवं मैपिंग
- प्रमुख किस्म से ब्लाइट प्रतिरोधी लोसाइ की मार्कर के माध्यम से बैकक्रॉसिंग एवं पुष्टीकरण

इस दिशा में अलसी की पितृ लाइनों आईआरएफ-4 एवं चंबल से 216 बहुरूपी एसएसआर की पहचान की गई (कुल 2001 प्राइमरों को जांचा गया)।

इन 216 में से 198 एसएसआर को लिंकेज मैपिंग के लिए उपयुक्त पाया गया। इन 198 एसएसआर में 191 एसएसआर की 15 लिंकेज समूहों में मैपिंग की गई। इन समूहों को LG1 से LG15 के रूप में चिन्हित किया गया।

द्वितीयक मेटाबोलाइटों के ग्लाइकोसिलेशन में कृत्रिम miRNA तकनीक के द्वारा अश्वगंधा के स्टेरोल ग्लाइकोसिलट्रांसफेरेज जीन परिवार का आंकलन

हमने कृत्रिम miRNA के प्रयोग के द्वारा जीन परिवार को अवरोधित करते हुए एवं विषाणु प्रेरित साइलेंसिंग पद्धति द्वारा अश्वगंधा (*विथानिया सोमनीफेरा*) के SGTL जीन परिवार की क्रियाओं का विश्लेषण किया। जीन अवरोधित पौधों ने गर्मी के प्रति सहनशीलता खो दी जिससे तनाव की परिस्थितियों में कोशिका हेमियोस्टैसिस बनाए रखने में इनकी भूमिका का पता चला।

एसजीटी एंजाइमों का गर्मी के तनाव में भूमिका का भी अध्ययन किया गया। ये एंजाइम स्टेरोल रूपान्तरण में शमिल होते हैं एवं तनाव के समय उपापचयी लचीलेपन में भी भाग लेते हैं।

Wsamisgt लाइनों में HSPs का प्रदर्शन संभवतः तनाव के दौरान शरीरकार्यिकी क्रियाओं में शामिल है। प्रोलीन के उच्च एकत्रीकरण को भी देखा गया जो कि संभवतः *Wsamisgt* लाइनों में पानी की कमी को रोकने में शामिल है।

अध्ययनों से पता चला कि अश्वगंधा में एसजीटी एंजामों की क्रिया उच्च तापमान के समय कोशिका झिल्ली में स्टेरोल ग्लाइकोसाईड एवं स्टेरोल के अनुपात को बनाए रख कर कोशिका में आंतरिक नुकसान को कम से कम सुनिश्चित करने के लिए आवश्यक है।

टमाटर में SlERF6 एवं SlERF8 का लक्षित हेरफेरः फल पकने एवं उत्पादकता के नियंत्रण में इनकी भूमिका

SlERF6 को अनेकों पादप वृद्धि क्रियाओं के प्रभावित करने के लिए जाना जाता है। इस अध्ययन के लिए जड़ों की वृद्धि को तीन सीजन में 1.5, 2.5 एवं 4.5 माह पर जांचा गया। भिन्न प्रयोगों के दौरान 1.5 एवं 2.5 माह के बीच, ट्रांसजीनिक लाइनों में जड़ के ताजा भार एवं शुष्क भार में स्पष्ट वृद्धि देखी गई। 4.5 माह पर (जीवन चक्र की समाप्ति पर) 1.4 से लेकर 2 गुना वृद्धि देखी गई। हालांकि, आश्चर्यजनक रूप से जड़ के कुल शुष्क भार में 2.5 माह की अपेक्षा 4.5 माह में कमी देखी गई। इसी अवधि में तने के जैव भार में कोई स्पष्ट परिवर्तन नहीं देखा गया।

एरबिडोप्सिस थैलियाना में ग्लोबल न्यूक्लियोसोमल रीमोडलिंग में NPR1 की भूमिका

NPR1 जीन एक ट्रांसक्रिप्शन को एक्टीवेटर है एवं सिस्टेमिक एक्वायर्ड रेजीस्टेंस (SAR) का केंद्रीय नियंत्रक है। यह विभिन्न सुरक्षा प्रतिक्रियाओं से जुड़े रोगजनन संबंधित जींसों की एक बड़ी मात्रा को SAR सिग्नल अणु सैलिसिलिक अम्ल की संवेदना के माध्यम से नियंत्रित करता है। हम *एरबिडोप्सिस थैलियाना* में न्यूक्लियोसोमल रीमोडलिंग में NPR1 की भूमिका का अध्ययन का रहे हैं। इसके लिए *एरबिडोप्सिस थैलियाना* में MNase-seq एवं ट्रांसक्रिप्टोमिक सीक्वेंसिंग की गई है।

नवीन नर बंध्य तंत्र के माध्यम से F-1 संकर कपास का विकास

एक नए नर बंध्य तंत्र के माध्यम से वाणिज्यिक रूप से सक्षम F1 संकर कपास के विकास की दिशा में प्रयास किए जा रहे हैं। इस तंत्र का विकास भी संस्थान द्वारा ही किया गया है। Cocker-312 की पारजीनी नर बंध्य (ms) एवं रिस्टोरर (fs) लाइनों हेतु एग्रोबैक्टीरियम आधारित आनुवांशिक रूपान्तरण प्रोटोकॉल का मानकीकरण किया जा रहा है।

पादप रक्षा में TBP-संबंधित कारकों की भूमिका का *एराबिडोप्सिस थैलियाना* में अध्ययन

पादप रोगजन संबंध में TAF4b एक ट्रांसक्रिप्शन को-एक्टीवेटर की भूमिका निभाता है। इस कार्य में रक्षा से संबंधित TAF4b संबंधी भागों को पहचानना था जो पौधों में प्रतिरक्षा विकसित करने में सहायक हों। अतः दो भिन्न तरीकों को अपनाया गयाः एक अनियमित मेटिंग दृष्टिकोण एवं एक बाइनरी मेटिंग दृष्टिकोण। अनियमित मेटिंग दृष्टिकोण के द्वारा 42 प्रोटीनों एवं बाइनरी मेटिंग दृष्टिकोण के माध्यम से 41 प्रोटीनों की पहचान की गई।

इसके अतिरिक्त TAF4b एवं एक अज्ञात प्रोटीन, जिसे TIP1 नाम दिया गया है, के सीक्वेंस को डोमेन संरचना के लिए NCBI-CDD टूल के द्वारा जांचा गया।

एनाकार्डिक अम्लः कपास में रेशों की उपज एवं गुणवत्ता बढ़ाने हेतु एक सक्षम अणु

एनाकार्डिक अम्ल कपास में उपज एवं रेशों की गुणवत्ता बढ़ाने के लिए एक महत्वपूर्ण अणु है। पौधों की वृद्धि नियामक के तौर पर इसका सामान्य परिस्थितियों में खेतों में प्रयोग किया गया। यह परीक्षण तीन स्थानों भटिंडा (पंजाब), औरंगाबाद (महाराष्ट्र) एवं हैदराबाद (तेलंगाना) में किए गए। प्राथमिक नतीजों ने कपास के गोलों के भार एवं रेशों की उपज में वृद्धि सुनिश्चित की है हालांकि विस्तृत अध्ययन अभी चल रहे हैं।

फेनॉकॉकस सोलेनोप्सिस में कल्पित लक्ष्यों की ट्रांस्क्रिप्टोम आधारित छंटनी एवं क्रियात्मक पुष्टीकरण

कपास मीलीबग के लिए H1-NMR के माध्यम से फ्लोएम-रस का विश्लेषण किया गया ताकि कृत्रिम आहार में घटकों का मानकीकरण किया जा सके। आहार में मुख्य घटक शर्करा, अमीनो अम्ल एवं कार्बनिक अम्ल पाए गए। कल्पित RNAi लक्ष्यों की छंटनी के लिए ट्रांस्क्रिप्टोम असेंबली का प्रयोग किया गया। अंडों, द्वितीय, तृतीय इंस्टार एवं वयस्क मादा से आरएनए लाइब्रेरी को सीक्वेंस किया गया। इस अध्ययन से इस कीट की सभी विकास अवस्थाओं के बहुमूल्य जीनोमिक संसाधनों का पता चला जिससे भविष्य में आणुविक अध्ययनों में सहायता प्राप्त होगी।

घरेलू परियोजनाएं

कैना जैविकीः पुनुरुत्पादन एवं कैना प्रजातियों का आनुवांशिक रूपान्तरण

बागवानी महत्व के जींस के द्वारा कैना का आनुवांशिक सुधार

कैना की चार किस्मों के प्रकंदों से प्राप्त हिस्सों को6-बेंजिलअमीनोप्यूरीन (6-BA), थिडियाजुरोन (TDZ) अथवा काइनेटिन के इंडोल-3-एसेटिक अम्ल (IAA) के साथ विभिन्न संयोजनों में एमएस माध्यम पर उगाया गया। सबसे सफल किस्म त्रिनेकेरिया वेरीगेटा रही जबकि अन्य में पिंक सनबर्स्ट, अग्निशिखा, एवं रक्तिमा रहीं।

कपास में कीट प्रतिरोध हेतु कीट उत्प्रेरित मेथेनोल उत्पादन

यह प्रदर्शित किया गया कि *एरबिडोप्सिस थैलियाना* एवं *एस्पर्जिलस नाइजर* से निकाले गए पेक्टिन मेथिलईस्टेरेज (PME) के अधिक प्रदर्शन से कीट प्रतिरोध प्राप्त होता है। चूंकि पारजीनों का लगातार अधिक प्रदर्शन कभी-कभी पादप विकास के लिए उपयुक्त नहीं होता है अतः घाव उत्प्रेरित प्रोमोटर के अंतर्गत अधिक प्रदर्शन करने वाले पारजीनी कपास के पौधे विकसित करने के प्रयास किए जा रहे हैं। इस प्रकार से विकसित पौधे कीट के काटने से उत्प्रेरित मेथेनोल उत्पादन प्रदर्शित करेंगे जिससे कीटों के प्रति प्रतिरोध उत्पन्न होगा।

पारंपरिक एवं आणुविक पद्धतियों के माध्यम से पौधों में आनुवांशिक सुधार

सीएसआईआर-एनबीआरआई के प्रांगण में पृथक्कृत क्यारियों में वाणिज्यिक विपणन हेतु विकसित उच्च थीबेन लाइनों के बीजों का बहुगुणन किया गया।

विगत 6 वर्षों में थीबेन लाइनों से प्राप्त डेटा को संकलित किया गया। NBIHT-1 एवं NBIHT-3 लाइनों ने वर्ष दर वर्ष ओपियम की उपज में स्पष्ट वृद्धि प्रदर्शित की। जबकि थीबेन की मात्रा में संभवतः पर्यावरणीय परिस्थितियों के कारण विविधता प्रदर्शित हुई। राजस्थान के चित्तौड़गढ़ एवं मध्य प्रदेश के मंदसौर जिलों में प्रत्येक में दो गांवों में500 मी^{2} क्षेत्र में थीबेन प्रचुर लाइनों NBIHT-1 एवं NBIHT-3 का बहुगुणन एवं ब्रीडर बीजों का विश्लेषण किया गया।

अलसी में SSR एवं SNP आधारित आनुवंशिक विविधता का आंकलन। अलसी में लिनोलेनिक अम्ल एवं अन्य कृषि उपयोगी लक्षणों हेतु लिंकेज/QTL मैंपिग

एसएनपी मार्करों के वृहद सेट का प्रयोग करते हुए (10,057SNPs) अलसी के 86 नमूनों की आनुवंशिक विविधता का आंकलन किया गया एवं विविध नमूनों के एक सेट को भविष्य के ब्रीडिंग कार्यक्रमों के लिए पहचाना गया।

161 SSR मार्करों पर आधारित अलसी के लिंकेज मैप को विकसित किया गया एवं क्यूटीएल मैपिंग की गई। कुल क्यूटीएल पहचाने गएः पौधे की ऊंचाई के लिए 2 क्यूटीएल, 3 क्यूटीएल कैप्सूल प्रति पौधे हेतु, 2 क्यूटीएल बीज प्रति कैप्सूल हेतु एवं 2 क्यूटीएल तेल की मात्रा के लिए।

वन्य एवं खेती की गईं टमाटर प्रजातियों में एसएनपी विविधता की *इन सिलिको* पहचान

मौजूदा बाजार में उपलब्ध टमाटर की किस्मों के सुधार के लिए उच्च उपज एवं तनाव सहिष्णु किस्मों का विकास आवश्यक है। एक्ल न्यूक्लियोटाइड पोलिमोर्फिज्म (SNPs), आनुवंशिक विविधता का एक महत्वपूर्ण स्रोत है जिसका अक्सर फसल सुधार कार्यक्रमों में प्रयोग किया जाता है। वर्तमान अध्ययन में क्रम एवं संरचना दोनों स्तरों पर न्यूक्लिओटाइड प्रतिस्थापन का प्रभाव देखने के लिए जंगली (*सोलेनम हाइब्रोकाइटेस*) एवं खेती किए जाने वाले (*सोलेनम लाइकोपर्सिकोन*) प्रजातियों में न्यूक्लिओटाइड पोलीमोर्फिज्म का इन सिलिको अध्ययन किया गया।

एराबीडोप्सिस थैलियाना की भारतीय आबादियों में डीएनए मेथिलीकरण पैटर्न में विविधता का अध्ययन

समुद्रतल से 700-3500 मी. की अलग-अलग ऊंचाइयों से *एराबीडोप्सिस थैलियाना* की 7 आबादियों से नमूने एकत्र किए गए। ये आबादियां*एराबीडोप्सिस थैलियाना* पर काम करने वाले वैज्ञानिकों के लिए नई हैं।

पादप सूक्ष्म-जीव समन्वयन, भेषज विज्ञान एवं पादप रसायन

पादप सूक्ष्मजीव संबंध

अनुदान प्राप्त परियोजनाएं

काबुली चने में पादप वृद्धि को बढ़ाने वाले राइजोबैक्टीरिया आधारित सूखा तनाव सुधार में miRNA की भूमिका का अध्ययन

काबुली चने के जीनोम में 290 संरक्षित miRNA के लिए कुल 572 चिन्हित जींस को पहचाना गया जबकि 73 नवीन miRNA के लिए 1481 चिन्हित जीनों का अनुमान लगाया गया। सात चयनित miRNA (चार संरक्षित एवं तीन नवीन) के नियंत्रित qRT पीसीआर, RAR, सूखा एवं सूखा +RAR उपचारों के माध्यम से प्रदर्शन विश्लेषण के द्वारा डीप सीक्वेंसिंग डेटा की पुष्टि की गई।

हमारे नतीजों से RNA-seq एवं qRT-PCR डेटा के बीच और साथ ही साथ miRNA एवं चिन्हित जीन प्रदर्शन के बीच बढ़िया सहसंबंध के संकेत प्राप्त हुए। कुल मिलाकर यह संकेत मिले कि RAR टीकाकरण, miRNA एवं चिन्हित जीन प्रदर्शन को बदल देता है जिससे काबुली चने की सूखा प्रतिरोधी किस्म में सूखे के प्रति प्रतिक्रिया में सुधार आता है।

शुष्कता तनाव में प्रमुख बाजरा फसलों की ट्रांसक्रिप्ट प्रोफाइलिंग एवं तनाव-प्रेरित ट्रांसक्रिप्शन फैक्टर्स का अभिलक्षणन

दो बाजरा किस्मों PRLT2/89-33 एवं H77/833-2 के पर्ण ऊतकों के समस्त आरएनए को ड्राई डाउन प्रोटोकॉल (NTR≥0.2) के माध्यम से सूखे से तनाव की स्थिति में रखा गया एवं इलुमिना MiSeq प्लेटफॉर्म के लिए प्रयोग किया गया। विभिन्न प्रकार से प्रदर्शित कुल 40880 जींस प्राप्त हुए जिनमें से 17709 अप-रेगुलेटेड एवं 22414 डाउन रेगुलेटेड थे। जीन ओंटोलोजी एनोटेशन में 'तनाव के प्रति प्रतिक्रिया', 'उद्दीपक के प्रति प्रतिक्रिया' प्रदर्शित करने वाले PRLT2/89-33 जींस एवं साथ ही 'विकास प्रक्रिया' एवं 'जैविक नियंत्रण' से संबन्धित जींस अधिक मात्रा में प्राप्त हुए।

दो नमूनों में सिंगल न्यूक्लियोटाइड पोलीमोर्फिस्म एवं सिम्पल सीक्वेंस मार्कर्स भी देखे गए। H77/833-2 की तुलना में PRLT2/89-33 में अधिक संख्या में SNP एवं SSR पाए गए।

संवेदी (H77/833-2) के तुलना में सहनशील जीनोटाइप (PRLT2/89-33) में अधिक प्रदर्शित 10 चयनित DEG के RNA-Seq मात्रा की qRT-PCR के प्रयोग से पुष्टि की गई।

बाजरा से एक जिंक फिंगर प्रोटीन कोडिंग जीन (*PgZnF*) को भी क्लोन किया गया एवं इसके प्रदर्शन को सूखा तनाव की विभिन्न अवस्थाओं में जांचा गया। यह पाया गया कि यह जीन तनाव की देर की अवस्थाओं में अप-रेगुलटेड था।

घरेलू परियोजनाएं

पादप आणुविक विषाणु विज्ञान अध्ययन

कॉटन लीफ कर्ल मुल्तान विषाणु एवं इससे संबन्धित बीटा सैटेलाइट का भारत में गुड़हल की लीफ कर्ल बीमारी से संबंध

गुड़हल के कुछ पौधों में एक संभावित बेगोमोवायरस संक्रमण के लक्षणों की जांच की गई। DNA की जांच से बेगोमोवायरस के संक्रमण के संकेत मिले साथ ही कॉटन लीफ कर्ल मुल्तान विषाणु से आनुवांशिक समानता देखी गई। कॉटन लीफ कर्ल विषाणु के दो नए प्रभेदो को पहचाना गया। पीसीआर के माध्यम से बीटासैटेलाइट से संबंध को जांचा गया जिससे भारत में पहली बार गुड़हल में कॉटन लीफ कर्ल मुल्तान विषाणु एवं कॉटन लीफ कर्ल बीटा सैटेलाइट की पुष्टि हुई।

भारत में *पारथीनियम हिस्टेरोफोरस* की लीफ कर्ल बीमारी से संबन्धित एक बेगोमोवाइरस, अल्फा सैटेलाइट एवं बीटा सैटेलाइट का आणुविक अभिलक्षणन

लखनऊ के खेतों में *पारथीनियम हिस्टेरोफोरस* के पौधों की पत्तियों में अत्यधिक घुमाव व अन्य लक्षण देखे गए। इस मामले में बेगोमोवाइरस, अल्फा सैटेलाइट एवं बीटा सैटेलाइट के संबंध की जांच के लिए डीएनए की जांच की गई जिससे संक्रामकों बेगोमोवाइरस, अल्फा सैटेलाइट एवं बीटा सैटेलाइट की पहचान क्रमशः ToLCV, PaLCuB एवं AYVIA के रूप में हुई।

भारत में जंगली सूरजमुखी को संक्रमित करने वाले बेगोमोवाइरस एवं बीटा सैटेलाइट का आणुविक अभिलक्षणन

राजस्थान के जयपुर में जंगली सूरजमुखी के पौधों पर बेगोमोवाइरस संक्रमण से मिलते जुलते लक्षणों को देखा गया। इन बीमार पौधों से स्वस्थ पौधों में सफेद मक्खी के माध्यम से संक्रमण का प्रसार भी देखा गया। लक्षणों की जांच के लिए डीएनए जांच से संक्रामकों के रूप में वाइरस एवं सैटेलाइट के रूप में क्रमशः AEV एवं ALCB की पहचान हुई।

भारत में कैना प्रजातियों में तीन विषाणु कुलों (बैडनावाइरस, पोटीवाइरस एवं कुकुमोवाइरस) का साथ-साथ पाया जाना

जनवरी 2012 से जनवरी 2014 के मध्य एनबीआरआई के कैना केंद्र में 10 किस्मों के पौधों में येलो मोसैक मोटल एवं वेन स्ट्रीक के मध्यम से लेकर गंभीर लक्षण देखे गए। इन पौधों में डीएनए जांच के द्वारा कैना येलो मोटेल वाइरस (CaYMV), बीन येलो मोसैक वाइरस (BYMV) एवं कुकुम्बर मोसैक वाइरस (CMV) की पहचान एवं पुष्टि की गई। भारत में इन तीनों वाइरसों के कैना में एक साथ संक्रमण को पहली बार सूचित किया गया है।

भेषज विज्ञान

अनुदान प्राप्त परियोजनाएं

संशोधित खेती एवं इन-विट्रो तकनीकों के माध्यम से कुछ संकटग्रस्त औषधीय पौधों के विशेष कीमोटाइपों से पादपरसायनों का निर्माण

कोलियस फोर्स्कोहलाई के 74 नमूनों एवं *ग्लोरीयोसा सुपर्बा* के 127 नमूनों को देश के विभिन्न स्थानों से एकत्र किया गया तथा इनकी पादप-भौगोलिक जानकारी एकत्र की गई। एकत्र किए गए जननद्रव्य के वानस्पतिक एवं भौतिक-रासायनिक मानकों का भी अभिलेखन किया गया। एकत्र किए गए नमूनों के सूक्ष्म लक्षणों में कोई विशेष परिवर्तन नहीं देखा गया।

मवेशियों में प्रतिरोधी कीटों के नियंत्रण हेतु संभावित पादप कीटनाशियों की कीमोप्रोफाइलिंग एवं क्रियात्मक अभिलक्षणन

एजेरेटम कोनेज्वायडिस के 96 नमूनों को 16 राज्यों से एकत्र किया गया एवं HPTLC के उपरांत मार्कर यौगिक एवं कीटरोधी क्रिया का आंकलन किया गया। HPTLC आंकड़ों से भिन्न क्षेत्रों से एकत्र किए नमूनों में मार्कर यौगिकों की मात्रा में भिन्नता के संकेत मिले। उत्तर प्रदेश, पश्चिम बंगाल, सिक्किम, तमिलनाडु एवं उत्तराखंड के नमूनों में प्रेकोसीनI की मात्रा पाई गई। NAC-01 नमूने में चार मुख्य यौगिक (Lead-I, II, III, IV) एवं CVP-05 नमूने में तीन यौगिक (VP1, VP3 and VP5) पहचाने गए।

ब्राह्मी के विशेष कीमोटाइपों के पहचान एवं पर्यावरण-भूगोल से संबंध

ब्राह्मी के कुल 150 नमूनों को देश के विभिन्न क्षेत्रों से एकत्र किया गया एवं जैव-भौगोलिक जानकारी एकत्र की गई। 78 नमूनों की आकारकीय एवं आंतरिक संरचना की जांच की गई, जिसमें कोई खास अंतर नहीं प्रदर्शित हुआ। चार जैव-मार्करों का मात्रात्मक आंकलन प्रारंभ किया गया एवं 67 का पूर्ण किया गया।

चयनित छोटे पौधों में पोषणात्मक प्रोफाइलिंग, फ्री रेडिकल की सफाई एवं ऐन्टी-ऑक्सीडेंट क्रियाएँ

विभिन्न औषधीय एवं खाद्य पौधों जैसे *अस्निया* प्रजाति, *थैलिक्ट्रम* प्रजाति, छोटे बाजरा, *सराका* प्रजाति, *टर्मिनेलिया* प्रजाति आदि में पोषण संबंधी, एंटीओक्सीडेंट एवं एंटी माइक्रोबियल क्रियाओं का अध्ययन किया गया। साथ ही बायोएक्टिव तत्वों के निष्कर्षण के लिए एक सोलवेंट सिस्टम का विकास किया गया एवं फ्री रेडिकल की सफाई को जांचा गया।

कुपोषण हेतु एक कम लागत का हर्बल मिश्रण विकसित करने के लिए कुछ अल्पज्ञात पौधों की पहचान एवं मूल्यांकन

PC3 सेल लाइनों पर ऐंटीकैंसर क्रिया को जाँचने के लिए *बाहुनिया वेरीगेटा*, पुष्प एवं कली, *बाहुनिया परप्यूरिया* के पुष्प एवं कली के साथ-साथ *ऑगजेलिस क्रॉनीकुलेटा* के सबसे अधिक प्रभावी मेथेनॉल अर्कों का मूल्यांकन किया गया। इन अर्कों ने कैंसर सेल लाइनों पर सांद्रता आधारित तरीके से फैलाव रोधी प्रभाव प्रदर्शित किया।

सिलेजिनेला ब्रायोप्टेरिस (संजीवनी) से निकले गए पॉलीफेनोल्स का जैव-रासायनिक एवं भेषज अध्ययन

चूहों पर किए गए अध्ययनों से प्राप्त नतीजों से पता चला कि संजीवनी से उपचरित चूहों की तनाव सहने की क्षमता में वृद्धि के नतीजे औषधि पादप *विथानिया सोम्नीफेरा* के प्रयोग से प्राप्त नतीजों के समान ही हैं।

लाईकेन प्रजातियों *अस्निया लोंगिसिमा* एवं *क्लैडोनिया फरकेटा* का आंत्र अल्सर में प्रयोग, मानकीकरण एवं पुष्टि

लाईकेन प्रजातियों में लगभग 800 द्वितीयक मेटाबोलाइट पाए जाते हैं जिनमें से अधिकांश सिर्फ इनमें ही मिलते हैं वहीं कुछ द्वितीयक मेटाबोलाइट कवक एवं अन्य उच्च पौधों में भी मिलते हैं।

अस्निया लोंगिसिमा एवं *क्लैडोनिया फरकेटा* से प्राप्त जानकारियों के आधार पर चूहों में अल्सर पर किए गए परीक्षणों में इनसे प्राप्त अर्क ने बीमारी के प्रति स्पष्ट प्रतिक्रिया प्रदर्शित की।

संभावित जैवक्रियाशील रासायनिक मार्कर यौगिकों की पहचान तथा *ग्लोरियोसा सुपर्बा* का जैविक अध्ययन एवं उसकी भौगोलिक विभिन्नताएं

पौधों में मौजूद पादप रसायन, विभिन्न बीमारियों से बचाव एवं उपचार में उनकी प्रभावोत्पादकता में महत्वपूर्ण भूमिका निभाते हैं एवं स्वास्थ्य रक्षा तंत्र पर काफी प्रभाव डालते हैं। *ग्लोरियोसा सुपर्बा* एक संकटग्रस्त औषधीय पौधा है। पेट के अल्सर पर इसके जैवक्रियाशील यौगिकों के जैविक अध्ययन का कार्य किया जा रहा है।

घरेलू परियोजनाएं

औद्योगिक उपयोग वाले भारतीय देशी औषधीय पौधों का गुणवत्ता आंकलन एवं वैज्ञानिक पुष्टीकरण तथा पारंपरिक ज्ञान आधारित हर्बल उत्पाद का विकास

औषधीय रूप से महत्वपूर्ण *टर्मिनेलिया* प्रजाति के विभिन्न भागों का तुलनात्मक भौतिक-पादप-रासायनिक आंकलन

औषधीय रूप से महत्वपूर्ण *टर्मिनेलिया* प्रजातियों जैसे *टर्मिनेलिया अर्जुना* एवं *टर्मिनेलिया बेलिरिका* के विभिन्न भागों का भौतिक-रासायनिक गुणों, कुल फेनोल की मात्रा, कुल लेवोनोइड मात्रा, गुणात्मक एवं मात्रात्मक एचपीटीएलसी आंकलन एवं एंटीओक्सीडेंट क्रिया हेतु परीक्षण किया गया।

अस्निया की चार प्रजातियों में एवरनिक एवं अस्निक अम्ल के आंकलन के लिए HPTLC डेंसीटोमेट्रिक पद्धति एवं एंटी ऑक्सीडेंट क्षमता की तुलना

अस्निया की चार प्रजातियों में एवरनिक एवं अस्निक अम्ल के आंकलन के लिए एक सरल, संवेदी एवं सटीक HPTLC डेंसीटोमेट्रिक पद्धति एवं का विकास किया गया।

थैलिक्ट्रम फोलियोलोसम में द्वितीयक मेटाबोलाइट, एंटी *माइक्रोबियल* एवं एंटी ऑक्सीडेंट क्षमताओं पर ऊंचाई का प्रभाव

थैलिक्ट्रम फोलियोलोसम को पारंपरिक रूप से औषधि के रूप में विभिन्न बीमारियों के उपचार में प्रयोग किया जाता रहा है। इसके अर्क के निरीक्षण से *कैंडीडा एल्बिकेंस, स्टैफाइलोकोकस ऑरियस, एश्चेरिचिया कोलाइ* एवं *स्यूडोमोनास आरुजिनोसा* के प्रति माध्यम से उच्च प्रतिक्रिया प्रदर्शित की।

पारंपरिक रूप से प्रयुक्त होने वाली आयुर्वेदिक औषधि *डिप्लोसाइक्लोस पोमेटस* (कुकुरबिटेसी) में फेनोलिक अम्लों का आंकलन

डिप्लोसाइक्लोस पोमेटस के वायुवीय भागों में फेनोलिक अम्लों एवं उनकी जैव-क्रियाशीलता क्षमता का आंकलन इन विट्रो एंटी ऑक्सीडेंट एसे के माध्यम से किया गया। वायुवीय भागों के फेनोलिक अम्लों में प्रचुर जैव-क्रिया देखी गई। प्राप्त संकेतों से भविष्य में रासायनिक अभिलक्षपन एवं भेषज पुष्टीकरण में सहायता प्राप्त होगी।

बायोफाइटम सेंसीटिवम में फेनोलिक यौगिकों का RP-HPLC मात्रात्मक आंकलन एवं जैविक आंकलन

बायोफाइटम सेंसीटिवम को विश्व भर की पारंपरिक औषधि पद्धतियों में औषधीय पादप के रूप में प्रयुक्त किया जाता है। वर्तमान अध्ययन में इसके फेनोलिक अम्लों पर परीक्षणों से इस पौधे में एंटीऑक्सीडेंट एवं मधुमेह रोधी क्रियाओं के संकेत मिले जो इसके पारंपरिक औषधीय प्रयोग को सही सिद्ध करते हैं।

हर्बल उत्पादों का विकासः

हर्बल सिंदूर स्टिक

हर्बल रंगों, वनस्पति तेलों, सुगंध एवं बी वैक्स को आधार पदार्थ के रूप में प्रयोग कर सिंदूर स्टिक बनाने की तकनीक विकसित की गई। यह उत्पाद विषैला नहीं है एवं भारी धातुओं या रसायनों से मुक्त है। यह प्रौद्योगिकी वाणिज्यिक विपणन हेतु तैयार है।

हर्बल एंटीऑक्सीडेंट फोर्मूलेशन

ऑक्सीडेटिव तनाव के प्रबंधन हेतु एक एंटीऑक्सीडेंट फोर्मूलेशन बनाने की दिशा में चयनित पादप अर्कों को भिन्न अनुपातों में मिला कर मिश्रण बनाया गया। इसकी मुख्य बातें हैं -

- इसमें आयुर्वेदिक पौधों का प्रयोग किया गया है जो आसानी से उपलब्ध हैं।
- यह कीमोथेरेपी एवं शल्य-चिकित्सा से मरीजों में उत्पन्न होने वाले तनाव को कम करने में लाभकारी है।
- फ्री रेडिकल्स को निकालकर आंतरिक एंटी ऑक्सीडेंट तंत्र को मजबूत करता है।
- इसमें पोलिफेनोल्स, विटामिन एवं खनिज मौजूद हैं।
- कम लागत की तकनीक।

हर्बल हैंड सैनीटाइजर

स्वच्छता की दिशा में तैयार इस हर्बल उत्पाद की मुख्य विशेषताएँ निम्न हैं:

- एल्कोहल रहित उत्पाद
- पादप जनित कवकनाशी एवं जीवाणुनाशियों का प्रयोग
- ग्राम-निगेटिव, ग्राम-पॉजिटिव जीवाणुओं एवं कवकों को मरने में सक्षम
- रोगजनक जीवाणुओं के बायो फिल्म के रूप में फैलाव को रोकने में सक्षम
- संक्रमण की रोकथाम एवं हाथों की पूर्ण स्वच्छता
- हाथों की कोमलता को बनाए रखता है

हर्बल टूथपेस्ट

कई आयुर्वेदिक पौधों पर आधारित यह उत्पाद *स्ट्रेपटोकोकस म्यूटेन्स* से दातों को होने वाले क्षय से बचाव में सक्षम है एवं साथ ही उच्च एंटी ऑक्सीडेंट क्रिया युक्त है। इसकी मुख्य विशेषताएँ निम्न हैं-

- आयुर्वेदिक पौधों एवं आवश्यक तेलों का प्रयोग
- प्राकृतिक माउथवाश प्रभाव
- दांतों एवं मसूढ़ों की समस्याओं के लिए उपयुक्त
- फ्लोराइड रहित

पादप रसायन विज्ञान

अनुदान प्राप्त परियोजनाएं

गैर-चिन्हित मेटाबोलोमिक पद्धति द्वारा गुग्गुल के भिन्न कीमोटाइपों में GC-MS एवं NMR स्पेक्ट्रोस्कोपी के प्रयोग से रासायनिक विभिन्नता की जांच

मेटाबोलिक विभिन्नता के अध्ययन के लिए गुग्गुल के तीन भिन्न कीमोटाइपों (NBRI-101, NBRI-102 and NBRI-103) की GC-MS, HPLC एवं NMR स्पेक्ट्रोस्कोपी के प्रयोग से मेटाबोलिक प्रोफाइलिंग की गई। रासायनिक रूप से भिन्न 132 मेटाबोलाइटों को पहचाना गया एवं मात्रात्मक विश्लेषण किया गया।

तनाव नियंत्रण हेतु *एमरेन्थस हाइपोकोंड्रियाकस* के स्क्वालीन की उच्च मात्रा प्रदान करने वाले कीमोटाइपों की मेटाबोलिक प्रोफाइलिंग

तनाव या उच्च रक्तचाप एक जटिल स्वास्थ्य समस्या है जिसके कारण रक्तचाप बढ़ने से हृदयाघात, किडनी के फेल होने जैसी अनेक खतरे उत्पन्न हो जाते हैं। इस संबंध में स्क्वालीन एक सक्षम स्वास्थ्य यौगिक है जिसे कई वानस्पतिक तेलों में भिन्न भिन्न सांद्रताओं में पाया गया है। एमेरन्थ स्क्वालीन का एक ऐसा ही स्रोत है जिसका अभी तक ठीक से दोहन नहीं किया गया है अतः इस दिशा में कार्य किया जा रहा है ताकि इसका खाद्य, प्रसाधन एवं औषधि उद्योग में उपयोग किया जा सके।

(अ) *एमरेन्थस हाइपोकोंड्रियाकस* की मेटाबोलिक प्रोफाईलिंग

एमरेन्थस हाइपोकोंड्रियाकस की आठ किस्मों क्रमशः NBRI-A1, NBRI-A2, NBRI-A3, NBRI-A4, NBRI-A5, PRA-1, PRA-2 एवं PRA-3 को सीएसआईआर-एनबीआरआई एवं वी.सी.एस.जी. उत्तराखंड बागवानी एवं वानिकी विश्वविद्यालय, रानीचौरी, उत्तराखंड से प्राप्त किए गए एवं इनमें स्क्वालीन एवं अन्य जैव-क्रियाशील मेटाबोलाइटों की मात्रा का आंकलन किया गया। स्क्वालीन की सान्द्रता 6.02 से 54.3 मिग्रा/ग्रा बीजभार के बीच देखी गई। सबसे कम सांद्रता NBRI-A2 में व अधिकतम सांद्रता PRA-3 में देखी गई।

(ब) स्क्वालीन प्रचुर तेल अंशों का विकास

एमेरन्थ के दानों के तेल अंशों से स्क्वालीन विकसित करने के एक तरीके का मानकीकरण किया गया। परीक्षणों से पता चला कि इसका उपयोग प्रसाधन एवं पोषण उत्पाद बनाने में किया जा सकता है।

उत्तर प्रदेश की सोडिक बंजर भूमि में खेती हेतु औषधीय पौधों का आंकलन

विथानिया सोमेनीफेरा की पांच किस्मों के पौधों के विभिन्न पादप अंगों में मौजूद छः मुख्य जैवसक्रिय यौगिकों के मात्रात्मक विश्लेषण हेतु एक उच्च क्षमता युक्त पद्धति का विकास एवं पुष्टीकरण किया गया। इस पद्धति के प्रयोग से प्राप्त आंकड़ों ने संकेत दिये कि यह पद्धति काफी आधुनिक त्वरित है एवं *विथानिया सोमेनीफेरा* के साथ-साथ अन्य समान पौधों की गुणवत्ता आंकलन हेतु उपयुक्त है।

कुछ अल्पज्ञात प्राकृतिक गोंद के पृथक्करण/निष्कर्षण हेतु कम लागत की तकनीक का विकास

विभिन्न फार्मुलेशन के निर्माण हेतु उ.प्र. के पांच जिलों क्रमशः वाराणसी, जौनपुर, सोनभद्र, लखीमपुर एवं लखनऊ के गांवों में एक गोंद उत्पादक पौधे *सेस्बानिया सेस्बन* हेतु सर्वेक्षण किये गये। इन अध्ययनों से विभिन्न जनजातियों द्वारा प्रयोग किये जाने वाले तीन नवीन, कम लागत के पादप गोंदों के बारे में जानकारी प्राप्त हुई।

50 से अधिक औषधीय, सगंध, सजावटी एवं आर्थिक रूप से महत्वपूर्ण पौधों की पहचान की गई एवं गोंद उत्पादन हेतु 15 से अधिक पौधों को एकत्र किया गया।

90 से अधिक गांवों में गोंद एवं अन्य जैव उत्पादों की पहचान, संग्रह एवं पृथक्करण हेतु प्रशिक्षण कार्यक्रम चलाये गये।

घरेलू परियोजनाएं

औषधीय एवं सगंध पौधों पर पादप-रासायनिक अध्ययन

दक्षिण भारत के पर्वतीय इलाकों में उगने वाले *आर्टीमिसिया नीलगिरिका* के तेल का रासायनिक संगठन एवं दीमक रोधी क्रिया

आर्टीमिसिया नीलगिरिका के वायुवीय अंगों से प्राप्त तेल का GC-MS स्पेक्ट्रोस्कोपी के माध्यम से विश्लेषण किया गया एवं साथ ही दीमक रोधी क्रिया का इन-विट्रो एवं इन-विवो परीक्षण किया गया। तेल में स्पष्ट दीमक रोधी क्रिया देखी गई।

क्षेत्र परीक्षण

गेहूं की फसल के दीमक से काफी प्रभावित होने के कारण एनबीआरआई द्वारा विकसित किए गए दीमक रोधी फोर्मूलेशन की क्रिया का खेतों में परीक्षण किया गया जिसमें कृत्रिम रासायनिक कीटनाशकों के मुकाबले अधिक दीमक रोधी क्रिया देखी गई।

स्ट्रेबलस एस्पर की मानव कैंसर सेल लाइन पर कैंसर रोधी क्रिया

स्ट्रेबलस एस्पर के मेथेनोल अर्क के विभिन्न अंशो SAH (द-हेक्सेन), SAC (क्लोरोफॉर्म), SAW (पानी) एवं SAB (द-ब्यूटेनोल) को तैयार कर ल्यूकेमिया (K562), फेफड़े (A549), हेपैटोमा (Hep-G2) एवं स्तन कैंसर (MCF-7) की मानव कैंसर सेल लाइनों पर इनकी क्रिया का परीक्षण किया गया। मात्र क्लोरोफॉर्म अंश ने हेपैटोमा कैंसर सेल लाइन पर प्रतिक्रिया प्रदर्शित की।

उच्च संस्थागत नेटवर्क परियोजनाएं

1. जैव संसाधनों एवं अन्य प्राकृतिक उत्पादों का जैव-पूर्वेक्षण

उत्तराखंड राज्य के उत्तरकाशी जिले मे स्थित गोविंद पशु विहार का वानस्पतिक लेखा कुल 11 स्थानीय दौरो द्वारा पूर्ण किया गया। जी पी एस टेगिंग के साथ आवृत्तबीजी की कुल 637, शैक की 352, ब्रायोफाइट की 381, शैवाल की 391 एवं टेरिडोफाईट की 88 प्रजातियाँ आलेखित की गयी, साथ ही लोकवानस्पतिक महत्व के 25 पौधों को भी आलेखित किया गया। विभिन्न पादप समूह जैसे- थिलोट्रेमेटेईड शैक (121 प्रजातियाँ), सिट्रेरिओईड शैक (47 प्रजातियाँ), पुष्पीय पौधों में *कोरीडेलिस* (23 प्रजातियाँ) एवं *फाईकस* (40 प्रजातियाँ) का वर्गिकी अध्ययन पूर्ण किया गया। भारत मे पाए जाने वाले *बर्जिनीया* (सेक्सीफ्रेगेसी) प्रजातियों का आणुविक वर्गिकी द्वारा अध्ययन पूर्ण किया गया। ब्रायोफाइटस की 20 प्रजातियों को संवर्धित कर एवं उनकी स्थापना संस्थान के मौस गृह में की गई।

टेरिडोफाईट के *औंक्यिम कौंटीगम, एथेरियम पेक्टीनेटम*तथा *ड्रायोप्टेरिस कोचिलएटा* प्रजातियों का प्रजनन जीव विज्ञान अध्ययन तथा कृत्रिम इन-विट्रो विधि द्वारा गुणन किया गया।

तीन प्लास्टिड लोकाई (matK, trnH-psbA, rbcL) के आधार पर औषधीय महत्व के 30 पौधों का डीएनए बारकोड पूर्ण किया गया। उत्तपन्न जानकारी को सफलतापूर्वक GenBank तथा BOLD डाटाबेस में सार्वजनिक संदर्भ के लिए प्रस्तुत किया गया।

बेटुला युटिलिस के छाल ऊतक (बार्क टिश्यू) से बर्टुलीन एवं बर्टुलिनिक एसिड के गुणात्मक एवं मात्रात्मक मापन अनुमान के लिए एक तीव्र एवं विश्वसनीय विधि विकसित कर उसकी पुष्टि की गयी। साथ ही *बेटुला युटिलिस* की छाल में उपस्थित आवश्यक तेलों से 22 यौगिको (कम्पाउंड्स) की पहचान की गई। इस तेल ने मानवीय रोगजनक (ह्यूमन पेथोजेन) के विरुद्ध सूक्ष्मजीवनिवारक गतिविधि (एंटीमाइक्रोबियल एक्टिविटी) को प्रदर्शित किया।

चार भिन्न भौगोलिक क्षेत्रों से संग्रहीत *हेडिचियम स्पाइकेटम* प्रकन्द (राईजोम) से उत्तपन्न आवश्यक तेल से 29 यौगिको (कम्पाउंड्स) की पहचान की गई। मानवीय कैंसर सेल लाईन्स के विरुद्ध कोशिकाविषी गतिविधि (साइटोट क्सिक एक्टिविटी) के लिए इन तेल नमूनों का मूल्यांकन किया गया। पंगोट (नैनीताल) से प्राप्त नमूने (सैंपल) मेंα-केडीनोल (α-Cadinol) की उपस्थिति के कारण इसने सभी कैंसर सेल लाईन्स के विरुद्ध उच्चतम सक्रियता प्रदर्शित की। *हेमिडेस्मस इंडिकस* की पत्तियों से पृथक दो यौगिको (कम्पाउंड्स) ने अतिग्लूकोसरक्तता सक्रियता (हाइपरग्लायसेमिक एक्टिविटी) प्रदर्शित की।

जस्टिशिया आधाटोडा से उत्तपन्न आवश्यक तेल से 20 यौगिको (कम्पाउंड्स) की पहचान की गई तथा यह पाया गया कि ये मानवीय रोगजनकों (ह्यूमन पेथोजेन) के विरुद्ध सूक्ष्मजीवनिवारक सक्रियता (एंटीमाइक्रोबियल एक्टिविटी) प्रदर्शित करते हैं।

हेडिशियम स्पाईकेटम के विभिन्न सुगंधित (एरोमेटिक) तेलों तथा रसायनों पर आधारित तीन सूत्रिकरणों की उम्र-रोधी (एंटी एजिंग) क्षमता हेतु परीक्षण किया गया।

हेडिशियम स्पाईकेटम के विभिन्न अर्कों (एक्स्ट्रेक्ट्स) से आठ विशिष्ट पोलिफीनोल्स (गेलिक एसिड, प्रोटोकेटेचुइक एसिड, क्रोजेनिक एसिड, फेरुलिक एसिड, केफिक एसिड, रुटिन, क्वेर्सेटिन तथा केमफेरोल) का मापन किया गया तथा साथ ही साथ कुल फेनोलिक मात्रा (कटैंट), कुल लेवोंनोइड मात्रा तथा एंटिआक्सिडेंट गतिविधि का भी अध्ययन किया गया।

ब्रायोफाइट की *मार्केंशिया पॉलीमोर्फा* प्रजाति का इन-विट्रो कोशिकाविष गतिविधि (साइटोटॉक्सिक एक्टिविटी) का मूल्यांकन चार कैंसर सेल लाईन्स {स्तन, बृहदांत्र, सिर और ग्रीवा तथा सामान्य उपकला कोशिकाओ (नॉर्मल एपिथेलियल सेल्स)} के विरुद्ध किया गया।

इन विट्रो तथा इन विवों म डेल प्रणाली के अंतर्गत सूक्ष्मजीवनिवारक (एंटिमाइक्रोबियल) बाईनेनों जेल (BIONANO gel) को (NBC-099) विकसित किया गया।

2. औषधीय पौधों एवं कृषि के लिए महत्वपूर्ण लक्षणों की जीनोमिक्स

पैपावरीन जैव-संश्लेषण से संबंधित कल्पित जींस के cDNA को पहचाना गया एवं क्लोनिंग की गई। उपापचयी उत्पादों में उतार चढ़ाव के अध्ययन हेतु विषाणु प्रेरित जीन साइलेंसिंग के लिए विभिन्न खंडों को विकसित किया गया एवं प्रयोग किया गया। साथ ही थीबेन प्रचुर पॉपी लाइनों के ट्रांस्क्रिप्टोम डेटासेट को भी स्थापित किया गया एवं अध्ययन किया जा रहा है। पके एवं कच्चे केले का ट्रांस्क्रिप्टोम अध्ययन एवं लघु आरएनए सीक्वेंसिंग का कार्य भी पूर्ण हो चुका है एवं miRNA परिवारों के विभिन्न जीनों का विस्तृत अध्ययन किया जा रहा है।

आमों की दशहरी एवं बॉगनपल्ली किस्मों के बाहरी एवं अंदरूनी हिस्सों के आरएनए की इल्यूमिना आधारित सीक्वेंसिंग पूर्ण की गई एवं विश्लेषण किया गया।

रोजा बर्बोनियाना एवं रोजा *हाईब्रिड़ा* के विलगन क्षेत्र विशेष ट्रांस्क्रिप्टोम डेटासेट के विश्लेषण से गुलाब में पंखुड़ियों के झड़ने में एथेलीन जैवसंश्लेषण एवं अन्य सिग्नलिंग क्रियाओं के लिए जिम्मेदार जीनों की पहचान में सहायता पाप्त हुई।

द्वितीयक पादप उत्पाद जैवसंश्लेषण में miRNA की भूमिका को स्थापित करने के लिए एराबिडोप्सिस के miR858a का क्रियात्मक विस्तृत अभिलक्षणन किया गया। इस अध्ययन से लैवोनोइड जैवसंश्लेषण एवं पादप वृद्धि एवं विकास में miR858a की भूमिका स्थापित की गई।

कपास में, रेशों के विकास से संबन्धित हिस्टोन रूपांतरणों में शामिल जीन परिवारों को पहचाना गया एवं विस्तार से अभिलक्षित किया गया। साथ ही, द्वीतीयक कोशिका भित्ति जैवसंश्लेषण के ट्रांस्क्रिप्शनल नियंत्रण, जो कि कपास के रेशों के विकास की एक महत्वपूर्ण अवस्था है, को विस्तार से अध्ययन किया गया।

इंडिका एवं जैपोनिका धान के कैलस संवर्धन की विभिन्न विकास अवस्थाओं के ट्रांस्क्रिप्टोम को स्थापित एवं विश्लेषित किया गया। दैहिक भ्रूण विकास के दौरान गतिशील ट्रांस्क्रिप्टोम लैंडस्केप ने धान की जैपोनिका एवं इंडिका उप-प्रजातियों में भिन्नात्मक स्टेम सेल प्रबंधन प्रोग्रामिंग के संकेत दिये। आर्सेनिक का कम संग्रहण करने वाली धान की किस्म विकसित करने की दिशा में, आर्सेनिक संदूषित मृदा क्षेत्र से *वेस्टरडाइकेल्ला आरंशिका* से एक नवीन आर्सेनिक मेथिलट्रांसफेरेज जीन को निकाला गया एवं क्रियात्मक अभिलक्षणन किया गया। इस जीन ने जीवाणुओं *ई. कोलाई* एवं *एस. सेरेविसी* में आर्सेनिक सहनशीलता में वृद्धि प्रदर्शित की। धान को इस आनुवांशिक रूप से सुधारित यीस्ट के साथ संवर्धित करने से धान में आर्सेनिक सहिष्णुता ने इस जीन के आर्सेनिक जैव-उपचार में संभावित भूमिका के संकेत दिये।

कपास की wtp12 (फर्न से निकाले गए एक कीटनाशक जीन) एवं WTP12 प्रोटीन का प्रदर्शन करने वाली पारजीनी लाइनों का विस्तृत अभिलक्षणन किया गया। कीटनाशक प्रोटीन की क्रिस्टल रचना स्थापित की गई जिसने कपर के संयोजन को दर्शाया एवं प्रोटीन रचना में दो डाइसल्फाइड बंधों का शामिल होना प्रदर्शित किया। सफेद मक्खी प्रतिरोध के साथ ही, पारजीनी लाइनों ने कॉटन लीफ कार्ल बीमारी के प्रति भी प्रतिरोध प्रदर्शित किया। उद्योगों को तकनीकी हस्तांतरण की संभावनाओं को तलाशा जा रहा है। इस अध्ययन से संबन्धित शोधपत्र प्रख्यात विज्ञान जर्नल नेचर बायोटेक्नोलोजी में प्रकाशित हो चुका है।

3. पादप विविधताः अनुकूलन जैविकी का अध्ययन एवं उपयोगी बायोएक्टिव हेतु औषधीय रूप से महत्वपूर्ण पौधों का अध्ययन/दोहन

भारतीय उष्ण कटिबंधीय पर्णपाती वन में जमीन से ऊपर जैव भार का आंकलन

जमीन से ऊपर का जैव भार पारिस्थिक तंत्र का एक महत्वपूर्ण मानक है जो इसकी क्रियाशीलता प्रदर्शित करता है। यह पारिस्थितिक कार्बन संग्रह एवं लक्स के आंकलन के लिए सीधे तौर पर महत्वपूर्ण है।

प्रस्तुत अध्ययन उत्तर प्रदेश के कतर्नियाघाट वन्य जीव अभयारण्य में वन के जैव-भार के आंकलन एवं कार्बन एवं पोषक तत्वों के परिचालन के नियंत्रण में उसकी भूमिका को समझने के लिए किया गया। हमने डीबीएच डेटा का प्रयोग करते हुए तीन वन समुदायों (शुष्क मिश्रित, साल मिश्रित एवं टीक वन) में वन के भूमि से ऊपर के जैव भार को आँका एवं उपरोक्त भिन्न प्रजाति संगठन, घनत्व एवं धरातलीय क्षेत्र वाले तीनों वन समुदायों वृक्षों में जैव भार कार्बन वितरण भी निर्धारित किया।

नियंत्रित परिस्थितियों की तुलना में सामान्य उद्यानों में *एराबिडोप्सिस थैलियाना* की ऊंचाई वाली स्थानों की आबादियाँ अधिक लचीलापन एवं अनुकूलन क्षमता

हमने पश्चिमी हिमालय के भिन्न स्थानों से प्राप्त *एराबिडोप्सिस थैलियाना* की तीन प्राकृतिक आबादियों (क्रमशः Deh-700mt, Mun-1800mt एवं Chit-3500mt) में आकारिकीय भिन्नता एवं लचीलेपन को विश्लेषित किया। हमने जीनोटाइप के कारण प्रदर्शित लचीलेपन के स्तरों की आपस में तुलना की एवं इसकी पर्यावरणीय लचीलेपन से तुलना की। आबादियों को दो परिस्थितियों में उगाया गयाः CG - एनबीआरआई में सामान्य उद्यान में एवं GH-नियंत्रित एराबिडोप्सिस संवर्धन कक्ष। वृद्धि की विभिन्न अवस्थाओं के दौरान आकारिकीय आंकड़े एकत्र किए गए। फीनोटिपिक लक्षणों, उनके लचीलेपन एवं चयन के हमारे विश्लेषण से संकेत मिले कि सामान्य उद्यान के पौधे सेहत के संबंध में नियंत्रित परिस्थितियों वाले पौधों से अधिक सफल रहे। इन पौधों की सेहत प्रकाश की तीव्रता एवं अधिकतम तापमान द्वारा प्रभावित हुई। विपरीत पर्यावरणीय परिस्थितियों का सामना करने के कारण आधिक ऊंचाई वाली आबादियाँ संभवतः मिश्रित परिस्थितियों में अच्छी तरह स्थापित होने के लिए विकसित हुईं अतः अधिकतम निचले स्थानों की आबादियों की तुलना में अधिक लचीलापन एवं अनुकूलन प्रदर्शित किया।

कमीफोरा वाइटाई (गुग्गुल) के मेटाबोलाइट्स में सीजनल भिन्नता

मेटाबोलिक विविधता के अध्ययन के लिए कमीफोरा वाइटाई के तीन भिन्न कीमोटाइपों (NBRI-101, NBRI-102 and NBRI-103) की पत्तियों, तनों एवं लेटेक्स नमूनों के जलीय एवं गैर-जलीय अर्कों की मेटाबोलिक प्रोफाइलिंग की गई। GC-MS, HPLC एवं NMR स्पेक्ट्रोस्कोपी आधारित मेटाबोलाइट प्रोफाइलिंग से रासायनिक रूप से भिन्न 132 मेटाबोलाइटों को पहचाना गया जिनमें 25 अमीनो अम्ल, 15 कार्बनिक अम्ल, 2 क्वार्टरनेरी अमीन, 6 शर्कराएँ, 1 एल्केलोइड, 31 वसीय अम्ल, 14 एल्केन, 7 प्रेग्नेन डेरीवेटिव, 2 कीटो-स्टेरोल, 2 स्टेरोल, 18 टर्पीन, 1 विटामिन एवं 1 पाँच सदस्यीय लैक्टम शामिल हैं। वर्तमान अध्ययन से पता लगा कि औषधीय उपयोगों के लिए गुग्गुल के संरक्षण हेतु वांछनित कीमोटाइपों को पहचानने में गैर-लक्षित मेटाबोलाइटों को प्रयोग किया जा सकता है। यह भी पता चला कि सर्दियों (जनवरी) में प्राप्त किए गए पादप अंगों से अधिकतम मात्रा में प्रभावी स्वास्थ्य रक्षा एजेंट प्राप्त होते हैं। रामदाना (*एमेरेन्थस हाइपोकोंड्रीयाकस*) के विभिन्न कल्टीवर्स से उनके मुख्य यौगिक स्क्वेलीन की विविधता को एचपीएलसी तकनीक द्वारा पहचाना गया। विभिन्न कल्टीवर्स में स्क्वेलीन की मात्रा भिन्न भिन्न पाई गई जिसका उपयोग हर्बल, पोषण एवं प्रसाधन उत्पाद बनाने में किया जा सकता है।

4. औषधीय रूप से महत्वपूर्ण पौधों की स्थापना, अनुकूलन, सुधार एवं कृषि

केना, ग्लैडिओलस एवं अन्य कंदार फसलों की उन्नत किस्मों का अभिलक्षणा एवं विकास

केना किस्मों पर प्रयोग

नई किस्मों के विकास हेतु गोल्डन गर्ल एवं रेड प्रेसीडेंट किस्मों के प्रकंदों को गामा रेडिएशन से उपचारित किया गया एवं उगाया गया। नए म्यूटेंट देखे गए जिनको पहचान कर अलग कर लिया गया जिन्होंने फूलों के रंग एवं संयोजनों में परिवर्तन में स्थायित्व प्रदर्शित किया। ऐसे दो म्यूटेंटों के आकारकीय लक्षणों का प्रलेखन किया गया।

ग्लैडिओलस का आनुवांशिक अभिलक्षणन

सभी नमूनों के हरित लवक सीक्वेंसों को Clustal W प्रोग्राम के प्रयोग के द्वारा पंक्तिबद्ध किया गया। ग्लैडिओलस किस्मों में psbA-trnH क्षेत्र के

पंक्तिबद्ध cpDNA सीक्वेंस औसत लंबाई 579 bp के साथ 556bp से 583 bp के बीच देखे गए। इसी प्रकार ग्लैडिओलस प्रजातियों में tmL-trnF क्षेत्र के पंक्तिबद्ध cpDNA सीक्वेंस औसत लंबाई 672 इच के साथ 671इच से 678 इच तक पाए गए। 62 ग्लैडिओलस किस्मों में आनुवांशिक विविधता हेतु EST उत्पन्न माइक्रोसैटेलाइट को विकसित एवं अभिलक्षित किया गया।

ग्लैडिओलस जनन द्रव्य की पहचान के लिए आईएसएसआर एवं आरएपीडी उत्पन्न एससीएआर मार्करों का विकास

ग्लैडिओलस जनन द्रव्य की पहचान एवं पुष्टीकरण के लिए आईएसएसआर एवं आरएपीडी खंडों से उत्पन्न एससीएआर मार्करों का विकास किया गया। एससीएआर मार्कर ScG12, ScG34 एवं ScG36 सभी 62 किस्मों के लिए विलक्षण हैं।

ग्लैडिओलस किस्मों में आनुवांशिक विविधता विश्लेषण हेतु *cpSSR* मार्करों का विकास

ग्लैडिओलस के क्लोरोप्लास्ट क्षेत्र के रिपीट सीक्वेंस से 12 नवीन माइक्रो सैटेलाइट मार्करों को को अलग कर विकसित किया गया। सिम्पल सीक्वेंस रिपीट की खोज के लिए ग्लैडिओलस के क्लोरोप्लास्ट क्षेत्र के कुल 1188 न्यूक्लियोटाइड सीक्वेंसों को प्रयोग किया गया एवं 108 सीक्वेंसों में 124 एसएसआर मार्कर पाए गए। 12 एसएसआर मार्करों के उपयोग से ग्लैडिओलस की 62 वाणिज्यिक रूप से महत्वपूर्ण किस्मों में आनुवांशिक विविधता का आंकलन किया गया।

पादप सुधार हेतु बिक्सा एवं कुरकुमा जनन द्रव्य संग्रह का विश्लेषण

हल्दी की एक नई किस्म 'केसरी', जिसको 8 फरवरी, 2016 को जारी किया गया था, में ठंड को सहने की उच्च क्षमता है साथ ही उच्च उपज क्षमता भी है जो कि सोडिक मृदा में भी नजर आती है। इस नई किस्म के प्रकंदों को लखनऊ के आस पास के आम के बागान वाले प्रगतिशील किसानों को उपलब्ध कराया गया। वर्ष 2016-17 में भी देरी से तैयार होने, शीघ्र प्रस्फुटन वाले, छाया प्रेमी एवं रोगमुक्त जनन द्रव्य की जांच हेतु 34 नमूनों का गांगेय मैदानों में सोडिक मृदा में परीक्षण जारी रहा।

बिक्सा के 17 नमूनों को संरक्षित किया गया एवं उनकी वृद्धि एवं गुणवत्ता प्रदर्शन हेतु सोडिक मृदा परिस्थितियों में उगाया गया एवं आंकलन किया गया। उनके आकारकीय प्रदर्शन, उपज, एवं गुणवत्ता के आधार पर इन नमूनों को 8 समूहों में बांटा गया। इन 17 नमूनों में से 5 बेहतर नमूनों को चयनित कर सीएसआईआर-एनईआईएसटी एवं सीएसआईआर-आईआईआईएम में बहु-स्थानीय प्रयोगों के अंतर्गत लगाया गया। इस वर्ष छंटाई से संबन्धित प्रयोग किए गए।

पौधों पर जैव-उर्वरकों एवं जैव पीडकनाशी के प्रदर्शन का आंकलन

विभिन्न स्थानों पर ग्लैडिओलस के पौधों पर पादप वृद्धि उत्प्रेरक के रूप में इनके प्रयोग को जांचा गया एवं अच्छे नतीजे पाये गए। फॉस्फेट घोलक जीवाणुओं पर आधारित फोर्मूलेशनों को न सिर्फ ग्लैडिओलस अपितु अन्य फसलों के लिए भी बायो-इनोकूलेंट बनाने के लिए वृहद स्तर पर प्रयोग किया जा सकता है।

5. स्वास्थ्य, रोग एवं पर्यावरणीय विषालुता के क्षेत्र में एकीकृत, अगली पीढ़ी का समेकित दृष्टिकोण

आर्सेनिक पादप निष्कर्षण एवं धान के दानों में अल्प आर्सेनिक हेतु अनुकूलन रणनीति

बोरो खेती के दौरान दानों में कम आर्सेनिक सांद्रता एवं उच्च उपज वाली चावल की एक किस्म CN-1794-2-CSIR-NBRI (मुक्ताश्री) को सीएसआईआर-एनबीआरआई एवं राइस रिसर्च स्टेशन, चुचुरा, पश्चिम बंगाल सरकार के द्वारा संयुक्त तत्वाधान में विकसित किया गया। इसे स्टेट वैराइटी रिलीज कमेटी, पश्चिम बंगाल द्वारा 15 जनवरी, 2016 को अनुमोदित किया गया। सफल बहू-क्षेत्रीय परीक्षणों के उपरांत आर्सेनिक प्रभावित क्षेत्रों में खेती के लिए इस किस्म का अनुमोदन कर दिया गया है।

फसलों के साथ आर्सेनिक संग्राहकों को उगाकर आर्सेनिक ग्राह्यता को कम करना

आर्सेनिक प्रभावित मृदा में तीन मुख्य उच्चसंग्राहकों *टेरिस विटाटा, फ्रैग्माइटिस* एवं *वेटिवेरिया* को क्यारियों में धान एवं गेहूं की फसलों के साथ उगाया गया। धान के साथ इन्हें उगाने पर मृदा में आर्सेनिक की मात्रा में कमी देखी गई। *फ्रैग्माइटिस* के साथ धान एवं गेंहू की फसल उगाने पर पर मृदा आर्सेनिक में क्रमशः 56 से 63% की कमी देखी गई।

धान की भूसी के अपघट्न द्वारा भूमि में कार्बन जब्ती हेतु मृदा में मौजूद प्रभावी सूक्ष्म जीवाणु

लगभग 100 सूक्ष्मजीव नमूनों में से सेलुलोलिटिक, पेक्टिनोलिटिक, लिगनोलिटिक क्रिया युक्त 23 संभावित जीवाणु विभेद एवं 12 ट्राइकोडर्मा आइसोलेट को छांटा गया। इनमें से 11 में पादप वृद्धि प्रेरक क्रिया देखी गई जबकि 3 जीवाणु प्रभेदों एवं 4 ट्राइकोडर्मा प्रभेदों में सिलिकोन मिनेरालाईजेशन क्षमता देखी गई। यह क्षमता धान की भूसी के अपघटन के लिए आवश्यक है।

पेट्रोलियम हाइड्रोकार्बन के त्वरित अपघट्न हेतु सूक्ष्म जीवाणु आधारित रणनीति का विकास

तैलीय कीचड़ से 12 विभिन्न जीवाणु प्रभेद अलग किए गए जिनमें इन-विट्रो परिस्थितियों में उच्च अपघट्न क्षमता देखी गई।*रोडोकोकस*प्रजाति एन12 एवं *स्यूडोमोनास एरुजिनोसा*PSA5 ने 10 दिनों में लोरैन्थीन की उच्च सांद्रता (200 ppm) का अपघटन प्रदर्शित किया वहीं उन्हीं परिस्थितियों में इन दोनों के संयोजन ने 97% तक अपघटन प्रदर्शित किया।

6. भारत के गांगेय मैदानों एवं हिमालयी क्षेत्रों में बदलते पर्यावरण एवं इसके प्रभावों का अध्ययन

पिछले कुछ दशकों में मानवीय गतिविधियों ने पर्यावरणीय परिवर्तनों की दर को तेज करने में विशेष भूमिका निभाई है। 1970 से 2004 के मध्य CO_2 उत्पादन में 80% तक की वृद्धि हुई है। CO_2 के बढ़ते स्तर का पौधों पर प्रभाव FACE तकनीक के प्रयोग से बेहतर रूप से अध्ययन किया जा सकता है जिसके माध्यम से प्राकृतिक परिस्थितियों में उच्चीकृत CO_2 का पौधों पर प्रभाव देखा जा सकता है। एथीलीन डाईयूरिया (EDU) के प्रयोग से खुले खेतों की स्थितियों में पौधों पर O_3 के प्रभावों का अध्ययन किया जा सकता है।

इस दिशा में सामान्य तौर पर उगाए जाने वाली गेंहू की तीन किस्मों पर अध्ययन किया गया। EDU के प्रयोग ने पौधों की ओजोन के हानिकारक दुष्परिणामों से रक्षा की। चयनित गेंहून की किस्मों में से HD2967 ने आकारिकी, कार्यिकी एवं जैव-रासायनिक प्रदर्शनों में बेहतर प्रदर्शन किया।

7. पादप, सूक्ष्मजीव एवं मृदा संबंध

मृदा के सूक्ष्मजीवाणुओं में पौधे की वृद्धि को बढ़ाने के गुण होते हैं परंतु तनाव की स्थिति में सभी सूक्ष्मजीवाणु पौधों के लिए पर्याप्त लाभकारी नहीं होते हैं। ऐसे में शोधकर्ताओं के लिए चुनौती है कि चरम वातावरण के प्रति अपने शोध को विस्तार करते हुए समर्थ जीवाणुओं को पृथक् करें जो विभिन्न प्रकार से पौधों के विकास के लिये लाभकारी तथा अजैविक वातावरण के प्रति सहिष्णु हों। वर्तमान अध्ययन में पौधों के विकास को बढ़ावा देने और अजैविक तनाव को कम करने के लक्षणों के आधार पर ज्वालामुखीय मिट्टी (चरम वातावरण) से मृदा जीवाणुओं का मूल्यांकन करने के लिए एक प्रयास किया गया है। इसके पश्चात चयनित जीवाणुओं में विभिन्न समय अंतराल पर अजैविक तनाव के कृत्रिम परिवेश में जीवित रहने हेतु (कॉलोनी निर्माण इकाई) फॉस्फेट घुलनशीलता, बायोफिल्म निर्माण, ऑक्सिन, अल्जीनेट और एक्सो-पॉलीसेकेराइड उत्पादन क्षमताओं का अध्ययन किया गया है। प्राकृतिक परिवेश में मक्का के बीजों का चयनित जीवाणुओं से उपचार के बाद पौधों के तने एवं जड़ की लम्बाई तथा भार (ताजा/सूखा) में महत्वपूर्ण वृद्धि पाई गई। फलस्वरूप पौधों के विकास में सहायक एवं अजैविक तनाव को कम करने में सक्षम जीवाणुओं के पहचान *ओक्रोबैक्ट्रम* एवं *स्यूडोमोनास* के रूप में की गई।

जंगली अथवा उद्यानों में उगने वाले गैर-फसली पौधों में विषाणुओं की पहचान का बहुत महत्व है। हमने गैर फसली पौधों पर अनेकों डीएनए एवं आरएनए विषाणुओं के संक्रमण का पता लगाया है। खेतों के आस पास उगने वाले गुड़हल पर कॉटन लीफ कर्ल मुल्तान विषाणु एवं कॉटन लीफ कर्ल मुल्तान बीटासैटेलाइट को पहचाना गया। ऐसे विषाणुओं के प्रबंधन हेतु हमने *पेनीबेसिलस लेंटीमोर्बस* B-30488 एवं CMV को मॉडल तंत्र के रूप में प्रयोग द्वारा पादप वृद्धि प्रेरक राइजोबैक्टीरिया आधारित दृष्टिकोण अपनाया एवं तंबाकू कए पौधों में आजमाया। नतीजों से पता चला कि B-30488 न सिर्फ मारक क्षमता एवं CMVRNA संग्रहण को 12 गुणा तक कम करता है बल्कि अनेकों जैव-रसायनिक तथा जैव-भौतिक गुणों में भी सुधार करता है। यह पादप वृद्धि मानकों को प्रभावी रूप से बढ़ता है एवं CMV संक्रमण घटनाओं की दर को भी कम करते हुए अंततः खेती की स्तिथियों में उपज गुणों में सुधार लाता है। आवश्यक परीक्षणों के बाद CMV के प्रबंधन हेतु फसल संरक्षण रणनीति के रूप में इसके उपयोग की संस्तुति की जा सकती है एवं साथ ही इसे अन्य फसलों में अन्य विषाणुओं हेतु भी प्रयोग किया जा सकता है।

8. महिलायों एवं बच्चों में कुपोषण से मुकाबला करने के लिए वैज्ञानिक एवं तकनीकी हस्तक्षेप

इस परियोजना में पोषक उत्पाद न्यूट्री जैम को बाराबंकी जिले के दफेदार का पुरवा ग्राम, उन्नाव जिले के दौन ग्राम एवं अमेठी जिले के तुलसीपुर ग्राम में में कुपोषण प्रभावित महिलाओं एवं बच्चों में वितरित किया गया। दौन, तुलसीपुर एवं दफेदार का पुरवा से क्रमशः 60, 58 एवं 169 लोगों से प्रतिक्रिया एकत्र की गई। यह पाया गया कि इस उत्पाद के प्रयोग से चयनित लोगों के बॉडी मास सूचकांक में बढ़ोत्तरी देखी गई जिससे उनके स्वास्थ्य में सुधार के संकेत मिले।

9. जड़ जैविकी एवं इसका सतत पादप विकास एवं मृदा उत्पादकता से संबंध

बीजपत्रीय नोड एक्सप्लांट्स में घाव से स्रावित होने वाले पॉलीफेनोल्स के निषेध द्वारा *एग्रोबैक्टीरियम* आधारित काबुली चने के रूपान्तरण में सुधार

बीजपत्रीय नोड एक्सप्लांट्स में घाव से स्रावित होने वाले पॉलीफेनोल्स *एग्रोबैक्टीरियम ट्यूमेफेसिएन्स* की जीवन क्षमता के लिए नुकसानदायक होते हैं जिससे रूपान्तरण प्रक्रिया धीमी हो जाती है। रिवर्स फेज हाई-परफोर्मेंस लिक्विड क्रोमटोग्राफी के द्वारा ऐसे 12 फेनोलिक यौगिकों एवं सैलिसिलिक अम्ल को पहचाना गया।

काबुली चने (*साईसर एरीटिनम*) के दो स्कैफोल्ड़ अटैच्मेंट क्षेत्रों का अभिलक्षणन एवं क्रियात्मक पुष्टीकरण

डीएनए के टुकड़ों की इलुमिना सीक्वेंसिंग के द्वारा काबुली चने के स्कैफोल्ड़ जुड़ाव क्षेत्रों का एक संग्रह तैयार किया गया। सात टुकड़ों को SAR संबंधित मोटिफों के आधार पर छांटा गया एवं काबुली चने के केन्द्रकीय स्कैफोल्डों के साथ उनके सम्बन्धों को जांचा गया।

तुलनात्मक प्रोटियोमिक्स दृष्टिकोण के उपयोग के द्वारा धान की जड़ में PEG उत्प्रेरित सूखा-तनाव प्रतिक्रिया की जटिल प्रवृति की व्याख्या

धान का प्रोटियोम, प्रोटीन के एक अभूतपूर्व स्रोत का प्रतिनिधित्व करता है जो सस्यविज्ञान की दृष्टि से महत्वपूर्ण लक्षणों, जैसे सूखे के प्रति सहिष्णुता, को नियंत्रित करता है। इस अध्ययन में एक सूखे के प्रति सहिष्णु धान की किस्म (हीना) के जड़ के जीवद्रवीय प्रोटियोम की PEG उत्प्रेरित सूखे की स्थितियों में तुलना की गई। PDQuest विश्लेषण द्वारा कुल 510 प्रोटीन धब्बे देखे गए एवं 125 भिन्नात्मक रूप से नियंत्रित धब्बों का MALDI-TOF MS-MS विश्लेषण किया गया जिनमें से 102 प्रोटीन धब्बों को चिन्हित किया गया जिनसे आगे चलकर 78 प्रोटीनों की पहचान की गई। ये 78 भिन्न भिन्न रूप से प्रदर्शित प्रोटीन संभावतः भिन्न भिन्न जैविक पॉथवे में सम्मिलित हैं। इन खोजों से सटीक अनुकूलन हेतु संभावित आणुविक लक्ष्यों के रूप में सूखा संवेदनशील प्रोटीनों का शीघ्र क्रियात्मक निर्धारण एवं प्राथमिकता निर्धारण हो सकेगा।

दो विरोधाभासी धान किस्मों की सूखे की स्थितियों में कर्यिकी प्रतिक्रिया

धान की दो किस्मों PR-115 एवं सुपर-7 को सूखे की स्थितियों में रख कर विभिन्न कार्यिकी लक्षणों को देखा गया जिससे इन किस्मों के सूखे में प्रदर्शन का आंक्लन किया जा सके। हालांकि दोनों ही किस्मों में कार्यिकी लक्षणों में कमी देखने को मिली किन्तु सुपर-7 में यह कुछ ज्यादा ही देखी गई। PR-115 एवं सुपर-7 की दानों की उपज में सामान्य रूप से सिंचित पौधों की तुलना में क्रमशः 17 एवं 54% कमी देखी गई। अध्ययन से पता चला कि PR-115 एक सूखा प्रतिरोधी जबकि सुपर-7 किस्म एक सूखा संवेदी किस्म है।

राइजोक्टोनिया सोलेनी के जैविक तनाव की स्थिति में बेसिलस अमाइलोलिक्विफेशिएन्स की मध्यस्थता के द्वारा बढ़े हुए धान के उत्पादन के पहलुओं को सुलझाना

वर्तमान अध्ययन में एक अजैविक तनाव सहिष्णु, पादप वृद्धि को बढ़ावा देने वाले राइजोबैक्टीरिया *बैसिलस अमाइलोलिक्विफेशिएन्स* (एसएन 13) को जैवनियंत्रक एजेंट के रूप में काम करते और धान में राइजोक्टोनिया सोलेनी के विरुद्ध विभिन्न शारीरिक, उपापचय, एवं आणुविक कार्यों को संशोधित कर प्रतिरक्षा प्रतिक्रिया को बढ़ाते हुए प्रदर्शित किया गया।

सुधारित एवं उत्प्रेरक रूप से कुशल सोने के नैनो कणों के विकास के लिए जैवसंश्लेषण के दौरान भौतिक-रासायनिक स्थिति अनुकूलन में सुधार

नैनोकणों के जैव-संश्लेषण को लागत प्रभावी और पर्यावरण के अनुकूल बनाने में बहुत ध्यान दिया गया है। वर्तमान अध्ययन में विभिन्न आकृतियों और आकारों के सोने के नैनोकणों को *ट्रायकोडर्मा विरीड* फिल्ट्रेट का उपयोग करते हुए विभिन्न भौतिक मापदंडों को संशोधित करके प्राप्त किया गया। इन कणों का दृश्य अवलोकन, डाइनेमिक लाईट स्कैटेरिंग, यूवी-विजिबल स्पेक्ट्रोस्कोपी, ट्रांसमिशन इलेक्ट्रॉन माइक्रोस्कोपी, फूरियर ट्रांसफार्म इन्फ्रारेड स्पेक्ट्रोस्कोपी और एक्स रे विवर्तन के आधार पर निरूपण किया गया। जबकि इन कणों का आकार 2-500 एनएम के बीच रहा, इनके आकार नैनोस्फेयर्स, नैनोट्राइएंगल, नैनोपेंटागंस, नैनोहेक्सागंस और नैनोशीट्स थे। नैनोकणों के आकृतियों और आकारों को नियंत्रित करने से बायोडिग्रेडेशन की प्रक्रिया में क्रांति आ सकती है जो वर्तमान परिदृश्य में सभी बाधाओं को दूर कर सकती है।

आर्सेनिक सहिष्णु *ट्राइकोडर्मा* प्रजाति द्वारा काबुली चने में आर्सेनिक प्रेरित तनाव में कमी

आर्सेनिक जैसे जहरीले मेटलॉइड न तो समाप्त हो सकते हैं और न ही पर्यावरण से नष्ट हो सकते हैं, हालांकि, उन्हें विषैले से कम/गैर विषैले रूपों में परिवर्तित किया जा सकता है। आर्सेनिक प्रजातियों के रूप और उनकी सांद्रता पौधों में इसकी विषाक्तता को निर्धारित करते हैं। इसलिए, आर्सेनिक का सूक्ष्मजीव मध्यस्थता द्वारा बायोट्रांजैक्शंस, पौधे द्वारा इसके ग्रहण और विषाक्तता के लिए महत्वपूर्ण है। वर्तमान अध्ययन में काबुली चने के पौधों में आर्सेनिक विषाक्तता व्यवस्थित करने में आर्सेनिक सहिष्णु *ट्रायकोडर्मा* की भूमिका का पता लगाया गया।

RESEARCH & DEVELOPMENT

CSIR-NBRI : MISSION AND MANDATE

The Council of Scientific and Industrial Research - National Botanical Research Institute (CSIR-NBRI), Lucknow, established in the year 1953, is one of the 38 constituent laboratories of CSIR, Department of Scientific and Industrial Research, Ministry of Science and Technology, Government of India. The institution has been in the forefront of plant sciences research in the country for the past six decades and is an institution of national importance. As a globally recognized advance centre of botanical research, the institute carries out multidisciplinary R&D programmes in almost all fields of plant sciences. The mandate of the institute is to undertake basic and applied research on various aspects of plant science, including conservation, systematics, documentation, prospection and genetic improvement with particular emphasis on under-exploited, non-traditional and wild plant genetic resources of the country for the sustainable development and human welfare. The institute has core strength in the following areas:

- Plant diversity, systematics and databases for lower and higher plant groups.
- Bioprospection and development of nutraceutical, cosmaceutical and health care products.
- Botanic garden, plant conservation and development of new varieties of floricultural plants.
- Microbes for enhanced plant productivity.
- Pollution remediation through plants and microbes.
- Climate change adaptation studies and carbon sequestration.
- Plant improvement through conventional and molecular breeding, and genetic engineering.
- Agro-technologies for sustainable development of sodic land and other wastelands.
- Societal development activities through outreach programmes.

The Institute is surging ahead with its envisioned goals of exploring the untapped potentials of the underexplored and unexplored plant diversity of the country for generating new knowledge, and affordable technologies for human health care, agriculture, and environmental protection. The year 2016-17 witnessed several significant achievements in the scientific, technological and outreach activities of CSIR-NBRI, a summary of which is given below:

BOTANIC GARDEN & DISTANT RESEARCH CENTERS

DU Leader: Dr. RK Roy/Dr. RS Katiyar

Scientists

Dr. SK Tewari, Mr. TS Rahi, Dr. Arvind Jain, Dr. Lal Bahadur, Dr. Devendra Singh, Dr. RC Nainwal

Technical Staff

Mr. SS Tripathi, Dr. Shanker Verma, Mr. Bhagwan Das, Dr. Daya Shanker, Dr. Atul Batra, Mr. Rajeev Kumar, Mr. Girdhari Sharma, Dr. MK Shukla, Mr. SK Sharma, Dr. Satish Kumar, Mrs. Shweta Singh, Mr. MG Prasad

BOTANIC GARDEN AND DISTANT RESEARCH CENTRES

Grant-in-Aid Projects

Standardization of protocols for organic seed production of turmeric (*Curcuma longa*) in Uttar Pradesh

India is the largest producer, consumer and exporter of turmeric in the world. India is also the global leader in value added products of turmeric and exports. To meet the increasing demand world over for organic materials, organic cultivation protocols are required for its profitable cultivation by the farmers. The studies to significantly improve the production economics of turmeric were continued.

An experiment was conducted using an integrated organic farming approach previously standardized for cultivation of turmeric. Studies on the number of mother rhizomes and number of primary rhizomes, the dry weight of rhizome (%) and rhizome oil (%) were all found to be non-significant in all the treatments tried. The content of Curcuminoids in dry rhizome (%) of turmeric like C (Curcumin), DMC (demethoxycurcumin) and BDMC (bisdemethoxycurcumin) was also found non-significant in all the treatments in both the years. The content of Curcuminoids (%) in rhizome oil of turmeric like β-tumerone, Ar-tumerone p-cymen and β-sesquiphellandrene were also found non-significant in all the treatments in both the years.

However, another set of experiment, in which the seeds were treated with *Trichoderma viride* showed very positive results. The yield of mother rhizomes, primary rhizomes and the total yield were significantly higher than the control. The result also indicated that application of different bio control treatments showed significant resistance against the disease infestation in turmeric crop.

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

The standardization of the sources and levels of organic matter for the cultivation of Kalmegh (*Andrographis paniculata*) was continued at Banthra Research Station during third year (Fig. 1). It is concluded from this investigation that farmers can get a benefit of Rs. 1,70,860 with the input cost of Rs. 56,280 by the application of FYM @ 15 t ha^{-1}. A benefit of Rs. 1,70,860 with the input cost of Rs. 47,040 can be achieved by the application of Pressmud @ 7.5 t ha^{-1} while a benefit of Rs. 84,780 with the input cost of Rs. 90,720 by the application of Vermi-compost @ 5.0 t ha^{-1} is possible. The application of Pressmud was more beneficial followed by FYM and Vermi-compost.

Fig. 1. Cultivation of Kalmegh (*Andrographis paniculata*) at Banthra Research Station

The physico-chemical properties of the soil showed that the soil pH, EC and bulk density decreased with increasing doses of all three organic manures (FYM, Pressmud and Vermi-compost) which are good indicators of the soil properties.

Maximum Nitrogen (N), Phosphorus (P) and Potassium (K) uptake by Kalmegh was recorded in Press mud experiment followed by Vermi-compost and FYM. The micronutrients (Fe, Zn, Cu) contents increased with increasing doses of FYM, PM or Vermi-compost. However, Manganese (Mn) content increased with increasing doses of FYM or Vermi-compost but decreased with increasing doses of Pressmud.

Agrotechnological development of *Aloe species* for popularization and training among farmers for cultivation on sodic degraded lands of Uttar Pradesh

Field experiments were initiated in a sodic degraded plot, of 60 x 25 m at DRC Banthra (80^{0}45–53E 26^{0}40–45N) for screening the sodicity tolerance associated with growth and productivity in the Aloe species: *Aloe vera*, *Aloe vera* accession and *Aloe maculata*. Soil samples were collected from each bed at two depths (0-15 and 15-30 cm). All samples were processed and analyzed for chemical parameters of pH, EC, OC (%), Available N, P, $CaCO_3$ (%) and micronutrients *viz* Cu, Fe, Mn and Zn. The pH ranged from 7.75 to 9.56 and from 8.20 to 10.20 at 0-15 and 15-30 cm depths, respectively. To determine the suitable sodicity levels, these Aloe species were grown on a range of ten pH levels. After four months of plantation, plant growth parameters were observed at every two months interval corresponding to varying range of pH and species under study.

- Plant height, length, width and number of leaves per plant of *Aloe vera* increased significantly from 2nd observational interval.
- Significant increase in plant growth of *A. vera* accession and *A. maculata* could be observed from 3rd interval of observation.
- Thickness of leaves and number of suckers per plant increased significantly at 4th interval from the interval

observation in all three *Aloe* species.

- Highest number of leaves per plant was found in *A. maculata* at 8.5 to 9.5 pH levels with maximum leaf width and greater leaf thickness in *A. vera* at almost all pH levels.
- Plant height, leaf length, number of leaves and suckers per plant were relatively high in *A. vera* accession at almost all pH levels at 4th interval of observation.
- Overall results indicate that *Aloe vera* accession appears to be superior for cultivation at high sodicity levels (Fig. 2).

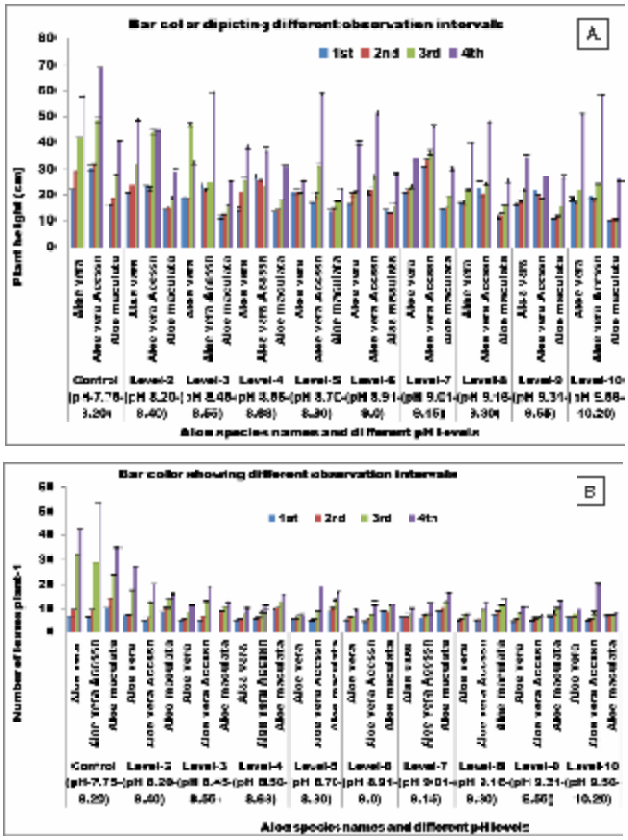


Fig. 2. Plant growth character graphs of experiment entitled as sodicity screening, plant growth and yield performance of Aloe species (*Aloe vera, Aloe vera* accession and *Aloe maculata*) at different sodicity levels

In-House Projects

Enrichment and Maintenance of the Germplasms Collection of Diversified Groups of Plants and Selected Ornamental Crops for Conservation, Education and Bioaesthetics

The Botanic Garden serves as a National Facility of the Institute. The garden has a rich collection of germplasm of about 5000 taxa. The Botanic Garden with its vast genetic resource is an education centre for the students, researchers and public as a whole.

The Botanic Garden serves and renders as a:

- A National Repository of germplasm collection of plants (Indian and exotic) including rare, endangered and threatened.
- Introduction, multiplication, assessment and utilization of new plant species from various sources.
- Commercial floriculture as a livelihood for farmers and entrepreneurs.
- Technical advice on development of ornamental and botanic gardens.
- Organization of flower shows, training, exhibitions, awareness programmes, etc. for societal purposes.
- Development of new and novel varieties of ornamental plants.
- Capacity building by organizing training programmes on various aspects of horticulture and garden management.

New varieties released

Chrysanthemum

Two new late blooming varieties: Chrysanthemum 'NBRI-CSIR75', commemorating the platinum jubilee celebrations of CSIR, and 'NBRI-Asha Kiran' were released on January 21, 2017.

- **NBRI-CSIR75:** Bright red (colour mutant) florets [Red-Purple Group 60A; RHS Fan-2) with central florets showing prominent yellow tinge at their apex (Fig. 3).

  Parent: Chrysanthemum 'Suneel'

Fig. 3. Chrysanthemum 'NBRI-CSIR75'

- **NBRI-Asha Kiran:** Bright-red (colour-mutant) [Red-Purple Group 71A; RHS Fan-2) and tubular (shape mutant) florets with larger capitulum size (9.0-9.5 cm) (Fig. 4).

  Parent: Chrysanthemum 'Suneel'

Fig. 4. Chrysanthemum 'NBRI-Asha Kiran'

Enrichment of Germplasm Collection

- *Dischidia major* (Vahl) Merr.: A single plant of this epiphyte species was collected from Assam (Fig. 5A). *Dischidia major* is commonly known as Ant plant. It has modified hollow leaves which offer accommodation to ants that provide carbon dioxide, nitrogen and protection from harmful animals and plants.
- *Hoya parasitica* Wall. ex Traill: Five plants of this sweet fragrant wax plant were introduced in the Botanic Garden. These were collected from Assam-Meghalaya border in vegetative stage. One plant showed initiation of flowering in late June 2016 (Fig. 5B).
- Cycads: Nong Nooch Botanical Garden, Thailand extended help in the enrichment of germplasm at the Cycad Conservation Centre by donating 70 seeds of seven rare and threatened cycads. Efforts are being made for future collaboration in *ex-situ* conservation and taxonomy of cycads with Nong Nooch Botanical Garden, Thailand and Montgomery Botanical Center, United States.
- Succulents: Four species of succulents were introduced in the Cactus and Succulent House. Though multiplication of succulents takes place throughout the year, mass multiplication and transplantation, both at the plant house and adjoining nursery take place in two major period viz.

A

B

Fig. 5. *Dischidia major* (Vahl) Merr. (A) and *Hoya parasitica* Wall. ex Traill inflorescence (B).

a) October-November and B) February-March. Mass propagation of several succulents is underway to increase the sale of these plants.

Enrichment of Threatened Species

Catamixis baccharoides, *Eremostachys phlomoides*, *Hypericum gaitii*, *Incarvillea emodi*, *Pittosporum eriocarpum* and *Selaginella adunca*

Enrichment of Succulents

Aptenia cordifolia and *Kalanchoe thyrsiflora*

Ex situ and *In situ* conservation material transfers

Selected plant material exchanged with the following parties –

International

Nong Nooch Botanical Garden, Bangkok

National

University of Calicut

Surendranath College, Kolkata

Brahmanand PG College, Kanpur

Biodiversity Inventory of the Botanic Garden

An initiative to inventory the biodiversity wealth of the Botanic Garden was taken up recently. A total of 103 invasive alien plant species under 86 genera and 36 families were recorded in the Botanic Garden. Besides these, 45 species of climbers belonging to 35 genera in 21 different families were also documented. These species have their origin in Asia (21), South America (13), Africa (6), North America (3) and Australia (2). Inventory of shrubs, and re-inventory of trees are in progress.

New Facilities Created

Indoor and Plants of Ancient Times Conservation Centre

The Indoor and Plants of Ancient Times Conservation Centre serves as the imperative facility of the Botanic Garden which provides education on different plant groups along with the practical knowledge of their display and conservation activities. The Conservation Centre consists of five features: a) Conservatory, the oldest and largest plant house in CSIR-NBRI Botanic Garden, b) Evolution Garden, c) Cycad Corner (Fig. 6), d) Adansonia Corner, and e) Orchid Acclimatization Study. The conservation centre was conceptualized to add more educative values to the idea of conserving plant diversities of different ages at one place. Plants of ancient times such as *Gingko biloba*, *Cycas* sp., *Zamia* sp., *Dioon* sp. and ferns constituted the evolution garden. The Cycad Corner is a sitting space near the entrance of the Conservatory. The corner constitutes three *Cycas* plants on a raised bed and few succulent plants. Four colourful sitting stones near the plant bed make the corner ideal place for enjoying the beauty of these ancient plants. Adansonia Corner consists of two young trees of *Adansonia rubrostipa*, an endangered tree species of Madagascar. Besides these facilities, there are two water bodies within the premise of the conservation centre. The different facilities of the conservation centre are connected to each other by pathways.

Fig. 6. Cycad Corner in the Botanic Garden

Orchidarium

The house contains about 80 different species of Orchids. Some of the Orchid species are economically important for cut-flower purpose while others are threatened. The Orchid House will serve as an *ex-situ* conservation centre besides a facility for botanical study and research on Orchids.

The Orchidarium was inaugurated by Dr. Girish Sahni, DG, CSIR and Secretary DSIR, Government of India on December 11, 2016 in the presence of Director, CSIR-NBRI, dignitaries and other Senior Scientists.

Distant Research Centre (Banthra Research Station)

The Distant Research Centre has five field units, Banthra, Biomass, Gehru, Aurawan and Ranipur rehabilitated under diverse land use systems viz. Floriculture, Herbiculture, Moriculture, Energy plantations, Field Gene Bank, Populatum, Bambusetum and semi-natural forest over the years. The centers are working on conservation of economically important species. R&D experiments are carried out for standardization of agro-technology of economically important plants on degraded sites. Emphasis is given on non-traditional crop plants, including floriculture and medicinal and aromatic plants.

Evaluation of *Curcuma* species for partially reclaimed sodic soil

Thirty six accessions of *Curcuma longa*, collected from various bio-geographical regions were planted in June 2016 for evaluation at Biomass Research Centre. Thirty Four germplasm of turmeric in two sets, planted at Aurawan Research Centre in 2015, were harvested in February 2017. NBH-4 was found to be the highest yielder. The qualitative analysis is in process. Four species of *Curcuma* viz. *C. longa*. *C. caesia*, *C. zeodoaria* and *C. amada* were grown in second year for evaluating their yield and quality. Biochemical analysis (total curcuminoids, total phenolic contents and Antioxidant activity) was also performed. Released turmeric variety "Kesari" was grown on farmer's field for performance evaluation and comparison with local grown variety

Evaluation of Chamomile for oil content and quality at different soil pH

Matricaria *(Chamomilla recutita)* seeds were sown in nursery and then seedlings were transferred to field at five locations with pH 7.8, 8.5, 9.43, 9.8 and 10.1. The plant height, number of branches and fresh flower weight were recorded. Essential oil was extracted from Clevenger type apparatus. The oil quantity was measured, and oil was subjected to GCMS analysis (Fig. 7) to see the effect of pH on oil content. β-Farnesene, Caryophyllene oxide, α-Bisabolol oxide-B, Chamazulene and α-Bisabolol were found to be the major compounds. The pH, organic carbon, Na and K contents of soil were measured just before the plantation and after harvesting. Soil pH, Na and K contents

were found to decrease after chamomile harvesting, probably because of absorption of Na and K by plants which leads to low pH and more organic carbon content.

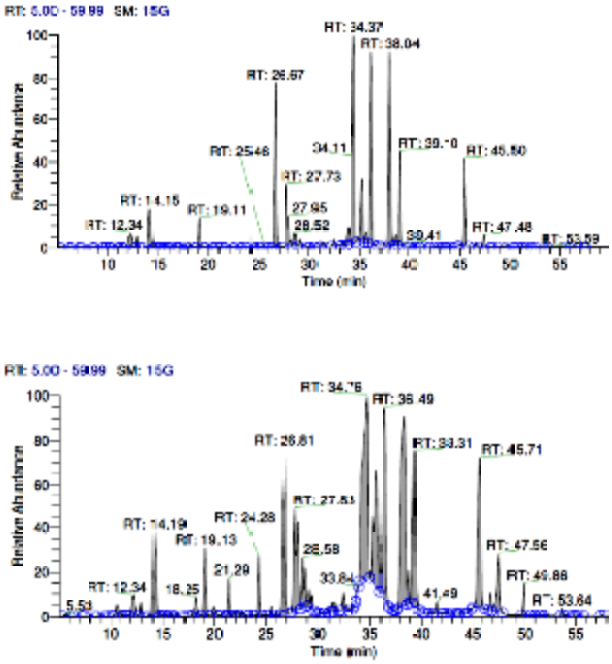


Fig. 7. GCMS profiling of Chamomile oil grown in different soil pH

Study on effect of pruning *Bixa orellana*

Bixa orellana, a dye yielding shrub, is one of the most widely used food colouring substances in the food industry. Seventeen accessions of *Bixa,* collected from different bio-geographical regions are being evaluated for growth, yield and quality. Based on morphological characterization, total collection has been arranged into seven groups. It is wise to prune branches after harvesting the capsules; as pruned plants yield better. Pruning is done to remove weak stems and also to balance the shape of the plant. Pruning enhances branching and reduces plant height for the ease of the harvesting.

The pruning was done in April 2016 from the height of one meter in 110 plants. Four plants died due to pruning. Few morphotypes showed adverse effect of pruning, reflected in poor fruiting and capsule setting. H1 type had mild effect, and showed slight reduction in yield. Few of the plants that did not flower in previous years, showed flowering for the first time. E1 type was severely affected by pruning, recording 85% reduction in yield (Fig. 8).

Evaluation of microbial consortia on plant growth and productivity of important rice varieties of Uttar Pradesh

A field experiment was conducted to evaluate the response of different microbial consortia on important rice

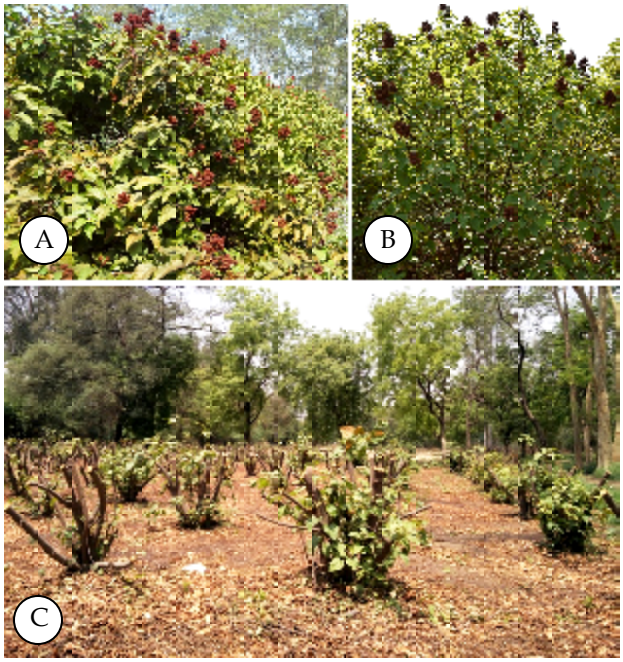


Fig. 8. *Bixa orellana:* before pruning (A,) after pruning (B), and Pruned field of *Bixa* (C).

varieties of Uttar Pradesh (Fig. 9). Experiment consisted of four rice varieties namely, Indrasan, Sarjoo 52, Sambha mansoori and NDR -359. The growth and yield of these varieties, as affected by diverse bacterial and fungal consortia have been studied in field condition. The results will be confirmed by repetition of the trial again in second year.

Response of PGPRs for alleviating water stress

A field experiment was conducted to examine the response of different PGPRs developed by the institute, on growth and development of two chickpea varieties, PUSA 362 (Desi) and PUSA 1003 (Kabuli), grown in field at different water stress levels. These varieties were treated with different PGPRs *viz*., *Trichoderma*, PSB and their combination before sowing. PUSA 1003 (Kabuli) performed better in terms of growth at different water stress levels. The higher number of branches per plant and grain yield were obtained from PUSA 1003 in different water stress condition. Among different water levels, combined treatment of *Trichoderma* and PSB, responded very well.

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 was the target of this research work. *Aloe* was identified as a potential species for the amelioration of the sodic soil. To carry forward this research work a germplasm bank of different *Aloe* spp was established at the Banthra Research Station.

Fig. 9. A Field experiment to evaluate the response of different microbial consortia on important rice varieties of Uttar Pradesh.

Five species / Accessions of *Aloe* have been collected from various locations in the country. These have been identified as *Aloe ammophilla, Aloe vera* accessions (IC281122, IC333202), *Aloe ciliaris* and *Aloe saponaria*. A total of twenty six *Aloe* species has been conserved and maintained in germplasm bank in sodic soil environment.

PLANT DIVERSITY, SYSTEMATICS AND HERBARIUM

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PLANT DIVERSITY, SYSTEMATICS AND HERBARIUM

Grant-in-Aid Projects

International consortium for renewable advanced bio-jet fuel technology

Data on lipid content of 70 algal strains available at Algology laboratory of CSIR-NBRI were compiled. These algal strains belonged to 14 genera, collected from different localities of India. Based on the high lipid content and their easy cultivability, two species, *Nannochloropsis* sp. (95.77 ± 1.7 mg/L) and *Scenedesmus* sp. (222 ± 8.1 mg/L) were selected for biomass production. Two raceway ponds with the dimensions of 50' length x 17' breadth x 1.5' depth were constructed for the biomass production. Each raceway pond holds approximately 20,000 litters of water. The ponds were roofed with transparent polycarbonate sheets and mesh nets on sides to prevent litter falling. In one of the ponds, approximately 16,000 liters of sewage water was filled and *Nannochloropsis* sp. was inoculated for mass cultivation. The semi treated sewage water was transported from '345 MLD Capacity Sewage Treatment Plant' located at Bharwara, Lucknow. The water quality and growth of algae were monitored regularly. The pond yielded 7.5 kg of dry biomass of *Nannochloropsis* sp. in 40 days with 8% of lipids, 15% w/w of carbohydrates and 15.44% mg/L of protein. The quality of the sewage water improved significantly during these days. In the other pond filled with approximately 15,000 liters of tap water supplemented with urea 1.5 gm/L and super phosphate 0.04 gm/L as nutrients, according media composition of BG11, yielded 4.7 kg of dry biomass of *Scenedesmus* sp. in 30 days with 9% lipids, 12% w/w of carbohydrates and 16.01% mg/L of protein.

Molecular approaches for production of sustainable bioenergies and value added products from microalgae

Biomass and lipid productivity of *Scenedesmus quadricuada* has been compared with other oleaginous microalgae isolated from different localities. Among the isolates, *Nannochloropsis oculata*, *Scenedesmus quadricuada*, *Chlorella vulgaris* and *Kirchneriella obesa* were found to be the fast growing algae with rich oil content. When compared in different media the highest biomass content was obtained in *S. quadricauda* (Dal Lake, Kashmir: 1.35 ± 0.06 g/L), followed by *Nannochloropsis oculata* (Uttar Pradesh: 1.29 ± 0.05 g/L), *Chlorella vulgaris* (Uttar Pradesh: 1.23 ± 0.05 g/L) and *S. quadricauda* (Uttar Pradesh: 1.01 ± 0.05 g/L) in TAP media. High lipid contents were obtained in both isolates of *Scenedesmus quadricuada* (305.4 ± 23.1 mg/L and 404.0 ± 30 mg/L) in TAP media. To evaluate the biotechnological potential of this strain, genome sequencing (using Ion Torrent) and annotation were performed, and their phylogeny was inferred. The analysis of lipid metabolism pathways will be done for further understanding of related genes. The partial rDNA sequence was obtained using the universal primers and submitted to NCBI gene bank (accession no. KY654954.1). *Agrobacterium* mediated transformation has been carried out in *S. quadricuada NBRI012* using *Agrobacterium* LBA4404 and binary vector pBI121, which will be further used for genetic and metabolic modification of the organism to ameliorate the lipid production.

Isolation, screening and nutritional profiling of promising microalgal strains

Extracts of five algal species (*Sphaerocystis schroeteri*, *Chlorella vulgaris*, *Chroococcus minor*, *Haematococcus pluvialis* and *Golenkinia radiata*) were analysed for their total phenolic contents, flavonoids, free radical scavenging activity, reducing power and antioxidant capacity. The highest value of total phenolic content, total flavonoid content and total antioxidant capacity was found in *Chlorella vulgaris* with 38.65 µg GAE/mg, 32.82 µg QE/mg and 567.12 µg quercetin/mg, respectively (Fig. 1). *Chlorella vulgaris* also exhibited highest value of the reducing power (0.889) at 3mg/ml concentration. Lowest value of reducing power was detected in *Chroococcus minor* (0.184) at 0.5mg/ml concentration (Fig. 2).

All the five algal strains showed a gradual increase in the free radical scavenging activity with the increase in concentration of the extract (10 mg/ml in 80% methanol). At lowest concentration of 50 µl, *C. vulgaris* exhibited

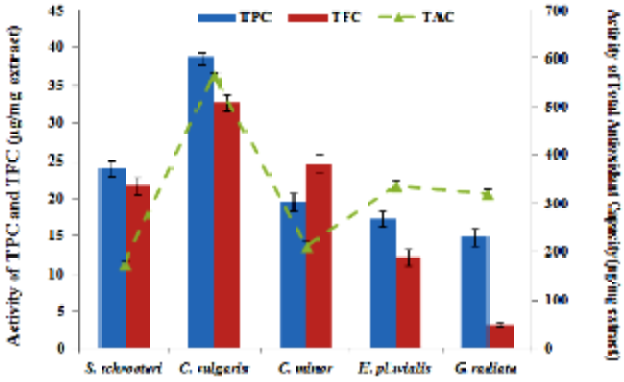

Fig. 1. Total phenolic content (TPC) µg gallic acid equivalents (GAE)/mg extract, the total flavonoid content (TFC) µg quercetin equivalents (QE)/mg extract and the total antioxidant capacity (TAC) (µg quercetin/mg extract) of five selected algal biomass.

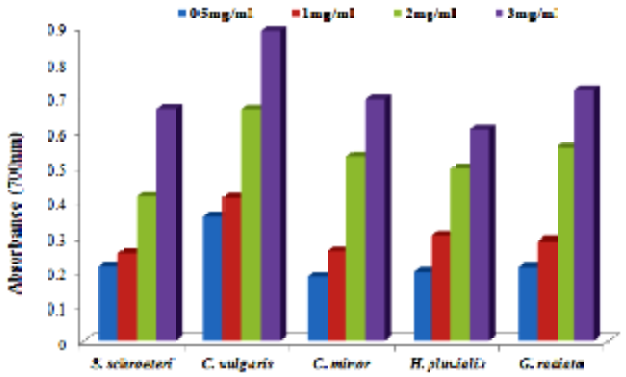

Fig. 2. Reducing power (RP) of five selected algal biomass at different concentrations

highest inhibition of 16.25%, whereas at highest concentration 300 µl, *G. radiata* exhibited highest inhibition with 58.97%. With this result it can be concluded that *C. vulgaris* extract is a better free radical scavenging species (Table 1). The highest IC_{50} value was found in *C. vulgaris* (319.05 mg/ml) while the lowest was in *G. radiata* (127.26 mg/ml) (Fig. 3).

Table 1. Free radical scavenging activity (FRSA) in terms of percentage inhibition of five selected algal biomass at six different concentrations

Sample	% inhibition					
	50µl	100µl	150µl	200µl	250µl	300µl
S. schroeteri	10.83	17.13	24.01	27.53	35.67	42.97
C. vulgaris	16.25	22.25	23.57	25.48	28.67	31.24
C. minor	9.08	14.06	17.42	20.64	24.57	28.89
H. pluvialis	8.20	11.86	18.01	24.16	32.56	40.78
G. radiata	11.27	21.23	29.87	38.65	49.46	58.97

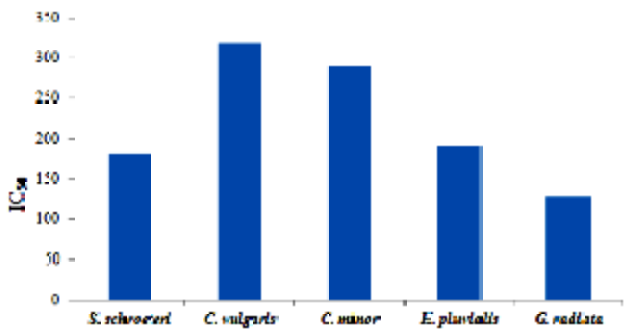

Fig. 3. Free radical scavenging activity (FRSA) in terms of IC_{50} (mg/ml) of five selected algal biomass

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

A total of 22 algal species were identified based on morphological and molecular features which belonged to class Chlorophyceae (10 taxa) and Cyanophyceae (12 taxa). Chlorophyceae members were identified as *Anabaena* sp., *Chlorella* sp1 to 6, *C. sorokiniana*, *C. thermophila*, *C. vulgaris*, *Chlamydomonas* sp., *Scenedesmus* sp., and *Selenestrum* sp. Cyanophyceae members belonged to *Phormidium* sp1 to 4, *Oscillatoria* sp1 to 6., and *Nostoc* sp. The sequences of the small-subunit (SSU) of 18S rRNA gene of Chlorophyceae members were submitted to NCBI gene bank with following accession numbers: *Chlorella* sp3. KY407757; *C. sorokiniana* KY285080; *C. thermophila* KY317933; and *C. vulgaris* KY407756. A neighbor joining (NJ) was constructed based on SSU 18S rRNA sequences (Fig. 4).

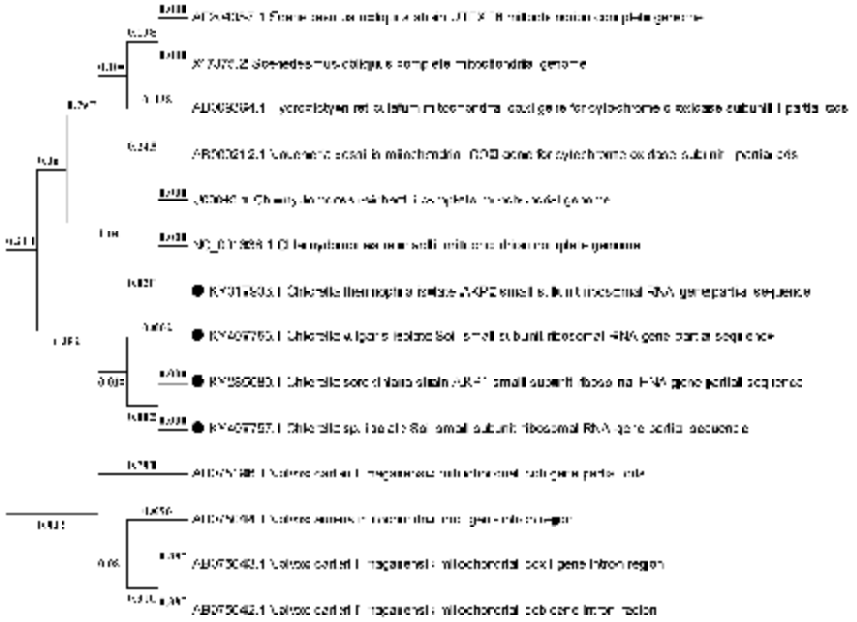

Fig. 4. Phylogenetic relationships between SSU 18S rRNA sequences of *Chlorella* sp. and other Chlorophyceae members available at NCBI genebank. (In-house sequence are marked with black circle)

Lipid was extracted from all the algal samples following Folch method, transesterified and biodiesel properties of the same were analyzed.

Alpine ecosystem dynamics and impact of climate change in Indian Himalaya

To conduct long term climate change monitoring studies, three highest summit points (HSP) in the Indian Himalayan region were surveyed for lichens and lichenometry analysis in and around Kabi and Tingda area of north Sikkim.

A total of 52 species of lichens belonging to 27 genera and 16 families were recorded from three HSPs. HSP II exhibited the maximum diversity of lichen species with 30 species, followed by HSP III and HSP I with 30 and 18 species, respectively. The lichen family Parmeliaceae showed its dominance in the area followed by Cladoniaceae, Lecanoraceae and Physciaceae. Among the different substrates, lichen species growing on tree bark exhibited their dominance over rock and soil. The lichen genus *Usnea* was the largest with 13 species dominating the region, followed by *Cladonia* (7 species). The lichen genera *Rhizocaron*, *Acarospora*, *Lecanora* (used in lichenometry) were totally absent in the study area.

The bryophytic diversity was marked with dominance of mosses, followed by liverworts. The bryo-diversity mainly exhibited mixed populations of temperate-subalpine bryo-flora, while typical alpine-subalpine elements were observed in lesser quantity.

Among liverworts, *Anastrepta orcadensis* (Hook.) Schhiffn., *Riccardia multifida* (L.) Gray, *Lophocolea sikkimensis* Herzog & Grolle, *Plagiochila semidecurrens* (Lehm. & Lindenb.) Lehm. & Lindenb., *Apomarsupella revoluta* (Nees) RM Schust., *Scapania ferruginea* (Lehm. & Lindenb.) Gottsche, *Blepharostoma trichophyllum* (L.) Dumort., *Pseudolepicolea trolli* (Herzog) Grolle & Ando, were the main components. Among mosses *Pogonatum urnigerum* (Hedw.) P. Beauv., *Campylopus gracilis* (Mitt.) A. Jaeger., *Pogonatum microstomum* (R.Br. ex Schwagr.) Brid, *Breutelia dicranacea* (Mull. Hal.) Mitt., *Pogonatum cirratum* (Sw.) Bridel. subsp. cirratum, *Pogonatum perichaetiale* (Mont.) A. Jaeger, were the common ones.

Breutelia dicranacea was the most abundant moss, available throughout. Though alpine-subalpine bryo-elements were not found frequently in the study sites, some typical Alpine-subalpine liverworts like *Anastrepta* and *Apomarsupella* could be selected as bryo-indicators for long term monitoring.

The Chanshal pass of Rohru area of Shimla district was represented by a total of 51 species of lichens belonging to 34 genera and 19 families from three HSPs, between an altitude of 3600 and 4150 m. Parmeliaceae family exhibited its dominance in the area, followed by Cladoniaceae, Physciaceae and Lecanoraceae with 12, 7, 6 and 5 species, respectively. The HSP I contained 34 species of lichens followed by HSP III and HSP II with 22 and 15 species, respectively. The growth pattern of lichen species *Rhizocarpon geographicum* was also monitored for carrying out lichenometric studies.

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

Pharmacological studies

Lichen taxa containing the usnic acid, lichesterinic acid, and other secondary metabolites were studied to evaluate their hepato protective potentials (Fig. 5). The lichen extracts (NBRI/L10/Ha1, NBRI/L8A/Ha1 and NBRI/L5A/Ha1) showed promising activity against carbon tetrachloride (CCl_4) induced toxicity in mice. In an attempt to model the liver fibrosis process, CCl_4 has been used to experimentally induce liver injury in rodents widely. Group I (Control) and Group II (CCl_4) mice were given the respective vehicles daily for 4 weeks (p.o.), Group III (Positive control) mice received silymarin daily for 4 weeks (100 mg/kg, p.o.), and the mice in Group IV and Group V were treated with NBRI/L10/Ha1 and NBRI/L5A/Ha1 (100 mg/kg; p.o.), respectively every day for 4

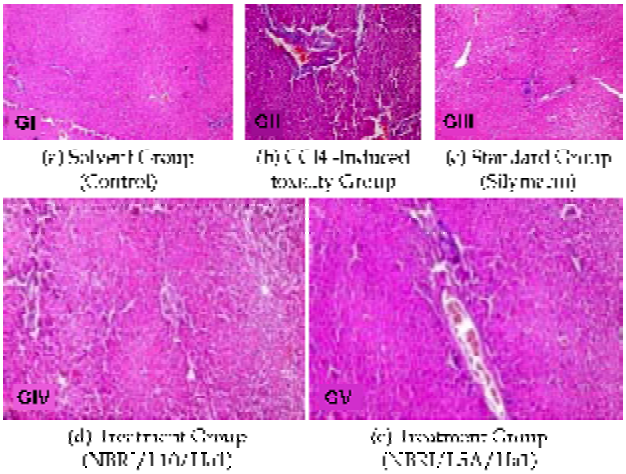

Fig. 5. Evaluation of hepato protective potentials in mice using lichen metabolites.

weeks on the beginning of the other day after the first double-dosage CCl_4 administration. Every 6 days during this month, CCl_4 dissolved in peanut oil (6.4 g/kg of body weight, s.c.), was administrated under the skin between head and neck to each group except Group I, and the dosage of CCl_4 was 12.8 g/kg at the first time. Group I was given peanut oil with the same dosage with other groups. The administration with CCl_4 (model, 6.4 g/kg of body

weight, s.c.) caused hepatotoxicity in mice, indicated by a marked increase in GOT and GPT serum levels, probably due to the damaged structural integrity of the liver (Fig. 5). GOT and GPT are cytoplasmic in location and are released into circulation after cellular damage and protected significantly the elevated levels of liver biochemical markers treated with NBRI/L10/Ha1 and NBRI/L8A/Ha1.

Phytochemical studies

Protocols were standardized for five potential extracts with significant anti-tubeculosis activity. Five different solvent systems were used for developing suitable system for separation and identification of specific chemomarkers.

Purification and chemical characterization of four lichens using HPLC & LC-MS have been carried out. Standards for all the compounds, chemical data and library of lichen compounds isolated from lichen natural thallus and mycobiont cultures have been maintained at CSIR-NBRI.

Lichen natural thallus (NBRI-LS5) of different weights viz. 0.5, 5 and 50g were extracted by cold & hot successive soxhlet methods with five different solvents including acetone and ethanol. The yield of acetone extracts varied from 0.24% to 1.68% while the yield of ethanolic extracts were higher and varied from 2.84% to 5.57%. Seven fractions were isolated for identification and chemoprofiling of major/minor compounds.

The identification and characterization of six known lichen acids were carried out in lichens NBRI-LS6 and NBRI-LS7 through HPLC and LC-MS. Lichen acids/compounds were separated and identified in acetone and alcohol extracts of NBRI-LS8 and NBRI-LS9. Chemomarkers were developed, fractionations of non-polar to polar compounds were made to identify depsones, depsides and lichen acids through chemo-profiling.

Separation and identification of chemo-markers in 26 coded extracts supplied by MSSRF, ARI and NBRI were carried out and five selected markers among them, were subjected to fractionation for isolation of compounds. Two pure markers were obtained through fractionation and separation through PTLC and Column chromatogravity. The markers were identified through chemoprofiling using HPTLC, HPLC and LC-MS.

Developing a system to monitor climate change with lichens in India

Studies regarding changes in atmospheric deposition during the last half century and its impact on lichen community structure were carried out in Darjeeling and Tawang area of Eastern Himalayas, Pindar valley in Western Himalayas and Mount Abu in North-western India.

The accumulation trends of trace elements and PAHs deposited and N accumulated in lichens reflected rapid urbanization of the study areas.

The study also highlights the importance of herbarium specimens for reconstructing historical trend in atmospheric deposition and to study the temporal variation in the community structure of lichens with respect to global climate or local microclimate change.

The sensitivity of different lichen growth forms against pollution exhibited a sequences of fruticose<foliose<crustose lichens, while the concentration of heavy metals and PAHs in lichens was directly proportional to anthropogenic activity in the area.

The lichen samples collected from humid and arid zone exhibited more or less similar selectivity sequence of metals, Fe<Zn<Cu and Fe>Zn>Pb, respectively, while the western and eastern Himalayan regions showed a different metal selectivity sequence as Fe>Zn>As and Fe>Zn>Mn.

The humid region of Darjeeling showed high pollution level, followed by arid zone of Mount Abu, Pindar valley and Tawang area.

The research demonstrated the potential use of herbarium specimens for mapping lichen diversity which can help as a tool for the assessment of environmental stress on toxitolerant lichens in the study area.

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

The study involves use of lichen secondary metabolites, amino acids and diversity of lichens to assess the response of rising temperature and ultra-radiance in Indian Himalayan region.

The lichen diversity existing above 3200m was found rich in pigmented lichen species, especially cyanobacteria containing lichens. This indicated that there could be a probable correlation between existing lichen diversity and the solar irradiance. Isolation and characterisation of potential ultraviolet protective class of compounds, Mycosporine like amino acids (MAA) authenticated this assumption. Further, in other high altitude sites certain Parmelioid lichens, containing green algae and producing lichen secondary metabolites having ultraviolet screening potential were found in abundance.

How the temperature variation influences lichen diversity has been established based on the use of fatty acids as biomarker in *Heterodermia diademata*. Abundance of saturated fatty acid reflected high temperature conditions at lower altitudes of Garhwal Himalayas.

Detection of organic pollutants at remote sites of Indian Himalayan region provided clear segregation of local and long range pollution, which clearly segregated PAHs and PCBs having major long range sources and NPAH and metals, originating from local sources.

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

The lichens recorded from 18 sites of Nilgiris Hills in Western Ghats, clearly differentiated the diverse micro and macroclimatic conditions of the area.

A total of 223 species belonging to 80 genera and 33 families have been recorded from the Nilgiris. The genus *Graphis* dominated the Nilgiris with 25 species, followed by *Usnea* and *Heterodermia* with 15 and 11 species, respectively. The study area was represented by a maximum number of crustose lichens with 132 species, followed by 58 foliose and 24 fruticose (including dimorphic species) lichens.

The distribution of lichens in forests patches of Silent Valley National Park was entirely different as compared with localities within the Nilgiris due to the dense canopy of the forests in Silent Valley National Park.

Several lichen species that were available in the past could not be traced in our present study, probably due to deforestation of exclusive tree species. 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 unavailability of tree diversity.

However, home gardens of local people still conserve many of the crustose species of lichens as trunks of cultivated trees *Areca catechu* and *Artocarpus heterophyllus* provide suitable environment for colonization of Graphidaceous and other crustose taxa of lichens. The high altitude, dense and protected forests provided an ideal condition for formation of large patches of moisture and shade loving lichens.

The high altitude sites (Avalanche dam area, around Lovedale and Doddabetta) are rich in lichen diversity as compared to low altitudinal localities. The dominance of Graphidaceous lichens in the Nilgiris forests, indicates that the forest patches are achieving a climax stage of plant succession. Most of the forests are old growth forests and exhibit those lichens, which require a tree girth of large circumference. Maintaining reserve forests and home gardens, propagation of lichen rich areas as lichen sanctuaries and lichen gardens could improve the situation of highly disturbed areas.

Barcoding Himalayan Lichens- cutting edge approaches to study Lichen Biodiversity and setting Lichen Conservation Strategies in India

The lichen genus *Usnea* and cetrarioid group of lichens from western and eastern Himalayan region were investigated for DNA barcoding.

Cetrarioid group: Among the different group of lichens, cetrarioid lichens are found with more cryptic species in India. A total of 75 accessions of cetrarioid lichen have been analyzed using ITS. PCR and sequencing success was 75% and 80%, respectively.

Usnea group: The DNA barcode studies on *Usnea* lichens indicated that all studied *Usnea* species in India could be successfully discriminated using the nuclear ribosomal ITS region, the standard DNA barcode for fungi.

(I). *Phylogenetic analysis:* All traditional *Usnea* species were recovered as monophyletic clades with strong statistical support [bootstrap support (BS) 88%] in the ITS tree. Additionally, the cetrarioid and *Cornicularia* clades were recovered as monophyletic with strong BS (84%) in the ITS topology, although the genus *Cornicularia* was recovered with only weak statistical support (BS<50%). Well-supported phylogenetic sub-structure was identified within *Cornicularia normoerica, Usnea longissima, U. baileyi, U. subfloridana,* and *U. himalayana*.

(II). *ITS genetic distances:*- The distribution of intraspecific pairwise distances for each species was estimated together with Clade-specific (i.e., cetrarioid, *Cornicularia*, and *Usnea* clades) intra- and interspecific genetic distances. Mean distance values, standard deviations, and the ranges of intraspecific distances within the 13 *Usnea* species occurring in India were also recorded. A slight overlap in intra- and interspecific distances was identified in comparisons among all *Usnea* species taken collectively. However, in clade-specific comparisons (i.e., Cetrarioid, *Cornicularia*, and *Usnea* clades), a barcode gap was detected for each clade, with the exclusion of outlier values in the *Cornicularia* clade. The interquartile range of genetic distances for the majority of species fell below the estimated 0.015–0.017 s/s intra-interspecific threshold.

Phylogenetic grouping of South Asian lichens of the Teloschistaceae (Ascomycota) for biotechnological purposes

The revisionary studies carried out on Teloschistacean lichens of India resulted into discovery of two species of *Rusavskia* as new to science: *R. indica* S. Y. Kondr. & D. K. Upreti and *R. upretii* S. Y. Kondr., G. K.

Mishra & S. Nayaka, while *Rusavaskia sorediata* (Vain.)S. Kondratyuk and Kärnefelt was reported as new record for India. Five lichenicolous fungi, *Oxneria huculica* S.Y. Kondr., *Variospora flavescens* (Hud.) Arup, Frödén & Søchting, and *Zeroviella esfahanensis* S.Y. Kondr. & B. Zarei-Darki, *Arthonia epiphyscia* Nyl., and *Zwackhiomyces zarei* S.Y. Kondr., were recorded as new to India.

Water quality monitoring of Ganga River from Gomukh to Hooghly, under National Mission for clean Ganga

All the information on algae collected from eleven sites under this project was compiled. The study revealed the occurrence of 37 species belonging to 24 genera. The localities surveyed had higher concentration of nutrients such as phosphorus and nitrogen as indicated by the luxuriant growth of Chlorophyceae, Cyanophyceae and Bacillariophyceae. The areas such as Ballia, Patna and Bhagalpur having agriculture land along the river bank exhibited low diversity of algae probably due to usage of chemical fertilizer and pesticide in the field. The localities near the cities such as Varanasi, Hooghly, Kanpur, Narora having disposal of sewage waters to the river had dominance of Cyanophycean algae. Although the study sites in Farrakka district were located away from city area with having comparatively clean waters, they exhibited less diversity of algae. This may be due to the presence of many porophytes (mango orchards) in these sites which do not allow penetration of sun rays to the water. Also, most of the water bodies were covered with luxuriant growth of microhytes which further may have restricted, the growth of algal population. Farrakha area also has running water like in Haridwar and Bhimgoda, where less algae are grown. However, stagnant water along the coast of Narora, Kannauj and Kanpur provide suitable condition for growth of many algal population.

A study was carried out to understand the diversity and distribution pattern of Pteridophytes across the stretch of Ganga River from Gomukh to Gangasagar. A total of 215 specimens were collected from Haridwar and Ganga Sagar. Taxonomic studies revealed 17 species of these belonged to 12 genera under 9 families.

Assessment of Bryophyte diversity, species richness and composition in Darjeeling hills with special reference to climate change and conservation strategies

The objectives of the study included the survey and sampling of bryophytes from selected sites of Darjeeling hills; to study the ecological aspects based on species composition at various habitats along the altitudinal gradients of species richness, between habitat diversity and species composition; ex-situ conservation of selected threatened (including endemic) bryophytes.

Bryophytes from herbarium data were identified and assessed for distribution along an altitudinal gradient ranging from 1000 m to 2500 m across six habitats, viz. soil, wet rocks, dry rocks, soil covered rocks, stony walls (terricolous habitats) and epiphytic habitats. A total of 316 bryophytes have been recorded from the three sets of primary data viz. Set 1. (1965), Set 2. (1981, 1983) and Set 3. (2002, 2003). Among these, 129 taxa of liverworts belonging to 51 genera and 29 families; 11 species of hornworts belonging to four genera and three families, and 176 moss taxa belonging to 89 genera and 29 families were recorded.

The species richness as calculated from the primary data indicated that over the decades, the species richness index was fluctuated at Tiger Hill and it had a steady increase at Llyod Botanical Garden (LBG). These differences could be due to the fact that Tiger hill is a site with greater tourist influx as compared to the LBG which has limited anthropogenic activities and also provides protected natural habitat to plants unlike Tiger Hill, where indiscriminate human activity and construction has been a regular feature. Better conclusive results can only be provided when recently collected data will be compared (under progress) to this data and other parameters are taken into consideration.

Sphagnum khasianum Mitt. has been raised *in vitro* by tip of vegetative explants, which is a novel method of its propagation as earlier workers could usually raise it in culture from spores.

Solenostoma schaulianum (Steph.) Váòa et D.G. Long, an important Asiatic species has been propagated *in vitro* and multiplied well in axenic culture. Leafy liverworts are difficult to propagate *in vitro* and their propagation is rarely accomplished under artificial conditions.

Study of Bryophyte diversity in the Eastern Ghats

Exploration of several bryophyte rich localities of Odisha viz., Similipal Tiger and Biosphere Reserve in Mayurbhanj District (Orchidarium, Kollah, Uski Falls, Barehipani, Joranda Falls, Matighati, Gurguria Research centre, Lanjighosra) and Mahendragiri Forest Reserve in Gajapati District (Bureakhata, Budighati, Ganesha Temple, Darpanchanchara), have been made. About 321 specimens have been collected. A critical morphotaxonomical investigation on the bryoflora of Eastern Ghats area of Odisha has been carried out, which revealed the occurrence of 75 species of liverworts and mosses. The mosses comprised 59 species belonging to 36 genera and 18 families, and 16 species of liverworts belonging to 13 genera and 7 families. An illustrated account of studied taxa with descriptions is under preparation alongwith their distribution data.

Ectropothecium dealbatum (Reinw. & Hornsch.) A. Jaeger, *Hypnum cupressiforme* Hedw., *Hypnum plumaeforme* Wilson, *Entodon pulchellus* (Griff.) A. Jaeger, *Entodon ovicarpus* Dixon, *Anomodon minor* (Hedw.) Lindb., *Thuidium assimile* (Mitt.) A Jaeger, *Thuidium kiasense* R.S. Williams, *Dicranodontium didymodon* (Griff.) Paris, *Ditrichum pusillum* (Hedw.) Hampe, *Stereophyllum tavoyense* (Hook. ex Harv.) A. Jaeger, *Chiloscyphus campanulatus* Steph. were recorded as new reports to South India, while *Entodon rubicundus* (Mitt.) A. Jaeger, *Anoectangium bicolor* Renauld & Cardot. *Fissidens ceylonensis* Dozy & Molk, *Fissidens bryoides* Hedw., *Sematophyllum humile* (Mitt.) Broth., *Aerobryidium filamentosum* (Hook.) M. Fleisch., *Cryptopapillaria fuscescens* (Hook.) M. Menzel, *Campylopus aureus* Bosch & Sande Lac., *Campylopus involutus* (Müll. Hall.) A. Jaeger, *Leucoloma taylorii* (Schwägr.) Mitt., *Entodontopsis nitens* (Mitt.) W.R. Buck & R.R. Ireland, *Reboulia hemisphaerica* (L.) Raddi, *Lophocolea heterophylla* (Schrad.) Dumort., *Plagiochila nepalensis* Lindenb. and *Jackiella javanica* Schiffner were new records to Eastern Ghats.

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

The project has been completed in November, 2016. *In vitro* study on three endangered liverworts viz., *Stephensoniella brevipedunculata* Kash., *Anthoceros macrosporus* Steph. and *Cryptomitrium himalayense* Kash.; two potential liverworts viz. *Marchantia polymorpha* L., *Conocephalum conicum* (L.) Lindenb. and a moss *Rhodobryum roseum* (Hedw.) Limpr. has been carried out and completed. Efforts have also been made to establish the axenic cultures of endangered and endemic liverwort, *Stephensoniella brevipedunculata* using tubers as explants which started to germinate after 3 days of inoculation in different media. Green coloured small innovations were emerged from single tuber after 3 days of inoculation. These tubers were subsequently developed in to thalli in 30 days. Plants exhibited best growth in Hoagland's medium and Half-strength Knop's + Vitamins as compared to all other culture media used. Thus, the study revealed that the plant population of *Stephensoniella brevipedunculata* Kashyap can be successfully grown on Hoagland and Half-strength Knop's + Vitamins under controlled laboratory conditions. Successfully grown plant population in Hoagland media has been transferred to soilrite in pots. This may lead to large biomass production of the taxon for conservation measures. It was for the first time that a considerable amount of germplasm could be raised from tubers and a protocol has been standardized to conserve this important rare liverwort.

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

The study confirmed that in India the tribe Delphineae is represented by 46 species and six infraspecific taxa distributed in three genera namely *Aconitum*, *Delphinium* and *Consolida*.

Aconitum L. is represented by 24 species and two varieties, which are chiefly distributed from temperate to alpine zones of the Indian Himalayas. One new species namely *Aconitum arunii* Agnihotri *et al.* has been discovered from Sikkim Himalaya (Fig. 6).

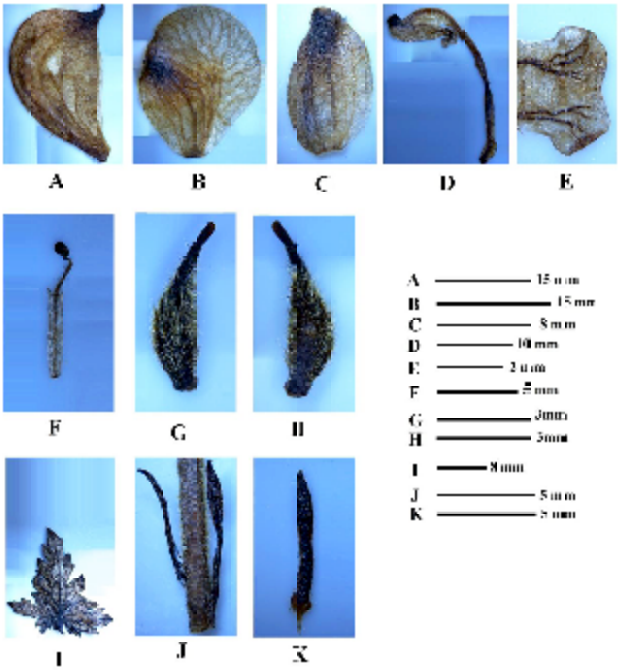

Fig. 6. *Aconitum arunii* Agnihotri, Husain & Husain: **A.** Upper Sepal, **B.** Lateral Sepal, **C.** Lower Sepal, **D.** Petal, **E.** Petal Lip, **F.** Stamens, **G. & H.** Carpel, **I.** Bract, **J.** attachment of bracteoles on pedicel, **K.** Bracteole (*T. Husain & P. Agnihotri* 257637, LWG).

Delphinium L. comprises of 21 species, one subspecies and three varieties, and *Consolida* Gray is represented by three species, namely *Consolida ambigua* (L.) Ball & Heywood, *C. orientalis* (J.Gay) Schrödinger and *C. schlagintweitii* (Huth) Munz.

Extensive surveys and collections were made in Western Himalaya (H.P., Uttarakhand), Eastern Himalaya (North and East Sikkim) and Western Ghats (Tamil Nadu) and 32 taxa of the tribe Delphineae were collected.

Few species of *Aconitum* such as *A. hetrophyllum*, *A. ferox*, and *A. deinorrhizum* are included in IUCN Red List and Red Data Book of India. Very small, scattered populations of two to three individuals of these species were found in the Himalayas. However, during real time

assessment of the genus *Delphinium* in the remote areas of the known localities and other likely habitats of the genus, could help locate and collect only a very few taxa in very small populations in nature, and it was observed that the taxa of the genus *Delphinium* are rarer than *Aconitum* species.

Molecular phylogeny in the tribe was inferred using both nuclear (ITS1 and ITS2) and chloroplast (*rbcL*, *mat*K, *atp*B, *trn*H-*psb*A and *trn*T-*trn*L) loci including 5 species of *Delphinium* and 8 species of *Aconitum*. The MP and ML analysis of various loci, *rbcL*, *mat*K, *atp*B, *trn*H-*psb*A and *trn*T-*trn*L revealed largely congruent tree topologies. Both MP & ML analyses of two chloroplast intergenic spacers *trn*H-*psb*A, *trn*T-*trn*L and nuclear ITS, segregated *Aconitum* and *Delphinium* in two separate clades with similar topologies.

Although, the monophyly of *Aconitum* was strongly supported in the *mat*k anlysis, the perennial species - *A. laeve* (*Aconitum* subgenus *Lycoctonum*) did not cluster with all other species of *Aconitum* (*Aconitum* subgenus *Aconitum*) in *trn*H-*psb*A, *trn*T-*trn*L analyses.

Detailed mitotic and meiotic studies have been made on different populations of *Delphinium, Aconitum* and *Consolida* species to solve these complexes on the basis of cytotaxonomy. Meiotic studies of *Consolida ambigua* showed chromosomal count of 2n=16 in the PMCs at diakinesis and diplotene stage. Meiotic division was not normal with stickiness, precocious movement and bridge in anaphase-I and micronuclei in telophase- I as major abnormalities. (Fig. 7)

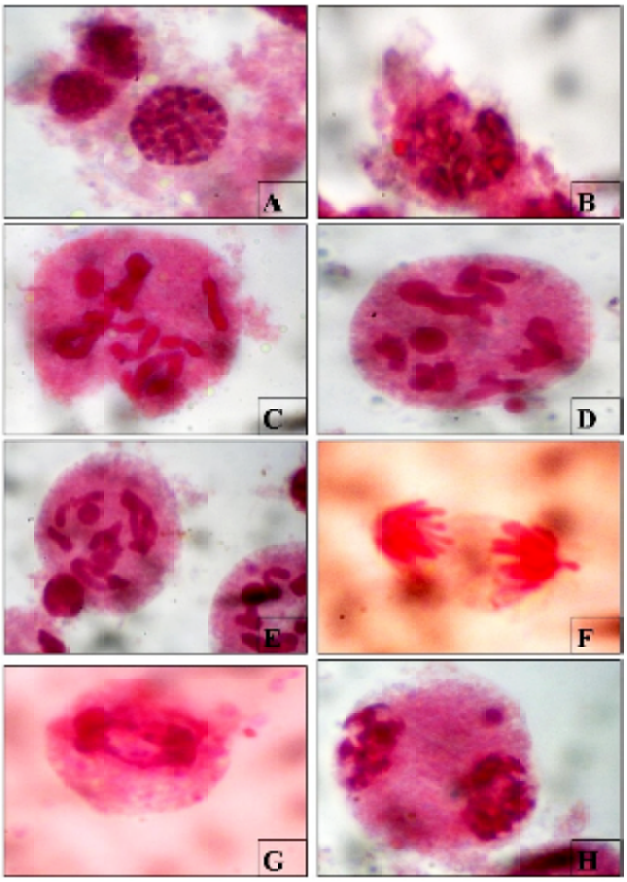

Fig. 7: Various stages of meiosis in *Consolida ambigua* A. Prophase, **B.** Diplotene, **C-E.** Chiasma formation in Diakinensis, **F.** Precocious movement in Anaphase, **G.** Bridge in Anaphase, **H.** Telophase I with Micronuclei

Mitotic Analysis were carried out in four species of *Delphinium* i.e., *D. vestitum*, *D. denudatum*, *D. roylei* and *D. viscosum*. During the present study it was observed that mitotic division is not normal in all the species. Chromosome number were found to be same in all the four species *i.e.*, 2n = 16. Mitotic index shows significant difference between the *D. vestitum* (18.16 ± 18.25) and *D. denudatum* (23.32 ± 22.17), *D. roylei* (22.52 ± 22.26), *D. viscosum* (21.72 ± 21.15) at $p<0.05$ (Table-2).

Lectotypification of four aconites, namely *Aconitum hookeri*, *A. nagarum*, *A. heterophylloides* var. *leucanthum*, *A. spicatum* was done.

Table 2: Chromosomal and Mitotic aberrations in five taxa of *Delphinium*.

Species	Chromosomal aberrations			Mitotic aberrations										
	No. of metaphase	Fragment	% Chromosomal aberration	No. of scored cells	No. of dividing cell	C-metaphase	Laggard	Bridge	Disorientation	Unequal separation	Condensation	% Aberrant cells	Multinucleate condition	% Micronuclei
D. vestitum	365	14	3.83	1500	357	05	10	07	21	36	93	48.17	3	0
D. denudatum	360	24	6.66	1500	360	06	08	04	20	45	118	55.83	2	1
D. roylei	355	18	5.07	1500	320	05	11	05	30	25	119	60.93	1	0
D. viscosum var. viscosum	370	19	5.13	1500	343	04	09	03	10	06	68	29.15	0	1
D. viscosum var. gigantobracteum	385	29	7.53	1500	334	06	18	08	34	34	56	46.70	2	0

Mapping of floristic diversity and conservation studies on plant resources of Kishanpur Wildlife Sanctuary

Kishanpur Wildlife Sanctuary (KWS), a magnificent sanctuary situated at 28° 24'01" N and 80°22'01" E in Uttar Pradesh, was established in the year 1972 for the protection of an endangered elusive cat, Bengal Tiger (*Panthera tigris tigris* L.). KWS covers an area of 227 sq. km. that lies in the Terai region of Uttar Pradesh.

Being situated in one of the most important phytogeographic regions of the country, better understanding of the biodiversity of the proposed protected area is needed to design environmental policies that would promote conservation and sustainable use of biodiversity in the area. Keeping in view the above considerations, it was envisaged to undertake the task of thorough survey, collection and study of plants of KWS, so as to prepare a complete and up-to-date inventory of its floristic diversity with all the necessary information that would be of use in prioritizing conservation of RET, economically valuable and endemic plant taxa.

Surveys were carried out in KWS for survey and collection of plant specimens. Voucher specimens were collected either in fruiting or in flowering stage. A total of 215 plant species have been collected from KWS.

The Herbaria of CAL, BSD, LWG & CDRI have been consulted for the authentication and assessment of plant wealth of the area from previous collection.

The identified plant specimens have been deposited in LWG for future reference. The nomenclature of plant species has also been updated. To establish identity of the herbal medicines used, plants were collected with the associated information that was obtained from medicine men of the villages in and around KWS.

The ecology of few climbers like, *Bauhinia vahlii*, *Tiliacora acuminata*, *Acacia concinna* and *Millettia extensa*, has also been studied.

Diversity assessment of angiospermic flora of Sonbhadra district, Uttar Pradesh

The present study has been initiated to provide a taxonomic account of angiosperms of Sonbhadra district in Uttar Pradesh. The district which comes under vindhyan region of Uttar Pradesh, is one of the richest areas in the state as far as plant diversity is concerned. It is spread over about 6788 km² of geographical area which constitutes about 36% forest cover on highly undulated land. The extensive survey of the area, critical examination of previous collections housed in various herbaria and review of published literature have resulted in a total of 705 species belonging to 459 genera under 110 families. Of these, 541 species (76.73%) under 354 genera (77.12%) and 89 families (80.90%) belong to dicots and 164 species (23.26%) under 105 genera (23.26%) and 21 families (19.09%) to monocots. The family Fabaceae (110 spp.) comprises of maximum number of species, followed by Poaceae (89 spp.), Asteraceae (38 spp.), Cyperaceae (33 spp.) and Malvaceae (33 spp.). The ten largest genera in the area are: *Cyperus* (14 spp.), *Ipomoea* (9 spp.), *Solanum* (9 spp.), *Ficus* (9 spp.), *Crotalaria* (7 spp.), *Desmodium* (7 spp.), *Bauhinia* (6 spp.), *Hibiscus* (6 spp.), *Fimbristylis* (6 spp.), and *Acacia* (5 spp.). The entire forest is chiefly dominated by trees like *Acacia catechu* (L.f.) Willd., *Boswellia serrata* Roxb. ex Colebr., *Butea monosperma* (Lam.) Taub., *Hardwickia binata* Roxb. and *Shorea robusta* Gaertn.

Inventorisation of plant diversity of Nawab Wazid Ali Shah Zoological Garden, Lucknow (U. P.)

In order to achieve the basic objective of the Convention of Biodiversity, it is imperative to know what component of biodiversity are found in a particular area or habitat. For the study of diversity preparation of herbarium specimens as voucher specimens is necessary to keep the record of biodiversity of any botanically rich area like Nawab Wazid Ali Shah Zoological Garden, situated at the heart of the city, Lucknow. It covers an area of *ca*. 29 ha. having the rich cover of plant diversity. It will not only serve as a resource for identification of plants, but also work as a data bank of plants resources of Zoo in particular and adjacent area in general. Such base line data are essential for proper monitoring and to frame out conservation strategies of the garden.

Frequent surveys were carried out in the Nawab Wazid Ali Shah Zoological Garden for survey and collection of voucher specimens. A total of 75 tree species have been collected and identified. The nomenclature of these species has also been updated. As many as 20 exotic tree species have been planted by the Zoo authority for shade, beautification and pleasant environment for wildlife. Two historically and botanically important trees namely, *Crateva religiosa* and *Adansonia digitata* are also present in the Zoo.

Plant diversity assessment of Dima Haso District in Assam

Today when the biodiversity conservation is gaining worldwide recognition, information on plant species occurring in any part of the world is highly essential. There is an urgent need to study the plant diversity of a particular area to guide decision on their conservation and sustainable utilization. In this perspective, Dima Hasao district of Assam has been selected for proper documentation and assessment of diversity of angiosperms with more emphasis on tree species as the area has not been explored extensively in the past. The outcome of the

study will be beneficial for students, botanist, researchers, NGO's, naturalists, environmental engineers, forest managers, conservation biologists, policy makers etc., for proper management of the forest and conservation of plants, especially of rare, endemic and threatened categories.

Dima Hasao is a hilly region of Assam with dense moist evergreen forest. Two tours have been taken to the area for habitat study and collection of plant specimens. About 150 species have been so far collected from the area.

Molecular systematics of the *Didymocarpus-Henckelia* generic complex (Gesneriaceae) in India

Compiled preliminary morphotaxonomic data on 26 species of *Henckelia* and 17 species of *Didymocarpus* by consulting 10 Indian (BSHC, BSD, BSI, CAL, CALI, DD, FRC, LWG, MH, TBGT) and 5 foreign virtual herbaria (E, G-DC, K, L, P).

Four field surveys were conducted in 18 localities in Southern Western Ghats (Kerala and Tamil Nadu), West (Uttarakhand) and East Himalayas (Sikkim). A total of 66 accessions of 12 species of *Henckelia* and 41 accessions of 5 species of *Didymocarpus* were collected in their natural habitats. Fresh leaf tissues of 88 accessions (56 *Henckelia* + 32 *Didymocarpus*) were collected for DNA isolation. Habitat features and Geo- coordinates (latitude/longitude/altitude) of each specimen were documented. A total of 145 herbarium vouchers were made from the above collections.

Detailed morphological studies were completed for 5 species of *Didymocarpus* and 12 species of *Henckelia*, based on field collections and herbarium materials.

DNA extraction procedures and PCR amplification of nrDNA ITS and cpDNA *trnL-F* regions were standardized for the collected samples of *Didymocarpus* and *Henckelia*. A total of 52 samples (20 samples of 5 species of *Didymocarpus* and 32 samples of 12 species of *Henckelia*) were PCR amplified for ITS and *trnL-F* regions using the universal primers. Sequencing of the PCR amplicons is in progress.

In-House Projects

Taxonomic studies and digitization of plant diversity of India

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

Algae

A total of seven fresh water algal samples were collected from Lucknow, which resulted in 12 algal taxa under 11 genera and 2 classes. Chlorophyceae is represented by five genera, namely *Cosmarium, Staurastrum, Mougeotia, Spirogyra* and *Zygnema*, while Cyanophyceae represented six genera namely *Scytonema, Lyngbya, Oscillatoria, Chroococcus, Aphanothece* and *Phormidium*.

Sequence of the SSU of 18S rRNA of seven algal strain have been submitted to NCBI gene bank, details of which are as follows, *Chlorella sorokiniana* (accession no. KY285080), *Chlorella thermophila* (accession no. KY317933), *Chlorella vulgaris* (accession no. KY407756) and *Chlorella* sp3. (accession no. KY407757) *Scenedesmus quadricauda* (accession no KY654954.1), *Oscillatoria* sp. RBD01 (accession no. KT445936.1), *Leptolyngbya* sp. RBD05 (accession no KT592515.1) and *Coelastrella* sp (accession no KY614790.1).

Lichens

The flood zone area along the river Ganga in Haridwar and Bhimgoda area were surveyed for lichens. A total of 100 specimens of lichens were collected and identified which revealed the occurrence of 32 species belonging to 25 genera and 11 families from the area. The area is dominated with crustose lichens followed by squamulose and foliose forms, of which mostly the toxitolerant members of the lichens dominates the region.

Bryophytes

An investigation on the Bryophytes from Terai region of Uttar Pradesh has revealed the occurrence of 29 species of bryophytes: 21 species belonging to 16 genera of 11 Families of Mosses; 6 species belonging to 3 genera of 3 families of Liverworts, and 2 species belonging to 1 genus of 1 family of Hornworts. This includes several new reports viz., *Dicranella microspora* Gangulee, *Entodontopsis tavoyense* (Hook. *ex* Harv.) W.R. Buck & R.R. Ireland, *Trachyphyllum inflexum* (Harv.) Gepp., *Weissia controversa* Hedw., *Fissidens crenulatus* Mitt., *Fissidens flaccidus* Mitt., and *Fissidens zollingeri* Mont. from Uttar Pradesh.

A study on diversity and distribution of liverworts (Marchantiophyta) in various habitats and across the altitudinal gradients at Pachmarhi Biosphere Reserve (PBR), central India has been carried out. The liverwort diversity was assessed in selected habitats at each site *viz*., soil, wet rocks, dry rocks, soil covered rocks, stony walls (terricolous habitats) and epiphytic habitat. Three altitudinal gradients were considered for distributional assessment. In all, 41 liverworts belonging to 21 genera and 15 families were encountered. Among the three altitudinal zones, 17 taxa were found at lower altitudinal gradient (400-800 m), whereas 12 liverworts were found at the higher altitudinal gradient (1001-1400 m). Maximum number of taxa (33) were present at the middle altitudinal

zone (801-1000 m). The sites at middle altitudes provided suitable conditions for the growth of bryophytes. In general, rocks, both moist and dry, formed the most ideal habitat for the liverworts. Evidently, the middle altitudinal gradient emerged as the zone harbouring maximum liverworts.

The liverwort, *Kurzia trichoclados* (K. Müller) Grolle (Fig. 8) has been reported new to the Indian bryoflora, which expands its distribution in South Asia. It belongs to Lepidoziaceae Limpr., a very diverse and complex family of liverworts. *Kurzia trichoclados* is a disjunct liverwort known from Europe, North America and Southeast Asia. By the present study its distribution in South Asia has been expanded to include India.

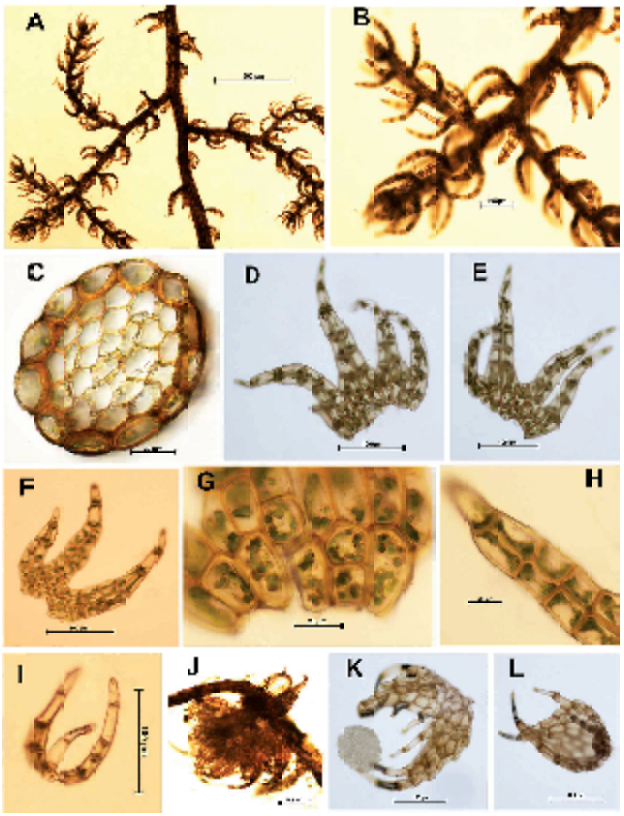

FIG. 8. *Kurzia trichoclados* (K. Müller) Grolle. A. Plant habit, B. plant portion, magnified, C. Stem T.S., D,E. Main stem leaves, F.Branch leaf, G. Cells of leaf disc, H. apical and subapical cells, I. Branch under leaf, J. Male inflorescence, K,L. Male bracts

A recent study on the mosses of Meghalaya has revealed the occurrence of six taxa of the genus *Entodon* viz., *E. concinnus* (De Not.) Par. ssp. *caliginosus* (Mitt.) Mizushima, *E. rubicundus* (Mitt.) Jaeg., *E. luridus* (Griff.) Jaeg., *E. plicatus* C. Muell., *E. scariosus* Ren. & Card. and *E. pulchellus* (Griff.) Jaeg., out of which *E. concinnus* (De Not.) Par. ssp. *caliginosus* (Mitt.) Mizushima is a new addition to eastern Himalaya and *E. scariosus* is a new record to Meghalaya.

The following plants were introduced in Moss House of NBRI Botanic Garden:

1) *Bryum coronatum* Schwaegr.
2) *Funaria hygrometrica* Hedw.
3) *Conocephalum conicum* (L.) Lindnb.
4) *Reboulia hemisphaerica* (L.) Raddi
5) *Wiesnerella denudata* (Mitt.) Steph.
6) *Marchantia polymorpha* L.

Pteridophytes

Prepared a checklist of Pteridophytes of Uttar Pradesh. About 151 specimens of old deposits of ferns and their allies in the NBRI Herbarium (LWG) have been studied and accessioned.

New introduction to the Fern House of CSIR-NBRI

Live plants of *Nephrolepis hirsutula* (G. Forst.) C. Presl, collected from Andaman Islands, was introduced in the fern house of the CSIR-NBRI (Fig. 9).

Fig. 9. *Nephrolepis hirsutula* (G. Forst.) C. Presl in CSIR-NBRI fern house.

Mass Propagation and Conservation

Mass multiplication of about 1200 individuals of 13 ornamental species, such as *Adiantum capillus-veneris, A. incisum, Colysis elliptica, Diplazium esculantum, Microlepia strigosa, Microsorum punctatum, M. alternifolium, Nephrolepes biserrata, N. cordifolia, N. exaltata, N. tuberosa, Pteris vittata, Tectaria macrodonta* and Sanjeevani Booti (*Selaginella*

bryopteris) was made for conservation, and experimental studies.

Molecular systematic studies in cultivated and wild species of Indian *Luffa* L. (Cucurbitaceae)

Molecular phylogeny of five taxa of Indian *Luffa* [*L. aegyptiaca* Mill. *L. acutangula* (L.) Roxb., *L. hermaphrodita* Singh and Bhandari, *L. echinata* Roxb., *L. graveolens* Roxb.] was examined through sequence analysis of *trnL-F* region of chloroplast DNA. A total of 35 accessions, including four out-groups, were analyzed. The sequence length of *trnL-F* region varied from 863 bp to 895bp, with 33.10% to 34.20% G+C content. The aligned *trnL-F* sequences formed a matrix of 971 base positions, of which 780 sites were conserved, 136 sites were variables, 47 sites were parsimony informative.

The sequence divergence ranged from 0 to 0.11, with an average of 0.22. The trees generated through Neighbor-joining (NJ), Maximum Parsimony (MP) and Maximum Likelihood (ML) methods grouped all the accessions of *Luffa* in two major clusters: Cluster-1 comprising *L. hermaphrodita* and *L. acutangula*, and Cluster-2 with two sub-clusters-sub-cluster 2a, comprising *L. echinata*; sub-cluster 2b, with two groups, 2b (i) with *L. graveolens* and 2b (ii) *L. aegyptiaca*. The *trnL-F* sequence data revealed a nested grouping of *L. hermaphrodita* (hermaphrodite form of ridge gourd) under *L. acutangula*, and also confirmed the inclusion *Luffa tuberosa* within *Momordica*.

Systematics and diversity of the genus *Ephedra* L. (Ephedraceae) in India

Ephedra foliata, commonly known as '*Shrubby Horsetail*', is widely distributed in deserts of Africa, Arabian Peninsula and India. It is a typical component of arid and semi-arid regions of north western India and is locally known as '*Unthphog*'. The assessment of genetic diversity and population structure in threatened and endangered species like *E. foliata* provide important information for development and implementation of conservation and management strategies.

Analysis of genetic variability and population genetic structure was carried out in 11 populations of *Ephedra foliata* collected from its distributional range in arid and semi-arid regions of north western India.

Twenty five (ISSR-15; DAMD-10) markers produced 449 fragments, of which 382 were polymorphic in nature, revealing 84.59% polymorphism.

ISSR markers revealed higher polymorphism (89.47%) than DAMD (79.70%). PIC value ranged from 0.11 to 0.34 with a mean of 0.22 per primer.

At population level variance within populations was much higher than that between populations. The three clustering approaches *viz.*, UPGMA, PCoA and STRUCTURE, grouped all the natural populations into two clusters revealing two genetic populations and the patterns of clustering of populations according to their geographic distribution.

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

As a part of organization and maintenance activity of Herbarium, about 836 bryophyte specimens collected from Odisha, Sikkim, Kumaun, Himachal Pradesh, Govind Wild Life Sanctuary (western Himalaya) and Darjeeling (eastern Himalaya) have been deposited to enrich the CSIR-NBRI Herbarium. Identification and incorporation of about 800 Herbarium specimens from Govind Wild Life Sanctuary (Uttarakhand), Eastern Ghats (Tamil Nadu), and Khasi hills (Meghalaya) has been completed.

Herbarium- A National Facility

Under the National Facility-Herbarium, routine activities, such as, general up-keep and developmental activities were carried out, besides rendering technical assistance to visiting students and researchers from various Research Institutes/Universities/Colleges, etc., particularly for 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 different phytogeographic zones and states such as Jammu & Kashmir, Himachal Pradesh, Odisha, Sikkim, Tamil Nadu, Uttarakhand, Uttar Pradesh and West Bengal.

The new additions included 1,036 specimens of seed plants, 2311 specimens of cryptogamic plants (Pteridophytes-280, Bryophytes-836, Algae-45) and 1150 Lichens.

Herbarium Holdings	
Seed plants (Angiosperms and Gymnosperms)	1,02,862
Pteridophytes	6138
Bryophytes	17,142
Lichens	1,51, 500
Algae	2675
Carpological collections	16,000
TOTAL HERBARIUM HOLDINGS	**2,96,317**

PLANT ECOLOGY AND ENVIRONMENTAL SCIENCES

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PLANT ECOLOGY AND ENVIRONMENTAL SCIENCES

Grant-in-Aid Projects

Study of impact on Arsenic contamination in rice using Ortho Silicic Acid formulation

Arsenic (As), a heavy metalloid, is finding its route to human food chain through intake of ground water contaminated with As as well as through the consumption of food grown on areas with high levels of arsenic. Silicon (Si) is beneficial to plant growth and helps against abiotic and biotic stresses. It is essential for sustainable production of rice, but Si transporters are the major entry route of As in rice. In the present study, impact of commercial formulation of stabilized Ortho Silicic Acid (OSA), the bioavailable form of silicon (Si), in reducing As accumulation in rice grains was analyzed.

Application of arsenate (As^{V}, 10 and 50 mgl^{-1}) and arsenite (As^{III}, 10 and 25 mgl^{-1}) affected plant growth in dose dependant manner. Results indicated that 25 mgl^{-1} As^{III} and 50 mgl^{-1} As^{V} significantly decreased the plant growth and yield attributes leading to lower yields. Addition of As to the plants influenced accumulation of other trace elements too. Grains from plant with As treatment had significantly lower levels of Zinc (Zn) and Cobalt (Co), while levels of Copper (Cu), Manganese (Mn) and Selenium (Se) increased significantly compared to control (Fig. 1).

Application of Si enhanced the growth and yield of plants under As stress by stimulating synthesis of thiols and activities of antioxidant enzymes, and greatly reduced grain As accumulation. The level of trace elements also increased in the grains of Si treated plants in presence or absence of As. Foliar application of Si was found to be more effective in reducing grain As level than soil-Si (Fig. 2). Results of the present study confirmed that application

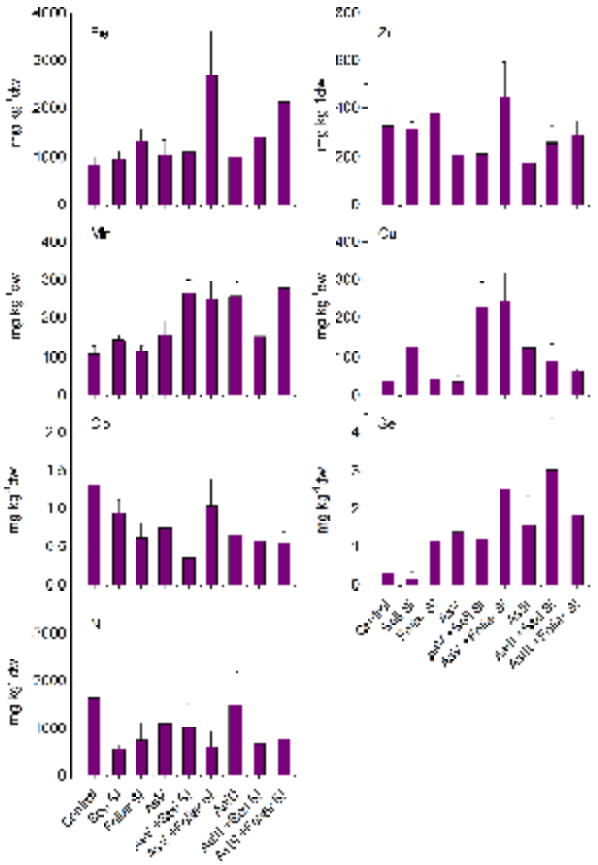

Fig. 1: Effect of soil and foliar Si application on minral nutrient accumulation in grains of rice cv. Saryu-52 during As^{V} and As^{III} exposure

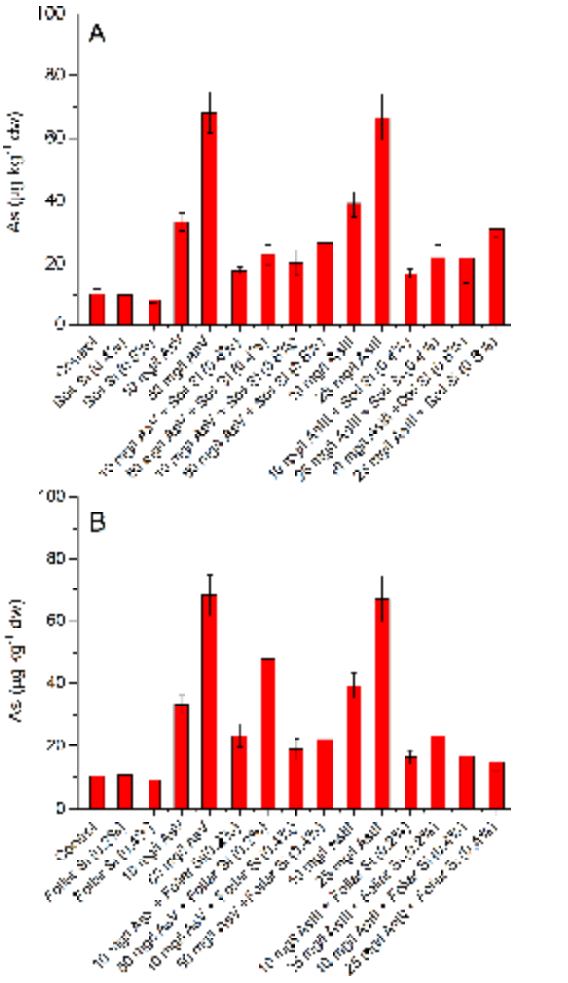

Fig. 2: Effect on arsenic accumulation in grains of rice cv. Saryu-52 during As^{V} and As^{III} exposure and Si application. (A) with soil application of Si and (B) with foliar application of Si in the form of Ortho Silicic Acid.

of OSA reduces negative impacts of As, not only in terms of economic yields but also improves the quality of grains.

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 rice varieties

Arsenic (As) exists in several chemical forms in environment. Inorganic arsenate (As^{V}) and arsenite (As^{III}) and organic methylarsonate (MA^{V}) and dimethylarsinate (DMA^{V}) are the main species found in soil in varying amount depending on previous use of soil and microbial activity. These species differ considerably for their availability for plant uptake and mobility inside the plant. Therefore, in planta speciation of As is an important tool to understand As metabolism. In the present study, accumulation, translocation and speciation of inorganic (As^{V}) and methylated As (MA^{V}, DMA^{V}) were investigated in roots and shoots of rice to understand metabolism of different As species.

Total uptake of As and accumulation in roots was higher in As^{V} exposed plants in comparison to methylated As species like MA^{V} and DMA^{V}. In As^{V} exposed plants most of the As was confined to the roots, only around 4% of total accumulated As was transported to shoots. While in MA^{V} and DMA^{V} exposed plants, around 15% and 81% of the accumulated As was transported to shoots respectively (Fig. 3A).

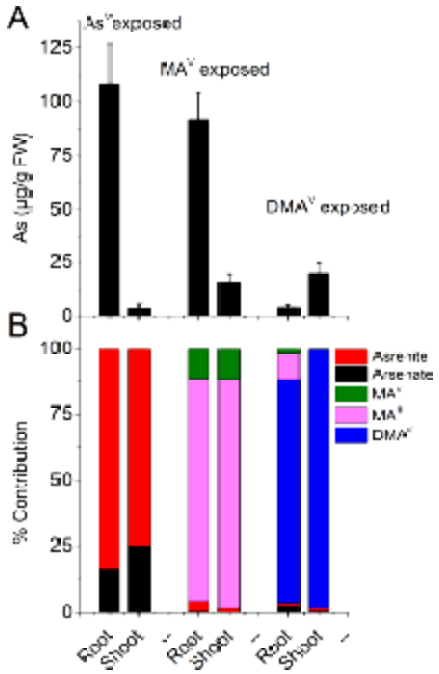

Fig. 3: Total accumulation of As in root and shoot of rice exposed to As^{V}, MA^{V} or DMA^{V} (A) and contribution of different As species separated through anion exchange chromatography coupled to ICP-MS (B). Values are mean ±SD, n=12.

Separation through anion exchange chromatography coupled to ICP-MS detector revealed that in As^{V} exposed plants, As^{III} was the main species contributing up to 84% and 75% of the total As in root and shoot, respectively. While in MA^{V} exposed plants, both in root and shoot, most of the MA^{V} was reduced to MA^{III} (84 to 86 % in root and shoot, respectively) and small quantities of As^{V} and As^{III} were also present. In DMA^{V} exposed plants most of the accumulated As remained as DMA^{V} (approx. 85% in root and 98% in shoot) (Fig. 3B).

Analysis of thiol complexation of As^{V}, MA^{V} and DMA^{V} in rice through RP-HPLC-(ICP-MS)-(ESI-MS) revealed a considerable diversity in As-thiol complexes. (Fig. 4A). In MA^{V} exposed rice root up to 16 As containing species were observed, of which 11 were identified as thiol bound (Fig. 4B).

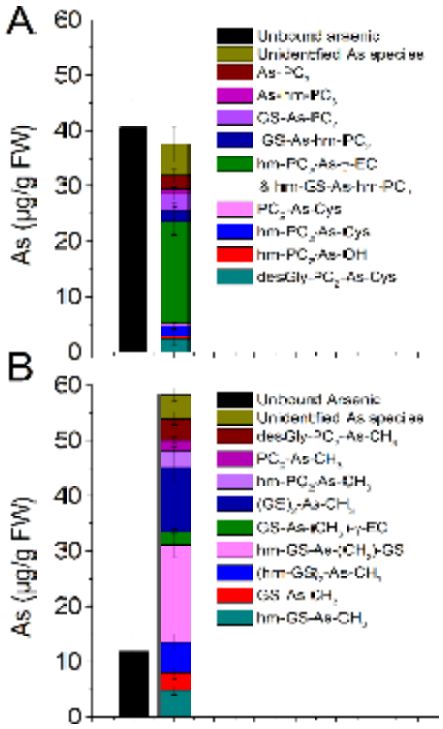

Fig. 4: Chromatogram of As species analyzed through HPLC-ICP-MS/ESI-MS in fresh root extract of rice exposed to (A) arsenate (As^{V}) and (B) methylarsonic acid (MA^{V}). Values are mean ±SD, n=12.

Presence of MAIII (78%) and AsIII (71%) in shoots, observed in the present study could be an important factor inducing straighthead (spikelet sterility disorder) in rice.

Development of bioaugmentation based safe cultivation practice for remediating arsenic contamination to paddy crop.

Reconnaissance of highly arsenic contaminated sites in West Bengal & Soil Characterization w.r.t arsenic

***contamination*:** A comprehensive survey has been made in West Bengal (as Phase – I of survey) to explore variability in the arsenic content of agriculture soils during April-May 2016. A total of 33 agriculture fields in 10 villages of 9 Blocks under 5 Districts of West Bengal were covered during the survey and soil samples were collected from paddy fields. Depending upon the total arsenic contents on higher range among the 33 field soil samples collected, a second round of survey (as Phase – II of survey) has been made during July 2016 in the Gotera and Ghetugachi villages of Chakdah Block of Nadia district, and Pipli village of Gaighata Block of North 24 Parganas district of West Bengal. A total of five paddy fields were visited per village to collect soil samples for characterizing total arsenic contents (ranging 6.64 to 31.11 mg As per kg). Among soil samples of 15 paddy fields of three villages, it was observed that the bioavailable fraction of soil arsenic (comprised of the water-soluble, weakly-adsorbed and specifically-adsorbed fractions) was ranging between 15-25% of the total arsenic contents in soils. Among the bioavailable fraction of soil arsenic, the water-soluble, weakly-adsorbed and specifically-adsorbed fractions ranges were 3-5%, 5-8% and 7-12%, respectively.

***Selection of sites at West Bengal for multilocation trials under project*:** Among the 15 paddy fields, three fields have been selected as one field in each village, viz., Gotera and Ghetugachhi villages of Chakdah Block of Nadia district, and Pipli village of Gaighata Block of North 24 Parganas district of West Bengal for conducting multilocation field trials in the project. For conducting multilocation trials at farmer's field of these three villages (Gotera, Ghetugachhi and Pipli) under the project, a local agency working on the farm trials for IRRI, AICRP, Directorate of Agriculture Govt. of West Bengal, namely "Nadia Zilla Farmers' Development Organization (NZFDO)" has been screened and identified for logistic support.

***Soil fungal strains*:** Four fungal strains as the lead strains obtained and studied for their superior performance for arsenic removal were selected for preparation of the fungal consortia formulation. The four fungal stains used are listed below.

1. *Westerdykella aurantiaca* (FNBR_3, MTCC 10845, NCBI gb# JN118571),
2. *Trichoderma longibraciatum* (FNBR_6, MTCC 10846, NCBI gb# JN102303),
3. *Lasiodiplodia* sp. (FNBR_13, MTCC 10847, NCBI gb# JN118572), and
4. *Rhizopus delmer* (FNBR_19, MTCC 10848, NCBI gb# JN118573)

A compatibility assay among these fungal strains has been studied by co-culturing them on PDA plates. No inhibitory effect of these fungal strains to each other's growth was observed showing their compatibilities together. Role of different additives and carrier materials have been studied; in which sucrose and talc, respectively were found most effective in terms of supporting longevity of fungal strains.

Modeling the Plant-Environment interaction with particular reference to chemicals for risk assessment

Understanding the extent of plant uptake of chemicals is important for evaluating the use of plants as bio-monitors of environmental contamination and for phytoremediation efforts. Quantitative structure-activity/property relationship (QSAR/QSPR) models can be used as screening tools to assess the effect of a large number of chemicals on the environment and human health. These models establish relationships between the molecular properties and chemical activity (endpoint property) of these diverse compounds.

A dataset of 63 volatile organic chemicals (VOCs) Water-Plant Cuticle Partition coefficient ($\log K_{MXw}$) was collected from literature and considered here for QSPR based predictive modeling. One and two dimensional (n=3839) molecular descriptors were calculated for all the chemicals. The relevant descriptors for QSPR modeling were selected from the pool of calculated molecular descriptor using the model-fitting approach. For QSPR modeling, the data were split into the training and test subsets using random distribution approach. Structural diversity of the considered molecules was evaluated using the Tanimoto similarity index (TSI).

Support vector machine (SVM) based QSPR models were developed for predicting the plant-chemical interaction in terms of uptake potential of the chemical for use in safety assessment process. A conceptual diagram of SVM method is shown below (Fig.5).

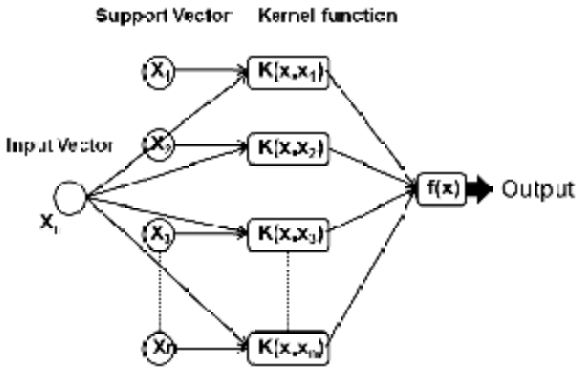

Fig. 5: Figure shows schematic diagram of the SVM modeling approach

SVM based QSPR model was developed for predicting the plant-chemical interaction in terms of partition coefficient of the VOCs. The SVM constructed with four descriptors [sum of first ionization potentials, (scaled on Carbon atom); Frequency of C-O at topological distance 1; squared Ghose-Crippen octanol-water partition coefficient and surface area of acceptor atoms] yielded correlation coefficient (R^2) of 0.992 and 0.983 between the measured and predicted log K_{MXw} with root mean squared error (RMSE) of 0.14 and 0.23 in training and test data arrays (Fig. 6).

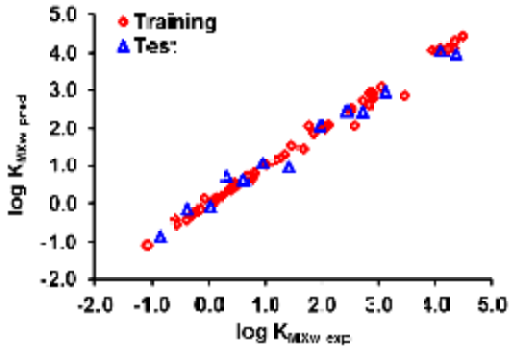

Fig. 6: Figure shows generalization and predictive abilities of the SVM model to predict water-plant cuticle partition coefficient of diverse VOCs.

The result suggest that developed model show good predictive and generalization abilities and can be used as tools for predicting log K_{MXw} of structurally diverse chemical compounds for regulatory purposes. These methods involve low-cost and lesser time and efforts to achieve more accurate results with considerably high throughput. A prior assessment of risk that can be posed by new chemicals can only be evaluated using the predictive models. In long term, in view of the needs and requirements, predictive modeling holds lot of potential.

In-House Projects

Bioremediation of organic and inorganic pollutants

Selenate mitigates arsenite toxicity in rice (*Oryza sativa* L.) by reducing arsenic uptake and ameliorates amino acid content and thiol metabolism

Arsenic (As) is a toxic element with the potential to cause health effects in humans. However, rice has become a source of As for billions of people consuming rice as the staple food. Selenium (Se) is an essential metalloid, which can regulate As toxicity by strengthening antioxidant mechanisms in rice plants. The present study was designed to investigate the role of SeVI to mitigate the stress effect of AsIII in rice. The levels of As, thiolic ligands and AAs were analyzed in rice seedlings after exposure to AsIII/SeVI alone and AsIII and SeVI treatments. Selenate supplementation (AsIII 25 µM and SeVI 25 µM) decreased total As accumulation in both root and shoot by 179 and 144%, respectively as compared to AsIII alone treatment. The AsIII and SeVI treatment also induced the levels of non-protein thiols (NPTs), glutathione (GSH) and phytochelatins (PCs) as compared to AsIII alone treatment and also modulated the activity of enzymes of thiol metabolism. The content of amino acids (AAs) was significantly altered with SeVI supplementation. Importantly, essential amino acids (EAAs) were enhanced in AsIII and SeVI treatment as compared to AsIII alone treatment. In contrast, stress related non-essential amino acids (NEAAs) like GABA, Glu, Gly, Pro and Cys showed enhanced levels in AsIII alone treatment. In conclusion, rice supplemented with SeVI tolerated As toxicity with reduced As accumulation and increased the nutrition quality by increasing EAAs.

Changes in biomass allocation to leaves, stems, fruits and roots under abiotic stress in seed plants

Alteration in metabolic pathways during drought stress in leaf tissue of *Gossypium* species

Drought causes a big economic loss due to reduced yield in Cotton an economically very important fiber yielding crop. In India, major cultivation of cotton is being done under rainfed conditions, experiencing frequent drought cycles. Four varieties of cotton were subjected to drought stress and the response of metabolites of different pathways to the stress was studied (Fig. 7). Drought tolerant varieties JKC-770 and JKC-717 accumulated comparatively more sugars, while sensitive varieties KC-2 and RAHS-187 did not show changes in sugar levels under drought condition. Simultaneously, γ-amino butyric acid (GABA) and proline also accumulated in tolerant varieties under water limiting condition. At the same time, fatty acid content also increased in tolerant varieties

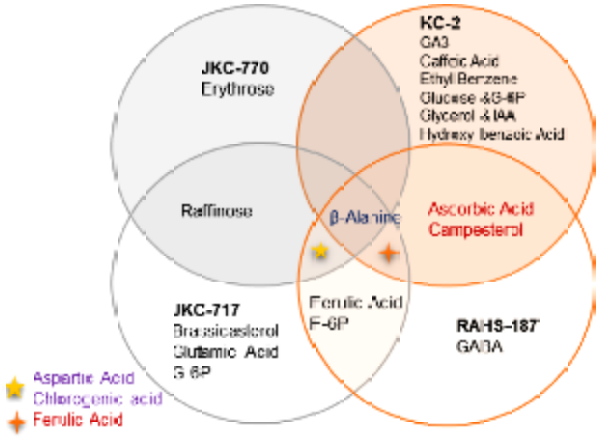

Fig. 7. Venn diagram of the metabolites identified as key metabolites for the tolerance or sensitivity of the cotton varieties, JKC-770, KC-2, JKC-717 and RAHS-187.

(palmitic acid in JKC-717 and propionic acid and decanoic acid in JKC-770 variety). Increased level of unsaturated fatty acids in cell membrane helps these varieties to protect from damages due to reactive oxygen species (ROS) produced under stress. These results correlated with the lipid membrane damage in the tolerant varieties and vice versa in the sensitive variety. Tolerant varieties also showed increased sitosterol and decreased campesterol under drought condition. Increased level of auxin and its precursor tryptophan probably leads to better growth in the drought tolerant varieties under drought stress. Thus, tolerant varieties showed enhanced osmo-protection due to the accumulation of carbohydrates (Fig. 8), sugar alcohols, and free amino acids (Fig. 9) which are lacking in the sensitive varieties and leads to the failure of plant survival under drought stress.

Role of salicylic acid in soybean under drought stress

Drought is a major concern for sustainable yield under changing environment to meet the global demands. Soybean, economically important oil and protein crop, is prone to drought resulting in yield instability. Salicylic acid (SA), multifaceted growth hormone, modulates the series of parallel processes to confer drought tolerance relieving yield limitations. The present study was performed in soybean plants treated with SA (0.5 mM) through seed pretreatment under drought regimes: severe stress (50% RWC, TS1) and moderate stress (75% RWC, TS2), and rehydration (TSR). Differential leaf proteome profiling with morphological, physiological and antioxidative metabolism studies performed at two developmental stages (vegetative and flowering). This explained the tolerance attribution to soybean throughout the development attaining yield stability. Ascorbate peroxidase (APX) activity during vegetative and flowering stages was significantly higher in TS1 than TS2 (Fig. 10). Glutathione reductase (GR) and Catalase (CAT) activities were also observed to be significantly higher under SA pretreatment with maximum activity in TS2 followed by TS1, TR and Control (TC), subsequently (Fig. 11,12). SA showed positive influence on yield in soybean under water stress (TS1 and TS2) by significantly affecting yield parameters like seed starch, seed weight per plant, seed number per plant, thousand seed weight and harvest index (Fig. 13,14). The proteins involved in photosynthesis and carbon metabolism were major proteins upregulated under SA in stressed plants contributing towards increased physiology, biomass and carbon (C) partitioning. Amino acid metabolism related protein abundance directed towards increased osmoprotectants accumulation like

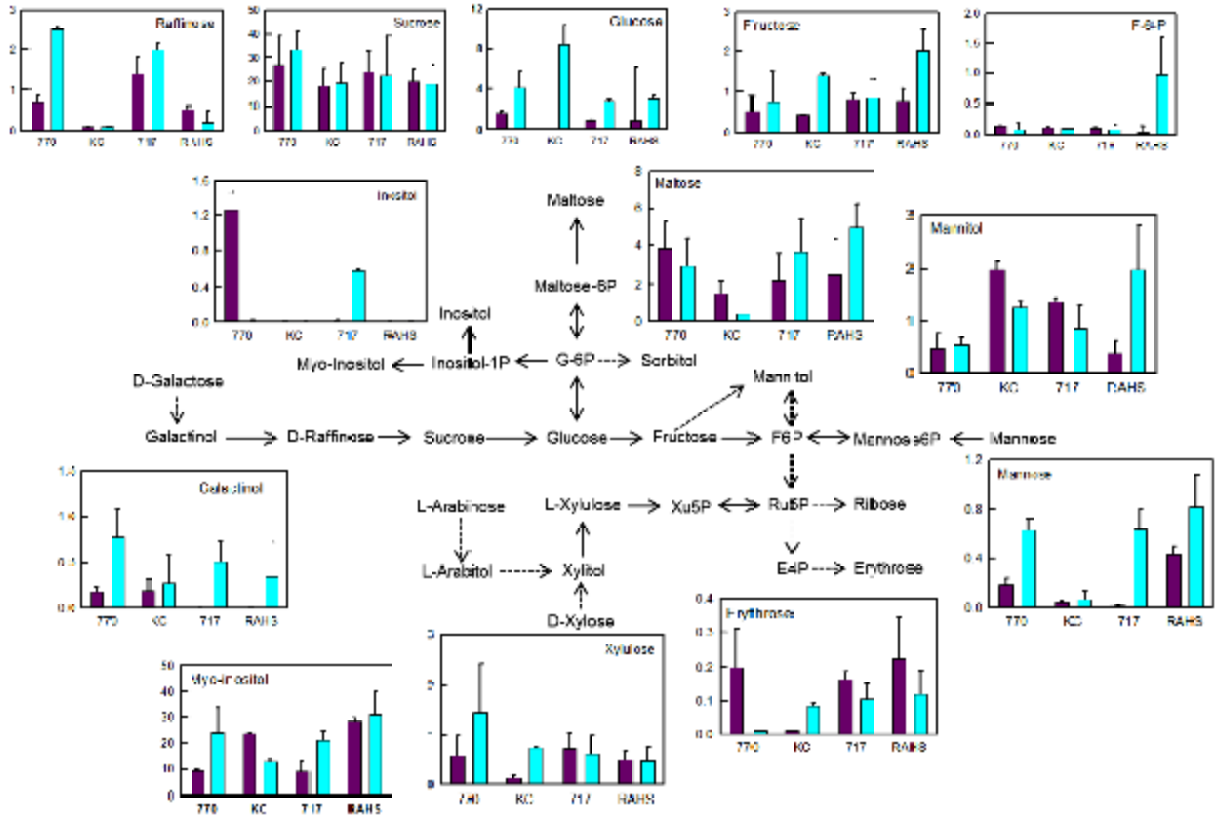

Fig. 8: Carbohydrate metabolism in leaf tissue of JKC-770, KC-2, JKC-717 and RAHS-187 *cotton varieties* under watering (dark pink bar) and drought (cyan bar) treated condition

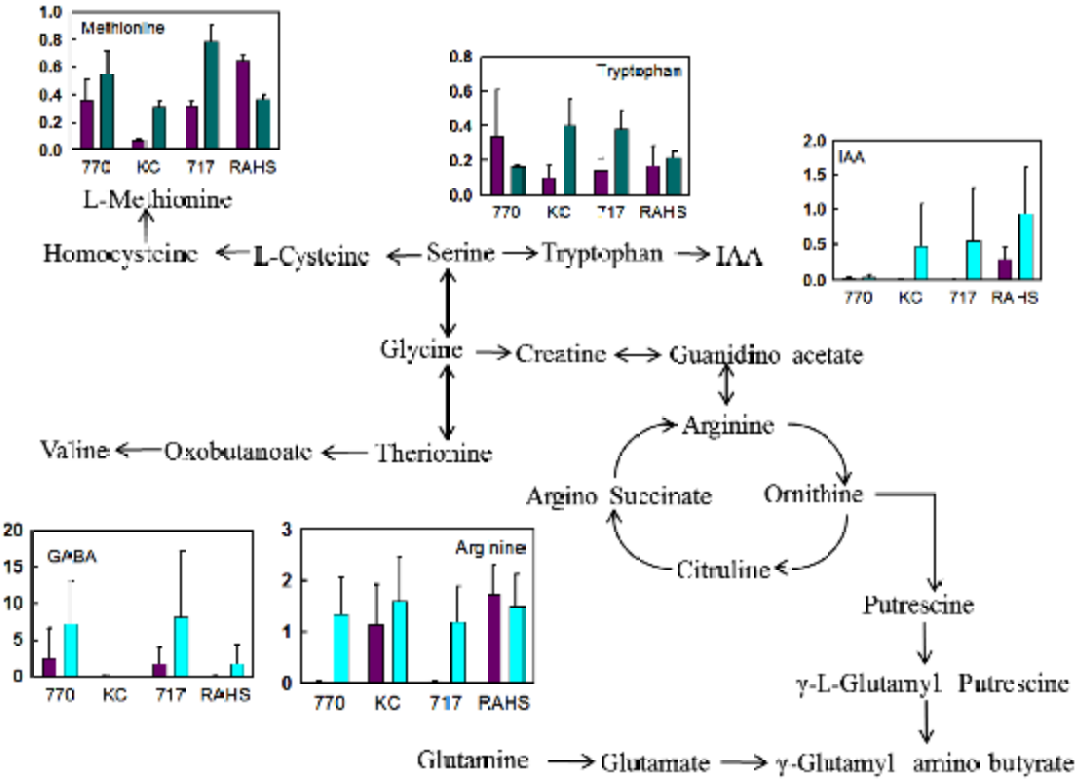

Fig. 9: Amino acid metabolism in leaf tissue of cotton varieties, JKC-770, KC-2, JKC-717 and RAHS-187 under watering (dark pink bar) and drought stress (cyan bar) condition.

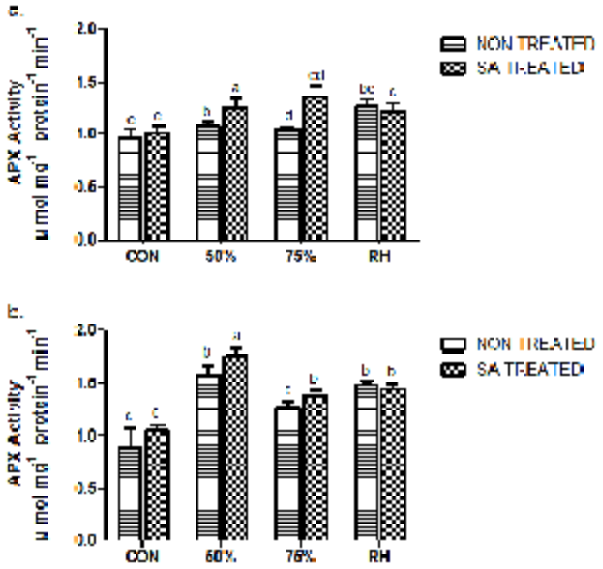

Fig. 10. Activity of antioxidative enzyme Ascorbate peroxidase (APX) under the interactive effect of SA with water stress (75% and 50%) and rehydration at a. Vegetative and b. Flowering stage. Bar represents mean ± standard deviation (n=3), letters (abc) represents level of significance through one way ANOVA post hoc Duncan's test ($p \leq 0.05$)

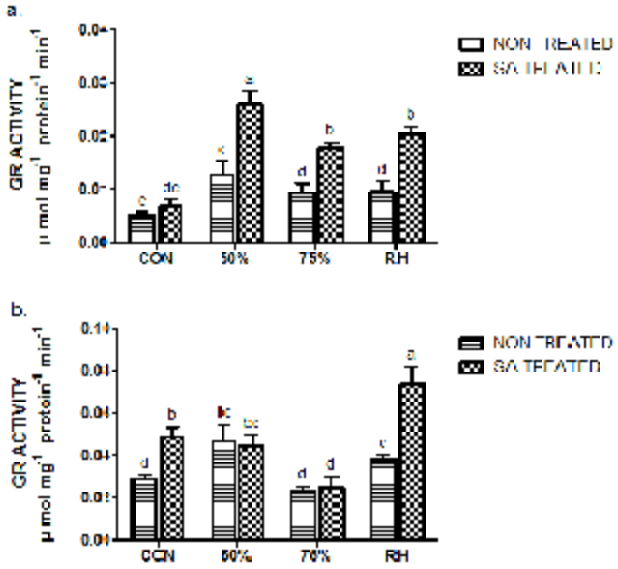

Fig. 11. Activity of antioxidative enzyme Glutathione Reductase (GR) under the interactive effect of SA with water stress (75% and 50%) and rehydration at a. Vegetative and b. Flowering Stage. Bar represents mean ± standard deviation (n=3), letters (abc) represents level of significance through one way ANOVA post hoc Duncan's test ($p \leq 0.05$)

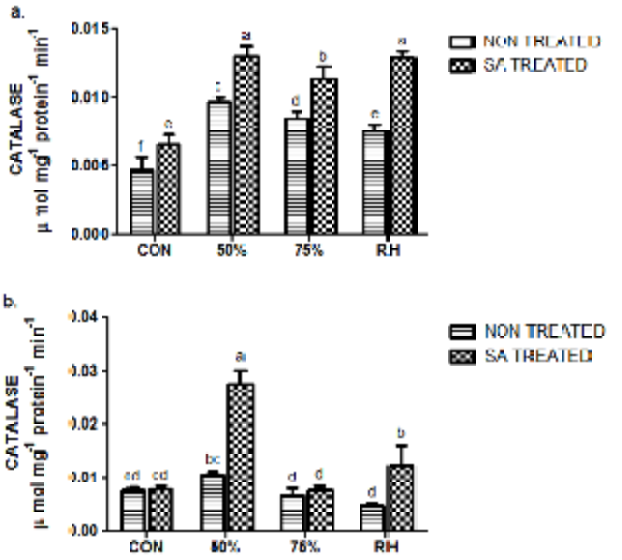

Fig. 12. Activity of antioxidative enzyme Catalase (CAT) under the interactive effect of SA with water stress (75% and 50%) and rehydration at a. Vegetative and b. Flowering stage. Bar represents mean ± standard deviation (n=3), letters (abc) represents level of significance through one way ANOVA post hoc Duncan's test ($p \leq 0.05$)

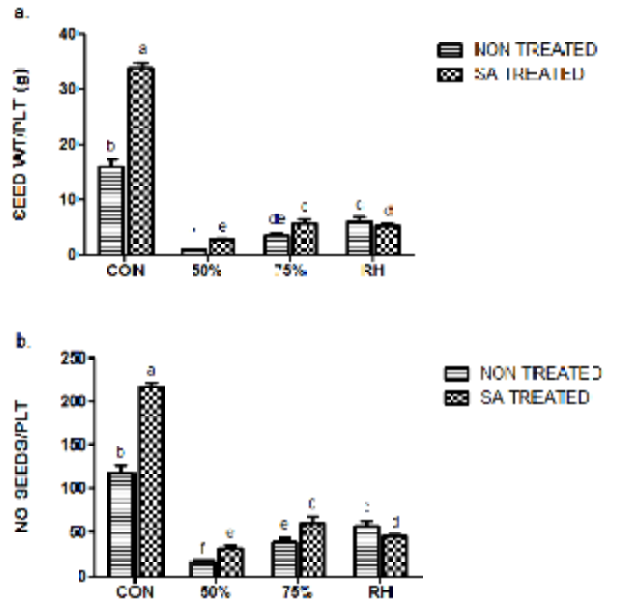

Fig. 13. Yield parameters a. Seed weight per plant; b. Number of seeds per plant under interaction of drought and rehydration with SA in soybean. Bar represents mean ± standard deviation (n=3), letters (abc) represents level of significance through one way ANOVA post hoc Duncan's test ($p \leq 0.05$)

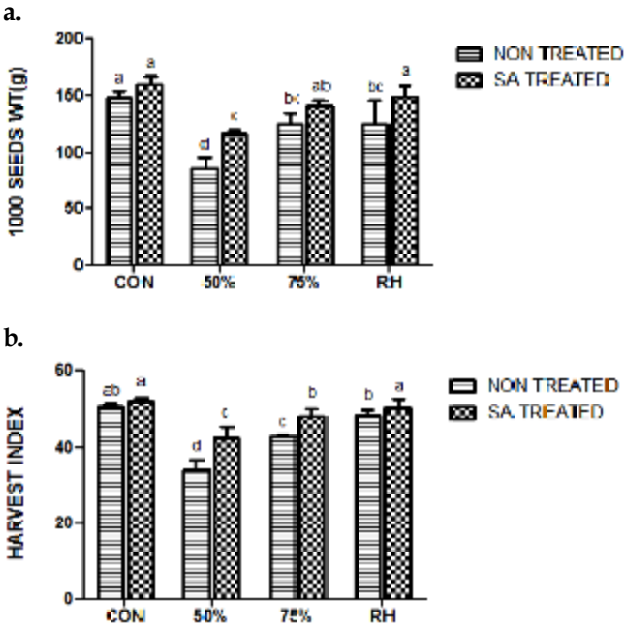

Fig. 14. Yield parameters a. Thousand seed weight; b. Harvest index (HI) under interaction of drought and rehydration with SA in soybean. Bar represents mean ± standard deviation (n=3), letters (abc) represents level of significance through one way ANOVA post hoc Duncan's test ($p \leq 0.05$).

proline at initial stage which contributed later towards nitrogen (N) remobilization to developing sink. Defensive mechanisms against redox imbalance and protein misfolding and degradation under stress were enhanced as depicted by the upregulated proteins involved in redox balance and protein synthesis, assembly and degradation at vegetative stage. At later stage, abundance of these proteins maintained redox homeostasis and N remobilization for improved sink strength. The redox homeostasis is supported by the increased antioxidative metabolism in SA treated plants. The downregulation in proteins at flowering stage also contributed towards N remobilization. Yield potential improved by SA under drought through plant survival and acclimation with enhanced N and C remobilization to sink demonstrated by increased yield parameters like seed number and weight per plant, thousand seed weight and harvest index.

GENETICS AND MOLECULAR BIOLOGY

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GENETICS AND MOLECULAR BIOLOGY

Grant-in-Aid Projects

Exploring transcriptional regulators involved in prickle formation in *Solanum khasianum*

Cellular characterization of prickle development in *S. khasianum* has been done. We have identified the structural and developmental stages of prickles of *S. khasianum* through SEM (Fig. 1).

We have observed that prickle development of *S. khasianum* initiates only from the base of glandular trichome, although, both the glandular and non-glandular type of multicellular trichomes were abundantly distributed on the stem surface of both the strains.

Studies of the transverse section of stem under light and SEM revealed that prickles are multicellular in structure and originated from the epidermal cells. Studies with confocal microscope are in progress.

High quality RNA was isolated from the epidermal tissues pealed from the stem of prickly and prickleless strains to perform differential mRNA-sequencing, generating a broad survey of the global transcriptional regulators associated to the prickle development and its functioning.

Statistics of sequencing and analysis of the transcriptome data is given below in the table 1 and Fig 2. Small RNA sequencing is under progress.

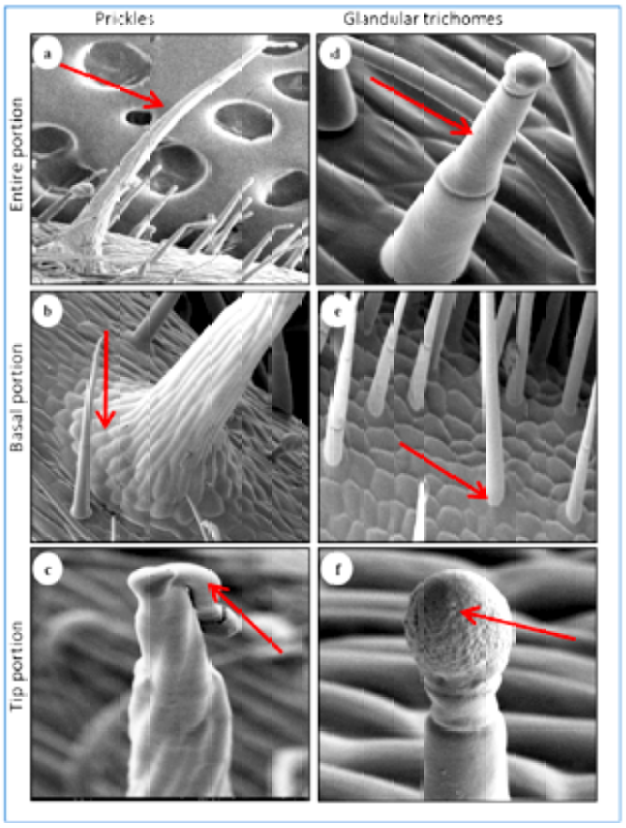

Fig 1. Structural similarity and difference between glandular prickle and glandular trichome of *S. khasianum*. [a] entire prickle, [b] basal portion of prickle, [c] tip portion of prickle, [d] entire glandular trichome, [e] base of trichome, [f] tip of trichome.

Table 1: Summary of the *de novo* sequence assembly and annotation of *S. khasianum*

	Prickly		Prickleless	
	R1	**R2**	**R1**	**R2**
No. of Reads	18175222	15851932	17096127	13586099
No. of HQ reads	17444985 (95.98%)	15153863 (95.60%)	16429445 (96.10%)	12992487 (95.63%)
No. of Contigs	150880		142861	
Largest Contig (bp)	59569		46421	
Smallest contig (bp)	201		201	
Average Length (bp)	1126.75		1117.51	
GC%	46.11%		46.70%	
NR Annotated transcript	73189		70970	
No of transcripts after clustering	156926			
Largest Contig	59569			
Smallest contig	201			
Average Length	1110.9			
GC%	39.30%			

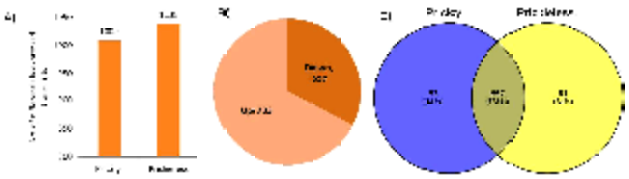

Fig. 2 Differential gene expression pattern in epidermis of prickly and prickleless strains (fold change < -1.5 and > 1.5). **(A)** Abundance of differentially expressed genes; **(B)** Up and down regulated genes; and **C)** Distribution of common and uniquely expressed genes

Till now the available literature reported that the prickles are the modification of multicellular trichomes. However, we have observed that initiation and development of prickle starts from the base of the selected few multicellular trichomes and the glandular trichome remained attached at the tip of the prickles.

Molecular genetics of guar (*Cyamopsis tetragonoloba*) using SNP markers

The project has two main objectives – First is Germplasm enrichment and characterization for major agronomic traits in guar. The second objective is to do Genotyping by sequencing of germplasm lines for SNP discovery and diversity analysis of available germplasm.

In order to enrich the germplasm and their characterization, a total of 268 accessions were collected/ obtained from various centers. Eighteen diverse and prominent accessions were obtained from RVSKVV, Gwalior, Madhya Pradesh. 100 diverse accessions were obtained from Rajasthan Agricultural Research Institute, (RARI), Jaipur and Rajasthan. Remaining, 150 accessions were obtained from NBPGR, Jodhpur Center, through material transfer agreement (MTA).

Genomic DNA from ~200 accessions was isolated, quantified and quality checked on 0.8 % agarose gel. Preparation of RAD libraries and SNP discovery through GBS is under progress.

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

This project was initiated with following objectives –

- Linkage analysis and mapping of *Alternaria* blight resistance loci
- Validation and marker assisted backcrossing (MABC) of blight resistance loci to elite variety.

In order to meet these objectives, a total of 216 polymorphic SSRs were identified (Out of 2001 primers screened) using DNA of parental lines JRF-4 and Chambal.

Out of 216, 198 SSRs were found suitable for linkage mapping. Eighteen SSRs were found to be distorted. Out of 198 SSRs, 191 SSRs mapped across 15 linkage groups. The 15 linkage groups were designated as LG1 to LG15 and covered altogether 1802.4 cM. Minimum distance between markers was 0.2 cM and maximum distance between markers was 45.0 cM. Average marker distance between adjacent markers in the map was 10.2 cM. The number of SSRs per LG ranged from 7 (LG15) to 20 (LG1).

Analysis of sterol glycosyltransferase (*sgt*) gene family of *Withania somnifera* using artificial miRNA technology in the glycosylation of secondary metabolite

We have analyzed the functions of *SGTL* family members of *W. somnifera* by suppressing the gene family using artificial miRNA and Virus Induced gene silencing (VIGS) method. We have modified the VIGS vector with amiRNA and developed a MIR-VIGS system against *WsSGTLs* gene members. This a MIR-VIGS system helps to avoid the off target gene silencing in the plants.

SGT silenced plants lost tolerance against heat stress indicating their role in maintaining cell homeostasis during stress conditions. We have elucidated the role of SGT enzymes under heat stress. SGTs are involved in sterol modification and participate in metabolic flexibility during stress. Silencing of *WsSGT* members, was inimical for important physiological parameters, such as electron transport rate, photochemical quantum yield, acceptor side limitation, non-photochemical quenching, Fv/Fm and net photosynthetic rate, whereas stomatal conductance, transpiration rate and dark respiration rates were increased (Fig. 3A-B).

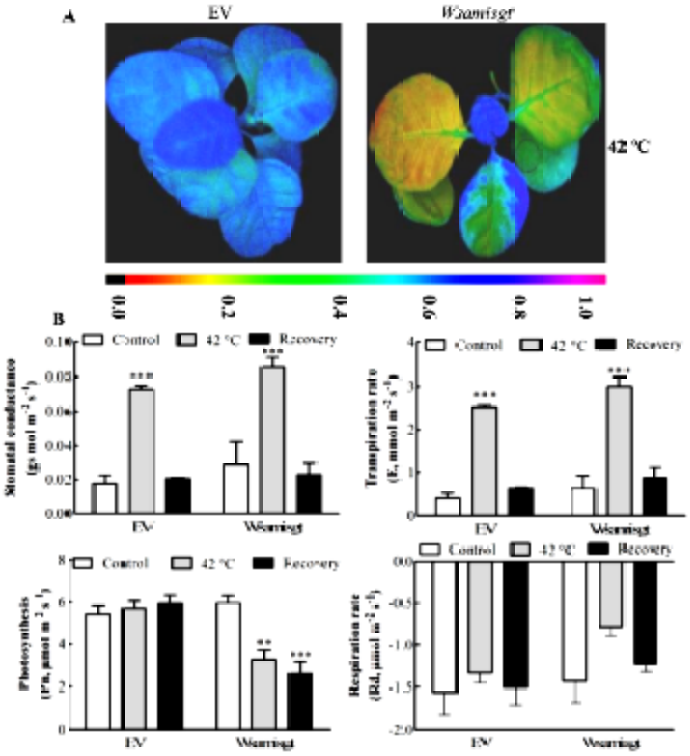

Fig. 3. (A) Chlorophyll Imaging Fluorescence (CFI) measurements after heat stress (B) Important physiological parameters such as stomatal conductance, transpiration rate, photosynthesis and respiration rate of *Wsamisgt* silenced lines before and after 3 h of heat stress. Data is presented as means ± SE and n=5 biological replicates and three technical replicates.

Heat stress resulted in increased H_2O_2, lipid peroxidation and nitric oxide production in the *SGT* gene silenced lines due to high ROS generation (Fig. 4A-B). The expression of HSPs in *Wsamisgt* lines might be involved in regulation of physiological processes during stress. We have also observed increased proline accumulation which might be involved in restricting water loss in the *Wsamisgt* lines (Fig 4C).

Observations revealed that SGT enzyme activity of *W. somnifera* is required to minimize the internal damages of the cell against high temperature by maintaining the sterol versus sterol glycosides ratio in the membrane.

For the functional analysis of members of *SGT* gene family, we have used for the first time, a successful combination of artificial mi-RNA (amiRNA) and virus induced gene silencing (VIGS) technology.

This is the first study in which we have proved the role of SGT enzymes in the modification of phytosterols and important withanolides and their striking effect on heat stress tolerance.

Targeted manipulation of SlERF6 and SlERF8 in tomato: their role in regulating fruit ripening and productivity

SlERF6 was previously shown to influence several plant growth processes that included an increase in root growth (ranging from 1.5–2-fold in root dry weight) in over-expressing lines (lines 1-4 and 2-4) in tobacco. To identify the stage when these changes occurred, root growth was monitored at 1.5, 2.5 and 4.5 months in three seasons. Root growth did not show any significant change in the first 1.5 months. Thereafter, between 1.5 and 2.5 months, root fresh weight and dry weight increased considerably in transgenic lines over that in control in different experiments with the increase in dry weight varying from 1.34–1.9-fold in both the lines in three successive years. At 4.5 months (the end of life cycle) the increase ranged from 1.4–2-fold in both the lines over the respective controls (Fig. 5). Interestingly, a decrease in total root dry weight was observed at 4.5 months compared to that in 2.5 months in controls and both the transgenic lines. During the same period, shoot biomass did not undergo a visible differential change between control and transgenic lines unlike in roots.

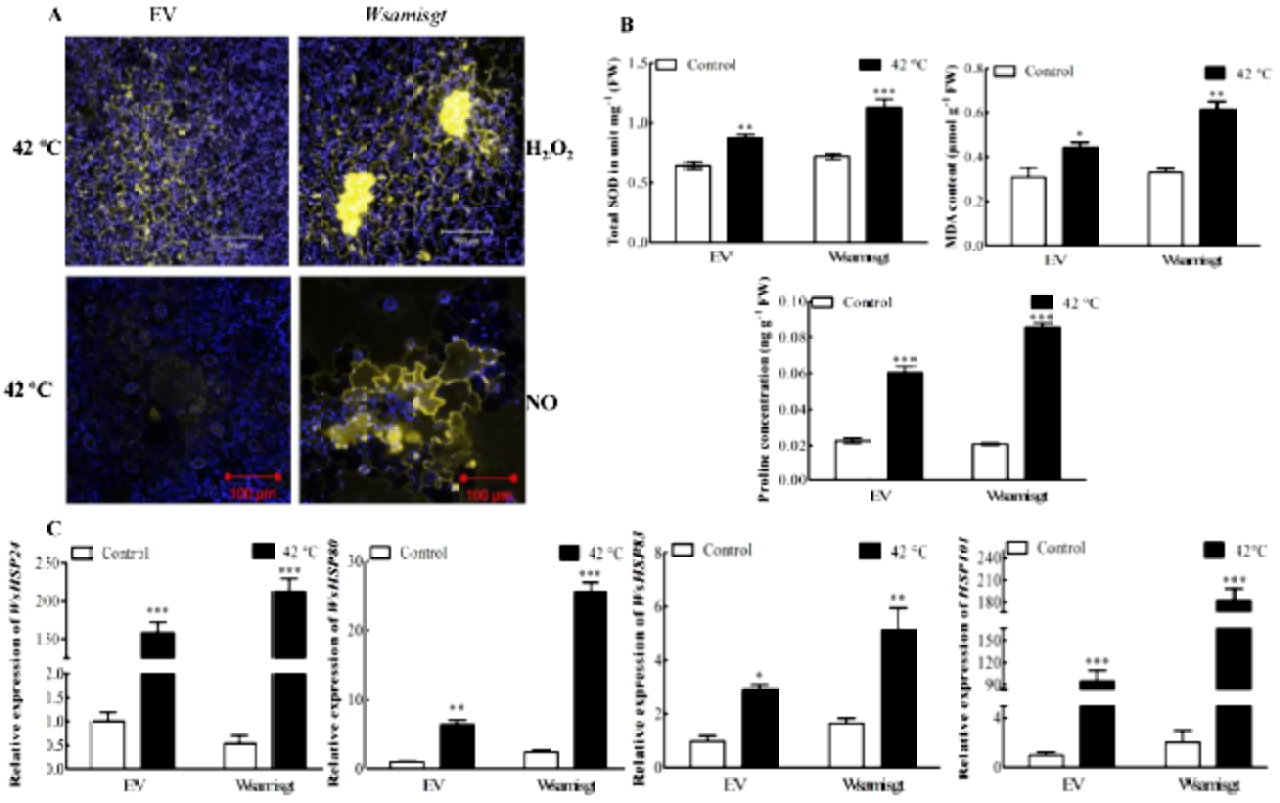

Fig. 4 A-C: (A). Effect of heat stress on the H_2O_2 and NO production in the *Wsamisgt* line (B). Total SOD activity, MDA analysis and accumulation of proline before and after 42 ºC, 3 h heat stress (C) Real-time expression analysis of the important *HSPs* such as *WsHSP24, WsHSP80, WsHSP83* and *WsHSP101* of *W. somnifera*. Data is presented as means ± SE and n=3 biological replicate and three technical replicates.

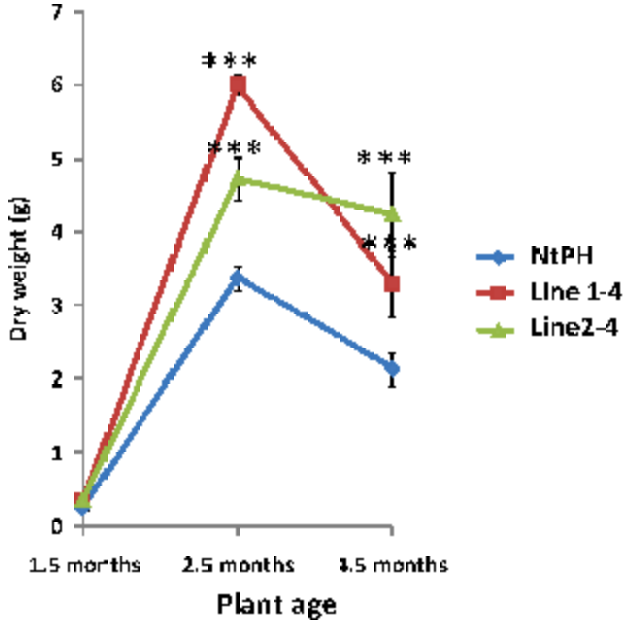

Fig. 5. Comparative age dependent effects on root growth in control and transgenic tobacco lines (Line1-4 and Line 2-4) over-expressing *SlERF6* during their life cycle (n = 5). NtPH - control tobacco (*N. tabacum*, Petit Havana)

Role of NPR1 in global nucleosomal remodelling in *Arabidopsis thaliana*

Nonexpressor of pathogenesis-related gene (NPR1) is a transcription coactivator and central regulator in systemic acquired resistance (SAR). It controls a wide range of pathogenesis related genes involved in various defense responses, by sensing SAR signal molecule Salicylic Acid (SA). Previous studies from our lab show correlation between global Nucleosome positioning and Salicylic acid-mediated transcriptional regulation in *Arabidopsis thaliana*. Currently, we are trying to unravel the role of NPR1 in the Nucleosome remodelling in *Arabidopsis thaliana*.

For this, MNase-seq and transcriptomic sequencing were done in *Arabidopsis thaliana* in response to Salicylic acid in Col-0 (wild type) and mutant (*npr1-1)* to identify global changes in nucleosomal positioning and modulation in gene expression respectively (Table 2). The distinct and fuzzy nucleosomes in different samples were found in the analysis (Table3).

Here C1, C2 are biological replicates from Control Arabidopsis plant. CS1, CS2 are biological replicates from Arabidopsis plant treated with Salicylic acid. N1, N2 are biological replicates from *npr1-1* mutant. NS1, NS2 are biological replicates from *npr1-1* mutant treated with Salicylic acid

Table 2: Mapping statistics of MNase-seq data from different samples

Sample	Total Number of Reads	Reads aligned concordantly exactly 1 time	% of Reads aligned concordantly exactly 1 time	Reads aligned concordantly >1 times	% of Reads aligned concordantly >1 times
C1	18155496	6776119	37.3226873	10161472	55.96912362
C2	16944754	6485196	38.27258867	9425727	55.62622508
CS1	14520427	5655242	38.94680232	7946324	54.72513997
CS2	14413234	5891945	40.87871605	7461254	51.76668886
N1	14854342	4967695	33.44271325	8782121	59.12157536
N2	14695406	4119635	28.03348883	9357026	63.67313703
NS1	15335319	3707193	24.17421509	10276219	67.01014175
NS2	16025547	3436310	21.44270021	11229628	70.07328985

Table 3: Identification of distinct and fuzzy Nucleosomes

Sample Name	Biological Replicate name	Number of Nucleosomes	Distinct nucleosomes	Fuzzy nucleosome	Total Nucleosomes
C	C1	230970	138750	43351	182101
	C2	233118			
CS	CS1	249259	135702	51051	186753
	CS2	239276			
N	N1	250120	113853	50008	163861
	N2	210609			
NS	NS1	237496	105503	54525	160028
	NS2	228658			

Further, analysis is in process to carry out the NPR1 role in chromatin remodeling and its effect on gene expression.

Development of F1-Hybrid Cotton using Novel Reversible Male Sterility System

F1 hybrid cotton possesses superior agronomic traits like better fiber quality over its parents and hence it is of tremendous global demand. We are in the process of developing commercially viable F1 hybrid cotton via a novel protocol called as reversible male sterility system. The *Agrobacterium* based plant genetic transformation protocols were standardised for achieving cotton transgenic male sterile (ms) and restorer (rs) lines of Cocker-312. The transgenic male sterile (ms) lines carried autophagy related gene BECLIN1 and herbicide resistance (H^R) gene BAR as selection marker. Hundred hypocotyls segments were used for agro-infection at a time for transformation with both ms and rs module. Explants were sub-cultured on callus induction media and followed by callus proliferation media after co-cultivation. Currently transformed explants are at callus proliferation and

embryogenic stage (Fig 6). Embryos isolated from the ms, msHR and rs module transformed callus transferred in magneta boxes. Regenerated plants after well developed root and shoot were transferred in soil and kept in hardening chamber (Fig 7).

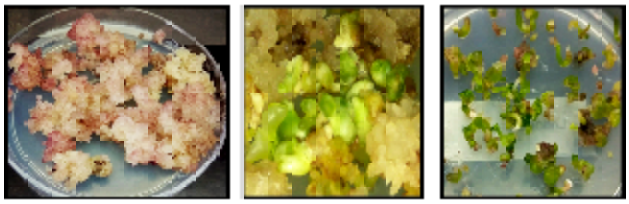

Fig 6:. Agrobacterium mediated transformed Cotton calli with binary vector pBI101 and pCAMBIA 1300 containing construct 1370/1374 and 1373 respectively.

Fig.7: Putative transgenic cotton plants regenerated through somatic embryo expressing ms, ms-H^R and rs module transferred in greenhouse and in the process of molecular analysis.

The Role of Arabidopsis TBP-Associated Factors (TAFS) in Plants Defence

TAF4b as a transcription co-activator mediates defence signaling during plant pathogen interaction as evident from our previous work (data unpublished). Protein-DNA and protein-protein interactions are crucial events in TAFs mediated transcription. The hypothesis of the present work is to identify a defence related TAF4b interacting component that regulates immunity in plants. So, we followed two different approaches i.e. a random mating approach (S_{Random}) and binary mating approach (S_{Binary}) for the identification of the genome wide interacting proteins against TAF4b using Yeast two hybrid system. The random mating approach resulted in identification of 42 proteins and the binary mating approach led to the identification of 41 proteins. Further the cytoscape network analysis showed significantly enriched pathways. The major GO terms for enriched pathways include transcription regulation, plant defence response through hormone and developmental process. The interaction strength studies further helped in screening of highly interacting protein out of 83 proteins. An orphan/novel protein was selected on the basis of interaction strength and its relative abundance in library screening.

Further, TAF4b and unknown protein, hereby named as TIP1 (TAF4b interacting protein1) sequences were screened for the domain architecture using NCBI-CDD tool. The TAF4b protein contains RST domain and TAF4 domain and the TIP1 protein shows presence of two DUF760 domains at both the termini of protein. In-depth domain interaction studies show that TAF4b-TIP1 interaction is non-redundant and specific to the RST domain. It also suggested that the TAF4 domain do not play any role in the interaction with the TIP1. Simultaneously, a vector switch experiment also was performed to further confirm the TAF4b and TIP1 interaction in yeast.

TAF4b-TIP1 interaction was proven in heterologous yeast genetic system using Y2H but there were false positives (bottle neck limitation of the technique). Therefore, we used *in-vivo* interaction validation using BiFC assay in plant system. The biolistic particle bombardment on onion peal followed by confocal microscope revealed the full length TAF4b and full length TIP1 interaction *invivo*.

Transcriptome based screening of putative targets and their functional validation in *Phenacoccus solenopsis*

The present study is being carried out to identify putative RNAi target genes in *P. solenopsis* using high-throughput screening platforms. This work involved diet optimization for *P. solenopsis*. The work was conducted to enrich the understanding of the external morphology of cotton mealybug from India and to differentiate developmental stages of mealybug, using compound microscope and scanning electron microscope

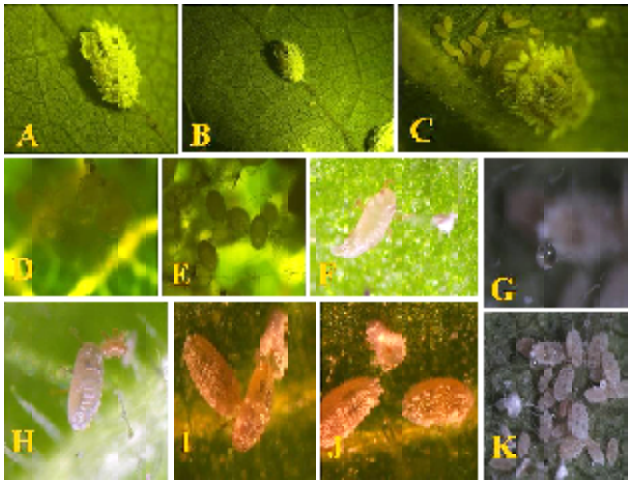

Fig 8A: Stereoscopic microscope observation of complete developmental cycle of cotton mealybug (*Phenacoccus solenopsis*), pre-moult and moult stages of different Instars on cotton leaves. A-B: Adult female, C: Adult female with cottony silken cocoons ovisacs, D: eggs pouch, E: Scattered eggs on cotton leaves, F: First Instar, G: Honeydew droplets H: Second Instar, I: Third Instar after final moulting, J: Third Instar with left over exuvia, K: Adult female colonization.

(SEM) as shown in Fig. 8A and B. Since in the available literature, no standard synthetic diet is present for cotton mealybugs, we made attempts to standardize the components of a synthetic diet based on phloem-sap analysis done through H1-NMR. The major components of the diet are sugars, amino acids, and organic acids. The diet components were optimized through available online tool "design-expert" based on response surface methodology principal. *De novo* transcriptome assembly was used to screen out putative RNAi target genes in *P. solenopsis*. We sequenced four RNA libraries from eggs,

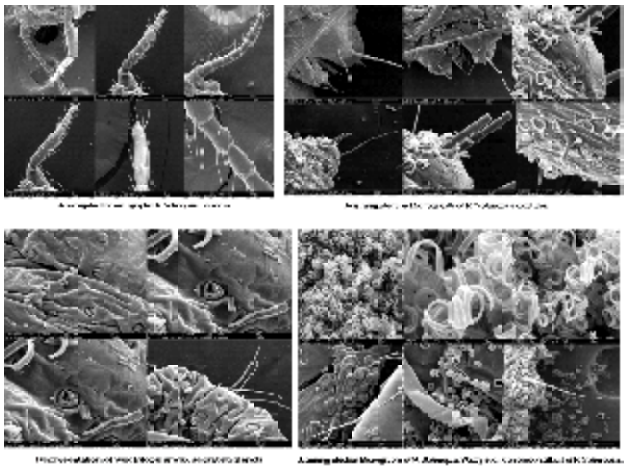

Fig. 8B: Scanning Electron micrographs of different morphological structures in *P. solenopsis*.

second, third instar and adult female, obtaining an overall total of around 245 million reads. The assembled *P. solenopsis* transcriptome contained 93,781 contigs with an average size of 871.4 bp, of which 35.69% presented positive Blast hits. These unigenes sequences were annotated and classified by performing Gene Ontology (GO), Acyrthosiphon pisum and Kyoto Encyclopedia of Genes and Genomes (KEGG) functional classifications. From the transcriptome, most of the core genes of the RNAi mechanism of hempiteran were identified indicating the potential suitability of *P. solenopsis* for gene silencing. To better understand the process of metamorphosis, we pairwise compared four developmental phases and obtained 29,415 differentially expressed genes. Functional enrichment analysis of differentially expressed genes showed a positive correlation with specific physiological activities of each stage, and these results were confirmed by qRT-PCR experiments (Fig. 9). Target genes based on high expression values or FPKM were selected, and dsRNA was synthesized (Table 4). This study provides a valuable genomic resource of *P. solenopsis* covering all its developmental stages and will promote future studies on biological processes at the molecular level.

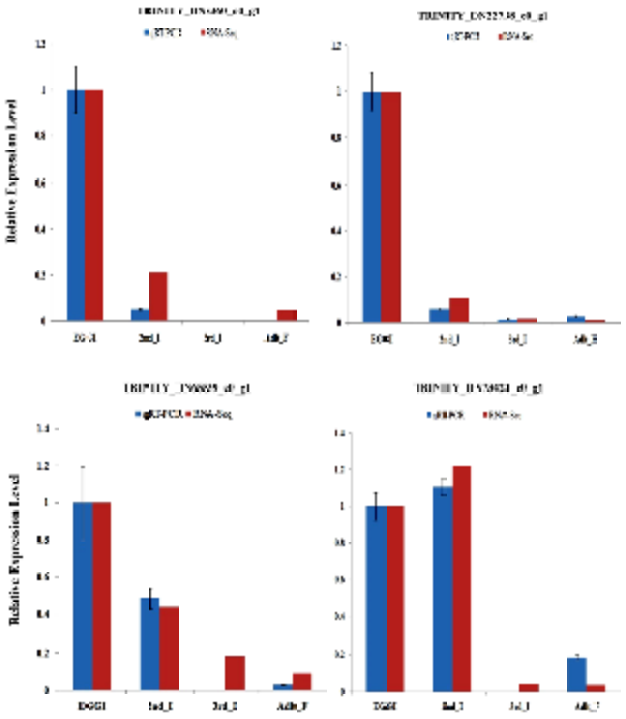

Fig. 9: qRT-PCR validation of differentially expressed genes (DEGs) result. The height of each bar chart represents the mean average of sample-specific $2^{-\Delta\Delta Ct}$ values. "EggI" represents the pooled samples stage from egg and first instar nymphs, "2nd_I" represents the 2nd Instar stage, "3rd_I" represents the 3rd instar stage, and "Adult_I" represents the adult female stage.

Table 4. List of potential RNAi targets genes against *P. solenopsis*.

GENE	% Identity	E-value	FPKM values normalized per library			
			Eggs/ 1st stage	2nd stage	3rd stage	adult
	Potential Target genes for RNAi					
Rpn7	67.33	1E-156	119.84	110.62	92	77.85
SNF7	88.11	3E-65	51.75	41.14	34.4	58.23
Surf4	72.86	2.00E-114	86.6	102.82	108.66	94.51
Vitellogenin	88.61	3E-124	12.32	17.17	20.79	1.58
Kruppel	82.88	2E-86	136.12	111.53	107.26	189.49
NiGTPase	98.12	8E-122	263.15	274.51	224.22	154.25
Ryanodine	90.54	0	79.03	98.39	132.65	790.14
Cs	75.98	0	18.7	9.13	12.78	11.23
Surf4	72.86	2.00E-114	86.6	102.82	108.66	94.51

CSIR Fast Track Translation Project

Anacardic Acid: A potential molecule to increase cotton fibre yield and quality

Anacardic acid (AA) is an important candidate molecule for the improvement of yield and fiber quality in cotton (Fig 10). Anacardic acid was used for field trial to check its applicability as a plant growth regulator for cotton under normal agricultural practices. Multi-location

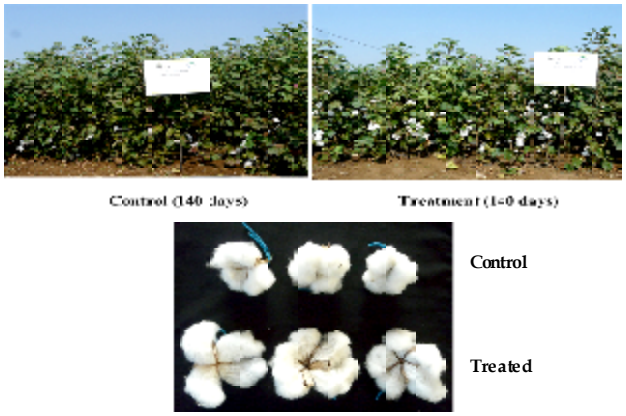

Fig 10: Boll weight and fiber yield was significantly increased in Anacardic acid treated plants as compared to control plants.

field trials of Anacardic acid were conducted at three locations viz., Bhatinda (Punjab), Aurangabad (Maharashtra) and Hyderabad (Telangana). Our preliminary results confirm an increase in boll weight and fiber yield, however complete data analysis is in progress. Our results suggest that more Multi-location field trials are required for optimizing dosages and concentration of anacardic acid for spraying. The technology using anacardic acid was demonstrated to UCP chemicals Ltd., Chennai and Ankur Seeds Ltd., Nagpur. The molecular and cellular analysis suggests, anacardic acids functioned through auxin and ethylene mediated pathways but further validations are needed.

In-House Projects

Genetic improvement of Canna with gene(s) of horticultural importance

A procedure for clonal propagation in four cultivars of Canna x generalis (Canna Lily) was developed from rhimzome. Explants were cultured on MS medium supplemented with different combinations of either 6-benzyl-aminopurine (6-BA), thidiazuron (TDZ) or kinetin along with indole-3-acetic acid (IAA). Trinacria variegata was the best responding variety, closely followed by Pink Sunburst, Agnishikha and Raktima respectively. Notably, 6-BA (2 mgl^{-1}) or TDZ (1.5 mgl^{-1}) along with IAA (0.1 mgl^{-1}) were the ideal concentrations among all the combinations tested. Highest regeneration was achieved in 36.36% explants of Trinacria Variegata cultured on 6-BA (2 mgl^{-1}) and IAA (0.1 mgl^{-1}), while it was 33.33% in the same variety cultured on TDZ (1.5 mgl^{-1}) along with IAA (0.1 mgl^{-1}). Kinetin failed to evoke any response. Regeneration was enhanced up to three folds by the supplementation of antioxidant compounds like ascorbic acid (100 mgl^{-1}) in addition to cytokinin 6-BA (2 mgl^{-1}) or TDZ (1.5 mgl^{-1}), into the culture medium, while the incorporation of L-cysteine (100 mgl^{-1}) or dithiothreitol (DTT, 100 mgl^{-1}), significantly inhibited the regeneration potential. The regenerated shoots developed 3-5 fibrous roots, upon sub-culturing on MS basal medium supplemented with indole-3-butyric acid (IBA, 0.5 mgl^{-1}). The plantlets having a pair of vegetative leaves and roots were transplanted into pots filled with sterilized potting mix and acclimatized to ambient conditions before transferring to glasshouse for further development. There was 100% survival rate of *in vitro* grown plantlets. Agrobacterium-mediated transformation was performed using pBI121 and transgene integration in the putative transformants was confirmed by PCR analysis and Southern hybridization.

Insect inducible methanol production in cotton for insect resistance

In our lab, as a proof of concept, we showed that the over-expression of Pectin methylesterase (PME) isolated from *Arabidopsis thaliana* (AtPME) and *Aspergillus niger* (AnPME) under constitutive promoter provides broad spectrum insect resistance. Continuous over-expression of transgene sometimes is not beneficial for plant development. Therefore attempts are being made to develop transgenic cotton plant over-expressing *AnPME* under the control of a wound inducible promoter (In-house developed). The transgenic plants so developed may provide insect bite regulated methanol production which will give resistance towards insect pests. The transgenic cotton plants, developed via somatic embryogenesis through Agrobacterium mediated genetic transformation (Fig.11), are being used for further studies.

We also identified other PME genes with better enzymatic activity as compared to AtPME or AnPME. For which, we selected Solanaceae family for further screening because Solanaceous plants emit high methanol. Our studies suggest high PME activity in *Datura stramonium* (Ds) and *Withania somnifera* (Ws) as shown in Table 5 and were selected for PME purification. Of these two selected PME's; kinetic parameters of WsPME were better than DsPME. Natural and modified WsPME is being used for developing transgenic plants.

Table 5 Kinetic Parameters of DsPME and WsPME

Enzyme	K_m (mg/ml)	Vmax (µmol/min)	K_{cat} (sec^{-1})
DsPME	0.0087 ± 0.001	16.96 ± 0.46	73.68 ± 4.27
WsPME	0.0071 ± 0.001	27.66 ± 0.75	93.76 ± 2.64

Present study demonstrated that methanol might work as an insect resistant molecule. *Wspme* and *Dspme*, purified and characterized in the current study, showed

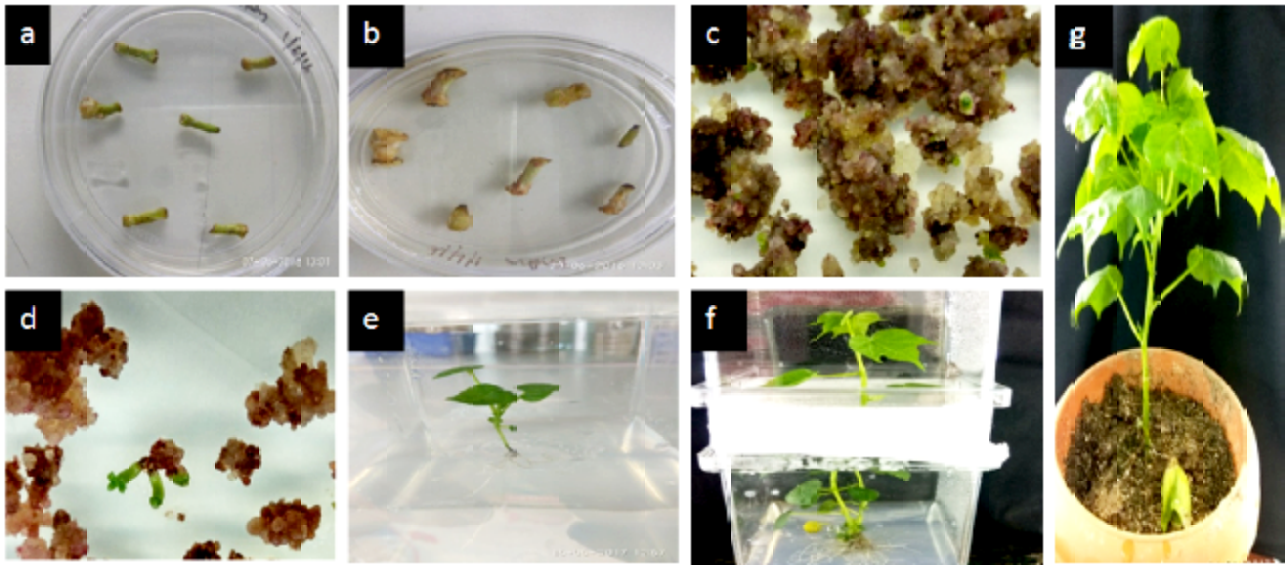

Fig. 11a-g: Different stages of transgenic cotton developed via somatic embryogenesis. (a) Hypocotyls as explants. (b) Callus formation from explants. (c) Embryogenic callus formation bearing globular embryos. (d) Bipolar embryo formation. (e-f) Plantlet formation. (g) Putative transgenic in glass house.

highest PME activity amongst other selected plants of the same family. *Wspme* gene expression under inducible promoter might provide broad spectrum resistance to insects.

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

Multiplication of breeder seeds of developed high thebaine lines (>10%) in isolation plots at CSIR-NBRI campus is being done for its commercialization. The data of advanced thebaine lines over six years (2009-10 to 2014-15) on various yield parameters have been compiled and presented in Fig. 12. The lines NBIHT-1 and NBIHT-3 showed a substantial increase in opium yield in subsequent years while thebaine content showed variation over the years probably due to environmental conditions as secondary metabolites fluctuate substantially according to climatic conditions.

Breeders seeds of thebaine rice lines NBIHT-1 and NBIHT-3 were multiplied and evaluated at two villages in Chittorgarh district of Rajasthan and Mandsaur district of Madhya Pradesh in an area of 500M² (Fig.13). Data is under compilation.

BC3F1 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. BC2F1 plants further back crossed with recipient parent and the F3 population of selected transgressive segregants of the cross between high yielding variety (NBRI-5 and NBRI-2) and papaverine line were grown. The promising plants were selected for further analysis.

The selected transgressive segregants from the F2 population of the cross between high yielding variety (NBRI-2) and papaverine line were subjected to further recurrent selection. Pedigree and recurrent selection among identified high narcotine lines having up to 15% narcotine content were done to develop lines with enhanced content of narcotine and total alkaloid. Plant progenies of germplasm lines having high morphine in the husk (more than 1.00%) were evaluated for their stabilization.

The breeder seeds of developed thebaine rich line(s) (>10%) of opium poppy (*Papaver somniferum* L.) was multiplied in isolation plots at CSIR-NBRI campus for its commercialization. The data recorded from the field of villages is under compilation. The data of 15 developed thebaine lines over six years on various yield parameters have been compiled. The lines NBIHT-1 and NBIHT-3 showed a substantial increase in opium yield in subsequent years while thebaine content showed variation over the years probably due to environmental conditions as secondary metabolites fluctuate substantially according to climatic conditions. The backcrossing program is also under way to transfer thebaine and papaverine trait into a high yielding variety. In linseed, genetic diversity in 185 lines of linseed based on morphological, biochemical and fatty acids was carried out statistically. High seed yielding and rich linolenic acid plant progenies were advanced in Linseed.

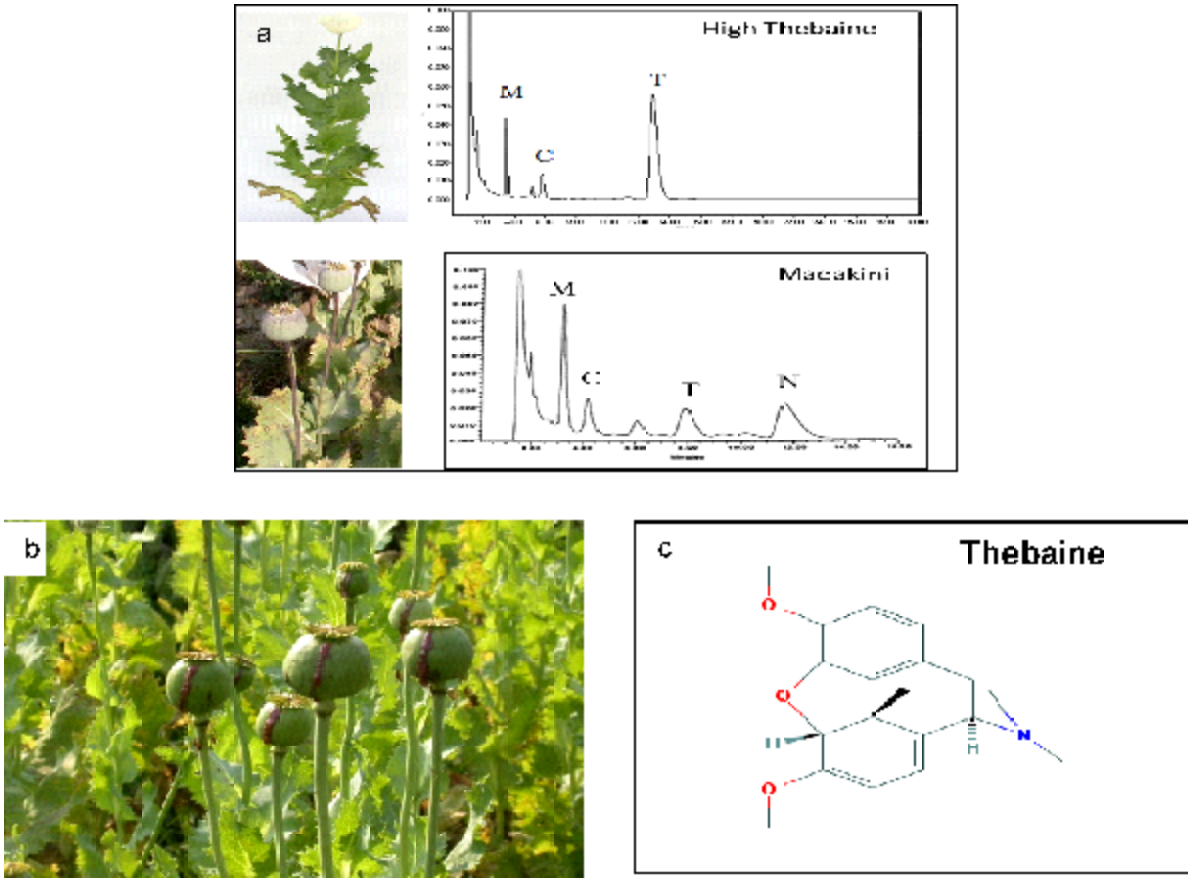

Fig. 12: Thebaine rich line of opium poppy developed by NBRI (a) Comparative HPLC profile of thebaine line and a variety (b) field view of thebaine line (c) chemical structure of Thebaine

Fig.13. Performance of Thebaine lines (NBIHT-1 and NBIHT-2) at various villages of Chittorgarh (Raj.) and Mandsaur (M.P.)

SSR and SNP based genetic diversity analysis in linseed

Genetic diversity of 86 linseed accessions was analyzed using large set of SNP markers (10,057 SNPs) and a set of diverse accessions identified for further breeding program

161 SSR based linkage map of linseed was developed and QTL mapping performed. A total of 9 QTLs were identified: 2 QTLs for plant height, 3 for capsules/plant, 2 for seeds/capsule and 2 for oil content.

In Silico identification of SNP diversity in cultivated and wild tomato species: insight from molecular simulations

Tomato is an economically and nutritionally important crop; it is also a model system for studying various fruit development traits. To improve different varieties of tomato in the present market, it is important to develop high yielding and stress tolerant varieties. Single Nucleotide Polymorphisms (SNPs), an important source of genetic variations, are often used in crop improvement programme. The present study represented comprehensive *in silico* analysis of nucleotide polymorphisms in the wild (*Solanum habrochaites*) and cultivated (*Solanum lycopersicum*) species of tomato to explore the consequence of substitutions both at sequence and structure level. The total EST and NGS data of both the species were downloaded from the public databases and used for the SNP analysis. A flow chart describing the process is represented in Fig 14A. A total of 8978 SNPs having Ts/

Tv (Transition/Transversion) ratio 1.75 were identified. Out of these, 1838 SNPs were non-synonymous and distributed in 988 protein coding genes. Among these, 23 genes containing 96 SNPs were involved in traits markedly different between the two species. Furthermore, there were 28 deleterious SNPs distributed in 27 genes, and a few of these genes were involved in plant pathogen interaction and plant hormone pathways. The results also showed that allele specific motif binding pattern had a biological role in various pathways related to fruit ripening (Fig 14 B). Molecular docking and simulations of several selected proteins showed the effect of SNPs regarding compactness, conformation and interaction ability. Observed SNPs exhibited various types of motif binding effects due to nucleotide changes. SNPs that provide the evidence of differential motif binding and interaction behaviour could be effectively used for the crop improvement program.

Variation in DNA methylation pattern in Indian populations of *Arabidopsis thaliana*

Epigenetic modifications provide a potential mechanism for adaptation beyond the DNA sequence level variation. Studies on epigenetic changes have recently gained momentum in relation to plant ecology and adaptation. Cytosine methylation is a type of epigenetic modification that is found in diverse eukaryotic organisms, which provides an additional layer of heritable information and gene regulation upon the DNA genetic code. It has been shown to regulate gene expression and transposon silencing. A number of studies have shown a high correlation between gene expression and methylation. Role of DNA methylation has also been shown in plant adaptation to climate, in both model and non-model species. Recent 1001 epigenome consortium has also sequenced more than 1000 worldwide accessions of Arabidopsis thaliana with the single base resolution. In-spite of several studies throughout the world, none of the Indian accessions is being considered in such a context. Through our earlier studies, we predict that these accessions might be relict populations and hence could contribute much to the studies on plant adaptation. Keeping the above facts in mind, we were interested in deciphering the epigenetic code of Indian populations of *Arabidopsis thaliana*. Seven populations were collected

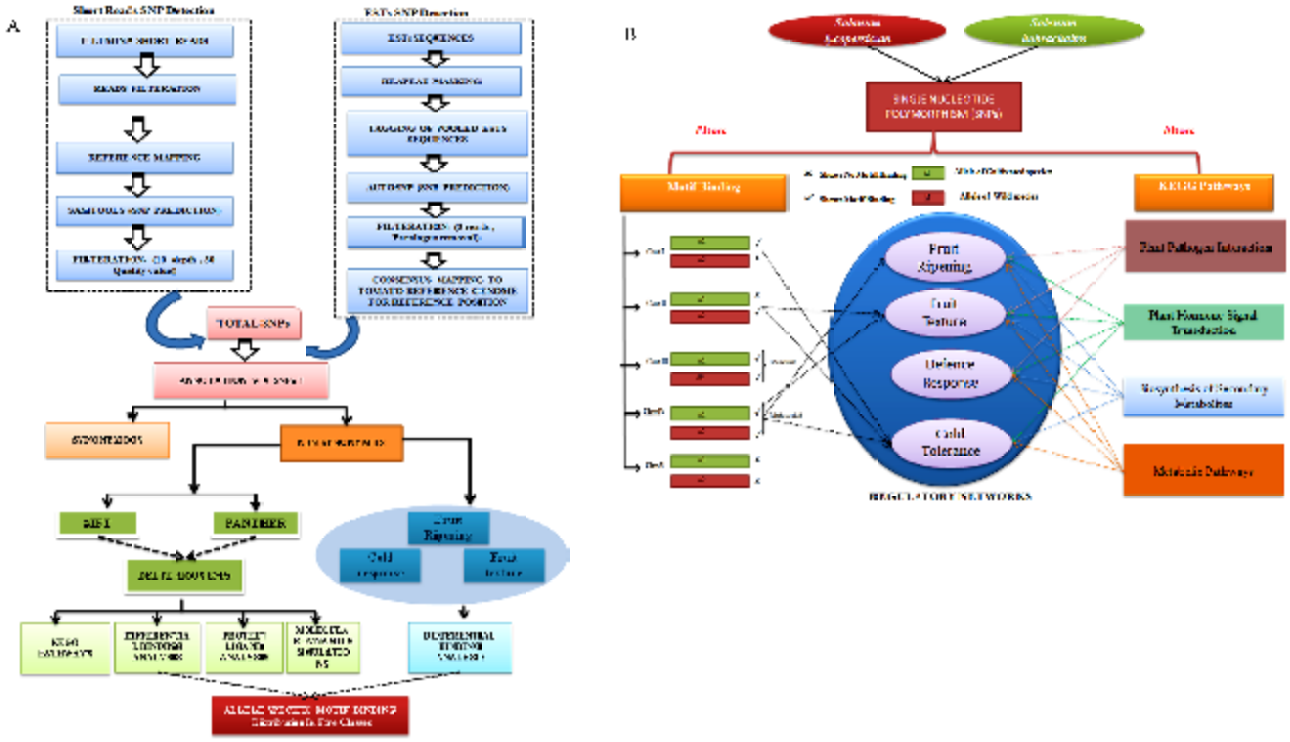

Fig 14 A-B: *Flow graph represents the step wise procedure of NGS and ESTs SNP prediction and downstream analysis:* ESTs and NGS illumina short reads were evaluated separately for *in-silico* as illustrated via Phase I (Illumina SNPs) and II (ESTs SNPs) stepwise procedure. Resulted cumulative set of all the SNPs were processed for the annotation via SNPeff and predicted deleterious SNPs via cumulative usage of SIFT and Panther. Impact of deleterious SNPs analysed at sequence (differential motif binding, KEGG pathways) and structural level (Protein ligand, Molecular simulations). B: *SNPs involved in multiple KEGG pathways consist of differential motif binding event.* Consequence of SNPs in genes regulating the fruit ripening, texture, cold and defense responses depicted via alteration in Motif binding behaviour and KEGG pathways.

along the altitudinal gradient ranging from 700-3500 mt above mean sea level. These populations are new to the community of scientists working on *A. thaliana*. Whole genome bisulfite sequencing carried out of fourteen accessions, corresponding to seven populations. Plants were collected from their native sites, and DNA was isolated from rosette leaves of the plants at mid-flowering stage. Whole genome bisulfite library was prepared from genomic DNA and was subsequently used for paired end sequencing using a standard protocol of whole genome bisulfite sequencing. On an average 4-5 GB of raw reads was obtained after sequencing for each accession. The reads were trimmed and filtered for high-quality bases and removing methylation-bias using Trimmomatic. The reads were mapped onto the respective reference genomes using Bowtie2 with 10% mismatch. The respective reference genome of each population was constructed by incorporating high confidence SNPs into the Col-0 reference genome. The SNPs were identified from our whole genome data sequenced earlier. An average unique mapping percentage of 41.87% was obtained. The bisulfite conversion rate was estimated by mapping reads onto the unmethylated chloroplast genome. The average conversion rate for all the samples was 98.81% ± 0.93%. The reads were further processed for methylation state extraction using Bismark methylation extractor. An average of 217999216 cytosines was analyzed for methylation status. On an average, 33.9% of cytosines were methylated in CG context, 14.9% were methylated in CHG context, and 6.6% were methylated in CHH context in our populations. Average methylation percentage of the populations in each cytosine context is shown in Fig. 15. Further the significantly methylated cytosines in each context (P value <0.05) were identified taking into consideration the bisulfite conversion rate. On an average, 1314862 cytosines were methylated in CG context, 1637764 cytosines were methylated in CHG context, and 8243725 cytosines were methylated in CHH context. Further the methylated sites that were covered by at least ten reads were used to cluster

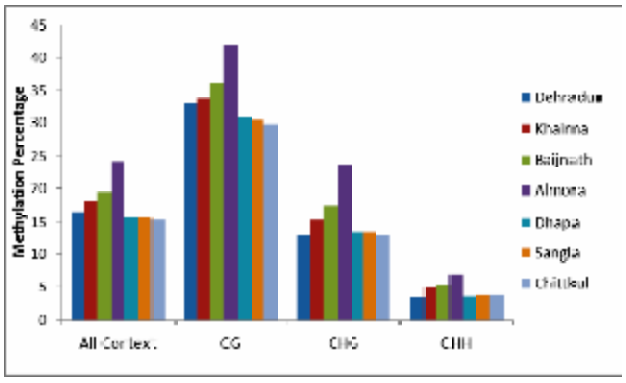

Fig.15: Bar diagram showing whole genome average methylation percentage of populations in each cytosine context.

the samples. This epigenome based correlation clustering showed that the most of the individuals grouped according to their populations of origin when CG context was considered. The mixing of the populations was seen in clustered on reviewing the methylation state in CHG and CHH context (Fig.16). On annotating the methylated regions where average methylation was more by at least 25%, we found that CG methylation was more enriched in the geneic regions while the CHG and CHH methylation was enriched in the transposons. On an average, genes were 18.7% more methylated in CG context than the transposons, while the transposons showed 27.4% and 25.0% increased methylation in CHG and CHH context respectively.

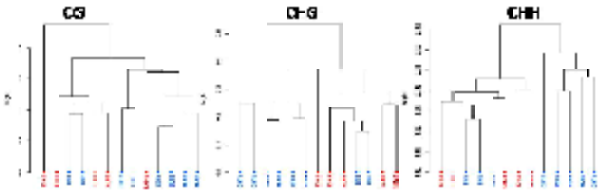

Fig.16: Clustering of individuals on the basis of methylation state

To find out the multivariate association of the methylation state and climate of the native sites we performed redundancy analysis taking climate data from WorldCom database over average methylation in each context. A significant association of the climatic variable was found with CG and CHG methylation context (Fig. 17). No significant association of climatic variables with CHH methylation was found. This analysis showed that the spatial gradients in temperature were majorly associated with epigenomic variation across the populations, specifically in CG and CHG context. Overall our study revealed that, like the genomic variations, the

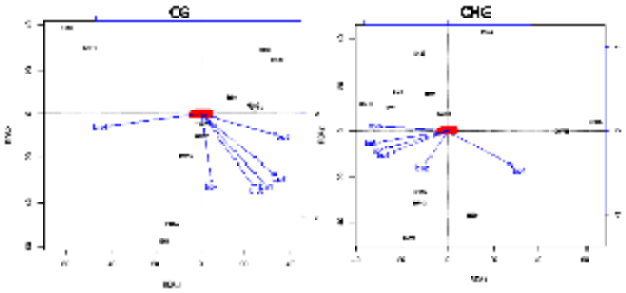

Fig.17 Redundancy Analysis with bioclimate variables and methylation state in CG and CHG context

epigenomic variations were also found to be population specific. The association of the epigenetic change with the climate may predict for the adaptive response of the populations towards their growth conditions. A considerable amount of this epigenetic variation could also be due to the underlying genetic changes, which need to be overruled.

PLANT MICROBE INTERACTION, PHARMACOGNOSY AND PHYTOCHEMISTRY

Plant Microbe Interaction, Pharmacognosy and Phytochemistry

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PLANT MICROBE INTERACTION, PHARMACOGNOSY AND PHYTOCHEMISTRY

PLANT MICROBE INTERACTIONS

Grant-in-Aid Projects

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

A total of 572 target genes were identified for 290 conserved miRNAs whereas 1481 target genes for 73 novel miRNAs were predicted from chickpea genome. The deep sequencing data was also validated by expression analysis of seven selected miRNAs (four conserved and three novel) through qRT PCR under control, RAR, drought and drought + RAR treatments. Four miRNAs (miR156, miR159, miR396 and novel miR12) exhibited similar expression pattern as those obtained from small RNA seq data.

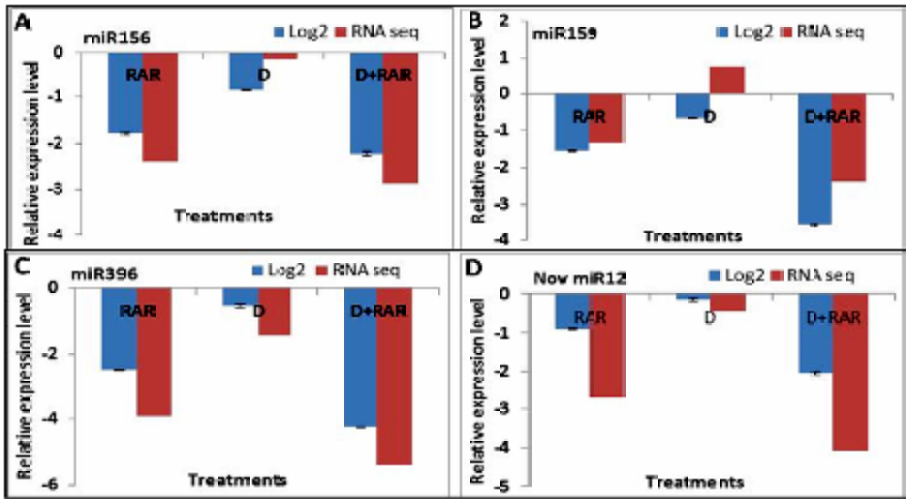


Fig 1 (A-D): qRT-PCR confirmation of RNA-seq results examining gene expression in roots from plants grown under well-watered, RAR, drought and drought + RAR conditions.

The expression analyses of their respective target genes was also carried out. Our results indicated a good correlation between RNA-seq and qRT-PCR data (Fig 1A-D) as well as between miRNA and target gene expression (Fig 2A-D).

The results revealed that RAR treatment resulted in alteration of expression of both miRNAs and target genes as compared to control. RA-inoculated drought stressed seedlings showed up-regulation in MYB, target of miR159 and GRF1, target of miR396, while SPL6, target of miR156 was down-regulated, and ABA5, target of novel miR12 showed basal expression. Overall results indicated that RAR inoculation alters miRNA and target gene expression for amelioration of drought stress response of chickpea drought tolerant cultivar

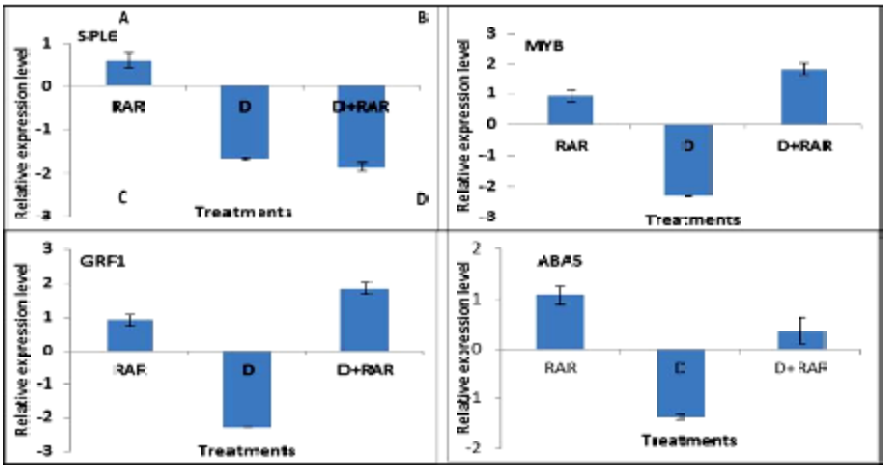


Fig 2 (A-D): Expression analysis of target gene in chickpea roots grown under well-watered, RAR, drought and drought + RAR conditions.

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

Total RNA from leaf tissues of contrasting pearl millet cultivars namely PRLT2/89-33 and H77/833-2 (parents of a mapping population) subjected to drought stress via dry down protocol (NTR≥0.2) were used for sequencing on Illumina MiSeq platform. A total of 40880 differentially expressed genes were obtained. Out of which 17709 were up-regulated (>+2.0) and 22414 were down-regulated (<-2.0). Gene ontology (GO) annotation revealed more number of PRLT2/89-33 genes representing 'response to stresses,' 'response to stimulus' and those related to 'developmental processes' and 'biological regulation' as compared to H77/833-2.

Single nucleotide polymorphism (SNP) and simple sequence markers have also been detected in two samples. PRLT2/89-33 has more number of SNPs and SSRs as compared to H77/833-2. RNA-Seq value of 10 selected differtially expressed genes (DEGs), which were overexpressed in tolerant genotype (PRLT2/89-33) as compared to sensitive (H77/833-2) were validated using qRT-PCR (Fig 3).

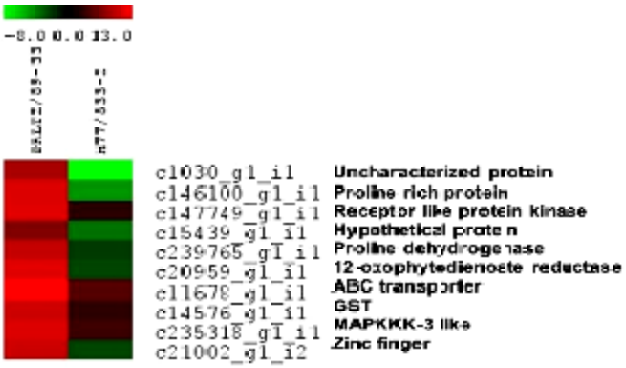


Fig 3: qRT-PCR confirmation of RNA-seq results examining gene expression in leaves of two contrasting pearl millet genotypes.

qRT-PCR data of all the selected DEGs were largely consistent with the expression level obtained through high throughput RNA-Seq data. A zinc finger protein coding gene (*PgZnF*) was also cloned from pearl millet and its expression was checked under different time points of drought stress. The gene was found to be up-regulated under late stress.

In-House Projects

Plant Molecular Virology Studies

Association of *Cotton leaf curl Multan virus* and its associated betasatellite with leaf curl disease of *Hibiscus rosa-sinensis* in India

Hibiscus (*Hibiscus rosa-sinensis*) is a perennial ornamental plant grown for its attractive flowers. Symptoms of severe leaf curling, vein thickening and enation were observed on 31% (13/42) hibiscus plants growing in a garden in Lucknow (Fig.4).

Total DNA was isolated and subjected to PCR using degenerate begomovirus primers. All samples of symptomatic leaves yielded a ~1.2 kb PCR product indicative of a begomovirus. Full-length genomes were amplified by the rolling circle amplification method (~2.7 kb) from two samples, and cloned and sequenced (GenBank Accession Nos. JN880418 and JN807763). Nucleotide sequence analysis revealed 99% identity between the two isolates, and 90-93% identity and close phylogenetic relationships with isolates of *Cotton leaf curl Multan virus* (CLCuMV). Hence, two new variants of

Fig. 4: Naturally infected *Hibiscus rosa-sinensis* twig showing leaf curl and enation symptoms

CLCuMV were identified. Association with a betasatellite was tested by PCR with degenerate primers. All 13 samples of symptomatic leaves produced the expected product of ~1.3 kb. One amplicon was cloned and sequenced (KT447040). The sequence had 98% nucleotide identity and close phylogenetic relationships with Cotton leaf curl Multan betasatellite (CLCuMB) isolates and was concluded to be an isolate of CLCuMB.

Molecular characterization of a begomovirus, α-Satellite, and β-Satellite associated with leaf curl disease of *Parthenium hysterophorus* in India

Parthenium hysterophorus plants exhibiting severe leaf curl and stunting symptoms were observed near agriculture fields in Lucknow, India (Fig. 5). The association of a begomovirus, β-satellite, and α-satellite with these symptoms of a parthenium disease was investigated by sequence analyses of virus and satellite DNA amplified by rolling circle amplification and polymerase chain reaction. The highest sequence identities and closest phylogenetic relationships for the begomovirus, β-satellite, and α-satellite detected in *P. hysterophorus* plants were to *Tomato leaf curl virus* (ToLCV), papaya leaf curl β-satellite (PaLCuB), and Ageratum yellow vein India α-satellite (AYVIA), respectively. These findings identified the virus and satellites infecting the *Parthenium* spp. as ToLCV, PaLCuB, and AYVIA, respectively.

Fig. 5: Naturally infected *Parthenium hysterophorus* plant showing (a) severe leaf curl, shortening and swelling of internodes, and stunting symptoms as compared to a healthy plant (b).

P. hysterophorus and tomato seedlings infected with cloned ToLCV, PaLCuB, and AYVIA by agro-inoculation developed leaf curl symptoms, whereas plants infected with ToLCV alone or with ToLCV and AYVIA developed mild yellowing (Fig. 6). The results show that this complex infects and causes disease in *P. hysterophorus* and tomato. *P. hysterophorus* is an invasive weed commonly found around agricultural fields and along roadsides. These results indicate that *P. hysterophorus* plants infected with ToLCV and associated satellite DNA act as an alternate host (reservoir), and that could lead to increased incidence of tomato leaf curl disease.

Molecular characterization of a begomovirus and betasatellite infecting wild sunflower (*Helianthus* spp.) in India

Wild sunflower (*Helianthus* sp.) plants exhibiting begomovirus disease like symptoms: yellow vein net and leaf curl were observed (Fig. 7) growing on road side in Jaipur (Rajasthan). The causal virus was successfully

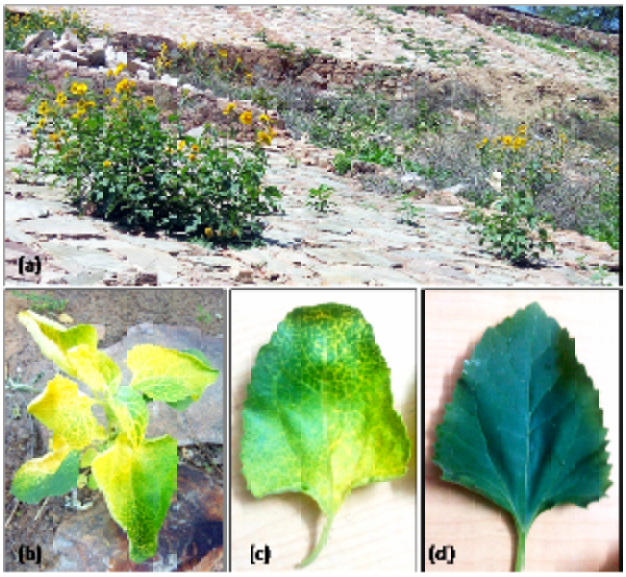


Fig. 7 Naturally infected wild sunflower (*Helianthus* sp.) plants growing in baron land at Jaipur, Rajasthan (a). A close view of a diseased plant showing symptoms of severe yellow vein net and leaf curl (b) and a diseased leaf (c) as compared to healthy plant (d).

transmitted on healthy seedlings of *Helianthus* spp. by whitefly (*Bemisia tabaci*) which induced similar symptoms to those of naturally infected plants that indicated presence of begomovirus. The association of begomovirus and betasatellite with these symptoms of *Helianthus* spp. was investigated by sequence analyses of viral DNA genome and satellite DNAs amplified by rolling circle amplification (RCA) and polymerase chain reaction (PCR), respectively (Fig. 8).

The highest sequence identities and closest phylogenetic relationships for the begomovirus and

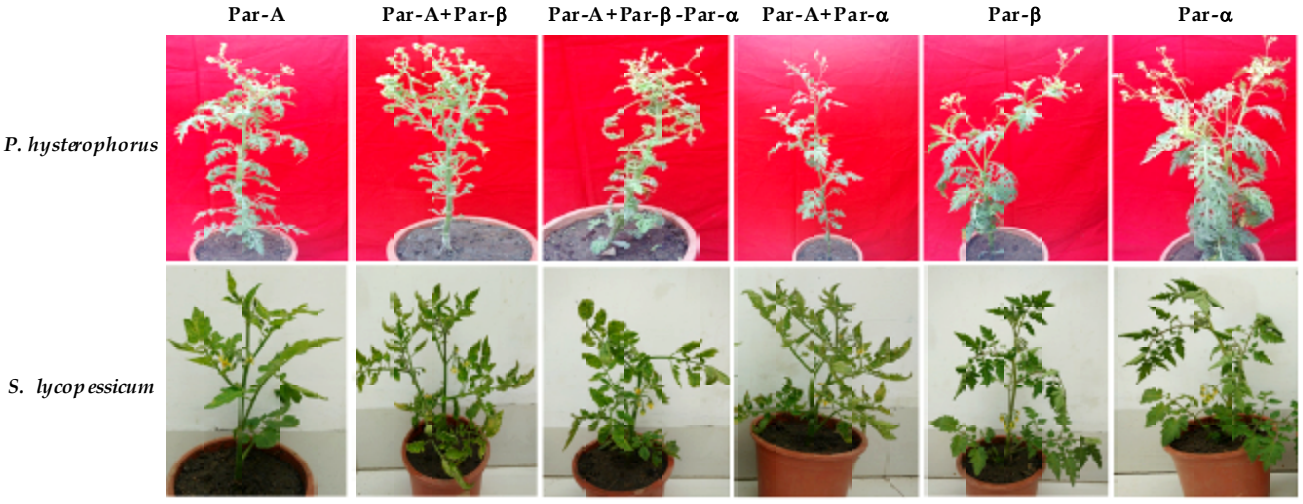


Fig. 6: Agro-infiltration of infectious cloned DNAs of viral components in host plants.

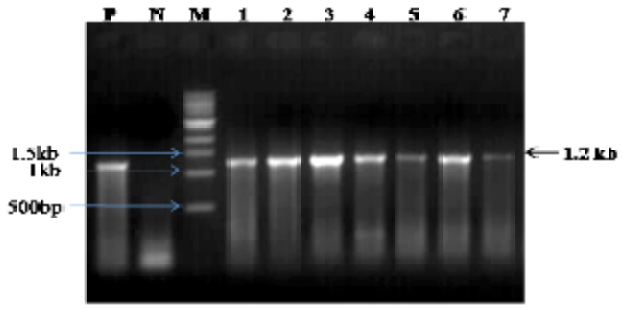


Fig. 8 Detection of begomovirus in naturally infected (5 plants) and whitefly transmitted (lane 6 and 7) wild sunflower plant, lane P = Positive control, N = Negative control and M = 1 Kb ladder marker.

betasatellite detected in *Helianthus* spp. were to *Ageratum enation virus* (AEV) and Ageratum leaf curl betasatellite (ALCB), respectively. These findings identified the virus and satellite DNAs infecting *Helianthus* spp. as AEV and ALCB, respectively. *Helianthus* spp. and tobacco (*Nicotiana glutinosa*) seedlings infected with cloned AEV and ALCB by Agro-inoculation developed yellow vein net and leaf curl symptoms, whereas plants infected with AEV alone or ALCB did not develop any symptom. The results show that this complex infects and causes disease in *Helianthus* spp. and tobacco. *Helianthus* spp. is an invasive weed commonly found around agricultural fields and along roadsides in Rajasthan, India. These results also indicate that *Helianthus* spp. plants infected with AEV and associated betasatellite DNA may act as an alternate host (reservoir) for other economically important plants.

Coexistence of three virus genera (Badnavirus, Potyvirus and Cucumovirus) in Canna species in India

Canna (*Canna* spp., family Cannaceae) are perennial plants grown in tropical and sub-tropical countries including India. They are largely used in borders of beds for their colourful foliages and flowers, besides being grown in lawns, parks, and other public places. Canna have large shiny foliage and attractive flowers of red, yellow, orange, pink colour or combinations of these colours. Canna cultivars (Allegheny, Bengal Tiger, Black Knight, Eileen Gallo, Encaster, Golden Girl, Golden Yellow Lucifer, Kanchan, New Delhi Yellow, and Red President) growing in the canna repository at the institute were observed to exhibit mild to severe yellow mosaic mottle and vein streak symptoms (Fig. 9). The disease incidences from 8.0-74.4% was recorded. Occurrence of single, double, and triple infections of *Canna yellow mottle virus* (CaYMV), *Bean yellow mosaic virus* (BYMV) and *Cucumber mosaic virus* (CMV) were detected in these cultivars by PCR/RT-PCR using their respective degenerate primers. The coexistence of CaYMV, BYMV and CMV was confirmed by sequencing of their cloned PCR products. Further, a high genetic diversity was observed amongst them and with other strains of CaYMV, BYMV and CMV in phylogenetic analysis. The coexistence of CaYMV, BYMV, and CMV in canna is being reported for the first time from India.

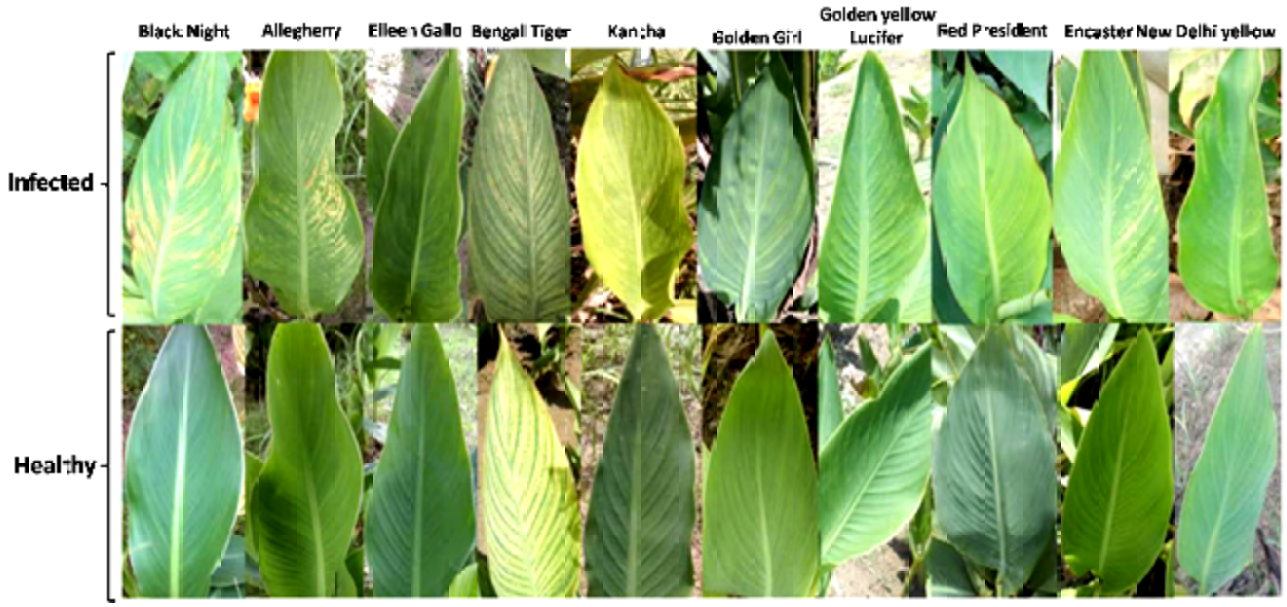


Fig. 9 Leaves from ten different *Canna* cultivars exhibiting streaks, mosaic accompanied with streaks, mottling, and severe mosaic symptoms gown in Canna repository at CSIR-NBRI. The healthy plant of each cultivar has also been shown as control

PHARMACOGNOSY

Grant-in-Aid Projects

Production of Phytochemical from elite chemotypes of some threatened medicinal plants through modified cultivation and *invitro* technologies

A total of seventy four samples of *Coleus forskohlii* and 127 samples of *Gloriosa superba* were collected from different phyto-geographic zones of the country. Passport data sheet of each sample was maintained to document its phyto-geographic information (CSIR-NBRI). Botanical and physico-chemical standard of collected germplasm were also documented. No significant variation in microscopical characters was observed within collected samples of *Coleus* and *Gloriosa* respectively. Quantification of Colchicine (% dry weight) in *G. superba* (80 samples), reveals that NBG-08 from Western Ghats had maximum (3.2 %) and NBG-20 from Eastern Ghats had minimum (0.02%) concentration (Fig. 10a). Estimation (% dry weight) of Forskolin in 65 samples of *Coleus forskohlii* reveals that maximum content (1.15%) was found in NBC-46 from Western coast of Malabar and minimum (0.004%) in NBC-36 from Western Ghats (Fig. 10b). Collected samples of targeted species were maintained in nursery under natural conditions and, transferred to field bed for mass multiplication and phytochemical analysis. In Multi-location cultivation feasibility studies of potential/ validated elite germplasms, among the collected samples of *G. superba* in 57 germplasm showed survival. In *C. forskohlii* 33 germplasm have survived, out of which, 19 germplasm exhibited healthy growth, these were transferred to the field bed for next generation study for quantification of forskolin.

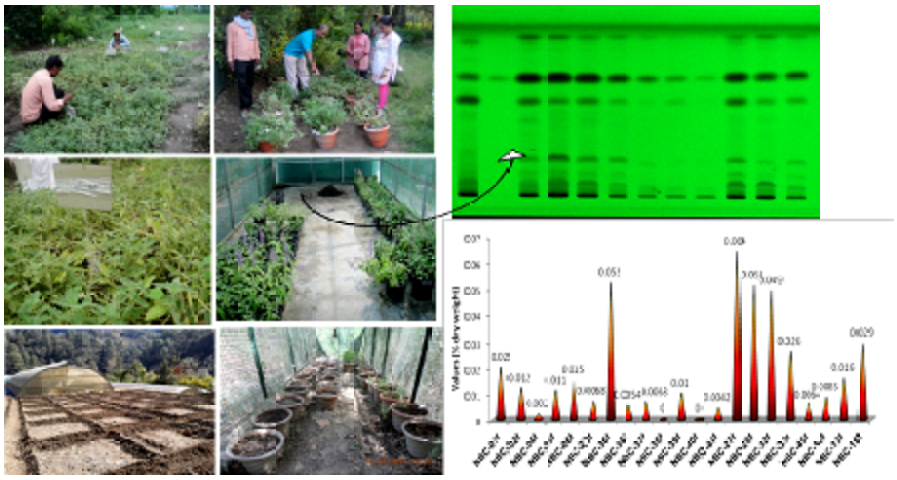


Fig. 10a: HPTLC quantification of colchicine in *G. superba* samples collected from different phytogeographical zones of India and maintenance of live germplasm at Botanical garden.

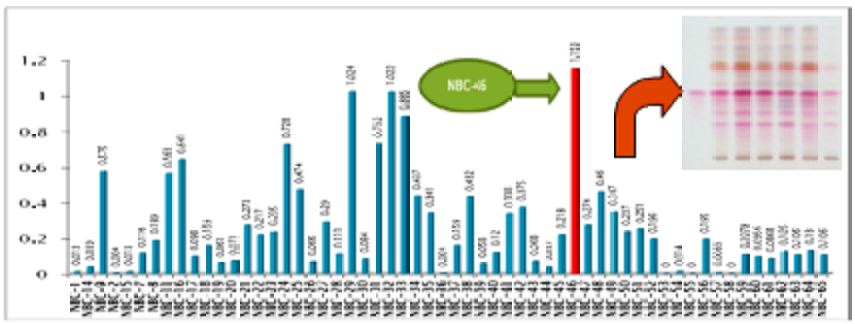


Fig. 10b: HPTLC quantification of forskolin in *C. forskohlli* samples collected from different phytogeographical zones of India.

Chemoprofiling of potential phytoacaricides and their functional characterization for controlling resistant cattle ticks

Ninety Six germplasms of *Ageratum conyzoides* L. were collected from sixteen states and the variation in marker compound and anti-tick activity was worked out. Germplasms with considerable amount of Precocene I were reported from Uttar Pradesh, West Bengal, Sikkim, Tamilnadu and Uttarakhand. Employing strategic chromatographic procedures, four lead compounds (Lead-I, II, III, IV) from NAC-01 and three compounds (VP1, VP3 and VP5) from CVP-05 were identified.

The synthesized lead molecule II showed more than 90% anti-larval activity as observed by *in vitro* laboratory standardized and peer reviewed protocol.

The lead-III, IV and VP3 compounds showed 70-80% adulticidal activity at 300 to 350 ppm within 48h of treatment. The same group of tick was found susceptible to deltamethrin at 34.12 times (i.e. LC95=1009.8 ppm) of baseline concentration (LC95 = 29.6 ppm). The details of the chemical structure and synthesis protocol are being protected.

Search for ellite chemotypes of *Centella asiatica* and their relationship with ecogeography

Total 150 accessions of *Centella asiatica* were collected from different phyto-geographical regions of the country. Passport data sheet of all collected accessions has been prepared containing details of phyto-geographical zone, altitude, latitude

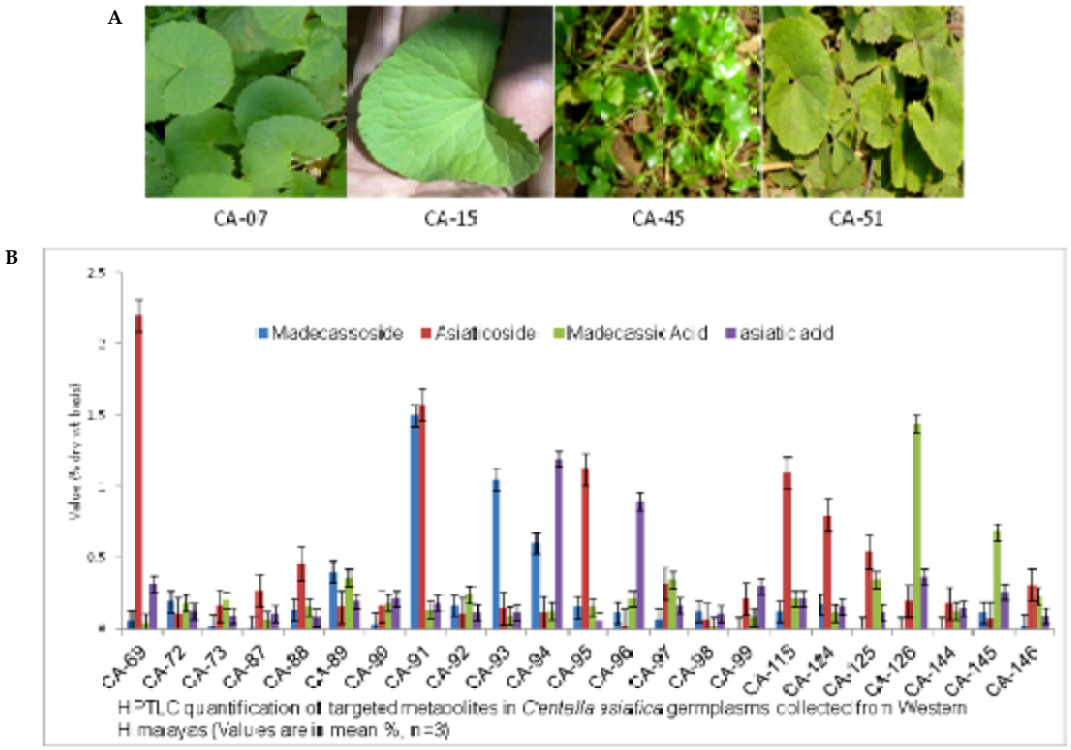


Fig. 11 Elite accessions of *Centella asiatica* plants (A). HPTLC quantification of targeted metabolites in *Centella asiatica* (B) collected from Western Himalayas (Values are in mean %, n= 3)

and longitude of collection, average rain fall; associated species are also recorded with this data. Variable concentration of targeted metabolite was quantified through HPTLC viz. CA-15 and CA-45 for asiaticoside (1.32% and 1.56%), CA-45 and CA-51 for madecassoside (4.06% and 6.09%) and CA-07 for Asiatic acid (0.44%). Among all the collected accessions, four elite accessions (CA-07, CA-15, CA-45 and CA-51) have been observed (Fig. 11).

Nutritional profiling, free radical scavenging and antioxidant activities of selected small millets

Many nutritional, antioxidant and antimicrobial properties have been characterized in different medicinal and dietary plants including *Usnea* species, small millets, *Thalictrum* species, *Saraca species*, and *Terminalia* species etc. Morever, a best solvent system for the extraction of bioactive substances has also developed and their free radical scavenging activity is being examined.

Identification and evaluation of some lesser known plants for malnutrition and development of a low cost herbal combination thereof

The most potent methanolic extracts of *Bauhinia variegata* L. flower, *B. variegata* L. bud, *B. purpurea* L. flower and *B. purpurea* L. bud along with *Oxalis corniculata* L. were evaluated for anticancer activity on PC3 cell-line in a concentration range from 500 µg/ml to 15.6µg/ml. These plant extract showed anti proliferative effect in a concentration dependent manner on cancer cell lines. Methanol extract of *B. variegata* flower effectively inhibit the migration of PC3 cells at potent anticancer concentration. These plant species at this stage of research are showing a positive lead to develop a nutritional supplement to combat diseases associated with nutrient related disorders and oxidative stress.

Phytochemical and pharmacological studies of the isolated polyphenols from the resurrection plant *Selaginella bryopteris* (Sanjeevani)

Selaginella bryopteris (Sanjeevani) is reported to promote growth and protect against heat shock and apoptic activities of ultraviolet and oxidative stress. Rats of either sex (200-250g) were used for forced swim endurance stress. The biochemical parameters like serum glucose, triglycerides, cholesterol, BUN, cortisol were evaluated. The weights of organs such as liver, adrenals, spleen of the experimental rats were also recorded (Fig. 12). The experimental study showed an increase in swim duration in rats pretreated with *Selaginella bryopteris* and were similar to the changes produced by reference drug *Withania somnifera*. During stress, blood glucose level increases, which is found to be significantly reduced in *Selaginella bryopteris* treated rats. Lowering of stress

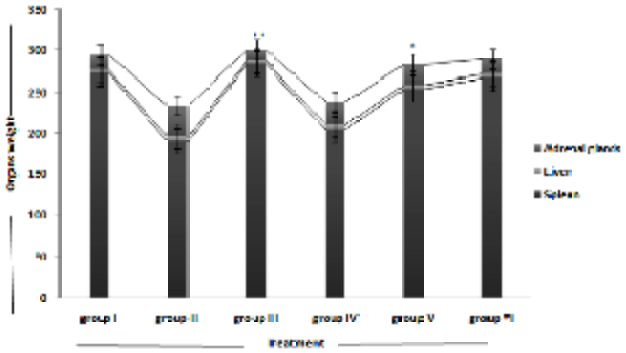


Fig. 12: Effect of ethanol extract of *Selaginella bryopteris* on Organs weight and Swimming time in Forced swimming endurance stress in rats

induced hyperglycemia is an indication of antistress, adaptogenic activity of plant. In response to stress, ACTH is released, which acts on the adrenal cortex to stimulate the synthesis and release of Cortisol. Increased plasma Cortisol influences the mobilisation of stored fat and carbohydrate reserves, which in turn increases blood glucose level. The increased Cortisol levels are reversed by anti-stress agents. *Selaginella bryopteris* significantly decreased stress induced elevated levels of Cortisol and blood glucose levels in both swim stress model.

Standardization and validation of lichen species; *Usnea longissima* and *Cladonia furcata* used in peptic ulcer

Lichen produces about 800 secondary metabolites (also called as lichen substances), most of which are unique to these organisms and only a few (c. 50-60) occur in other fungi or higher plants. Lichen metabolites exert a wide variety of biological actions. 'Chharilla' (lichen) is used in Ayurvedic and Unani systems of medicine. However, they have been neglected by mycologists and overlooked by pharmaceutical industry. Keeping the potential value of the IPR leads from *Usnea longissima* and *Cladonia furcata* (Fig. 13) were subjected to test against peptic ulcer and oesophagal refluxes in rats. Both the lichens extracts showed significant activity against gastro-esophageal reflux disease (GERD) in rats.

Fig. 13: Lichen species; (a) *C. furcata* and (b) *U. longissima*

Identification of potential bioactive chemical marker compounds and biological studies of *Gloriosa superba* and their geographical variations

The phytochemicals present in plants play a key role in their efficacy for the prevention or treatment of diseases and have tremendous impact on the health care system. *Gloriosa superba* Linn., is one of the endangered species among the medicinal plants (Fig. 14). It is one of the seven upavishas in the Indian medicine, which cure many ailments but may prove fatal on misuse. The phytoconstituents colchicines and 3-demethylcolchicine were identified from *G. superba*. The detailed investigation on the bioactives present in the *Gloriosa superba* is under investigation.

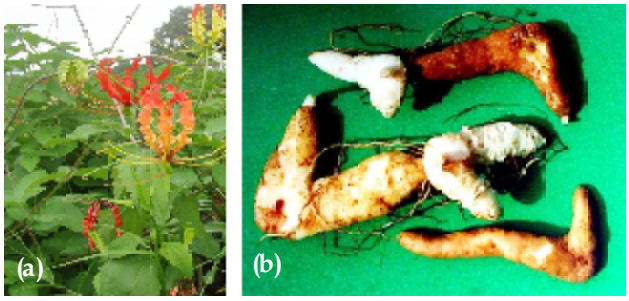


Fig. 14: (a) *Gloriosa superba* and (b) Tuberous roots of *G. superba*

In-House Projects

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

Comparative Physico-phytochemical analysis of different parts of medicinally important *Terminalia* species

Different parts of medicinally important *Terminalia* species viz. *T. arjuna* Wight & Arn. and *T. bellirica* (Gaertn.) Roxb. (Family: Combretaceae) have been undertaken for physicochemical analysis, total phenolic Content (TPC), total flavonoid Content (TFC), qualitative as well as quantitative HPTLC analysis and antioxidant activity. *T. arjuna* commonly known as Arjun in Hindi, is traditionally know to have cardioprotective activity. Comparative analysis of different parts of *T. arjuna* indicated TPC in the order bark >leaf>twig and TFC in the order bark >twig>leaf. The HPTLC analysis showed the presence of lupeol, gallic acid, ellagic acid in all three parts, stigmasterol in bark and twig while β-sitosterol, ferulic acid and ursolic acid in leaf parts only. The quantity of all the components varies from part to part i.e. ellagic acid and lupeol were found maximum in the bark, gallic acid

and stigmasterol were maximum in twigs. *T. bellerica*, commonly known as Bahera in Hindi, possesses an esteemed status in medicinal plants with diverse biological potentials. Comparative analysis of different parts of *T. bellerica* indicated that the TPC and TFC of the samples were in the order leaf>fruit>bark. HPTLC analysis also showed that the phenolics are present in larger quantity as compared to the triterpenoids. Ellagic acid was the most predominant constituent and was found to be present in all the samples of *T. bellerica*.

HPTLC densitometric method for simultaneous determination of evernic and usnic acids in four *Usnea* species and comparison of their antioxidant potential

A simple, sensitive and precise high-performance thin-layer chromatography (HPTLC) method with densitometric scanning was developed for the simultaneous determination of evernic (EV) and usnic acids (USN) in *Usnea aciculifera* (UA), *U. ghattensis* (UG), *U. longissima* (UL) and *U. stigmatoides* (US) lichens (Fig. 15). This method was also validated according to The International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human Use (ICH) guidelines.

Usnic acid was estimated in all four *Usnea* species but evernic acid was detectable in only two species with varied quantity. Comparative antioxidant activity revealed that US is potential free radical scavenger in comparison to other three *Usnea* species. Further, these results indicated that USN and EV are not solely responsible for antioxidant potential but it may be due to synergistic effect.

Effect of altitude on secondary metabolites, antimicrobial and antioxidant potential of *Thalictrum foliolosum*

Thalictrum foliolosum DC. is traditionally being used as tonic, antiperiodic, diuretic, febrifuge, purgative and stomachic. It is also considered as a remedy for atonic dyspepsia, useful in convalescence after acute diseases and as application for opthalmia. The roots of *T. foliolosum* were collected from four locations at different elevations, Bhowali (1709m), Sankri (2031m), Taluka (2111m) and Kedarkantha (3086m) in North India and evaluated for altitudinal variation in its phytoconstituents, antioxidant and antimicrobial activities. The ethanolic, 50% aqueous ethanolic and aqueous extracts were prepared for comparative study. The results revealed that the berberine content varied inversely with altitude; on the contrary there was an increase in the phenol and flavonoid content of the *T. foliolosum* with increase in altitude. The *T. foliolosum* extracts with high berberine content showed relatively significant anti-lipid peroxidation, β-carotene bleaching and reducing power, while *T. foliolosum* extracts with higher phenol and flavonoid content showed better scavenging of DPPH free radicals. All the *T. foliolosum*

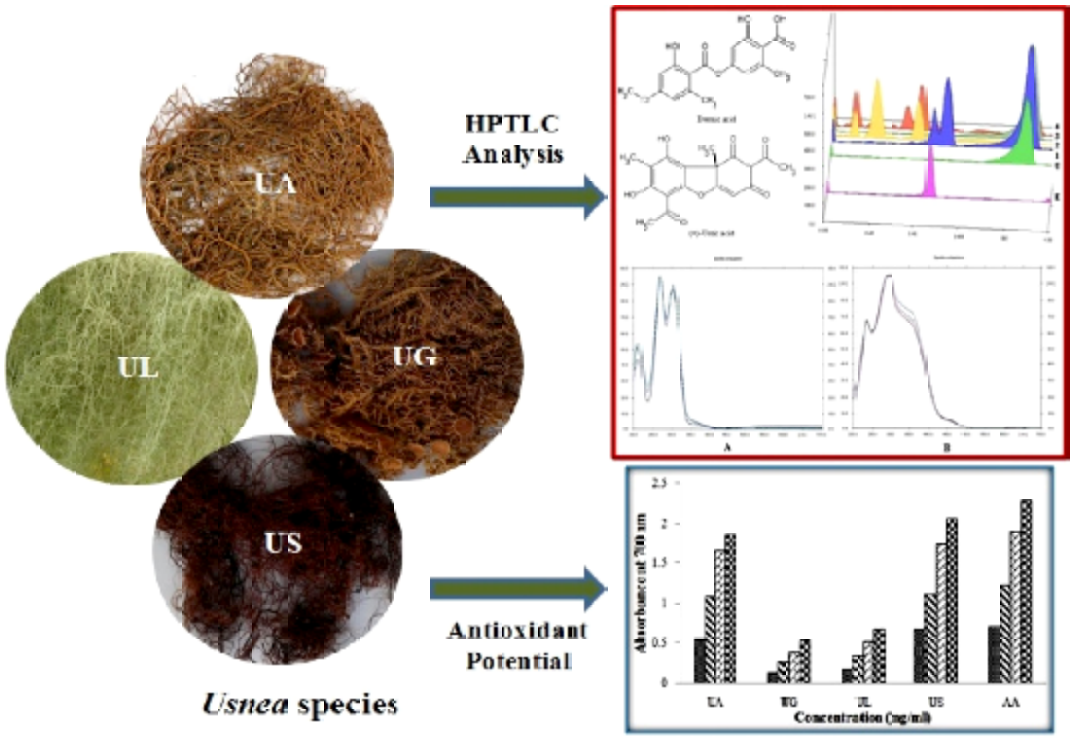


Fig 15. HPTLC densitometric analysis and comparison of the antioxidant potential in *Usnea aciculifera* (UA), *U. ghattensis* (UG), *U. longissima* (UL) and *U. stigmatoides* (US)

extracts showed moderate to high activity against *Candida albicans*, *Staphylococcus aureus*, *Escherichia coli* and *Pseudomonas aeruginosa*. Extracts with high berberine content were most effective against *C. albicans* and *S. aureus*.

Simultaneous-HPLC quantification of phenolic acids in traditionally used ayurvedic herb, *Diplocyclos palmatus* (L.) Jeffrey.

HPLC-quantification of phenolic acid(s) in the aerial parts of *Diplocyclos palmatus* (Cucurbitaceae) and evaluation of their bioactivity potential through *in vitro* antioxidant assay's was carried out. The HPLC elution was done using C18 column using gradient (binary phases) solvent system. Total phenolic and, flavonoid contents were determined and the antioxidant potential was estimated by four assay's *viz* DPPH radical scavenging assay, ferric reducing power assay, total antioxidant capacity and 2-deoxy ribose assay. The species is rich in three phenolic acids, among which chlorogenic acid (3529 µg/g) is in maximum concentration followed by gallic acid (1708 µg/g), caeffic acid (437 µg/g) and protocateuchic acid (338 µg/g). Total phenolic content was higher (10.5 mg/g) than flavonoid content (3.78 mg/g) and TAC was found at 0.137 mg/g ASE (ascorbic acid equivalent). IC50 of *D. palmatus* extract for scavenging of hydroxyl radical by 2-deoxy ribose and DPPH was at concentration of 126 ± 0.83 (µg/ml) and 354 ± 0.66 (µg/ml) respectively. *In vitro* antidiabetic potential, via inhibition of alpha amylase enzyme through starch iodine and 3,5-DNS assay reveals the IC50 of extract at 146 ± 0.41 µg/ml and 286 ± 0.67 µg/ml respectively. The species (aerial part) was rich in phenolic acid with potential bioactivity, identified leads will be useful in further chemical characterization and pharmacological validation.

Resversed-phase High-Performance Liquid Chromatography (RP-HPLC) quantification of five phenolic compounds in *Biophytum sensitivum* (L.) DC. (Oxalidaceae) and their biological evaluation

Biophytum sensitivum is a widely used medicinal plant in traditional medicinal systems across the globe. The present study deals with the RP-HPLC quantification of five phenolic acids, along with the *in vitro* antioxidant and antidiabetic activity of the aerial parts of the plant as a scientific investigation of traditional claims of its use as an antioxidant and antidiabetic agent. Anatomy of the stem was done to aid in exploring identification parameters for this plant. Among the five identified phenolic markers, caffeic acid exhibits the highest concentration (353 µg/gm), followed by ferulic acid (242 µg/gm), gallic acid (234 µg/gm), chlorogenic acid (192 µg/gm), and rutin (65 µg/gm). The total phenolic and flavonoid contents in the methanolic extract were found to be 87.0 ±0.404 mg/gm GAE and 14.3 ± 0.055 mg/gm QE, respectively. The IC50 value for the *in vitro* DPPH method was 0.164 ± 0.411 mg/ml. *In vitro* antidiabetic activity was analyzed by the starch-iodine assay and the 3,5-DNS method which displayed IC50 values of 0.64 ± 0.05 mg/ml and 1.2 ± 0.04 mg/ml, respectively. The *in vitro* study results suggest promising antioxidant and antidiabetic activity of the plant which supports its use in the traditional systems of medicine.

Development of Herbal Products:

Hebal Sindoor Stick

The technology for Sindoor Stick was developed with herbal colours, vegetable oils, aroma and bees wax as base material. The product is non-toxic, without any heavy metals (like red lead oxide) or chemicals. The technology is ready for commercialization.

Herbal antioxidant formulation

A bio-combination comprising Ayurvedic plant ingredients was developed for the management of ROS stress and chemotherapy of cancer patient by quenching free radicals and by enhancing endogenous antioxidant system. The selected plant extracts are mixed in different ratio and formulated to develop an acceptable herbal formulation.

Herbal hand sanitizer

The hand sanitizer is made from a combination of essential oil emulsions of medicinal plants as herbal ingredients. The formulation keeps the hands supple and soft. The selected essential oils are mixed in different ratio in polymer-based gel and developed into a acceptable gel-based formulation which is useful in killing germs of hand and skin.

Herbal toothpaste

An herbal toothpaste developed jointly by CSIR-NBRI and CSIR-CIMAP containing polyherbal formulation from known Ayurvedic medicinal plants has been developed. The formulation is useful in preventing tooth decay caused by *Streptococcus mutans*, provide natural mouthwash effect and also exhibits strong antioxidant activity. The product is fluoride free.

PHYTOCHEMISTRY

Grant-in-Aid Projects

Non-targeted metabolomics approach for monitoring chemical diversity in distinct chemotypes of *Commiphora wightii* using GC-MS and NMR spectroscopy

Commiphora wightii (Arn.) Bhandari, commonly known as guggul, produces a medicinally important gum-resin which is used extensively by Ayurvedic physicians to treat a variety of ailments. Metabolite profiling of three distinct chemotypes (NBRI-101, NBRI-102 and NBRI-103) of *C. wightii* was performed using GC-MS, HPLC and NMR spectroscopy to study metabolic diversity. One hundred and thirty-two chemically diverse metabolites were identified and quantified three different chemotypes of *C. wightii* consisted of 25 amino acids, 15 organic acids (mono-, di-, cyclohexanecarboxylic acids), 2 quaternary amines, 6 sugars and 1 alkaloid, 31 fatty acids, 14 alkanes, 7 pregnane derivatives, 2 keto-steroids, 2 sterols, 18 terpenes (mono-, di-, tri- and sesqui-), 1 vitamin (α-tocopherol) and 1 five-membered lactam (*n*-methylpyrrolidone). Statistical analyses on the metabolites clearly revealed a significant variation in all the three distinct chemotypes. Multivariate principal component analysis (PCA) was applied to the ^{1}H NMR spectrum dataset and quantified data obtained from GC-MS analysis to evaluate comparative metabolic differences in the three chemotypes of *C. wightii*. The PCA score plots of leaves, stem and latex showed significant metabolic differences among the chemotypes (Fig. 16A-D). The corresponding PCA loading plot were used to identify the differentiated metabolites responsible for the separation among chemotypes. Results of the study suggest that quinic acid in leaves may be used as a marker metabolite for identifying the high guggulsterone yielding elite chemotypes of *C. wightii* due to its negative correlation in the concentration of guggulsterones. This will avoid unnecessary tapping of gum-resin for quality control of guggulsterones from stem of *C. wightii* which is fatal to the plant. The present study concluded that the non-targeted metabolomics could be used to identify desired chemotypes for planting and conservation of *C. wightii* for pharmaceutical or healthcare applications.

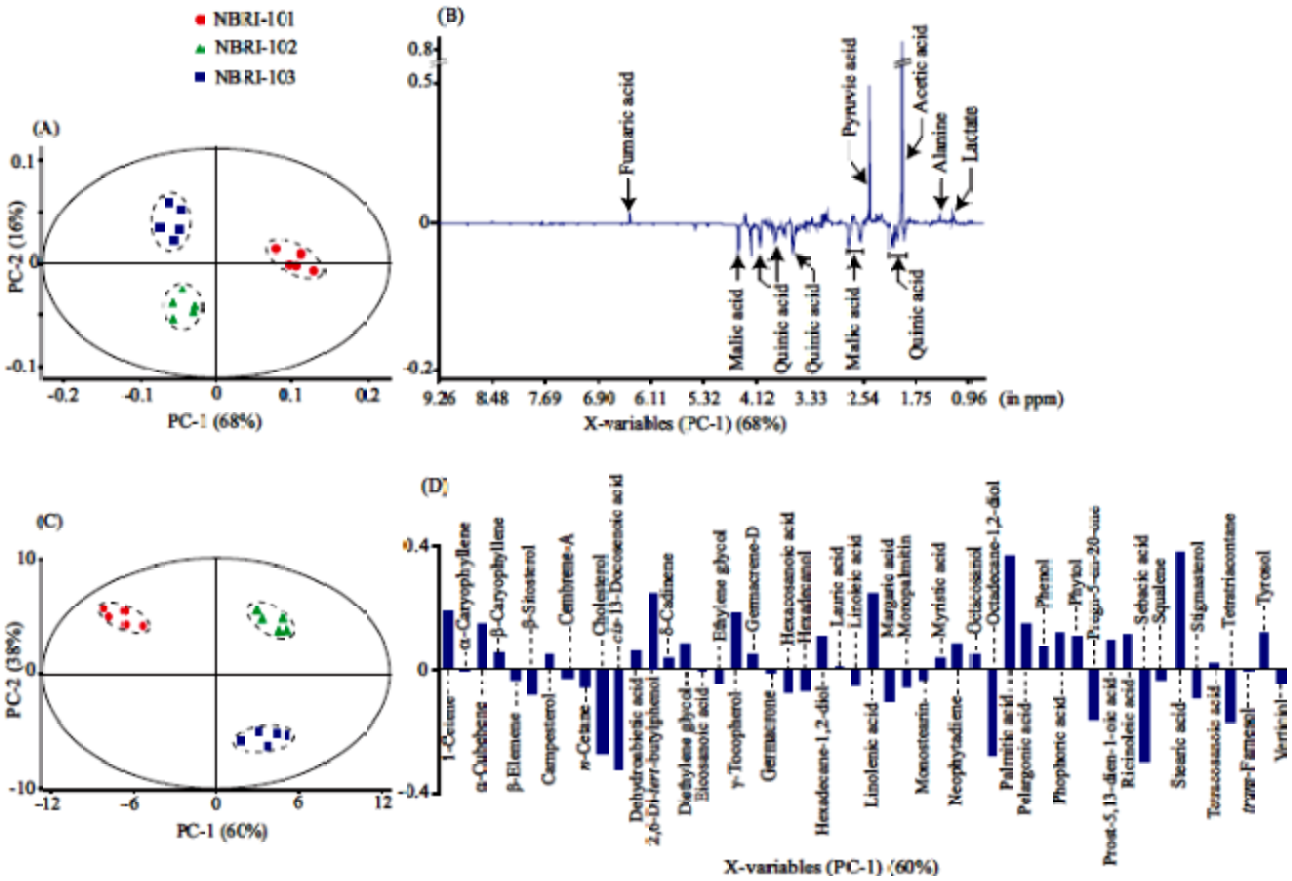


Fig. 16 A-D: 1. PCA scores plot (A) PC-1 loading plot (B) obtained from the PC analysis of ^{1}H NMR spectra of aqueous extracts and PCA scores plot (C) PC-1 loading plot (D) obtained from the PC analysis of GC-MS analysis of non-aqueous extracts of leaves from *Commiphora wightii*.

Metabolite profiling of *Amaranthus hypochondriacus* for high squalene yielding chemotypes in control of hypertension.

Hypertension (HTN) or high blood pressure (BP) is a chronic medical condition in which the BP in the arteries is elevated, causes risk factors for strokes, heart attacks, arterial aneurysm, and kidney failure. Squalene, a potent healthcare agent has been identified in many plant oils in different concentrations. Amaranth is an underexploited plant source of squalene, a compound of high importance in the food, cosmetic and pharmaceutical industries.

(a) Metabolite profiling of *Amaranthus hypochondriacus*.

Eight cultivars/varieties of *Amaranthus hypochondriacus* namely NBRI-A1, NBRI-A2, NBRI-A3, NBRI-A4, NBRI-A5, PRA-1, PRA-2 and PRA-3 were obtained from CSIR-NBRI, Lucknow and V.C.S.G. Uttarakhand University of Horticulture and Forestry, Ranichauri, Uttarakhand to investigate variations in their squalene content and other bioactive metabolites. Ten non-aqueous metabolites consisting of fatty acids, phenolics, sterols, α-tocopherol and triterpene (squalene) were identified from non-aqueous extracts of amaranth seeds using GC-MS. Variations in squalene content among different cultivars of amaranth was investigated using analytical reverse phase HPLC. The concentration of squalene varied significantly among different accessions. The squalene concentration varied from 6.02 to 54.3 mg/g seed wt. The lowest being in NBRI-A2 and the highest in PRA-3 with an average of 31.8 mg/g (Fig. 17).

Fig. 17: Quanitative variations in squalene content among different cultivars of *Amaranthus hypochondriacus*.

(b) Development of squalene enriched fraction

A method was standardized to developed squalene enriched fraction from amaranth grain oil. The antioxidant activity and analytical data of enriched fraction supports that it can be used for development of cosmaceutical and nutraceutical products.

Evaluation of Medicinal plants for cultivation in sodic waste land of U.P.

An ultra-high performance liquid chromatography electrospray ionization tandem mass spectrometry method has been developed and validated for simultaneous quantification of six major bioactive compounds in leaf, stem and root of 5 varieties of *Withania somnifera* in various plant parts. The analysis was accomplished on C18 column with linear gradient elution of water/formic acid (0.1%) and acetonitrile at a flow rate of 0.3 mL min^{-1} The proposed method was validated with acceptable linearity (r^2, 0.9989–0.9998), precision (RSD, 0.16–2.01%), stability (RSD, 1.04–1.62%) and recovery (RSD = 2.45%), under optimum conditions. The method was successfully applied for the simultaneous determination of six marker compounds in twenty-six marketed formulations. Hierarchical cluster analysis and principal component analysis were applied to discriminate these twenty-six batches based on characteristics of the bioactive compounds. The results indicated that this method is advanced, rapid, sensitive and suitable to reveal the quality of *W. somnifera* and is also capable of performing quality evaluation of polyherbal formulations having similar markers/raw herbs.

Development of low cost technology for extraction/isolation of some lesser know natural gums and value addition thereof

Villages of five different districts of U.P., which included Varanasi, Jaunpur, Sonebhaddra, Lakhimpur and Lucknow; were surveyed for *Sesbania sesban* as a gum bioresource plant. Our study revealed three new, cost effective, and feasible plant gums being used among seven tribal population namely Tharu, Baiga, Chero, Gond, Mushar, Kharwar and Koal. These plant gums were lesser known. Studies were conducted to explore the potential of these plant gums for/as natural binders and stabilizer of food, colour, and develop as a natural additive and as nutritional supplement/food and value addition.

We identified more than 50 medicinal, aromatic, ornamental and economical useful plants/plant exudates and also collected more than 15 gum bearing plants and gums (six targeted and four additional) for extraction/isolation and value addition. Identified edible gums for nutrition and health supplements on ethnobotanical claims/use; two nutritional supplements formulated using identified plant gum binders ie. Binder food for children; Binder food for women and identified three plant based material binders (Sticking material for paper, floral crafts and bindi).

Trainings and awareness programs to teach identification, collection, separation/isolation of gums

and bio-material was carried out in more than nineteen villages; in three tribal village of Tharu tribal community, in Dudhwa region (more than 100 people), and more than sixteen villages including Mushar, OBC and SC communities in Jaunpur in Varanasi region (more than 50 people) and Baiga, Koal, Chero, Gond and kharwar tribes of Sonbhadra region (more than 400 people).

In-House Projects

Phytochemical studies of medicinal and Aromatic plants

Extraction, isolation, purification and phytochemical studies of some medicinal, aromatic and economically important plants viz. different *Cassia*, *Acacia* and *Sesbania* species, *Trigonella foenumgraaecum*, *Lepidium sativum*, *Moringa oliefera*, *Boswelia serrata*, *Acacia nilotica*, *Cyamopsis tetragonoloba*, *Tamarindus indica*, *Sterculia urens* were carried out for development of economically useful phytochemicals, natural additives, formulations and products. Chemical profiling of more than twenty five separated/isolated plant gums, mucilage, medicinal plant extracts and modified films was accomplished for identification of functional groups, and development of chemomarkers which were compared with commercial standards/ drugs. More than ten seed gums are under study for anti-inflammatory, antioxidant and antimicrobial activities. Production of more than one kilogram of endospermic gum (different forms based on purity and sizes) and seed meal each from six leguminous seeds for characterization and utilization is under way.

Value addition and modifications in biodegradable gum/gum films to develop four saponin carrying films NBRg-11, NBRg-13, NBRg-15, NBRg-17 and NBRg-21) out of ten explored materials. Preparation of three best identified and analysed interacted combinants NBRg-13+ SLS, NBRg-13 + sap & NBRg-13 + Ac.co. at 1 & 2% concentrations at two different volumes in different conditions using one most potential gum were standardized and upscaled for producing them in larger quantity for its specific detail evaluations, feasibility, cost range and determination of acceptable forms and dose for effective delivery as compared to commercially available synthetic material as SLS. Exploitation of best potential combinants is in process for its technological prospects as a plant based detergent and cleansing agent.

Processing, extraction and phytochemical investigation of more than twenty flowers from plants grown in NBRI garden of different colours and textures were carried out for extraction of colour and antioxidants. Total colours and antioxidants were determined and quantified. Physicochemical characteristics were evaluated and chemomarkers developed for sustainable utilization and formulations. Seven plant gums exploited for extracted colour stabilization and its development. Standardization and optimisation of protocol/process for preparation of stable plant colours, (dark red and yellow) using seed/exudate gums in powder and other acceptable forms (extracts; film /strip; tablet; capsule etc.) is in process. Flowers with significant antioxidant activities are also under exploration for health care products.

Seeds of 3 species of *Sesbania viz. S. sesban (Jait), S. grandiflora (Agast)* and *S. bispinosa (Dhaincha)* were

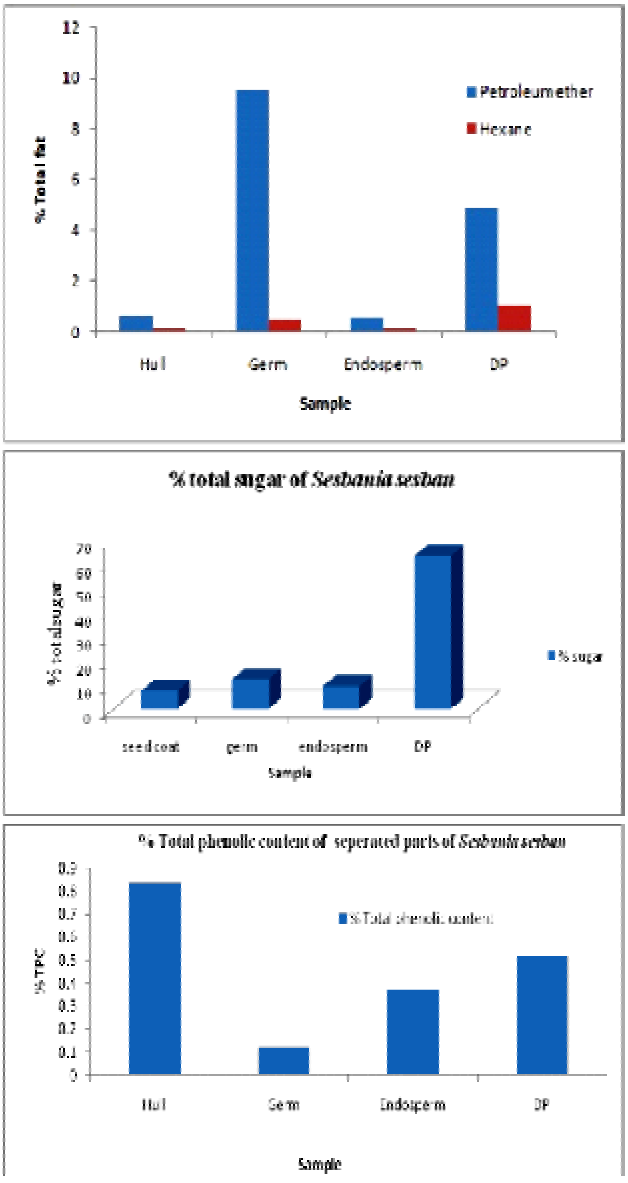


Fig. 18: Percentage of total fat, sugar and phenolic content in different parts of *S. sesban*

investigated for nutraceutical and pharmaceutical prospects. Different parts of the seeds including endosperm and meal were separated through mechanical methods of grinding and sieving in controlled and standardized conditions. Extraction and isolation of seeds; endospermic gum and seed oil was done for identification of constituent sugars and fatty acids in *S. sesban* (Fig. 18). Extraction of seeds by cold and hot (successive soxhlet) methods was accomplished. Total sugar/ starch, protein, phenolics and antioxidants were quantified and functional groups were identified in seeds/ isolated endospermic gum through FTIR.

Chemical composition and termiticidal activity of *Artemisia nilagirica* essential oil growing in southern hilly regions of India

Essential oil isolated from aerial parts of *Artemisia nilagirica* was analyzed using gas chromatography–mass spectroscopy. Chemical constituents were identified by. Total forty constituents were identified which is 93.55% of the essential oil. The major constituents of essential oil were α-thujone (33.78%), germacrene-D (9.31%), β-thujone (6.01%), caryophyllene (5.86%), caryophyllene oxide (6.17%) and borneol (2.16%). The essential oil consist of 41.34% monoterpene hydrocarbon, 30.9% sesquiterpene hydrocarbon, 10.24% monoterpene alcohol, 8.33% sesquiterpene oxide along with 2.74% sesquiterpene alcohol. Antitermite activity of isolated essential oil was tested *in vitro* and *in vivo*. The essential oil exhibited significant antitermite activity against *Microtermes beesoni* termites (Fig. 19). ED_{50} for termite repellency was found 4.44mg/g and 5.81mg/g for termite mortality as compared to that of 1.53mg/g of Chlorpyriphos 20%TC used as control.

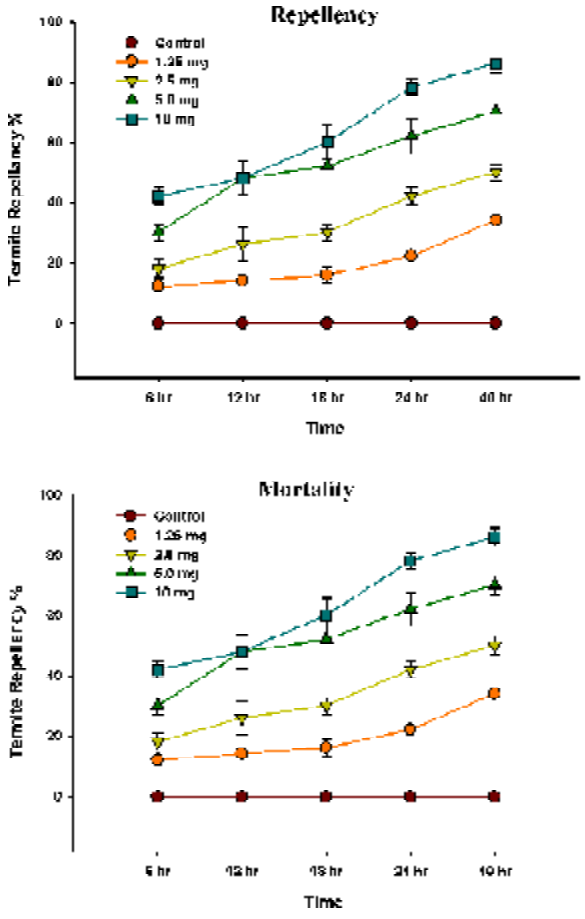


Fig. 19: Termite repellency and mortality of *Artemisia nilagirica* essential oil

Field Trial

Wheat crop is very prone to termite attack. Antitermite activity of a formulation developed by NBRI was tested under field condition at Harikansh Garhi village of Mohanlalganj, Lucknow, in four rows of wheat crop at tillering stage in December 2016 covering 129 square meter area (Each plot of size 10 sqm). Two different doses i.e. 5.0 ml/L water and 3.5 ml/L water of NBRI antitermite formulation and a synthetic pesticide (control) at a dose 3.5 ml/L of water were tested. NBRI formulation showed significant termite mortality rate as compared to that of the synthetic pesticide (Fig. 20).

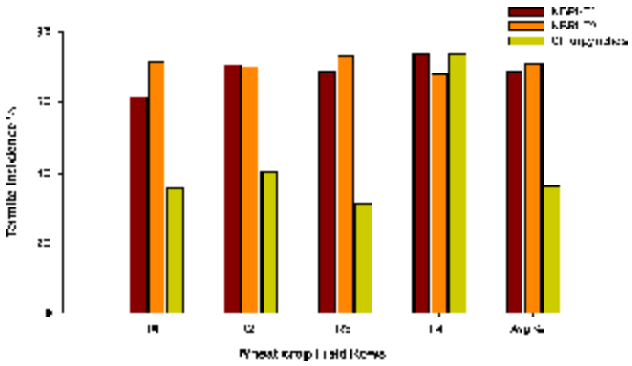


Fig. 20: Field trial results of NBRI formulation in wheat crop field.

Anticancer activity of *Streblus asper* on human cancer cell lines

Cytotoxicity studies were carried out on different fractions SAH (n-Hexane), SAC (Chloroform), SAW (Water) and SAB (n-Butanol) prepared after fractionation from methanolic extract of *S. asper* (SA). These extracts were tested against Leukemia (K562), Lung (A-549), Hepatoma (Hep-G2) and Breast (MCF-7) human cancer cell lines at different concentrations to determine the IC_{50} value by SRB assay. The SRB assay was done in triplicate to evaluate the cytotoxic activity of this plant. Adriamycin drug has been used as a standard in all above human cell lines.

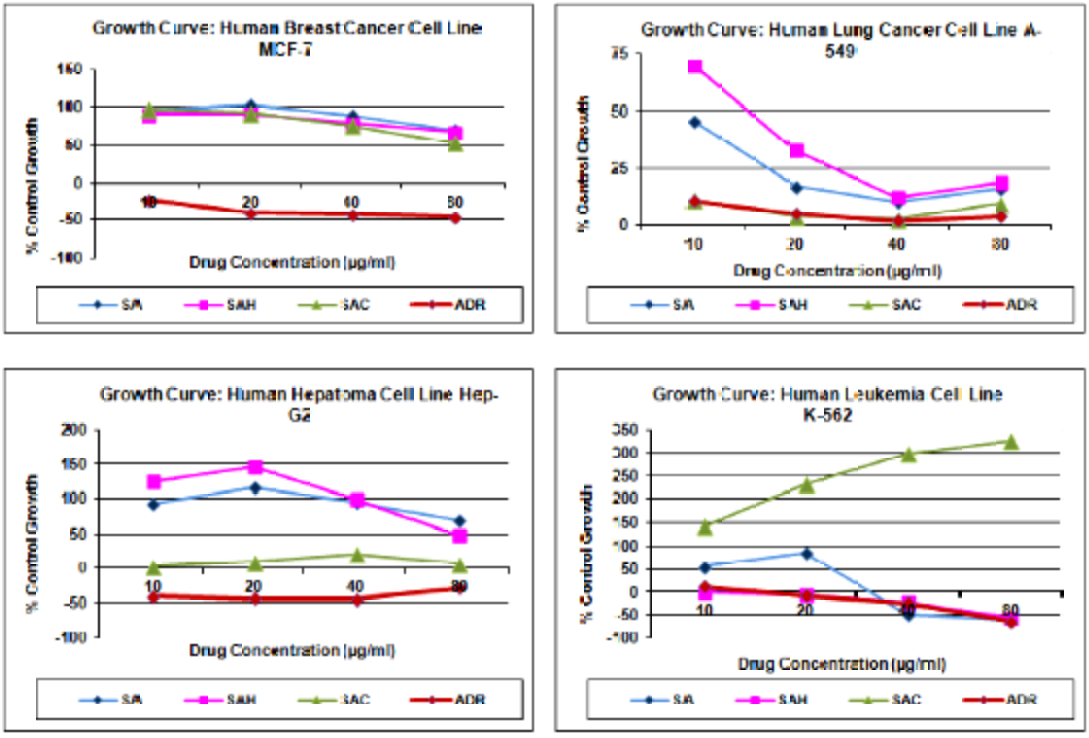


Fig. 21: Cytotoxic activity of solvent extracts from *S. asper* leaf against human cancer cell lines.

Methanolic extract of *S. asper* and its fractions were potentially active on all four cancer cell lines. Methanolic extract and hexane fractions were active against leukemia cancer cell line. Among the different fractions only chloroform fraction showed activity against hepatoma cancer cell line (Fig. 21).

SUPRA-INSTITUTIONAL NETWORK PROJECTS

SUPRA-INSTITUTIONAL NETWORK PROJECTS

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

Nodal Scientist: DK Upreti

Scientists:

Kanak Sahai, Sudarshan Kumar, Tariq Husain, AKS Rawat, TS Rana, KN Nair, Anand Prakash, LB Chaudhary, Alok Lehri, Ch V Rao, Sayyada Khatoon, Mahesh Pal, Sharad Srivastava, Sanjeeva Nayaka, AK Asthana, SK Ohja, OP Sidhu, Subha Rastogi, Soumit K Behra, AP Singh, Manjoosha Srivastava, SK Bag, Sribash Roy, Baleshwar, Priyanka Agnihotri, BN Singh, VV Wagh

Technical Staff:

Bhaskar Dutt, Anil Kumar, Abhishek Niranjan, Sushma Verma, Sandeep K Behera, Vinay Sahu, MM Pandey, KK Rawat, KK Ingle

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

Nodal Scientist: PK Trivedi

Scientists:

SA Ranade, Sudhir Shukla, SV Sawant, AP Sane, VA Sane, PK Singh, CS Mohanty, HK Yadav, Mehar H Asif, Debasis Chakrabarty, PC Verma, SN Jena, SK Bag

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

Nodal Scientist: Nandita Singh/Vivek Pandey

Scientists:

SA Ranade, Kanak Sahai, PA Shirke, LB Chaudhary, OP Sidhu, PK Srivastava, Soumit K Behera, Sribash Roy

Technical Staff:

Anil Kumar, KK Rawat

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

Nodal Scientist: RK Roy/SK Tewari

Scientists:

RS Katiyar, TS Rana, PS Chauhan, Poonam C Singh, Devendra Singh, RC Nainwal

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

Nodal Scientist: Shekhar Mallick

Scientists:

Nandita Singh, Debasis Chakrabarty, PK Srivastava, Suchi Srivastava, Poonam C Singh

Technical Staff:

Sanjay Dwivedi, Babita Kumari

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

Nodal Scientist: Vivek Pandey

Scientists:

CS Nautiyal, PA Shirke, OP Sidhu, Aradhana Mishra

7. Plant-microbe and soil interactions (PMSI)

Nodal Scientist: CS Nautiyal/ PS Chauhan

Scientists:

Aradhana Mishra, Manoj Kumar, Charu Lata

8. S&T interventions to combat malnutrition in women and children

Nodal Scientist: CS Nautiyal & AKS Rawat

Scientists:

SK Tewari, Ch V Rao, Sayyada Khatoon, Sharad Srivastava, SK Ojha, Subha Rastogi

Technical Staff:

MM Pandey

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

Nodal Scientist: CS Nautiyal/SK Tewari

Scientists:

PA Shirke, Vivek Pandey, SV Sawant, AP Sane, VA Sane, Alok Lehri, OP Sidhu, Indraneel Sanyal, Mehar H Asif, Debasis Chakrabarty, Suchi Srivastava, SK Bag, Aradhana Mishra, PS Chauhan, Poonam C Singh, Devendra Singh, RC Nainwal

SUPRA-INSTITUTIONAL NETWORK PROJECTS

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

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:

- The Floristic account of Govind wildlife sanctuary, Uttarkashi district of Uttrakhand was completed with 11 field trips. Along with GPS tagging, a total of 637 species of Angiosperms, 352 lichens, 381 bryophytes, 391 taxa of algae and 88 species of pteridophytes have been documented. Additionally, a list of 25 ethnobotanically important plants have also been documented.
- Taxonomic studies on various groups such as Thelotrematoid (121 spp.), Cetrarioid lichens (47 species), *Corydalis* L., (23 spp.) and *Ficus* (40 species) have been completed. Molecular systematics of the genus *Bergenia* Moench (Saxifragaceae) in India has also been completed.
- Propagated and introduced twenty bryophyte species in moss house of CSIR NBRI.
- Studies related to reproductive biology and *in vitro* multiplication *of Onychium contiguum*, *Athyrium pectinatum* and *Dryopteris cochleata* pteridophytes have been completed.
- DNA barcode of 30 medicinally important plants completed, based on three plastid loci (*matK, trnH-psbA, rbcL*). The generated data have been successfully submitted to GenBank and BOLD database for public references.
- A rapid and reliable method was developed and validated for qualitative and quantitative estimation of betulin and betulinic acid directly from bark tissue of *Batula utilis*. Metabolite profiling of different plant parts of *B. utilis* showed a substantial quantity of betulin in thin branches.
- Twenty two compounds have been identified in the essential oil of *Betula utilis* bark. The oil showed antimicrobial activity against human pathogens.
- Twenty nine compounds were identified in the essential oil of *Hedychium spicatum* rhizome, collected from four different geographical regions. Oil samples evaluated for cytotoxic activities against human cancer cell lines. Sample of Pangot (Nainital) showed highest activity against all cancer cell lines due to presence of α-Cadinol. Two compounds isolated from *Hemidesmus indicus* leaves showed anti-hyperglycemic activity.
- Twenty compounds have been identified in the essential oil of *Justicia adhatoda* and found to have antimicrobial activity against human pathogens.
- Three formulations, based on various aromatic oils and chemicals of *Hedychium spictum*, were tested for their anti-ageing potential.
- Quantification of eight specific Polyphenols (Gallic acid, protocatechuic acid, chlorogenic acid, ferulic acid, caffeic acid, rutin, quercetin and kaempferol) in various extracts of *Hedychium spicatum* has been carried out along with estimation of total phenolic content, total flavonoid content and antioxidant activity.
- *Marchantia polymorpha* a bryophyte, has been evaluated for *in vitro* cytotoxic activity against four cancer cell lines (Breast, Colon, Head & Neck and normal epithelial cells).
- Antimicrobial BIONANO gel (NBC-099) has been developed and tested for its wound healing potential under *in-vitro* and *in-vivo* model systems.

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

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 elucidate various biological processes and pathways involved in secondary plant product biosynthesis as well as proper growth, development and stress response of the plant.
- Utilisation of the information generated for translational research for human health.
- Commercial utilization for better plant varieties for improved productivity and stress tolerance.

Highlights

Full-length cDNAs of putative genes involved in uncharacterized steps of Papaverine biosynthesis were identified and functionally characterized. Various constructs have been developed and used for Virus Induced Gene Silencing (VIGS) to study the modulation of metabolite content. In *Ps3'OMT* silenced plants, the reduction in *Ps3'OMT* transcript levels was approximately 70% compared with controls. This reduction in transcript level led to a significant reduction (50%) in the papaverine content in *Ps3'OMT*-silenced plants. There was no effect on content of thebaine and codeine but high levels of morphine were detected. The expression of biosynthetic genes catalyzing the early steps in BIA and papaverine metabolism like *6OMT, 4'OMT* and *N7OMT* were not affected by the silencing of *Ps3'OMT* which accredits the decrease in papaverine level to suppression of *Ps3'OMT* and thus confirming the role of *Ps3'OMT* in papaverine biosynthesis. In addition, transcriptome datasets of thebaine-rich (>10% of the latex) poppy lines and its parents as well as *Psoralea corylifolia* have been established and being analysed.

Transcriptome and small RNA sequencing of ripe and unripe stages of banana completed and detailed analysis of various gene and miRNA families carried out. Analysis of small RNA libraries suggested that MaMiRNA-47, MaMiRNA-62, MaMiRNA-66, and MaMiRNA-67 were least expressed during ripening of fruit whereas corresponding target genes encoding GTs, Expansin and AGO1B showed enhanced expression. Analysis showed that the expression of MaMiRNA-62 was significantly down-regulated in all development stages of fruit whereas the corresponding target Expansin was highly up-regulated in ripe stage. Expansin plays an important role in cell wall hydrolysis during the ripening process.

The Dashehari mango is a popular N. Indian variety famous for its taste, thin stone and reduced fibre. It suffers from excessive softening near the stone that reduces its marketability. To obtain insights into the molecular changes that occur during ripening, an Illumina-based transcriptome analysis of inner and outer zones of Dashehari was carried out. Analysis of expression profiles from 70 million reads revealed up-regulation of 1447 genes and down-regulation of 2003 genes (> 2 fold, p-value < 0.05) in midripe stage as compared to unripe stage. Prominent amongst the genes identified included the ethylene pathway genes with 6 ACSs, 7 ACOs (2 up-regulated), 3 ETRs (one up-regulated), 2 CTRs, 2 EIN3s (one up-regulated) and 44 AP2 domain family transcription factors with 39 of the ERF sub-family. Cell wall softening, an important feature of ripening, accounted for several ripening related genes that included 11 expansins (3 up-regulated), 17 XTHs (3 up-regulated), 8 pectatelyases (4 up-regulated), 6 pectin methyl esterases (3 down), 11 endoglucanases (5 up-regulated) and 26 galactosidases (5 alpha and 21 beta galactosidases). Other major ripening related pathways that were represented included the flavor/aroma genes, carotenoid/tocopherol genes, terpenoids, etc. Besides Dashehari, Banganpalli mango transcriptome was also analysed. The genes related to ripening and aroma showed differential expression pattern in these two varieties.

In rose, the fragrant variety *R. bourboniana* (Gruss a Teplitz, known as Desi Gulab in Hindi) is sensitive to endogenous and exogenous ethylene with petal fall occurring within hours of exposure to ethylene. In contrast, the hybrid variety, *R. hybrida* shows greatly reduced sensitivity to ethylene and does not abscise in absence of ethylene. To understand the molecular basis of differences in ethylene sensitivity, an Illumina based transcriptome sequencing (coupled with 454 GSFLX sequencing data) of rose abscission zone (AZ) cDNA was performed. Comparative analysis was performed between AZ cDNA from 0 h and 8 h ethylene treated flowers of *Rosa bourboniana,* 8 h ethylene treated *Rosa hybrida* and 8 h ethylene treated petals of *Rosa bourboniana*. A total of about 162 million reads from *Rosa bourboniana* and about 60 million from *Rosa hybrida* were obtained. The analysis revealed a total of 1278 up-regulated transcripts and 2213 down-regulated transcripts in 8 h ethylene treated abscission zones of *Rosa bourboniana* against 0 h AZ cDNA. A comparison of the 8 h ethylene treated abscission zones of *Rosa bourboniana* and *Rosa hybrida* revealed up-regulation of 8415 and down-regulation of 8893 transcripts in *Rosa hybrida*. A comparison of ethylene treated samples of abscission zones of *Rosa bourboniana* with ethylene treated petals revealed up-regulation of a total of 1474 transcripts and down-regulation of 539 transcripts in petal samples. These

probably represent petal specific transcripts. Further analysis is in progress.

To establish involvement of miRNAs in secondary plant product biosynthesis, a detailed functional characterization of Arabidopsis miR858a was carried out. The study established the potential role of miR858a in flavonoids biosynthesis and plant growth and development. As promoter of miR858a contains light-responsive cis-regulatory elements, experiments were carried out to study regulation of miR858 by HY5 and/or PIF in light-dependent manner. WT, *hy5-215*, *cop1*, *pifq* (mutant for PIF1,3,4,5) were grown in light and dark for 5 days and expression of miR858 was studied in different genetic background (Fig. 1). Expression analysis of miR858 suggests that light dependent regulation is through HY5 and not through PIF.

In cotton, gene families involved in histone modifications related to fiber development were identified and characterized. In addition, transcriptional regulation of secondary cell wall (SCW) biosynthesis, which is an important stage of the cotton fiber development, has been studied in greater detail. For this, *Gossypium hirsutum* GDSL

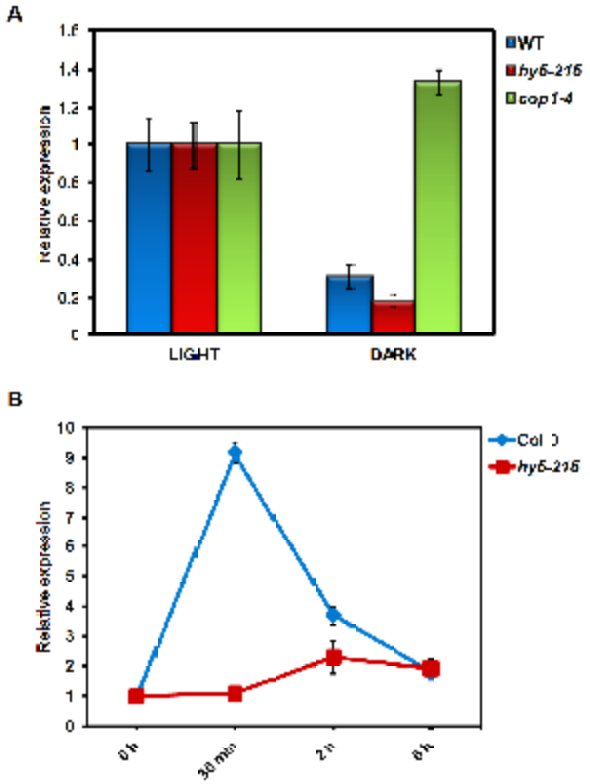


Fig. 1. The expression of miR858a is up-regulated by light and requires HY5. (A) qRT-PCR analysis of miR858a expression in WT (Col-0), *hy5-214* and *cop1-4*, in dark condition. **(B)** qRT-PCR analysis of miR858a expression in WT (Col-0) and *hy5-215* on exposure to light (150 µmol/m²/s) at the indicated times. Error bars indicate ±SE (n=3) from three biological replicates.

(*GhGDSL*) lipase/hydrolase gene (CotAD_74480), which is expressed during SCW biosynthesis (19 through to 25 days post anthesis; DPA) has been functionally characterized. T1-transgenic cotton lines expressing the β-glucuronidase (gus) reporter under the control of a 1026-bp promoter fragment of *GhGDSL* (P_{GhGDSL}) showed 19 DPA stage-specific increase in GUS expression. Fifty two deletions indicated that the 194-bp fragment between –788 and –594 relative to the transcription start site was essential for this stage-specific expression (Fig. 2). Site-directed mutagenesis of eight transcription factor binding sites within P_{GhGDSL} demonstrated that the MYB1AT motif (AAACCA) at –603/–598 was critical for the 19 DPA-specific reporter gene expressions. Yeast one-hybrid (Y1H) analysis identified nine proteins, including GhMYB1 (CotAD_64719) interacting with P_{GhGDSL} promoter. This analysis suggest that *GhGDSL* and its promoter are potential tools for the improvement of cotton fiber quality traits.

Transcriptome of callus culture from different developmental stages of Indica and Japonica rice was established and analysed. Dynamic transcriptome landscape during somatic embryo development suggested differential stem cell maintenance programming among japonica and indica rice sub-species. In order to develop low arsenic accumulating rice varieties, a novel arsenic methyltransferase gene (WaarsM) of *Westerdykella aurantiaca* was isolated from arsenic contaminated soil and functionally characterized. The expression of WaarsM enhanced arsenic resistance in *E. coli* (*Δars*) and *S. cerevisiae* (*Δacr2*) strains by biomethylation and required endogenous reductants, preferably GSH, for methyltransferase activity. Arsenic tolerance in rice after co-culture with genetically engineered yeast suggested its potential role in arsenic bioremediation (Fig. 3).

Detailed characterization of cotton transgenic lines expressing *tma12* (an insecticidal gene isolated from a fern) and Tma12 protein was carried out. Crystal structure of insecticidal protein was established, which showed association of Cu and involvement of two disulfide bonds in the protein structure. In addition to whitefly resistance, transgenic lines also show protection against cotton leaf curl disease. Exploration of possibilities for transfer of technology to industry is underway.

Chickpea (*C. arietinum L.*) is the major legume in India accounting for 40% of the total legumes grown in India. Unfortunately, several biotic and abiotic stresses reduce chickpea yields with the pod borer *Helicoverpa armigera* being one of the primary insects for its devastation. To obtain an insight into the earliest plant responses to *H. armigera* attack an Illumina-based transcriptomic analysis of chickpea leaves 20 minutes after simulated herbivory

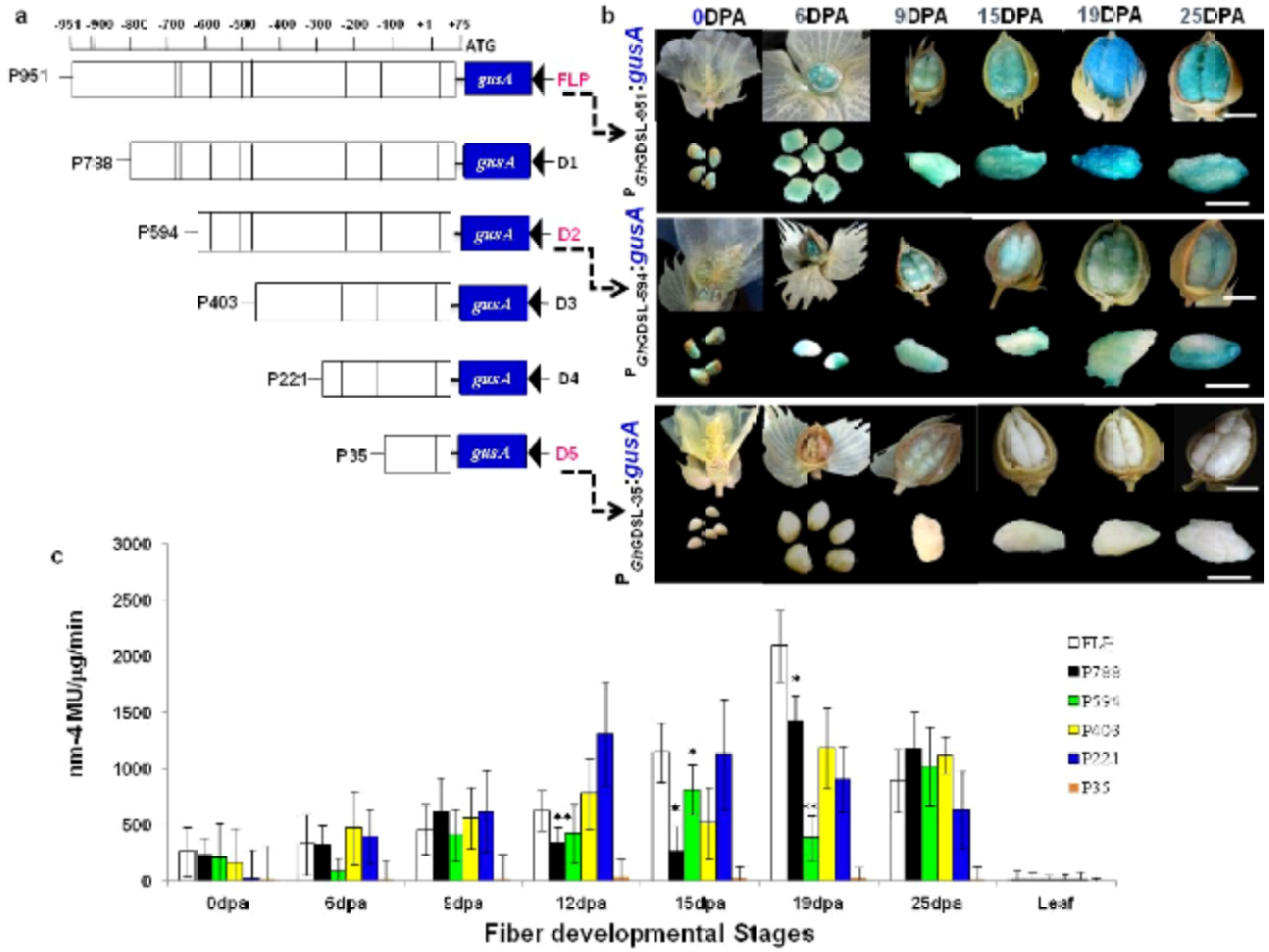


Fig. 2. Deletion analysis of *GhGDSL* promoter.(a) Schematics of P_{GhGDSL} deletions D1, D2, D3, D4 and D5 along with full length promoter. +1 represents TSS. Scale bar represent the length of promoter (-951/+75) from start codon ATG. (b) Histochemical GUS analysis of cotton T1-transgenic lines carrying deletions construct: Upper panel shows GUS staining of transgenic cotton fiber with native promoter (P_{GhGDSL}) during development stages (0-25 DPA). Middle panel shows GUS staining of transgenic cotton carrying $P_{GhGDSL\text{-}594}$:*gusA* (D2) construct. In lower panel staining was not observed in transgenic cotton fiber with $P_{GhGDSL\text{-}35}$:*gusA* (D5) construct. (c)Fluorometric GUS expression analysis of cotton transgenic lines carrying deletion (D1-D5) constructs.

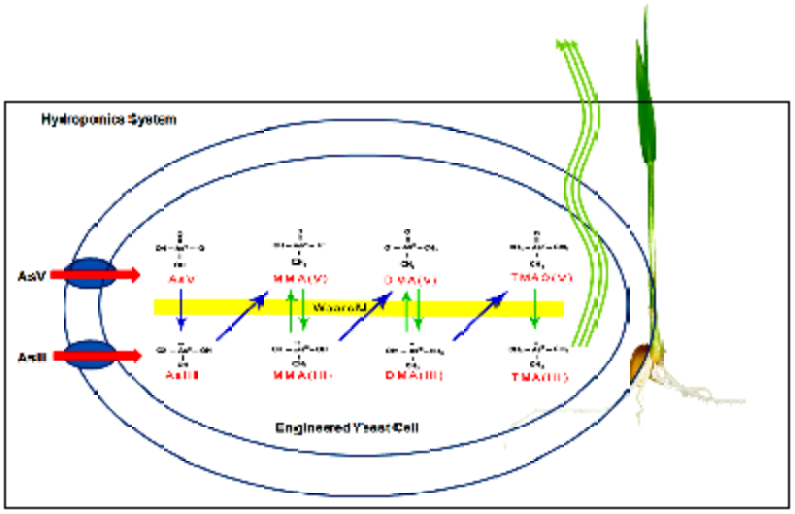


Fig. 3. Detailed model providing insights into the arsenic metabolism by *WarsM* and potential approach for its use in bioremediation process.

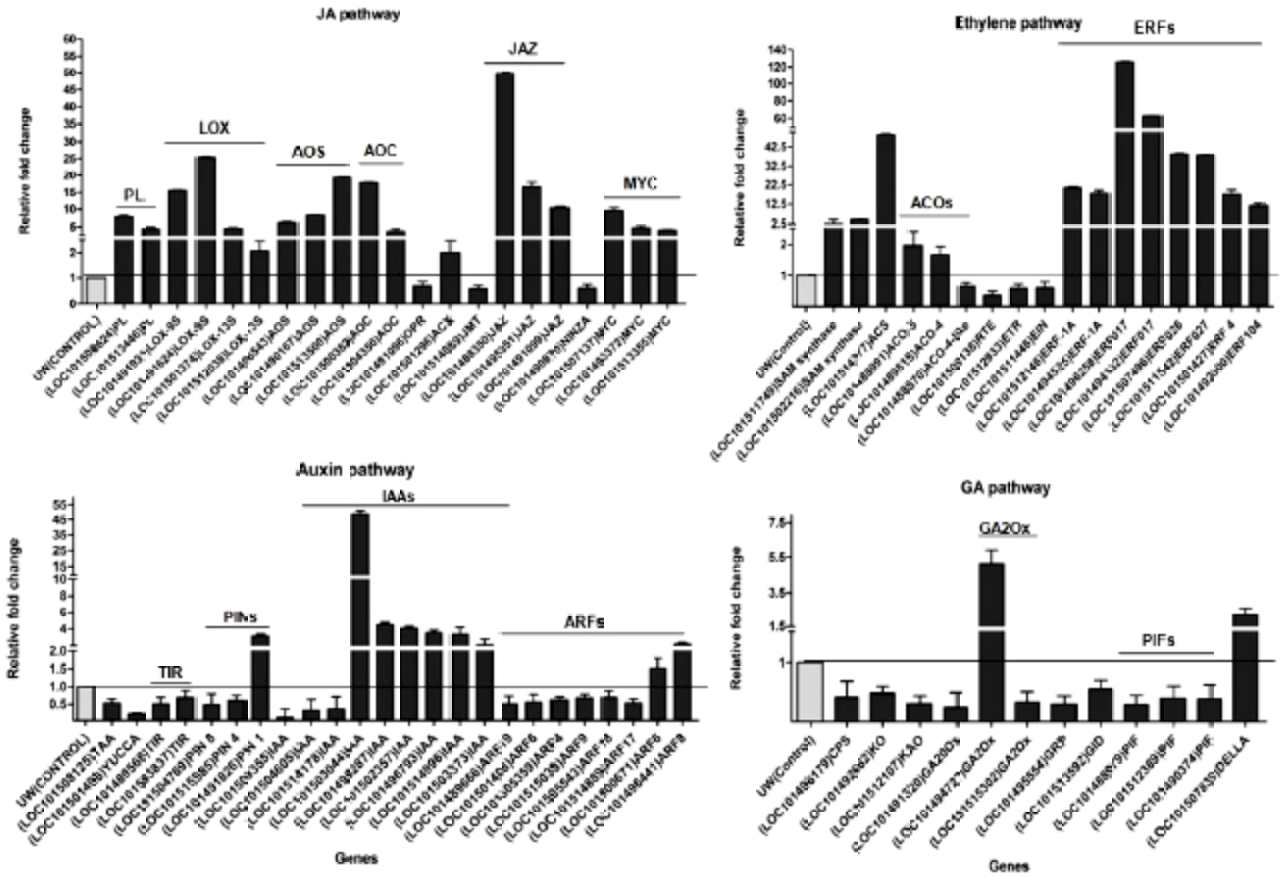


Fig. 4. Regulation of various hormone pathways within 20 minutes of simulated herbivory

was performed, using oral secretions of *H. armigera* coupled with mechanical wounding. Expression profiles revealed up-regulation of 1334 genes and down-regulation of 501 genes upon wounding (log_2-fold change |FC| ≥ -1 and ≥ 1; FDR value ≤ 0.05) together accounting for differential regulation of 8.4% of the total leaf transcriptome. Defense-related genes of the phenylpropanoid pathway, pathogenesis, oxidases and CYTP450 were up-regulated along with differential regulation of kinases, phosphatases and transcription factors of the WRKY, MYB, ERF, bZIP families. An interesting feature of the wound response was its rapid influence on hormonal networks with up-regulation of JA and ethylene pathways and suppression of growth associated pathways of GA and auxin within 20 minutes of wounding (Fig. 4). The activation/suppression of the respective hormone pathways was observed at the level of biosynthesis as well as signaling with both negative and positive regulators being targeted. Differences were observed in the scale of expression upon treatment with oral secretions compared to mechanical damage alone.

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

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 FACE and field conditions in different ecosystem.

Above ground biomass assessment in Indian tropical deciduous forest

The above ground biomass (AGB) of an ecosystem is one of the fundamental parameters describing its functioning. Measurement of AGB of dominant tree species in different forest communities is of great importance because the dominant tree species greatly influence the magnitude and pattern of energy flow that is stored in different parts of the plant in the form of various organic substances. These organic substances remain in continuous circulation between biotic and abiotic components of the ecosystem. Thus, biomass is a useful measure for assessing changes in forest structure. It is a useful measure for comparing structural and functional attributes of forest ecosystems across a wide range of environmental conditions. AGB is thus of direct applied importance for estimating ecosystem carbon storage and fluxes.

Very few studies on the AGB and biomass carbon are available from Indian tropical deciduous forest particularly on Terai regions of northern India. The present study was undertaken at Katerniaghat wildlife sanctuary (KWLS) of Uttar Pradesh. The AGB of three forest communities (dry mixed, sal mixed and teak forests) was measured using tree diameter at breast height (DBH) data and determined the biomass carbon distribution of trees in above three forest types having distinct species composition, stand density and basal area. The AGB (Mg ha^{-1}) were 424, 434, 440 and 450 in dry mixed; 429, 438, 445 and 456 in sal mixed; 291, 306, 313 and 326 in teak forests for the four inventory years, respectively (Fig. 1). The relationship of forest community microclimate, community structural and functional variables with AGB was then identified by principal component analysis (PCA). There is a strong positive correlation between species richness and AGB in all four inventory years. The relationship of community structural factors such as species diversity, stem density and basal cover, leaf area index (LAI) on AGB was investigated for first time for Indian tropical deciduous forests. A strong positive correlation between AGB and key functional parameter i.e., litter fall in all three forest types was observed. PCA revealed that stand AGB is mainly affected by absolute humidity (AH) and air temperature (AT) as major microclimatic variables, having maximum PCA component matrix controlling higher carbon sequestration and standing biomass.

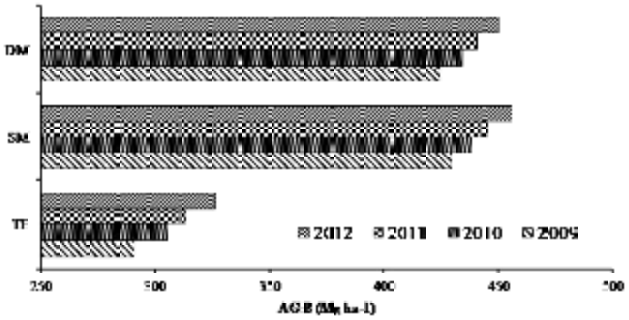


Fig. 1. Total AGB patterns among three tropical deciduous forest types at Katerniaghat Wildlife Sanctuary, Uttar Pradesh, India. (DM, dry mixed; SM, sal mixed, TP, teak plantation).

High altitude population of *Arabidopsis thaliana* is more plastic and adaptive under common garden than controlled condition

Plants as sessile organisms are often exposed to heterogeneous environmental conditions that influence evolution of traits. It can favour either local adaptation (adaptive differentiation/ specialization) or evolution of plastic genotypes that respond through phenotypic plasticity (generalization). Both adaptive differentiation and phenotypic plasticity act as major factors in generation of inter-individual variation and plant diversity. In this study, we determined the phenotypic differentiation and plasticity of three natural populations of *Arabidopsis thaliana* originated from different altitudes of West Himalaya (viz. Dehradun, Deh-700m, Munsyari, Mun-1800m and Chitkul, Chit-3500m). We compared the level of plasticity exhibited due to genotypes and compared with that of environmental plasticity. The populations were grown under two conditions: CG – common garden in NBRI field and GH-controlled Arabidopsis culture room. Morphological measurements in different stages of growth were recorded.

The three populations grown in CG and GH varied significantly for almost all the traits (Fig. 2). The post hoc pair wise comparison indicated that the Deh was more similar to the Mun than the Chit when grown in GH. However, in CG the Mun and the Chit were more similar. The differences in phenotypic trait expression between the two conditions also varied at different level (Fig. 3). Flowering time increased in Chit while that of Deh and Mun decreased in GH as compared to CG. The fertility

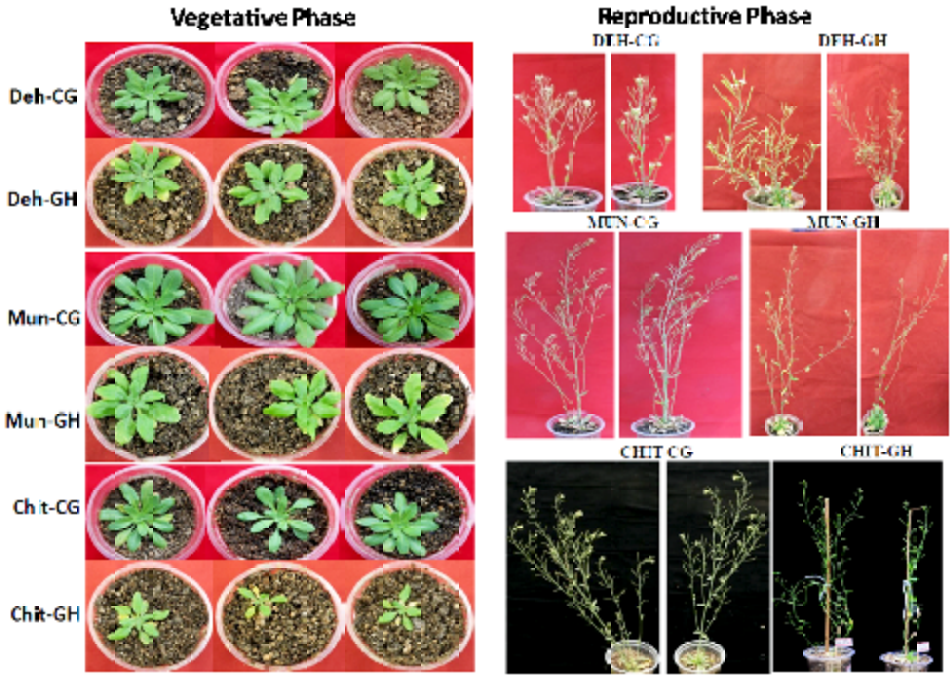


Fig. 2. Phenotypic variations observed in three populations of *Arabidopsis thaliana* grown under common garden (CG) and controlled condition (GH).

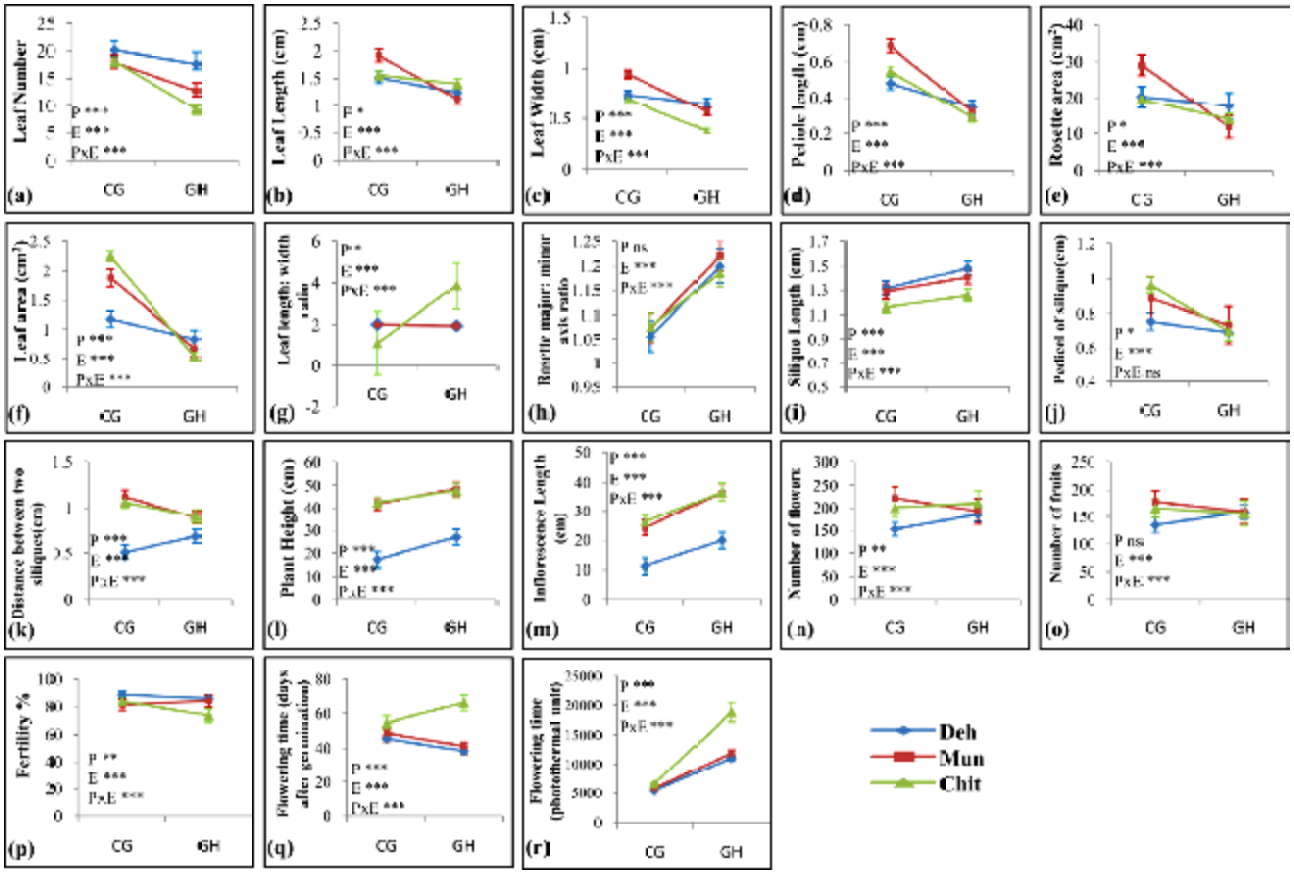


Fig. 3. Graphical representation of difference in trait means of three populations in two conditions. Each point represents the least square mean of each population in common garden (CG) and controlled conditions (GH). Bars above the lines represent the 95% confidence interval error bars. The results of ANOVA for each independent variable (P= population; E= growth environment) and their interaction (PxE) is also shown in the graph. * = $P<0.05$, ** = $P<0.01$, *** = $P<0.001$, ns = not significant

percentage was less in Chit and higher in Deh and Mun in GH than in CG. Chit and Mun produced more number of fruits in CG as compared to GH where as Deh produced less seeds in CG as compared to GH. Germination percentage was significantly higher in CG produced seeds than GH in all populations. The overall plasticity of Chit was significantly higher than Mun followed by Deh. Most of the reproductive traits of Chit were less plastic as compared to Deh and Mun. On the other hand Mun exhibited greater plasticity for most of the reproductive traits as compared to Deh and Chit. In either condition the populations had sufficient amount of phenotypic variations to distinguish the three populations as indicated by the discriminant analysis (Fig. 4).

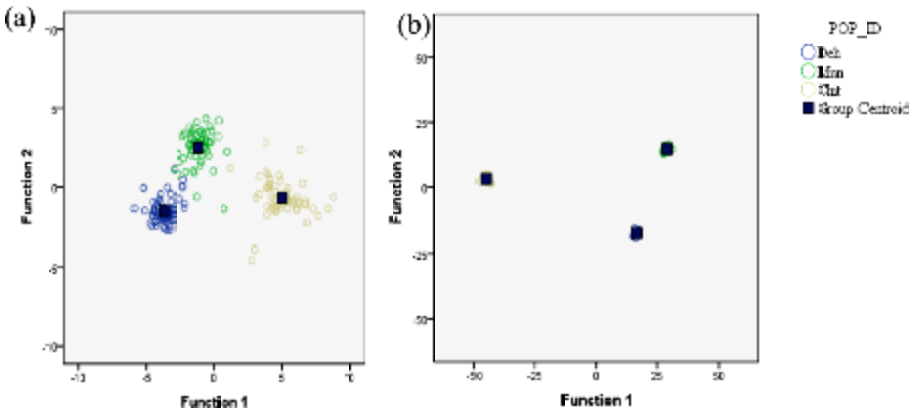


Fig. 4. Clustering of the three populations on Discriminant function1 and Discriminant function 2 on the basis of: (a) Phenotypic traits; (b) Amount of phenotypic plasticity.

Our analysis of phenotypic traits, their plasticity and selection indicate that common garden plants were more successful in terms of fitness as compared to the plants grown under controlled condition. The plant fitness of these populations was influenced by the light intensity and the maximum temperature. The high altitude population exposed to harsh environmental condition might have evolved to fit well in the heterogeneous condition thus showing maximum plasticity and fitness as compared to the lower altitude populations. An association of phenotype under common growth condition to its native altitude and climate predicts for an adaptive genetic differentiation of these populations reducing chance of being a random processes. These differences are also expected to indicate the abiotic stress experienced by the populations in the field conditions.

Seasonal variations in metabolites of *Commihora wightii* (Guggul)

Seasonal variations in metabolite profiling of aqueous extracts of leaves, stem and latex of three accessions of *C. wightii* were examined out using NMR spectroscopy and multivariate statistical analysis techniques. Based on the therapeutical use of the plant, the approach has been employed in order to study the metabolic changes during different seasons. The multivariate principal component analysis (PCA) applied on NMR raw data revealed clear distinctions in the metabolites between two distinct seasons (Fig. 5). The results clearly show that the leaves of *C. wightii* harvested in winter have the highest yield of potential healthcare agents namely, glycine, myoinositol and quinic acid. This suggests that the active principles in leaves of *C. wightii* that are responsible for its biological activities vary in quantity during different seasons of the year and reach the peak during winter.

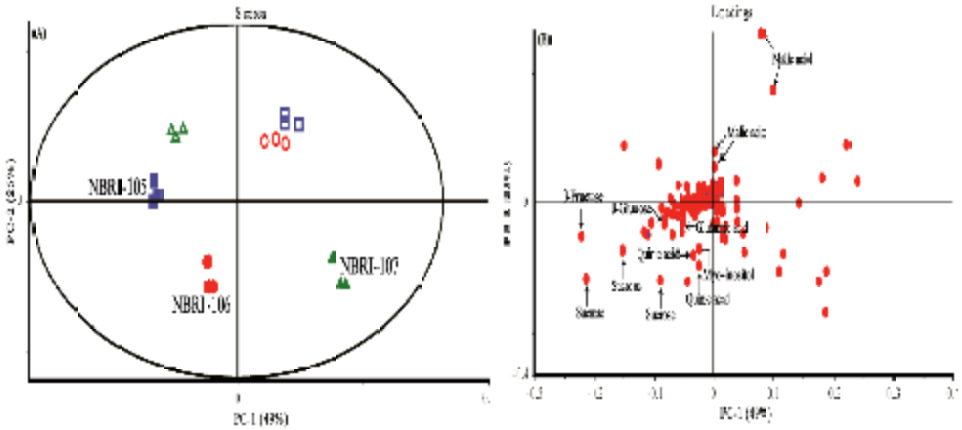


Fig. 5. PCA score plot (A) and its corresponding scattered loading plot (B) obtained from the PC analysis of ^{1}HNMR spectra of aqueous extracts of leaves samples of NBRI-105, NBRI-106 and NBRI-107 of *C. wightii* of winter (filled symbols) and summer (vacant symbols) seasons.

Extraction, isolation, purification and characterization of biologically active metabolites from *Commiphora agallocha*

A novel therapeutic compound was identified from *Commiphora agallocha,* which showed significant anti-inflammatory and arthritic properties by inhibiting the mediators responsible for inflammation including, tumor necrosis factor alpha (TNF-α).

2,4 ditertbutyl phenol, a potent antioxidant was isolated, purified and identified from chloroform extract of latex of *C.agallocha* (Fig.6).

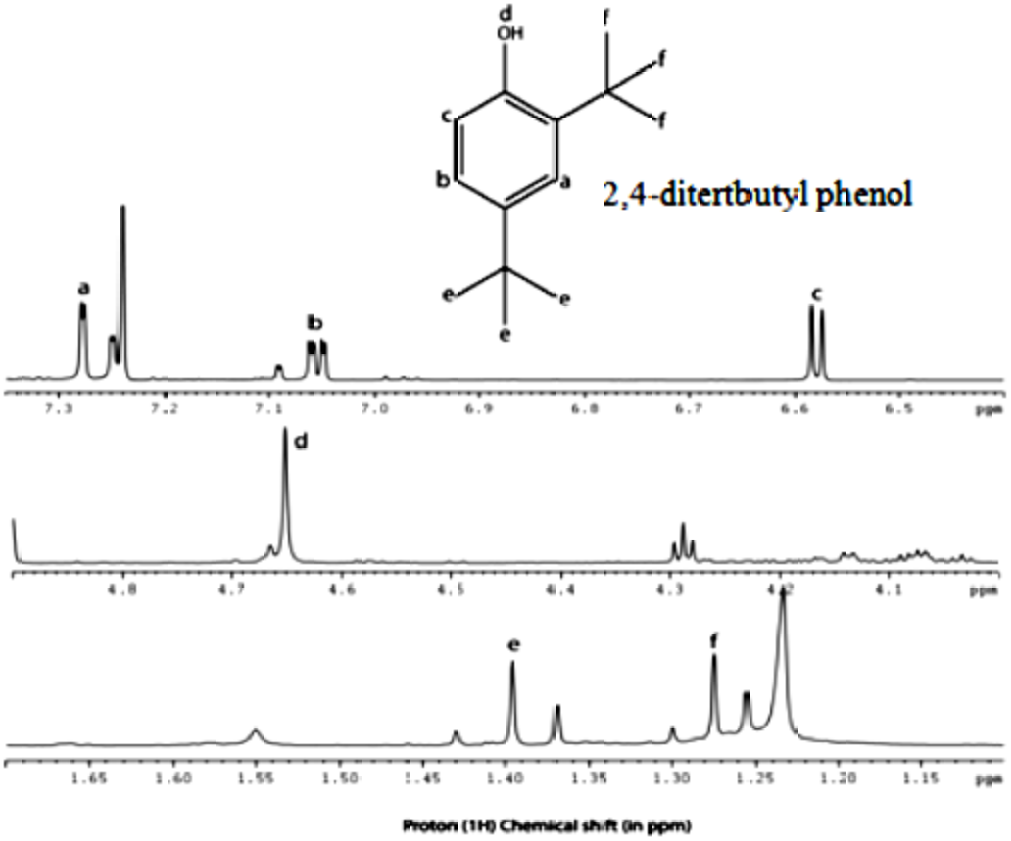


Fig. 6. ^{1}H NMR spectrum of purified fraction of 2,4-ditertbutyl phenol along with NMR assignment data: (in $CDCl_3$) δ 1.29(s,9H), δ 1.41(s,9H), δ 4.68(s,1H), δ 6.60(d,1H,J=7.95Hz), δ 7.07(dd,1H), δ 7.29 (d,1H,J=2.33Hz).

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

Objectives:

- Characterization and development of improved varieties of *Canna*, *Gladiolus* and other bulbous crops.
- Evaluation of *Bixa* and *Curcuma* germplasm collection for plant improvement.
- Evaluation of Damask Rose for the sodic soils.
- Performance and evaluation of elite plant material and/or cultivars through multi-locational coordinated trials.
- Evaluation of performance of biofertilizers and biopesticides on plants.

Characterization and development of improved varieties of Canna, Gladiolus and other bulbous crops

Mutants from Canna Varieties

New mutants were created after gamma radiation treatment of Canna varieties, Golden Girl and Red President. The mutants selected and isolated showed stability with respect to change of flower colour and combination.

Genetic Characterization of Gladiolus

Development of ISSR and RAPD derived SCAR markers for identification of Gladiolus germplasm

Sequence-characterized amplified region (SCAR) markers from the RAPD and ISSR fragments were developed for the identification and authentication of *Gladiolus* germplasm. The SCAR markers *viz*., ScG12, ScG34 and ScG36 distinguished *Gladiolus* from other taxa of the family Iridaceae, whereas marker ScAm was specific to 'Amethyst' cultivar.

Development of cpSSR markers for analysis of genetic diversity in Gladiolus cultivars

12 novel microsatellite (cpSSR) markers isolated from repeat sequences of chloroplast region of *Gladiolus* were developed. A total of 1188 nucleotide sequences of chloroplast region of *Gladiolus* were used to search for simple sequence repeats and 108 sequences were found to contain 124 SSRs. Dinucleotide repeat SSRs were most frequent (94.4%) with the AT/AT (59.7%) repeat motif, followed by TA/TA (31.5%). Assessment of genetic diversity among 62 commercially important *Gladiolus* cultivars was carried out using 12 SSR markers. Out of 12 SSR markers, only six showed polymorphism with allelic variation ranging from 2 to 8. These six SSR markers revealed high genetic diversity (84.6%) across different *Gladiolus* cultivars. The SCAR and cpSSR markers developed could be easily employed as valuable tools to identify newly developed *Gladiolus* cultivars.

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

A new variety of *Curcuma longa* L., named as "Kesari" which was released on 8th Feb. 2016 has a specialty of cold tolerance, with high yield potential (~35 t/ha fresh weight) even under partially reclaimed sodic soil. The rhizomes of this new variety were provided to progressive farmers, having mango orchards, around Lucknow. The field evaluation of 36 Turmeric accessions under sodic waste land condition of Indo-Gangetic plains for late senescing and early sprouting, shade loving, disease free germplasm was continued in the year 2016-17.

Seventeen accessions of *Bixa* were conserved and evaluated for their growth and quality performance under sodic soil conditions. Out of these, five accessions showing better yield were selected and are successfully being grown at CSIR-NEIST and CSIR-IIIM, under multi-location trials. The pruning experiment was conducted during the year under report.

One *Bixa* selection, having high seed yield and Bixin content has been identified.

Evaluation of performance of biofertilizers and biopesticides on plants

Phosphate solubilizing bacteria (PSB) was evaluated for their plant growth promoting attributes on Gladiolus at different locations and showed promising results. This PSB based formulation can be taken up for large scale bioinoculants preparation for not only Gladiolus but also other floriculture crops.

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

Objectives

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

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

A rice variety CN-1794-2-CSIR-NBRI (Muktashree) exhibiting low grain As accumulation (147 µg kg^{-1}) during Boro cultivation with higher yield (*kharif*: 4.17 t h^{-1} and *rabi:* 5.24 t ha^{-1}) was developed under a joint collaboration between CSIR-NBRI and Rice Research Station, Chuchura, Govt. of West Bengal. This was further approved by State Variety Release Committee for West Bengal on Jan. 15, 2016. The variety is being approved for cultivation in arsenic affected areas of Bengal following successful multi-locational field trials.

Lowering of arsenic uptake by cultivating crops with arsenic accumulators

Three known hyper accumulators viz. *Pteris vitata*, Phragmites and Vetiver were planted along with rice and wheat in the plots in As (50 mg kg^{-1}) contaminated soil. The soil arsenic was reduced when accumulators were grown with rice. Reduction of 56 to 63% arsenic level in the soil was achieved in rice and wheat plants cultivated with Phragmites respectively.

Potential microbes involved in soil carbon sequestration through rice straw decomposition

After a wide screening of microbial strains, a microbial formulation consisting of three *Trichoderma* and one *Bacillus* strain was formulated for *in situ* application in the fields having remains of rice stubble (~1 feet long). Application of the formulation resulted in faster degradation of rice straw in the field cultivated with wheat. Formulation was also found to enhance the productivity of the subsequent crop, wheat. Analysis of carbon pool in terms of oxidizable organic carbon (OOC) showed enhanced sequestration of OOC in the plots treated with microbial formulation with remains of rice stubble. Similarly micronutrient analysis through ICP-MS was also found to be modulated as compared to control (Fig 1).

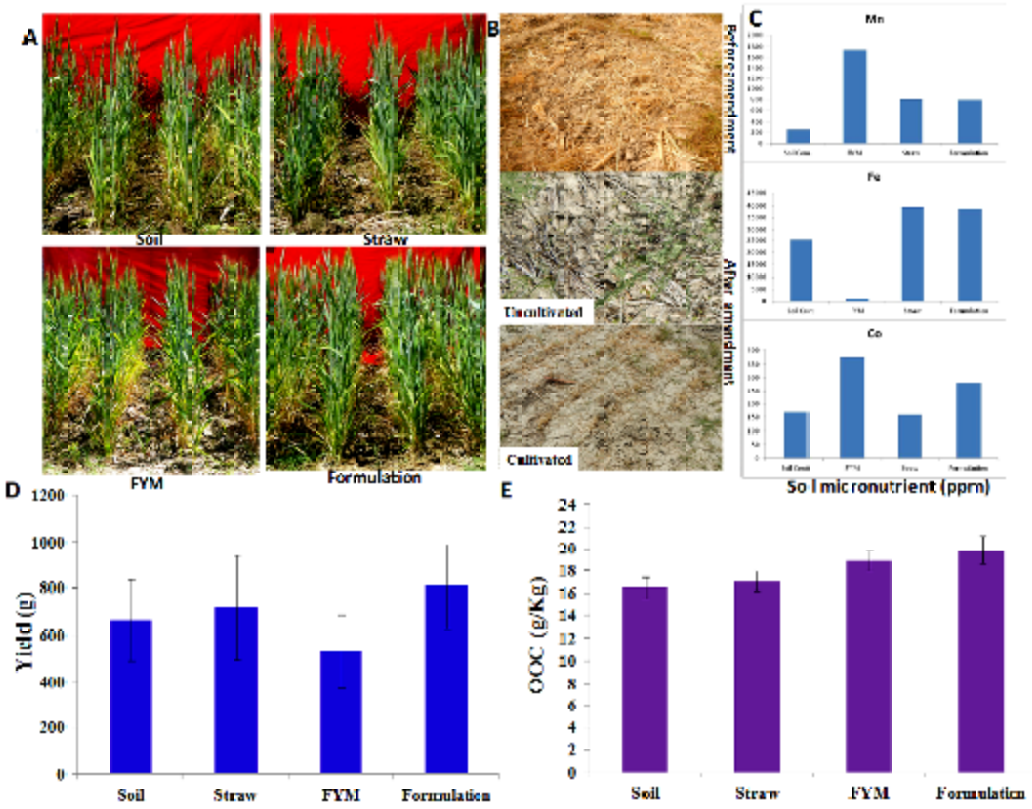


Fig. 1. Field application of microbial formulation for enhanced productivity of wheat (A, D); faster degradation of rice straw (B) and enhanced nutrient pool of the soil (C, E).

Development of a microbe based strategy for faster degradation of petroleum hydrocarbons

Twelve different bacterial strains exhibiting faster degradation ability for high molecular weight, polycyclic aromatic hydrocarbons (PAHs) and alkanes were isolated from oily sludge. A very high concentration (200 ppm) of fluoranthene was degraded (74% and 61%) by *Rhodococcus* sp. NJ2 and *Pseudomonas aeruginosa* PSA5, respectively in 10 days of incubation in minimal salt medium (MSM). A consortium of these two bacteria degraded fluoranthene by 97% under the same condition (Fig.2)

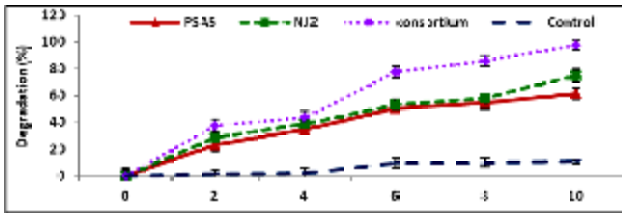


Fig. 2. Biodegradation of fluoranthene by bacteria in MSM

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.3).

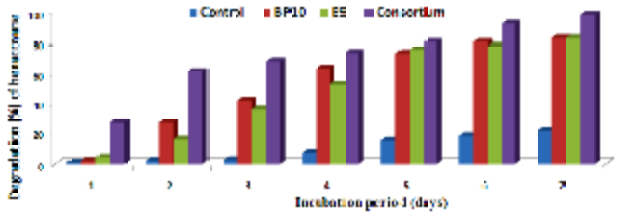


Fig. 3. Degradation of hexacosane by *Pseudomonas* sp. BP10 and *Stenotrophomonas nitritireducens* E9.

Biodegradation of aromatic compound, anthracene has been investigated by three bacterial strains i.e. *Corynebacterium sp.* PSM10, *Pseudomonas aeruginosa* PSA5 and *Rhodococcus* sp. NJ2 *in vitro* conditions in MSM supplemented with 1000 ppm of anthracene as carbon source. Highest degradation (94%) was observed in the presence of *Pseudomonas aeruginosa* PSA5, followed by *Corynebacterium sp.* PSM10 (84%) and least (78%) was contributed by *Rhodococcus* sp. NJ2 (Fig.4).

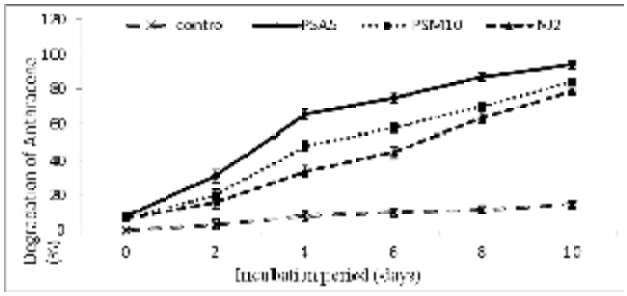


Fig. 4. Degradation of anthracene in presence of different bacterial strains

A significant induction of four degradative enzymes i.e. catechol 1,2 dioxygenase, catechol 2,3 dioxygenase, protocatechuate 3,4 dioxygenase and protocatechuate 4,5 dioxygenase involved in the degradation process of anthracene. The highest activities of these enzymes were recorded in the case of *Pseudomonas aeruginosa* PSA5.

Degradation of Total petroleum hydrocarbons (TPH) in soil spiked with different concentrations of crude oil in presence of microbial consortium:

Soil were spiked with different concentration of crude oil i.e. 20, 30, 40 and 50% (w/w) and were treated with consortium of bacterial and fungal strains i.e., *Psuedomonas* sp. BP10 and *Penicillium oxalicum* PS10. Microbial consortium degraded maximum 49% of TPH when grown in 30% crude oil spiked soil after one month of incubation. Rate of degradation decreased with increasing the concentration of crude oil (Fig.5).

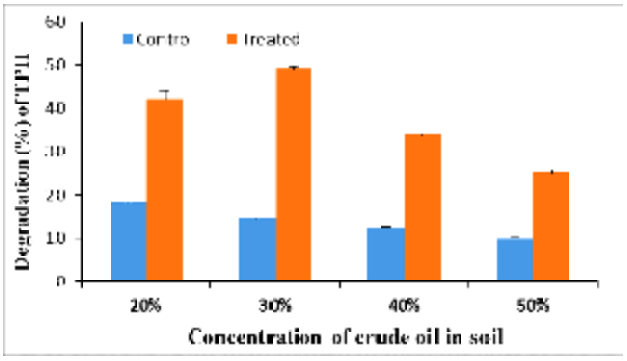


Fig. 5. Degradation of Total petroleum hydrocarbons (TPH) by Microbial Consortium

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

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

Response of wheat varieties to elevated carbon dioxide and EDU treatment

Over the last few decades, human activity has accelerated atmospheric changes. CO_2 emissions have increased by about 80 % between 1970 and 2004. In parallel, increasing NO*x* and hydrocarbon emissions have resulted in higher tropospheric ozone (O_3) concentrations. The effect of rising CO_2 on plants can be best studied by using Free Air CO_2 Enrichment (FACE) technology which provides desired elevated CO_2 concentration under natural field condition. Ethylene diurea (EDU) has been used as an alternative approach to evaluate the effects of O_3 on plants in open field conditions. EDU is known to specifically suppress acute and chronic injury due to O_3 in a wide range of plants without appreciable effects on its own. Interestingly, CO_2 and O_3 have opposing effects on plants; elevated O_3 typically decreases photosynthesis, growth and crop yield, whereas elevated CO_2 typically stimulates productivity of plants. Even if emission rates are stabilized or reduced, a continued increase in atmospheric CO_2 is committed and under current emission scenarios, background tropospheric O_3 is also predicted to increase in the coming decades. Identifying mechanisms that improve stress tolerance traits against increased background O_3 with the help of antiozonant while enabling crops to exploit rising CO_2 for yield enhancement is a critical step towards adapting crops to future changing environments.

Present study was conducted to understand response of three wheat varieties to elevated carbon dioxide and EDU treatment. Commonly grown three wheat varieties PBW343, LOK1 and HD2967 having similar growth condition, fertilizer requirement and maturation period were selected for the study. During the study period average ambient O_3 concentration was about 60 ppb. Ambient CO_2 level was 406 ppm and that of elevated CO_2, was about 480 ppm. Plants were harvested at 3 phases viz, vegetative, flowering and harvesting. In vegetative phase PBW343 and LOK1 showed decrease in total chlorophyll content with EDU treatment while HD2967 showed increased response under ambient CO_2 (aCO_2). However when plants were grown in elevated (eCO_2) with EDU treatment all three varieties showed increased amount of total chlorophyll. At flowering phase all three varieties showed increased chlorophyll content with EDU treatment in aCO_2 as well as in eCO_2 condition. In vegetative phase PBW343 and LOK1 accumulated less biomass while HD2967 showed increased biomass with EDU treatment in both CO_2 conditions. At flowering phase, PBW343 with EDU treatment showed decrease in biomass grown in aCO_2. LOK1 and HD2967 showed increased biomass with EDU treatment in both aCO_2 and eCO_2 conditions. Similar results were observed for PBW343 with EDU treatment in eCO_2 condition (Fig. 1).

In vegetative phase PBW343 and LOK1 showed increased MDA content with EDU treatment while HD2967 shows decreased response in aCO_2. However, when plants were grown in eCO2 with EDU treatment opposite results were found. At flowering phase PBW343

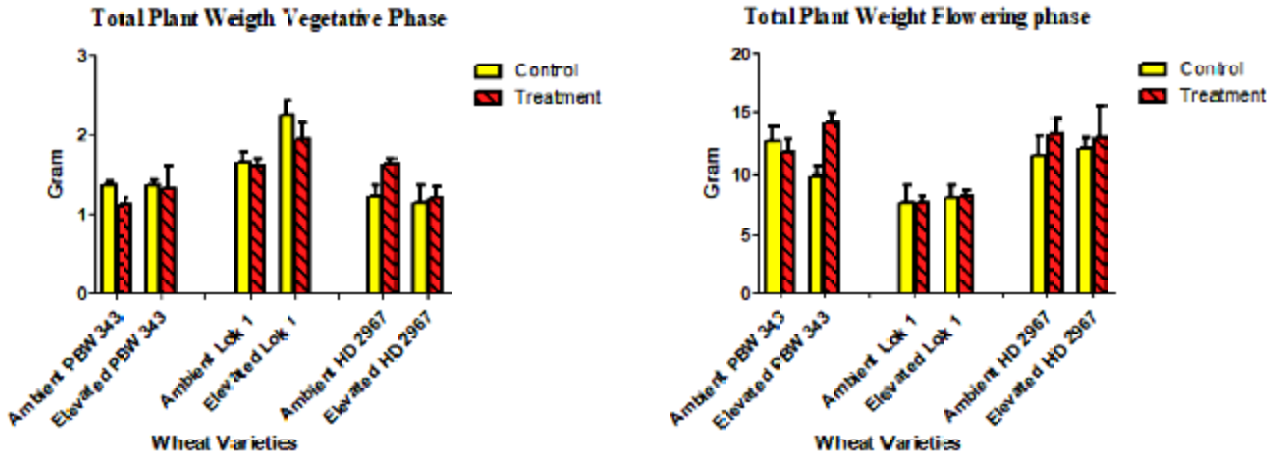


Fig. 1. Effect of elevated CO_2 and EDU application on total plant biomass of *Triticum aestivum* cultivars at vegetative and flowering phase

showed decreased MDA content with EDU treatment in controlled as well as eCO_2 condition. LOK1 and HD2967 show decrease in aCO_2 condition and increase in eCO_2 with EDU treatment.

In vegetative phase, SOD activity increased in PBW343 and HD2967 and decreased in LOK1 in aCO_2 condition with EDU treatment. In eCO_2 with EDU treatment LOK1 and HD2967 showed increased and PBW343 showed decreased SOD content. In flowering phase, SOD level increased in LOK1 and HD2967 and decreased in PBW343 in aCO_2 with EDU treatment. In eCO_2 with EDU treatment PBW343 and LOK1 showed increased and HD2967 showed decreased SOD activity.

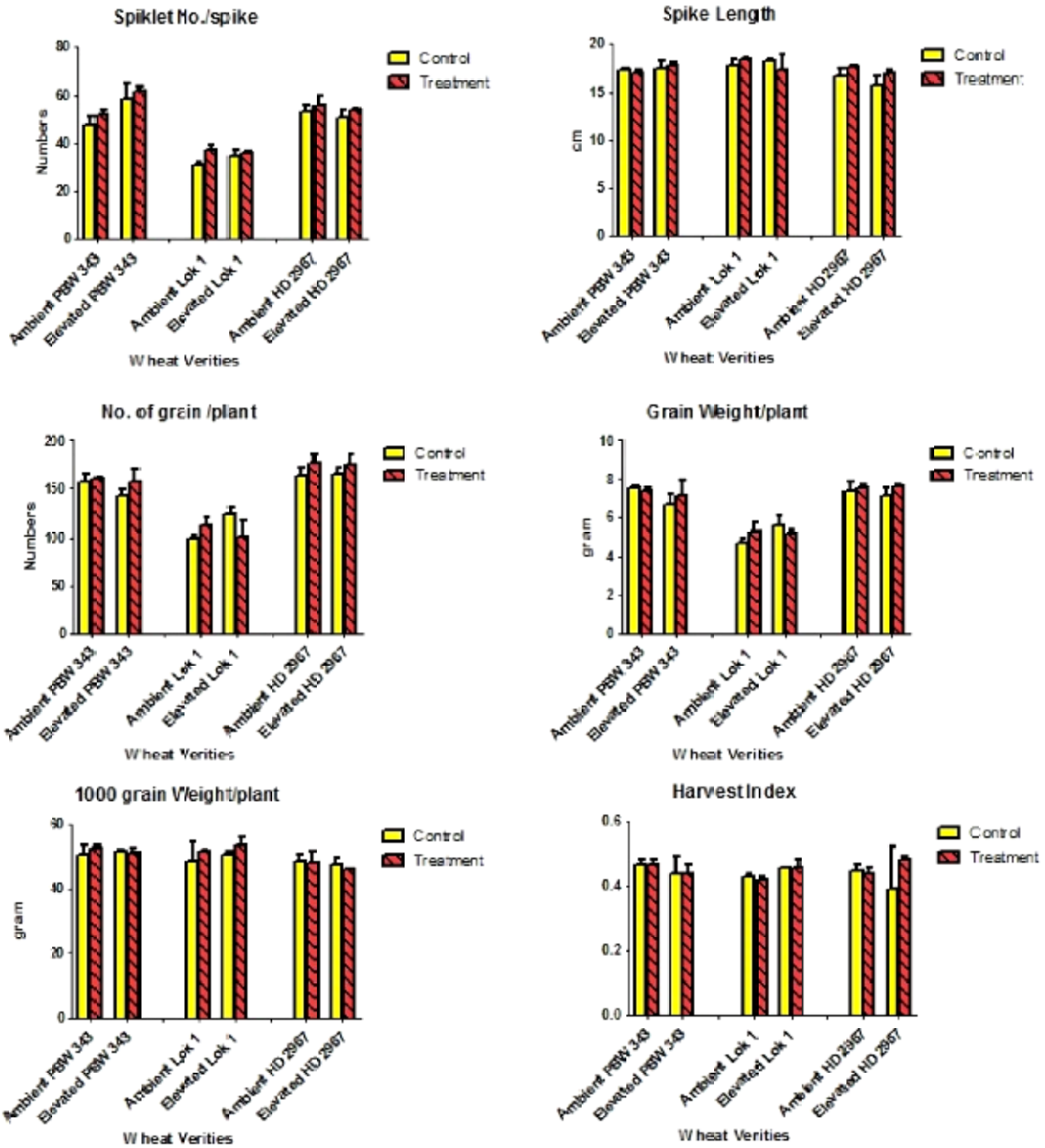


Fig. 2. Effect of elevated CO_2 and EDU application on yield parameters in *Triticum aestivum* cultivars

In vegetative phase, catalase enzyme levels decreased in PBW343 and HD2967 when plants were grown either in aCO_2 or eCO_2 condition with EDU treatment. For LOK1 its level increased in aCO_2 and decreased in eCO_2 condition with EDU treatment. In flowering phase, enzyme level increased in PBW343 and LOK1 when plants were grown either in aCO_2 or eCO_2 condition with EDU treatment. HD2967 showed decreased enzyme levels with EDU treatment.

In vegetative phase, Ascorbate peroxidase levels were decreased in PBW343 and LOK1 and increased in HD2967 with EDU treatment under aCO_2. In eCO_2 LOK1 and HD2967 showed increased and PBW343 showed decreased APX enzyme activity. In flowering phase, enzyme levels increased in PBW343 and LOK1 and decreased in HD2967 in aCO_2 condition with EDU treatment. In eCO_2 with EDU treatment all varieties showed lower enzyme levels.

In vegetative phase, GR decreased in PBW343 and HD2967 and increased in LOK1 in aCO_2 condition with EDU treatment. In eCO_2 with EDU treatment LOK1 and HD2967 showed increased and PBW343 showed decreased GR content. In flowering phase, enzyme levels decreased in PBW343 and LOK1 and increased in HD2967 in aCO_2 and eCO_2 conditions

Number of spiklets per spike increased for all three varieties with EDU treatment under both conditions. Spike length decreased in PBW343 and increased for LOK1 and HD2967 with EDU treatment under ambient condition. In elevated condition with EDU treatment LOK1 showed decreased while PBW343 and HD2967 showed increased Spike length (Fig. 2). Number of grains per plant was increased for all varieties with EDU treatment under ambient condition while in eCO_2 LOK1 showed decreased and PBW343 and HD2967 showed increased number of grains per plant with EDU treatment. Grain weight per plant were decreased for PBW343 and increased for LOK1 and HD2967 under ambient condition while in eCO_2 LOK1 showed decreased and PBW343 and HD2967 showed increased grain weight with EDU treatment (Fig. 2). In aCO_2 with EDU treatment, thousand Grain weight (TGW) increased in PBW343 and LOK1 while it decreased in HD2967. When EDU was applied in eCO_2 condition, TGW was decreased in PBW343 and HD2967 while LOK1 showed increased TGW (Fig. 2). No significant changes were observed in Harvest index (HI) of PBW343 in both growing conditions with EDU treatment. While LOK1 showed decreased HI under ambient and no change in elevated condition with EDU treatment. Decreased HI was found for HD2967 in ambient condition with EDU treatment while increased HI was found in elevated condition with EDU treatment (Fig. 2).

The present study indicated that ozone concentrations in and around Lucknow city have increased significantly affecting various physiological and biochemical characteristics of wheat cultivars. EDU application protected plants against harmful effects of ozone. HD2967 among the selected wheat varieties, performed better in morphology, physiology and biochemical response selected for experiments with EDU treatment in eCO_2 condition.

7. Plant-microbe and soil interactions (PMSI)

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 controlled conditions and fields
- Characterizing plant interactions with PGPR ad viruses

Exotic *Pseudomonas* spp. and *Ochrobactrum* sp. from Volcanic Soil Possess Multiple Plant Beneficial Traits along with Abiotic Stress Tolerance Capabilities

An attempt was made to evaluate soil bacteria from extreme environments of volcano soils based on plant growth promoting and abiotic stress mitigating characteristics. The screening led to eight bacterial isolates, (NBRISH4, NBRISH6, NBRISH10, NBRISH11, NBRISH13, NBRISH14, NBRISH16 and NBRISH26) capable of withstanding stress, namely temperature (up to 45 °C), salt (up to 2M NaCl) and drought (up to 60% Poly Ethylene Glycol 6000) *in vitro*.

Further, the selected isolates were very promising *in vitro* temporal performance with regards to their survival (in terms of colony count), phosphate solubilization, biofilm formation, auxins, alginate and exo-polysaccharide production abilities under abiotic stresses i.e. 40 °C temperature; 500 mM NaCl salt and 250 mM LiCl drought conditions. *In vivo* seed treatments of individual selected bacterium to maize plants resulted into significant enhancement in root and shoot length, root and shoot fresh and dry weight and no. of leaves per plant (Fig. 1). Overall, the plant growth promoting and abiotic stress tolerance ability was prominent for NBRISH6 bacterial isolate which was identified as *Ochromobactrum* sp. using 16S rRNA based phylogenetic analysis (Fig. 2). NBRISH6 having multiple plant beneficial and abiotic stress tolerance characteristics can be considered for its application in agriculture under stress conditions.

Fig. 1. Growth representation of *Zea mays* plant inoculated with selected isolates. A represent Control; B represent NBRISH4; C represent NBRISH6; D represent NBRISH10; E represent NBRISH11; F represent NBRISH13; G represent NBRISH14; H represent NBRISH16; I represent NBRISH26

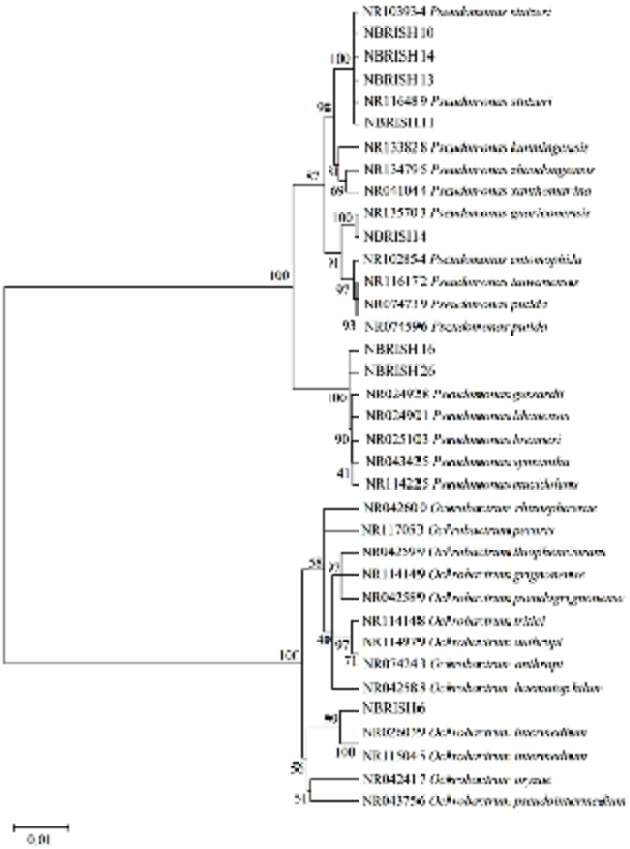


Fig. 2. Phylogenetic relationship based on the 16S rRNA gene sequences using neighbor-joining method (MEGA 6). The data of all genera obtained, are from Genbank database. The numbers above each node on the tree indicates the percentages of bootstrap sampling derived from 1,000 replications. Bar infers nucleotide substitutions per nucleotide.

Interaction of Cucumovirus with Gerbera

Maintenance of virus-free Gerbera plants: The polyhouse grown gerbera (*Gerbera jamesonii* L.) cultivar Zingaro plants at CSIR-NBRI, Lucknow were observed to be infested with the severe yellow mosaic symptoms. The infection was confirmed by reverse transcription-PCR detection method to be of *Cucumber mosaic virus* (CMV). The gerbera plants were made free from CMV infection through floral bud culture method coupled with viralzole chemical at concentration of 30 mg/l. These CMV-free plants are being propagated using tissue culture method. Plants have been multiplied from the mother culture and rooted in Gerbera rooting media (Fig. 3).

Fig. 3. Rooted and acclimatization of gerbera plants in glasshouse conditions.

Screening of *in vitro* regenerated gerbera plants for CMV persistence

The absence of CMV in *in vitro* raised plants was confirmed by reverse transcription-PCR (RT-PCR) method using degenerate primers of CMV which amplifies ~0.7 kb band in infected plants.

Interaction of Potyvirus with Gladiolus

The tissue culture raised *Bean yellow mosaic virus* (BYMV)-free gladiolus plants of cultivars Shagun, Tiger flame, Decisso, Vink's glory and Aldebaron are being maintained under culture room conditions and are also being multiplied by clonal propagation in experimental plots.

Assessment of PGPR for induction of growth and disease (virus)-resistance in gladiolus cultivars

The plant growth promoting rhizobacteria (PGPR), *Paenibacillus lentimorbus* B-30488 (referred as B-30488), was used to assess its impact on induction of growth and BYMV-resistance in gladiolus cultivars. The gladiolus cultivars Tiger flame, Vink's glory and Aldebaron were were grown to 3-4 leaves stages in 12 inches (diameter) pots in soil and maintained in glasshouse for further experiments. AB-30488 cell suspension was used to drench pot soil twice at weekly interval. Morphological analysis showed that B-30488 inoculation of soil significantly enhanced the plant vigour in terms of shoot length, shoot thickness, fresh weight and dry weight of plants as compared to mock (buffer) inoculated plants.

Paenibacillus lentimorbus inoculation enhances tobacco growth and extenuating the virulence of cucumber mosaic virus

Previous studies with *Paenibacillus lentimorbus* B-30488, a plant growth promoting rhizobacteria (PGPR) isolated from cow's milk, revealed its ability to improve plant quality under normal and stress conditions. Present study investigates its potential as a biocontrol agent against an economically important virus, *Cucumber mosaic virus* (CMV), in *Nicotiana tabacum* cv. White Burley plants and delineates the physical, biophysical, biochemical and molecular perturbations due to the trilateral interactions of PGPR host-CMV. Soil inoculation of B-30488 enhanced the plant vigor while significantly decreased the virulence and virus RNA accumulation in systemic leaves of CMV infected tobacco plants as compared to the control ones.

Histology of these leaves revealed improved tissue health and least aging signs in B-30488 inoculated tobacco plants, with or without CMV infection, and showed lesser intercellular spaces between collenchyma cells, reduced amount of xyloglucans and pectins in connecting primary cells, and higher polyphenol accumulation in hypodermis layer extending to collenchyma cells (Fig. 4).

These improvements led tobacco plant to produce more flowers and seeds with no negative impact on plant health. The present study may advocate the applicability of B-30488 for crop yield improvement in virus infested areas.

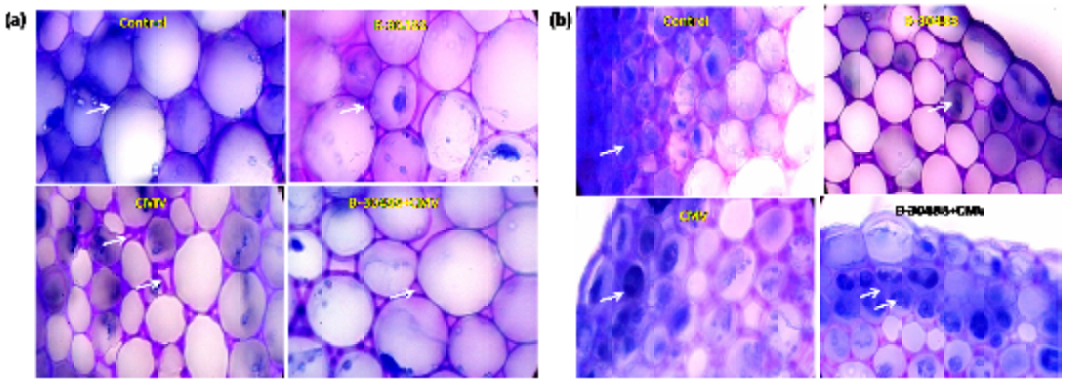


Fig. 4 Histological analysis of stem tissue of *N. tabacum* plants showing effect of PGPR in presence and absence of CMV. (a) Healthy collenchyma cells are observed in control, B-30488 and CMV+ B-30488 treatments while CMV infection caused shrinkage of the cells altering the intercellular space (shown by the arrows) and thickened cell connecting corners (b) Stem tissue showing polyphenol accumulation in hypodermis layer (shown by arrows).

8. S&T interventions to combat malnutrition in women and children

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 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, leaflets 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 in pilot scale.

The CSIR-NBRI nutritional product, "Nutri-Jam" (IPR covered vide application no. 2506/DEL/2004) was provided to undernourished women and children. The product was distributed to the selected individuals of Dafedar ka Purva village of Barabanki district, Daun village of Unnao and Tulsipur village of Amethi district. Several visits each of Dafedar ka purva, Tulsipur and Daun village were conducted. Feedback from the selected 60, 58, 169 individuals from Daun, Tulsipur and Dafedar Ka Purva respectively were taken. Based on BMI of individuals it was concluded that after consumption of the product the BMI of the individuals was found to be increased which indicate positive impact on the health of selected individuals.

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

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.

Improvement in *Agrobacterium*-mediated transformation of chickpea (*Cicer arietinum* L.) by the inhibition of polyphenolics released during wounding of cotyledonary node explants

Agrobacterium-mediated transformation of chickpea (*Cicer arietinum* L.) was performed using cotyledonary node explants (CNs), which release phenolics upon excision that are detrimental to the viability of *Agrobacterium tumefaciens* and result in low transformation frequency. Twelve low molecular weight phenolic compounds and salicylic acid were identified in the exudates released upon excision during the preparation of cotyledonary nodes by reverse phase high-performance liquid chromatography (RP-HPLC). Zone inhibition assays performed with the explant exudates released at periodic intervals after excision showed the inhibition of *A. tumefaciens*. Agroinoculation of freshly excised cotyledonary nodes of chickpea showed 98-99 % inhibition of colony forming units (cfu). Osmium tetraoxide fixation of excised tissues showed enhanced accumulation of phenolics in the sub-epidermal regions causing enzymatic browning, affecting the viability and performance of *A. tumefaciens* for T-DNA delivery. The periodic analysis of exudates released from excised CNs showed enhanced levels of gallic acid, chlorogenic acid, and quercetin, which were detrimental to *A. tumefaciens*. Quantitative assays and the elution profile showed the maximum leaching of phenolics, flavonoids, and salicylic acid immediately after the excision of explants and continued till 4 to 8 h post-excision. Pre-treatment of excised explants with inhibitors of polyphenol oxidase like L-cysteine, DTT, and sodium thiosulfate before co-cultivation showed the recovery of *A. tumefaciens*, cfu decreased the accumulation of phenolics, and improved transformation frequency (Fig. 1). Our results show the hypersensitive response of excision stress for the

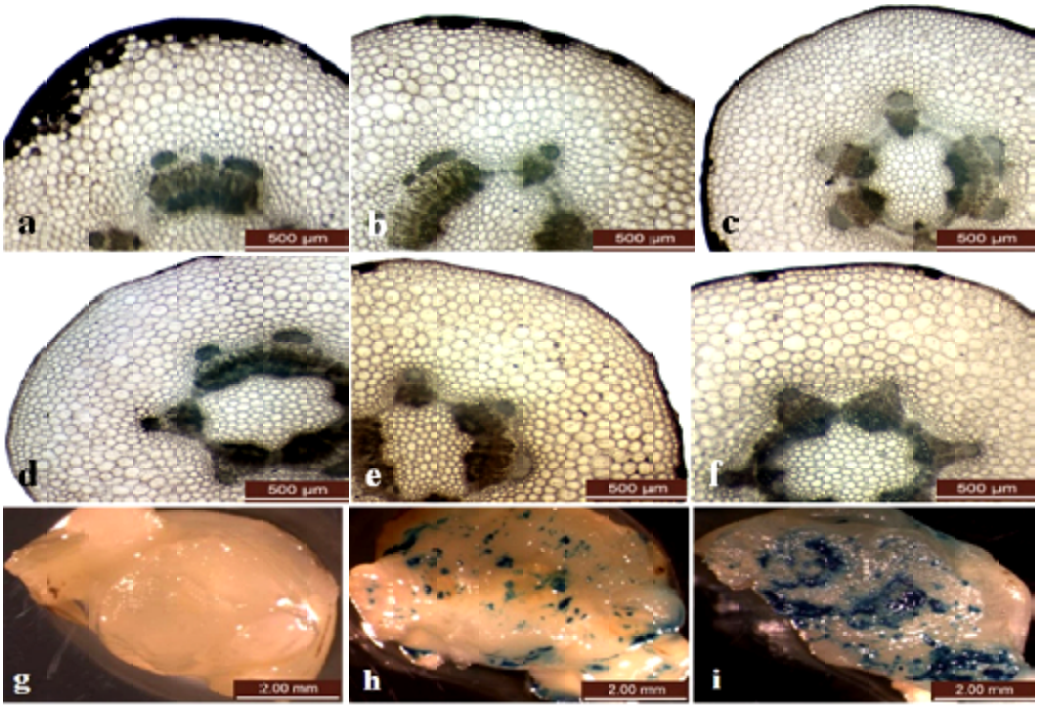


Fig. 1. Histochemical determination of phenolics in chickpea CN by osmium tetraoxide post-fixation method. a T.S. of freshly excised explant. b Overnight pre-incubated explants. c Explants soaked for 1 h in water and then pre-incubated on MS semi-solid medium. d L-cysteine (100 mg/l). e Sodium thiosulfate (100 mg/l) and f DTT (100 mg/l) treated explants, respectively. Histochemical GUS assay in CN explants. g Control explant, h freshly excised explant, and i explant treated with L-cysteine

expression of defense response-related genes and synthesis of metabolites in grain legume chickpea against pathogen infestation including *Agrobacterium*.

Characterization and functional validation of two scaffold attachment regions (SARs) from *Cicer arietinum*

A library of SARs has been prepared from chickpea by Illumina sequencing of DNA fragments that co-isolate with the nuclear scaffold by lithium diiodosalicylate treatment. Seven fragments were screened on the basis of SAR associated motifs and their interactions were tested with the nuclear scaffold of chickpea by *in vitro* binding assay. SAR 1 and SAR 2 bind strongly in comparison to other SARs to the nuclear scaffold of chickpea and tomato during *in vitro* binding assay. To investigate the effect of SARs on transgene expression and variation among transformants, NBRI 1.1 (harbouring GUS expression cassette with single SAR1 fragment), NBRI2.1 (with single SAR2 fragment) and NBRI1.2 (with two SAR1 fragments) vectors were prepared for plant transformation and transgenic tomato plants were developed, plants transformed with pBI121 functioned as a control. The enzymatic activity of GUS increased 9.52 fold in NBRI2.1, 17.82 fold in NBRI 1.1 and 51.4 fold increase in NBRI1.2 in comparison to pBI121. Chickpea was transformed with NBRI 1.2 and pBI121, where GUS enzymatic activity increased 13.789 fold in NBRI 1.2 in comparison to pBI121 (Fig. 2).

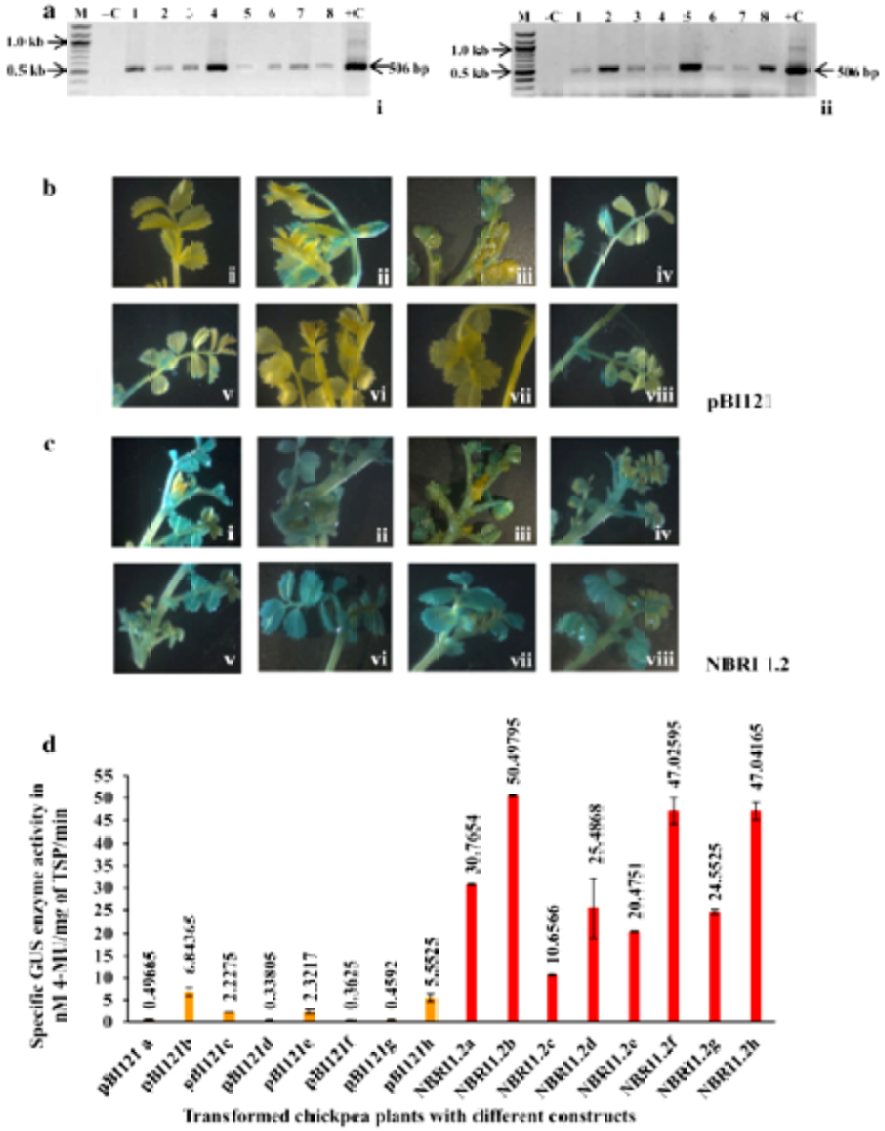


Fig. 2. a PCR amplification of uidA gene of T0 transgenic plants of chickpea transformed with different chimeric constructs. i pBI121 and ii NBRI 1.2. GUS histochemical assay. The chickpea leaves of eight randomly selected independent T0 transgenic events developed with chimeric construct. b pBI121. c NBRI 1.2 showing GUS expression. d Quantitative GUS expression by fluorometric assay of T0 transgenic chickpea plants developed by different chimeric constructs.

Elucidation of complex nature of PEG induced drought-stress response in rice root using comparative proteomics approach

Along with many adaptive strategies, dynamic changes in protein abundance seem to be the common strategy to cope up with abiotic stresses which can be best explored through proteomics. Understanding of drought response is the key to decipher regulatory mechanism of better adaptation. Rice (*Oryza sativa* L.) proteome represents a phenomenal source of proteins that govern traits of agronomic importance, such as drought tolerance. In this study, a comparison of root cytoplasmic proteome was done for a drought tolerant rice (Heena) cultivar in PEG induced drought conditions. A total of 510 protein spots were observed by PDQuest analysis and 125 differentially regulated spots were subjected for MALDI-TOF MS-MS analysis out of which 102 protein spots identified which further led to identification of 78 proteins with a significant score (Fig. 3). These 78 differentially expressed proteins appeared to be involved in different biological pathways. The largest percentage of identified proteins are involved in bioenergy and metabolism (29%) and mainly consists of malate dehydrogenase, succinyl-CoA, putative acetyl-CoA synthetase, and pyruvate dehydrogenase. This was followed by proteins related to cell defense and rescue (22%) such as monodehydroascorbate reductase and stress-induced protein *sti1*, followed by protein biogenesis and storage class (21%) e.g. putative thiamine biosynthesis protein, putative beta-alanine synthase, and cysteine synthase. Further, cell signaling (9%) proteins like actin and prolyl endopeptidase, and proteins with miscellaneous function (19%) like Sgt1 and some hypothetical proteins represent a large contribution towards drought regulatory mechanism in rice. We propose that protein biogenesis, cell defense, and superior homeostasis may render better drought-adaptation. These findings might expedite the functional determination of the drought-responsive proteins and their prioritization as potential molecular targets for perfect adaptation (Fig. 4).

Physiological performance of two contrasting rice varieties under water stress

Two rice varieties PR-115 and Super-7 were imposed to water stress and different physiological traits were monitored to evaluate the performance of these varieties under drought. Under water stress condition although the relative water content, osmotic potential, chlorophyll content, photosynthesis rate, carbon discrimination and

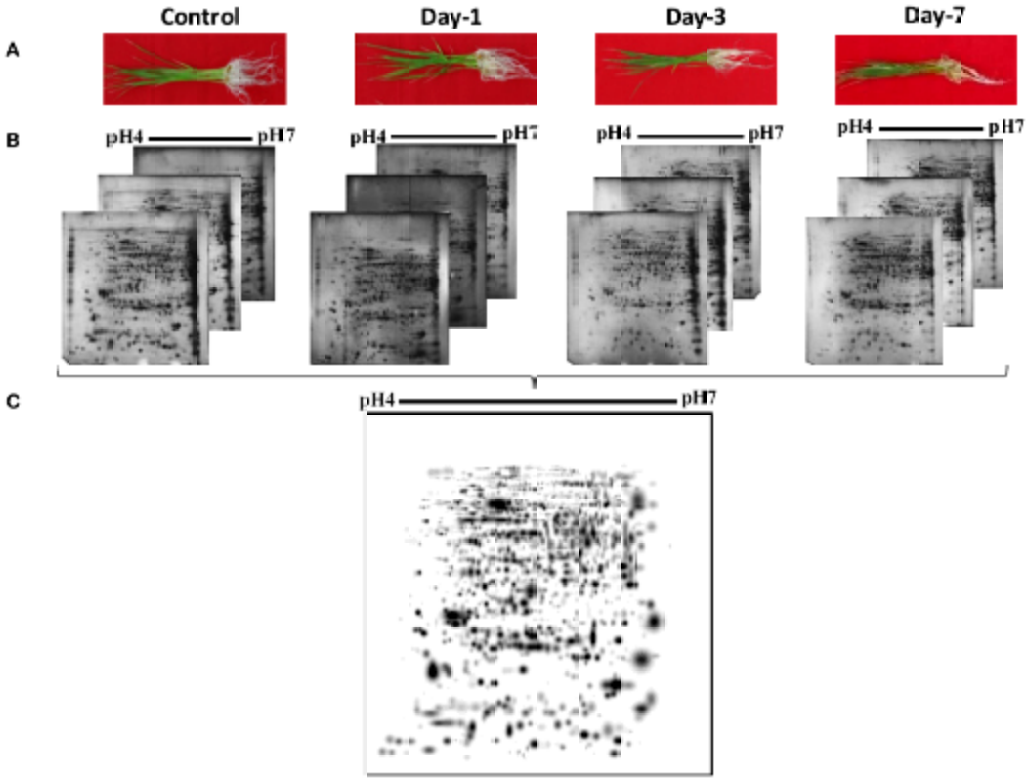


Fig. 3. 2-DE analysis of root proteome of rice. (A) Rice plant showing different stages of drought. (B) Proteins were extracted from rice root tissue and equal amounts (250 µg) of proteins were separated by 2-DE as described in Materials and Methods Section. (C) Three replicate silver-stained gels for each stage were computationally combined using PDQuest software and one representative master standard gel image was generated.

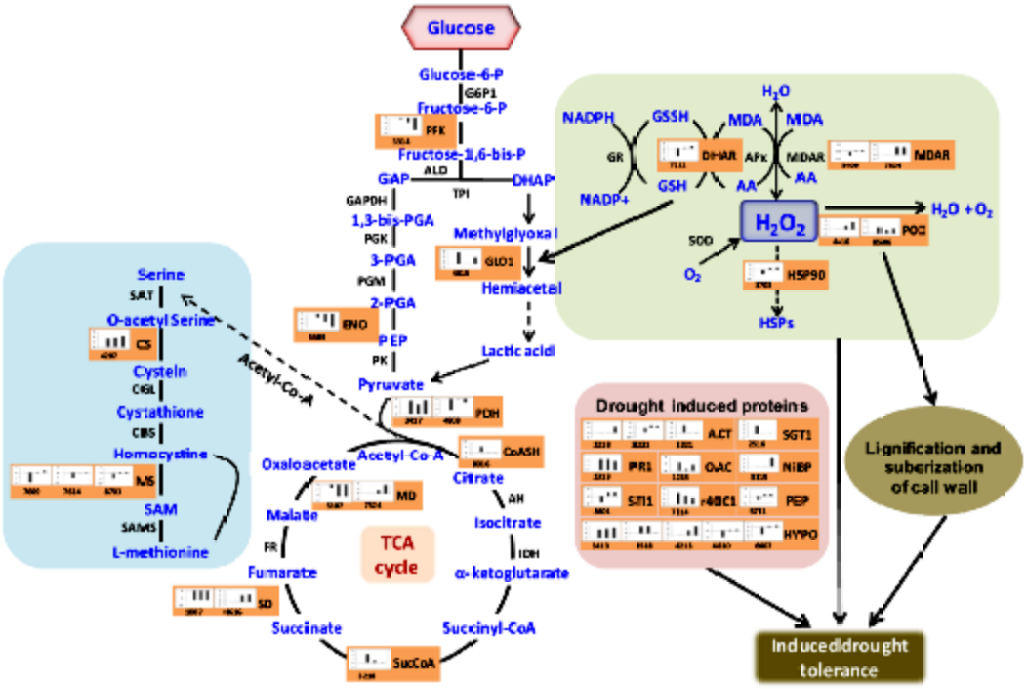


Fig. 4. Illustration of role of differentially regulated proteins involved in different pathways in rice for sustaining during drought stress. Proteins engaged in carbon breakdown, protein synthesis and ROS pathway are displayed on the corresponding metabolic pathways. Graphs are the representatives of expression profile of individual protein and number given below in each graph indicates the protein identification number

biomass decreased in both the varieties, however, the reduction was more pronounced in Super-7 variety (Fig. 5). Oryzanol a trans-ester of ferulic acid functions as antioxidant and it increased along with total phenolic and anthocyanin content in both the varieties under drought stress. However, gallic acid, 4 hydroxy benzoic acid,

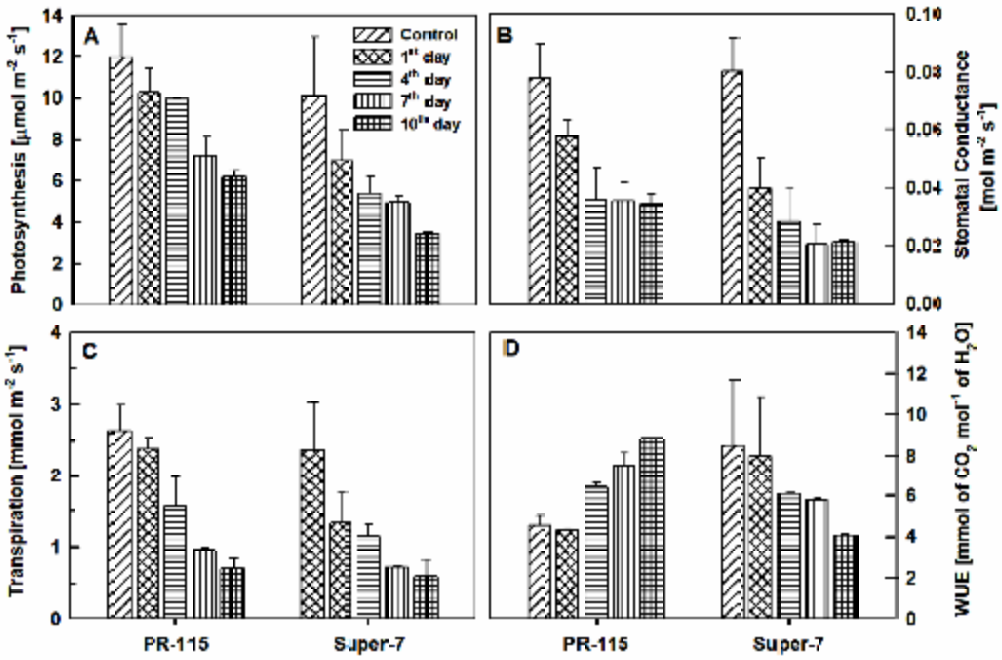


Fig. 5. Net photosynthesis rate (A), stomatal conductance (B), transpiration rate (C), and water use efficiency (D) in leaves of PR-1115 and Super-7 varieties at 0, 1st ,4th ,7th and 10th day of drought. Data showed as average ± standard deviation of five samples

syringic acid and chlorogenic acid showed differential pattern in both of the varieties under water limiting conditions. Under drought, grain yield was penalized by 17 and 54% in PR-115 and Super-7 varieties, respectively in comparison to watered plants. Super-7 variety showed pronounced electrolyte leakage and malondialdehyde enhancement under water stress condition. High non photochemical quenching and reduction in non-regulated energy dissipation and Photochemical quantum yield of photo system II indicated balanced energy management in tolerant PR-115 variety. The studies showed that PR-115 is a drought tolerant variety while Super-7 is drought sensitive in nature.

Unraveling aspects of *Bacillus amyloliquefaciens* mediated enhanced production of rice under biotic stress of *Rhizoctonia solani*.

Rhizoctonia solani is a necrotrophic fungi causing sheath blight in rice leading to substantial loss in yield. Excessive and persistent use of preventive chemicals raises human health and environment safety concerns. As an alternative, use of biocontrol agents is highly recommended. In the present study, an abiotic stress tolerant, plant growth promoting rhizobacteria *Bacillus amyloliquefaciens* (SN13) is demonstrated to act as a biocontrol agent and enhance immune response against *R. solani* in rice by modulating various physiological, metabolic, and molecular functions (Fig. 6). A sustained tolerance by SN13 primed plant over a longer period of time, post *R. solani* infection may be attributed to several unconventional aspects of the plants' physiological status. The prolonged stress tolerance observed in presence of SN13 is characterized by (a) involvement of bacterial mycolytic enzymes, (b) sustained maintenance of elicitors to keep the immune system induced involving non-metabolizable sugars such as turanose besides the known elicitors, (c) a delicate balance of ROS and ROS scavengers through production of proline, mannitol, and arabitol and rare sugars like fructopyranose, β-D-glucopyranose and myoinositol and expression of ferric reductases and hypoxia induced proteins, (d) production of metabolites like quinazoline and expression of terpene synthase, and (e) hormonal cross talk. As the novel aspect of biological control this study highlights the role of rare sugars,

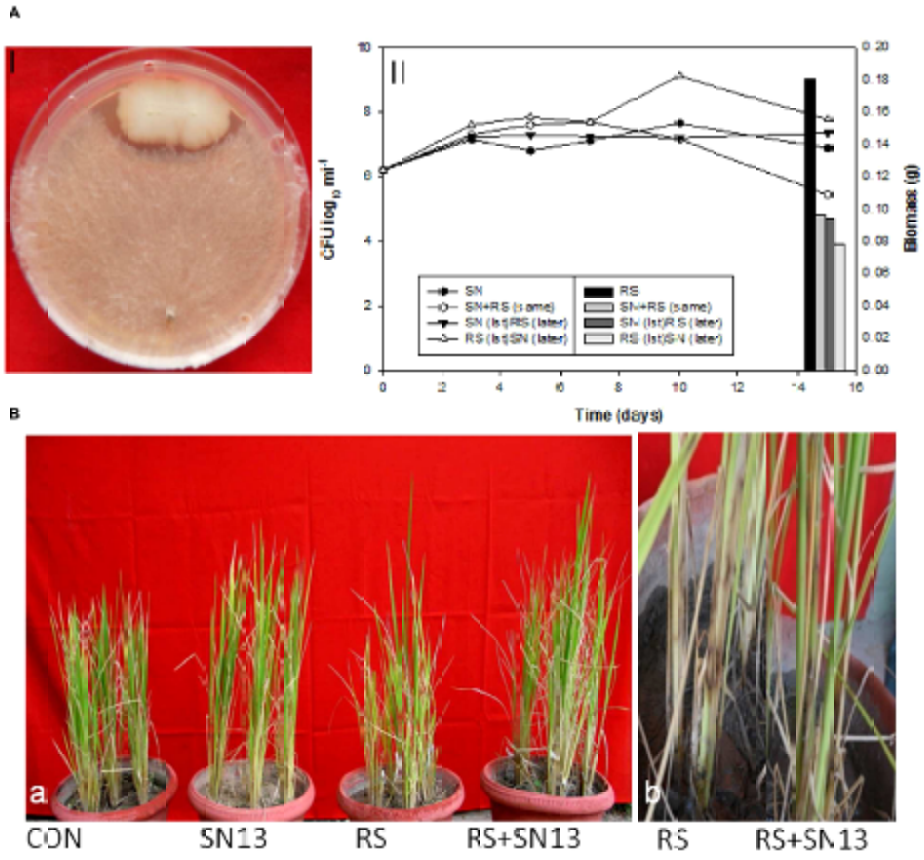


Fig. 6. (A) Biocontrol efficacy of *Bacillus amyloliquefaciens* (SN13) against *Rhizoctonia solani* (*R. solani*) in dual culture method (I) and broth conditions (II) (primary axis) SN13 growth, (secondary axis) *R. solani* biomass. (B) Effect of SN13 on plant growth and biocontrol of rice sheath blight (a) 45 dpi (b) close view of lesion development in RS and SN13 + RS at 15 dpi. CON, control; SN13, biocontrol agent; *R. solani*, pathogen; dpi, days post infection.

maintenance of hypoxic conditions, and sucrose and starch metabolism in *B. amyloliquefaciens* (SN13) mediated sustained biotic stress tolerance in rice.

Physico-chemical condition optimization during biosynthesis lead to development of improved and catalytically efficient gold nanoparticles

Biosynthesis of nanoparticles has gained great attention in making the process cost-effective and eco-friendly. In the present study, gold nanoparticles (GNPs) of various shapes and sizes were obtained by modulating different physical parameters using *Trichoderma viride* filtrate (Fig. 7). The particles were characterized on the basis of visual observation, dynamic light scattering, UV-visible spectroscopy, transmission electron microscopy, fourier transform infrared spectroscopy, and X ray diffraction. While the size varied from 2–500 nm, the shapes obtained were nanospheres, nanotriangles, nanopentagons, nanohexagons, and nanosheets. Changing the parameters such as pH, temperature, time, substrate, and culture filtrate concentration influenced the size and geometry of nanoparticles. Catalytic activity of the biosynthesized GNP was evaluated by UV-visible spectroscopy and confirmed by gas chromatography-mass spectrometric analysis for the conversion of 4-nitrophenol into 4-aminophenol which was strongly influenced by their structure and dimension. Common practices for biodegradation are traditional, expensive, require large amount of raw material, and are time taking. Controlling shapes and sizes of nanoparticles could revolutionize the process of biodegradation (Fig. 8).

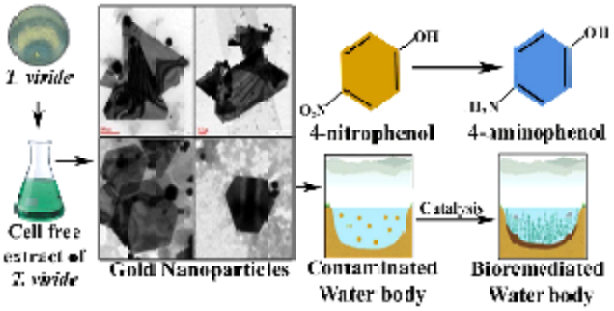


Fig. 8. Overall graphical abstract illustrating diverse shapes biosynthesized GNP and its ability to degrade 4-nitropdhenol into 4-aminophenol.

Arsenic tolerant *Trichoderma* sp. reduces arsenic induced stress in chickpea (*Cicer arietinum*)

Toxic metalloids including arsenic (As) can neither be eliminated nor destroyed from environment; however, they can be converted from toxic to less/non-toxic forms. The form of As species and their concentration determines its toxicity in plants. The microbe mediated biotransformation of As is crucial for its plant uptake and toxicity. In the present study the role of As tolerant *Trichoderma* in modulating As toxicity in chickpea plants was explored. Chickpea plants grown in arsenate spiked soil under greenhouse conditions were inoculated with two plant growth promoting *Trichoderma* strains, M-35 (As tolerant) and PPLF-28 (As sensitive). Total As concentration in chickpea tissue was comparable in both the *Trichoderma* treatments, however, differences in levels of organic and inorganic As (iAs) species were observed. The shift in iAs to organic As species ratio in tolerant *Trichoderma* treatment correlated with enhanced plant growth and nutrient content. Arsenic stress amelioration in tolerant *Trichoderma* treatment was also evident through rhizospheric microbial community and anatomical studies of the stem morphology. Down regulation of abiotic stress responsive genes (MIPS, PGIP, CGG) in tolerant *Trichoderma* + As treatment as compared to As alone and sensitive *Trichoderma* + As treatment also revealed that tolerant strain enhanced the plant's potential to cope with As stress as compared to sensitive one. Considering the

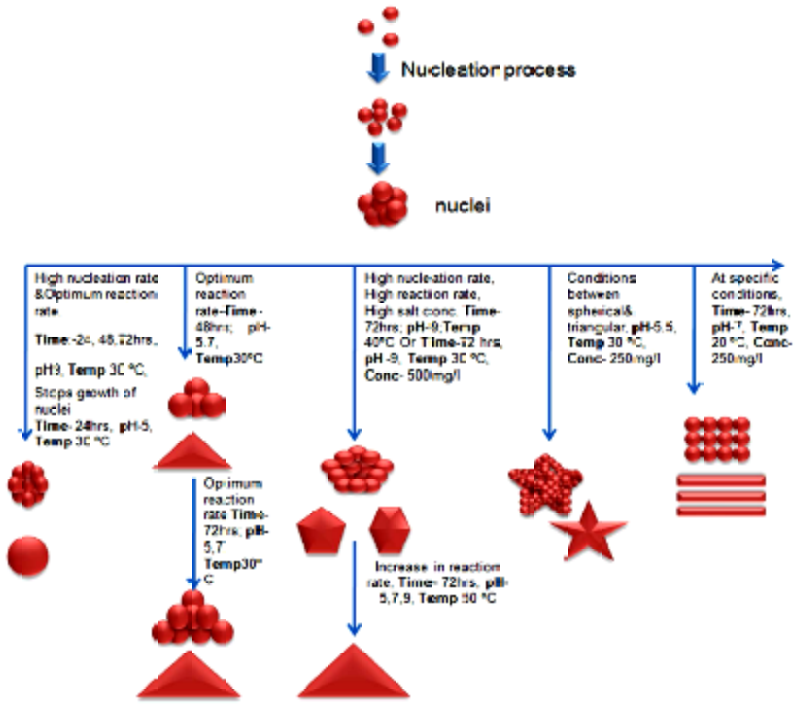


Fig. 7. Schematic diagram representing mechanism of formation of gold nanoparticles of different shapes and sizes under different reaction conditions.

bioremediation and plant growth promotion potential, the tolerant *Trichoderma* may appear promising for its utilization in As affected fields for enhancing agricultural productivity (Fig. 9).

The functional validation of *GheCAMTA* and *NAC*-2 genes in chickpea in response to water stress. Our aim is to develop drought-tolerant chickpea

Chickpea seeds of variety P-362 were surface sterilised and allowed to germinate for seven days. The cotyledonary nodes (CNs) were prepared using 17-19 days old germinated seedlings. The excised CNs was pre-conditioned for 24 h in the culture room on MS medium supplemented with 1 mg/l BAP. After 24 h, the CNs was co-cultivated with *Agrobacterium* harbouring the *CAMTA* gene for drought tolerance. The shoots were allowed to develop on shoot elongation medium in the presence of hygromycin for 15 days. The shoots surviving the antibiotic selection regime were sub-cultured on medium supplemented with silver nitrate for further elongation. The selected shoots were grafted into seedling stocks and allowed to grow for 15 days in plastic cups in a hardening chamber. After 15 days, the plants were transferred into a growth chamber. Later the plantlets were transferred to pots filled with soil and farmyard manure under glasshouse conditions for pod development.

Functional Characterization of PGPR induced rice gene in Arabidopsis

One of abiotic stress related genes, i.e., stress, ripening gene (OsASR6, LOC_Os01g73250) was found to be up-regulated (five folds) by PGPR treatment in rice roots. To examine the potential role of *OsASR6* in plant development, heterologous expression in *Arabidopsis thaliana* was carried out. 549 bp long *OsASR6* orf was cloned in plant expression vector and then used for Arabidopsis transformation. Out of seven transgenic lines, progeny test of three transgenic lines showed segregation ratio of 3:1 (resistance: susceptibility to kanamycin), suggesting a single copy insertion of the transgene. These lines were analyzed for OsASR6 transcript through real-time PCR, and almost equal expression level of OsASR6 was found in fully expanded leaves of T3 generation plants. OsASR6 expressed constitutively in different plant parts in Arabidopsis transgenic lines. Further progenies were checked for various phenotypic analyses. The transgenic Arabidopsis plants expressing *OsASR6* showed better plant growth with respect to control. Transgenic plants were 34.7% taller compared to control plants with an average height of 32.2±3.2 cm and leaves were longer by 69.1% as compared to control leaf. Roots of fully grown plants were longer in transgenic plants with increased root density than control plants. Root hairs also increased in transgenic roots compared to control when observed under a stereomicroscope. The transgenic plants showed an increase in root dry weight and a 78% increase in dry shoot weight. The increase in the root growth and the root density of transgenic plants suggests that the transgenic plants might be more capable of searching for nutrition and water in the soil in deficient conditions. Further work on transgenic lines is under progress.

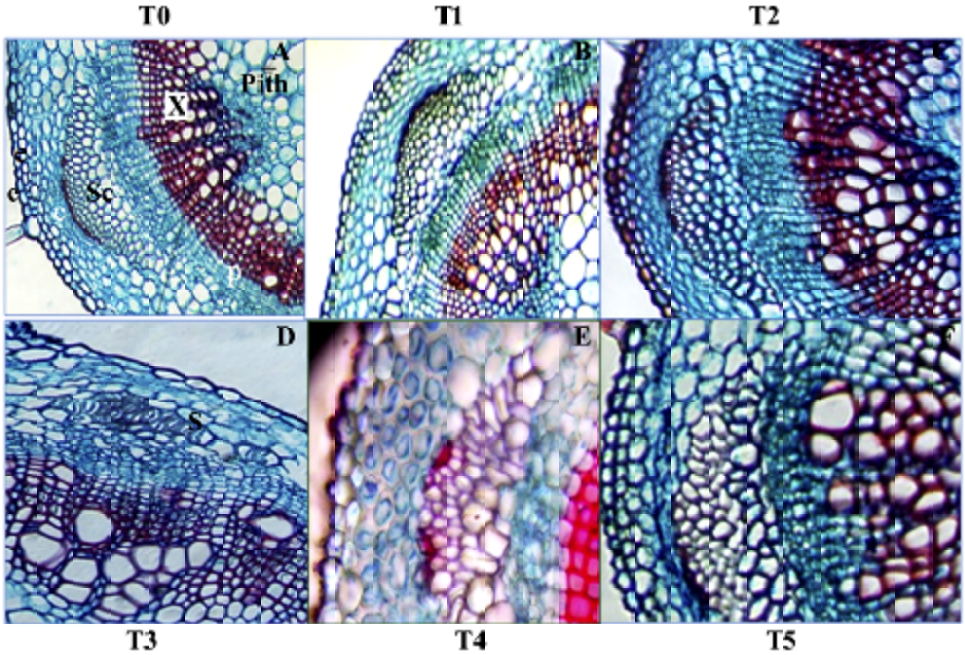


Fig. 9. Transverse section of chickpea stem, (A) T0,Un-inoculated control (B) T1, sensitive Trichoderma, (C) T2, tolerant Trichoderma (D) T3, As alone (E) T4, sensitive Trichoderma + As (F) T5, tolerant Trichoderma + As. e - epidermis; c - cortex; sc - sclerenchymatous cells; p - phloem; x - xylem; H - healthy cells; S - shrunken cells. Magnification: AeC (10X), DeF (20X).

R&D OUTPUTS

PUBLICATIONS

Research Papers

1. Agnihotri P, Husain D and Husain T (2016) – Aconite from Sikkim Himalaya, India. ***Current Science***, **111**(6): 984-985.
2. Agnihotri P, Husain D, Katiyar P and Husain T (2016) - Notes on the typification of four Himalayan aconites. ***Kew Bulletin***, **71**(4):52.
3. Agnihotri P, Husain T, Shirke PA, Sidhu OP, Singh H, Dixit V, Khuroo AA, Amla DV and Nautiyal CS (2017) – Climate change-driven shifts in elevation and eco-physiological traits of Himalayan plants during the past century. ***Current Science***, **112**(3): 595-601.
4. Agnihotri P, Katiyar P and Husain T (2016) – Ethnobotanically important plants of Kishanpur Wildlife Sanctuary, Uttar Pradesh, India. ***Pleione***, **10**(1): 32-42.
5. Agrawal L, Gupta S, Mishra SK, Pandey G, Kumar S, Chauhan PS, Chakrabarty D and Nautiyal CS (2016) - Elucidation of complex nature of PEG induced drought-stress response in rice root using comparative proteomics approach. ***Frontiers in Plant Science***, **7**: 1466.
6. Anand KK, Jena SN, Chaudhary LB, Singh M (2016) - Conflict between morphological and molecular data: A case study in *Ficus krishnae* DC. (Moraceae). ***Phytotaxa***, **247**(2):143–147.
7. Anjali DB, Mohabe S, Nayaka S and Reddy AM (2016) – *In-vitro* antimicrobial activity of lichen *Ramalina conduplicans* Vain. collected from Eastern Ghats, India. ***Science Research Reporter***, **6**(2): 99-108.
8. Ansari A, Sikarwar PS, Lade S, Yadav HK and Ranade SA (2016) - Genetic diversity clusters in germplasm of cluster bean (*Cyamopsis tetragonoloba* L., Taub), an important food and an industrial legume crop. ***Journal of Agricultural Science and Technology***, **18**(5): 1407-1418**.**
9. Anwar MS, Kapri A, Chaudhry V, Mishra A, Ansari MW, Souche Y, Nautiyal CS, Zaidi MG and Goel R (2016) - Response of indigenously developed bacterial consortia in progressive degradation of polyvinyl chloride. ***Protoplasma***, **253**(4): 1023-1032.
10. Arora D, Siddiqui MH, Sharma PK, Singh SP, Tripathi A, Mandal P, Singh US, Singh PK and Shukla Y (2016) - Evaluation and physiological correlation of plasma proteomic fingerprints for deltamethrin-induced hepatotoxicity in Wistar rats. ***Life sciences***, **160**: 72-83.
11. Asthana AK and Omar I (2016) – *Archidium acanthophyllum* Snider, a new record to moss flora of India. ***Phytotaxonomy***, **16**(1): 38-41.
12. Asthana AK and Priyanshu S (2016) – Three Mosses New to Bryoflora of Eastern Ghats. ***Cryptogam Biodiversity and Assessment*** **1**(1): 64-70.
13. Asthana AK, Srivastava P and Omar I (2016) – New national and regional bryophyte records: *Brotherella harveyana* (Mitt.) Dixon, *Syntrichia norvegica* F. Weber. ***Journal of Bryology***, **38**(1): 48-57.
14. Azmi L, Gupta SS, Shukla I, Kant P, Upreti DK and Rao ChV (2016) - Gastro protective effects of *Usnea longissima* metabolites on probiotic *Lactobacillus casei*. ***International Journal of Pharmacognosy***, **3**(3): 140-148.
15. Bajpai O, Pandey J and Chaudhary LB (2016) - Ethnomedicinal uses of tree species by Tharu Tribes in the Himalayan Terai Region of India. ***Research Journal of Medicinal Plant***, **10**(1): 19-41.
16. Bajpai O, Pandey J and Chaudhary LB (2016) - Periodicity of different phenophases in selected trees from Himalayan Terai of India. ***Agroforestry Systems***, **91**(2): 363-374.
17. Bajpai R, Mishra S, Dwivedi S and Upreti DK (2016) – Change in atmospheric deposition during last half century and its impact on lichen community structure in Eastern Himalaya. ***Scientific Reports***, **6**: 30838.
18. Bajpai R, Singh CP, Shukla P and Upreti DK (2016) – Preliminary lichenometric studies in eastern and north-western Himalaya. ***Journal of the Geological Society of India***, **87**: 535-538.
19. Baruah R, Mishra SK, Kalita DJ, Silla Y, Chauhan PS, Singh AK and Deka Boruah HP (2017) - Assessment of bacterial diversity associated with crude oil-contaminated soil samples from Assam. ***International Journal of Environment Science and Technology***, 1-18.
20. Bauddh K, Kumar A, Srivastava S, Singh RP and Tripathi RD (2016) - A study on the effect of cadmium on the antioxidative defense system and alteration in different functional groups in castor bean and Indian mustard. ***Archives of Agronomy and Soil Science***, **62**(6): 87-91.
21. Behera SK, Sahu N, Mishra AK, Bargali SK, Behera MD and Tuli R (2017) – Aboveground biomass and carbon stock assessment in Indian tropical deciduous forest and relationship with stand structural attributes. ***Ecological Engineering***, **99**: 513-524.
22. Bhambhani S, Lakhwani D, Shukla T, Pandey A, Dhar YV, Asif MH and Trivedi PK (2017) – Genes encoding members of 3-hydroxy-3-methylglutaryl coenzyme A reductase (HMGR) gene family from *Azadirachta indica* and correlation with azadirachtin biosynthesis. ***Acta Physiologiae Plantarum***, **39**(2): 65.
23. Bhardwaj A, Dhar YV, Asif MH and Bag SK (2016) - *In Silico* identification of SNP diversity in cultivated and wild tomato species: insight from molecular simulations. ***Scientific Reports***, **6**: 38715.
24. Bharti N, Barnawal D, Wasnik K, Tewari SK and Kalra A (2016) - Co-inoculation of *Dietzia natronolimnaea* and *Glomus intraradices* with vermicompost positively influences *Ocimum basilicum* growth and resident microbial community structure in salt affected low fertility soils. ***Applied Soil Ecology***, **100**: 211-225.
25. Bhat M, Goni R, Verma S and Upreti DK (2016) – New additions to lichen flora of Jammu and Kashmir state

(India). ***Tropical Plant Research***, **3**(1): 157-161.

26. Bhatia A, Meena B, Shukla SK, Sidhu OP, Upreti DK, Mishra S, Roy R and Nautiyal CS (2017) - Determination of pentacyclic triterpenes from *Betula utilis* by High Performance Liquid Chromatography and High Resolution Magic Angle Spinning Nuclear Magnetic Resonance Spectroscopy. ***Analytical letters***, **50**(1): 233-242.
27. Chandra LR, Gupta S, Pande V and Singh N (2016) - Impact of forest vegetation on soil characteristics: a correlation between soil biological and physico-chemical properties. ***3 Biotech***, **6**(2):188.
28. Chandra P, Kannujia R, Saxena A, Srivastava M, Bahadur L, Pal M, Singh BP, Ojha SK and Kumar B (2016) – Quantitative determination of multi markers in five varieties of *Withania somnifera* using ultra-high performance liquid chromatography with hybrid triple quadrupole linear ion trap mass spectrometer combined with multivariate analysis: Application to pharmaceutical dosage forms. ***Journal of Pharmaceutical and Biomedical Analysis***, **129**: 419–426.
29. Chandrawati, Singh N, Kumar R, Kumar S, Singh PK, Yadav VK, Ranade SA and Yadav HK (2017) - Genetic diversity, population structure and association analysis in linseed (*Linum usitatissimum* L.). ***Physiology and Molecular Biology of Plants***, **23**: 207-219.
30. Chandrawati, Singh N, Yadav VK, Kumar R, Kumar S and Yadav HK (2016) - Genetic variability and interrelationship among morphological and yield traits in linseed *(Linum usitatissimum* L.). ***Genetika***, **48**(3): 881 – 892.
31. Choudhury MP, Sarma M and Nayaka S (2016) – A preliminary study on lichens of ancient historical ruins of Bamuni Hills, Tezpur, Assam, North-east India. ***The Bioscan***, **11**(3): 1493-1496.
32. Choudhury MP, Sarma M, Nayaka S and Upreti DK (2016) – Distribution of lichens on few ancient monuments of Sonitpur district, Assam, North East India. ***International Journal of Biodiversity and Conservation***, **8**(11): 291-296.
33. Cottee-Jones HEW, Bajpai O, Chaudhary LB and Whittaker RJ (2016) - The importance of *Ficus* (Moraceae) trees for tropical forest restoration. ***Biotropica***, **48**(3): 413-419.
34. Deeba F, Pandey AK and Pandey V (2016) - Organ specific proteomic dissection of *Selaginella bryopteris* undergoing dehydration and rehydration. ***Frontiers in Plant Science***, **7**: 425.
35. Dixit RB, Patel AK, Toppo K and Nayaka S, 2017 – Emergence of toxic cyanobacterial species in the Ganga River, India, due to excessive nutrient loading. ***Ecological Indicators***, **72**: 420-427.
36. Dixit V, Irshad S, Singh H, Agnihotri P, Husain T, and Khatoon S (2017) – High-Performance Thin-Layer Chromatographic determination of three therapeutic phenolic components in *Leucas* Species. ***JPC- Journal of Planar Chromatography- Modern TLC***, **30**(1): 25–31.
37. Ellis L, Asthana AK and Srivastava P *et al*., (2016) – New national and regional bryophyte records 46. **Journal of Bryology**, **38**(1): 47-63.
38. Ellis LT, Alatas M and Asthana AK *et al*., (2016) – New national and regional bryophyte records 47. **Journal of Bryology**, **38**(2): 151-167.
39. Ellis LT, Aleffi M, Alegro A, Segota V, Asthana AK, Gupta R, Singh VJ et al. (2016) - New national and regional bryophyte records, 48. ***Journal of Bryology***, **38**(3): 235-259.
40. Fatima N, Ahmad MK, Ansari JA, Khan HJ, Rastogi N, Srivastava SK, Ahmad S and Ali Z (2016) – Antiproliferative and antioxidant studies of *Anthocephalus cadamba* (Roxb.) Miq. Bark. ***Indian Journal of Pharmaceutical Sciences***, **78**(4): 525-531.
41. Gautam A, Rao ChV, Paswan SK and Verma P (2017) - Poisonous Plant *(Gloroisa superb L.*): Its Pharmacological and therapeutic profile. ***Elixir – Applied Botany***, **104**: 45969-45972.
42. Gautam A, Verma P, Paswan SK, Shukla I and Rao ChV (2017) - Antihyperlipidemic activity of ethanolic extract of *Amorphophallus paeoniifolius* tuber in triton wr 1339 induced hyperlipidemic rats. ***International Journal of Pharmacognosy***, **4**(1): 15-22.
43. Gunapati S, Naresh R, Ranjan S, Nigam D, Hans A, Verma PC, Gadre R, Pathre UV, Sane AP and Sane VA (2016) - Expression of GhNAC2 from G. herbaceum, improves root growth and imparts tolerance to drought in transgenic cotton and *Arabidopsis*. ***Scientific Reports***, **6**: 24978.
44. Gupta P, Suman S, Mishra M, Mishra S, Srivastava N, Kumar V, Singh PK and Shukla Y (2016) - Autoantibodies against TYMS and PDLIM1 proteins detected as circulatory signatures in Indian breast cancer patients. ***Proteomics- Clinical Applications***, **10**(5): 564-573.
45. Gupta R (2016) – Genus *Schwetschkeopsis* Broth. (Bryophyta): new addition to Central India. ***Cryptogam Biodiversity and Assessment***, **1**(2): 83-87.
46. Gupta R and Asthana AK (2016) – Diversity and distribution of liverworts across habitats and altitudinal gradient at Pachmarhi Biosphere Reserve (India). ***Plant Science Today***, **3**(4): 354-359.
47. Gupta R, Asthana AK and Singh VJ (2016) – New national and regional bryophyte records: *Brachythecium rivulare* Schimp., *Oxyrrhynchium hians* (Hedw.) Loeske. ***Journal of Bryology***, **38**(3): 237.
48. Gupta R, Nath V and Asthana AK (2016) – Genus *Brachymenium* at Pachmarhi Wildlife Sanctuary, (M.P.) India. ***Tropical Plant Research***, **3**(2): 283-288.
49. Gupta R, Nath V and Asthana AK (2016) – Present status of family Dicranaceae (Bryophyta) in Pachmarhi Wildlife Sanctuary, Central India. ***Taiwania***, **61**(3): 253-259.
50. Gupta SS, Azmi L, Mohapatra PK and Rao ChV (2017) – Flavonoids from whole plant of *Euphorbia hirta* and their evaluation against experimentally induced gastro-esophageal reflux disease in rats. ***Pharmacognosy Magazine***, **13**(49): 127-134.

51. Gupta SS, Azmi L, Shukla I, Pal L, Mohaptra PK and Rao ChV (2016) – *Serpyllifolia* leaves extract on streptozotocin-induced diabetic rats. ***International Journal of Pharmacognosy***, **3**(8): 346-353.

52. Husain D, Katiyar P, Agnihotri P and Husain T (2016) - Lectotypification of Two names in *Omphallogramma* Franchet (Primulaceae). ***Phytotaxa***, **280**(3): 297-300.

53. Husain D, Katiyar P, Agnihotri P and Husain T (2016) – Proposal to add a new paragraph to Recommendation 9A. ***Taxon***, **65**(2):413.

54. Husain D, Katiyar P, Agnihotri P and Husain T (2016) – Proposals to add the term lectoparatype to the Code. ***Taxon***, **65**(2): 410-411.

55. Husain D, Katiyar P, Agnihotri P and Husain T (2016) – Three more proposals on typification and the definition of a gathering. ***Taxon***, **65**(4): 898-899.

56. Imran M, Pant P, Shanbhag YP, Sawant SV and Ghadi SC (2017) – Genome Sequence of *Microbulbifer mangrovi* DD-13(T) Reveals Its Versatility to Degrade Multiple Polysaccharides. ***Marine Biotechnology***, **19**(1): 116-124.

57. Ingle KK, Nayaka S and Suresh HS (2016) – Lichens in 50 ha permanent plot of Mudumalai Wildlife Sanctuary, Tamil Nadu, India. ***Tropical Plant Research***, **3**(3): 694-700.

58. Ingle KK, Trivedi S, Nayaka S and Upreti DK (2017) – The lichen genera *Dictyomeridium* and *Polymeridium* (Trypetheliales: *Trypetheliaceae*) in India. ***Taiwania***, **62**(1): 50-54.

59. Irshad S, Rawat AKS, Misra PK and Khatoon S (2016) – Authentication of commercial samples of Shankhpushpi through physicophytochemical analysis and TLC fingerprinting. ***Indian Journal of Traditional Knowledge***, **15**(4): 646-653.

60. Jain A, Mahmoudi A, Chaudhary M, Thakur R and Raina SN (2016) – Comparative chromosome morphology and physical mapping of 18S-5.8S-26S and 5S ribosomal DNA loci in diploid and newly synthesized autotetraploids of *Phlox drummondii* Hook. ***Phytomorphology***, **66**: 51-55.

61. Jha S, Agarwal S, Sanyal I and Amla DV (2016) – Single-step purification and characterization of a recombinant serine proteinase inhibitor from transgenic plants. ***Applied Biochemistry and Biotechnology***, **179**: 220-236.

62. Johari D and Singh AP (2017) - A new taxonomic circumscription of *Selaginella ciliaris* (Selaginellaceae) from Terrai regions of Uttar Pradesh. ***National Academy Science Letters***, **40**(1):61-66.

63. Joshi S and Upreti DK (2016) – Lichens of the Western Ghats new to India. ***Current Research in Environvironmental & Applied Mycology***, **6**(4): 328-333.

64. Kashyap AK, Bahadur L and TewariSK (2017) – Integrated nutrient management of in Oat (*Avena sativa* L.) under reclaimed sodic soil. ***Indian Journal of Agricultural Research***, **51**(1):78-81.

65. Khan F, Upreti P, Singh R, Shukla PK and Shirke PA (2017) – Physiological performance of two contrasting rice varieties under water stress. **Physiology and *Molecular Biology of Plants***, **23**(1): 85–97.

66. Khatoon S (2017) – A Novel Histological Approach for Identification of Alkaloid Bearing Plants. ***International Journal of Botany***, **13**(1): 28-36.

67. Khatoon S, Singh S, Singh AP, Singh N and Rawat AKS (2016) – Chemical evaluation of different parts of *Juglans regia* L. and simultaneous determination of important polyphenols by thin layer chromatography. ***International Journal of Research in Pharmacy and Chemistry***, **6**(4): 773-781.

68. Khuraijam JS and Roy RK (2016) – Indian *Cycas* under severe threat. ***Current Science***, **111**(11): 1756-1758.

69. Kondratyuk SY, Lokos L, Halda JP, Roux C, Upreti DK, Schumm F, Mishra GK, Nayaka S, Farkas E, Park JS, Lee BG, Liu D, Woo JJ, Hur JS (2017) – New and noteworthy lichens-forming and lichenicolous fungi 6. ***Acta Botanica Hungarica***, **59**(1-2): 137-260.

70. Kondratyuk SY, Lokos L, Halda JP, Upreti DK, Mishra GK, Moniri MH, Farkas E, Park JS, Lee BG, Liu D, Woo JJ, Layalal RGU, Oh SO and Hur JS (2016) – New and noteworthy lichen-forming and lichenicolous fungi. ***Acta Botanica Hungarica***, **58**(3-4): 319-396.

71. Kondratyuk SY, Lokos L, Upreti DK, Nayaka S, Mishra GK, Ravera S, Jeong MH, Jang SH, Park JS and Hur JS (2017) – New monophylectic branches on the teloschistaceae (Lichen-forming ascomycota) proved by three gene phylogeny. ***Acta Botanica Hungarica***, **59**(1-2):71-136.

72. Kumar A, Dixit G, Singh AP, Dwivedi S, Srivastava S, Mishra K and Tripathi RD (2016) - Selenate mitigates arsenite toxicity in rice (*Oryza sativa* L) by reducing arsenic uptake and ameliorates amino acid content and thiol metabolism. ***Ecotoxicology and Environmental Safety***, **133**:350-359.

73. Kumar B, Shukla P, Niranjan A, Misra A, Srivastava S and Rawat AKS (2017) – Simultaneous RP-HPLC quantification of four phenolic compounds along with pharmacognostic and pharmacological investigations in *Biophytum sensitivum* DC. ***Indian Journal of Traditional Knowledge***, **16**(2): 319-324.

74. Kumar P, Mandotra SK, Suseela MR, Toppo K and Joshi P (2016) – Characterization and transesterification of fresh water microalgal oil. ***Energy Sources, Part A: Recovery, Utilization, and Environmental Effects***, **38**(6): 857-864.

75. Kumar R, Toppo K. Mandotra SK, Suseela MR, Seth MK, Minhas U, Kesherwani R, Swati PG (2016) – Quantitative analysis and first report of *Euglena tuba* from Himachal Pradesh, India. ***International Journal of Science and Research***, **5**(12): 1336-1339.

76. Kumar S, Jaidi M and Raj SK (2016) - Molecular characterization of a Begomovirus and Betasatellite infecting wild sunflower (*Helianthus* spp.) in India. ***Virology Research Journal***, **1**(1):1-9.

77. Kumar S, Singh A, Bajpai V, Srivastava M, Singh S, Ojha S and Kumar B (2016) – Simultaneous determination of

bioactive monoterpene indole alkaloids in ethanolic extract of seven *Rauvolfia* Species using UHPLC with Hybrid Triple Quadrupole linear ion trap mass spectrometry. ***Phytochemical Analysis***, **27**(5): 296-300.

78. Kumar S, Srivastava A, Jaidi M, Chauhan PS and Raj SK (2016) - Molecular characterization of a *Begomovirus*, a-satellite, and b-satellite associated with leaf curl disease of *Parthenium hysterophorus* in India. ***Plant Disease***, **100**: 1-7.
79. Kumar S, Verma S and Trivedi PK (2017) – Involvement of Small RNAs in Phosphorus and Sulfur Sensing, Signaling and Stress: Current Update. ***Frontiers in Plant Science***, **8**: 285.
80. Kumari A, Lal B and Rai UN (2016) - Assessment of native plant species for phytoremediation of heavy metals growing in the vicinity of NTPC sites, Kahalgaon, India. ***International Journal of Phytoremediation***, **18**(6): 592-597.
81. Kumari A, Raj R, Kumar S, Chauhan PS and Raj SK (2016) - Coexistence of three virus genera (*Badnavirus*, *Potyvirus* and *Cucumovirus*) in *Canna* species in India. ***Annals of Virology and Research***, **2**(1): 1008.
82. Kumari B and Singh DP (2016) - A review on multifaceted application of nanoparticles in the field of bioremediation of petroleum hydrocarbons. ***Ecological Engineering***, **97**: 98-105.
83. Kumari B, Singh SN and Singh DP (2016) - Induced degradation of crude oil mediated by microbial augmentation and bulking agents. ***International Journal of Environmental Science and Technology***, **13**(4): 1029-1042.
84. Kumari M, Mishra A, Pandey S, Singh SP, Chaudhry V, Mudiam MKR, Shukla S, Kakkar P and Nautiyal CS (2016) - Physico-chemical condition optimization during biosynthesis lead to development of improved and catalytically efficient gold nano particles. ***Scientific Reports***, **6**: 27575.
85. Kumari M, Shukla S, Pandey S, Giri VP, Bhatia A, Tripathi T, Kakkar P, Nautiyal CS and Mishra A (2017) – Enhanced cellular internalization: A bactericidal mechanism more relative to biogenic nanoparticles than chemical counterparts. ***ACS Applied Materials & Interfaces***, **9**(5): 4519-4533.
86. Lone JA, Lone FA, Suseela MR and Toppo K (2016) - Phycological studies in Himalayan Dal Lake ecosystem: Seasonal composition and role of physic-chemical parameters. ***International Journal of Current Research***, **8**(5): 30147-30155.
87. Lucking R, Nelsen MP, Aptroot A, Benatti MN, Binh NQ, Gueidan C, Gutierrez MC, Jungbluth P, Lumbsch HT, Marcelli MP, Moncada B, Naksuwankul K, Orozco T, Salazar-Allen N, Upreti DK (2016) – A pot-pourri of new species of Trypetheliaceae resulting from molecular phylogenetic studies. ***The Lichenologist***, **48**(6): 639-660.
88. Mahfooz S, Singh SP, Rakh R, Bhattacharya A, Mishra N, Singh PC, Chauhan PS, Nautiyal CS and Mishra A (2016) - A comprehensive characterization of simple sequence repeats in the sequenced *Trichoderma* genomes provides valuable resources for marker development. ***Frontiers in Microbiology***, **7**: 575.
89. Maurya R and Yadav HK (2016) - Development of interspecific hybrid of *J. curcas x J. integerrima* and its molecular characterization using SSR markers. ***Journal of Agroecology and Natural Resource Management***, **3**(1): 101-105.
90. Meena B, Tiwari V, Singh N,Mahar KS, Sharma YK and Rana TS (2016) **–** Estimation of genetic variability and population structure in *Ephedra gerardiana* Wall. ex Stapf (Ephedraceae) :An endangered and endemic high altitude medicinal plant. ***Agri Gene***, **1**: 116-125**.**
91. Mishra BK, Mishra R, Jena SN and Shukla S (2016) – Gene actions of yield and its attributes and their implications in the inheritance pattern over three generations in Opium Poppy (*Papaver somniferum* L.). ***Joumal of Genetics***, **95**(3): 705-717.
92. Mishra MK, Srivastava M, Singh G, Tiwari S, Niranjan A, Kumari N and Misra P (2016) - Overexpression of *Withania somnifera* SGTL1 gene resists the interaction of fungus *Alternaria brassicicola* in *Arabidopsis thaliana*. ***Physiological and Molecular Plant Pathology***, **97**: 11-19.
93. Mishra S, Afeld M, Sobotka R, Andresen E, Falkenberg G and Küpper H (2016) - Analysis of sublethal arsenic toxicity to *Ceratophyllum demersum*: subcellular distribution of arsenic and inhibition of chlorophyll biosynthesis. ***Journal of Expterimental Botany***, **67**(15): 4639-4646.
94. Mishra S, Dwivedi S, Kumar A, Chauhan R, Awasthi S, Mattusch J and Tripathi RD (2016) - Current status of ground water arsenic contamination in India and recent advancements in removal techniques from drinking water. ***International Journal of Plant and Environment***, **2**(1-2): 1-15.
95. Mishra S, Joshi S, Upreti DK and Srivastava AK (2016) – An updated account on graphidoid taxa from the foot hills of Indian Himalaya. ***Current Research in Environmental & Applied Mycology***, **6**(4): 312-327.
96. Mishra S, Mattusch J and Wennrich R (2017) - Accumulation and transformation of inorganic and organic arsenic in rice and role of thiol-complexation to restrict their translocation to shoot. ***Scientific Reports***, **7**: 40522.
97. Mishra SK, Khan MH, Misra S, Dixit VK, Khare P, Srivastava S and Chauhan PS (2016) – Characterisation of *Pseudomonas* spp. and *Ochrobactrum* sp. isolated from volcanic soil. ***Antonie van Leeuwenhoek International Journal of General and Molecular Microbiology***, **110**: 253-270.
98. Mishra T, Arya RK, Meena S, Joshi P, Pal M, Meena B, Upreti DK, Rana TS and Datta DD (2016) – Isolation, characterization and anticancer potential of cytotoxic triterpenes from *Betula utilis* bark. ***PLoS One***, **11**(7): e0159430.

99. Mishra T, Srivastava M, Kumar A, Pal M and Tewari SK (2017) – Chemical composition and termiticidal activity of *Artemisia nilagirica*, essential oil growing in southern hilly regions of India. ***Journal of Essential Oil Bearing Plants***, **20**(1): 247-252.

100. Misra A, Srivastava A, Srivastava S and Rawat AKS (2016) - Simultaneous reverse-phase HPLC determination of major antioxidant phenolics in *Commelina benghalensis* L. tubers. ***Acta Chromatographica***, **28**(4): 541-554.

101. Misra A, Srivastava S, Srivastava P and Rawat AKS (2016) – Chemotaxonomic variation in forskolin content and its correlation with eco-geographical factors in natural habitat of *Coleus forskohlii* Briq. collected from Vidarbha (Maharashtra, India). ***Industrial Crops and Products***, **84**: 50-58.

102. Misra S, Srivastava AK, Verma S, Pandey S, Bargali SS, Rana TS and Nair KN (2016) – Phenetic and genetic diversity in Indian *Luffa* (Cucurbitaceae) inferred from morphometric, ISSR and DAMD markers. ***Genetic Resources and Crop Evolution***, **64**: 995-1010.

103. Mohabe S, Anjali DB, Nayaka S and Reddy AM (2016) – New species and new records of *Graphis* (Ostropales: Graphidaceae) from Eastern Ghats, India. ***Tropical Plant Research***, **3**(3): 611–615.

104. Naik P, Nair A, Nayaka S and Sajankila SP (2016) – Antimutagenic activity of ethanolic extract of *Roccella montagnei* against sodium azide – An *in vitro* study. ***Cryptogam Biodiversity and Assessment***, **1**(2): 89-92.

105. Nainwal RC, Katiyar RS, Singh D and Tewari SK (2016) – Genetic studies in relation to improvement of gladiolus grown in partially reclaimed sodic soil. ***Indian Journal of Horticulture***, **73**(3): 396-399.

106. Nainwal RC, Singh D, Katiyar RS, Tripathi SS, Sharma SK, Singh S, Sharma LK, Chaturvedi V and Tewari SK (2016) – Rehabilitation of sodic waste land through agro-forestry system. ***International Journal of Plant and Environment***, **2**(1-2): 29-35.

107. Narzary D, Ranade SA, Divakar PK and Rana TS (2016) – Molecular differentiation and phylogenetic relationship of the genus *Punica* (Punicaceae) with other taxa of the order Myrtales. ***Rheedea***, **26**(1): 37- 51.

108. Pal M, Mishra T, Kumar A and Tewari SK (2016) - Biological evaluation of terrestrial and marine plant originated labdane diterpenes (A Review). ***Pharmaceutical Chemistry Journal***, **50**(8): 558-567.

109. Pandey A, Alok A, Lakhwani D, Singh J, Asif MH and Trivedi PK (2016) - Genome-wide expression analysis and metabolite profiling elucidate transcriptional regulation of flavonoid biosynthesis and modulation under abiotic stresses in banana. ***Scientific reports***, **6**: 31361.

110. Pandey MM, Khatoon S, Rastogi S and Rawat AKS (2016) – Determination of flavonoids, polyphenols and antioxidant activity of *Tephrosia purpurea*: a seasonal study. ***Journal of Integrative Medicine***, **14**(6): 447-455.

111. Pandey N, Kumar A, Niranjan A, Lehri A, Meena B, Rana TS, Tewari SK and Upreti DK (2016) – Biochemical composition of *Betula utilis* D. Don bark, collected from high altitude of Indian Himalayas. ***Medicinal Plants-International Journal of Phytomedicines and Related Industries***, **8**(1): 33-39.

112. Pandey S, Rana TS and Nair KN (2016) - Revision of the *Trichosanthes tricuspidata - bracteata* complex (Cucurbitaceae) in India. ***Rheedea***, **26**(2): 83-93.

113. Pandey SP, Srivastava S, Goel R, Lakhwani D, Singh P, Aisf MH and Sane AP (2017) – Simulated herbivory in chickpea causes rapid changes in defense pathways and hormonal transcription networks of JA/ethylene/GA/ auxin within minutes of wounding. ***Scientific Reports***, **7**: 44729.

114. Pandey VC (2016) - Phytoremediation efficiency of *Eichhornia crassipes* in fly ash pond. ***International Journal of Phytoremediation***, **18**(5): 450-452.

115. Pandey VC, Bajpai O and Singh N (2016) - Plant regeneration potential in fly ash ecosystem. ***Urban Forestry & Urban Greening***, **15**: 40-44.

116. Pandey VC, Sahu N, Behera SK and Singh N (2016) - Carbon sequestration in fly ash dumps: comparative assessment of three plant association. ***Ecological Engineering***, **95**: 198-205.

117. Pathak A, Upreti DK and Dikshit A (2016) – Antidermatophytic activity of the fruticose lichen *Usnea orientalis*. ***Medicines***, **3**(24): 1-6.

118. Pathak AK, Singh V, Pal M, Mishra T, Gupta VS and Goel K (2017) - Evaluation of topical application of Vajradanti gel in prevention of gingivitis. ***Open Journal of Stomatology***, **7**(2): 105-112.

119. Pattanayak R, Misra G, Rout PK, Chanotiya CS and Mohanty CS (2016) - Semiochemical profile of four Indian Coccinellidae (*Coleoptera*). ***The Canadian Entomologist***, 2016, **148**(2): 171-186.

120. Ponmurugan P, Ayyappadasan G, Verma RS and Nayaka S (2016) - Survey, distribution pattern and elemental composition of lichens in Yercaud hills of Eastern Ghats in southern India. ***Journal of Environmental Biology***, **37**(3): 407.

121. Poonam, Upadhyay MK, Gautam A, Mallick S and Srivastava S (2017) – A successive application approach for effective utilization of three aquatic plants in arsenic removal. ***Water, Air, & Soil Pollution***, **228**(2): 54.

122. Prasad MG, Roy RK and Sunojkumar P (2017) – Re-establishment of the overlooked species *Torenia godefroyi* (Linderniaceae), and notes on the identity of *T. lindernioides*. ***Nordic Journal of Botany***, **35**(1): 45-47.

123. Prateeksha, Singh BR, Shoeb M, Sharma S, Naqvi AH, Gupta VK and Singh BN (2017) – Scaffold of selenium nanovectors and honey phytochemicals for inhibition of *Pseudomonas aeruginosa* quorum sensing and biofilm formation. ***Frontiers in cellular and infection microbiology***, **7**: 93.

124. Rai A, Singh AK, Ghosal N and Singh N (2016) - Understanding the effectiveness of litter from tropical dry forests for the restoration of degraded lands. ***Ecological Engineering***, **93**: 76-81.

125. Rai A, Singh AK, Pandey VC, Ghosal N and Singh N (2016) - The importance of *Butea monosperma* for the restoration of degraded lands. ***Ecological Engineering***, **97**: 619-23.

126. Rajaram SK, Innasimuthu GM, Alexander RA, Varghese R, Munusamy M, Nayaka S and Upreti DK (2016) - Antioxidant activity of lichen *Parmotrema austrosinense* and its antimicrobial effect on selected plant pathogens. ***Cryptogam Biodiversity and Assessment***, **1**(2): 70-75.

127. Rawat KK, Alam A and Verma PK (2016) – Checklist of mosses (Bryophyta) of Gangetic Plains, India. ***Bangladesh Journal of Plant Taxonomy***, **23**(2): 97-106.

128. Rawat KK, Asthana AK and Sahu V (2016) – *Gymnomitrion crenatilobum* Grolle (Marchantiophyta: Gymnomitriaceae): A rare liverwort, new to India. ***Cryptogamie Bryologie***, **37**(3): 291–293.

129. Rawat KK, Sahu V and Asthana AK (2016) – New national and regional bryophyte records: *Splachnum sphaericum* Hedw. ***Journal of Bryology***, **38**(1): 57.

130. Rawat KK, Sahu V and Asthana AK (Ellis LT et al.) (2017) – New national and regional bryophyte records: *Lophozia ventricosa* (Dicks.) Dumort. var. *ventricosa*. ***Journal of Bryology***, **39**(1): 8.

131. Rawat KK, Sahu V, Verma PK and Asthana AK (2016) – *Kurzia trichoclados* (Lepidoziaceae, Marchantiophyta) – A disjunct liverwort newly reported for India. ***Phytotaxa***, **261**(3): 287-290.

132. Rawat P, Saroj LM, Kumar A, Singh TD, Tewari SK and Pal M (2016) – Phytochemicals and cytotoxicity of *Launea procumbens* on human cell lines. ***Pharmacognosy Magazine***, **12**(Suppl 4): S431-435.

133. Roy RK and Singh S (2016) – Migration and domestication of Bougainvillea: A historical review. ***Chronica Horticulturae***, **56**(2): 10-15.

134. Sahai K, Rawat KK and Gupta D (2016) – A note on precocious pollen germination in *Woodfordia fruticosa* (L.) Kurz. ***Tropical Plant Research***, **3**(3): 606-610.

135. Sahu V and Asthana AK (2016) – Mosses of Govind wild life sanctuary, Uttarakhand, Western Himalaya, India. ***Geophytology***, **46**(2): 147-155.

136. Sardar SS, Pradhan K, Shukla RP, Saraswat R, Srivastava A, Jena SN and Das AB (2016) - *In silico* mining of EST-SSRs in *Arachis hypogaea* L. and their utilization for genetic structure and diversity analysis in Odisha-wide cultivars/breeding lines. ***Molecular Breeding***, **36**(4): 49.

137. Sardar SS, Pradhan K, Shukla RP, Saraswat R, Srivastava A, Jena SN and Das AB (2016) - In silico mining of EST-SSRs in *Arachis hypogaea* L. and their utilization for genetic structure and diversity analysis in cultivars/breeding lines in Odisha, India. ***Molecular Breeding***, **36**(4): 49.

138. Saroj LM, Rawat P, Neetu, Kumar A, Tewari SK, Singh R and Pal M (2016) – Pharmacological evaluation for anti-obesity activity of the crude extracts of *Tamarindus indica* (Leguminosae) in high fat diet induced obese rats. ***International Journal of Scientific and Innovative Research***, **4**(1): 145-160.

139. Saxena SC, Nainwal RC and Singh D (2016) – Evaluation of integrated nutrient management practices for soybean based cropping systems in Uttrakhand. ***Progressive Research***, **11** (Sp-VIII): 5432-5434.

140. Sharma D, Tiwari M, Pandey A, Bhatia C, Sharma A and Trivedi PK (2016) - MicroRNA858 is a potential regulator of phenylpropanoid pathway and plant development in Arabidopsis. ***Plant Physiology***, **171**: 944-959.

141. Sheik MA, Raina AK and Upreti DK (2016) – Lichens: Enshrouding the bare rocks in Pappad area of Samba district, Jammu & Kashmir. ***International Journal of Current Research and Review***, **8**(10): 29-32.

142. Shivhare R and Lata C (2016) – Exploration of genetic and genomic resources for abiotic and biotic stress tolerance in Pearl Millet. ***Frontiers in Plant Science***, **7**: 2069.

143. Shukla AK, Upadhyay SK, Mishra M, Saurabh S, Singh R, Singh H, Thakur N, Rai P, Pandey P, Hans AL, Srivastava S, Rajapure V, Yadav SK, Singh MK, Kumar J, Chandrashekar K, Verma PC, Singh AP, Nair KN, Bhadauria S, Wahajuddin M, Singh S, Sharma S, Omkar, Upadhyay RS, Ranade SA, Tuli R and Singh PK (2016) – Expression of an insecticidal fern protein in cotton protects against whitefly. ***Nature Biotechnology***, **34**(10): 1046-1051.

144. Shukla I, Azmi L, Gupta SS, Kant P and Rao ChV (2016) - Performance Enhancing Traditional Medicines in Sports. ***The Pharma Review***, **4**(4) 124-131.

145. Shukla PK, Misra A, Srivastava S and Rawat AKS (2016) – Reversed phase High-performance liquid chromatographic ultra-violet (Photo Diode Array) quantification of oleanolic acid and its isomer ursolic acid for phytochemical comparison and pharmacological evaluation of four *Leucas* species used in Ayurveda. ***Pharmacognosy Magazine***, **12**(46), S2: S159-S164.

146. Shukla PK, Misra A, Kumar M, Rajan S, Agrawal PK, Rawat AKS and Srivastava S (2016) – Intra-specific chemotypic variability of forskolin content in *Coleus forskohlii* (Willd.) Briq. growing in Nilgiri hills of India. ***JPC-Journal of Planar Chromatography***, **29**(5): 347–355.

147. Shukla S, Hegde S, Kumar A, Chaudhary G, Tewari SK, Upreti DK and Pal M (2017) – Chemical composition and antibacterial activity of essential oil from leaves of *Justicia adhatoda* methicillian resistant and sensitive strain along with their clinical isolates. ***Journal of Essential Oil Bearing Plants***, **20**(1): 116-122.

148. Shukla S, Maurya KN, Mishra BK and Rastogi A (2016) – Identification of heterotic crosses based on the combining ability of novel genotypes in opium poppy *(Papaver somniferum* L.). ***Russian Agricultural Sciences***, **42**(2): 137-143.

149. Shukla S, Mishra T, Pal M, Meena B, Rana TS and Upreti DK (2016) – Comparative analysis of fatty acids and antioxidant activity of *Betula utilis* bark collected from different geographical regions of India. ***Free Radicals and Antioxidants***, **7**(1): 80-85.

150. Siddiqui A, Shukla S, Rastogi A, Bhargava A, Niranjan A and Lehri A (2016) - Relationship among phenotypic and quality traits in indigenous and exotic accessions of linseed. ***Pesquisa Agropecuária Brasileira***, **51**(12): 1964-1972.

151. Sinam G, Sahu V, Pandey N and Asthana AK (2016) - Effect of Arsenic on Biochemicals and antioxidant enzymes in two species of *Marchantia* L. (Marchantiophyta): Role of enzymes in stress acclimatization. ***Journal of Environmental and Agricultural Sciences***, **8**:79–85.

152. Singh AK, Rai A and Singh N (2016) - Effect of long term land use systems on fractions of glomalin and soil organic carbon in the Indo-Gangetic plain. ***Geoderma***, **277**: 41-50.

153. Singh AP and Johari D (2016) - *Hymenophyllum javanicum* Spreng: An Addition to the Pteridophytic Flora of Central India. ***Proceedings of the National Academy of Sciences, India Section B: Biological Sciences***, p.1-7.

154. Singh AP, Johari D and Khare PB (2017) - Studies on Ontogeny and reproductive behavior of *Lepisorus nudus* (Hook.) Ching. (Polypodiaceae). ***Journal of Plant Research***, **130**(2): 281-290.

155. Singh CP, Bajpai R, Singh RP, Upreti DK (2016) – Improving bioclimatic envelop modeling for lichen through remote sensing based substratum correction: A study over Indian Himalaya. ***Cryptogam Biodiversity and Assessment***, **1**(2): 1-19.

156. Singh D, Nainwal RC, Bahadur L and Tewari SK (2016) – Site specific nutrient management in oat (*Avena sativa* L.) under partially reclaimed sodic soil. ***Progressive Research***, **11**(Sp-VIII): 5230-5233.

157. Singh G, Tiwari M, Singh S, Singh R, Singh S, Shirke P, Trivedi PK and Misra P (2017) - Sterol glycosyltransferases required for adaptation of *Withania somnifera* at high temperature. ***Physiologia Plantarum***, **160**(3): 297-311.

158. Singh G, Tiwari M, Singh SP, Singh S, Trivedi PK and Misra P (2016) – Silencing of sterol glycosyltransferases modulates the withanolide biosynthesis and leads to compromised basal immunity of *Withania somnifera*. ***Scientific Reports***, **6**: 255-262.

159. Singh H, Srivastava A, Husain T (2016) - Lectotypification of *Thalictrum cultratum* (Ranunculaceae). ***Phytotaxa***, **289**(1): 099-100.

160. Singh N, Gupta S, Marwa N, Pandey V, Verma PC, Rathaur S and Singh N (2016) - Arsenic mediated modifications in Bacillus aryabhattai and their biotechnological applications for arsenic bioremediation. ***Chemosphere***, **164**: 524-534.

161. Singh N, Kumar R, Kumar S and Yadav HK (2016) - Study on genetic combining ability estimates for yield and related traits in linseed *(Linum usitatissiumu* L.). ***Australian Journal of Crop Science***, **11**(11): 1594-1600.

162. Singh N, Meena B, Pal AK, Roy RK, Tewari SK, Tamta S, and Rana TS (2017) - Nucleotide diversity and phylogenetic relationships among *Gladiolus* cultivars and related taxa of family Iridaceae. ***Journal of Genetics***, **96**(1): 135-145.

163. Singh N, Pal AK, Roy RK, Tewari SK, Tamta S and Rana TS (2016) – Assessment of genetic variation and population structure in Indian Gladiolus cultivars inferred from molecular markers. ***The Nucleus***, **59**: 235-244.

164. Singh N, Srivastava S, Rathaur S and Singh N (2016) - Assessing the bioremediation potential of arsenic tolerant bacterial strains in rice rhizosphere interface. ***Journal of Environmental Sciences***, **48**: 112-129.

165. Singh NK, Raghubanshi AS, Upadhyay AK and Rai UN (2016) - Arsenic and other heavy metal accumulation in plants and algae growing naturally in contaminated area of West Bengal, India. ***Ecotoxicology and Environmental Safety***, **130**: 224-33.

166. Singh PC, Shukla S, Fatima T, Nautiyal CS and Johari JK (2017) - Biological Control of *Fusarium* sp. NBRI-PMSF12 Pathogenic to Cultivated Betelvine by *Bacillus* sp. NBRI-W9, a Potential Biological Control Agent. ***Journal of Plant Growth Regulation***, **36**(1): 106-117.

167. Singh S, Joshi Y and Rawat AKS (2016) – Evaluation of phytochemical constituents of Cryptogams of Almora District, Uttarakhand for their total phenolic content, total flavonoid content and antioxidant potential. ***International Journal of Research in Pharmacy and Chemistry***, **6**(4): 833-842.

168. Singh S, Khatoon S, Joshi Y, Prgyadeep S, Upreti DK and Rawat AKS (2016) – A validated HPTLC densitometric method for simultaneous determination of Evernic and Usnic acids in four *Usnea* Species and comparison of their antioxidant potential. ***Journal of Chromatographic Science***, **54**(9): 1670-1677.

169. Singh S, Roy RK, Chandra S and Kumar S (2016) – Comparative analysis of growth and floral characteristics of Indian *Bougainvillea* varieties. ***Plant Archives***, **16**(1): 252-256.

170. Singh S, Sharma SK, Chaturvedi V, Upadhyay RK, Chauhan PS, Pal M and Tewari SK (2016) – Growth, Yield and Quality of *Bixa orellana* L. morphotypes. ***Research Reviews: Journal of Botanical Science***, **5**(3): 40-42.

171. Singh V, Goel R, Pande V, Asif MH, Mohanty CS (2017) – De novo sequencing and comparative analysis of leaf transcriptomes of diverse condensed tannin-containing lines of underutilized *Psophocarpus tetragonolobus* (L.) DC. ***Scientific Reports***, **7**: 44733.

172. Singh V, Singh P and Singh N (2016) - Synergistic influence of Vetiveria zizanioides and selected rhizospheric microbial strains on remediation of endosulfan contaminated soil. ***Ecotoxicology***, **25**(7): 1327-1337.

173. Soni N, Singh V, Mohammad S, Singh RK, Pal US, Singh R, Aggrwal J and Pal M (2016) - Effects of honey in the management of alveolar osteitis: A study. ***National journal of Maxillofacial Surgery***, **7**(2): 136-147.

174. Srivastava A and Asthana AK (2016) – Genus *Entodon* Müll. Hal. (Bryophyta) in Meghalaya. ***Cryptogam Biodiversity and Assessment*** **1**(1): 43-51.

175. Srivastava A, Kumar S, Jaidi M and Raj SK (2016) - Association of *Cotton leaf curl Multan virus* and its associated betasatellite with leaf curl disease of *Hibiscus rosa-sinensis* in India. ***New Disease Reports***, **33**: 4.

176. Srivastava J, Chandra H, Singh N and Kalra SJ (2016) - Understanding the development of environmental resistance among microbes: A review. ***CLEAN–Soil, Air, Water***, **44**(7): 901-908.

177. Srivastava M, Sharma S and Misra P (2016) - Elicitation Based Enhancement of Secondary Metabolites in *Rauwolfia serpentina* and *Solanum khasianum* Hairy Root Cultures. ***Pharmacognosy magazine***, **12**(Suppl. 3): S315-320.

178. Srivastava PK, Gupta M, Singh N and Tewari SK (2016) - Amelioration of sodic soil for wheat cultivation using bioaugmented organic soil amendment. ***Land Degradation & Development***, **27**(4): 1245-1254.

179. Srivastava S, Bist V, Srivastava S, Singh PC, Trivedi PK, Asif MH, Chauhan PS and Nautiyal CS (2016) - Unraveling aspects of *Bacillus amyloliquefaciens* mediated enhanced production of rice under biotic stress of *Rhizoctonia solani*. ***Frontiers in Plant Science***, **7**: 587.

180. Srivastava S, Misra A, Mishra P, Shukla P, Kumar M, Sundaresan V, Negi KS, Agarwal PK and Rawat AKS (2017) – Molecular and chemotypic variability of forskolin in *Coleus forskohlii* Briq., a high value industrial crop collected from Western Himalayas (India). ***RSC Advances***, **7**: 8843–8851.

181. Srivastava S, Singh RK, Pathak G, Goel R, Asif MH, Sane AP and Sane VA (2016) - Comparative transcriptome analysis of unripe and mid-ripe fruit of *Mangifera indica* (var. "Dashehari") unravels ripening associated genes. ***Scientific reports***, **6**: 32557.

182. Tiwari S, Pandey S, Chauhan PS, Pandey R (2017) – Biocontrol agents in co-inoculation manages root knot nematode [*Meloidogyne incognita* (Kofoid & White) Chitwood] and enhances Essential oil content in *Ocimum basilicum* L. ***Industrial Crops and Products***, **97**: 292-301.

183. Tiwari V, Meena B, Nair KN, Upreti DK, Tamata S and Rana TS (2017) – Assessment of genetic diversity and population structure of *Bergenia stracheyi* (Saxifragaceae) in the Western Himalaya (India). ***Biochemical Systematics and Ecology***, **70**: 205-210.

184. Toppo K, Mandotra SK, Nayaka S and Suseela MR (2016) – Algal diversity of high altitude zones in Govind Wild Life Sanctuary, Uttarakhand, India. ***Journal of Indian Botanical Society***, **95**(3 & 42): 283-287.

185. Tyagi A, Yadav A, Tripathi AM, Roy S. (2016) - High light intensity plays a major role in emergence of population level variation in Arabidopsis thaliana along an altitudinal gradient. ***Scientific Reports***, **6**: 26160.

186. Upadhyay AK, Mandotra SK, Kumar N, Singh NK, Singh L and Rai U (2016) – Augmentation of arsenic enhances lipid yield and defense responses in alga *Nannochloropsis* sp. ***Bioresource technology***, **221**: 430-437.

187. Upadhyay RK, Singh VR and Tewari SK (2016) – New agro-technology to increase productivity of chamomile. ***Industrial Crops and Products***, **89**: 10-13.

188. Uppadhyay V, Ingle KK, Trivedi S and Upreti DK (2016) – Diversity and distribution of lichens from the monuments of Gwalior division, Madhya Pradesh with special reference to rock porosity and lichen growth. ***Tropical Plant Research***, **3**(2): 384-389.

189. Usmani MA, Suseela MR, Toppo K and Sheikh S (2016) – Algal diversity in different habitats from Northern region of Idukki district, Kerala, India. ***Journal of Indian Botanical Society***, **95**(1 & 2): 28-36.

190. Usmani MA, Toppo K, Nayaka S, Suseela MR and Sheikh S (2016) – Observation on fresh water algal flora of Sitapur district, Uttar Pradesh. ***Cryptogam Biodiversity and Assessment***, **1**(2): 1-7.

191. Ved A, Gupta A and Rawat AKS (2017) – Antioxidant and hepatoprotective potential of phenol-rich fraction of *Juniperus communis* Linn. leaves. ***Pharmacognosy magazine***, **13**(49): 108-113.

192. Ved A, Rawat AK and Gupta A (2016) - Antioxidant and hepatoprotective potential of phenol-rich fraction from *Piper sylvaticum* roxb. roots. ***Current Topics in Nutraceuticals Research***, **14**(3): 207.

193. Verma N, Jena SN, Shukla S and Yadav K (2016) – Genetic diversity, population structure and marker trait associations for alkaloid content and licit opium yield in India-wide collection of poppy (*Papaver somniferum* L.). ***Plant Gene***, **7**: 26-41.

194. Verma P, Paswan SK, Raj A, Rastogi C, Srivastava S, Rao ChV (2016) - Hepatoprotective and antioxidant effect of *Dolichousnea longissima* (Ach.) articus extract against cisplatin induced liver damage in wistar rats. ***European Journal of Medicinal Plants***, **17**(4): 1-8.

195. Verma P, Paswan SK, Verma S, Singh SP, Rao ChV, Srivastava S and Gupta RK (2017) – Assessment of hepatoprotective activity of *Musa paradisica* Linn. whole plant extract against carbon tetrachloride induced hepatotoxicity in Wistar rats. ***International Journal of Pharmaceutical Sciences and Research***, **8**(1):126-131.

196. Verma PK, Verma S, Meher AK, Pande V, Mallick S, Bansiwal AK, Dhankher OP, Tripathi RD and Chakrabarty D (2016) - Overexpression of rice glutaredoxins (OsGrxs) significantly reduces arsenite accumulation by maintaining glutathione pool and modulating aquaporins in yeast. ***Plant Physiology and Biochemistry***, **106**: 208-217.

197. Verma PK, Verma S, Pande V, Mallick S, Tripathi RD, Dhankher OP and Chakrabarty D (2016) - Overexpression of rice glutaredoxin OsGrx_C7 and OsGrx_C2.1 reduces

intracellular arsenic accumulation and increases tolerance in *Arabidopsis thaliana*. ***Frontiers in Plant Science***, **7**:740.

198. Verma S, Gupta A, Ramana MV and Rawat AK.(2016) - High-performance thin-layer chromatographic analysis for the simultaneous quantification of gallic acid, vanillic acid, protocatechuic acid, and quercetin in the methanolic fraction of *Limonia acidissima* L. fruits. ***JPC-Journal of Planar Chromatography-Modern TLC***, **29**(5): 356-60.
199. Verma S, Verma PK, Pande V, Tripathi RD and Chakrabarty D (2016) - Transgenic *Arabidopsis thaliana* expressing fungal arsenic methyltransferase gene (WaarsM) showed enhanced arsenic tolerance via volatilization. ***Environmental and Experimental Botany***, **132**:113-120.
200. Wagh VV (2016) - Preliminary study on Ethno-medicinal plants used for treating malarial fever in Pilibhit Tiger Reserve, Uttar Pradesh, India. ***International Journal of Bioassays***, 5(7): 4672-4675.
201. Wagh VV and Jain AK (2016) - Conservation status of threatened ethno-medicinal plants in western Madhya Pradesh, India. ***Journal of Biodiversity Management and Forestry***, **5**(2).
202. Yadav AK, Mishra PK, Jain PK, Rao ChV, Tiwari S and Singh V (2016) – Investigation of *Calendula officinalis* whole plant as a gastroprotective and antioxidant in peptic ulcer. ***British Journal of Medical and Health Research***, **3**(7): 67-76.

Review Articles

1. Kumari B and Singh DP – A review on multifaceted application of Nanotechnology in bioremediation of petroleum hydrocarbons. ***Ecological Engineering***, 2016, **97**: 98-105.
2. Nayak SK, Bajpai R, Upreti DK and Satapathy KB – Diversity of lichen flora of Odisha, India - A review. *Studies in Fungi*, 2016, **1**(1): 114-124.
3. Pal M, Mishra T, Kumar A and Tewari SK – Biological evaluation of terrestrial and marine plant originated labdane diterpenes (A Review). ***Pharmaceutical Chemistry Journal***, 2016, 50 (8):558-567.

Books

1. Roy RK – Home Garden, II edition. *CSIR-NBRI*, Lucknow, 2016: pp. 95.
2. Chaudhary LB, Kushwaha AK and Bajpai O – Trees of Uttar Pradesh Part-1. Bennette, Coleman and Co. Ltd, Lucknow 2016: pp. 364.

Chapter in Books

1. Nainwal RC, Katiyar RS, Singh D, Sharma SK, Singh S and Tewari SK – Agroforestry as a reservoir for biodiversity conservation, soil fertility and mitigation of climatic hazards. *In* : Holistic Development of Agroforestry (Eds. S Tewari, VK Sah and SK Lavania), *Jaya Publishing House*, Delhi, 2016 : 203–211.
2. Dasgupta CN and Nayaka S – Comprehensive screening of micro and macroalgal species for bioenergy. *In*: Algal Biofuels Recent Advances and Future Prospects (Eds. SK Gupta, A Malik and F Bux). *Springer International Publishing*, Switzerland, 2017: 39-56.
3. Bahadur L, Pal M, Yadav RK and Singh SR – Bio-active compounds of medicinal and aromatic plants cultivated under salt stress and organic production system. *In* : 'Innovative Approaches and Advances in Organic Agriculture for Sustainable Crop Production (Eds. T. Damodran, VK Mishra and SK Jha), *CSSRI- RRS*, Lucknow, 2016 : 111-121.
4. Augusto S, Shukla V, Upreti DK, Paoli L, Vannini A, Loppi S, Nerín C, Domeño C, Schuhmacher M – Biomonitoring airborne persistent organic pollutants using lichens. *In*: Biomonitoring of Air Pollution using Mosses and Lichens: Passiveand Active Approach – State of the Art and Perspectives (Eds. MA Uroševiæ, G Vukoviæ and MTomaševiæ), *Nova Science Publishers*, New York, US, 2016 : 137-175.
5. Mohabe S, Anjali DB, Reddy MA, Nayaka S and Shankar PC – An appraisal of lichen biota in Chittoor district of Andhra Pradesh, India. *In*: Biodiversity in India. Vol. 8 (Eds T Pullaiah and SS Rani), *Astral International (P) Ltd*., New Delhi, 2016: 247-297.
6. Nayaka S – Sensitizing biodiversity conservation at school-college level: An experiment with workshops of Uttar Pradesh State Biodiversity Board. *In*: Mainstreaming Biodiversity: Sustaining People and their Livelihoods (International Day for Biological Diversity). *Uttar Pradesh State Biodiversity Board*, Lucknow, 2016: 56-60.
7. Srivastava, PK – Fungal bioaugmentation of the rice root-zone to reduce arsenic uptake by rice from soils. *In*: Arsenic Research and Global Sustainability: Proceedings of the Sixth International Congress on Arsenic in the Environment (As2016). *CRC Taylor & Francis*, UK, 2016, 144: 329-330.
8. Singh M, Srivastava PK, Jaiswal VK, Kharwar RN – Biotechnological applications of microbes for the remediation of environmental pollution. *In*: Biotechnology: Trends and Applications. *Studium Press LLC*, USA, 2016: 179-214.
9. Pandey N, Iqbal Z, Pandey BK and Sawant SV – Phytohormones and drought stress: Plant responses to transcriptional regulation. *In*: Mechanism of Plant Hormone Signaling under Stress. *John Wiley & Sons, Inc.*, Hoboken, NJ, USA 2017: 10.1002/9781118889022.ch34.
10. Misra P, Singh G, Mishra MK, Pandey V and Saema S – Functional analysis and the role of members of SGT gene family of *Withania somnifera*. *In*: Transgenesis and Secondary Metabolism, Reference Series in Phytochemistry (Ed. S Jha). *Springer International Publishing*, Switzerland, 2017:1-14.
11. Srivastava V, Chauhan PS, Misra S, Sharma S, Misra A and Nautiyal CS – *Bio-prospecting for improving soil health and crop productivity: Indian patent landscape*. *In*: **Intellectual Property Issues in Biotechnology.** *CABI* Nosworthy Way Wallingford Oxfordshire, UK, 2016, 7:58-79.

Popular Articles

1. Khuraijam JS and Sharma SC – Cycads: The plants of Jurassic Period. *Pushpanjali,* Lucknow Nagar Nigam, Lucknow, 2017: 77-78.
2. Khuraijam JS and Sharma SC – History of the Bougainvillea. *Ann. Bougainvillea Journal*, 2017, 27: 32-33.
3. Khuraijam JS and Roy RK (2016) – Conservation of Orchids at CSIR-NBRI Botanic Garden. ***Orchid Conservation News***, **2**: 3-5.
4. Khuraijam JS and Roy RK (2016) – *Dendrobium kentrophyllum* (Orchidaceae) – A new record for the orchid flora of Manipur, India. ***Richardiana***, **16**: 273-276.
5. Khuraijam JS and Roy RK (2016) – *Ex-situ* conservation of Cycads at CSIR-National Botanical Research Institute, Lucknow. ***Cycads***, **1**(1): 26-27.
6. Khuraijam JS and Singh R (2016) – Illegal trade of *Cycas* cones in India, Bangladesh and Myanmar. ***Cycads***, **1**(1): 20-21.
7. Sharma SC, Katiyar RS and Chaurasia R – Saga of the Bougainvilleas. *Pushpanjali, Lucknow Nagar Nigam, Lucknow,* 2017: 75-76.
8. Mohanty CS, Pushpangadan P - Sustainable utilization of plant-diversity in homestead garden of Uttar Pradesh for providing nutrition security in the household, *Souvenir*-Uttar Pradesh Biodiversity Board, Lucknow, 2016: 116-119.
9. Singh AP and Johari D – Sustainable utilization of Biodiversity: Role of Pteridophytes in livelihoods of tharu tribes of Uttar Pradesh. *Souvenir*-Uttar Pradesh Biodiversity Board, Lucknow, 2016: 116-127.
10. Verma A, Mishra T, Shukla S, Pal M and Upreti DK - Effect of yoga in Diabetes, *Anusandhan Shodh Patrika*, 2017, 14(1):
11. उस्मानी एम ए, सुशीला एम आर, शेख एस एवं टोप्पो के – खाद्य स्वास्थ्य और पोषण सुरक्षा में शैवालीय जैव विविधता की भूमिका। हमार गांव, 2016, 27: 27-29।
12. रावत के के – उभयोदभिद : ब्रायोफाइटा समूह के लिए प्रस्तावित एक नवीन हिंदी नाम। वनस्पति वाणी, 2016, 25 : 56।
13. बत्रा ए एवं कटियार आर एस – रजनीगंधाः एक मनभावन पुष्प। पुष्पांजलि- पुष्प एवं श्वान प्रदर्शनी स्मारिका, लखनऊ नगर निगम, 2017।
14. बत्रा ए एवं कटियार आर एस – रजनीगंधाः एक मनभावन व सुगन्धित पुष्प। पुष्पांजलि – पुष्प एवं श्वान प्रदर्शनी स्मारिका, लखनऊ नगर निगम, 2017।
15. बत्रा ए एवं कटियार आर एस – समाज की सेवा में सीएसआईआरः ग्रामीण क्षेत्र के बेरोजगारों हेतु लघु उद्योग। पुष्प निर्जलीकरण। विज्ञान प्रगति, 2016, 8: 64-65।

Bulletins

1. सिंह डी, नैनवाल आर सी, कटियार आर एस, शर्मा एस, एवं तिवारी एस के – पान की आधुनिक उत्पादन तकनीकी। *सीएसआईआर-एनबीआरआई*, लखनऊ, 2016।
2. सिंह डी, नैनवाल आर सी, शर्मा एस, कुमार पी एवं तिवारी एस के – हल्दी की व्यावसायिक खेती। *सीएसआईआर-एनबीआरआई*, लखनऊ, 2016।

विज्ञान वाणी 2016, अंक 22

1. गुप्ता आर एवं अस्थाना ए के – हरितोद्भिद पादप सरंक्षण एवं संवर्धन का वैज्ञानिक एवं व्यवसायिक महत्वः 1-3।
2. सिंह ए के एवं जौहरी डी – अनुसंधान और विकास गतिविधियों में टेरिड़ोफाइट्स की भूमिका – भविष्य परिप्रेक्ष्य एक दृष्टि मेंः 4-8।
3. सरोज एल एम, रावत पी एवं पाल एम – उच्च वसीय आहार प्रेरित मोटापा में इमली सार का औषधीय मूल्याकनः 9-14।
4. राही टी एस, इरम एफ, लाल एम एवं प्रकाश ए – एलोवेरा की ऊसर भूमि में खेतीः स्वास्थ्य लाभ, धन अर्जन व पर्यावरण सरंक्षण हेतु एक नई किरणः 15-21।
5. नैनवाल आर सी, सिंह डी, कटियार आर एस, शर्मा एस एवं तिवारी एस के – पर्वतीय क्षेत्रों में गहत की उन्नत खेतीः 22-24।
6. दास बी, शर्मा एस, चतुर्वेदी वी के, सिंह एस एवं तिवारी एस के – नक्षत्र वाटिकाः 25-28।
7. श्रीवास्तव ए एवं श्रीवास्तव एम – घृत कुमारीः औषधीय गुण, महत्व तथा उपयोगः 29-31।
8. टोप्पो के एवं उस्मानी एम ए – जीवाश्म आटाः 32-33।
9. शुक्ला पी एन, प्रसाद आर, लांडे एस एवं रानाडे एस ए – गिलोयः अनेक रोगों के लिए गुणकारीः 34-36।
10. गयासुद्दीन – दालचीनी का घरेलु उपयोगः 37-39।
11. अतुल बत्रा – तुलसीः एक औषधीय पौधाः 40-41।
12. आरिफ एम, साहू आर एवं श्रीवास्तव एम– पादप यौगिकों द्वारा कर्क रोगों की रोकथामः 42-44।
13. बिंद्रा ए – नीम के औषधीय गुणः 45-46।
14. यादव आर – *कोक्युलस हिरसुटस* एक बहुउपयोगी पौधाः 47।
15. सिंह पी एवं सिंह एस – कैक्टसः 48-49।
16. दास बी – वनस्पति वाटिका के कुछ महत्वपूर्ण वृक्षः 50-52।
17. बोहरा पी, अरुण वी ए, रंगनाथ के जी एवं सिंह पी के – चकोतराः एक अनूठा नींबू : 53-55।
18. खुराईजम जे एस, सिंह एस, कुमार एस एवं रॉय आर के – कैक्टस एवं सैकुलेंट का भू-परिदृश्य में उपयोगः 56-58।
19. जोशी बी, दीक्षित वी एवं कौर आर – यूकेलिप्टिस के वन सरंक्षण में उच्च तकनीकी पौधशाला की एक महत्वपूर्ण भूमिकाः 59-62।
20. मिश्रा पी, पुरुषोत्तम डी के एवं नौटियाल सी एस – *वेल्विसिया मिरैबिलिस* का उतक संवर्धनः 63-64।
21. बत्रा ए एवं कटियार आर एस – भारतीय किसानों के उत्थान हेतु महत्वपूर्ण फसलः ग्लेडियोलसः 65-68।
22. सिंह एस एवं प्रसाद आर – बड़े पौधों को छोटे रूप में घर में उगायेः 69-71।

23. सत्यभामा - आकर्षक गुलमोहरः 72।
24. आनंद प्रकाश - भारतीय व्रत, उपवास, पर्व, तीज, त्यौहार व आहार-विहार में स्वास्थ्य नियंत्रक उपयोगी पादपः 73-84।
25. शर्मा एस, श्रीवास्तव एस, मीना बी एल एवं श्रीवास्तव वी के - वै.औ.अ.प.-राष्ट्रीय वनस्पति अनुसन्धान संस्थान द्वारा विकसित एवं बाजार में उपलब्ध प्रौद्योगिकियाँः 85-87।
26. मीना बी एल, श्रीवास्तव वी के, प्रसाद आर एवं शर्मा एस - उत्तर प्रदेश भौगोलिक संकेतः एक अध्ययनः 88-91।
27. सिंह पी एवं सिंह एस - कैक्टस की अभिलाषाः 92।
28. पाल एच - नमन कलामः 93-94।
29. उजाला एस - पर्यावरण प्रदूषणः समस्या और समाधानः 95-97।
30. कैन एम एल - मेरा भारत स्वच्छ बने-आज की यह आवश्यकता हैंः 98।
31. श्रीवास्तव एल - आत्मस्वरुप की पहचानः 99।
32. रावत के के - दि बिग बैंग थ्योरी ऑफ सोशल भड़ासः 100-101।
33. श्रीवास्तव एस, शर्मा एस, गुप्ता आर एन एवं श्रीवास्तव वी के - वै.औ.अ.प.-राष्ट्रीय वनस्पति अनुसन्धान संस्थान में भविष्योन्मुखी शोधः 102-104।
34. सिंह बी - वह जलती रहीः 105 ।
35. राम चरन - श्रमिक की प्रार्थनाः 106।
36. मेहरोत्रा एस - अब बिरह की वेदना का क्या करोगे?ः 107।
37. मेहरोत्रा एस - गज़लः 108।
38. मिश्र पी - गज़लः 108।

PATENTS GRANTED / FILED

PATENTS GRANTED

Sl. No.	Title	Inventors	Application No.	Country and grant date	Patent No.
1.	A gene for inducing male sterility in plants	Sawant S, Tuli R, Singh SP	2009321261	AU/14/07/2016	2009321261
2.	*Allium fistulosum* Leaf Agglutinin Protein, its Encoding Gene, Primer and Process for Preparation Thereof	Singh PK, Rai P, Singh R, Upadhyay SK, Sharad S, Singh H, Verma PC, Chandrashekhar R, Tuli R	14/368443	US/17/01/2017	9545107

PATENTS FILED

S. No.	Title	Inventors	Country	Filing Date/NF No.
1.	A method for production of transgenic cotton plant	Sawant SV, Tripathi RK and Idris A	US (USA) BR (Brazil) AU (Australia)	08/04/2016/0092NF2013/US 11/04/2016/0092NF2013/BR 11/04/2015/0092NF2013/AU
2.	Novel reversible expression system for transgene expression in plants	Sawant SV, Singh SP	WO	18/04/2016/0174NF2014/WO
3.	Herbal Composition for the Management of Diabetes	Nautiyal CS, Rao ChV, Ojha SK, Rawat AKS, Mani D, Pal A, Kumar D	LK (Sri Lanka) MY (Malaysia)	08/09/2016/0097NF2014/LK 08/09/2016/0097NF2014/MY

HUMAN RESOURCE DEVELOPMENT

CSIR-NBRI PARTICIPATION IN TRAININGS/EXHIBITIONS/WORKSHOPS/FLOWER SHOWS

S. No.	Event Details	Venue	Date
1.	Bougainvillea Festival	IARI, New Delhi	April 01-03, 2016
2.	Creating livable planet earth	Dr. APJ Abdul Kalam Memorial Youth Conclave, Lucknow	July 26-27, 2016
3.	Exhibitions in Agri-Tech India 2016	BIEC, Bangalore	August 26, 2016
4.	HR Group Meet	HRDC, Ghaziabad	September 01, 2016
5.	Tech-Exhibition 2016	Vigyan Bhawan, New Delhi	September 26, 2016
6.	District level science exhibition and competition	CMS, Gomti Nagar, Lucknow	October 22, 2016
7.	Post-Harvest Expo -2016	Integral University, Lucknow	November 12, 2016
8.	National Children Science Congress – 2016	Pioneer Montessori School, Eldeco, Lucknow	November 13-14, 2016
9.	CSIR Platinum Jubilee Techno-Fest under 36th India International Trade Fair	Pragati Maidan, New Delhi	November 14-27, 2016
10.	India International Science Festival – 2016	CSIR-NPL, New Delhi	December 06-12, 2016
11.	104th Indian Science Congress	Tirupati, Andhra Pradesh	January 3-7, 2017
12.	Innovation Festival 2017	Regional Science City, Lucknow	January 23-25, 2017
13.	Kisan Mela	CSIR-CIMAP, Lucknow	January 31, 2017
14.	State Flower Show 2017	Raj Bhawan Garden, Lucknow	February 25-26, 2017
15.	Nagar Nigam Flower Show 2017	E-park Mahanagar, Lucknow	March 4-5, 2017
16.	Udyanotsav – 2017	Rashtrapati Bhawan, New Delhi	March 10, 2017
17.	Micro, Small and Medium Enterprises (MSME) Trade Fair	Bhubaneswar, Odisha	March 5-11, 2017

INDIVIDUAL TRAINING/WORKSHOP ATTENDED

SI. No.	Name of Person (s)	Subject of Training Course	Organizer/Place	Date/Period
1.	Dr. RN Gupta	Managerial effectiveness for Technical Officers	CSIR-HRDC, Ghaziabad	September 28-30, 2016
2.	Dr. PK Srivastava	Certificate course for NABL Assessor ISO/IEC 17025:2005	NITTR, Chandigarh	October 17-21, 2016
3.	Dr. Lal Bahadur	Agro-Ecotourism - An Emerging Enterprise for Agricultural Diversification	ICAR-Central Coastal Agricultural Research Institute, Ella, Old Goa	October 30 - November 09, 2016
4.	Mr. SK Sharma and Dr. S Singh	Science and technologies for rural societies	Indian Institute of Public Administration, New Delhi	November 07-11, 2016
5.	Dr. Charu Lata	Work-life balance for women scientists and officers	HRDC, Ghaziabad	December 21-23, 2016
6.	Dr. Lal Bahadur and Mr. Y Misra	Workshop on "Art of Public Speaking and Technical Writing"	CSIR-HRDC, Ghaziabad	April 11-13, 2016

SI. No.	Name of Person (s)	Subject of Training Course	Organizer/Place	Date/Period
7.	Dr. GG Sinam	Capacity Building for Technical Officers	CSIR-HRDC, Ghaziabad	July 25-29, 2016
		Uncertainty Measurement as per ISO/IEC-17025-2005	CIPET, Lucknow	September 14-16, 2016
8.	Dr. KK Rawat	Managerial Effectiveness for Technical Officers	CSIR-HRDC, Ghaziabad	September 28-30, 2016
9.	Dr. RC Nainwal	Soil Safety and Soil Health: Issues of Concern for Agriculture, Environment and Human Health	Department of Soil Science & Agricultural Chemistry, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Krishi Nagar, Jabalpur (M.P.)	September 27 – October 17, 2016
10.	Dr. L Bahadur, Scientist and Dr. GG Sinam	Design and Analysis of Experiments	CSIR-HRDC, Ghaziabad	January 18-20, 2017
11.	Dr. P Mishra	Sexual harassment of woman at workplace	CSIR-HRDC, Ghaziabad	January 27-28, 2017
12.	Dr. S Srivastava and Dr. Poonam C Singh	Science and Technology for Rural Societies	Indian Institute of Public Administration, New Delhi	February 20-24, 2017
13.	Dr. A Mishra and Dr. Charu Lata	Emerging Trends in Science, Technology and Governance	Indian Institute of Public Administration, New Delhi	February 13-17, 2017

GROUP TRAINING IMPARTED

S. No.	Name of the Organization	Subject of training	No. of participants	Date/Peroid
1.	Gardeners, High Court, Lucknow Bench	Garden Management	09	July 4-18, 2016 July 18-Aug 4, 2016
2.	General Public (House wives, teachers, students and garden lovers)	Bonsai Technique	12	September 2, 2016
3.	Family Welfare Centre, AMC Centre and College, Lucknow	Dehydrated Floral Crafts and Bonsai Technique	50	September 6-7, 2016
4.	Farmers of Lucknow, Unnao, Sitapur and Barabanki districts	Betelvine Cultivation	40	September 7, 2016
5.	General Public (House wives, teachers, students and garden lovers)	Home gardening	18	September 19, 2016
6.	General Public (House wives, teachers, students and garden lovers)	Bonsai Technique	90	March 21-23, 2017
7.	General Public (House wives, teachers, students and garden lovers)	Dehydrated Floral Crafts	43	March 28-30, 2017

Student Training Imparted

Fifty Four post-graduate students of different universities/institutes were imparted training on various topics of their interest, during April 2016 to March 2017. A sum of ₹ 8,76,000.00 was realized from themas training fee.

HONOURS/AWARDS/DISTINCTIONS

CSIR-NBRI with CSIR-CIMAP SHARED CSIR TECHNOLOGY AWARD FOR LIFE SCIENCES-2016

CSIR TECHNOLOGY AWARD FOR LIFE SCIENCE 2016 was conferred jointly to CSIR-National Botanical Research Institute and CSIR-Central Institute of Medicinal and Aromatic Plants, Lucknow for development of Herbal Composition (NBRMAP-DB) for the Management of Diabetes Type II.

NBRI & CIMAP officials receiving the CSIR Technology Award at the CSIR Foundation Day ceremony at New Delhi on September 26, 2016

NBRMAP-DB is a scientifically validated and standardized herbal formulation developed jointly by CSIR-NBRI and CSIR-CIMAP, Lucknow. The drug has been marketed by AIMIL Pharmaceuticals (India) Limited, New Delhi-the licensee, under the trade name of BGR-34. NBRMAP-DB is an anti-diabetic, hypoglycemic formulation with immune-modulatory properties and provides relief to people suffering from diabetes through management of blood glucose level. During a short span of less than a year, more than one million diabetic patients have been benefited by this formulation throughout the country with a sale of approximately Rs. 60 crores. Success of this formulation has given a thrust to cultivation of medicinal plants and thus value addition to the agricultural sector, towards generating employment and thereby uplifting the socio-economic status of farmers. This award inspires researchers engaged in finding innovative solutions, for affordable healthcare through the amalgamation of modern scientific methods, and India's rich traditional knowledge.

The team CSIR-NBRI included former Director Dr. CS Nautiyal, Dr. AKS Rawat, Dr. ChV Rao and Dr. SK Ojha and team CSIR-CIMAP included Prof. AK Tripathi (Director), Dr. DN Mani, Dr. A Pal, and Dr. Dinesh Kumar. Dr. Harsh Vardhan Hon'ble Union Minister for Science & Technology & Earth Sciences, Shri Y.S. Chowdary Hon'ble Minister of State for Ministry of Science & Technology & Earth Sciences and Dr. Girish Sahni, DG, CSIR felicitated the R&D teams on the occasion of CSIR-Foundation Day on September 26, 2016.

CSIR-NBRI won Gold Award in CSIR Platinum Jubilee Techno-Fest under 36th India International Trade Fair under Agriculture & Floriculture theme in held during November 14-27, 2016 at Pragati Maidan, New Delhi.

Individual Honours/Awards/Recognitions

Sl. No.	Name of the Person(s)	Award(s)
1.	Agnihotri P	Prof. Shiv Mangal Singh Smriti Paryavaran Sanrakshan Samman for the year 2015-2016 by Sri Prabhu Devi Vidya Mandir Pratisthan, Lucknow.
2.	Bajpai R	Best Reviewer Certificate by the Journal *Ecological Indicators*.
3.	Charu Lata	Awarded with Indo-Australia Early & Mid-Career Researchers Fellowship 2016-17 for duration of three months at the University of Queensland, Brisbane, Australia administered by the Indian National Science Academy, New Delhi, India and supported by Department of Science & Technology (DST), Government of India.
4.	Kannaujia R	Rashtriya Gaurav Award for the meritorious services, outstanding performance and remarkable role by India International Friendship Society, New Delhi on March 25, 2017 in National Seminar on Economic Growth and National Integration, New Delhi.
5.	Mishra GK	Dr. Dharni Awasthi Award 2016 by International Association for Lichenology, in the 8th IAL Symposium held at Helsinki, Finland.
6.	Nainwal RC & Singh D	Young Scientist Award for the year 2016 for contribution in the field of Agronomy by the Society for Scientific Development in Agriculture and Technology, Meerut

Sl. No.	Name of the Person(s)	Award(s)
7.	Ojha SK	Aryabhatt Award 2016 for excellence in Ayurvedic Research, by Association of Ayurvedic Professionals of North America (AAPNA)
8.	Rawat AKS	Dr. SK Jain Medal for the year 2015-16 by the Society of Ethnobotanists
9.	Singh BN	Young Scientist Award of Biotech Research Society of India (BRSI) in recognition of his significant contributions in the area of Medical Biotechnology

Member/Editor, Referee, Expert, Reviewer, Judge, etc. (selected, recognized, enrolled, empanelled, nominated)

1.	Asthana AK	• Fellow of Indian Botanical Society and Association for Plant Taxonomy
2.	Chakrabarty D	• Member of Plant Tissue Culture Association (India) 2016 • Evaluator of projects in the executive agency for higher education research, development and innovation funding (UEFISCDI), Romania
3.	Charu Lata	• Elected Member of the National Academy of Sciences India (NASI), Allahabad, India • Selected as one of the 20 founding Member/Fellow of the India National Young Academy of Science (INYAS), New Delhi for a period of five years (April 24, 2015-December 31, 2019)
4.	Khatoon S	• Appointed as an Expert of a Panel 'for issuing the License to the Unani Pharma companies for manufacturing the Unani products' from Unani Directorate, UP, Lucknow • Editor of *Asian J. Pl. Sci., Intl. J. Bot., Res. J. Med. Pl., J. bot. Sci., Pharmacog. J. and J. Develop. Biol. Tissue*
5.	Ojha SK	External Expert for the monitoring of National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Disease and Stroke (NPCDCS) at District Lakhimpur-Kheri: A AYUSH Project under Central Research Institute of Unani Medicine, Ministry of Health & Family Welfare.
6.	Rao ChV	• Member, Research Council, Amity University, Lucknow, Jawaharlal Nehru Tropical Botanic Garden & Research Institute, Thiruvanathapuram, Integral University, Lucknow, Dr. APJ Abdul Kalam Technical University, Lucknow • Fellow of National Society of Ethno-pharmacology, Kerela
7.	Rawat AKS	Appointed as an Expert of a Panel 'for issuing the License to the Ayurvedic Pharma companies for manufacturing the Ayurvedic products' from Ayurveda Directorate, UP, Lucknow.

Ph.D. Awarded

1. Mr. Amit K. Dey

Biodiversity assessment of lichens and evaluation of their role as ecological indicators in Nagaon district of Assam, North East India

Guides: **Prof. J Rout**, Department of Ecology & Environmental Science, Assam University, Silchar and **Dr. DK Upreti**, Chief Scientist, CSIR-NBRI, Lucknow

University: Assam University, Silchar

2. Amit Pal Singh

Modulation of Arsenite Induced Toxicity by Nitric Oxide and Salicylic Acid in Rice (*Oryza sativa* L.)

Guide: **Dr. RD Tripathi**, Retd. Former Chief Scientist, CSIR-NBRI, Lucknow

University: Academy of Scientific and Innovative Research (AcSIR), New Delhi.

3. Mr. Anukool Srivastava

Development of Genetic markers (SSRs, SFPs & SNPs) in Indian Genotypes of *Gossypium herbaceum* and *Gossypium hirsutum*

Guide: **Dr. S N Jena**, Senior Scientist, CSIR-NBRI, Lucknow

University: Academy of Scientific and Innovative Research (AcSIR), New Delhi.

4. Mr. Gaurav Singh

Functional analysis of sterol glycosyltransferase gene (SGTs) family members of *Withania somnifera* using artificial miRNA technology

Guides: **Dr. P Misra**, Principal Scientist, CSIR-NBRI, Lucknow and **Dr. Surendra Singh**, BHU, Varanasi

University: Banaras Hindu University (BHU), Varanasi

5. Mr. KN Maurya

Study of components of variance and linkage disequilibrium in a population subjected to biparental mating in opium poppy (*Papaver somniferum* L.).

Guides: Dr. S Shukla, Senior Principal Scientist, CSIR-NBRI, Lucknow and **Dr. Geeta Asthana**, Lucknow University, Lucknow

University: Lucknow University, Lucknow.

6. Ms. Mamta Bhat

Studies on lichen diversity of Rajouri district with assessment of impact of air pollution

Guides: Dr. S Verma, Associate Professor, Centre for Biodiversity Studies, School of Biosciences and Biotechnolgy, BGSB University, Rajouri and **Dr. DK Upreti**, Chief Scientist, CSIR-NBRI, Lucknow

University: BGSB University, Rajouri

7. Manisha Mishra

Guide: **Dr. P K Singh**, Principal Scientist, CSIR-NBRI, Lucknow

Effective Control of *Bemisia tabaci* via strategically identified biomolecules

University: Academy of Scientific and Innovative Research (AcSIR), New Delhi.

8. Ms. Manvi Singh

Remediation potential of soil fungi to reduce arsenic contamination from agricultural soils of Uttar Pradesh.

Guides: **Dr. RN Kharwar**, BHU, Varanasi and **Dr. PK Srivastava**, Senior Scientist, CSIR-NBRI, Lucknow

University: Banaras Hindu University (BHU), Varanasi

9. Nidhi Thakur

RNAi Mediated Suppression of Vital Genes in Whitefly (*Bemisia tabaci*) and Development of Transgenic Plants for Resistance to the Pest

Guide: **Dr. P K Singh**, Principal Scientist, CSIR-NBRI, Lucknow

University: Academy of Scientific and Innovative Research (AcSIR), New Delhi.

10. Mrs. Nidhi Verma

Genetic characterization of indigenous germplasm lines of opium poppy (*Papaver somniferum* L.) through morphological, biochemical and molecular approaches

Guides: **Dr. S Shukla**, Senior Principal Scientist, CSIR-NBRI, Lucknow and **Dr. K Yadav**, Lucknow University, Lucknow

University: Lucknow University, Lucknow

11. Ms. Monika Dwivedi

Novel combinations of medicinal plants viz. *Piper longum*, *Piper nigrum* and *Zingiber officinale* with known anticancer agents curcumin and oleanolic acid: Formulation and evaluation

Guides: Dr. AKS Rawat, Senior Principal Scientist, CSIR-NBRI, Lucknow and **Dr. S Paliwal**, Banasthali University, Tonk

University: Banasthali University, Tonk

12. Ms. Nishi Srivastava

Variation in secondary metabolites of *Bergenia Ciliata* collected from different altitudes of Himalaya and explorations of biosynthetic biogenesis pathways of secondary metabolites of *Andrographic paniculata, Artemisia annua* and *Birgenia ciliata*

Guides: **Dr. AKS Rawat**, Senior Principal Scientist, CSIR-NBRI, Lucknow and **Prof. AR Khan**, Integral University, Lucknow

University Integral University, Lucknow

13. Ms. Neha Karakoti

Ecophysiological attributes of selected lichen species of Garhwal Himalayas along an altitudinal gradient

Supervisors: Dr. DK Upreti, Chief Scientist, CSIR-NBRI, Lucknow and **Prof. (Mrs.) Kiran Bargali**, Kumaun University, Nainital

University: Kumaun University, Nainital

14. Ms. Rekha Singh

Genetic variability, diversity and stability analysis in grain amaranth (*Amaranthus hypocondriacus* L.)

Guides:: **Dr. S Shukla**, Senior Principal Scientist, CSIR-NBRI, Lucknow and **Dr. Suresh BG**, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Allahabad

University: Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Allahabad

15. Ms. Saba Irshad

Botanical, Chemical and Molecular Characterization of a Controversial Drug 'Shankhpushpi' and evaluation of its antioxidant potential

Guides: Dr. Sayyada Khatoon, Principal Scientist, CSIR-NBRI, Lucknow and **Prof. PK Mishra**, Lucknow University, Lucknow

University: Lucknow University, Lucknow

16. Mr. SK Mandotra

Screening of potential algal species for biofuel production and optimization of growth conditions for high lipid accumulation

Guides: **Dr. MR Suseela,** Retd. Senior Principal Scientist, CSIR-NBRI, Lucknow and **Prof. PW Ramteke**, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Allahabad

University: Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Allahabad

17. Ms. Shweta Singh

Selection and gamma induced mutation for development of high yielding superior quality genotypes of *Curcuma longa* L.

Guides: **Dr. SK Tewari**, Senior Principal Scientist, CSIR-NBRI, Lucknow and **Dr. Manjul Dhiman**, KLDAV College, Roorkee.

University : HNB Garhwal University, Srinagar, Garhwal

18. Ms. Syed Saema

Functional characterization of sterol glycosyltransferase (SGT) L1 gene of *Withania somnifera*

Guides: **Dr. P Misra**, Principal Scientist, CSIR-NBRI, Lucknow and **Dr. Iffat Zareen Ahmad**, Integral University, Lucknow

University: Integral University, Lucknow

Ph.D. Theses Submitted

1. Ms. Aarti Kumari

Molecular detection, characterization of viruses infecting *Canna* spp. and development of virus-free Canna plants

Guides: Dr. PS Chauhan, Senior Scientist, CSIR-NBRI, Lucknow and **Dr. SK Raj**, Retd. Chief Scientist, CSIR-NBRI, Lucknow

University: Academy of Scientific and Innovative Research (AcSIR), New Delhi

2. Ms. Ameena Siddiqui

Diversity analysis, gene interactions and association among different traits in Linseed (*Linum usitatissimum* L.)

Guides: **Dr. S Shukla**, Senior Principal Scientist, CSIR-NBRI, Lucknow

University: Academy of Scientific and Innovative Research (AcSIR), New Delhi

3. Asmita Gupta

Functional analysis of SlERF6 during Tomato Plant Growth and Ripening

Guide: **Dr. A P Sane**, Senior Principal Scientist, CSIR-NBRI, Lucknow

University: Academy of Scientific and Innovative Research (AcSIR), New Delhi.

4. Ms. Archana Bhardwaj

Design and development of plant specific model based SNP pipeline

Guides: Dr. SK Bag, Senior Scientist, CSIR-NBRI, Lucknow

University: Academy of Scientific and Innovative Research (AcSIR), New Delhi

5. Ms. Astha Gupta

Mapping quantitative trait loci for traits related to biomass in *Arabidopsis thaliana*

Guides: Dr. HK Yadav, Senior Scientist, CSIR-NBRI, Lucknow

University: Academy of Scientific and Innovative Research (AcSIR), New Delhi

6. Ms. Chandrawati

Genetic diversity analysis and QTL mapping in linseed (*Linum usitatissimum* L.)

Guides: Dr. HK Yadav, Senior Scientist, CSIR-NBRI, Lucknow

University: Academy of Scientific and Innovative Research (AcSIR), New Delhi

7. Ms. Deepali Johari

In-vitro studies on mating system and colonization potential of some threatened Pteridophytes

Guides: Prof. LM Tiwari, Kumaun University, **Dr. PB Khare**, Retd. Chief Scientist and **Dr. AP Singh**, Senior Scientist, CSIR-NBRI, Lucknow

University: Kumaun University, Nainital

8. Ms. Deepika Lakhwani

Integrating bioinformatics approaches to identify gene expression profile and networks regulating fruit ripening in Banana

Guides: Dr. MH Asif, Senior Scientist, CSIR-NBRI, Lucknow

University: Academy of Scientific and Innovative Research (AcSIR), New Delhi.

9. Mr. Krishna Mohan Rai

Exploring the role of JMJC domain containing histone demethylases in epigenetetic regulation of cotton fiber development

Guides: Dr. Veena Pande, Dr. KK pandey, Department of Biotechnology, Kumaun University, Nainital and **Dr. SV Sawant**, Senior Principal Scientist, CSIR-NBRI, Lucknow

University: Kumaun University, Nainital

10. Mr. Nayan Sahu

Eco-physiological studies of understory woody species of tropical moist deciduous forest ecosystem of northern India.

Guides: Prof. SS Bargali, Department of Botany, DSB Campus, Nainital and **Dr. S Nayaka**, Principal Scientist, CSIR-NBRI, Lucknow

University: Kumaun University, Nainital

11. Mr. Niraj Singh

Physiological studies and molecular characterization of Gladiolus germplasm using molecular markers

Guides: **Dr. TS Rana**, Senior Principal Scientist, CSIR-NBRI, Lucknow and **Dr. S Tamta**, Assistant Professor, Kumaun University, Nainital

University: Kumaun University, Nainital

12. Mr. Pankaj K Verma

Functional characterization of arsenic-responsive glutaredoxin genes of rice (*Oryza sativa* L.)

Guides: Dr. D Chakrbarty, Senior Scientist, CSIR-NBRI, Lucknow and **Dr. Veena Pande,** Head, Department of Biotechnology, Kumaun University, Nainital

University: Kumaun University, Nainital

13. Mr. Rajeev Tripathi

Functional validation of *SQUAMOSA* promoter binding like (SPL) transcription factor in cotton fiber development

Guides: Dr. Veena Pande, Dr. KK Pandey, Department of Biotechnology, Kumaun University, Nainital and **Dr. SV Sawant**, Senior Principal Scientist, CSIR-NBRI, Lucknow

University: Kumaun University, Nainital

14. Ms. Reena Yadav

Potentiating the insecticidal activity of Bt-Cry1Ab toxin in transgenic tomato by the co-expression of a plant serine protease inhibitor

Guides: Dr. Veena Pande, Professor, Department of Biotechnology, Kumaun University, Nainital and **Dr. I Sanyal**, Principal Scientist, CSIR-NBRI, Lucknow

University: Kumaun University, Nainital

15. Ms. Ridhi Goel

Bioinformatics of WRKY gene family: Evolution, Expression and Neofunctionalization in higher plant

Guides: Dr. MH Asif, Senior Scientist, CSIR-NBRI, Lucknow

University: Academy of Scientific and Innovative Research (AcSIR), New Delhi

16. Sameer Dixit

Enhancement of Methanol Production in Tobacco for Broad Spectrum Insect Resistance

Guide: Dr. Praveen C Verma, Senior Scientist, CSIR-NBRI, Lucknow

University: Academy of Scientific and Innovative Research (AcSIR), New Delhi.

17. Ms. Shilpi Singh

Study on Indian bred Bougainvillea through morphological and molecular approaches

Guides: Dr. RK Roy, Senior Principal Scientist, CSIR-NBRI, Lucknow and **Dr. S Chandra**, Assistant Professor, Kumaun University, Nainital

University: Kumaun University, Nainital

18. Ms. Shikha Verma

Identification and characterization of a novel arsenic methyltransferase from *Westerdykella aurantiaca* isolated from arsenic contaminated agricultural soil

Guides: Dr. D Chakrbarty, Senior Scientist, CSIR-NBRI, Lucknow and **Dr. Veena Pande,** Head, Department of Biotechnology, Kumaun University, Nainital

University: Kumaun University, Nainital

19. Ms. Smrati Srivastava

Spatial and Temporal Regulation of Ripening in Two Indian Varieties of Mango (*Mangifera indica*)

Guide: **Dr. Vidhu Sane**, Principal Scientist, CSIR-NBRI, Lucknow

University: Academy of Scientific and Innovative Research (AcSIR), New Delhi

20. Ms Sujata Misra

Taxonomic reappraisal and genetic diversity assessment in Indian *Luffa* Mill. (Cucurbitaceae) through morphological and PCR-based DNA marker analyses

Guides: **Dr. KN Nair**, Senior Principal Scientist, CSIR-NBRI, Lucknow and **Prof. SS Bargali**, Kumaun University, Nainital

University: Kumaun University, Nainital

21. Mr. Surendra Pratap Singh

Novel strategy for developing male sterile plants and fertility restoration of F1 hybrid through regulated expression system

Guides: Dr. RR Singh, Department of Botany, Lucknow University and **Dr. SV Sawant**, Senior Principal Scientist, CSIR-NBRI, Lucknow

University: Lucknow University, Lucknow

22. Tapsi Shukla

Understanding arsenic stress responses using natural variation in *Arabidopsis thaliana*

Guide: Dr. Prabodh K Trivedi, Senior Principal Scientist, CSIR-NBRI, Lucknow

University: Academy of Scientific and Innovative Research (AcSIR), New Delhi.

23. Ms. Varsha Srivastva

Cytotaxonomic studies on some threatened and medicinally important plants from Indian Himalayan Region.

Guides: Prof. Kumkum Mishra, Lucknow University and **Dr. P Agnihotri**, Senior Scientist, CSIR-NBRI, Lucknow

University: Lucknow University, Lucknow

24. Mr. Verendra Kumar

To explore the role of histone deacetylases in epigenetic regulation of fiber development in *Gossypium hirsutum*

Guides: Dr. Gauri Saxena, Department of Botany, Lucknow University and **Dr. SV Sawant**, Senior Principal Scientist, CSIR-NBRI, Lucknow

University: Lucknow University, Lucknow

25. Mr. Vikash K Yadav

Identification and characterization of long range chromatin interactions involved in regulation of gene expression in *Arabidopsis thaliana*

Guides: Dr. SV Sawant, Senior Principal Scientist, CSIR-NBRI, Lucknow

University: Academy of Scientific and Innovative Research (AcSIR), New Delhi

S & T SUPPORT

Information, Publication & Library

Dr. P A Shirke, Dr. K N Nair, Dr. C S Mohanty, Mr. Yogendra Nath, Mr. Yogendra Mishra, Mr. M L Kain, Mr. R R Rastogi

Planning Monitoring & Evaluation

Dr. A K Gauniyal, Dr. R N Gupta, Mr. V K Gupta

Technology Transfer & Business Development

Dr. A K Gauniyal, Mr. Vivek Srivastava, Mrs. Swati Sharma, Mr. B L Meena

ICT

Dr. Sudarshan Kumar, Mr. Surjit Kumar, Mrs. Leena Wahi Gupta, Mr. Prashant Srivastava, Mr. Devranjan

Essential and Civil Services

Mr. A A Mallick, Mr. V D Tripathi, Mr. L K Srivastava, Mr. Harendra Pal, Mr. Somanath Swain

S & T SUPPORT SERVICES

INFORMATION, PUBLICATION & LIBRARY (IPL)

IPL, one of the core S&T support systems of the Institute, 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, scientific education materials including 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 2016-2017:

i) *CSIR-NBRI Newsletter*, 2016, Vol. **43**, Nos. 2-4 and 2017, Vol. **44,** No.1.

ii) Educational Material (Calendar) for the year 2017 was designed and produced, with the theme - "Bougainvillea-CSIR-NBRI Varieties".

iii) CSIR-NBRI Annual Report**:** Annual Report 2015-2016 was compiled and brought out. It was released on the occasion of Annual Day of the Institute on October 25, 2016 by Prof. Pramod Tandon, CEO, Biotech Park, Lucknow and Padmashree Dr. P Pushpangadan, DG, AIHBPD, Thiruvananthapuram and Former Director, CSIR-NBRI, Lucknow.

iv) 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 2015-2016.

Sale of Publications :**₹ 14,735/-**

Parliament Questions: Forty Five parliament questions received from CSIR HQ and other agencies were answered.

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, University Students, Research Scholars and other user groups as well. 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.

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.

PLANNING, MONITORING & EVALUATION

The Planning, Monitoring and Evaluation Division of the Institute assist the Director and acts as a liaison between Director and various R&D groups: CSIR HQ and other organizations. 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. The activities of the division include scrutiny, coordination and evaluation of new research proposals, monitoring the progress of research projects and maintenance of repository of R&D projects in both physical documents as well as electronic databases.

During 2016-17, 41 Grant-in-Aid/Consultancy projects were populated in the R&D module as a part of

LIBRARY HOLDINGS (As on 31.3.2017)

Books & Journals	
1. Number of books and journals added during 2016-2017	
(i) Books Purchased	Nil
(ii) Books received on gratis/ exchange	05
(iii) FAO's Books received	12
(iv) Bound Journals	06
Total number of books added during 2016-17	**23**
2. Number of books and bound journals as on 31.3.2017	60903
Current Periodicals	
(i) Print only	67
(ii) Print + Online	Nil
(iii) Online only	20
(iv) Online received through CSIR consortium (NKRC) on share basis	475
(v) Complimentary/Exchange	14
Total number of Periodicals (titles) received during 2016-2017	**576**
Database received through CSIR Consortium (NKRC) on share basis	02
Document Delivery Services	
Reprography Service	06
Total number of photocopies of documents and scientific publications provided to the scientists of the Institute during 2016-2017	7300

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 necessary project receipts of the FY 2016-17 of ongoing projects were processed in the Centralized Valuable Receipt (CVR).

The major activities carried out during the year were:

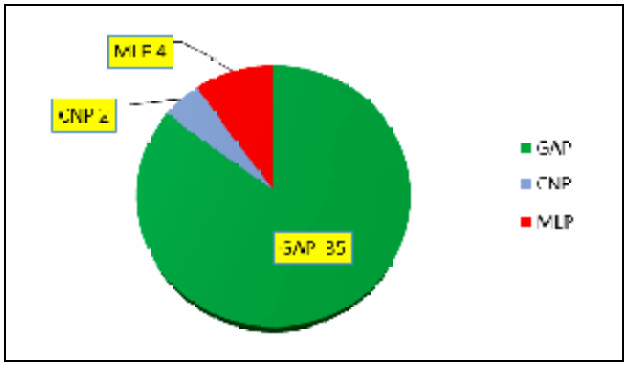
- Prepared CSIR-NBRI Policy and Road Map Document
- Prepared Document on Performance Appraisal Board (PAB)
- Mapping of new Contract R&D Projects in R&D Project Module
- Document for renewal of registration for availing customs / central excise duty exemption certificate
- Technical manpower planning and human resource development.
- Coordination between various agencies with respect to R&D activities
- Project evaluations of new research proposals (through Project Evaluation Committee).
- The necessary project receipts of the FY 2016-17 of ongoing projects were processed in the CVR
- Database maintenance for R&D projects (in-house, sponsored, collaborative, Grant-in-aid, Consultancy, NMITLI, Plan Projects & Network Projects)
- Organization of 45th and 46th Research Council (RC) meetings held during April 22, 2016 and March 15, 2017, respectively.
- 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
- Examination, evaluation and processing of indents
- Public Financial Management System (PFMS): As an Agency Administrator of PFMS of CSIR-NBRI, details of all the utilization certificates (UCs) funded by various funding agencies were checked and approved in the PFMS portal (https://pfms.nic.in/Users/LoginDetails/Login.aspx?ReturnUrl=%2f)).
- Processing of foreign deputation cases of researchers for various R&D purposes.
- The visit of foreign scientists/nationals was facilitated through ISTAD, CSIR HQ, New Delhi.

Projects Initiated during 2016-17

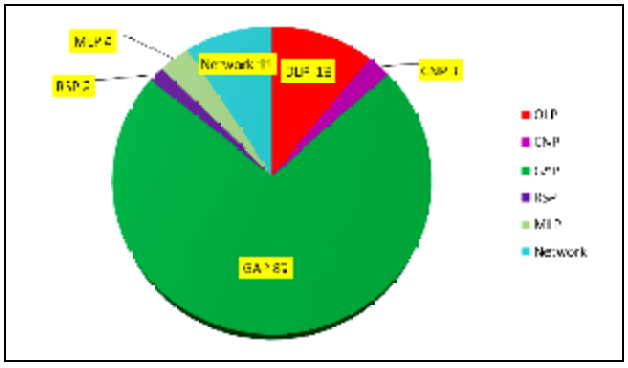
S. No.	Project	Project title	Funding Agency	Project Co-ordinator/ Investigator	Duration
1.	MLP 0007	Thebaine-rich opium poppy lines for suitable cultivation through narcotics department	CSIR	Dr. Sudhir Shukla	18 Months w.e.f. 20-Jul-16
2.	MLP 0008	Development of low grain arsenic rice cultivar for arsenic contaminated areas	CSIR	Dr. Shekhar Mallick	18 Months w.e.f. 06-Sep-16
3.	MLP 0009	Anacardic Acid: A potential molecule to increase cotton fibre yield and quality	CSIR	Dr. Samir V. Sawant	18 Months w.e.f. 06-Sep-16
4.	MLP 0022	Development of microbial formulations that serve as stress buster and biofertilizer for improving crop productivity in stressed agriculture	CSIR	Dr. P.S. Chauhan	25 Months w.e.f. 10-Feb-17
5.	CNP 3042	Consultancy for improvement of alkaline land of Rail Coach Factory (RCF), Raebareli	Rail Coach Factory (RCF), Raebareli	Dr. S.K. Tewari	07 Months w.e.f. 11-Apr-16
6.	CNP 3043	Consultancy study for expansion of Obra Thermal Power Plan by addition of 2x660 MW at Obra, Tehsil Robertsganl, District Sonebhadra, Uttar Pradesh I. Assessment of soil health and recommendation of decontamination strategies II. Mitigation of fly-ash contaminated agriculture soil-technology demonstration for environmental management.	Uttar Pradesh Rajya Vidyut Utpadan Nigam Ltd, Lucknow	Dr. Vivek Pandey	18 Months w.e.f. 06-Jun-16
7.	GAP 3370	Exploring transcriptional regulators involved in prickle formation in *Solanum Khasianum*	SERB, New Delhi	Dr. Pratibha Mishra	36 Months w.e.f. 04-Apr-16
8.	GAP 3371	Assessment of population dynamics and carbon sequestration potential in conjunction with sustainable utilization of some medicinally important plant species to expedite conservation goals	SERB, New Delhi	Dr. Soumit K. Behera/ Dr. N. Manika	24 Months w.e.f. 08-Apr-16
9.	GAP 3372	Monitoring of organochlorine pesticides (OCPs) pollution of River Ganga at Kanpur, India	NASI, Allahabad	Dr. Alok Lehri/Dr. Vandana Singh	24 Months w.e.f. 01-Apr-16
10.	GAP 3373	Search for elite chemotype(s) of *Centella asiatica* and their relationship with ecogeography	NMPB, Ministry of AYUSH, New Delhi	Dr. Sharad Srivastava	36 Months w.e.f. 17-May-16
11.	GAP 3374	Identification of Potential Bioactive Chemical Marker Compounds and Biological Studies of *Gloriosa superba* and their geographical variations	NMPB, Ministry of AYUSH, New Delhi	Dr. Ch.V. Rao	36 Months w.e.f. 17-May-16
12.	GAP 3375	Identification of elite chemotype(s) and evaluation of biological properties of essential oils from *Cyperus rotundus* Linn. from different phytogeographical zones of India	SERB, New Delhi	Dr. Sharad Srivastava/Dr. Priyanka Dhar	18 Months w.e.f. 01-Jun-16
13.	GAP 3376	Investigation of the biological roles of MYB1 transcription factor and its regulatory microRNAs in secondary cell wall biosynthesis in cotton (*Gossypium* sp.) fibers	SERB, New Delhi	Dr. Samir V. Sawant/ Dr. Pravin Prakash	24 Months w.e.f. 11-Jul-16
14.	GAP 3377	International consortium for renewable and advanced fuel technologies (i-CRAFT)	INDO-US Science and Technology Forum, New Delhi	Dr. Sanjeeva Nayaka	36 Months w.e.f. 25-Jul-16

15.	GAP 3378	To decipher the histone acetylation dynamics regulating the yield and quality of cotton fiber	DST, New Delhi	Dr. Samir V. Sawant/ Dr. Amita Dubey	36 Months w.e.f. 08-Aug-16
16.	GAP 3379	Exploration of native endophytic fungi from *Bacopa monnieri* involved in bacoside biosynthesis	SERB, New Delhi	Dr. Aradhana Mishra/ Dr. Sumit Kumar Soni	24 Months w.e.f. 08-Aug-16
17.	GAP 3380	Modeling the plant-environment interactions with particular reference to chemicals for risk assessment	SERB, New Delhi	Dr. Shekhar Mallick/ Dr. Shikha Gupta	24 Months w.e.f. 01-Sep-16
18.	GAP 3381	Enhancement of solasodine content in shoot cultures of *Solanum khasianum* Clarke through biotic elicitors and expression analysis of the genes associated with solasodine biosynthesis	SERB, New Delhi	Dr. Pratibha Mishra/ Dr. Archana Prasad	24 Months w.e.f. 17-Aug-16
19.	GAP 3382	Development of insect resistant chickpea lines expressing the cryIAc (Bt) gene under a strong early acting wound inducible promoter for improved efficacy of the Bt toxin	SERB, New Delhi	Dr. A.P. Sane/ Dr. Krishna Kumar	24 Months w.e.f. 19-Sep-16
20.	GAP 3383	Investigation of plant diversity of Nawab Wazid Ali Shah Zoological Garden, Lucknow	Nawab Wazid Ali Shah Zoological Garden, Lucknow	Dr. Tariq Husain	12 Months w.e.f. 21-Dec-16
21.	GAP 3384	Microbial roles in yield management of scented rice of North-East, India	DBT, New Delhi	Dr. A.K.S. Rawat	36 Months w.e.f. 27-Oct-16
22.	GAP 3385	Seed multiplication of high thebaine lines of Opium Poppy (*Papaver somniferum* L.) at different locations of Rajasthan and Madhya Pradesh	Govt. Opium and Alkaloids Factories, Deptt. of Revenue Ministry of Finance, GoI, New Delhi	Dr. Sudhir Shukla	12 Months w.e.f. 20-Oct-16
23.	GAP 3386	Chemotyping and molecular profiling of bioactive metabolites in *Hemidesmus indicus* and *Costus speciosus*, adapted to different phytogeographical zones and identification of candidate genes related to metabolic pathways	NASF, ICAR, New Delhi	Dr. Sharad Srivastava	14 Months w.e.f. 01-Jan-17
24.	GAP 3387	Studies on role of endophytes in variation of acaricidal properties of two acaricide producing plant species NBA22/F1 and NBA18/D1 from North-Eastern States	DBT, New Delhi	Dr. Sharad Kumar Srivastava	36 Months w.e.f. 11-Feb-17
25.	GAP 3388	Chemical, structural and functional characterization of identified anti-tick lead phytochemicals and optimization of delivery matrix for effective application of natural formulation for control of acaricide resistant ticks	NASF, ICAR, New Delhi	Dr. A.K.S. Rawat	14 Months w.e.f. 01-Jan-17
26.	GAP 3389	Functional Characterization of rice class I Metallothionein (MT) gene family	SERB, New Delhi	Dr. Debasis Chakrabarty	36 Months w.e.f. 06-Feb-17
27.	GAP 3390	Plant Diversity Assessment of Dima Hasao district in Assam	ASBB, Guwahati, Assam	Dr. L.B. Chaudhary	24 Months w.e.f. 04-Feb-17
28.	GAP 3391	Assessment of F and Cr in soil, Plants and water in and around the Unnao region of Uttar Pradesh	UPCST, Lucknow	Dr. Shekhar Mallick/ Dr. Gayatri Singh	24 Months w.e.f. 02-Dec-16
29.	GAP 3392	Role of NPR1 in global nucleosomal remodeling in *Arabidopsis thaliana*	SERB, New Delhi	Dr. Samir V. Sawant	36 Months w.e.f. 15-Feb-17

30.	GAP 3393	Metabolomic analysis for isoquinoline alkaloids from therapeutically important genus *Berberis* L.	SERB, New Delhi	Dr. Sharad Srivastava	36 Months w.e.f. 06-Feb-17
31.	GAP 3394	Development of consensus genetic linkage map for *Gossypium* L. spp. with SNP markers and QTL analysis for fiber trait	DBT, New Delhi	Dr. Samir V. Sawant/ Dr. S.N. Jena	36 Months w.e.f. 21-Feb-17
32.	GAP 3395	Exploring a novel role of SkMSM1 and SkR2R3-Myb315-like transcriptional regulators in the development of prickles of *Solanum khasianum*	DBT, New Delhi	Dr. Pratibha Misra	36 Months w.e.f. 30-Jan-17
33.	GAP 3396	Biofortification of essential metal nutrients (Fe, Zn) in *Oryza sativa* L. through microbes	SERB, New Delhi	Dr. Shekhar Mallick	36 Months w.e.f. 03-Mar-17
34.	GAP 3397	Exploration of plant diversity in un/underexplored areas of Manipur and Nagaland: Inventory, conservation of threatened and endemic plants, field germplasm bank and bioprospection of selected taxa for using as bioresources	IBSD, Imphal	Dr. S.K. Barik (PC) / Dr. Tariq Husain (PI)	24 Months w.e.f. 21-Mar-17
35.	GAP 3398	Meta-genomic and transcriptomic studies on *Termitomyces* growing fungal combs of termites found in Assam for bioprospection	DBT, New Delhi	Dr. T.S. Rana	36 Months w.e.f. 17-Jan-17
36.	GAP 3399	Monographic studies on the genus *Geranium* with special emphasis on the phytosociological and conservation status	SERB, New Delhi	Dr. V.V. Wagh	36 Months w.e.f. 15-Mar-17
37.	GAP 3400	Programme support secondary plant product pathway engineering for enhanced nutritional quality and yield	DBT, New Delhi	Dr. P.K. Trivedi	60 Months w.e.f. 24-Mar-17
38.	GAP 3401	Combining Proteomics and Transcriptome sequencing to identify putative RNAi targets for mealybug (*Phenacoccus solenopsis*) and their functional validation	SERB, New Delhi	Dr. P.C. Verma	48 Months w.e.f. 20-Mar-17
39.	GAP 3402	Development of plant based synergistic natural supplement and its pharmacological validation to alleviate gouty arthritic conditions	DST, New Delhi	Dr. Sharad Srivastava/ Dr. Ankita Misra	36 Months w.e.f. 22-Mar-17
40.	GAP 3403	Molecular Systematics of the Genus *Betula* L. (*Betulaceae*) in India	SERB, New Delhi	Dr. T.S. Rana	48 Months w.e.f. 17-Mar-17
41.	GAP 3405	Studies on microbiome mediated defense signaling against *Bipolaris sorokiniana* (spot-blotch) infestation in wheat	SERB, New Delhi	Dr. P.S. Chauhan/ Dr. Sudeep Tiwari	21 Months 13 days w.e.f. 27-Jul-2016



New projects initiated during 2016-17



Projects in operation during 2016-17

Deputation of NBRI Scientists/Fellows Abroad

S.N.	Name of Scientist	Country of Visit	Visit Duration	Purpose of visit
1.	Dr. Alok Lehri	Kathamandu, Nepal	June 18-19, 2016	To attend meeting regarding final assessment audit of "Instrument Section and Natural Product Research Lab, Department of Plant Resources"
2.	Dr. Pankaj Kumar Srivastava	KTH Royal Institute of Technology, Stockholm, Sweden	June 19-23, 2016	To participate and for oral presentation in 6th International Congress Arsenic in the Environment - Arsenic Research and Global Sustainability (AS2016)
3.	Dr. D.K. Upreti	Sunchon National University, South Korea	July 20-23, 2016	To attend an International Symposium and workshop on "Lichen Biodiversity in Asia and Biological Activity of Lichen Bioresources"

TECHNOLOGY TRANSFER & BUSINESS DEVELOPMENT, PATENT, RTI & 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:

- To interact with industries, agencies for increasing business possibilities for the Institute.
- To make 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.
- Training Cell of the division manages 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.
- Patent Cell of the division helps in 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.

MoUs/MoAs/MTAs SIGNED

S. No.	Details	Client	Date
1.	MTA for germplasm of guar *(Cyamopsis teragonoloba)*	ICAR – NBPGR, New Delhi	April 04, 2016
2.	Agreement for the project of development of F1 hybrid cotton using novel reversible male sterility system	DBT, New Delhi	May 26, 2016
3.	Agreement for the study for expansion of Obera Thermal Power Plant	Uttar Pradesh Rajya Vidyut Utpadan Nigam Ltd., Lucknow	June 06, 2016
4.	MTA for *pNIA* plasmid for nuclear localization	State University of New York, New York, USA	June 17, 2016
5.	MTA for procurement of germplasm of *Lepidium* spp., *Vitex* spp., *Aegle marmelos* and *Limonia acidissima*	ICAR – NBPGR, New Delhi	June 21, 2016
6.	MTA for procurement germplasm of tomato varieties	ICAR – NBPGR, New Delhi	June 22, 2016

7.	MTA for procurement of vectors	China Agriculture University and Seoul National University, Korea through ADDGENE, USA	August 09, 2016
8.	Agreement for CSIR-NBRI technologies marketing	CSIR-TECH Private Ltd., 100 NCL Innovation Park, DR. Homi Bhabha Road, Pune	August 26, 2016
9.	Secrecy Agreement for evaluation of product – Herbi Chew	Vasundhara Green Dehydration Pvt. Ltd., Gujrat	September 20, 2016
10.	Secrecy Agreement for evaluation of Anacardic Acid	UCP Chemicals India Pvt. Ltd., Chennai	September 27, 2016
11.	MTA and Commercial Use Agreement (CUA) for Whitefly Technology	Punjab Agriculture University (PAU), Ludhiana, Punjab	October 04, 2016
12.	MTA for procurement of germplasm of chickpea	Indian Institute of Pulses Research, Kanpur	October 25, 2016
13.	MoA for project entitled 'Genome wide epigenetic variations'	DBT, New Delhi	November 29, 2016
14.	Secrecy Agreement for Hair Dye evaluation	KTC Products, Baddi (HP)	December 22, 2016
15.	MTA for procurement of seed material of Pearl millet	ICAR-NBPGR, New Delhi	December 26, 2016
16.	Agreement for technical services	Assam State Biodiversity Board, Aranya Bhawan, Panjabari, Guwahati	January 06, 2017
17.	MoA for project 'To decipher protein interaction network of TAF4b	DBT, New Delhi	January 19, 2017
18.	Secrecy Agreement for Herbichew	Eximburg International Pvt. Ltd., Gujrat	February 07, 2017
19.	MTA for procurement of plasmid	ADDGENE, USA From Donald Danforth Plant Science Center, USA	February 15, 2017
20.	MoU for Academics Purposes	Dr. SMNR University, Lucknow	February 23, 2017

CENTRAL INSTRUMENTATION FACILITY (CIF)

Technical Services Provided and Achievements

Central Instrumentation Facility of the institute, maintains major sophisticated equipment's like GCMS, IRMS, TD-NMR, HPLC-ICP-MS, HPLC, HPTLC, LC/MS, GLC, AAS, Flash Chromatography, Microwave Digestion system, Stereo Microscope, Refractometer, Tintometer, and SCFE, etc. CIF provides 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 during reporting period is given below:

Analytical testing services provided (1st April 2016 to 31st March 2017)

No. of external samples analyzed for industries/institutes/organization : **65**

Total revenue generated : **Rs.1,79,391.00 (training + testing)**

No. of internal samples analyzed : **7888**

Participated in International and National PT/ILC programme-Total : **3**

Entrepreneurs/ individuals benefited : **19**

NABL-Accreditation

CSIR-NBRI has been accredited since 2008 as per the requirements of ISO-IEC-17025, 2005 from NABL (National Accreditation Board for Calibration and Testing of Laboratories), Department of Science and Technologies (DST), Govt. of India, New Delhi.

Reassessment audit has been conducted in July 2016 and the audit report recommended continuation of NABL-accreditation of the Institute up to July 2018, with the Certificate No. T-1381.

Area of Scope of CIF - Herbal drugs, Essential oils, Vegetable oils & Soil

Information and Communication Technology

CSIR-NBRI Sub-Distributed Information Centre (DIC)

The CSIR-NBRI Sub-DIC was established during 1999-2000, this Centre facilitates the following activities related to biodiversity informatics:

- Established a state-of-the-art Ethernet switch based network in CSIR-NBRI and also the institute's website (www.nbri.res.in) for providing global access to all R&D groups and promote research in bioinformatics & biotechnology.
- Updated and upgraded database of over 2030 species of legumes of South Asia covering countries India, Pakistan, Nepal, Bhutan, Bangladesh, Sri Lanka & Maldives under the aegis of the International Legume Database and Information Service (ILDIS), U.K.
- Initiated development of database standards, software's, digitization of plant diversity information, including nomenclature and geo-occurrence.
- Digitized herbarium of CSIR-NBRI (LWG) and the virtual herbarium was launched by the Honorable Minisiter of S&T and Earth Sciences, Dr. Harsh Vardhan on April 20, 2016.
- To develop network and establish linkages with global networks so as to bring bioinformatics to many biotechnologists, traditional botanists and several Institutions at regional, national and international level.

EXPOSITION

The Exposition showcases the history and the R&D activities of the institute in form of posters, models, photographs and articles. This year the exposition was visited by several dignitaries and Guests of the institute. On the special occasions of National Technology Day, CSIR Foundation Day, National Science Day and during several Out-Reach Programmes of the institute the institute and the Exposition was kept open for the common public, school children, college and university students, teachers, scientists, researchers and other academicians to inspire and make aware the visitor with the research activities of the institute. Several thousands individuals visited the Exposition on these open days.

ENVIS-Center

The Environmental Information System (ENVIS) at CSIR-NBRI is focused on Plants and Pollution.

- The ENVIS-NBRI updated its website, databases and subject area panel and developed new databases. The Centre organized outreach-cum-training programmes for general public and students. The Centre has developed an android mobile application on plants for air pollution control. The total number of visits to the website were 1222442. A total number of 177 queries were obtained and answered.
- ENVIS-NBRI organized the following outreach-cum-training programmes during this period.
  - ❖ Orientation-cum-Training Programme on ENVIS-NBRI by CSIR-National Botanical Research Institute at National Post Graduate College (N.P.G.C), Lucknow, on September 14, 2016

  - ❖ ENVIS-NBRI outreach in India International Science Festival (IISF-2016) with Vigyan Bharati at CSIR NBRI on November 11, 2016

❖ ENVIS-NBRI outreach during Flower Show at CSIR-NBRI on December 10-11, 2016

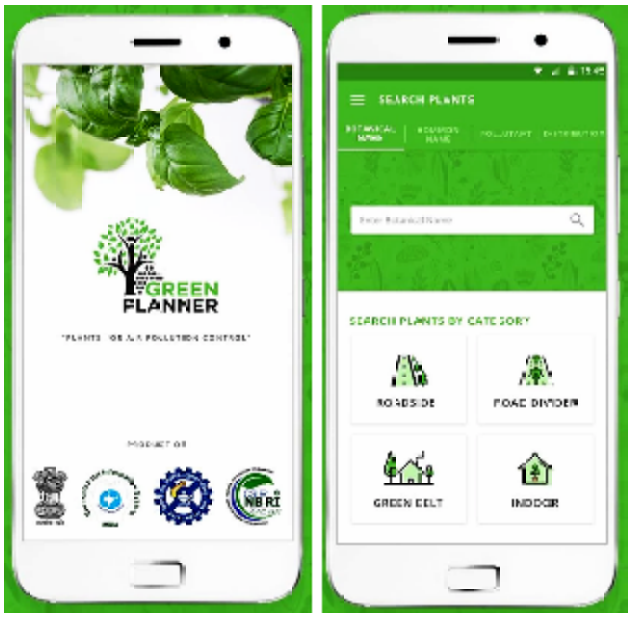
❖ ENVIS-NBRI orientation at Munshi Raghunandan Prasad Sardar Patel Post Graduate College, Barabanki on February 11, 2017

- Four Quarterly ENVIS-NBRI Newsletters have been published during 2016-17, viz., Vol. 12 No. 1: Indoor Air Pollutants; Vol. 12 No. 2: Biomonitoring; Vol. 12 No. 3: Forest Fire; Vol. 12 No. 4: Carbon Sequestration.

  (http://nbrienvis.nic.in/Publication Common.aspx?LinkId=740)

- Android Mobile App – Green Planner:

An android mobile application "Green Planner" covering detailed information on air pollution mitigant plants has been developed and released at Google Play Store for different stakeholders (https://play.google.com/store/apps/details?id=com.nbri_csir&hl=en). This Green Planner App was released by Shri Ajay Narayan Jha, Secretary, MoEF&CC, Govt. of India in the National Evaluation Workshop of ENVIS Scheme organized by MoEF&CC at Gandhinagar, Gujrat during March 17-18, 2017. The "Green Planner" is a database to provide information on different plants for mitigating air pollution. These plants can be planted on roadside, road-dividers, in greenbelts, and in indoor premises. The plantation of such locally suitable and pollutant mitigant plants will help to ameliorate the deleterious effects of different air pollutants from industrial emissions, vehicular exhausts, and indoor premises. The plant list in the Green Planner will provide the botanical and common names of pollution tolerant and mitigant plants, their distribution in India and suitable planting sites along with economic and ecological benefits as well as other relevant information.



राजभाषा यूनिट

संस्थान में वर्ष 2016-2017 के दौरान राजभाषा कार्यान्वयन समिति के तत्वाधान में हिन्दी के प्रगामी प्रयोग से सम्बन्धित निम्नांकित गतिविधियाँ की गयीं व संस्थान में राजभाषा विभाग, गृहमंत्रालय, भारत सरकार द्वारा जारी दिशा निर्देशों के अनुसार निर्धारित समय में तिमाही बैठकों का आयोजन किया गया।

संस्थान द्वारा हिन्दी प्रयोग को प्रोत्साहित करने हेतु अधिकारियों व कर्मचारियों के लिए वर्ष में चार हिन्दी कार्यशालाओं का आयोजन किया गया।

संस्थान से प्रकाशित होने वाली राजभाषा गृह पत्रिका 'विज्ञानवाणी' के 22 वें अंक का सफल सम्पादन किया गया, जिसमें संस्थान में होने वाले क्रियाकलापों से सम्बंधित वैज्ञानिक, तकनीकी तथा जनप्रिय लेखों को प्रकाशित किया गया।

हिंदी पखवाड़े का आयोजन

संस्थान द्वारा 1-14 सितम्बर 2016 के दौरान एक हिन्दी पखवाड़े का आयोजन किया गया, जिसमें विभिन्न प्रतियोगिताओं द्वारा हिन्दी में दक्षता बढ़ाने का प्रयास किया गया व इस अवसर पर संस्थान के पुस्तकालय में उपलब्ध हिन्दी पुस्तकों की एक प्रदर्शनी भी लगायी गयी व इसके अतिरिक्त गतवर्ष की भांति हिन्दी में कार्य करने वाले कर्मचारियों को प्रोत्साहित करने हेतु पुरस्कृत किया गया।

पखवाड़े के समापन समारोह में तद्भव पत्रिका के प्रधान सम्पादक श्री अखिलेश जी मुख्य अतिथि के रूप में उपस्थित रहे। श्री अखिलेश जी, ने उक्त कार्यक्रम में अपना हिन्दी से सम्बंधित ओजस्वी व्याख्यान प्रस्तुत किया।

हिंदी पखवाड़ें की कुछ झलकियाँ

EVENTS

S. No.	Date	Salient Feature
1.	April 8, 2016	Under the CSIR- Rural Development Programme (CSIR-800), CSIR-NBRI organized a Farmers Interaction Programme (Kisan Mela) on April 8, 2016 at its Distant Research Centre, Banthra. Seven hundred selected farmers from different villages of Lucknow, Barabanki, Mau, Sultanpur, Amethi and Unnao districts participated in the programme.
2.	April 20, 2016	Dr. Harsh Vardhan, Union Minister for Science & Technology and Earth Sciences, Govt. of India visited the Institute on April 20, 2016. He addressed the scientists and staff members and exhorted to think out of box and plan to work towards development on innovation driven research. In a major event of the day Dr. Harsh Vardhan, launched "CSIR-NBRI Herbarium Online" on the CSIR-NBRI website (www.nbri.res.in) and thus making One Hundred thousand Herbarium collections accessible worldwide. Dr. Harsh Vardhan appreciated the efforts of scaling up of CSIR-NBRI and CSIR-CIMAP joint product BGR-34 which has got overwhelming response among Diabetes Type-II patients throughout India. Dr. Harsh Vardhan, specifically directed CSIR-NBRI scientists to take up work on scaling up of "Herbi Chew" on a priority basis as a potentially useful product to replace the tobacco based Gutka's currently available in the market, which causes cancer and other diseases among the citizens. Dr. Harsh Vardhan visited different plant houses of the Botanic Garden and planted a sapling of Rakt Chandan.
3.	April 26-28, 2016	CSIR-NBRI organized a training programme on "Bonsai Technique" during April 26-28, 2016. A total number of 16 candidates including housewives, doctors, students and general garden lovers participated in the programme.
4.	May 03-04, 2016	CSIR-NBRI organized a two day training programme on 'Dehydration of Flower and Foliage' at MR Mahila College, Darbhanga, Bihar, during May 3-4, 2016. Teachers and students of the college participated in the training. The students were imparted hands on training on dehydration techniques, making artefacts and their maintenance.
5.	May 11, 2016	CSIR-NBRI celebrated National Technology Day on May 11, 2016. The day was observed as 'Open Day' and large number of students drawn from various local schools and colleges visited different facilities, viz., Exposition, Herbarium, Library, Botanic Garden and various R&D Laboratories. Prof. Asis Datta, Distinguished Scientist and Former Director, National Institute of Plant Genome Research, New Delhi, was the Chief Guest and delivered The National Technology Day Lecture on 'Dream to bring science to society'.
6.	August 15, 2016	**INDEPENDENCE DAY**
7.	September 09, 2016	A Cleanliness Drive under Swacch Bharat Abhiyaan was organized on September 09, 2016 at the Botanic Garden of the institute. All the staff members actively participated in the drive.
8.	सितंबर 1–14, 2016	सीएसआईआर–राष्ट्रीय वनस्पति अनुसंधान संस्थान, लखनऊ में दिनांक 1–14 सितंबर 2016 के मध्य हिन्दी पखवाड़े का आयोजन किया गया। जिसके अंतर्गत संस्थान में कार्य करने वाले अधिकारियों/कर्मचारियों को प्रेरणा–प्रोत्साहन व हिन्दी के प्रयोग को बढ़ावा देने के उद्देश्य से विभिन्न प्रतियोगिताएं आयोजित की गयी। इनमें मुख्यतः हिन्दी टिप्पण आलेखन प्रतियोगिता, हिन्दी ज्ञान पहेली, हिन्दी वर्ग पहेली प्रतियोगिता, कर्मचारियों के बच्चों के लिए हिन्दी निबंध प्रतियोगिता, कवि सम्मेलन (कर्मचारियों द्वारा) व पुस्तकालय में हिन्दी पुस्तकों की प्रदर्शनी सम्मिलित थी।

S. No.	Date	Salient Feature
9.	September 27 , 2016	CSIR-NBRI, celebrated the 74th Foundation Day of Council of Scientific and Industrial Research, New Delhi on September 27, 2016. The Institute observed a "Open Day", over 600 students, researchers and general public visited various laboratories, exposition, herbarium and garden on this occasion. Dr. Shalendra Rajan, Director, ICAR-Central Institute for Subtropical Horticulture (CISH), Lucknow, was the Chief Guest of the function. Dr. Rajan mentioned that "CSIR-NBRI is reaching to the common man of the city as well as state through its research in the area of floriculture and the flower shows it organizes." Dr. Rajan, distributed certificates and mementoes to two employees who had completed 25 years of CSIR service and to 34 employees who retired during 2015-16. Dr. DK Upreti, the then Acting Director, distributed prizes and certificates to those children of staff who participated and won in the Science Essay competition organized on this occasion.
10.	October 25, 2016	CSIR- NBRI celebrated its 63rd Annual Day on October 25, 2016. Padmshree Prof. Pramod Tandon, CEO, Biotech Park, Lucknow was the Chief Guest and Padmshree Dr. P Pushpangadan. DG, Amity Institute of Herbal and Biotech Product Development, Thiruvananthapuram was the Guest of Honour. The Institute's Annual Report was released by the dignitaries. Dr. DK Upreti, the then Acting Director, presented the annual progress for 2015-16 and apprised about the various activities and achievements of the Institute during the reporting year. Dr. PK Singh and his team were felicitated for their outstanding research work on Whitefly resistant cotton and publication of the research findings in the prestigious journal, *Nature Biotechnology*. The recipients for the CSIR-Technology Award in the area of Life Science for the product BGR 34, a herbal formulation for diabetes management were also honoured. Scientists and research scholars of the institute who had published their research work in journals with high impact factors were also felicitated.
11.	November 03-10, 2016	CSIR-NBRI, organized a training course on "Classical and Modern Methods in Plant Taxonomy and Biosystematics" during November 03-10, 2016. Dr. GS Rawat, Scientist 'G' and Dean, Faculty of Wildlife Sciences, Wildlife Institute of India, Dehradun was the Chief Guest of the Inaugural Function. During his inaugural speech, he emphasized the need and importance of plant taxonomy and taxonomists in the country for documentation of plant resources. About 32 participants from various institutions, colleges, universities, and other departments representing 10 states of India participated in the training course.
12.	November 11, 2016	CSIR-NBRI organized a One Day Outreach Programme to celebrate the 2nd India International Science Festival (IIFS-2016) on November 11, 2016. A poster exhibition of R&D Products of the Institute was displayed in the Institute for students, teachers, research scholars and the public. A film on the activities and achievements of CSIR-NBRI and a documentary film on Vijnana Bharati (VIBHA) were also screened at the Institute's auditorium for the students and visitors. In the concluding event, the Chief Guest of the function Prof. Sunil Bajpai, Director, Birbal Sahani Institute of Paleosciences, Lucknow, felicitated over 30 science innovators (including school children who received recognition at State or National level), science teachers, science journalists, senior science scientists, NGOs/ Individuals.
13.	November 25, 2016	Her Excellency Prof. Ameenah Gurib-Fakim, President of Mauritius visited CSIR-NBRI, Lucknow on 25th November, 2016. She planted a Sapling of Sandalwood in the garden. Later, she visited the Cycad and Cacti houses at the botanic garden. Her Excellency also interacted with the scientists of the institute.
14.	November 26, 2016	CSIR-NBRI, Lucknow celebrated Constitution Day on November 26, 2016. Prof. Shashikant Pandey, Associate Professor, BBAU, Lucknow delivered the constitution Day Lecture.

S. No.	Date	Salient Feature
15.	December 10-11, 2016	Dr. Girish Sahni, DG, CSIR and Secretary, DSIR, New Delhi during his maiden visit to CSIR-NBRI as DG, CSIR, addressed the scientists, research scholars and staff of the Institute. Dr. Sahni discussed the vision of the CSIR in development of the nation. He stated that CSIR with its tremendous wealth and potential contributed a lot in development of the nation. He emphasized on the need for transforming the existing CSIR wealth (General Science) to market and industry. Dr. Sahni advised scientists to be positive towards young researchers and encourage them for innovative and creative research. Dr. Girish Sahni and Mrs. Chander Kanta respectively, were the Chief Guest and Guest of Honour at the Chrysanthemum and Coleus – 2016 show held during December 10-11, 2016 at the Central Lawn, Botanic Garden of CSIR-NBRI. They distributed the prizes in a ceremony held on December 10, 2016. A total of 81exhibitors participated in the show with a total of 802 exhibits. A total of 23 Cups and Shield (Running Shields. and Cups) were distributed to the winners of the show. Dr. Alok Dhawan, Director, CSIR-IITR, Lucknow was the Chief Guest & Mr. CA Macfarlane, Principal, La Martiniere College, Lucknow was the Guest of Honour of the closing ceremony held on December 11, 2016.
16.	January 06-07, 2017	CSIR-NBRI in collaboration with Indian National Science Academy (INSA), National Academy of Science, India (NASI) and Uttar Pradesh Academy of Sciences (UPAS) organized a two day Faculty Training, Motivation and Adoption of Schools and Colleges Programme during December 06-07, 2016. Padmshree Dr. Nitya Anand, former Director, CSIR-CDRI, Lucknow was the Chief Guest at the inaugural function. The main objective of the programme was to create interest, excitement and excellence in science education at school and undergraduate level to raise the standard of science education and capabilities. A total of 31 teachers from 13 colleges of 7 districts of UP participated in the training programme.
17.	January 10, 2017	Prof. RK Kohli, Vice Chancellor, Central University of Punjab, Bhatinda, delivered a lecture on "Let's save ourselves from self-inflicted pollution" at the institute on January 10, 2017. Prof. Kohli spoke about the several common issues of pollution, its causes and remedies.
18.	January 21-22, 2017	A two day Rose and Gladiolus Show was organized during January 21-22, 2017 in the central lawn of the Institute. Prof. SK Barik, Director, CSIR-NBRI released two late blooming new Chrysanthemum varieties: 'NBRI-CSIR75' (commemorating the platinum jubilee celebrations of CSIR) and 'NBRI-Asha Kiran'. These varieties were developed by the floriculture group of the institute through gamma ray mutation. These varieties can be used as cut-flower and potted as well as bed plants. The number of entries for the show was 521 by 59 exhibitors from Lucknow and outstation. A total of 26 running cups/shields/trophies along with 266 prizes (First - 92, Second – 81 and Commendation – 93) were given to the winners of the show under different sections.
19.	January 26, 2017	**REPUBLIC DAY**
20.	January 31, 2017	CSIR-NBRI organized Science Popularization Lecture on "Health through Herbs" at Maharana Pratap Post Graduate College, Jangal Dhoosad, Gorakhpur on January 31, 2017 and at Digvijai Nath Post Graduate College, Gorakhpur on February 01, 2017. A total number of 300 students and 30 teachers participated in the programme.

S. No.	Date	Salient Feature
21.	फरवरी 02, 2017	राजभाषा कार्यान्वयन समिति द्वारा फरवरी 02, 2017 को एक हिंदी कार्यशाला का आयोजन किया गया। श्री दिनेश कुमार, भण्डार एवं क्रय अधिकारी, सीएसआईआर–एनबीआरआई, लखनऊ ने क्रय/विक्रय के नियमों पर व्याख्यान प्रस्तुत किया। श्री बिजेंद्र सिंह, हिंदी अधिकारी ने स्वागत भाषण के साथ कार्यशाला का शुभारम्भ किया। कार्यक्रम का समापन श्री संजीव शेखर, वित्त एवं लेखा अधिकारी के धन्यवाद ज्ञापन के साथ हुआ।
22.	February 11, 2017	CSIR-NBRI organized a lecture programme on "Herbs for Health and Plants for Controlling Environmental Pollution" at Munshi Raghunandan Prasad Sardar Patel Mahila PG College, Barabanki on February 11, 2017. Approximately 350 undergraduate and post-graduate students from science and arts streams and 20 teachers participated in the programme. The programme was followed by Exhibition cum training on controlling environmental pollution.
23.	February 15-17, 2017	Bonsai training programme was organized by CSIR-NBRI.
24.	February 28, 2017	CSIR-NBRI celebrated the National Science Day on February 28, 2017. The theme for this year's science day was 'Science and Technology for specially abled persons'. The day was observed as 'Open Day' for general public and students. In addition to 300 students, specially abled students drawn from local 8 schools/organizations also visited CSIR-NBRI Botanical Garden which included the tactile garden, Jurassic gallery, Cactus House, Fern Hose and Bonsai House. On the National Science Day, a MoU was signed with Dr. Shakuntala Mishra National Rehabilitation University, Lucknow (DSMNRU) for participation in teaching and research programmes in various streams of plant sciences. This MoU will provide an opportunity to students for registering in Ph.D. programmes with DSMNRU.
25.	March 06-07, 2017	CSIR-NBRI organized a workshop on "Eco-friendly Technologies for setting up Cottage Industry" on March 6-7, 2017 at Amity Institute of Biotechnology, Amity University, Lucknow. A total of 115 participants including faculty members and students participated in the workshop. The workshop intended to apprise and demonstrate the methodology for dehydrating and utilizing fresh flowers for a long period of time.
26.	March 4, 2017	**The National Safety Day**
27.	March 21-23, 2017	Bonsai training programme was organized by CSIR-NBRI.
28.	March 28-30, 2017	CSIR-NBRI organized a three day Training Programme on Preparation of Dehydrated Floral Crafts at the Botanic Garden during March 28-30, 2017. A total of 43 persons including students, teachers, housewives, etc. participated in the programme.

Glimpses of CSIR-NBRI Events

Farmers Interaction Programme -'Kisan Mela' at Banthra

Dr. Harsh Vardhan, Hon'ble Union Minister for Science & Technology & Earth Sciences, Govt. of India visits CSIR-NBRI

Training on Floral Dehydrated Crafts

Glimpses of CSIR-NBRI Events

National Technology Day

CSIR Foundation Day

Glimpses of CSIR-NBRI Events




Training Course on Classical and Modern Methods in Plant Taxonomy and Biosystematics



CSIR-NBRI Annual Day Celebrations

Glimpses of CSIR-NBRI Events




Out-Reach Programme Under IISF-2016



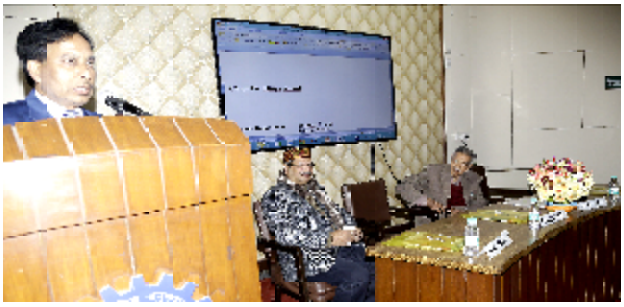

Her Excellency Prof. Ameenah Gurib-Fakim, President of Maurititus visited CSIR-NBRI

Glimpses of CSIR-NBRI Events

Constitution Day Lecture Programme

Glimpses of the Annual Chrysanthemum and Coleus Flower Show 2016

Glimpses of CSIR-NBRI Events

Faculty Training, Motivation and Adoption of Schools and Colleges Programme






Annual Rose and Gladiolus Show 2017

Glimpses of CSIR-NBRI Events

Invited Lecture by Prof. RK Kohli

National Science Day Celebrations

Glimpses of CSIR-NBRI Events

Workshop on Dehydrated Floral Craft

ACADEMY OF SCIENTIFIC AND INNOVATIVE RESEARCH (AcSIR)

Coordinator:
Dr. S V Sawant/Debasis Chakrabarty

The **Academy of Scientific & Innovative Research** or **AcSIR** is an Indian institute of national importance, currently head quartered in CSIR Campus, Taramani, and Chennai. The Academy was established for the purpose of granting doctoral and post-graduate 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 formalized by an Act of Parliament (Academy of Scientific & 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.

Mission

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 2506 full-time faculty members from CSIR Laboratories and over 4000 students enrolled in various programmes.

Courses offered at AcSIR-NBRI

S. 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 Environemnt 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 Biochem and Biotech	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

Number of students enrolled for Ph.D until 31st March 2017	**97**
Ph.Ds awarded during 2016-17	**4**
Ph.D theses submitted during 2016-17	**12**

RESEARCH COUNCIL (As on 31.03.17)

Prof. SK Sopory Former Vice Chancellor, Jawaharlal Nehru University, 584, Sector 14, **FARIDABAD -121007**	Chairman	**Dr. Ehrlich Desa** CSIR Distinguished Scientist, CSIR-4 PI, NAL Belur Campus **BENGALURU-560 037**	DG Nominee
Prof. R. Uma Shankar Professor & Head, Dept. of Crop Physiology and School of Ecology & Conservation, University of Agricultural Sciences, GKVK, **BENGALURU-560 065**	Member	**Dr. AK Tripathi** Director CSIR- CIMAP, P.O. CIMAP, Near Kukrail Picnic Spot **LUCKNOW – 226 015**	Director, Sister Laboratory
Prof. PK Gupta Hon. Emeritus Professor & NASI Senior Scientist Department of Genetics & Plant Breeding, Ch. Charan Singh University, **MEERUT – 250 004**	Member	**Dr. RA Vishwakarma** Director CSIR- Indian Institute of Integrated Medicine, Canal Road, **JAMMU - 180 001**	Cluster Director
Prof. JS Singh Professor Emeritus, Department of Botany, Banaras Hindu University, **VARANASI-221 005**	Member	**Prof. SK Barik** Director CSIR-National Botanical Research Institute, Rana Pratap Marg, **LUCKNOW – 226 001**	Member
Prof. JP Khurana Coordinator (UGC-SAP) 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**	Permanent Invitee
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 – 182 320**	Member
Dr. Paramjit Singh Director Botanical Survey of India, CGO Complex, Salt Lake City, **KOLKATA – 700 064**	Agency	**Dr. SK Tewari** Senior Principal Scientist CSIR-National Botanical Research Institute Rana Pratap Marg, **LUCKNOW – 226 001**	Member-Secretary

MANAGEMENT COUNCIL (As on 31.03.17)

Prof. SK Barik Director CSIR-National Botanical Research Institute **Lucknow - 226 001**	Chairman
Prof. Alok Dhawan Director CSIR-Indian Institute of Toxicology Research **Lucknow 226001**	Member
Dr. Sanjay Kumar Director CSIR-Indian Institute of Himalayan Bioresource Technology **Palampur- 176062**	DG Nominee
Dr. SK Tewari Senior Principal 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
Mr. Y Nath Principal Technical Officer CSIR-National Botanical Research Institute **Lucknow - 226 001**	Member
Dr. Pratibha Mishra Principal Scientist CSIR-National Botanical Research Institute **Lucknow - 226 001**	Member
Dr. PK Singh Principal Scientist CSIR-National Botanical Research Institute **Lucknow - 226 001**	Member
Dr. Poonam C Singh Scientist CSIR-National Botanical Research Institute **Lucknow - 226 001**	Member
Controller of Finance & Accounts/Finance & Accounts Officer CSIR-National Botanical Research Institute **LUCKNOW - 226 001**	Member
Controller of Administration CSIR-National Botanical Research Institute **LUCKNOW - 226 001**	Member Secretary

EXPENDITURES AND EARNINGS 2016-17 (As on 31.03.17)

I. EXPENDITURE	Figure in Lakhs of Rupees
A. Revenue	
1. Salary & Sal. Linked Allowances	2531.078
2. Other Allowances	
a. Re-imburs. of Med.Exp./CGHS/Med.charges	61.000
b. Overtime Allowance	0.939
c. Honorarium	1.007
d. Leave Travel Concession	17.500
e. T.A. (India)	14.949
f. T.A. (Foreign)	
g. Professional Update Allowance	10.400
h. Total Other Allowances (a to g)	105.795
3. Total Salaries (1+2h)	**2636.873**
4. P-04 Contingencies	579.000
5. P-05 H.R.D.	
6. P-06 Lab. Maintenance	225.008
7. P-701 Staff Qrs. Maintenance	80.174
8. P07 Chemical/Consum.& Other Res.Exp.	240.604
9. Total Revenue (3 to 8)	**3761.659**
B. Capital	
a) P-50 Land Cost	
a) P-50 Land Cost	
b) (i) P-50 Works & Services/Elec. Installations (Lumpsum)	230.269
b) (ii) P-50 Works & Services/Elec. Installations (Other)	
c) P-50 App. & Equip./Computer Equipments	923.852
d) P-50 Workshop Machinery	
e) P-50 Office Equipment	0.709
f) P-50 Furniture & Fittings	5.372
g) P-50 Library (Books/ Journals/ e-Journal)	50.156
h) P-50 Model & Exhibits	
i) P-50 Vehicles	2.576
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)	69.665
m) (ii) P-702 Staff Qrs.(Construction) (Other)	
Total Capital (a to m)	**1282.599**
Total A+B	**5044.258**
C. Special Proj. SIP/NWP/FAC/IAP/RSP/HCP/12th Plan Proj.	
1. Revenue	
(i) T. A. (India)	21.864
(ii) T.A. (Foreign)	
(iii) Contingencies	212.740

(iv) Maintenance	57.650
(v) Chemical, Consum.& Other Res.Exp.	1602.857
Total Rev. (C1)	**1895.111**
2. Capital	
(i) Work's & Services	30.000
(ii) Appartus & Equipment	6.070
(iii) Other Capitals	
Total Capital(C2)	**36.070**
C. Total allocation SIP/NWP/FAC/IAP/RSP/HCP/12th Plan (C1+C2)	**1931.181**
Total National Labs. (A+B+C)	**6975.439**
D. CENTRAL ADMINISTRATION	
P-804 Pension & Other retirement benefits	2064.925
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 House (Science Centre)	
P80806 Celebrations	
P906- Advance	
(i) Conveyance/Computer Advance	0.900
(ii) House Building Advance	
(iii) Others	
Total Central Admin.	**2065.825**
II. Earnings	
RECEIPTS	
R04 DONATION	
R05 CONTRIBUTION	
R06 MISC RECEIPTS	69.067
R906 RECOV. OF ADV.	9.579
TOTAL R06+R906	**78.646**
R071 LAB RESERVE	
a) Royality Premia	0.020
b) Testing & Analytical Charges	1.655
c) Other Technical Service	6.240
d) Job Work	10.744
e) Rest of R 071 heads	24.809
Total Lab Reserve(R-071)	**43.468**
R909 EXTERNAL CASH FLOW	
a) Govt deptt./PSU's	954.709
b) Private agencies	1.304
c) Foreign govt/agencies	
TOTAL ECF (a+b+c)	**956.013**
Royalty & Premia for distribution (R907)	**1.604**

PERSONNEL (As on 31.03.17)

Director
SK Barik

Chief Scientists
DK Upreti
RS Katiyar

Sr. Principal Scientists
S Kumar
Tariq Husain
A K S Rawat
P A Shirke
S K Tewari
T S Rana
A K Gauniyal
K N Nair
Sudhir Shukla
Anand Prakash
P K Trivedi
L B Chaudhary
Vivek Pandey
S V Sawant
A P Sane

Principal Scientists
Talewar Singh
Pratibha Misra
Vidhu A Sane
Alok Lehri
Ch. V Rao
Sayyada Khatoon
P K Singh
Mahesh Pal
Sharad Srivastava
Sanjeeva Nayaka
A K Asthana
S K Ojha
O P Sidhu
Subha Rastogi
Indraneel Sanyal

Senior Scientists
Arvind Jain
Vivek Srivastava
C S Mohanty
H K Yadav
Mehar H Asif
Debasis Chakrabarty
Shekhar Mallick
P K Srivastava
Soumit K Behera
Suchi Srivastava
P C Verma
S N Jena
A P Singh
Manjoosha Srivastava
S K Bagh
Sribash Roy
Aradhana Mishra
Baleshwar
P S Chauhan
Poonam C Singh

Scientists
Lal Bahadur
Devendra Singh
Priyanka Agnihotri
R C Nainwal
B N Singh
Manoj Kumar
V V Wagh
Charu Lata

Pr. Technical Officers
A A Malick
S S Tripathi
Yogendra Nath
M L Kain
Yogendra Misra
V D Tripathi

Sr. Tech. Officers (3)
A C Little
R K Tripathi
D K Purshottam
Alok Kumar
Shankar Verma

Sr. Tech. Officers (2)
L K Srivastava
Anil Kumar
Daya Shanker
Bhagwan Das
Atul Batra
Sanjay Dwivedi
Abhishek Niranjan

Sr. Tech. Officers (1)
R N Gupta
Sushma Verma
Rajeev Kumar
G Sharma
Harendra Pal
Sandeep K Behera
Vinay Sahu
M K Shukla
Kiran Toppo
M M Pandey

Technical Officers
Surjit Kumar
Swati Sharma
Leena Wahi
S K Sharma
K N Maurya
Babita Kumari
G G Sinam
Sumit Yadav
K K Rawat
D D Toppo
Somanath Swain
Satish Kumar
Prashant Srivastava
Jai Chand

Technical Assistants
Shweta Singh
Rameshwar Prasad
Rekha Kannaujia
S K Mishra
K K Ingle
B L Meena
V K Gupta
R R Rastogi
Devranjan
Vandana Tiwari
M G Prasad

Administration
Mukund Sahai, CoA
Rajhans Gautam, CoF&A
Sanjeev Shekhar, F&AO
Dinesh Kumar, SPO
R S Chowdhary, SPO
Prasoon Misra, SO
Shiva Kant Mishra, SO
Sachin Mehrotra, SO
R K Verma, SO
S K Singh, SO
Prabha Tirkey, SO
Ram Badal, SO
B P Pande, PS
Bijendra Singh, Hindi Officer
S K Pandey, Security Officer

NOTES

NOTES

NOTES

CSIR-National Botanical Research Institute

(Council of Scientific & Industrial Research, New Delhi)
Rana Pratap Marg, Lucknow - 226 001, U.P., India

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