वार्षिक प्रतिवेदन
Annual Report
2017-2018

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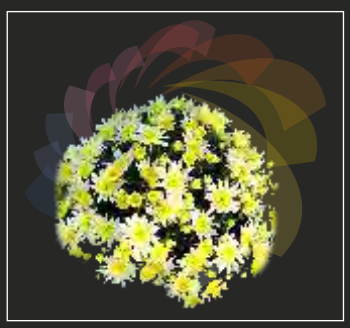
Acknowledgements
Research and Management Councils
R & D Agencies
Decision Unit Leaders, Nodal Scientists
Project Leaders, Scientists and Administration
for cooperation and providing information



Cover Photo: 'NBRI Him-Jyoti', a new dwarf, late blooming Chrysanthemum variety, developed by gamma irradiation of the parent variety, 'Himanshu'

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With best compliments from :

Director
CSIR-NBRI
Lucknow

सीएसआईआर–राष्ट्रीय वनस्पति अनुसंधान संस्थान
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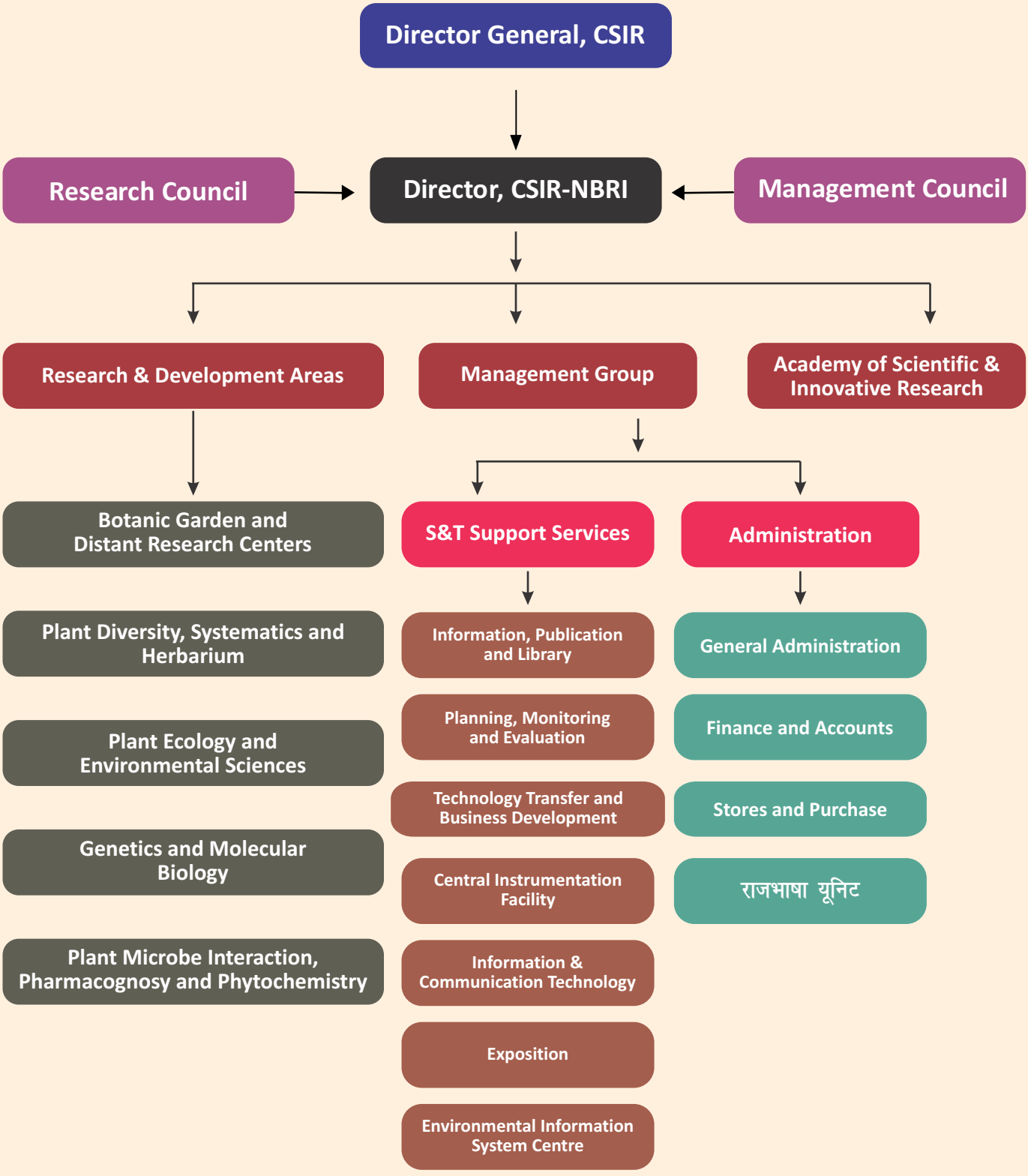
Organizational Set-Up



Contents

Annual Progress At A Glance

CSIR-NBRI

Publications

101	SCI Journals
2.792	Average Impact Factor
281.993	Cumulative Impact Factor

Patents

03	Filed Abroad
03	Granted Abroad
03	Granted in India

Herbal Products Developed

- Herbal formulation to alleviate urolithialis
- Herbal Acaricide

Technologies Transfered

- Herbal Sindoor Stick
- Hand Sanitizer
- Nutri Jam & Anti Cough Herbal Formulation
- Herbal Gulal
- Dental Cream

PhD Produced

30	Awarded
16	Submitted

Extra Budgetary Resources (In Lakh Rupees)

1883.467	ECF
90.529	LRF
1973.996	EBR (ECF+LRF)

Staff Strength

57	Group IV
49	Group III
43	Group II
30	Group 30
102	Administration

New Projects Initiated

33	GAP	01	NWP
01	CNP	01	TSP
02	HCP	09	OLP

निदेशक की कलम से.....

सीएसआईआर-राष्ट्रीय वनस्पति अनुसंधान संस्थान (सीएसआईआर-एनबीआरआई), लखनऊ के इतिहास में वर्ष 2017-18 एक और उत्पादक वर्ष रहा है। इस वर्ष संस्थान द्वारा नए पादप आधारित उत्पाद और किस्म विकास, प्रौद्योगिकी हस्तांतरण, प्रकाशन, पेटेंट, मानव संसाधन विकास और आउटरीच गतिविधियों के संदर्भ में कई महत्वपूर्ण मील के पत्थर स्थापित किए गए।

इस वर्ष हमने दो नए हर्बल फॉर्मूलेशन विकसित किए। एक हर्बल फॉर्मूलेशन यूरोलिथियासिस को कम करने के लिए और मवेशी किलनियों को नियंत्रित करने के लिए एक नवीन हर्बल क्षुद्र-कीटनाशी (एकैरिसाइड)। इस क्षुद्र-कीटनाशी को आईसीएआर-भारतीय पशु चिकित्सा अनुसंधान संस्थान, इज्जतनगर, बरेली, उत्तर प्रदेश के साथ संयुक्त रूप से विकसित किया गया। इसके अतिरिक्त छह हर्बल उत्पादों की तकनीकी जानकारियों को सात कंपनियों को स्थानांतरित किया गया है जिनमें हर्बल सिंदूर स्टिक, हर्बल गुलाल, न्यूट्री जैम, एंटीकफ फॉर्मूलेशन, डेंटल क्रीम, और अल्कोहल मुक्त हैंड सेनेटाईजर शामिल हैं।

इस वर्ष के दौरान गुलदाउदी की एक बौनी, देर से खिलने वाली और फूलदार नई किस्म, 'एनबीआरआई हिम-ज्योति' विकसित और जारी की गई। हम संस्थान में अनुरक्षित *इन-विट्रो* तने और जड़ संवर्धनों से, *सोलनम वायरम* के 'निष्कंटक' नामक एक कांटारहित, उच्च एल्केलॉएड उत्पादक उपभेद को अलग करने में सक्षम रहे हैं। संस्थान द्वारा विकसित ओपियम पॉपी की उच्च थीबेन प्रचुर लाइनों के प्रजनक बीजों को पंजीकरण के लिए आईसीएआर-नेशनल ब्यूरो ऑफ प्लांट जेनेटिक रिसोर्सेज (एनबीपीजीआर), नई दिल्ली में जमा किया गया है। संभावित जैव-अणुओं के संदर्भ में *सेंटेला एशियाटिका, कोस्टस स्पेशिओसस, ग्लोरियोसा सुपरबा* और *हेमेडेस्मस इंडिकस* जैसे चार अति महत्वपूर्ण औषधीय पौधों के सात विशेष कीमोटाइप्स को व्यापक कीमोप्रोफाईलिंग अध्ययनों के माध्यम से पहचाना गया है।

औषधीय महत्व के संदर्भ में अल्पज्ञात एवं अज्ञात स्वदेशी पौधों के जैव-रासायनिक पूर्वेक्षणों ने कई महत्वपूर्ण सुराग प्रदान किए हैं। *बकोपा मोनेरी* की पत्तियों से तीन अन्तः पादपीय कवक प्रभेद अलग किए गए, जो जैव-सक्रिय बकोसाइड्स के प्राकृतिक स्रोत का काम कर सकते हैं। *कमिफोरा एगालोचा* की पत्तियों, पतली शाखाओं और क्षीर से एक संभावित कैंसर-रोधी और विषाणु-रोधी घटक जर्माक्रोन को अलग कर शुद्ध किया गया। अनार के फल के छिलके के अर्क से एक दीमक-रोधी अंश को पहचाना गया। *डायोस्पाइरोस कॉर्डिफोलिया* की पत्तियों से आठ जैव-सक्रिय यौगिकों और *एंड्रोग्राफिस पैनीकुलेटा* के तने से 12 यौगिक अलग किए गए। *एकाइरेन्थस बाइडेंटेटा* को उच्च एंटीऑक्सीडेंट और मधुमेहरोधी गतिविधि युक्त एक संभावित औषधीय पौधे के रूप में पहचाना गया। एंटीऑक्सीडेंट क्षमता के लिए उत्तर-पूर्व भारत की 10 सुगंधित चावल की किस्मों के बीच किए गए विश्लेषण में 'चखाओमुखी' को श्रेष्ठ किस्म पाया गया। *सिलेजिनेला ब्रायोप्टेरिस* से अलग किए गए पादप-अणु, 2'', 3''- डाईहाइड्रोहिनोकिफ्लावोन में जख्म भरने और फ्री रैडीकल की सफाई की संभावित क्षमता पाई गई।

पौधों और आर्थिक रूप से महत्वपूर्ण सूक्ष्मजीवों के नए जीनोमिक संसाधनों को विकसित करने के हमारे प्रयासों ने सराहनीय परिणाम प्रदर्शित किए हैं। सूक्ष्मशैवाल *सेनेडेस्मस क्वाड्रीकॉडा* एलडब्लूजी 2002611, डैफोडिल की एक प्रजाति *नार्सिसस टजेट्टा* से अलग किए गए *सिर्टेन्थस एलेटस विषाणु- I*, एजेरेटम एनेशन विषाणु (एईवी) और इससे संबंधित एजेरेटम लीफ कर्ल बीटासैटेलाइट (एएलसीबी) के पूरे जीनोम अनुक्रमित किए गए। ग्वार में कुल 43, 052 सिंगल न्यूक्लियोटाइड पॉलिमॉर्फिज्म (एसएनपी) मार्कर, और अलसी के बीजों के जननद्रव्य में 191 पॉलिमॉर्फिक सिंगल सीक्वेंस रिपीट्स (एसएसआर) एवं 10 क्वांटिटेटिव ट्रेट लोसाई (क्यूटीएल) का पता लगाया गया, जिन्हें इन फसलों में आणुविक सहायता प्रदत्त चयन एवं प्रजनन सहायता के लिए एक महत्वपूर्ण जीनोमिक संसाधन के रूप में उपयोग किया जा सकता है। बाजरा के सूखा सहिष्णु (पीआरएलटी 2/89-33) और सूखा संवेदनशील (टीटी-1 और एच 77/833-2) जीनोटाइप को आकारकीय, जैव-रासायनिक और आणुविक अभिलक्षणन के माध्यम से पहचाना गया। विंग्ड बीन में टैनिन जैव-संश्लेषण में शामिल कुछ अद्वितीय प्रतिलेखों की भी पहचान की गई है।

पादप जीनोमिक्स, ट्रांसक्रिप्टोमिक्स और प्रोटीयोमिक्स में मौलिक शोध के परिणामस्वरूप महत्वपूर्ण सुराग प्राप्त हुए हैं। पौधों में जड़ों के विकास और कैल्शियम परिवहन में CAMTA (कैल्मोडुलिन बाइंडिंग ट्रांसक्रिप्शन एक्टिवेटर) की भूमिका का प्रदर्शन किया गया। कपास के रेशों के विकास में CAMTAa (GhCAMTA2A-2 एवं GhCAMTA7A), समूह II हिस्टोन डीएसिटाईलेज (GhHDA5), और हीट शॉक प्रोटीन (एचएसपी 90 और एचएसपी 70) की भूमिकाओं पर नए निष्कर्ष भी निकाले गए। दशहरी आम में फॉस्फोमेवैलोनेट काईनेज (एमआईपीएमके) के तुलनात्मक एमआरएनए अभिव्यक्ति विश्लेषण ने अधपकी अवस्था में 1.5 गुना अभिव्यक्ति प्रदर्शित की। *विथानिया सोम्नीफेरा* से विथैनोलॉइड जैव-संश्लेषण में शामिल

स्टेरोल Δ-7 रिडक्टेज के दो पैरालॉग्स (WsDWF5-1 और WsDWF5-2) की पहचान की गई है। *ऑपियम पॉपी* में पैपावेरिन जैव-संश्लेषण में Ps3'OMT और फेनिलप्रोपोनोइड मार्गों में *एराबिडॉप्सिस थैलियाना* pri-miRNA8585a की भूमिकाएं भी स्पष्ट की गईं। *जट्रोफा कर्कस* में लिपिड जैव-संश्लेषण मार्ग विश्लेषण से ग्लिसरॉल-3-फॉस्फेट एसिलट्रांसफेरेज (जीपीएटी) जीन परिवार के दो सदस्यों - JcGPAT1 एवं JcGPAT2 की पहचान की गई। सूखे और नमक-तनाव ग्रसित काबुली चने में *स्यूडोमोनास प्यूटिडा* RA के इनोक्यूलेशन से पता चला कि सूखे और नमक-तनाव के उन्मूलन में RA महत्वपूर्ण भूमिका निभाता है। टमाटर में *SlERF6* और *SlERF8* के लक्षित हेरफेर ने बीज अंकुरण और पौधों के विकास में *SlERF6* की भूमिका का खुलासा किया। चावल में एब्सिसिक अम्ल (एबीए) मध्यस्थ सूखा संकेतन में *ओराइजा सैटाइवा* FKBP और SK2 प्रकार डीहाइड्रिन (OsDhn-Rab16D) समूह की मुख्य भूमिका पाई गई। आर्सेनिक तनाव की स्थिति के तहत विभिन्न एंटीऑक्सीडेंट तंत्रों के संकेतन नेटवर्क को सक्रिय करने में *ओराइजा सैटाइवा* क्लास III पेरोक्सीडेज (OsPRX38) की भूमिका पाई गई। *सोलेनम वाएरम* के *इन-विट्रो* तने संवर्धनों में दो एलिसिटर, टीएचएफ (एक कवक संवर्धन फिल्टर) और पीबी-1 (एक जीवाणु पृथक) सोलासोडाइन के उत्पादन को बढ़ाते पाए गए।

प्रदूषण, भारी धातु संदूषण और वर्धित पादप संरक्षण और उत्पादकता का सामना करने के लिए नवीन पादप एवं सूक्ष्म-जीव आधारित तरीकों का विकास किया गया। उत्तरी और उत्तर-पूर्वी भारत में चावल के सात खेतों से उच्च जिंक घुलनशीलता गुण युक्त तीन सूक्ष्म जैविक उपभेदों की पहचान की गई। स्वर्ण नैनोकणों (जीएनपी) और योशीदा प्रभाव के गुणों को जोड़कर जीवाणुओं के प्रभावी अनुवांशिक परिवर्तन के लिए एक नई विधि विकसित की गई । एक नवीन प्रोटोप्लास्ट फ्यूसेंट (*हायपोक्रिया लिक्सीआई* MTCC 5659) विकसित किया गया था जो काबुली चने में पौष्टिकता और रक्षा गतिविधि को बढ़ा सकता है। टमाटर में 'अर्ली ब्लाईट' बीमारी के लिए रजत नैनोकणों को जैव-संश्लेषित किया गया है। ओजोन प्रदूषण के संभावित उन्मूलकों के रूप में चार प्रजातियों, *नेरियम इंडिकम, प्लूमेरिया रूबरा, पॉलीएल्थिया लांगीफोलिया,* और *फाईकस बेंगालेंसिस* को पहचाना गया है। खेतों में उगने वाली फसलों में ओजोन विषाक्तता का आंकलन करने के लिए इथिलीन डाईयूरिया (ईडीयू) को एक अच्छे शोध उपकरण के रूप में प्रयोग करने का सुझाव दिया गया। एक स्मार्ट फोन ऐप, 'ग्रीन प्लानर' को विकसित और लॉन्च किया गया जिसमें 70 वायु प्रदूषण उन्मूलक पौधों का डेटाबेस उनकी छवियों के साथ शामिल है।

देश के महत्वपूर्ण पादपों और शैकों के व्यवस्थित अध्ययन और संरक्षण के साथ-साथ हमने उत्तर-पूर्व भारत, पूर्वी हिमालय और पूर्वी घाटों के अल्पज्ञात वानस्पतिक क्षेत्रों का पता लगाने के हमारे प्रयासों को जारी रखा है। शैक कुल *बुएलिया* और *राईनोडिना,* टेलोशिस्टेसियन शैकों और *जेरेनियम* पर पुनरीक्षण अध्ययन शुरू किए गए। उभयोद्भिद कुल *हिप्नम* की वर्गिकी का पुनरीक्षण किया गया। *डिडिमोकार्पस-हेंकेलिया* कुल समूह (जेस्नेरिएसी), *बेटुला* (बेटुलेसी), और *सोनेरेशिया* (लिथरेसी) पर आणुविक वर्गिकी अध्ययन जारी रखे गए। गहन वर्गिकी विश्लेषणों ने नए टैक्सा की खोज के साथ-साथ कई पौधों और शैक टैक्सा के भारत में नए राष्ट्रीय और क्षेत्रीय भौगोलिक अभिलेखों के रूप में कई नवीनताएं प्रकाश में लाईं। एक नया शैक कुल *उप्रेतीया* एवं एक नवीन शैक प्रजाति *गैलोवायेल्ला अवस्थियाना* को खोजा गया। म्यांमार सीमा के नजदीक मणिपुर के कामजोंग जिले से एक वैश्विक रूप से संकट ग्रस्त प्रजाति *होया पैंडूरेटा,* भारत में पहली बार दर्ज की गई। उभयोद्भिद के नए भौगोलिक अभिलेखों में भारत में छः प्रजातियों की नई सूचना जबकि पूर्वी घाट से 58 प्रजातियां, दक्षिणी प्रायद्वीपीय भारत से 12 प्रजातियां, नागालैंड में 53 प्रजातियां, और मणिपुर में 34 प्रजातियां की सूचना शामिल हैं। जैव विविधता जागरूकता कार्यक्रम के हिस्से के रूप में, 'भारत के शैक' नामक एक गैर-लाभकारी यू-ट्यूब चैनल (wwwyoutube.com/lichensofindia) बनाया गया है। संस्थान के पादपालय (LWG) को 2,912 नए नमूनों से समृद्ध किया गया जिसमें बीजी पौधों के 216 नमूने और अबीजी पौधों के 2,696 नमूने (टेरिडोफाइट्स -201, उभयोद्भिद -475, शैवाल -20 और 2000 शैक) शामिल थे जिनसे पादपालय के नमूनों के कुल संख्या 2,99,229 पहुंची।

संकटग्रस्त प्रजातियों पर संरक्षण जैविक अध्ययनों ने एक दुर्लभ और रोचक मृतोपजीवी मॉस, *स्प्लेकनम स्फैरिकम* के *इन-विट्रो* प्रवर्धन के लिए एक नया प्रोटोकॉल विकसित करने में सक्षम किया, इसके अतिरिक्त तीन अन्य उभयोद्भिद *लुनुलेरिया क्रूसियाटा, एंथोसेरोस भारद्वाजाई,* और *रिंकोस्टेजेएल्ला स्कैब्रीसेटा* के *एक्स-सीटू* प्रवर्धन तरीकों को भी मानकीकृत किया गया। एक फर्न *माइक्रोलेपीया स्पेलुंकी* की विकास जैविकी पर अध्ययन किए गए।

संस्थान के वनस्पति उद्यान को ऑर्किड, बांस, फर्न, और भारत के विभिन्न पादप-भौगोलिक क्षेत्रों से संकटग्रस्त पौधों की 125 प्रजातियों के नए नमूनों के साथ समृद्ध किया गया। नए जननद्रव्यों के *एक्स-सीटू* संरक्षण के लिए प्रसार विधियों और गुणन प्रोटोकॉल स्थापित किए गए। 'भारत के मसाले एवं औषधीय पौध गृह' के रूप में एक नई सुविधा इस साल बनाई गई, जिसमें वर्तमान में मसालों और औषधीय पौधों की 67 प्रजातियां उपलब्ध हैं।

संस्थान के दूरस्थ अनुसंधान केंद्र (डीआरसी) ने विभिन्न आर्थिक रूप से महत्वपूर्ण पौधों जैसे कि सजावटी पौधे (ट्यूबरोज), चावल, औषधीय और सुगंधित पौधों (अश्वगंधा, कालमेघ, हल्दी, इसबगोल, शंखपुष्पी) एवं रंजक उत्पादक पौधों (बिक्सा) की खेती के माध्यम से सोडिक मृदा प्रबंधन पर अपने विभिन्न शोध प्रयोगों को जारी रखा। केंद्र ने अच्छी कृषि प्रथाओं (जीएपी) के पुनर्मूल्यांकन और महत्वपूर्ण एवं संकटग्रस्त औषधीय पौधों के लिए कृषि प्रौद्योगिकियों के विकास के लिए नई पहल भी की।

संस्थान ने कई प्रशिक्षण, कार्यशालाएं और आउटरीच कार्यक्रम आयोजित किए। इस वर्ष 92 व्यक्तियों ने सात कौशल विकास कार्यक्रमों जैसे उद्यान देखभाल, मृदा एवं जल परीक्षण, पादप ऊतक संवर्धन तकनीकें एवं हर्बल औषधि गुणवत्ता परीक्षण आदि में भाग लिया। इनमें से अधिकांश कार्यक्रम 'एग्रीकल्चर स्किल काउंसिल ऑफ इंडिया' द्वारा मान्यता प्राप्त हैं। पादप वर्गीकरण, बागवानी, भूनिर्माण, बोन्साई, औषधीय और सुगंधित पौधों की खेती, कृषि तकनीक, जैव उर्वरक, पर्यावरण प्रदूषण, फूलों की खेती और पुष्प शिल्प सहित विभिन्न विषयों पर विभिन्न हितधारकों के समूहों को

भी प्रशिक्षण दिया गया। इन प्रशिक्षणों के लाभार्थियों में विभिन्न सरकारी और निजी संगठनों के किसान, महिलाएं, शिक्षक, छात्र, और अधिकारी एवं कर्मचारी शामिल थे। विभिन्न विश्वविद्यालयों/संस्थानों के स्नातकोत्तर छात्रों को पौधों के आणुविक जीवविज्ञान, सूक्ष्म जीवविज्ञान, फार्माकोलॉजी, पर्यावरण वनस्पति विज्ञान और वर्गीकरण समेत पादप विज्ञान के विभिन्न विषयों का भी प्रशिक्षण दिया गया।

इस रिपोर्टिंग वर्ष के दौरान संस्थान ने 47 नई परियोजनाएं शुरू कीं, 281.99 के इम्पैक्ट फैक्टर के साथ (आईएफ 2.97 प्रति पेपर) एससीआई जर्नल्स में 101 शोध पत्र प्रकाशित किए, विदेशों में 3 पेटेंट दायर किए गए, 6 पेटेंट हासिल किए गए (भारत और विदेश में 3 प्रत्येक) और 30 छात्रों को अकादमी ऑफ साइंटिफिक एंड इन्नोवेटिव रिसर्च (एसीएसआईआर) और अन्य विश्वविद्यालयों द्वारा पीएचडी की डिग्री से सम्मानित किया गया।

मैं इस अवसर पर सीएसआईआर-एनबीआरआई को उपलब्धियों और मान्यताओं के गौरवशाली मार्ग पर अग्रसर रखने के प्रयासों के लिए संस्थान के सभी वैज्ञानिक, तकनीकी और प्रशासनिक कर्मचारियों एवं विद्यार्थियों को बधाई देता हूं। मैं पादप विज्ञान के सबसे चुनौतीपूर्ण क्षेत्रों में मौलिक और अनुवादपरक शोध, दोनों को लागू करने में उत्कृष्टता प्राप्त करने के लिए टीम-एनबीआरआई के प्रत्येक सदस्य के समर्पण और वचनबद्धता की ईमानदारी से सराहना करता हूं। स्वस्थ जीवन, स्वच्छ वातावरण बनाने एवं युवाओं के लिए अधिक नौकरियाँ उत्पन्न करने के लिए हमें आम आदमी की समस्याओं के लिए किफायती तकनीकी समाधान विकसित करने के हमारे प्रयासों को जारी रखना चाहिए। चूंकि हमें हमारे शहरी और ग्रामीण नागरिकों के लिए पादप आधारित आय उत्पादक उद्यमिता पर विशेष ध्यान देने की आवश्यकता है अतः सीएसआईआर-एनबीआरआई को पादप विज्ञान के विभिन्न क्षेत्रों में उच्च स्तर के अनुसंधान के द्वारा ज्ञान सृजन में सहयोग देने की आवश्यकता है।

मैं संस्थान के अनुसंधान एवं विकास प्रबंधन को सुव्यवस्थित करने में सक्रिय समर्थन और मार्गदर्शन के लिए सीएसआईआर के महानिदेशक डॉ. गिरीश साहनी के प्रति ईमानदारी से कृतज्ञता व्यक्त करना चाहता हूं। हम प्रोफेसर दीपक पेंटल, अध्यक्ष, शोध परिषद और संस्थान की अनुसंधान और प्रबंधन परिषदों के सभी सम्माननीय सदस्यों के, अनुसंधान और विकास और आउट-रीच गतिविधियों के सुचारु और सफल कार्यान्वयन में, मूल्यवान मार्गदर्शन के लिए आभार व्यक्त करते हैं। हमारे अनुसंधान एवं विकास और आउटरीच कार्यक्रमों के प्रभावी निष्पादन के लिए हमारे साथियों, शुभचिंतकों और समर्थकों से लगातार मदद और सहयोग से हमें बहुत फायदा हुआ है। हम अपने सभी भावी प्रयासों में आपकी निरंतर सहायता, समर्थन और सलाह के लिए आशान्वित हैं।

सरोज बारिक

(सरोज के बारिक)
निदेशक

FROM THE DIRECTOR'S DESK .....

2017-18 has been another productive year in the annals of CSIR-National Botanical Research Institute (CSIR-NBRI), Lucknow. The year witnessed several significant milestones in terms of new plant- based products and variety development, technology transfers, publications, patents, human resource development and outreach activities achieved by the Institute.

We have developed two new herbal formulations this year. An herbal formulation to alleviate urolithiasis, and novel herbal acaricides to control cattle ticks. The acaricides were developed jointly with ICAR-Indian Veterinary Research Institute, Izatnagar, Bareilly, Uttar Pradesh. The knowhow for six herbal products has been transferred to seven clients. These products included Herbal Sindoor Stick, Herbal Gulal, Nutri Jam, Anticough Formulation, Dental cream, and Alcohol Free Hand Sanitizer.

During the year a new dwarf, floriferous and late blooming variety of Chrysanthemum 'NBRI Him-Jyoti' was developed and released. We have been able to isolate a prickleless, high alkaloid yielding strain of *Solanum viarum,* named 'Nishkantak', from *in vitro* shoot and root cultures maintained at the Institute. Breeder seeds of high thebaine -rich lines of opium popy developed by the Institute (NBIHT-3) have been deposited at ICAR- National Bureau of Plant Genetic Resources (NBPGR), New Delhi, for registration. Seven elite chemotypes of four high value medicinal plants, such as *Centella asiatica, Costus speciosus, Gloriosa superba* and *Hemidesmus indicus,* have been identified with respect to potential biomolecules through comprehensive chemoprofiling studies.

Biochemical prospecting of underexplored and unexplored indigenous plants yielded several significant leads. Three endophytic fungal strains were isolated from *Bacopa monnieri* leaves, which could serve as a natural source of the bioactive bacosides. Germacrone, a potential anti-cancer and anti-viral agent, was isolated and purified from leaves, thin branches and latex of *Commiphora agallocha*. An antitermite fraction was identified from pomegranate fruit rind extract. Eight bioactive compounds from leaves of *Diospyros cordifolia* and 12 compounds from the leaves and stem of *Andrographis paniculata* were isolated. *Achyranthes bidentata* was identified as a potential medicinal plant with high antioxidant and antidiabetic activities. 'Chakhaoamubi' was found to be a superior variety among the 10 scented rice varieties from North-east India analyzed for their antioxidant potentials. The phytomolecule, 2", 3"-Dihydrohinokiflavone, isolated from the resurrection plant, *Selaginella bryopteris* has been shown to have potential wound healing and free radical scavenging properties.

Our efforts to develop new genomic resources of plants and microbes of economic interests have shown appreciable outcomes. The whole genomes of the microalga, *Scenedesmus quadricauda* LWG002611, *Cyrtanthus elatus virus-A* isolated from a species of daffodil, *Narcissus tazetta,* and *Ageratum enation virus (AEV)* and associated *Ageratum Leaf Curl Betasatellite* (ALCB), were sequenced. A total of 43052 Single Nucleotide Polymorphism (SNP) markers in guar, and 191 polymorphic Single Sequence Repeats (SSR) and 10 Quantitative Trait Loci (QTL) were detected in linseed seed germplasms, which could be used as a vital genomic resource for molecular assisted selection and breeding in these crops. Drought tolerant (PRLT2/89-33) and drought sensitive (TT-1 and H77/833-2) genotypes of pearl millet have been identified through morphological, biochemical and molecular characterization. Some unique transcripts involved in tannin biosynthesis in winged bean have also been identified.

Fundamental researches in plant genomics, transcriptomics and proteomics resulted in significant leads of translational value. The role CAMTA (Calmodulin binding Transcription Activator) in root development and calcium transport in plants was demonstrated. New inferences have also been made on the roles of CAMTAs (GhCAMTA2A.2 and GhCAMTA7A), class II histone deacetylase (GhHDA5), and heat shock proteins (HSP90 and HSP70) in cotton

fibre development. Comparative mRNA expression analysis of Phosphomevalonate kinase (MiPMK) in Dashehari Mango showed a 1.5 folds expression in the midripe stage. Two paralogs of Sterol Δ-7 reductase (WsDWF5-1 and WsDWF5-2) involved in withanolide biosynthesis have been identified from *Withania somnifera*. The roles of Ps3'OMT in papaverine biosynthesis in opium popy and *Arabidopsis thaliana* pri-miR858a in phenylpropanoid pathways have also been elucidated. Lipid biosynthesis pathway analysis in *Jatropha curcas* identified two members of the glycerol-3-phosphate acyltransferase (GPAT) gene family- JcGPAT1 and JcGPAT2. *Pseudomonas putida RA* inoculation in drought and salt-stressed chickpea showed that *RA* plays a key role in abiotic stress alleviation in chickpea. Targeted manipulation of *SlERF6* and *SlERF8* in tomato revealed the involvement of *SlERF6* I in seed germination and plant development. *Oryza sativa FKBP* and SK2 type dehydrin (*OsDhn-Rab16D*) complex was found to play a key role in abscisic acid (ABA) mediated drought signaling in rice. *Oryza sativa* class III peroxidase *(OsPRX38)* was found to activate the signaling network of different antioxidant systems under As stress condition. Two elicitors, THF (a fungal culture filtrate) and PB-1 (a bacterial isolate) were found to enhance production of solasodine in *in vitro* shoot cultures of *Solanum viarum*.

Novel plant and microbe-based methods were developed for combating pollution, heavy metal contamination, and enhanced plant protection and productivity. Three microbial strains with high Zinc solubilization property were identified from seven rice fields in Northern and North-eastern India. A new method was developed for effective genetic transformation of bacteria by combining the properties of gold nanoparticles (GNPs) and the Yoshida effect. A novel protoplast fusant (*Hypocrea lixii* MTCC 5659) was developed that could enhance the nutritional value and defence activity in chickpea. Biosynthesized silver nanoparticles (BSNPs) for early blight disease in tomato have been synthesized. Four species, *Nerium indicum, Plumeria rubra, Polyalthia longifolia,* and *Ficus benghalensis* have been identified as potential mitigants of ozone pollution. Ethylene diurea (EDU) has been suggested as a good research tool to assess ozone toxicity in field -grown crops. A smart phone App, "Green Planner", containing a database of 70 air pollution-mitigating plants with their images, was developed and launched.

We have continued with our efforts to explore the unexplored floristic areas in North-east India, Eastern Himalayas, and the Eastern Ghats, along with systematic studies and conservation of important plant and lichen biota of the country. Revisionary studies on lichen genera *Buellia* sensu lato and *Rinodina,* the Teloschistacean lichens, and *Geranium* were initiated. The taxonomy of the moss genus, *Hypnum* was revised. Molecular systematic studies on the *Didymocarpus-Henckelia* generic complex (Gesneriaceae), *Betula* (Betulaceae), and *Sonneratia* L.f. (Lythraceae) were continued. In-depth taxonomic analyses brought to light several novelties in terms of discovery of new taxa as well as new national and regional geographic records of several plant and lichen taxa to India. A new lichen genus *Upretia* S. Y. Kondr.& A. Thell and and a new lichen species, *Gallowayella awasthiana* S. Y. Kondr. & D. K. Upreti, were discovered. *Hoya pandurata,* a globally threatened flowering plant species, was recorded from India for the first time from Kamjong district of Manipur, bordering Myanmar. The additional geographic records of Bryophytes included the new report of six species to India, 58 species to Eastern Ghats, 12 species to southern peninsular India, 53 species to Nagaland, and 34 species to Manipur. As part of biodiversity awareness program, a non-profit YouTube Channel named "Lichens of India" (www.youtube.com/lichensofindia) has been created.

The herbarium of the Institute (LWG) was enriched with new addition of 2912 specimens that included 216 specimens of seed plants and 2696 specimens of cryptogamic plants -Pteridophytes-201, Bryophytes-475, Algae-20 and 2000 lichens, making the total holdings to 2,99,229.

Conservation biological studies on threat- prone species enabled to develop a new protocol for *in-vitro* propagation of a rare and interesting saprophytic moss, *Splachnum sphaericum,* besides standardizing ex-situ propagation methods for three other bryophytes viz., *Lunularia cruciata, Anthoceros bharadwajii,* and *Rhynchostegiella scabriseta*. Studies on developmental biology of the fern, *Microlepia speluncae* were carried out.

The botanic garden of the Institute was enriched with new introduction of 125 plant species of orchids, bamboos, ferns, and threatened plants from different phytogeographic regions of India. Propagation methods and multiplication protocols were established for *ex situ* conservation of the new germplasms. A new facility in the form of a 'House for Spice and Medicinal Plants of India' was created this year, which currently houses about 67 species of spices and medicinal plants.

The Distant Research Centres (DRC) of the Institute continued with their various research experiments on sodic soil management through cultivation of diverse economically important plants such as ornamentals (Tuberose), rice, medicinal and aromatic plants (Aswagandha, Kalmegh, Curcuma, Isabgol, Sankupushpi), and dye-yielding

plants (Bixa). The centre also made new initiatives for revalidation of Good Agricultural Practices (GAPs) and development of agrotechniques for high value and threatened medicinal plants.

The Institute conducted a number of trainings, workshops and outreach programs. During the year under report, 92 persons attended seven skill development programmes namely garden maintenance, soil and water testing, plant tissue culture technqiues and quality analysis of herbal drugs. Most of these programmes are recognized by the Agricultural Skill Council of India (ASCI). Trainings were also imparted to various stakeholder groups on various themes, including plant taxonomy, gardening, landscaping, bonsai cultivation, cultivation of medicinal and aromatic plants, agrotechniques, biofertilzers, environmental pollution, floriculture and floral crafts. The beneficiaries of these training included farmers, women, teachers, students, and officer and staff of different government and private organizations. Post-graduate students from various universities/institutes were also imparted training different disciplines of plant sciences, including plant molecular biology, microbiology, pharmacology, environmental botany, and taxonomy.

The Institute during the reporting year initiated 47 new projects, published 101 research papers in SCI journals, with a cumulative impact factor of 281.99 (IF 2.97 per paper), filed 3 patents abroad, 6 patents granted (3 each in India and abroad), and 30 students awarded their PhD degree by the Academy of Scientific and Innovative Research (AcSIR) and other Universities.

I take this opportunity to congratulate all the scientific, technical and administrative staff, and students of the Institute for their untiring efforts to take CSIR-NBRI to the glorious path of greater achievements and recognitions. I sincerely appreciate the dedication and commitment of each member of Team-NBRI for having excelled in implementing both fundamental and translational researches in the most challenging areas of plant science. Our efforts to develop affordable technological solutions to the problems of the common man must be continued to create a healthy life, cleaner environment and more jobs for the youth. While we need to emphasize on plant product-based income generating entrepreneurships for our rural and urban citizens, CSIR-NBRI must contribute to knowledge generation in diverse fields of plant science with high level of innovation.

I wish to place on record my sincere gratitude to Dr Girish Sahni, the Director General of CSIR for his active support and guidance in streamlining the S&T management of the Institute. We extend our sincere gratitude to Prof. Deepak Pental, Chairman, Research Council and all the honorable members of both the Research and Management Councils of the Institute for their valuable guidance in smooth and successful implementation of the research and development programs of the Institute. We have been greatly benefitted by the unflinching help and cooperation from our peers, well-wishers and supporters for effective execution of our R&D and outreach activities. We look forward to all your continued help, support and advice in our future endeavors.

(Saroj K Barik)
Director

EXECUTIVE SUMMARY

The National Botanical Research Institute (CSIR-NBRI), Lucknow, is one of the 38 constituent laboratories of the Council of Scientific and Industrial Research (CSIR), Department of Scientific and Industrial Research, Ministry of Science and Technology, Government of India. Established in 1953 as the then National Botanical Garden, CSIR-NBRI has now been transformed into a globally recognised advanced centre of botanical research. Its dedicated research and development efforts over the past six decades made CSIR-NBRI a national institute of importance. The Institute has a wholesome expertise in plant biodiversity, biotechnology and bioprospecting. Equipped with state - of - art laboratories and associated facilities, the Institute undertakes trandisciplinary R& D programs in almost all areas of plant sciences. The mandate of the Institute is to carry out basic and applied research on plant sciences, with special focus on conservation, systematics, documentation, bioprospecting and genetic improvement in underexploited, non-traditional, and wild plant genetic resources of the country for 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
- Bioprospecting and development of nutraceuticals, cosmaceuticals, and herbal 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

In the face of the current and impending challenges of biodiversity loss, climate change, pollution, poverty, malnutrition and diseases, CSIR-NBRI is poised to address these issues through integrated R&D on systematic documentation, conservation and bioprospecting of the plant wealth of our country for generation of new knowledge and affordable technologies for health care, agriculture, and environmental protection.

In the year 2017-18, CSIR-NBRI achieved several milestones in its R&D and outreach programmes, with significant scientific and societal impact. A summary of these achievements is presented below:

Exploration, documentation and conservation of plant diversity

The Institute continued its efforts to explore the unexplored floristic areas in North-east India, Eastern Himalayas, and the Eastern Ghats, along with systematic studies and conservation of important plant and lichen biota of the country. Plant exploration in Manipur and Nagaland resulted in documentation of 315 species of angiosperms, three gymnosperms, 102 bryophytes, 110 lichens and 79 species of algae till date. An enumeration of about 600 species, including 272 species of 169 herbs and shrubs, 20 climbers, and 83 trees, has been made as part of the ongoing plant diversity assessment in Dima Haso District of Assam. Floristic studies in Kishanpur Wildlife Sanctuary (KWLS) of Uttar Pradesh recorded 470 flowering plant species under 260 genera and 58 families. A preliminary floristic survey in Suhelwa Wildlife Sanctuary of Uttar Pradesh resulted in identification of 69 species of flowering plants, nine species of Pteridophytes, 8 species of Bryophytes, 21 taxa of algae, and 70 species of lichens. An enumeration of trees and shrubs of the Nawab Wazid Ali Shah Zoological Garden in Lucknow was made with 92 species under 70 genera and 32 families.

A reassessment of the bryophyte flora of Darjeeling revealed the occurrence of 48 species under 36 genera and 22 families from Tiger hill and 63 species under 46 genera and 31 families in Senchal Wildlife Sanctuary. Exploration of the bryophyte- rich areas of Eastern Ghats in Tamil Nadu, Andhra Pradesh and Odisha resulted in documentation of 109 species of mosses, 46 species of liverworts, and one species of hornwort. Diversity and ecology of lichens in relation to different fragile forest habitats of central Western Ghats in Karnataka was taken up to assess the impacts of anthropogenic factors on lichen biota, and to develop conservation strategies for threatened lichens.

Systematic studies on several complex genera of plants and lichens were taken up. Revisionary studies on lichen genera *Buellia* sensu lato and *Rinodina* (Caliciales) in India, and the Teloschistacean lichens

were initiated. The taxonomy of the moss genus, *Hypnum* comprising eight taxa was revised. Taxonomic revision of *Geranium* (Geraniaceae), with special emphasis on the phyto-sociological and conservation status, was taken up. Molecular systematic studies on the *Didymocarpus-Henckelia* generic complex (Gesneriaceae), *Betula* (Betulaceae), and *Sonneratia* L.f. (Lythraceae) were continued.

In an effort to identify and prospect potential micro-algae for sustainable production of bio-energy, 13 micro-algae were isolated and maintained in CSIR- NBRI. *Scenedesmus quadricauda* LWG002611 was found to be the most efficient strain for biomass (1.41±0.13 g/L) and lipid production (404±30 mg/L). The whole genome of *Scenedesmus quadricauda* LWG002611 was sequenced and a total of 13514 genes were predicted *de novo* and 16739 genes from reference sequences. Reference assembly of whole genome sequence was submitted to NCBI BioProject and assigned an accession number NNCB00000000.

In depth taxonomic analyses brought to light several novelties in terms of discovery of new taxa as well as new national and regional geographic records of several plant and lichen taxa to India. The revisionary study on Teloschistacean lichens resulted in the discovery of a new genus, *Upretia* S. Y. Kondr.& A. Thell, and a new species, *Gallowayella awasthiana* S. Y. Kondr. & D. K. Upreti. *Hoya pandurata,* a globally threatened flowering plant species, was recorded from India for the first time from Kamjong district of Manipur, bordering Myanmar. The additional geographic records of Bryophytes included the new report of six species to India, 58 species to Eastern Ghats, 12 species to southern peninsular India, 53 species to Nagaland, and 34 species to Manipur.

As part of biodiversity awareness program, a non-profit YouTube Channel named "Lichens of India" (www.youtube.com/lichensofindia) has been created. The channel includes nine videos featuring different aspects of lichenology in India and it has received more than 4000 views and 207 subscribers from all over the world.

The herbarium of CSIR-NBRI (LWG), which is a national facility and a designated national repository by the National Biodiversity Authority of India, was enriched with new addition of 2912 specimens that included 216 specimens of seed plants and 2696 specimens of cryptogamic plants -Pteridophytes-201, Bryophytes-475, Algae-20 and 2000 lichens, making the total holdings to 2,99,229.

Conservation biological studies on threat- prone species enabled to develop a new protocol for *in vitro* propagation of a rare and interesting saprophytic moss, *Splachnum sphaericum,* besides standardizing *ex situ* propagation methods for three other bryophytes viz., *Lunularia cruciata, Anthoceros bharadwajii,* and *Rhynchostegiella scabriseta*. The conservation status of an endemic and threatened hornwort, *Anthoceros* macrosporus, was reassessed as "Endangered" at global level using the IUCN Red list criteria. Studies on developmental biology of the fern, *Microlepia speluncae,* indicated that the delayed sex expression as a probable reason for its population decline.

The Botanic Garden serves as a National Facility of the Institute. A wide range of germplasm comprising of five thousand taxa has been maintained under ex-situ conservation in the arboretum and different plant houses. These live germplasm collections serve as unique material for botanical studies and research, besides their use in landscaping for recreation purposes. This year, a new, dwarf, floriferous and late blooming variety of Chrysanthemum 'NBRI Him-Jyoti' was released. 'Him-Jyoti 'was developed through gamma irradiation of the parent variety, 'Himanshu'. The botanic garden was enriched with new introduction of 125 plant species of ornamental, botanical, conservation, medicinal and other economic interests. The new additions encompassed such diverse plant groups as orchids, bamboos, ferns, and threatened plants from different phytogeographic regions of India. Propagation methods and multiplication protocols were established for *ex situ* conservation of the new germplasms. A new facility in the form of a 'House for Spice and Medicinal Plants of India' was created this year, which currently houses about 67 species of spices and medicinal plants.

The Distant Research Centres (DRC) of the Institute continued with their various research experiments and trials on sodic soil management through cultivation of diverse economically important plants such as ornamentals (Tuberose), rice, medicinal and aromatic plants (Aswagandha, Kalmegh, Curcuma, Isabgol, Sankupushpi), and dye-yielding plants (Bixa). The centre also made new initiatives for revalidation of Good Agricultural Practices (GAPs) and development of agrotechniques for high value and threatened medicinal plants, including *Coptis teeta* and *Viola pilosa,* two important medicinal herbs of the Indian Himalayas.

Green technologies for bioremediation

The environmental biotechnology and bioremediation research at the Institute was focused on developing novel and eco-friendly green solutions to the

problems of environmental pollution, heavy metal contamination, plant protection and plant productivity.

Three microbial strains with high Zinc solubilization property (185.73 µg /ml- 228 µg /ml) were identified from seven rice fields in Uttar Pradesh, Haryana, Punjab, Manipur and Meghalaya.

A cost-effective method was developed for effective genetic transformation of bacteria by combining the properties of gold nanoparticles (GNPs) and the Yoshida effect.

A novel protoplast fusant (*Hypocrea lixii* MTCC 5659) was reported to enhance the nutritional value and defence activity in chickpea by increasing the amino acids and mineral content of chickpea by fusant inoculation.

The interaction of biosynthesized silver nanoparticles (BSNP) with native soil via plant transport in model pathosystem of *Arabidopsis thaliana* and *Alternaria brassicicola* revealed that the BSNPs have the potential to act as strong antimicrobial agent for plant disease management without altering the native soil microflora. BSNPs have also been found to inhibit *Alternaria solani,* the causative agent of early blight disease in tomato in vitro and in vivo.

Application of the biofertilizer, *Trichoderma reesei* MTCC5659 (BF) on paddy crop under elevated CO_2 condition (eCO_2) resulted in increased stress tolerance by increased antioxidant activity and increase in the number of meta-xylem cells in the root tissues of the rice plant.

Seed priming with endophytic *Bacillus amyloliquefaciens* and *Pseudomonas fluorescens* individually and in combination demonstrated enhanced vigour index and germination rate, and remarkably reduced plant mortality (71.40%) under *Alternaria alternata* stress in *Withania somnifera*.

Synergistic activity of a rhizobacteria, *Pseudomonas putida*, and a microalga, *Chlorella vulgaris* was found to enhance plant growth in rice under both arsenic and arsenic with phosphate stress conditions.

The plant growth promoting strain of *Bacillus amyloliquefaciens* SN13 was found to play a vital role in ameliorating various abiotic stresses such as salt, drought, desiccation, heat, cold, and freezing on a popular rice cv. Saryu-52.

The extrapolations of the crop production data from 2002-2016 in Indo-Gangetic Plains showed that application of rice straw residue will be helpful in regaining soil organic carbon and could partially fulfil the need of nutrients such as potassium and phosphorus to improve soil fertility. The group is prospecting microbial application to ensure judicious use of the agricultural residues.

Bioremediation studies on Maize grown on polycyclic aromatic hydrocarbons (PAH) contaminated soils revealed 99.4% reduction in soil PAH under experiment regime of soil + PAH + Fertilizer + Microbial Combination of *Pseudomonas* sp. BP10 and *Pencillium* sp. PS10).

A three-month experimental trial on nine tree species under FACE facility identified four species, *Nerium indicum, Plumeria rubra, Polyalthia longifolia,* and *Ficus benghalensis* as potential mitigants of ozone pollution. Another experimental study on two wheat varieties revealed the potential of an aromatic compound, Ethylene diurea (EDU), as a good research tool to assess ozone toxicity in field -grown crops.

Physiological studies on leaf reflectance, pigment concentration, and photosynthetic properties in three varieties of guar (*Cyamopsis tetragonolobus*) showed that optical properties and photosynthetic characteristics can be used as indicators for assessing drought stress.

Bioaugmentation trails were carried out in four high arsenic (As) accumulating rice varieties under different treatment regimes in three sites in Nadia and North 24 Parganas Districts of West Bengal. The study showed reduction in As content in rice grains (24-54%), in husk (26-36%), tillers (37-64%) and roots (41-58%) in the experiment with fungal consortium to paddy crop along with soil treatment.

Studies on assessment and monitoring Flouride contamination in Unnao and Arsenic contamination in 20 Arsenic prone districts of Uttar Pradesh were also initiated.

A smart phone App, "Green Planner" was developed on iOS platform, now available in Tunes Store. The App contains a database of 70 air pollution-mitigating plants with their images.

Genetic improvement of plants through conventional and molecular intervention

Conventional and 'omics-centred' approaches were made to develop genetic and genomic resources for plant improvement by deciphering the molecular diversity and mechanisms behind plant development, biosynthetic pathways, and abiotic and biotic stresses.

Breeding lines with high thebaine content (10%) in latex of opium popy were developed. Multi-location trials of two thebaine-rich poppy lines- NBIHT-1 and NBIHT-

3 were conducted in farmers fields in Madhya Pradesh and Rajasthan. Seeds of NBIHT-3 have been deposited at ICAR- National Bureau of Plant Genetic Resources (NBPGR), New Delhi, for registration. The seeds of NBIHT-1 and NBIHT-3 are in possession of the Narcotic Department for commercial cultivation in suitable agro-climatic zones.

A prickleless mutant of *Solanum viarum,* named 'Nishkantak', was isolated from among the germplasms of prickly and prickleless strains conserved in *in vitro* shoot and root cultures at the Institute. Comparative phenotypic, biochemical and molecular characterization of the wild type and prickleless strains showed the prickleless strains were stable and contained high amount of alkaloids, and high fruit yield (1.57 tonns / hectare).

Illumina sequencing of 220 accessions of guar *(Cyamopsis tetragonolobus)* resulted in identification of 43052 Single Nucleotide Polymorphism (SNP) markers (with an allele frequency of <0.05), which can be used as an important genomic resource for agro- economic trait identification in guar germplasms.

Linkage mapping and Quantitative Trait Loci (QTL) analysis in two parental lines of linseed (JRF-4 and Chambal) using 191 polymorphic SSR markers resulted in identification of 10 QTLs, 4 for capsule / plant, and 2 each for capsule weight, seed weight / plant, and Alternaria blight resistance. The data will be used for marked assisted selection and breeding of linseed for Alternaria resistance and other desirable traits.

Mutagenesis and association mapping studies were initiated for identification of major fatty acids and altering fatty acid profiles in linseed and for identification and validation of molecular markers for narcotene and papverine in opium poppy for molecular assisted selection (MAS).

Simple Sequence Repeat (SSR) markers were identified from whole genome and transcripts of *Aspergillus* strains and used for comparative diversity analyses in in two pathogenic strains (*A. niger* and *A. terreus*) and two non-pathogenic strains (*A. nidulans* and *A. oryzae*).

In an effort to improve the nutritional value of the underutilized winged bean (*Psophocarpus tetragonolobus*), a comparative transcriptome analysis of diverse condensed tannin containing lines (HCTW and LCTW) was carried out, which revealed some unique transcripts responsible for tannin biosynthesis in winged bean. Quantitative assays identified monomeric Pelargondin, Delphinidin and Cyaniidin in different concentrations.

Cotton genomics research at the Institute progressed with new findings. Developmental biological and transcriptome analyses in *Arabidopsis thaliana* revealed that CAMTA (Calmodulin binding Transcription Activator) plays a vital role in root development and calcium transport in plants. Genome wide screening of three species of *Gossypium,* viz. *G. arboretum* (A genome), *G. raimondii* (D genome), and *G. hirsutum* (AD genome) was performed to trace the evolutionary history and phylogeny of the CAMTA family. Phylogentic analysis resolved five CAMTA lineages, of which the Group II CAMTA expressed high evolutionary pressure leading to faster evolution in diploid cotton. Micro array data analysis showed that two GhCAMTAs, GhCAMTA2A.2 and GhCAMTA7A, express profoundly in different stages of cotton fibre development. Expression analysis of the class II histone deacetylase (GhHDA5) in transgenic RNai cotton lines showed that GhHDA5 plays an important role in fibre initiation in cotton. Another study in cotton biology demonstrated that heat shock proteins (HSP90 and HSP70) induce oxidative stress and suppress fiber development in cotton.

Comparative mRNA expression analysis of Phosphomevalonate kinase (*MiPMK*) in Dashehari Mango showed a 1.5 folds expression in the midripe stage as compared to the unripe stage in inner zone. Functional characterization of the mango PMK showed that the purified protein was of 54.8. KD.

sRNA sequencing of four contrasting genotypes of *Solanum viarum* resulted in identification of 77 and 147 novel miRNAs ,respectively, from the prickly and prickleless strains of this high value medicinal plant. Additionally, the role of SkMSM1 and SkR2R3-Myb315-like transcriptional regulators in the development of prickle in *Solanum viarum* has also been examined. Two elicitors, THF (a fungal culture filtrate) and PB-1 (a bacterial isolate) were found to enhance production of solasodine in *in vitro* shoot cultures of *Solanum viarum*.

Genoimcs and transcriptome analyses in *Withania somnifera* concluded that the paralogs of Sterol Δ-7 reductase (WsDWF5-1 and WsDWF5-2) are localized in the endoplasmic reticulum (ER) and play an indispensable role in withanolide biosynthesis. In opium poppy the suppression of Ps3'OMT through VIGS caused a significant reduction in the level of papaverine, and functionally unique Ps3'OMT were involved in benzylisoquinoline alkaloid metabolism using NH pathway as the primary course to papaverine biosynthesis. Elucidation of flavonoid biosynthesis in *Arabidopsis thaliana* using the intervention of CRISPR/ Cas9 system showed that *Arabidopsis thaliana* pri-miR858a encodes a small peptide (miPEP858a) which

regulates the expression of pri-miR858a, leading to modulation in the expression of target genes involved in the phenylpropanoid pathway as well as plant growth and development.

Over expression studies of *AtMYB12* resulted in the development of a model that suggests requirement of HY5 and flavonol-specific MYB regulatory factors for low temperature-induced flavonol synthesis.

Targeted manipulation of *SlERF6* and *SlERF8* in tomato revealed that *SlERF6 I* is involved in seed germination and plant development through regulation of ABA levels and responses.

Lipid biosynthesis pathway analysis in *Jatropha curcas* identified two members of the glycerol-3-phosphate acyltransferase (GPAT) gene family- *JcGPAT1* and *JcGPAT2*. Heterologous expression of *JcGPAT1* and *JcGPAT2* under constitutive and seed specific promoter in *Arabidopsis thaliana* increased total oil content, i.e. 43-60% more oil in transgenic seeds of JcGPAT2-OE lines than the control seeds.

Transcriptome analysis of wild type and transgenic lines over expressing the nuclear complex of *Oryza sativa* FKBP and SK2 type dehydrin (OsDhn-Rab16D) revealed the role of OsDhn-Rab16D and OsFKBP in abscisic acid (ABA) mediated drought signaling in rice and as also a probable positive transcriptional co-regulator. In another transcriptome study, the over expression of *Oryza sativa* class III peroxidase (OsPRX38) in transgenic *Arabidopsis thaliana* was found to activate the signaling network of different antioxidant systems under As stress condition, significantly enhance the plant tolerance by reducing As accumulation due to high lignifications.

Expression analysis of three anti-oxidative genes, namely APX, GlutR and SOD in six pearl millet genotypes showed differential expression patterns. Based on various morphological, biochemical and molecular parameters, the genotype, PRLT2/89-33 was found to be drought tolerant, and TT-1 and H77/833-2 as drought sensitive genotypes.

Expression patterns of nine miRNAs (miR159, miR160, miR166, miR167, miR169, miR171, miR172, miR393 and miR396) in drought and salt-stressed chickpea exposed to *Pseudomonas putida RA* inoculation suggested *RA* is the key player of abiotic stress alleviation in chickpea.

The sequence analysis of full-length viral genome and associated betasatellite revealed the occurrence of *Ageratum enation virus (AEV)* and *Ageratum leaf curl betasatellite (ALCB)*, respectively. This study clearly demonstrated that AEV infection causes reduction in the metabolite contents as observed by GCMS and HPLC analysis, resulting in decrease in the commercial value of opium popy.

Full length genome of *Cyrtanthus elatus virus-A*, isolated from a species of daffodil, *Narcissus tazetta*, was sequenced.

Bioprospecting and natural product development

The Institute's effort to prospect the untapped potential of indigenous plant resources and associated traditional knowledge continued with development of new herbal formulations and new leads for further evaluation and value-addition.

The following herbal formulations were developed during 2017-18:

i) A herbal formulation to alleviate urolithiasis

ii) Two novel herbal acaricides to control cattle ticks (jointly developed with ICAR-Indian Veterinary Research Institute, Izzatnagar - Bareilly, Uttar Pradesh).

Metabolite profiling and chemotypic evaluation in promising medicinal and other economically plants resulted in following leads:

Three best endophytic fungal strains were isolated from *Bacopa monnieri* leaves, which could serve as a natural source of the bioactive saponins - bacosides.

Germacrone, a potential anti-cancer and anti-viral agent, was isolated and purified from leaves, thin branches and latex of *Commiphora agallocha*, and its structure was determined by NMR spectroscopy.

A partially purified column fraction (PGR) of pomegranate fruit rind was found to be significantly effective against the termite, Microcerotermes beesoni.

Eight bioactive compounds namely, isorhmnetin, myricetin, 3, 5-O-cyclodiospyrin, chromenone ester, chromenone acid, kaempferol glucoside, epicatechin and 1-hexacosanol were detected in essential oil of Diospyros cordifolia using an Ultra Performance Liquid Chromatography-Triple Quadrupole-linear Ion Trap Mass Spectrometry method (UPLC-ESI-QTOF/MS).

UPLC-ESI-QTOF/MS method in multiple-reaction monitoring mode was developed for the rapid determination of 12 bioactive compounds in the leaf and stem of *Andrographis paniculata* grown in sodic waste lands.

Chemoprofiling for detection of diosgenin in *Costus speciosus* (85 samples) and for vanillin in *Hemidesmus*

indicus (52 samples) resulted in identification of two elite chemotypes, NBCS-37 (*Costus speciosus,* Ramgarh, Jharkhand), with the highest diosgenin content (0.3678%), and NBH-35 (*Hemidesmus indicus*, Gaya, Bihar), with the highest vanillin content (0.0127%).

Chemotypes of *Centella asiatica* were identified withy high concentration of madecassoside (4.8%) and asiaticoside (4.3%) in CA109 (Palaghat, Kerala). Madecassic acid (3.06%) in CA114 (B.R. Hills, Karnataka) and asitaic acid (3.2%) CA79 germplasms collected from Ooty, Tamil Nadu.

Two promising gloriosine and colchicine rich germplasm of *Gloriosa superba* (NBG-27 and NBG26) were identified from Sikkim Himalayas.

Chemical profiling of more than twenty separated/ isolated plant gums, resins, mucilage, medicinal plant extracts and modified films was carried out for identification of sugar/starch, volatile/ phenolic compounds, functional groups, and development of chemo-markers.

Pharmacognostic studies were carried out on medicinally important plant species, such as *Acorus calamus* and *Achyranthes* species. Comparative pharmacological (antioxidant and anti-diabetic) evaluation in *Achyranthes* revealed higher antioxidant and antidiabetic activities in *A. bidentata* than in *A. aspera*.

Antioxidant activity in shoot and root of 10 scented rice varieties of North-east India was carried out. The rice variety, 'Chakhaoamubi' was found superior to Chakhaoporeiton in terms of antioxidant potentials in the rice grains.

Hydroalcoholic extracts (70%) of 11 samples of Termitomyces species, collected from Assam, were analysed for their antioxidant attributes, and potential extracts with highest antioxidant attributes were identified.

Acute and sub-acute toxicity studies on the bioactive fraction of *Selaginella bryopteris,* the resurrection plant, showed potential wound healing and free radical scavenging of the phytomolecule, 2", 3"-Dihydrohinokiflavone.

HPTLC densitometric method was developed for simultaneous quantification of phenolic and terpenoid markers in five plant species considered as the traditional ayurvedic drug, 'Shankhpushpi'.

Qualitative and quantitative estimation of recocene-I, precocene-II and caryophylline was carried out using HPTLC in two anti-tick plants, *Ageratum conyzoides* and *Blumea lacera*.

Explored the in vivo antioxidant and anti-aging potentials of Juniper berry essential oil (JBEO) by using *Caenorhabditis elegans* as a model organism and investigated the impact of different doses (0, 10, 50, 100ppm) on life span and health span of C. elegans.

Skill development and Outreach

The Institute conducted a number of trainings, workshops and outreach programs. During the year under report 92 persons attended seven skill development programms, viz. garden maintenance, soil and water testing, plant tissue culture techniques and quality analysis of herbal drugs. Most of these programmes were either fully supported or semi sponsored by industry and government organisations, and recognised by the Agriculture Skill Council of India (ASCI).

Trainings were also imparted to various stakeholder groups on various themes, including plant taxonomy, gardening, landscaping, bonsai cultivation, cultivation of medicinal and aromatic plants, agrotechniques, biofertilzers, environmental pollution, floriculture and floral crafts. The beneficiaries of these training included farmers, women, teachers, students, and officer and staff of different government and private organizations.

Projects, Publications, Patents and Awards

The Institute during the reporting year initiated 47 new projects, published 101 research papers in SCI journals, with a cumulative impact factor of 281.99 (IF 2.97 per paper), filed 3 patents abroad, 6 patents granted (3 each in India and abroad), and 30 students awarded their PhD degree by the Academy of Scientific and Innovative Research (AcSIR) and other Universities.

Distinguished Visitors

Visit of Prof. Dinesh Sharma, Hon'ble Deputy Chief Minister, Government of Uttar Pradesh

on June 05, 2017

Distinguished Visitors

Visit of Mr. Brajesh Pathak, Hon'ble Minister
Departments of Law and Justice, Additional Resources of Energy & Political Pension,
Government of Uttar Pradesh

on December 09, 2017

Important Events

CSIR-KVS Scientist Student Connect Programme

on June 14-16, 2017

Important Events

First SA Ranade Memorial Lecture

on October 05, 2017

Important Events

64th Annual Day of CSIR-NBRI

on October 25, 2017

Important Events

Prof. K N Kaul Memorial Lecture

on February 19, 2018

अनुसंधान एवं विकास

संस्थान का अधिदेश

वर्ष 1953 में स्थापित वै.औ.अ.प.-राष्ट्रीय वनस्पति अनुसंधान संस्थान, लखनऊ, वैज्ञानिक एवं औद्योगिक अनुसंधान परिषद, वैज्ञानिक एवं औद्योगिक अनुसंधान विभाग, विज्ञान एवं प्रौद्योगिकी मंत्रालय, भारत सरकार के 38 संस्थानों में से एक है। संस्थान पिछले छह दशकों से राष्ट्रीय महत्व के संस्थान के रूप में पादप अनुसंधान के क्षेत्र में पूरे देश में अग्रणी रहा है। विश्व स्तर पर वानस्पतिक अनुसंधान के एक आधुनिक केंद्र के रूप में मान्यता प्राप्त यह संस्थान पादप विज्ञान के लगभग सभी क्षेत्रों में बहुआयामी अनुसंधान एवं विकास कार्यक्रम चला रहा है। संस्थान का मूल उद्देश्य सतत विकास एवं मानव कल्याण हेतु देश के गैर-पारंपरिक, अल्प-प्रयुक्त एवं वन्य पादप आनुवांशिक संसाधनों पर विशेष ध्यान देते हुए पादप विज्ञान के विभिन्न पहलुओं जैसे कि संरक्षण, वर्गिकी, प्रलेखन, पूर्वेक्षण एवं आनुवांशिक सुधार आदि पर बुनियादी एवं प्रायोगिक अनुसंधान करना है। संस्थान निम्न क्षेत्रों में प्रमुख सामर्थ्य रखता है।

- पादप विविधता, वर्गिकी एवं निम्न तथा उच्च पादप समूहों के लिए डेटाबेस
- पूर्वेक्षण तथा पौष्टिक-औषधीय, प्रसाधन-औषधीय एवं स्वास्थ्य देखभाल हेतु उत्पादों का विकास
- वनस्पति उद्यान, पादप संरक्षण एवं पुष्प कृषि हेतु पौधों की नवीन किस्मों का विकास
- वर्धित पादप उत्पादकता हेतु सूक्ष्मजीवी
- पौधों एवं सूक्ष्मजीवियों द्वारा प्रदूषण उपचार
- जलवायु परिवर्तन अनुकूलन अध्ययन एवं कार्बन जब्तीकरण
- पारंपरिक एवं आणुविक प्रजनन द्वारा पादप सुधार एवं आनुवांशिक अभियांत्रिकी
- सोडिक एवं अन्य बंजर भूमि के सतत विकास हेतु कृषि-प्रौद्योगिकियाँ
- आउटरीच कार्यक्रमों के द्वारा समाज कल्याण हेतु गतिविधियां

वनस्पति उद्यान तथा दूरस्थ अनुसंधान केन्द्र

घरेलू परियोजनाएं

संरक्षण, शिक्षा और जैव-सौंदर्य के लिए पौधों के विविध समूहों और चयनित सजावटी फसलों के जननद्रव्य संग्रह का संवर्धन और रखरखाव

संस्थान का वनस्पति उद्यान एक राष्ट्रीय सुविधा के रूप में कार्य करता है। वनस्पति वाटिका के साथ-साथ विभिन्न पौध गृहों में *एक्स-सीटू* संरक्षण के तहत 5,000 टैक्सा सहित जननद्रव्य की एक विस्तृत श्रृंखला को रखा गया है। ये जीवित जननद्रव्य संग्रह मनोरंजन उद्देश्यों के लिए भूनिर्माण में उपयोग के अलावा वानस्पतिक अध्ययन और अनुसंधान के अद्वितीय स्रोत हैं। अपने विशाल अनुवांशिक संसाधन के कारण वानस्पतिक उद्यान छात्रों, शोधकर्ताओं और जनता के लिए स्कूल से अलग शिक्षा के एक केंद्र की भांति हैं।

जनन द्रव्य संग्रह का संवर्धन

वनस्पति उद्यान में लगभग 20 दुर्लभ और रोचक प्रजातियां शामिल की गईं-*एस्काइनेन्थस हूकेराई, एस्क्लेपियास कुरासाविका, कैमेलिया साइनेंसिस, डाइटिस ग्रैंडीफ्लोरा, इलायोकार्पस एंगस्टीफोलियस, इलायोकार्पस फ्लोरीबेंडस, इफेडरा सैक्साटिलिस, यूरेल फेरोक्स, होया लोंगीफोलिया, होया पैंडूरेटा, आइरिस हूकेरियाना, आइरिस केमाओनेन्सिस, नेपेंथिस मिराबिलिस, पार्किया रोक्सबर्घाई, रेनन्थेरा इम्सूटियाना, रिंकोस्टाइलिस रेटचूसा, साल्वीनिया कुकुलेटा, वेंडा सेरूलिया, विस्टेरिया साइनेंसिस* एवं *जैंथोजाइलम आर्मेटम*। कुछ मांसल पौधे जैसे *कैलांचो थिर्सीफ्लोरा, पेरेस्किया अक्यूलिएटा 'गॉडसेफिया'', सेडम मोरोगनेरियम* को भी शामिल किया गया। आर्किड की चार प्रजातियों (*डेंड्रोबियम एफिल्लम, डेंड्रोबियम हरबेसियम, डेंड्रोबियम मोस्केटम एवं डेंड्रोबियम पैकीएंथम*) को कायिक तरीके से प्रवर्धित किया गया। कुछ महत्वपूर्ण प्रजातियों जैसे *नेपेंथिस खासियाना, एडेनसोनिया डिजिटेटा, पर्किया टिमोरियाना, स्टर्कुलिया फेओटिडा* एवं *हायलोसीरिअस अंडेटस* की बीजों के अंकुरण का सफलतापूर्वक अध्ययन भी किया गया। *सैपिंडस मुकुरोस्सी, स्पोंडियस पिन्नेटा, इलियोकार्पस फ्लोरिबंडस, जग्लंस रेजिया* एवं *कोइक्स लैक्राईमा-जोबी* के बीजों को अंकुरण अध्ययन एवं संरक्षण के लिए एकत्र किया गया।

आर्किड, जिंजिबर, *बिगोनिया, होया, कैलाथिया, साइकस पेक्टीनेटा,* फर्न, पाम एवं जलोद्भिद पौधों की 80 से अधिक प्रजातियों के लगभग 500 पौधों को *एक्स-सीटू* संरक्षण हेतु संस्थान के वनस्पति उद्यान में एकत्र किया गया। जीवित जननद्रव्य को दुर्लभ पौधों के प्रसारण गृह एवं आर्किड गृह में संरक्षित किया जा रहा है। सजावटी पौधे *मुसेंडा ग्लैब्रा* की कटिंग को भी एकत्र किया गया।

बांस गृह में जननद्रव्य को समृद्ध करने के लिए बांस की चार प्रजातियों के 14 पौधों को मणिपुर से एकत्र किया गया। विशाल बांस *डेंड्रोकैलेमस जाइगेंटस* के नन्हें पौधों को भी एकत्र किया गया। बांसगृह की समुचित देखभाल के साथ अधिक से अधिक प्रजातियों को शामिल करने की दिशा में प्रयास किए जा रहे हैं।

पुष्पीय पौधों एवं संकट ग्रस्त पौधों की निम्नलिखित प्रजातियों को संस्थान के वनस्पति उद्यान में संरक्षण हेतु शामिल किया गया: *एडेनोकैलिमा कोमोसम, एरिस्टोलोकिया एक्यूमिनेटा, अयपना ट्रिप्लीनर्विस, बैकाउरिया कोर्टालेन्सिस, सिनामोनम वेरम, क्लीसोस्टोमा रैसीमीफेरम, कोप्टिस टीटा, कुल्लेनिया एक्सेरिलेटा, इलेटेरिया कार्डोमम, एंबलिया राइब्स, एरेंजियम फोटिडम, गार्सीनिया गम्मी-गुट्टा, गार्सीनिया इंडिका, हेमीग्राफिस आल्टर्नेटा, होपिया पार्वीफ्लोरा, नेपेंथिस मिराबिलिस, पिमेंटा डायोका, प्लेक्ट्रेन्थस वर्टीसिलेटस, पॉलीएल्थिया कोफ्फोयडिस, रूटा कलेपेन्सिस, शाइजिगियम एरोमैटिकम, शाइजिगियम स्टॉकसाई, ट्राईस्टेलेरिया ऑस्ट्रेलिस, टर्पीनिया मलाबारीका, वाटेरिया इंडिका* एवं *वेटिवेरिया जिजानोईडिस*।

भारत के मसाले एवं हर्बल औषधीय पौधों का गृह

संस्थान में एक नवीन 'मसाले एवं हर्बल औषधीय पौध गृह' निर्मित किया गया। इस अनूठे पौध गृह में पादप जगत के दो महत्वपूर्ण समूहों, 'मसालों' एवं 'औषधीय पौधों' से संबन्धित पौधों को संरक्षण एवं प्रदर्शन हेतु बनाया गया है। यह 680 वर्ग मी. क्षेत्रफल में बना हुआ है। वर्तमान में लगभग 67 टैक्सा इस गृह में संरक्षित हैं जिनमें से कुछ प्रमुख प्रजातियाँ *क्रोकस सैटाइवस* (केसर), *सिनामोनम कंफोरा* (कपूर), *सिनामोनम वेरम* (दालचीनी), *मिरिस्टिका फ्रेग्रेंस* (जायफल), *कॉफिया अरेबिका* (कॉफी), *पाईपर निग्रम* (काली मिर्च), *एलो वेरा, विथानिया सोम्नीफेरा* (अश्वगंधा), *इफेड्रा फोलिएटा* (सोमलता) आदि हैं।

कृषि प्रणालियों के उत्पादन को बढ़ाने, कौशल विकास और आउटरीच कार्यक्रमों के माध्यम से सामाजिक-आर्थिक विकास

सोडिक मिट्टी के लिए गैर पारंपरिक आर्थिक पौधों का मूल्यांकन

सोडिक मिट्टी में ट्यूबरोज (*पॉलिएंथेस ट्यूबरोसा*), अश्वगंधा (*विथानिया सोम्नीफेरा*) और ईसबगोल (*प्लांटैगो ओवेटा*) के मूल्यांकन हेतु संग्रह, संरक्षण और मूल्यांकन की दिशा में ट्यूबरोज की 18, अश्वगंधा की 8 एवं ईसबगोल की 7 किस्मों को उनकी वाणिज्यिक खेती एवं किसानो की आय बढ़ाने हेतु आंशिक रूप से सुधार की गयी सोडिक मृदा की परिस्थितियों में उगाया गया।

सोडिक अपशिष्ट भूमि के सुधार हेतु औद्योगिक अपशिष्ट जैसे फ्लाईएश एवं प्रेस मड का सुरक्षित उपयोग और ट्यूबरोज के विकास और फूलों के गुणों पर इसकी प्रतिक्रिया का अध्ययन किया गया। जड़ के विकास और अश्वगंधा के एल्कोलॉयड की मात्रा को बढ़ाने में पादप वृद्धि को बढ़ावा देने वाले राइजोबैक्टेरिया (पीजीपीआर) की प्रतिक्रिया का अध्ययन किया गया। उपज और गुणवत्ता निर्धारित करने के लिए शंखपुष्पी (*इवोल्वुलस माइक्रोफिल्लस*) का विभिन्न सोडिक स्तरों के तहत मूल्यांकन किया गया। बढ़ते सोडिक स्तर के साथ परिपक्वता दिनों में वृद्धि हुई और पौधे का जैवभार उत्पाद उपज भी कम हुआ।

कालमेघ की जैवभार उपज और गुणवत्ता पर कार्बनिक पदार्थ के विभिन्न स्रोतों और स्तरों के प्रभाव का अध्ययन करने के लिए प्रयोग किए गए। पौधों की ऊंचाई, तने का व्यास, पौधे का घेरा, जैव भार आदि खाद, प्रेस मड एवं वर्मीकंपोस्ट की मात्रा के साथ बढ़ती देखी गई।

अन्य सहयोगी प्रयोग

आंशिक रूप से सुधार की हुई सोडिक मृदा में धान की किस्मों (एनडीआर 359, सांबा महसूरी, सरजू 52, इंद्रासन) के विकास और उपज के लिए जीवाणु और कवक संघ का मूल्यांकन किया जा रहा है। मिट्टी के जैव-इनोकुलेंट्स भौतिक रासायनिक और एंजाइमेटिक गुणों का प्रतिक्रिया अध्ययन किया गया है।

सोडिक भूमि के भौतिक-रासायनिक गुणों और गेहूं की पैदावार एवं उपज पर विघटित सामग्री की प्रतिक्रिया की जांच और धान की भूसी के अपघटन के लिए सूक्ष्मजैविक उपभेदों का मूल्यांकन किया गया।

घरेलू परियोजनाएं

क्राइसेंथेमम मॉरीफोलियम में कोशिकीय अध्ययन शुरू किए गए हैं ताकि विभिन्न किस्मों के जननद्रव्य में पॉलीप्लोइडी की घटना एवं गुणसूत्र संख्या को वर्णित किया जा सके।

विकसित की गयी नई किस्म

गुलदाऊदी 'एनबीआरआई-हिमज्योति'

एनबीआरआई-हिम ज्योति एक नवीन, बौनी (30 सेमी तक ऊंचाई), 'एनिमोन' प्रकार की गुलदाउदी की किस्म है जो क्रीम रंग के पुष्प धारण करती है जो नवंबर माह के अंत से जनवरी माह की शुरुआत तक खिलते हैं। यह नई किस्म पितृ किस्म 'हिमांशु' पर गामा उपचार के द्वारा विकसित की गई है।

अनुदान प्राप्त परियोजनाएं

औषधीय पौधों की खेती हेतु कृषि प्रौद्योगिकी विकसित करने के लिए अच्छी कृषि प्रथाओं का पुनर्मूल्यांकन

फाइलेन्थस अमारस और *साइपेरस रोटुंडस* का जननद्रव्य एकत्र किया गया और विभिन्न कृषि प्रथाओं के मूल्यांकन के लिए परीक्षण आयोजित किए जा रहे हैं।

कॉप्टिस टीटा, एक दुर्लभ एवं संकटग्रस्त प्रजाति, को अरुणाचल प्रदेश की मिशमी पहाड़ियों से एकत्र किया गया एवं ऊतक संवर्धन तथा कंद की कटिंग से प्रसारण के द्वारा इसके घरेलू परिस्थितियों में उगाने के प्रयास किया जा रहे हैं। इसी प्रकार *वायोला पाइलोसा* को भी आईसीएआर-नेशनल ब्यूरो ऑफ प्लांट जेनेटिक रिसोर्सेज, भोवाली, उत्तराखंड से एकत्र किया गया एवं घरेलू परिस्थितियों में उगाने के प्रयास किए जा रहे हैं।

पादप विविधिता, वर्गिकी एवं पादपालय

घरेलू परियोजनाएं

विभिन्न पादप समूहों की जैव-संसाधन सूची, वर्गिकी एवं संरक्षण

उत्तर प्रदेश में स्थित सुहेलवा वन्य जीव अभ्यारण्य की पादप विविधता एवं इससे संबंधित पारंपरिक ज्ञान का आंकलन करते हुए इसके व्यवस्थित अभिलेखन, संरक्षण एवं उपयोग में लाने के अध्ययन प्रारम्भ किये गये हैं। इस दिशा में किए गए एक सर्वेक्षण में अभ्यारण्य के 12 स्थानों से आठ शैवालों, 200 शैकों, 42 उभयोद्भिदों, 22 टेरिडोफाइटों एवं 150 पुष्पीय पौधों को एकत्र किया गया जिनका वर्गिकी अध्ययन किया जा रहा है। उच्च शैक विविधता के चलते यह संकेत मिले हैं कि यह वन एक अनछुआ, नम एवं उष्ण वन है।

अनुदान प्राप्त परियोजनाएं

सूक्ष्म शैवाल से उत्पाद विकास एवं जैव-ऊर्जा उत्पादन हेतु आणुविक दृष्टिकोण

लखनऊ के 11 विभिन्न स्थानों से 32 कुलों की 40 शैवाल प्रजातियों का पता चला। *सेंट्रीट्रैक्टस बेलोनोफोरस* को पहली बार उत्तर प्रदेश में पाया गया। तेरह सूक्ष्म शैवालों को अलग किया गया जिनमें से *सेनेडेस्मस क्वाड्रीकॉडा* को जैव भार एवं लिपिड उत्पादन के लिए सर्वोत्तम प्रभावी पाया गया। *सेनेडेस्मस क्वाड्रीकॉडा* के मिश्रण के वसीय अम्ल मेथिल ईस्टर के ईंधन गुणों को यूरोपियन मानकों की सीमा के अंदर पाया गया।

सेनेडेस्मस क्वाड्रीकॉडा के जीनोम की पूरी लंबाई को सीक्वेंस किया गया एवं 13514 जीनों का डी-नोवो आंकलन किया गया जबकि 16739 जीनों का संदर्भ सामग्री के आधार पर आंकलन किया गया। पूरे जीनोम सीक्वेंस की रिफरेंस असेंबली को एनसीबीआई बायोप्रोजेक्ट के तहत जमा किया गया जिसे नमूना संख्या NNCB00000000 प्रदान किया गया है। जीन अभिव्यक्ति विश्लेषण के माध्यम से 6167 जीन कोशिकीय प्रक्रमों में, 6558 जीन जैवीय प्रक्रमों में, 8348 जीन आणुविक प्रक्रमों में एवं 283 जीन लिपिड उपापचय में शामिल पाये गए। *सेनेडेस्मस क्वाड्रीकॉडा* के अन्य शैवालों से वंशागत संबंधों के अध्ययन एवं सही पहचान स्थापित करने हेतु 18s राइबोसोम उपइकाई आरएनए जीन को सीक्वेंस किया गया जिसे NCBI जेनबैंक में जमा किया गया (नमूना संख्या KY654954.1.)

अक्षय एवं आधुनिक ईंधन प्रौद्योगिकियों हेतु अंतरराष्ट्रीय संघ (i-CRAFT)

जैव भार उत्पादन हेतु, उच्च लिपिड मात्रा एवं आसानी से उगाये जा सकने के आधार पर, सूक्ष्म शैवालों की दो प्रजातियों *नैनोक्लोरोप्सिस* एवं *सेनेडेस्मस* का अध्ययन किया गया जिन्हें दो कृत्रिम तालाबों में उगाया गया। समय के साथ इनके साथ *क्लोरेल्ला* एवं अन्य शैवालों की उपस्थिति भी देखी गई। सर्वाधिक जैव-भार *सेनेडेस्मस, नैनोक्लोरोप्सिस* एवं *क्लोरेल्ला* के सह-संयोजन के अंतर्गत जुलाई 2017 में पाया गया। सर्वाधिक लिपिड का प्रतिशत सितंबर माह में पाया गया जिसमें सर्वाधिक मात्रा *सेनेडेस्मस* व *क्लोरेल्ला* की देखी गई।

सेनेडेस्मस क्वाड्रीकॉडा के निष्कर्षण किए गए जैव-भार का आंकलन करने पर वसीय अम्ल सूची में सर्वाधिक प्रमुख अम्ल क्रमशः पामीटिक अम्ल, ओलेक अम्ल, लिनोलेक अम्ल एवं लिनोलेनिक अम्ल पाए गए। अन्य वसीय अम्ल बहुत सूक्ष्म मात्रा में पाए गए।

जैवप्रौद्योगिकी प्रयोगों हेतु दक्षिण एशियाई शैकों के टीलोशिस्टेसी समूह की वंशावली वर्गिकी

अध्ययन में एक नए कुल *उप्रेतिया* एवं एक नई प्रजाति *गैलोवाएल्ला अवस्थीयाना* को भारत से खोजा गया।

भारतीय टीलोशिस्टेसी समूह का वर्गिकी अध्ययन करने के लिए पहली बार तीन जीन वंशावली वृक्ष की सहायता ली गई। *कैलोप्लाका* की 15 प्रजातियों को जम्मू एवं कश्मीर से एकत्र किया गया। भारत में *कैलोप्लाका, आयोप्लाका, रूसावस्किया* एवं *जन्थोरिया* वंशों की वर्तमान स्थिति का अध्ययन किया जा रहा है।

भारत में विशेष रूप से आर्थोनिएसी वंश के संदर्भ में लाइकेनाइज्ड एवं लाइकेनिकोलस कवक की पारिस्थितिकी, वंशावली एवं गणनात्मक दृष्टिकोण

अध्ययन का उद्देश्य भारत में आर्थोनिएसी वंश के इतिहास, विविधता, आणुविक वर्गिकी एवं पारिस्थितिकी का अध्ययन एवं साथ ही शैकों की पहचान हेतु एक वेब आधारित एप्लिकेशन एवं मैनुअल का विकास करना है। जम्मू से करीब 100 एवं कर्नाटक से 250 नमूने एकत्र किए गए। इसके अतिरिक्त आम जनता में शैकों के प्रति जागरूकता बढ़ाने हेतु यू ट्यूब पर 'लाईकेन ऑफ इंडिया' नाम से एक नया चैनल चालू किया गया है।

मध्य पश्चिमी घाट, कर्नाटक के भंगुर वन्य पारिस्थितिक तंत्र के शैकों की विविधता, पारिस्थितिकी एवं संरक्षण

इस परियोजना का मुख्य उद्देश्य कर्नाटक के मध्य पश्चिमी घाट के विभिन्न भंगुर वन्य आवासों के संबंध में शैकों की विविधता एवं पारिस्थितिकी का अध्ययन करना, शैकों पर मानवजनित कारकों के प्रभावों का आंकलन करना एवं संकटग्रस्त शैकों के लिए संरक्षण रणनीतियाँ विकसित करना है। इसके अंतर्गत उत्तर कन्नड एवं शिवमोगा जिलों से 500 से अधिक शैक नमूने एकत्र किए गए। शिवमोगा जिले में होसागुंडा नामक पवित्र वन स्थान से शैकों की 40 से अधिक प्रजातियाँ एकत्र की गईं जो इस क्षेत्र में किसी भी पवित्र वन स्थान से ज्ञात सर्वाधिक संख्या है।

भारत में शैक वंश *बुएलिया* एवं *राइनोडिना* का अध्ययन

बुएलिया एवं *राइनोडिना* दो सहसंबंधी शैक कुल हैं। इस अध्ययन का उद्देश्य भारत में दोनों कुलों की वर्तमान स्थिति का आकारिकीय, रासायनिक एवं आणुविक आंकड़ों के आधार पर विस्तृत वर्गिकी अध्ययन करना है। संस्थान के पादपालय में उपलब्ध नमूनों की पुनः जांच कर 186 नमूनों को *बुएलिया*, 18 को *डिप्लोटोमा*, 21 को *अमंडिनिया*, 2 को *बैकुलिफेरा*, 5 को *हाफेलिया* एवं 393 को *राइनोडिना* में पृथक किया गया।

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

दार्जिलिंग की पहाड़ियों से कुल 316 उभयोद्भिदों को तीन भिन्न सेटों में अभिलेखित किया गया है। इन सेटों में लिवरवर्ट्स के कुल 129, हॉर्नवर्ट्स के 11 एवं मॉस के 176 टैक्सा शामिल हैं। पूर्व के सभी नमूनों को ऊंचाई के आधार पर तीन समूहों में विभक्त किया गया है: निम्न ऊंचाई क्षेत्र (1000-1500 मी), मध्यम ऊंचाई क्षेत्र (1501-2000 मी) एवं अधिक ऊंचाई का क्षेत्र (2001-2500 मी)। वर्तमान अध्ययन में टाइगर हिल की 48 एवं सेंचल वन्यजीव अभ्यारण्य की 63 प्रजातियों का प्रलेखन किया गया है।

इसके अतिरिक्त *हिप्नम* वंश पर भी अध्ययन किया जा रहा है जिससे दार्जिलिंग पहाड़ियों में इस वंश के आठ टैक्सा के वितरण एवं विविधता की जानकारी प्राप्त हुई है। यह सभी प्रजातियाँ पूरे पूर्वी हिमालय क्षेत्र में इस वंश का प्रतिनिधित्व करती हैं। इन सभी टैक्सा का ऊंचाई एवं आवास स्थान के आधार पर वितरण का भी अध्ययन किया गया। सबसे अधिक प्रजातियों की संख्या 2001-2500 मी ऊंचाई के क्षेत्र में प्राप्त हुई। साथ ही पत्थर एवं पेड़ों की छाल सर्वोत्तम उपयुक्त आवास स्थान के रूप में पाए गए।

दो प्रजातियों *फ्रूलेनिया ऑर्निथोसेफेला* एवं *मार्केन्शिया सबजेमिनेटा* को भारत में पहली बार देखा गया जबकि चार प्रजातियों क्रमशः *गोलेनिया रुगिनोसा, ट्राइकोस्टोमम हायलीनोब्लास्टम, फिस्सीडेंस जोलिंगेरी* एवं *ब्रैकीथेसियम गढ़वालेंसे* को पूर्वी हिमालय क्षेत्र में पहली बार देखा गया।

संरक्षण हेतु तीन प्रजातियों क्रमशः *लुनुलेरिया क्रूसिएटा, एंथोसेरोस भारद्वाजाई* एवं *रिंकोंस्टेजिएल्ला स्कैब्रीसेटा* का *एक्स-सीटू* प्रवर्धन किया गया।

पूर्वी घाटों में उभयोद्भिद विविधता का अध्ययन

तमिलनाडु, आंध्र प्रदेश एवं ओडिशा में पूर्वी घाटों के उभयोद्भिद प्रचुर क्षेत्रों की विविधता का अध्ययन किया जा रहा है। अध्ययन में मॉस की 109, लिवरवर्ट्स की 46 एवं हॉर्नवर्ट्स की एक प्रजाति का पता चला। मॉस में सर्वाधिक प्रजाति विविधता पॉटीएसी कुल में जबकि लिवरवर्ट्स में लेजूनिएसी कुल में देखी गई। *रिक्सिया बोलीविएन्सिस* एवं *वीसिया पैराजैपोनिका* को भारत में पहली बार देखा गया।

मणिपुर एवं नागालैंड के अज्ञात/अल्पज्ञात क्षेत्रों में पादप विविधता का आंकलनः संकट ग्रस्त पौधों का सूचीकरण, संरक्षण, फील्ड जर्मप्लाज्म बैंक एवं जैव-संसाधन के रूप में प्रयोग हेतु चयनित प्रजातियों का जैव-पूर्वेक्षण

मणिपुर एवं नागालैंड के वानस्पतिक विविधता के संदर्भ में अज्ञात एवं अल्पज्ञात क्षेत्रों में सर्वेक्षण किए गए। कुल 4022 नमूने एकत्र किए गए जिनमें 1870 पुष्पीय पौधे, 30 अनावृतबीजी, 110 टेरिडोफाइट, 182 उभयोद्भिद, 1800 शैक एवं 15 शैवाल सम्मिलित हैं। इसके अतिरिक्त कुछ दुर्लभ एवं संकटग्रस्त पौधे भी एकत्र किए गए। एक वैश्विक रूप से संकटग्रस्त पौधे *होया पैंडूरेटा* को भारत में पहली बार मणिपुर के कामजोंग जिले से ढूंढा गया।

आर्किड, फर्न एवं जलीय पौधों की लगभग 70 प्रजातियों के पौधों को ला कर संस्थान के वनस्पति उद्यान में स्थापित किया गया। औषधीय रूप से महत्वपूर्ण पौधों *जैंथोजाइलम आर्मेटम, सिनामोमम जिलेनिकम* एवं *कॉस्टस स्पेशिओसस* को जैव-पूर्वेक्षण हेतु एकत्र किया गया।

सात उभयोद्भिद प्रजातियों को पूर्वी हिमालय में पहली बार देखा गया जबकि मॉस की 31 एवं लिवरवर्ट्स की 3 प्रजातियों को मणिपुर में पहली बार देखा गया। इसी प्रकार नागालैंड से 89 प्रजातियों को पहचाना गया। *प्लैजियोकाइला ट्रैबेकुलेटा* एवं *एट्राइकियम क्रिस्पूलम* को भारत में पहली बार देखा गया जबकि मॉस की 40 एवं लिवरवर्ट्स की 13 प्रजातियों को नागालैंड से पहली बार वर्णित किया गया।

किशनपुर वन्यजीव अभ्यराण्य की पादप विविधता का सर्वेक्षण एवं पादप संसाधनों का संरक्षण अध्ययन

यह वन उष्ण कटिबंधीय नम पर्णपाती प्रकार के हैं। पूरे क्षेत्र में मुख्यतः साल, टीक, सेमल एवं मिश्रित साल वन की बहुलता है। अलग अलग समय पर क्षेत्र से 470 प्रजातियों को एकत्र किया गया। फैबेसी कुल सर्वाधिक प्रचुर है जिसके बाद पोएसी,एस्टेरेसी, मालवेसी, रूबीएसी, टीलिएसी, यूफोरबिएसी एवं लैमिएसी का स्थान आता है। *बाहुनिया वाहलाई* एवं *मिलेशिया एक्स्टेंसा* सबसे अधिक व्याप्त काष्ठीय बेलें हैं। खाली स्थानों पर विदेशी प्रजातियों का कब्जा देखा गया। वन में कुछ घास के मैदान भी देखे गए जहां मुख्यतः पोएसी कुल के सदस्यों की बहुलता देखी गई। झाड़ियों में प्रमुख रूप से *हेलिक्टेरेस इसोरा, सेना ओक्सीडेंटेलिस, टैमेरिक्स डाइओका, ग्रेविया एशियाटिका* आदि व्याप्त देखी गईं।

शाकीय पौधे मुख्यतः वन के तल और किनारों पर, सड़कों के किनारे एवं जलीय स्थानों के आस-पास पाए गए जिनमें से प्रमुख *हेल्मिन्थोस्टैकस जेलेनिका, जिंजिबर कैपिटेटम, कमेलाइना एटेनुएटा, एक्सेकम टेट्रागोनम, पेपरोमिया पेलुसिडा, पोलीगोनम ग्लेब्रम* आदि हैं।

लखनऊ (उत्तर प्रदेश) के नवाब वाजिद अली शाह प्राणि उद्यान की पादप विविधता का सूचीकरण

कुल 70 वंशों की 92 प्रजातियों का अभिलेखन किया गया। इनमें से 62 प्रजातियाँ भारतीय हैं जबकि शेष विदेशी प्रजातियाँ हैं। सर्वाधिक व्याप्त कुलों में सर्वप्रथम फैबेसी का स्थान है जिसके पश्चात मोरेसी, एरेसी, एपोसाइनेसी आदि का स्थान है। प्रयोग के मामले में जाँची गई प्रजातियों में से 43 सजावटी, 19 लकड़ी प्रदान करने वाली, 13 औषधीय, 12 खाए जाने वाले एवं 5 धार्मिक रूप से महत्वपूर्ण पौधे हैं।

असम के दीमा हासो जिले मे पादप विविधता का आंकलन

कुल छह सर्वेक्षणों में 1200 से अधिक नमूनों को एकत्र किया गया जिनकी प्रारम्भिक जांच से करीब 600 प्रजातियों का पता लगा है जिनमे से करीब 272 प्रजातियों (169 शाक, 20 बेलें एवं 83 वृक्ष) को पहचाना जा चुका है। एकत्र किए गए पौधों की सटीक पहचान के लिए देहरादून स्थित वन शोध संस्थान के पादपालय में उपलब्ध नमूनों का भी निरीक्षण किया गया।

भारत में *डिडिमोकार्पस-हेंकेलिया* वंश (जेस्नेरिएसी) समूह की आणुविक वर्गिकी

भारत के 10 एवं आठ विदेशी पादपालयों में उपलब्ध *हेंकेलिया* की 29 प्रजातियों के 971 एवं *डिडिमोकार्पस* की 17 प्रजातियों के 407 नमूनों

का अध्ययन किया गया। भारत के पाँच राज्यों के 11 जिलों के 31 स्थानों का सर्वेक्षण किया गया। वर्गिकी एवं आणुविक वंशागत अध्ययनों हेतु *हेंकेलिया* की 12 प्रजातियों के 77 एवं *डिडिमोकार्पस* की 10 प्रजातियों के 39 नए नमूने एकत्र किए गए। इसके अतिरिक्त 108 नमूनों को डीएनए निष्कर्षण हेतु एकत्र किया गया। इन सभी नमूनों का पीसीआर प्रवर्धन किया गया। सीक्वेंसिंग के नतीजों में कई नमूनों से 69 ITS, 39 *trnL-F*, एवं 47 *matK* सीक्वेंसों का पता चला। सभी सीक्वेंसो का बायोएडिट एलाइनमेंट एडिटर का प्रयोग करते हुए विश्लेषण किया गया।

भारत में *बेटुला* वंश की आणुविक वर्गिकी

विभिन्न पादपालयों में उपलब्ध भारतीय *बेटुला* की 4 प्रजातियों (*बेटुला अल्नोयडिस, बे. सिलिंड्रोस्टैकिया, बे. यूटिलिस, बे. यूटिलिस* उपजाति *जैकवेमोंटाई*) के 400 से अधिक नमूनों का अध्ययन किया गया। भारतीय हिमालय एवं पूर्वोत्तर भारत के सात राज्यों में 5 सर्वेक्षण यात्राएं की गई एवं चारों प्रजातियों के कुल 400 नमूनों को एकत्र किया गया जिनका आणुविक वर्गिकी अध्ययन किया जा रहा है।

आणुविक मार्करों की सहायता से भारत में *सोनेरेशिया* वंश की विविधता एवं वर्गिकी का अध्ययन

सोनेरेशिया की पाँच प्रजातियों (*सो. अल्बा, सो. एपेटला, सो. सीसोलेरिस, सो. ग्रिफिथियाई* एवं *सो. ओवेटा*) के कुल 120 नमूनों का अध्ययन किया गया। पूर्वी घाट, पश्चिमी घाट एवं अंडमान द्वीपों के मैंग्रूव इलाकों के पाँच सर्वेक्षण किए गए तथा 170 नमूने एकत्र किए गए। *सोनेरेशिया ग्रिफिथाई* एवं *सो. अल्बा* के भौगोलिक वितरण की पुनः जांच की गई एवं पश्चिम बंगाल एवं ओडिशा में *सोनेरेशिया ग्रिफिथाई* के वितरण की सभी पूर्व सूचनाएँ गलत पाई गईं। यह प्रजाति मात्र अंडमान द्वीप समूह में ही पाई जाती है।

जैव-पूर्वेक्षण हेतु असम में पाई जाने वाली दीमकों द्वारा उगाई जाने वाली कवक *टर्मिटोमाइसिस* का मेटा जीनोमिक एवं ट्रांस क्रिप्टोमिक अध्ययन

असम से एकत्र की गई *टर्मिटोमाइसिस* की 11 प्रजातियों के हाइड्रो-अल्कोहलिक अर्क तैयार कर एंटीऑक्सीडेंट गुणों हेतु जाँचे गए। सर्वाधिक एंटी ऑक्सीडेंट क्रिया M22 में देखी गई। M32 ने सर्वाधिक कार्बोहाइड्रेट मात्रा जबकि M21 ने सर्वाधिक प्रोटीन मात्रा प्रदर्शित की।

पादप-सामुदायिक एवं संरक्षण स्थिति के विशेष संदर्भ में *जिरेनियम* वंश का प्रबंध लेखन अध्ययन

विभिन्न पादपालयों एवं वानस्पतिक अभिलेखों के अध्ययन के द्वारा *जिरेनियम* की 27 प्रजातियों की आकारिकी, भौगोलिक वितरण, पुष्पन एवं फलन से संबन्धित आंकड़ों को एकत्र किया गया एवं 520 नमूनों का अध्ययन किया गया। पूर्वी (कश्मीर एवं हिमाचल प्रदेश) एवं मध्य हिमालय (उत्तराखंड) क्षेत्र में चार सर्वेक्षण किए गए जिनमें 16 जिलों के 32 स्थानों को शामिल किया गया जहां से कुल 420 नमूने एकत्र किए गए। कुल 12 प्रजातियों (*जि. क्लार्कियाई, जि. हिमालएन्से, जि. लूसीडम, जि. मस्कटेंसे, जि. ओसेलेटम, जि. नेपालेंसे, जि. पोलीएंथस, जि. प्रिटेंसे, जि. पूसीलम, जि. रोबर्टीआनम, जि. सिब्रिकम, जि. वालीचियानाम*) का विस्तृत वर्गिकी अध्ययन पूर्ण किया गया।

अन्य शोध उपलब्धियां:

मृतोपजीवी मॉस *स्प्लेकनम स्फेरिकम* का *इन-विट्रो* प्रवर्धन

स्प्लेकनम स्फेरिकम को भारत में सर्वप्रथम अरुणाचल प्रदेश में देखा गया था। यह प्रजाति याक के गोबर पर उगती हुई पाई गई थी। इस दुर्लभ एवं रोचक प्रजाति के *इन-विट्रो* प्रवर्धन के लिए एक नवीन प्रोटोकॉल विकसित किया गया (साहू एवं अन्य, 2017, इन्टरनेशनल जर्नल ऑफ प्लांट एंड एनवायरमेंट 3(2): 47-50) जो इस दुर्लभ प्रजाति के प्रवर्धन के साथ इसके अध्ययन में भी सहायक होगा।

एंथोसेरोस मैक्रोस्पोरस (एंथोसेरोटोफाइटा) की संरक्षण स्थिति

एंथोसेरोस मैक्रोस्पोरस एक दुर्लभ एवं संकटग्रस्त हॉर्नवर्ट है जो महाराष्ट्र एवं गुजरात के कुछ इलाकों से ही ज्ञात है। आईयूसीएन के रेड लिस्ट मानदंडों के आधार पर इसकी संरक्षण स्थिति का आंकलन किया गया। वर्तमान में यह प्रजाति दोनों राज्यों के मात्र पाँच स्थानों में बहुत गंभीर रूप से खंडित आबादियों के रूप में वितरित है जिसके 'आवास की सीमा' 5000 वर्ग किमी से कम एवं 'अत्यधिक प्रतिबंधित आवास क्षेत्र' होने के नाते इसे आईयूसीएन रेड लिस्ट के मानदंडों के आधार पर वैश्विक स्तर पर 'संकट ग्रस्त' श्रेणी में रखा गया।

माइक्रोलेपिया स्पेलुंकी (डेंस्टेडिएसी) की प्रजनन जैविकी

अध्ययन से पता चला कि बीजाणुओं के बोए जाने के 10वें दिन एकल प्रारम्भिक राइजोइडल कोशिका के साथ प्रोटोनीमा का उद्भव होता है जबकि 16वें दिन 4-5 कोशिकीय, धागे नुमा, 31वें दिन चमचेनुमा एवं 48वें दिन हृदयाकार युग्मकोद्भिद विकसित होता है। मादा युग्मकधानी 54वें दिन एवं नर युग्मकधानी 70वें दिन पर अलग-अलग पौधों पर उत्पन्न होती हैं जिससे द्विलिंगी जनन के बारे में पता चलता है। निषेचन के उपरांत 90वें दिन बीजाणुद्भिद उत्पन्न होता है। लैंगिक अभिव्यक्ति में आने वाला अंतर इस प्रजाति की आबादी की घटती संख्या का कारण हो सकता है।

पादपालय-एक राष्ट्रीय सुविधा

सामान्य पादपालय गतिविधियों के अतिरिक्त अन्य गतिविधियों के अतिरिक्त 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 पादपालयों 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 संग्रह में बीजी पौधों के 216 नमूने एवं अबीजी पौधों (टेरिडोफाइट-201, उभयोद्भिद-475, शैवाल-20 एवं 2000 शैक) के 2696 नमूने सम्मिलित हैं।

पादपालय संग्रह

बीजी पौधे (आवृतबीजी एवं अनावृतबीजी पौधे)	1,03,078
टेरिडोफाइट	6,339
उभयोद्भिद	17,617
शैक	1,53,500
शैवाल	2695
बीज संग्रह	16,000
कुल पादपालय संग्रह	2,99,229

पादप पारिस्थितिकी एवं पर्यावरण विज्ञान

घरेलू परियोजनाएं

प्रदूषण की निगरानी एवं आंकलन तथा जैव उपचार द्वारा निराकरण

सूक्ष्मजैविक संघटन एवं उर्वरक से संवर्धित मक्का उगाकर पॉलीएरोमैटिक हाइड्रोकार्बनों का तुलनात्मक मूल्यांकनः अपटेक और एंटीऑक्सीडेंट रक्षा प्रतिक्रिया में व्यवस्थीकरण

पॉलीएरोमैटिक हाइड्रोकार्बन (पीएएच) पर्यावरण में सर्वव्यापी हैं और कैंसरजन्य होते हैं, इसलिए फसलों में इनकी स्थिति का निर्धारण आवश्यक है। इस अध्ययन में, मक्के की किस्म NMH 589 को पीएचएच मिश्रण (फेनेंथेरिन 300 माइक्रोग्रा प्रति ग्रा., एंथ्रेसीन 300 माइक्रोग्रा प्रति ग्रा., पाईरिन 200 माइक्रोग्रा प्रति ग्रा. और फ्लोरेनथ्रीन 200 माइक्रोग्रा प्रति ग्रा.), पेट्रोलियम हाइड्रोकार्बन को कम करने वाले सूक्ष्म जैविक संघटन एवं कार्बनिक उर्वरक से संवर्धित मिट्टी में लगाया गया ताकि वृद्धि की विभिन्न अवस्थाओं के दौरान इनके अवशोषण को निर्धारित किया जा सके।

32 दिनों के बाद, पौधों के विकास के साथ मिट्टी में पीएएच मिश्रण में, गैर-रोपण वाली मिट्टी (31%) की तुलना में रोपण वाली मिट्टी में अधिक (49.7%) गिरावट देखी गई। कार्बनिक उर्वरकों एवं सूक्ष्मजैविक संघटन को मिलाने से पीएएच के अपघटन में 99.4% तक की वृद्धि देखी गई।

पीएएच दूषित मिट्टी में, सूक्ष्मजीव और पौधे एक सहक्रियात्मक संबंध दिखाते हैं, जहां पौधों ने सूक्ष्मजैविक गणना को बढ़ाया (503% तक), जबकि सूक्ष्मजैविक संघटन के प्रयोग ने पीएएच तनाव को कम कर दिया।

पीएएच प्रेरित तनाव में कमी पौधों की एंटीऑक्सीडेंट गतिविधियों में कमी के अनुरूप है। इसके अलावा, पौधों में संचित पीएएच विभिन्न पादप ऊतकों को वितरित किया जाता है जिससे इसकी विषाक्तता कम हो जाती है।

वन्य कार्बनिक मात्रा का आंकलन और शहरी वायु प्रदूषण को कम करने वाले पौधे

शहरी क्षेत्रों में वायु प्रदूषण धीरे-धीरे एक बड़ी चुनौती बन रहा है। हरे पौधे कुछ वायु प्रदूषकों को कम करने में उनकी भूमिका के लिए जाने जाते हैं और वायु प्रदूषण पर नियंत्रण के लिए हरी बेल्ट विकसित करने तथा शहरी हरित स्थानों के लिए इनकी व्यापक रूप से अनुशंसा की जाती है।

नौ सामान्य रूप से पाई जाने वाली पादप प्रजातियों, *एजादिराकता इंडिका, बोगेनविलिया स्पेक्टाबिलिस, फाइकस बेंगालेन्सिस, फाइकस रिलीजिओसा, नेरियम इंडिकम, प्लूमेरिया रुबरा, पॉलीएलथिया लोंगीफोलिया, टैबर्नेमोन्टाना डाईवैरीकेटा, टर्मिनेलिया अर्जुना* को FACE सुविधा के तहत तीन महीने के लिए AO_3 परिवेश और + 20 ppb EO_3 परिवेश में रखा गया। इन सभी प्रजातियों में निम्नलिखित मापदण्डों का अध्ययन किया गयाः वायु प्रदूषण सहिष्णुता सूचकांक, डस्ट लोडिंग क्षमता, रंध्र सघनता, आकार एवं गैस आदान-प्रदान।

उच्च ओजोन परिस्थितियों में *फाइकस बेंगालेन्सिस, नेरियम इंडिकम, प्लूमेरिया रुबरा, पॉलीएलथिया लोंगीफोलिया, टैबर्नेमोन्टाना डाईवैरीकेटा* में उच्च वायु प्रदूषण सहिष्णुता देखी गई।

उच्च ओजोन मात्रा में विकसित पत्तियों में अध्ययन किए गए रंध्र लक्षणों से पता चला है कि *एजादीरकता इंडिका, प्लूमेरिया रूबरा, पॉलीएल्थिया लांगीफोलिया* और *टैबर्नेमोंटाना डाईवेरिकेटा* प्रजातियों में EO_3 में रंध्र घनत्व कम हुआ जबकि गार्ड कोशिकाओं की लंबाई में वृद्धि हुई। गार्ड कोशिकाओं की लम्बाई में वृद्धि संभवतः रंध्र घनत्व में कमी की क्षतिपूर्ति करने के लिए थी ताकि कुल प्रकाश संश्लेषण दर को बनाए रखा जा सके।

हमारे परिणामों से पता चलता है कि *फाईकस बेंगालेंसिस, नेरियम इंडिकम, प्लूमेरिया रूबरा, पॉलीएल्थिया लांगीफोलिया* में ओजोन प्रदूषण को कम करने की प्रबल संभावनाएं हैं।

इथिलीन डाईयूरिया का उपयोग करके गेहूँ पर ओजोन परिवेश के प्रभाव का आंकलन

ओजोन एक शक्तिशाली ऑक्सीडेंट है जो ऑक्सीडेटिव तनाव, निम्न रंध्र क्रिया और प्रकाश संश्लेषण, त्वरित जीर्णता, और पौधों की उत्पादकता में सामान्य कमी का कारण बनता है। एक सुगंधित यौगिक एथिलीन डाई यूरिया (ईडीयू) को आमतौर पर खेतों में पौधों और पेड़ों के लिए ओजोन रक्षक के रूप में प्रयोग किया जाता है।

गंगा के भारतीय पूर्वोतर मैदानी इलाकों में उगाई जाने वाली गेहूं की दो किस्मों, कुंदन और पीबीडब्लू-343 की वृद्धि, कार्यिकी, उपज और प्रोटीयोम पर ईडीयू के प्रभाव एवं ओजोन संवेदनशीलता में भिन्नता का अध्ययन किया गया।

प्रयोग के दौरान ओजोन परिवेश एकाग्रता 15-100 (औसत 60) पीपीबी थी। दोनों किस्मों में ईडीयू उपचार के कारण प्रकाश संश्लेषण, फ्लोरोसेंस और क्लोरोफिल मात्रा ने कोई महत्वपूर्ण बदलाव नहीं दिखा। बिना उपचार की तुलना में ईडीयू उपचारित किस्मों में लिपिड परोक्सीडेशन की सीमा कम थी। दोनों चरणों में दोनों किस्मों में ईडीयू उपचार के कारण सभी एंटीऑक्सीडेटिव एंजाइमों में महत्वपूर्ण बदलाव दिखा। यह दिलचस्प है कि कुंदन में दोनों ईडीयू उपचारों के दौरान पीबीडब्ल्यू 343 की तुलना में भारी प्रोटीन परिवर्तन दिखा।

परिणामों से पता चला है कि लखनऊ के आसपास मौजूद ओजोन सांद्रता ने गेहूं की दोनों किस्मों पर प्रतिकूल प्रभाव डाला और प्राकृतिक स्थितियों के तहत फसलों में ओजोन विषाक्तता का आंकलन करने के लिए ईडीयू एक अच्छा शोध उपकरण है।

ग्वार में सूखा तनाव के संकेतक के रूप में प्रकाशिक गुण और वर्णक सघनता

इस अध्ययन का उद्देश्य ग्वार किस्मों में सूखे और जल की परिस्थितियों में 'लीफ रिफलेकटेन्स स्पेक्ट्रोस्कोपी' में परिवर्तन के प्रति प्रतिक्रियाओं का मूल्यांकन करना था। ग्वार की तीन किस्मों क्रमशः RGC-1002, RGC-936 एवं RGC-1066 को आठ दिन तक जल तनाव की स्थिति में रखा गया। गैस आदान प्रदान, वर्णक के कार्यिकी लक्षणों एवं पत्तियों के वर्णक्रमीय गुणों को देखा एवं आंकलित किया गया।

ग्वार की पत्तियों ने आरजीसी-1002, आरजीसी-936 और आरजीसी -1066 किस्मों में जीर्णता की विभिन्न अवधियों पर स्पेक्ट्रा के दृश्यमान और निकट अवरक्त क्षेत्रों में बड़े बदलाव दिखाए। सूखे के तनाव के तहत 500 से 750 नैनो मी. स्पेक्ट्रा के बीच दिखाई देने वाली सीमा में प्रतिबिंब और स्कैटरिंग गुणांक में वृद्धि हुई। पानी की तनाव की स्थिति के तहत बढ़ते संचरण के पैटर्न को भी देखा गया।

परावर्तक स्पेक्ट्रा से, हमने विभिन्न स्पेक्ट्रल रिफ्लेक्टेंस इंडेक्स जैसे कि फोटोकैमिकल रिफ्लेकटेंस इंडेक्स, प्लांट सेनेसेन्स रिफ्लेक्टेंस इंडेक्स, नोर्मलाइज्ड डिफरेंस वेजीटेशन इंडेक्स, और मोडीफाइड रेड एज नॉर्मलाइज्ड डिफरेंस वेजेटेशन इंडेक्स की गणना भी की। ये सूखे के तनाव के दौरान पत्तियों में कार्यात्मक और वर्णक परिवर्तनों के बारे में जानकारी प्रदान करते हैं।

शारीरिक गुणों और ऑप्टिकल अध्ययनों ने दिखाया कि आरजीसी -1002 अध्ययन की गई तीन किस्मों में सूखे की प्रतिरोधक क्षमता है।

हमारे अध्ययन से पता चलता है कि पौधों की कार्यिकी की स्थिति की अधिक आसानी से, तेजी से एवं बिना नुकसान पहुंचाए समीक्षा करने हेतु बड़ी आबादी को जांचने के लिए प्रकाश संश्लेषक विशेषताओं के साथ पत्ती के वर्णक्रमीय मापन को एक तरीके के रूप में उपयोग किया जा सकता है।

अनुदान प्राप्त परियोजनाएं

धान की फसल में आर्सेनिक प्रदूषण के उपचार हेतु जैव-वृद्धि आधारित आर्सेनिक मुक्त खेती का विकास

पश्चिम बंगाल के आर्सेनिक ग्रसित स्थलों के लिए विस्तृत सर्वेक्षण किए गए हैं। तीन गांवों की पहचान की गई है जहां मिट्टी में आर्सेनिक की मात्रा एफएओ (>20 मिग्रा प्रति किग्रा) के प्रारंभिक स्तर से ऊपर है। परियोजना के तहत बहुस्तरीय परीक्षण करने के लिए इन तीन गांवों में धान के खेतों का चयन किया गया है, और स्थानीय स्तर पर बहुस्तरीय परीक्षणों के सफल कार्यान्वयन हेतु प्रगतिशील किसानों के साथ-साथ स्थानीय स्तर पर सहयोग प्राप्त करने लिए एक स्थानीय एजेंसी की पहचान की गई है। खड़िया और चारकोल पर आधारित कंसोर्शिया फॉर्मूलेशन तैयार किए गए हैं और जीविता तथा अनुकूलता जाँचें की गईं। बोरो और अमान-सीजन के दौरान चावल के पादप भार में आर्सेनिक ग्रहण की प्रतिरोधित क्षमता की भूमिका के लिए तैयार मिट्टी के कवक संघ का परीक्षण वर्ष 2017 में किया गया है, और जिसे आगे 2018 में प्रमाणित किया जा रहा है। 2017 और 2018 के वर्षों में धान के लगातार चार फसली सीजनों के आधार पर, अत्यधिक कुशल मृदा कवक आर्सेनिक उपचारक जैव उर्वरक जारी किया जाएगा।

उत्तर प्रदेश के आर्सेनिक ग्रसित जिलों में आर्सेनिक प्रदूषण की निगरानी

भारत में 12 राज्यों में 96 जिलों के भूजल को उच्च आर्सेनिक प्रदूषण ने प्रभावित किया है। भारत में मात्र 35 जिलों में ही लगभग 7 करोड़ लोग आर्सेनिक युक्त भूजल से प्रभावित हैं। आर्सेनिक युक्त भूजल के प्रयोग से एक लाख से ज्यादा मौतों और 2-3 लाख बीमारियों के मामलों की पुष्टि हो चुकी है। भारत सरकार ने गंगा-मेघना-ब्रह्मपुत्र (जीएमबी) मैदान के अंतर्गत उत्तर प्रदेश के 20 जिलों की एक सूची तैयार की है जो आर्सेनिक मैपिंग परियोजना के लक्षित क्षेत्र हैं। यह जिले बहराइच, बरेली, बस्ती, बिजनौर, चंदौली, गाजीपुर, गोंडा, गोरखपुर, लखीमपुर-खीरी, मेरठ, मिर्जापुर, मुरादाबाद, रायबरेली, संत कबीर नगर, शाहजहाँपुर, सिद्धार्थनगर, संत रविदास नगर एवं उन्नाव हैं। इन 20 जिलों में कुल 264 ब्लॉक शामिल किए गए हैं। यह परियोजना उत्तर प्रदेश के 20 परियोजना जिलों की कृषि प्रणाली में आर्सेनिक प्रदूषण की विस्तृत रिपोर्ट प्रदान करेगी।

मानव उपभोग हेतु चावल के दानों में निम्न आर्सेनिक वाली धान की किस्म

सीएसआईआर-एनबीआरआई एवं आरआरएस, चुचुरा द्वारा संयुक्त रूप से विकसित, दानों में निम्न आर्सेनिक वाली, चावल की किस्म सीएन 1794-2-एनबीआरआई की पश्चिम बंगाल में आर्सेनिक संदूषण के विभिन्न स्तरों में खेती की गई। खमरगाछी (जिला हुगली) में निम्न संदूषित क्षेत्र, बीरनगर (जिला नादिया) में मध्यम संदूषित एवं गायघाटा (जिला 24 परगना) में सर्वाधिक संदूषित क्षेत्र को आस (खरीफ पूर्व) एवं अमान (खरीफ) सीजन के लिए चयनित किया गया।

धान की 3 किस्मों (मुक्ताश्री, गोत्र बिधान-1 एवं शताब्दी) की आस एवं अमान सीजन में खेती और फसल कटाई की जा चुकी है। दोनों सत्रों के बीच और विभिन्न स्थानों के बीच एक समग्र भिन्नता थी। आस सीजन में सीएन 1794-2-एनबीआरआई (मुक्ताश्री) में अनाज आर्सेनिक स्तर (माइक्रोग्रा प्रति किलो) बीरनगर (48.38 ± 0.15) और खमरगाछी (113.49 ± 1.74) की तुलना में गाइघाटा में सर्वाधिक (251.65 ± 5. 81) पाई गई। वहीं अमान सीजन के दौरान CN1794-2-एनबीआरआई (मुक्ताश्री) में यह मात्रा गाईघाटा, बीरनगर एवं खमरगाछी में क्रमशः 73. 45 ± 0.18, 38.28 ± 2.46 एवं 80.62 ± 0.14 पाई गई।

बहु-स्थान परीक्षणों के लिए गैर-आर्सेनिक क्षेत्रों में उगाए गए सीएन-1794-2-एनबीआरआई के बीज का उपयोग करते हुए राइस रिसर्च स्टेशन, चुचुरा, पश्चिम बंगाल सरकार द्वारा जनवरी, 2018 से शुरू होने वाले बोरो सीजन के लिए अतिरिक्त परीक्षण स्थलों को शामिल किया गया। खमरगाछी में मुक्ताश्री की उपज अमान सीजन (3.6 टन/ हेक्टेयर) में आस सीजन (2.9 टन/हेक्टेयर) से अधिक अधिक पाई गई।

ओराईजा सैटाइवा में आवश्यक धातु पोषक तत्वों (आयरन, जिंक) का सूक्ष्मजीवों के माध्यम से जैव-वर्गीकरण

घुलनशील जिंक स्रोत पर वृद्धि के साथ गुणात्मक और मात्रात्मक परख के आधार पर विभिन्न स्थानों से एकत्रित मिट्टी के नमूनों से जिंक घुलनशील सूक्ष्मजैविक उपभेदों को अलग किया गया। चयनित उपभेदों का साइडरफोर, फॉस्फेट घुलनशीलता और ऑक्सिन उत्पादन के लिए भी

गुणात्मक विश्लेषण किया गया। सामान्य विशेषताओं के साथ-साथ मिट्टी की परिस्थितियों में पौधों के विकास को बढ़ावा देने वाले उपभेदों का चयन किया गया (Ban 9, P2.21, D2.8, D2.1, D1.4, D1.20, D1.16, D1.17, D1.2 एवं D2.16)। जिंक फॉस्फेट का उपयोग जिंक के अघुलनशील स्रोत के रूप में करते हुए जिंक घुलनशीलता क्षमता के लिए चयनित उपभेदों का अभिलक्षणन किया गया। उक्त नौ उपभेदों में से तीन क्रमशः D2.16, D1.20, D1.2 ने अधिक जिंक घुलनशीलता प्रदर्शित की (185.73 माइक्रोग्रा प्रति मिली से 228.55 माइक्रोग्रा प्रति मिली) जबकि D2.1, D1.16 एवं D2.8 ने मध्यम (204.13 माइक्रोग्रा प्रति मिली से 155.07 माइक्रोग्रा प्रति मिली) एवं Ban 9, D1.17 एवं D2. 21 ने न्यूनतम (131.73 माइक्रोग्रा प्रति मिली से 31.6 माइक्रोग्रा प्रति मिली) घुलनशीलता प्रदर्शित की।

जोखिम आंकलन हेतु रसायनों के विशेष संदर्भ में पादप-पर्यावरण परस्पर क्रियाकलाप मॉडलिंग

पर्यावरण में, रसायन वायु या पानी के माध्यम से पौधे के साथ संपर्क में रहते हैं। बहुत तेजी से बढ़ रहे बहु-आयामी प्रयोगात्मक डेटाबेस के समय में, यह महसूस किया गया है कि उन्नत गणनात्मक विधियों की उपलब्धता, भविष्य में रसायनों के उपयोग से पूर्व उनसे होने वाले नफा-नुकसान के आंकलन के लिए नियामक हेतु आवश्यक हैं। गुणात्मक पैदावार या बहुलक्षीय रिग्रेशन का उद्देश्य एक साथ कई वास्तविक महत्वपूर्ण निष्कर्षों/लक्ष्य चर की भविष्यवाणी करना है और इनसे बेहतर गणनात्मक दक्षता वाले सरल मॉडल बनाने में लाभ होता है। 63 अस्थिर कार्बनिक रसायनों (वीओसी) के बहु-लक्षित डेटा सेट साहित्य से एकत्र किए गए और यहां एमटी-क्यूएसएआर विश्लेषण के लिए चयनित किए गए।

जिन एकत्रित प्रयोगात्मक आंकड़ों को संज्ञान में लिया गया उनमें *लाइकोपेर्सिकॉन एस्कुलेंटम* में 'वाटर-प्लांट क्यूटिकुलर पॉलिमर मैट्रिक्स मेम्ब्रेन पार्टीशनिंग', 'एयर-प्लांट क्यूटिकुलर पॉलिमर मैट्रिक्स मेम्ब्रेन पार्टीशनिंग', एवं गैस वॉटर कोफिशिएंट्स वैल्यूस ऑफ वीओसी' थे।

हमारे परिणामों से एमटी-क्यूएसएआर मॉडल ने विभिन्न कार्यात्मक समूहों (एलिलिक/विनाईल नाइट्राइल्स, एपोक्साइड, एस्टर्स, न्यूट्रल ऑर्गेनिक्स, फेनोल्स, विनाईल/एलिल हैलाइड्स) के साथ विस्तृत रासायनिक वर्गों को कवर करने के साथ-साथ विभिन्न रसायनों के पादप-रासायनिक संबंधों की सफलतापूर्वक भविष्यवाणी की।

यहां विकसित किया गया प्रस्तावित एमटी-क्यूएसएआर मॉडल पादप-रासायनिक संबंधों पर आँकड़े उत्पन्न करने में मदद करेगा, जो बहुत कम प्रयास, समय और गणनात्मक लागत के साथ रसायनों के जोखिम/सुरक्षा मूल्यांकन के लिए आवश्यक है।

उत्तर प्रदेश के उन्नाव क्षेत्र एवं उसके आस-पास पौधों एवं पानी में फ्लोरीन एवं क्रोमियम का आंकलन

फ्लोरीन एक आवश्यक तत्व है जो बहुत ही कम मात्रा में आवश्यक होता है किन्तु पानी में इसकी 1 मिग्रा प्रति लीटर से अधिक मात्रा मनुष्यों के लिए विषाक्त हो सकती है। इसके पूर्व में अनेकों अनुसंधानकर्ताओं द्वारा उन्नाव क्षेत्र के फ्लोराइड संदूषण की समस्या का उल्लेख किया जा चुका है। इस क्षेत्र के अध्ययन में सतह जल में फ्लोराइड की मात्रा मानक स्तर से कम पाई गई। यह भी देखा गया कि भूजल में फ्लोराइड की मात्रा सीधे -सीधे pH से प्रभावित होती है, एवं 7.9 से अधिक pH वाले पानी के नमूनों में फ्लोराइड की मात्रा देखी गई।

उत्तर प्रदेश के गांगेय मैदानों में दो दलहनों में मृदा कार्बन जब्तीकरण में सूक्ष्म-जलवायु की भूमिका

उत्तर प्रदेश के बांदा जिले के उजरेसता ग्राम के खेतों में काबुली चने की आठ किस्मों (HK94-134, JG-11, PANTG-186, राधे, अवरोधी, शुभ्रा, उज्जवल एवं DCP-92-3) के परीक्षण किए गए। विकास की विभिन्न अवस्थाओं के दौरान विभिन्न आकारकीय लक्षणों जैसे पौधे की ऊंचाई, जड़ की लंबाई, पत्ती का क्षेत्रफल सूचकांक, शाखाओं की संख्या, फलियों की संख्या एवं बीजों की संख्या को मापा गया। पूर्ण विकास अवस्था के दौरान विभिन्न कर्यिकी पहलुओं जैसे प्रकाश संश्लेषण दर, वास्पोत्सर्जन एवं रंध्र व्यवहार, ईटीआर को मापा गया। परिपक्व पौधों की कटाई की गई और वायवीय एवं भूमिगत भार, फली वजन और पौधे के कुल जैव भार का अनुमान लगाया गया।

चने की आठ किस्मों पर किए परीक्षणों में राधे किस्म ने खेतों में सबसे अच्छी उपज एवं वृद्धिदर का प्रदर्शन किया, जिसे 23.5 क्विंटल/हेक्टेयर की उपज के साथ-साथ भारतीय गंगा के मैदानों के लिए सबसे अच्छी किस्म के रूप में देखा गया। इसके बाद अवरोधी और शुभ्रा में क्रमशः 20.3 क्विंटल/हेक्टेयर और 17.8 क्विंटल/हेक्टेयर की उपज देखी गई।

आनुवंशिकी एवं आणुविक जैविकी

घरेलू परियोजनाएं

धान में शुष्कता सहिष्णुता लाने हेतु एक नवीन OsDHN-FKBP समूह द्वारा ABA अनुक्रियाशील संकेतन

ABA नियंत्रित संकेतन के माध्यम से शुष्कता सहिष्णुता बढ़ाने में डीहाइड्रिन-FKBP समूह की भूमिका एवं धान की जड़ों के स्थापत्य में सुधार

यह ज्ञात है कि शुष्कता तनाव का सामना करने में डीहाइड्रिन एक संरक्षक की भूमिका निभाते हैं। इस दिशा में *ओराइजा सैटाइवा FKBP* एवं SK2 टाइप डीहाइड्रिन (*OsDhn-Rab16D*) के एक नवीन केन्द्रकीय समूह, जो ABA संकेतन से संबन्धित है, का आंकलन किया गया। धान के पौधों में शुष्कता, एब्सिसिक अम्ल एवं हाइड्रोजन परॉक्साइड अनावृत्ति की प्रतिक्रिया में *OsDhn-Rab16D* के ट्रांसक्रिप्ट को प्रवेश कराया गया। *OsDhn-Rab16D* पारजीनी लाइनों की एक्टोपिक अभिव्यक्ति ने शुष्कता के प्रति अधिक सहिष्णुता प्रदर्शित की।

एराबिडोप्सिस थैलियाना में ओराईजा सैटाइवा समूह III परॉक्सीडेज (*OsPRX38*) की अधिक अभिव्यक्ति से एपोप्लास्टिक लिग्नीकरण के कारण आर्सेनिक संग्रहण में कमी

समूह III परॉक्सीडेज बहुजीनी पादप-विशिष्ट परॉक्सीडेज एंजाइम हैं। यह विभिन्न कार्यिकी एवं विकास की गतिविधियों जैसे कोशिका वृद्धि, ऑक्सिन अपचय, कोशिका उपापचय, विभिन्न जैविक, अजैविक तनावों एवं लिग्नीकरण आदि में भाग लेते हैं। वर्तमान अध्ययन में धान के एक समूह III परोक्सीडेज को पहचाना गया है (*OsPRX38*) जो आर्सेनिक तनाव के दौरान अपनी अभिव्यक्ति को काफी बढ़ा देते हैं। *एरॉबिडोप्सिस थैलियाना* में *OsPRX38* की अधिक अभिव्यक्ति से आर्सेनिक सहिष्णुता में स्पष्ट वृद्धि होती है। *OsPRX38* की अधिक अभिव्यक्ति से पारजीनी पौधों में कुल जैव भार एवं बीज उत्पादन वृद्धि के माध्यम से पादप वृद्धि पर भी प्रभाव देखा गया है। पारजीनी पौधों में आर्सेनिक संग्रहण भी कम देखा गया। इसके अतिरिक्त, पारजीनी पौधों में कोशिका भित्ति संबंधित परॉक्सीडेज में वृद्धि के साथ लिग्नीकरण में भी धनात्मक संबंध देखे गए। अतः पारजीनी पौधों में कम आर्सेनिक संग्रहण का संभावित कारण जड़ कोशिकाओं में लिग्निन का एकत्र होना हो सकता है। कुल मिलाकर यह अध्ययन यह संकेत देता है कि आर्सेनिक तनाव की स्थिति में *एरॉबिडोप्सिस थैलियाना* में *OsPRX38* की अधिक अभिव्यक्ति विभिन्न एंटीऑक्सीडेंट एंजाइम तंत्रों के सिग्नल तंत्र को सक्रिय कर देती है, जिससे अधिक लिग्नीकरण के चलते कम आर्सेनिक संग्रहण होता है एवं पौधे की सहिष्णुता बढ़ती है।

एसएनपी मार्करों के प्रयोग से ग्वार (*सायमोप्सिस टेट्रागोनोलोबा*) की आणुविक आनुवंशिकी

ग्वार के कुल 285 नमूनों की 16 मात्रात्मक लक्षणों के लिए जांच की गई, जिनमें 50% पुष्पन की अवधि, पौधों की ऊंचाई, विकसित होने में लगा समय, शाखाएँ प्रति पौधा, फल युक्त शाखाएँ प्रति पौधा, फल वाले नोडों की संख्या प्रति तना, फलियाँ प्रति समूह, फलियों की संख्या प्रति पौधा, कुल फल उपज प्रति पौधा (ग्रा), फली की लंबाई (मिमी), फली की चौड़ाई (मिमी), कुल बीज प्रति फली, बीज भार प्रति 1000 बीज (ग्रा), बीज उपज प्रति पौधा (ग्रा), एवं प्रोटीन मात्रा (%) शामिल हैं। प्राथमिक आंकड़ों से जांच किए गए नमूनों में विभिन्न लक्षणों में स्पष्ट विभिन्नता पाई गई। इसके अतिरिक्त ग्वार में SNP की खोज हेतु 220 नमूनों से जीनोमिक डीएनए को ddRAD लाइब्रेरी बनाने के लिए प्रयुक्त किया गया एवं इलुमिना प्लेटफॉर्म पर सीक्वेंस किया गया। कुल 220 नमूनों में मुख्य एलील बारंबारता <0.05 के साथ कुल 43052 SNP को पहचाना गया।

अलसी (*लाईनम यूसीटैटीसिमम*) में आल्टर्नेरिया ब्लाइट प्रतिरोधी लोसाई की टैगिंग एवं मार्कर द्वारा सहायता प्राप्त बैक क्रॉसिंग

अलसी में लिंकेज आंकलन एवं मैपिंग हेतु पैरेंटल लाइनों जेआरएफ-4 एवं चंबल में से कुल 2001 SSR की छंटनी की गई। इन 2001 मार्करों में से 191 पॉलीमोर्फिक एसएसआर को लिंकेज मैप बनाने एवं आल्टर्नेरिया ब्लाइट एवं अन्य सस्य विज्ञान लक्षणों हेतु क्यूटीएल की पहचान हेतु प्रयोग किया गया। कुल 10 क्यूटीएल को पहचाना गयाः कैप्सूल प्रति पौधा हेतु 4 QTL तथा कैप्सूल भार प्रति पौधा, बीज भार प्रति पौधा एवं आल्टर्नेरिया ब्लाईट प्रतिरोध, प्रत्येक हेतु 2 QTL, LG14 एवं LG9 पर 3 QTL पाए गए, LG9 पर 2 QTL एवं LG 6 एवं LG 2 दोनों पर एक QTL। फीनोटिपिक परिवर्तनशीलता प्रतिशत 1.0 से 10.5 देखी गई।

ट्रांसजेनिक्स एवं आधुनिक प्रजनन तरीकों से पादप सुधार

अलसी में वसीय अम्ल प्रोफाइल को सुधारने के लिए प्रचलित किस्म "नीलम" को म्यूटाजेनेसिस के लिए प्रयोग किया गया। इस प्रयोग हेतु चयनित किस्म को 0.3, 0.5, 0.65 एवं 0.8% EMS से उपचारित किया गया। प्रत्येक उपचार के लगभग 500 बीजों को उत्परिवर्ती पौधे उगाने हेतु क्यारियों में बोया गया। कुल 523 M1 पौधे प्राप्त किए गए एवं बीजों को अगले सीजन में M2 पीढ़ी प्राप्त करने के लिए एकत्र किया गया। इसके अतिरिक्त 86 नमूनो में 10057 SNP एवं 10 मात्रात्मक लक्षणों का प्रयोग करते हुए 'एसोसिएशन मैपिंग' भी की गई। इस विश्लेषण से 7 लक्षणों से संबंधित SNP की पहचान की गई जिसमें से पूरे वर्ष एवं विभिन्न प्रयोगों में स्थायी रूप से 50% पुष्पन एवं बीज भार प्रति पौधे प्रत्येक के लिए 2 SNP, तथा शाखाएँ प्रति पौधा एवं तेल की मात्रा, प्रत्येक के लिए 1 SNP देखे गए। कैप्सूल भार प्रति पौधा एवं बीज भार प्रति पौधा दोनों के लिए एक ही SNP, LuP16861 को पहचाना गया।

नारकोटिक विभाग के माध्यम से समुचित कृषि हेतु थीबेन प्रचुर *ओपियम पॉपी* लाइनों का विकास

अफीम के लेटेक्स में पाए जाने वाले विभिन्न एल्कोलॉएड में से थीबेन एक ऐसा गैर-नारकोटिक एल्कोलॉएड है जिसे उद्योगों द्वारा अनेकों यौगिकों जैसे ऑक्सीकोडोन, नैलोक्सोन, बुप्रेनोर्फीन, ओक्सीमोर्फोन, नाल्बुफीन, नाल्ट्रेक्सोन, एवं ईटोर्फीन आदि जो कि फार्मास्यूटिकल औषधियों में काफी अधिक प्रयुक्त होते हैं, के लिए उपयोग किया जाता है। थीबेन प्रचुर किस्मों

के अभाव में भारत में थीबेन उत्पादन इसकी मांग को देखते हुए काफी कम है। वर्ष 2016-17 में मध्य प्रदेश एवं राजस्थान के विभिन्न कृषि-जलवायु क्षेत्रों में दो थीबेन प्रचुर लाइनों NBIHT-1 एवं NBIHT-3 की जांच की गई एवं बड़ी मात्रा में बीज उत्पादन किया गया। आकारकीय एवं अन्य लक्षणों के लिए 11 थीबेन प्रचुर लाइनों के पासपोर्ट डेटा को एकत्र किया गया एवं साथ ही थीबेन मात्रा को भी जांचा गया। थीबेन प्रचुर लाइन (NBIHT-3) के बीजों को आवश्यक दस्तावेजों के साथ NBPGR, नई दिल्ली में पंजीकरण हेतु जमा कराया गया। दो लाइनों NBIHT-1 एवं NBIHT-3 के बीज, उनके वाणिज्यिक उत्पादन हेतु संभावनाएं तलाशने हेतु नारकोटिक विभाग के अधिकार में हैं।

प्रमुख वसीय अम्लों के लिए आणुविक मार्करों की पहचान एवं MAS हेतु *ओपियम पॉपी* में नारकोटिक एवं पैपावरीन हेतु आणुविक मार्करों की पहचान एवं मान्यता

ओपियम पॉपी की 195 लाइनों का अभिलक्षणन किया गया एवं दो नारकोटिक प्रचुर लाइनों (BR 059 एवं BR 262) को पहचाना गया। एल्कोलॉयड विशेष मार्करों के विकास हेतु नारकोटिन एवं पैपावरीन की विरोधाभासी लाइनों को भी पहचाना गया।

कम उपयोग में आने वाली विंग्ड बीन (*सोफोकार्पस टेट्रागोनोलोबस*) में प्रोएंथोसायनिन के जैव-संश्लेषण के लिए जिम्मेदार जींस/ट्रांसक्रिप्शन कारकों का आणुविक अभिलक्षणन

मानव उपभोग की दृष्टि से *सोफोकार्पस टेट्रागोनोलोबस* के बीज कवच पर प्रोएंथोसायनिन का अत्यधिक जमाव एक बड़ी समस्या है। एक निश्चित मात्रा से अधिक मात्रा में टैनिन का जमाव बीज-प्रोटीन की गुणवत्ता को काफी कम कर देता है एवं मानव जैसे मोनोगैस्ट्रिक्स के पाचन तंत्र को प्रभावित करता है। संघनित टैनिन फ्लेवोन-3-ऑल इकाइयों के ओलिगोमर या पॉलीमर होते हैं।

औषधीय पौधों की क्रियात्मक जीनोमिक्सः औषधीय रूप से महत्वपूर्ण अणुओं के उन्नत संश्लेषण के लिए जटिल मार्गों की व्याख्या और दोहन

विथानिया सोम्नीफेरा से प्रमुख नियामक कदमों को उत्प्रेरित करने वाले जीनों के बारे में विस्तृत आणुविक जानकारी हासिल की गई है। टर्पेनोइड बैकबोन के जैव संश्लेषण के मध्यवर्ती चरणों के लिए जीन एन्कोडिंग एंजाइमों के पूर्ण-लंबाई के सीक्वेंसों और उनके पैरालॉग्स को जैव सूचना विज्ञान दृष्टिकोण का उपयोग करके उनके कार्यात्मक, संरचनात्मक गुणों और वंशावली हेतु पहचाना गया है। अभिव्यक्ति विश्लेषण से पता चलता है कि ये जीन अलग-अलग ऊतकों, कीमोटाइपों और सैलिसिलिक एसिड और मिथाइल जैस्मोनेट उपचारों के जवाब में भिन्न-भिन्न प्रकार से अभिव्यक्त किए जाते हैं।

हमारे पहले के अध्ययनों ने पौधे के विकास और फ्लैवोनॉयड जैवसंश्लेषण में miR858a की भागीदारी के संकेत दिये थे। miR858a के नियंत्रण को समझने के लिए हमने गहन अध्ययन किए और दिखाया कि *एराबिडॉप्सिस थैलियाना* का pri-miR858a एक छोटे पेप्टाइड (miPEP858a) को इनकोड करता है जो कि pri-miR858a की अभिव्यक्ति को नियंत्रित करता है जिससे फेनिलप्रोपनोइड मार्ग में शामिल लक्षित जीन की अभिव्यक्ति में मॉडुलन एवं साथ ही पौधे की वृद्धि और विकास होता है। miR858a गतिविधि पर miPEP858a के प्रभाव का अध्ययन करने के लिए हमने CRISPR/Cas9 सिस्टम का उपयोग करके miPEP858a के साथ-साथ miR858 परिवार के सदस्यों के नॉक-आउट म्यूटेंट विकसित किए हैं।

फ्लैवोनॉयड जैव संश्लेषण के नियामक पहलुओं से संबंधित हमारे अध्ययन, कम तापमान द्वारा बढ़ाए गए फ्लैवोनोल जैव संश्लेषण के लिए, प्रकाश की नितांत आवश्यकता का सुझाव देते हैं।

एराबिडॉप्सिस में जंगली प्रकार (WT) की तुलना में इलॉन्गेटेड हाइपोकॉटिल (hy5) और myb11myb111myb12 ट्रिपल म्यूटेंटों में जैव-संश्लेषित जीनों की निम्न तापमान-प्रेरित अभिव्यक्ति के साथ-साथ फ्लैवोनोल संचय में बाधा उत्पन्न हुई थी।

हमने एक मॉडल विकसित किया जो कम तापमान-प्रेरित फ्लैवोनोल संश्लेषण के लिए HY5 और फ्लैवोनोल-विशिष्ट MYB नियामक कारकों की आवश्यकता का सुझाव देता है।

अनुदान प्राप्त परियोजनाएं

तेल जैवसंश्लेषण पाथवे की पहचान एवं अभिलक्षणन

बीज विकास के दौरान तेल और वसा को ट्रायएसिलग्लिसरॉल के रूप में भ्रूणपोष में संग्रहित किया जाता है। संग्रह वसा जैव संश्लेषण में तीन एसिल ट्रान्स्फेरेसेज भाग लेते हैं एवं ग्लिसेरॉल मेरुदंड के चरणबद्ध एसिलेशन को उत्प्रेरित करते हैं। इस अध्ययन में जट्रोफा के बीजों में GPAT जीन परिवार के दो सदस्यों की पहचान की गयी। JcGPAT1 लवकों में जबकि JcGPAT2 अन्तः प्रद्रव्यी जालिका में पाए जाते हैं एवं बीज विकास की पूरी अवधि में अभिव्यक्त होते हैं। JcGPAT2-OE लाइन के पारजीनी बीजों में सामान्य बीजों की अपेक्षा 43-60% अधिक तेल संग्रहित हुआ जबकि लवकीय GPAT के अधिक अभिव्यक्ति वाले एरॉबिडोप्सिस लाइन के बीजों में तेल की मात्रा में केवल 13-20% की वृद्धि देखी गई।

सोलेनम वायरम में काँटों के बनने में भाग लेने वाले ट्रांसक्रिप्शन नियामकों की खोज

कांटे के विकास से जुड़े संभावित miRNA की पहचान करने के लिए कांटेदार और कांटारहित प्रभेदों की बाह्यत्वचीय परत के sRNA का अनुक्रमण किया गया। *सोलेनम वायरम* के mRNA अनुक्रमण द्वारा उत्पन्न ट्रांसक्रिप्ट डेटा का उपयोग करके miRNA लक्ष्यों का अनुमान लगाया गया।

सोलेनम वायरम में काँटों के विकास में SkMSM1 एवं SkR2R3-Myb315-जैसे ट्रांसक्रिप्शन नियामकों की नवीन भूमिका की खोज

जीन SkMSM1 एवं इसके प्रमोटर क्षेत्र की पूरी लंबाई की क्लोनिंग कर अभिव्यक्ति वेक्टर में अभिव्यक्त किया गया। SkR2R3-Myb315-जैसे ट्रांसक्रिप्शन नियामक की भी पूरी लंबाई की क्लोनिंग के प्रयास जारी हैं। दोनों ही जीनों के RNAi रचनाओं को बनाया जा चुका है।

जैविक इलिसीटर्स द्वारा *सोलेनम वायरम* के तने के संवर्धन में सोलसोडाइन की मात्रा में वृद्धि एवं सोलसोडाइन जैव संश्लेषण से संबंधित जीनों का अभिव्यक्ति आंकलन

सोलेनम वायरम के तने के संवर्धनों पर विभिन्न औषधीय पौधों की जड़ों के आस पास की मृदा से प्राप्त जैव इलिसीटर्स की विभिन्न मात्राओं का प्रयोग किया गया। प्रयोग किए गए छः भिन्न इलिसीटर्स में से दो इलिसीटर्स को *सोलेनम वायरम* के संवर्धनों में वृद्धि प्राप्त करने के लिए पहचाना गया।

सोलेनम वायेरम का कांटा मुक्त उत्परिवर्ती

सोलेनम वायेरम (ट्रॉपिकल सोडा एपल) एक औषधीय पौधा है जिसमें औषधीय रूप से महत्वपूर्ण स्टेरॉयडल एल्कोलॉयड की उच्च मात्रा पाई जाती है। संस्थान ने इस पौधे के एक कांटारहित उत्परिवर्ती प्रभेद की पहचान की है जिसका नाम 'निष्कंटक' रखा गया है।

सोलेनम वायेरम के काँटेदार एवं कांटारहित दोनों ही जर्मप्लाज्म को *इन-विट्रो* स्थितियों में तने के संवर्धनों एवं जड़ संवर्धनों के रूप में संरक्षित किया गया है। काँटा रहित पौधे सामान्य फील्ड परिस्थितियों में 35 वर्षों से स्थायी प्रदर्शन कर रहे हैं।

काँटों का विकास पर्यावरण से प्रभावित होता है। जैसा कि *सोलेनम वायेरम* मे देखा गया कि, काँटों का विकास गर्मियों की अपेक्षा सर्दियों में अधिक होता है। काँटा रहित उत्परिवर्ती 'निष्कंटक' में तने पर पूरे वर्ष कांटे नहीं पाये गए किन्तु सर्दियों में पत्तियों पर 2-4 कांटे पाए गए। बोए जाने के समय में हेर-फेर कर के यह संभव है कि फसल मई माह में तैयार हो जब सर्दियों की पत्तियाँ गिर चुकी हों एवं बिना कांटे वाली नई पत्तियाँ निकाल आई हों। काँटा रहित प्रभेदों के विकास से पौधों की सघन बुआई, पकने के बाद कटाई एवं इस प्रकार अधिक उपज प्राप्त करने में आने वाली समस्याओं का समाधान संभव है। काँटा युक्त प्रभेद में फल उपज 1.29 टन प्रति हेक्टेयर एवं कांटा रहित उत्परिवर्ती में फल उपज 1.57 टन प्रति हेक्टेयर पाई गई।

काँटेदार एवं कांटारहित प्रभेदों में आनुवंशिक संबंध हेतु SNP आंकलन

काँटेदार एवं कांटारहित प्रभेदों में आनुवंशिक संबंध हेतु SNP आंकलन किया गया। इस आंकलन से यह पता चला कि दोनों ही प्रभेद मात्र सूक्ष्म अंतर के साथ आनुवंशिक रूप से आपस में संबंधित हैं।

क्यारियों में एवं *इन-विट्रो* परिस्थियों में उगाए गए *सोलेनम वायेरम* के काँटेदार एवं कांटारहित पौधों के कृषि लक्षणों का प्रारूपी आंकलन एवं एल्कोलोएड रूप रेखा

इन-विट्रो परिस्थितियों में स्थापित संवर्धनों में वृद्धि एवं एल्केलॉयड जैव संश्लेषण उत्पादन गतिकी का HPLC विश्लेषण किया गया। *सोलेनम वायेरम* के दो महत्वपूर्ण कांटेदार एवं कांटारहित प्रभेदों में सोलासोडाइन, सोलानिडाइन एवं एल्फा-सोलानिन मात्राओं के तुलनात्मक विश्लेषण हेतु HPLC विश्लेषण के लिए विभिन्न ऊतकों का रासायनिक निष्कर्षण किया गया।

टमाटर में *SIERF6* एवं *SIERF8* का लक्षित हेरफेरः फल पकने एवं उपज में इनकी भूमिका

तंबाकू में इसके पूर्व के अध्ययनों में यह देखा गया कि SlERF6 की अधिक अभिव्यक्ति विभिन्न प्रक्रमों में अनेकों ABA प्रतिक्रियाओं का मंदन करती है। टमाटर में CaMV35S प्रमोटर के अंतर्गत *SIERF6* की अधिक अभिव्यक्ति एवं मंदित लाइनों का विकास किया गया एवं इन निष्कर्षों को सुनिश्चित किया गया। *SIERF6* की मंदित अभिव्यक्ति वाली पारजीनी टमाटर लाइनों में विलंबित बीज अंकुरण जबकि अधिक अभिव्यक्ति वाली लाइनों में बीज अंकुरण शीघ्र देखने को मिला।

SIERF6 हेराफेरी के प्रभाव मात्र बीज अंकुरण तक ही सीमित नहीं रहे बल्कि बाद की अवस्थाओं में वृद्धि पर भी देखने को मिले। इन्होने पत्तियों की आयु एवं रंध्रों के खुलने एवं बंद होने को भी प्रभावित किया। इस प्रकार *SIERF6,* टमाटर में विभिन्न ऊतकों एवं प्रक्रियाओं में ABA प्रतिक्रियाओं को ऋणात्मक रूप से नियंत्रित करता है। इस अध्ययन से संकेत मिलते हैं कि *SIERF6* बीज अंकुरण एवं पादप वृद्धि को ABA स्तरों एवं प्रतिक्रियाओं के माध्यम से नियंत्रित करता है।

एरॉबिडोप्सिस थैलियाना की जड़ों के विकास में कैल्मोडुलिन-बाइंडिंग ट्रांसक्रिप्शन एक्टीवेटर 5 संबंधित कैल्शियम आयात

एराबिडोप्सिस थैलियाना की जड़ों के विकास में कैल्मोडुलिन-बाइंडिंग ट्रांसक्रिप्शन एक्टीवेटर 5 (CAMTA5) की भूमिका को पहचाना गया। एराबिडोप्सिस थैलियाना के अन्य ऊतकों की तुलना में जड़ ऊतकों में CAMTA5 की सापेक्षिक अभिव्यक्ति अधिक पाई गयी। दो स्वतंत्र T-डीएनए प्रविष्टि CAMTA5 उत्परिवर्तियों में प्राथमिक एवं पार्श्व जड़ों का अकस्मात विकास प्रदर्शित हुआ जो जड़ों के स्थापत्य में CAMTA5 की संभावित भूमिका की ओर संकेत करते हैं।

गॉसीपियम प्रजातियों में कैल्मोडुलिन-बाइंडिंग ट्रांसक्रिप्शन एक्टीवेटर 5 (CAMTA5) का जीनोम व्यापी तुलनात्मक एवं विकासात्मक विश्लेषण

कपास में कैल्मोडुलिन-बाइंडिंग ट्रांसक्रिप्शन एक्टीवेटर (CAMTA) वंश की संभावित भूमिका एवं उद्विकासी लक्षणों की एकीकृत जानकारी प्राप्त करने के लिए इस वंश का *गॉसीपियम आर्बोरियम, गॉसीपियम रैमोंडाइ* एवं *गॉसीपियम हिर्सुटम* में अभिलक्षणन किया गया। CAMTA वंश के जीनों के लिए A-जीनोम (*गॉसीपियम आर्बोरियम*), D-जीनोम (*गॉसीपियम रैमोंडाइ*), एवं AD-जीनोम (*गॉसीपियम हिर्सुटम*) की जीनोम व्यापी जांच से क्रमशः 6, 7 एवं 9 CAMTA जीनों की पहचान की गई। इन नतीजों से यह पता चला कि सभी CAMTA जीन केंद्रक में सीमित थे एवं कैल्मोडुलिन-बाइंडिंग डोमेन (CaMBD) युक्त थे।

कपास के CAMTA जीनों की उद्विकासी उत्पत्ति एवं वंशावली को समझने के लिए, सर्व सुलभ जीनोम सीक्वेंसों से विभिन्न पादप प्रजातियों के CAMTA प्रोटीन सीक्वेंसों को निष्कर्षित किया गया। पौधों के CAMTA को पाँच मुख्य समूहों (I to V) में समूहबद्ध देखा गया जबकि कपास के CAMTA प्रोटीनों को चार समूहों में पाया गया। समूह II के CAMTA पर अधिक उद्विकासी तनाव पाया गया जिसके कारण द्विगुणित कपास का अधिक तेजी से विकास हुआ।

वर्तमान अध्ययन में कपास के CAMTA की संभावित भूमिका एवं क्रिया को पुनः स्थापित करने हेतु रेशों के विकास की विभिन्न अवस्थाओं में विभिन्न CAMTA का *गॉसीपियम हिर्सुटम* के माइक्रोएरे डेटा में अभिव्यक्ति का विश्लेषण किया गया। यह देखा गया कि कपास के रेशों के विकास की विभिन्न अवस्थाओं में GhCAMTA2A.2 एवं GhCAMTA7A अच्छी तरह अभिव्यक्त होते हैं।

गॉसीपियम हिर्सुटम में H3K9 डीएसीटीलेशन एवं रेशों के विकास के आरंभ में GhHDA5 की भूमिका

GhHDA5 एक समूह II हिस्टोन डीएसीटीलेस है जो रेशों के विकास के आरंभ के समय स्पष्ट रूप से अभिव्यक्त होता है। GhHDA5 की भूमिका का आंकलन करने के लिए कपास की RNAi पारजीनी लाइनें विकसित की गईं। ऐसी तीन लाइनों ने छोटा बॉल आकार, नीचा बॉल एवं कम बीज संख्या प्रदर्शित की, साथ ही ODPA अंडाणुओं में रेशों के विकास का अधिक्रमण प्रदर्शित किया जिसके कारण कपास की कुल उपज में कमी आई। साथ ही वंशावली अध्ययनों में *GhHDA5* RNAi लाइनों में छोटे रेशों युक्त बड़े बीज भी देखे गए। विस्तृत आणुविक एवं जीनोमिक अध्ययनों से संकेत मिले कि GhHDA5 प्रमुखतः H3K9ac हिस्टोन के माड्यूलन माध्यम से क्रिया करता है जिससे रेशों के विकास से जुड़े अनेकों हार्मोनों, तनाव एवं विकास संबंधित जीनों की अभिव्यक्ति का नियंत्रण होता है। इस प्रकार कुल मिलकर यह देखा गया कि GhHDA5 रेशों के विकास की शुरूआत के लिए महत्वपूर्ण है।

ऊष्ण आघात प्रोटीनों HSP90 एवं HSP70 के दमन से ऑक्सीडेटिव तनाव प्रेरण एवं कपास के रेशों के विकास का दमन

विभिन्न विकास अवस्थाओं में ऊष्ण आघात प्रोटीनों की भूमिका देखी गई। वर्तमान कार्य में रेशों के विकास पर प्रभाव देखने हेतु ऊतक संवर्धन में HSP90 एवं HSP70 के दमन के प्रभाव का आंकलन किया गया जिसके लिए HSP90 एवं HSP70 समूह की प्रोटीनों का दमन करने वाले ज्ञात अवरोधकों नोवोबायोसिन एवं पिफीथ्रिन से अंडाणुओं को उपचारित किया गया। इस उपचार से कम मात्रा में रेशों का विकास आरंभ हुआ एवं रेशों की लंबाई में भी कमी देखी गई। नतीजों से रेशों के विकास एवं लंबे होने की प्रक्रिया के दौरान HSP70 एवं HSP90 की महत्वपूर्ण भूमिका इंगित हुई।

एरॉबिडोप्सिस थैलियाना में ग्लोबल न्यूक्लियोसोमल रीमॉडलिंग में NPR1 की भूमिका

NPR1 एक ट्रांसक्रिप्शन सह-उत्प्रेरक एवं सिस्टेमिक एक्वायर्ड रेसिस्टेंस पाथवे का केंद्रीय नियंत्रक है। यह अनेकों रोगजनन संबंधी जीनों को नियंत्रित करता है। इसमें उत्परिवर्तन के चलते रोगजनक संक्रमण के प्रति संवेदनशीलता बढ़ जाती है। इस अध्ययन का उद्देश्य न्यूक्लियोसोमल रीमॉडलिंग में NPR1 की भूमिका को पहचानना है। इसके लिए *एरॉबिडोप्सिस थैलियाना* न्यूक्लियोसोमल पोजीशनिंग एवं जीन अभिव्यक्ति में मॉडुलन को जानने के लिए MNase-seq एवं ट्रांसक्रिप्टोमिक सीक्वेंसिंग की गई। पुनर्निर्मित न्यूक्लियोसोमों को तीन समूहों में बांटा गया : दखल परिवर्तन, स्थिति परिवर्तन एवं अस्पष्ट परिवर्तन।

पादप सूक्ष्म-जीव संबंध, भेषज विज्ञान एवं पादप रसायन

पादप सूक्ष्म-जीव संबंध

घरेलू परियोजनाएं

पादप आणुविक विषाणु विज्ञान अध्ययन

एजेरेटम इनेशन विषाणु के संक्रमण के कारण *पैपावर सोम्नीफेरम* में योजनाबद्ध कोशिका मृत्यु का प्रेरण एवं मेटाबोलाइटों के जैव संश्लेषण में बदलाव

एक अज्ञात बीमारी, जो नर्सों के गंभीर रूप से मोटे होने और पत्तियों के अंदर की ओर मुड़ने का कारण बनती है, कई अफीम (*पैपावर सोम्नीफेरम*) के पौधों में देखी गई। विषाणु के जीनोम की संपूर्ण लंबाई और संबंधित बीटासैटेलाईट के अनुक्रम विश्लेषण से क्रमशः एजेरेटम ईनेशन वायरस (एईवी) और एजेरेटम लीफ कर्ल बीटासैटैलाइट (एएलसीबी) की उपस्थिति की जानकारी प्राप्त हुई। विषाणु-संक्रमण ने कई महत्वपूर्ण मेटाबोलाइट्स के जैव-संश्लेषण को बदल दिया।

अध्ययन से पता चला है कि एईवी संक्रमण मेटाबोलाइट मात्रा में कमी का कारण बनता है जैसा कि जीसीएमएस और एचपीएलसी विश्लेषण द्वारा देखा गया, जिसके परिणामस्वरूप फसल के वाणिज्यिक मूल्य में कमी आती है।

भारत में नार्सीसस टजेट्टा से अलग किए गए *सिरटैनथुसेलेटस* विषाणु-ए के जीनोम की पूर्ण लंबाई का अनुक्रमण

नार्सीसस टजेट्टा एक सजावटी पौधा है जो इसके सुगंधित फूलों के लिए लोकप्रिय है, जो इसे आर्थिक रूप से महत्वपूर्ण पौधा बनाते हैं। *नार्सीसस* कवक, जीवाणुओं, कृमियों और विषाणुओं से पैदा होने वाली कई बीमारियों के लिए अतिसंवेदनशील पाया गया है। भारत से पहली बार *नार्सीसस टजेट्टा* की किस्म 'पेपर व्हाइट' की 'लीफ क्लोरोटिक स्ट्राइप' बीमारी से संबंधित एक पॉटीवाइरस, सिरटैनथुसेलेटस विषाणु-ए (CEVA-NBRI 16) को आंशिक कोट प्रोटीन जीन अनुक्रम के आधार पर अलग किया गया। इसके पूर्ण लंबाई के जीनोम अनुक्रमण को भारत द्वारा पहली बार सूचित किया गया।

पौधों में जैविक एवं अजैविक तनावों से निपटने के लिए सूक्ष्मजैविक उपाय

आर्सेनिक और फॉस्फेट तनाव की परिस्थितियों में पौधों की वृद्धिदर बढ़ाने के लिए पादप वृद्धि प्रेरक राइजोबैक्टीरिया और *क्लोरेल्ला वल्गेरिस* की सहक्रियात्मक गतिविधि का अध्ययन

आर्सेनिक एवं फॉस्फेट की अधिकता की परिस्थितियों में उगाए गए चावल के पौधों पर सूक्ष्मशैवाल *क्लोरेल्ला वल्गेरिस* और पादप वृद्धि प्रेरक राइजोबैक्टीरिया *स्यूडोमोनास प्युटिडा* की संभावित भूमिका को स्पष्ट करने के लिए अध्ययन किया गया। यह देखा गया कि आर्सेनिक और आर्सेनिक के साथ-साथ फॉस्फेट तनाव, दोनों ही स्थितियों में *स्यूडोमोनास प्युटिडा* और *क्लोरेल्ला वल्गेरिस* की सहक्रियात्मक गतिविधि पौधों की वृद्धि में बढ़ोत्तरी को प्रेरित करती हैं। *स्यूडोमोनास प्युटिडा* और *क्लोरेल्ला वल्गेरिस* की सहक्रिया ने पौधे के विषहरण तंत्र में सुधार के माध्यम से पौधों में आर्सेनिक संग्रहण को कम भी किया। इस सहक्रियात्मक संयोजन ने चावल के पौधों में फॉस्फेटःआर्सेनिक एवं आर्सेनिकः जैवभार अनुपात को व्यवस्थित करते हुए आर्सेनिक संग्रहण को कम करने के लिए फॉस्फेट आवागमन को भी व्यवस्थित किया।

चावल में अजैविक तनाव सहिष्णुता और पादप-हार्मोन प्रतिक्रिया में *बैसिलस एमाइलोलिक्विफेशिएन्स* की भूमिका को समझना

धान की एक प्रचलित किस्म सरयू-52 पर विभिन्न अजैविक तनावों (जैसे कि लवणता, सूखा, गर्मी, ठंड, एवं ठंड से जमाव) में सुधार में *बैसिलस एमाइलोलिक्विफेशिएन्स* एसएन 13 के पादप वृद्धि प्रेरक उपभेदों की भूमिका की जांच की गई। विभिन्न अजैविक तनावों के अंतर्गत, एसएन 13 इनोक्यूलेशन के साथ और उसके बिना हाइड्रोपोनिक स्थितियों में अध्ययन किए गए और क्रमशः 1, 3, 10 तथा 24 घंटों की अवधि पर पादप-हार्मोन जैसे कि एबसिसिक अम्ल, सैलीसिलिक अम्ल, जैस्मोनिक अम्ल एवं एथेफोन की बाह्य आपूर्ति की गई।

अजैविक तनावों एवं पादप-हार्मोनों के प्रति चावल के अंकुरों की विभिन्न प्रतिक्रियाओं के आधार पर किए गए विश्लेषण ने विभिन्न अजैविक तनावों एवं पादप-हार्मोनों के उपचारों के प्रति चावल की प्रतिक्रिया पर एसएन 13 इनोक्यूलेशन के प्रभावों पर समग्र दृष्टिकोण की पुष्टि की जिसके आधार पर क्रॉस-टॉक के लिए एक मॉडल भी बनाया गया।

सूक्ष्मजैविक हस्तक्षेप द्वारा मिट्टी की उत्पादकता में सुधार के लिए चावल की भूसी के अवशेषों की उपलब्धता और मिट्टी में प्रयोग करने की क्षमता का आंकलन

लगातार एवं लंबे समय तक खेती, मृदा कार्बनिक कार्बन (एसओसी) को कम कर देती है जिससे मृदा बांझपन और भूमि की गुणवत्ता में गिरावट की समस्या उत्पन्न होती है। एसओसी को बहाल करने के लिए, कार्बनिक संशोधन के नवीकरणीय स्रोतों की आवश्यकता है।

हमने एसओसी बहाल करने और टिकाऊ कृषि के लिए पारिस्थितिक तंत्र सेवाओं को बढ़ावा देने हेतु मिट्टी के पुनर्नवीनीकरण और पोषक तत्व बहाली हेतु अतिरिक्त फसल अवशेष (सीआर) की संभावनाओं का आंकलन किया।

अध्ययन से पता चला कि चावल के भूसे के अवशेष का उपयोग मिट्टी के कार्बनिक कार्बन को पुनः प्राप्त करने में सहायक होगा और मिट्टी की उर्वरता में सुधार के लिए पोटेशियम और फास्फोरस जैसे पोषक तत्वों की आवश्यकता को आंशिक रूप से पूरा कर सकता है।

आल्टर्नेरिया आल्टर्नेटा तनाव के अंतर्गत *विथानिया सोम्नीफेरा* में रक्षा-उत्तरदायी जीन और प्रतिरोध की अन्तःपादपीय जीवों की मध्यस्थता द्वारा मॉडुलन

पौधे के स्वास्थ्य में एक महत्वपूर्ण भूमिका निभाने के लिए अन्तःपादपीय जीवों का पता लगाया जाता रहा है। हालांकि, पौधे के शारीरिक कार्य और रोग प्रबंधन पर उनके प्रभाव स्पष्ट नहीं हैं। एकल एवं विभिन्न मापदंडों

के संयोजन में अन्तः पादपीय जीवों की क्षमताओं एवं *विथानिया सोम्नीफेरा* में *आल्टर्नेरिया आल्टर्नेटा* के विरुद्ध रक्षा तंत्र का विश्लेषण करने के लिए अध्ययन किया गया। अन्तः पादपीय *बैसिलस एमाईलोलिक्वीफेसिएंस* और *स्यूडोमोनास फ्लोरोसेंस* के साथ व्यक्तिगत रूप से और संयोजन में बीज की प्राइमिंग ने विगर सूचकांक एवं अंकुरण दर में वृद्धि का प्रदर्शन किया।

कुल मिलाकर यह अध्ययन अन्तःपादप-*आल्टर्नेरिया आल्टर्नेटा*-*विथानिया सोम्नीफेरा* के त्रिपक्षीय संबंधों में अंतर्निहित तंत्र के विषय में नवीन जानकारी प्रदान करता है एवं रोगजनक तनाव के अंतर्गत पौधे के स्वास्थ्य को बढ़ावा देने की उनकी क्षमता को रेखांकित करता है।

अन्तः पादपीय (एंडोफाईट्स) जीवाणुओं द्वारा जैविक तनाव के तहत *विथानिया सोम्नीफेरा* में विथैनोलॉइड जैव-संश्लेषण पाथवे और शारीरिक प्रदर्शन को व्यवस्थित करना

विभिन्न फसलों में वृद्धि को बढ़ाने के लिए अन्तः पादपीय (एंडोफाईट्स) सूक्ष्म जीवों की निरंतर खोज के बावजूद, चिकित्सीय रूप से महत्वपूर्ण द्वितीयक मेटाबोलाइट्स के उत्पादन पर उनके प्रभाव के बारे में जानकारी दुर्लभ है। वर्तमान अध्ययन में, काईटिनोलाइटिक बैक्टीरियल एंडोफाईट्स को चयनित औषधीय पौधों से पृथक किया गया और उनकी माईकोलेटिक क्षमताओं के साथ-साथ पौधों की वृद्धि को संभावित रूप से बढ़ावा देने की क्षमताओं का मूल्यांकन किया गया। उनमें से दो सबसे कुशल जीवाणुरोधी एंडोफाइट्स अर्थात् *बैसिलस एमाईलोलिक्वीफेशिएन्स* (एमपीई 20) और *स्यूडोमोनास फ्लोरोसेंस* (एमपीई 115) व्यक्तिगत रूप से एवं साथ ही साथ संयोजन में *विथानिया सोम्नीफेरा* में *आल्टर्नेरिया आल्टर्नेटा* के खिलाफ सहिष्णुता एवं विथैनोलाइड जैवसंश्लेषण पाथवे को संशोधित करने में सक्षम पाए गए।

कुल मिलाकर, उपरोक्त खोज एंडोफाइट्स के उपयोग में अंतर्निहित तंत्र के संबंध में नवीन जानकारी को रेखांकित करती है और *आल्टर्नेरिया आल्टर्नेटा* के कारण उत्पन्न जैविक तनाव के तहत *विथानीया सोम्नीफेरा* में विथैनोलॉइड के जैवसंश्लेषण को तेज करने की उनकी क्षमता को प्रदर्शित करती है।

पादप-रोगजनक नैनोकण संबंध के दौरान पादप परिवहन के माध्यम से मृदा के देशज सूक्ष्मजीवों पर जैवसंश्लेषित चांदी के नैनोकणों का प्रभाव

इस अध्ययन में, *एराबिडॉप्सिस थैलियाना* और *आल्टर्नेरिया ब्रैसिसिकोला* की मॉडल रोगप्रणाली में पादप परिवहन के माध्यम से देशज मृदा के साथ जैवसंश्लेषित चांदी के नैनोकणों (बीएसएनपी) के संबंधों का मूल्यांकन किया गया। बीएसएनपी में मृदा के देशज सूक्ष्मजीवों को बदले बिना पौधे के रोग प्रबंधन के लिए मजबूत सूक्ष्मजीवरोधी एजेंट के रूप में कार्य करने की क्षमता है।

जैवसंश्लेषित स्वर्ण नैनोकणों द्वारा जीवाणु डीएनए परिवर्तन के लिए एक आसान तरीका ढूँढना

बैक्टीरिया के अनुवांशिक हेरफेर के दौरान सामने आने वाली एक बड़ी समस्या उनकी प्राकृतिक गैर-योग्यता के कारण परिवर्तित होने में असमर्थता है। इस अध्ययन में, इस समस्या को दूर करने के लिए, स्वर्ण नैनोकणों (जीएनपी) और योशीदा प्रभाव के गुणों को जोड़कर प्रभावी विधि विकसित की गई। जीएनपी, जीवाणुओं में बेहतर परिवर्तन के लिए एक वाहन के रूप में कुशलतापूर्वक उपयोग किये जा सकते हैं।

सोलेनम लाइकोपर्सिकम में 'अर्ली ब्लाइट' बीमारी के खिलाफ जैवसंश्लेषित चांदी के नैनोकणों की सुरक्षात्मक भूमिका

अर्ली ब्लाइट बीमारी के कारण हर साल टमाटर की फसल का भारी नुकसान होता है। यह अध्ययन *इन-विट्रो* और *इन-विवो* स्थितियों में टमाटर में 'अर्ली ब्लाइट' बीमारी के कारक *आल्टर्नेरिया सोलेनी* के प्रभावी अवरोध पर केंद्रित है। जैवसंश्लेषित चांदी के नैनोकणों में पादप रोग प्रबंधन में क्रांतिकारी बदलाव की संभावना है।

काबुली चने में पौष्टिकता और रक्षा गतिविधि को बढ़ाने के लिए एक नवीन ट्राइकोडर्मा प्रोटोप्लास्ट फ्यूसेंट

हाल के वर्षों में, खाद्य खपत में वृद्धि के कारण, ज़्यादातर ध्यान कृषि फसलों की उपज बढ़ाने पर केंद्रित किया गया है, जिसके परिणामस्वरूप पोषण की गुणवत्ता की अनदेखी हुई है। अमीनो एसिड और खनिज मात्रा को बढ़ाकर फलियों, अनाज और मुख्य खाद्य फसलों के पौष्टिक गुणों को बढ़ाने के लिए प्रयास किए जाने की आवश्यकता है। इस दिशा में, काबुली चने में पौष्टिकता और रक्षा गतिविधि को बढ़ाने की क्षमता हेतु एक प्रोटोप्लास्ट फ्यूसेंट (*हाईपोक्रिया लिक्सीआई* एमटीसीसी 5659) का मूल्यांकन किया।

अनुदान प्राप्त परियोजनाएं

आनुवांशिक विविधता के आंकलन एवं मार्करों के विकास हेतु पादप रोगजनक *एस्पर्जिलस* प्रजाति में माइक्रो सैटेलाईटों की तुलना

अधिकांश कवक जीनोम में माइक्रोसैटेलाइट्स (एसएसआर) की उपस्थिति देखी गई है, हालांकि इसकी प्रचुरता अलग-अलग प्रजातियों में भिन्न होती है। *एस्पर्जिलस* उपभेदों के पूरे जीनोम और प्रतिलेखों में माइक्रो सैटेलाइटों की आवृत्ति का विश्लेषण किया गया और दो पादप-रोगजनक उपभेदों (*ए. नाइजर* और *ए. टेरेयस*) और दो गैर-रोगजनक उपभेदों (*ए. निडुलांस* और *ए. ओराइजी*) के बीच तुलना की गई। इस जांच में पाए गए दस भिन्न/बहुरूपी मार्करों ने *एस्पर्जिलस* के विभिन्न निष्कर्षणों में आनुवंशिक विविधता के आंकलन के लिए हाल ही में तैयार किए गए एसएसआर मार्करों की उपयोगिता को प्रदर्शित किया।

उच्चीकृत CO_2 के प्रति पादप प्रतिक्रिया का अध्ययन एवं जड़-मृदा-सूक्ष्मजीव संबंधों में इसके निहितार्थ

जैव उर्वरक *टी. रीसियाई* MTCC5659 (BF) का धान की फसल पर प्रभाव का अध्ययन उच्चीकृत CO_2 परिस्थिति में किया गया। नतीजे बताते हैं कि जैव-उर्वरक उपचारित किस्म की उपज में परिवर्तन का प्रतिशत न्यूनतम था, जिसने CO_2 तनाव को कम करने में *ट्रायकोडर्मा* MTCC5659 की दक्षता का संकेत दिया।

अंकुरण और नन्हें अंकुरों की अवस्थाओं में बाजरा के जीनोटाइप की स्क्रीनिंग

विभिन्न कृषि संबंधी लक्षणों के लिए प्रारंभिक अंकुर अवस्थाओं में पीईजी प्रेरित ऑस्मोटिक तनाव के प्रभाव का विश्लेषण करने के लिए

बाजरे के छह जीनोटाईप क्रमशः PRLT2/89-33, H77/833-2, PPMI 69, PPMI 301, 863B-P2 एवं TT-1 को प्रारम्भिक एवं विलंबित अंकुर अवस्थाओं में ऑस्मोटिक तनाव के विभिन्न स्तर पर सूखा तनाव के अंतर्गत रखा गया। विभिन्न आकारिकीय, जैव रासायनिक और आणुविक मानकों के आधार पर इस अध्ययन ने PRLT 2 / 89-33 को सूखे के प्रति अधिक सहनशील होने का संकेत दिया, जबकि TT-1 और H 77/ 833-2 जीनोटाइप सूखे के प्रति संवेदनशील पाए गए।

काबुली चने में आरए-मेडिएटेड अजैविक तनाव सहिष्णुता में miRNA की भूमिका को समझने के लिए miRNA एवं उनके संबंधित लक्ष्य जीनों का अभिव्यक्ति आंकलन

काबुली चने में सूखे और लवण के तनाव की प्रतिक्रिया में miRNA और उनके लक्षित जीनों की अभिव्यक्ति को संशोधित करने में *स्यूडोमोनास पुटिडा* आरए की भूमिका का अध्ययन करने के लिए जांच की गई। नौ संरक्षित miRNA क्रमशः miR159, miR160, miR166, miR167, miR169, miR171, miR172, miR393 और miR396 की अभिव्यक्ति प्रोफाइल पर आरए-इनोक्यूलेशन के प्रभाव की जांच के लिए काबुली चने की एक सूखा सहिष्णु 'देसी' किस्म BG-362 का चयन किया गया। सभी चयनित संरक्षित miRNA एवं उनके लक्ष्यों ने काबुली चने में सूखे एवं लवण के तनावों के अंतर्गत भिन्नात्मक अभिव्यक्ति प्रदर्शित की एवं साथ ही तनाव प्रतिक्रिया के नियंत्रण में भी असर दिखाया। अध्ययन ने सामान्य अथवा RA इनोक्यूलेशन उपचारित, सूखा एवं लवण तनाव ग्रसित पौधों में कम से कम एक समय बिन्दु पर miR 159, miR160, miR166, miR167, miR169, miR171, miR172, miR393 और miR396 के अभिव्यक्ति पैटर्न में में महत्वपूर्ण परिवर्तन प्रदर्शित किए जिससे इनके काबुली चने में अजैविक तनाव उन्मूलन के लिए प्रमुख कारक होने के संकेत मिले।

काबुली चने में *फ़्यूसेरियम ऑक्सीस्पोरम* के संक्रमण के दौरान टायलोसिस बनने के लिए जिम्मेदार जीनों का वर्णन

काबुली चने में *फ़्यूसेरियम ऑक्सीस्पोरम* के संक्रमण के दौरान टायलोसिस बनने के लिए जिम्मेदार जीनों के वर्णन हेतु अध्ययन जारी हैं। काबुली चने की विषम विल्ट प्रतिरोधी किस्मों को उगाया गया एवं *फ़्यूसेरियम ऑक्सीस्पोरम* से संक्रमित किया गया। जाइलम कोशिकाओं से आरएनए को अलग करने के लिए काबुली चने की जड़ों की जाइलम मृदूतक कोशिकाओं से लेजर कैप्चर माइक्रो डिसेक्शन (LCM) द्वारा काट कर आरएनए प्राप्त किया गया।

बकोपा मोनेरी से बकोसाइड उत्पादन में भाग लेने वाले एंडोफिटिक कवक का विश्लेषण

औषधीय रूप से महत्वपूर्ण बकोसाइड के उत्पादन में सक्षम एंडोफिटिक कवक उपभेदों को अलग करने और पहचानने के लिए अध्ययन किए गए। *बकोपा मोनेरी* की पत्तियों से सैपोनिन उत्पादन करने वाले एंडोफेटिक कवक उपभेदों को अलग किया गया। कवक से अर्क तैयार किए गए और एचपीएलसी का उपयोग करके बकोसाइड्स और विथैनोलॉइड के उत्पादन के लिए विश्लेषण किया गया। यह एंडोफाइट्स के माध्यम से बकोसाइड्स और विथैनोलॉइड के उत्पादन की पहली सूचना है।

पादप-रसायन विज्ञान

घरेलू परियोजनाएं

डायोस्पाईरोस कॉर्डीफोलिया का जैव-पूर्वेक्षण

डायोस्पाईरोस कॉर्डीफोलिया की पत्तियों में आवश्यक तेल

डायोस्पाईरोस कॉर्डीफोलिया की पत्तियों में आवश्यक तेलों की मात्रा के लिए जांच की गई। आवश्यक तेल की औसत मात्रा 0.05 ± 0.2% पाई गई। नौ यौगिकों, जो तेल के 71.28% का प्रतिनिधित्व करते थे, को मात्राबद्ध किया गया। यौगिकों के मुख्य वर्ग थे, टर्पेनोइड्स, डाइटर्पीन और वसीय अम्ल। आवश्यक तेल में प्रमुख यौगिक हेक्साहाइड्रोफार्नेसिल एसीटोन (30.58%) पाया गया जिसे स्वाद और सुगंध के लिए उपयोग किया जाता है। एक और प्रमुख यौगिक फाइटोल एसीटेट (8.41%) को खाद्य योजक के रूप में प्रयोग किया जाता है। आइसोप्रोपाइल मिरिस्टेट को प्रसाधन और त्वचा हेतु औषधीय सामग्री में प्रयोग किया जाता है जहां त्वचा में अच्छा अवशोषण वांछित हो।

UPLC-ESI-QTOF/MS द्वारा *डायोस्पाईरोस कोर्डीफोलिया* से जैव-अणुओं की पहचान

UPLC-ESI-QTOF/MS में आठ यौगिकों अर्थात् आइसोरेंनेटिन, माइरेसेटिन, 3,5-ओ-साइक्लोडाइस्पिरिन, क्रोमेनोन एस्टर, क्रोमेनोन अम्ल, कैम्पेफेरोल ग्लूकोसाइड, एपीकैटेकिन और 1-हेक्साकोसैनोल का पता लगाया गया था। यौगिकों के आणुविक द्रव्यमान को उनके सकारात्मक और नकारात्मक 'आयन इलेक्ट्रोस्प्रे द्रव्यमान स्पेक्ट्रा' (ईएसआई-एमएस) से प्राप्त किया गया, जिसने प्रोटोनेटेड और डिप्रोटोनेटेड स्यूडोमोल्यूलर आयनों का वर्णन किया गया।

पुनिका ग्रेनेटम की दीमक-रोधी क्रिया

पादप अर्कों के जैव-सक्रिय यौगिक, फसलों के कीट/पीड़क नियंत्रण समस्या का प्राकृतिक जैव-अपघटनीय उपाय प्रदान कर सकते हैं एवं रासायनिक पीड़क/कीटनाशकों से संबन्धित समस्याओं को सुलझा सकते हैं। दीमक मृत्यु-दर के लिए दीमक की एक प्रजाति *माइक्रोसेरोटर्मस बीसोनी* के विरुद्ध विभिन्न ध्रुवीय अंशों (पोलरिटी फ्रैक्शन) का आंकलन किया गया। विभिन्न अंशों में एक आंशिक रूप से शोधित कॉलम अंश को स्पष्ट रूप से प्रभावी पाया गया।

जैव-पूर्वेक्षण हेतु *कमीफोरा एगालोचा* की पादप-रासायनिक जांच

कमीफोरा एगालोचा की इसके रासायनिक घटकों के लिए कोई व्यवस्थित रूप से जांच नहीं की गई है। मेटाबोलाइट प्रोफाइलिंग के परिणामस्वरूप *कमीफोरा एगालोचा* की पत्तियों, पतली शाखाओं एवं लेटेक्स में जर्माक्रोन को एक प्रमुख द्वितीयक मेटाबोलाइट के रूप में पहचाना गया। *कमीफोरा एगालोचा* को एक संभावित कैंसर-रोधी और विषाणु-रोधी एजेंट जर्माक्रोन के समृद्ध जैव-संसाधन के रूप में पहचाना गया। जर्माक्रोन को पृथक करके शुद्ध किया गया और इसकी संरचना एनएमआर-स्पेक्ट्रोस्कोपी द्वारा निर्धारित की गई। *कमीफोरा एगालोचा* के विभिन्न नमूनों में विश्लेषणात्मक एचपीएलसी का उपयोग करके जर्माक्रोन की मात्रा का गुणात्मक और मात्रात्मक अनुमान लगाया गया। *कमीफोरा एगालोचा* के विभिन्न नमूनों में जर्माक्रोन जर्ममाट्रोन मात्रा में काफी परिवर्तन

देखा गया। नियंत्रित पर्यावरण स्थितियों के तहत मैक्रो-प्रोपेगेशन तकनीक के माध्यम से उच्च जर्माक्रोन उत्पादक नमूनों की पहचान की गई और बढ़ोत्तरी की गई।

कुछ महत्वपूर्ण औषधीय, सगंध एवं सजावटी पौधों का पादप-रासायनिक अध्ययन

नवीन न्यूट्रास्यूटिकल, फार्मास्यूटिकल फॉर्मूलेशन और अन्य व्यावसायिक रूप से व्यवहार्य उत्पादों के विकास के लिए कुछ औषधीय, सगंध और सजावटी रूप से महत्वपूर्ण पौधों के निष्कर्षण और पादप-रासायनिक अध्ययन किए गए। एचपीएलसी, एचपीटीएलसी, एफटीआईआर, जीसी-एमएस, एलसी-एमएस और एनएमआर का उपयोग करके अर्क, बायोमार्कर्स और संभावित जैव-सक्रिय का अभिलक्षणन किया गया।

कैसिया फिस्टुला, कैसिया सियामिया, अकेसिया निलोटिका, ल्यूसिना ल्यूकोसेफैला, सेसबेनिया सेस्बान, सेसबेनिया ग्रैंडीफ्लोरा, ट्राइगोनेल्ला फेनम-ग्रैकम, सायमोप्सिस टेट्रागोनोलोबा, बिक्सा ओरेलाना, टैमेरेंडस इंडिका, स्टर्कुलिया यूरेंस, लेपीडियम सैटाइवम, रोसा इंडिका, टैगेटस इरेक्टा, बोगेनविलिया, थेवेटिया पेरुवियना एवं एरीथ्रिना प्रजाति में आर्थिक रूप से उपयोगी पादप-रसायनों, गोंद, रेजिन, प्राकृतिक संयोजकों, फॉर्मूलेशनों और जैव-अपघटनशील प्राकृतिक उत्पादों का अध्ययन किया गया।

कैसिया प्रजातियों जैसे *कै. सियामिया, कै. फिस्टुला, कै. जवानिका* और *कै. यूरेंस* की पत्तियों में एलो एमोडिन का मात्रा का निर्धारण किया गया। संदर्भ सामग्री हेतु एवं स्तन कैंसर कोशिका लाइनों पर कैंसर रोधी क्रिया के लिए उच्च पैदावार विशिष्ट विलायक अर्क और दो प्रमुख मार्कर एलो एमोडिन और सेनोसाइड्स, पहचान, अलगाव, शुद्धिकरण एवं वर्णन के दौर में हैं। जैविक गतिविधि के लिए मार्करों और जैव सक्रिय यौगिकों के अलगाव, शुद्धिकरण और वर्णन के लिए तीन शैक प्रजातियों का जैव-पूर्वेक्षण कार्य प्रगति पर है। मधुमेह रोधी गतिविधि के लिए दो शैक प्रजातियों के चार प्रमुख मार्करों का अभिलक्षणन किया जा चुका है।

अनुदान प्राप्त परियोजनाएं

यूपी की सोडिक अपशिष्ट भूमि में खेती के लिए औषधीय पौधों का मूल्यांकन

मिट्टी की विभिन्न स्थितियों अर्थात मिट्टी की सोडिकता और जैविक खाद के उपयोग का औषधीय पौधे *एंड्रोग्राफिस पैनिकुलेटा* के जैव-सक्रिय पादप घटकों की उपज और मात्रा पर प्रभाव का अध्ययन किया गया। औषधीय पौधों की खेती के लिए सोडिक अपशिष्ट भूमि की उपयोगिता का मूल्यांकन किया गया।

एंड्रोग्राफिस पैनिकुलेटा के तनों एवं पत्तियों में 12 जैव-सक्रिय यौगिकों के शीघ्र निर्धारण के लिए बहु-प्रतिक्रिया निरीक्षण मोड में एक अल्ट्रा परफोर्मेंस लिक्विड क्रोमैटोग्राफी-ट्रिपल क्वाड्रोपोल-लीनियर आयन मास स्पेक्ट्रोमेट्री विधि को विकसित किया गया। परिणामों ने *ए. पैनिकुलेटा* के डाइटर्पीनोइड्स, फ्लैवोनोइड्स, फिनोलिक्स और ट्राइटर्पीनोइड में महत्वपूर्ण मात्रात्मक मतभेद प्रदर्शित किए। 3.5% कार्बनिक खाद के साथ लवण युक्त चिकनी-लोम मिट्टी में उगाए *ए. पैनिकुलेटा* की पत्तियों में एंड्रोग्राफोलॉइड और नियोएंड्रोग्राफोलॉइड की उच्चतम मात्रा का पता चला।

भेषज विज्ञान

घरेलू परियोजनाएं

औषधीय अनुप्रयोग हेतु हर्बल उत्पादों का विकास

दो *एकाइरेन्थस* प्रजातियों के तुलनात्मक फार्माकोग्नोस्टिक और फार्माकोलॉजिकल मूल्यांकन

एकाइरेन्थस एक ज्ञात प्रसिद्ध जड़ी बूटी है जिसे परंपरागत चिकित्सा प्रणाली में चिकित्सकीय महत्व के लिए प्रयोग किया जाता है। काफी आपसी समानता की वजह से लोगों एवं हर्बल उद्योगों द्वारा दो प्रजातियों, *एकाइरेन्थस* अस्पेरा एवं *एकाइरेन्थस बाइडेंटेटा* का एक दूसरे की जगह प्रयोग किया जाता रहा है। वर्तमान अध्ययन, दोनों प्रजातियों के फार्माकोग्नोस्टिक और फार्माकोलॉजिकल गुणों का तुलनात्मक मूल्यांकन करने के लिए किया गया। यह अध्ययन कच्चे माल के गुणवत्ता नियंत्रण मानकों की उचित स्थापना के लिए आंकड़े उत्पन्न करता है।

सिक्किम हिमालय (भारत) से एकत्र *ग्लोरियोसा सुपरबा* के विशिष्ट कीमोटाइपों की पहचान के लिए हाई परफोर्मेंस थिन लेयर क्रोमैटोग्राफिक डेंसिटोमेट्रिक क्वांटीफिकेशन और जैवसक्रिय यौगिकों की पुनः प्राप्ति

ग्लोरियोसा सुपरबा को, उच्च कोल्चीसिन एल्कोलोइड के कारण इसकी संभावित एंटीमाईटोटिक गतिविधि के चलते, गठिया में सहायक उपचार के रूप में उपयोग किया जाता है। इस अध्ययन का लक्ष्य *ग्लोरियोसा सुपरबा* में जैवसक्रिय एल्कोलोइड (कोल्चीसिन और ग्लोरीयोसीन) के एक साथ मात्रात्मक विश्लेषण हेतु एक आसान, सस्ती और सटीक हाई परफोर्मेंस थिन लेयर क्रोमैटोग्राफिक (एचपीटीएलसी) प्रक्रिया का विकास करना एवं सिक्किम हिमालय (भारत) से *ग्लोरियोसा सुपरबा* के विशिष्ट कीमोटाइपों की पहचान करना था। विकसित विधि आईसीएच दिशानिर्देशों (2005) के अनुसार सटीकता, पुनः प्राप्ति और सटीक अध्ययन के संदर्भ में मान्य है और फाइटोफर्मास्यूटिकल्स में कोल्चीसिन और ग्लोरीयोसीन के एक साथ मात्रात्मक विश्लेषण के लिए अपनाया जा सकता है। इसके अलावा, यह अध्ययन व्यावसायिक और औषधीय उद्देश्यों के लिए मेटाबोलाइट मात्रा में कीमोटाइपिक परिवर्तनशीलता का पता लगाने के लिए प्रासंगिक है।

एकोरस कैलेमस का भेषज अध्ययन

एकोरस कैलेमस, जिसे आमतौर पर 'स्वीट फ्लैग' या 'वच' के नाम से जाना जाता है, एक प्रसिद्ध औषधीय पौधा है जिसके कंद और पत्तियां पारंपरिक दवाओं में उपयोग किए जाते हैं। कंद स्पंजी, पीला या भूरा अथवा कभी-कभी नारंगी-भूरे रंग का होता है। इसके भौतिक-रासायनिक मानकों का अध्ययन किया गया था जिसमें आवश्यक तेल असारोन लगभग 85% तक पाया गया।

'शंखपुष्पी' पौधों में फेनोलिक और टर्पेनोइड मार्करों के एक-साथ मात्रात्मक विश्लेषण के लिए एचपीटीएलसी डेंसिटोमेट्रिक विधि

'शंखपुष्पी' प्राचीन काल से ज्ञात, आयुर्वेदिक चिकित्सकों द्वारा निर्धारित एक तंत्रिका टॉनिक है, लेकिन दवा में मिलावट/प्रतिस्थापन की समस्या इसकी गुणवत्ता और प्रभाव को प्रभावित करता है। इस संबंध में एचपीटीएलसी डेंसिटोमेट्रिक विधि को 'शंखपुष्पी' पौधों (*कोनवोलवुलस*

प्ल्यूरीकालिस, क्लाइटोरिया टर्नेशिया, टेफ्रोसिया परप्यूरिया, एवोल्वुलस नुम्मूलेरियस एवं *एवोल्वुलस अल्सीनोइडिस*) में फेनोलिक और टर्पेनोइड मार्करों के एक साथ मात्रात्मक विश्लेषण के लिए विकसित किया गया। विकसित विधि बैच स्थिरता को बनाए रखने और फार्मास्यूटिकल इकाइयों में दवा के उत्पादन के दौरान कच्ची सामग्री में मिलावट/ प्रतिस्थापन की पहचानने में मदद करेगी।

हर्बल उत्पादों का विकास

यूरोलिथियासिस, नेफ्रोलिथियासिस और पोस्ट लिथोट्रिप्सी स्थितियों को सुधारने के लिए एक संभावित हर्बल संयोजन

यूरोलिथियासिस को सुधारने के लिए एक हर्बल फॉर्मूलेशन विकसित किया गया है। यह उत्पाद यूरोलिथियासिस और नेफ्रोलिथियासिस के खिलाफ मौजूदा उपलब्ध हर्बल ब्रांडों की तुलना में प्रभावशाली और लागत प्रभावी है।

नवीन हर्बल एकेरिसॉइड

मवेशियों में स्वास्थ्य खतरों से संबंधित समस्याओं को दूर करने की दिशा में मवेशी किलनियों को नियंत्रित करने के लिए आईसीएआर की एनएआईपी योजना के तहत आईसीएआर-भारतीय पशु चिकित्सा अनुसंधान संस्थान, इजतनगर-बरेली (यूपी) के साथ संयुक्त रूप से दो नवीन हर्बल एकेरिसॉइड विकसित किए गए।

अनुदान प्राप्त परियोजनाएं

पूर्वोत्तर राज्यों से दो एकेरिसॉइड उत्पादक पादप प्रजातियों के एकेरिसॉइड गुणों में अन्तःपादपीय जीवों की भूमिका पर अध्ययन

असम के छः क्षेत्रों से दो एकेरिसॉइड पौधों *अर्जीमोन मैक्सीकाना* एवं *दतूरा मेटेल* को राएजोस्फ़ेरिक मृदा के नमूने के साथ में एकत्र किया गया। छाया में सुखाए एवं चूर्ण बनाए गए पादप नमूनों के एथेनोल अर्कों का एकेरिसॉइड क्रिया हेतु *इन-विट्रो* एवं *इन-विवो* विश्लेषण किया गया।

चिन्हित किलनी रोधी पादप-रसायन का संरचनात्मक और कार्यात्मक विश्लेषण एवं एकेरिसॉइड प्रतिरोधी किलनियों के नियंत्रण के लिए प्राकृतिक फॉर्मूलेशन के प्रभावी अनुप्रयोग हेतु डिलीवरी मैट्रिक्स की पहचान

इस अध्ययन का उद्देश्य भारत के विभिन्न भौगोलिक क्षेत्रों से एकत्रित *एजेरेटम कोनीजोइड्स* और *ब्लूमिया लैसेरा* की पादप-रासायनिक भिन्नता और किलनी रोधी गतिविधि का पता लगाना था। एचपीटीएलसी का उपयोग करके पादप-रसायन मार्कर, रिकोसिन-1 और प्रेकोसीन-2 का गुणात्मक एवं मात्रात्मक अनुमान लगाया गया।

विभिन्न पादप-भौगोलिक क्षेत्रों से अनुकूलित *हेमीडेस्मस इंडिकस* और *कॉस्टस स्पेशीओसस* में जैव-सक्रिय मेटाबोलाइट्स की कीमोटाईपिंग और आण्विक प्रोफाइलिंग एवं उपापचय मार्ग से संबंधित जीन की पहचान

इस अध्ययन का उद्देश्य प्रमुख मेटाबोलाइट क्रमशः वैनिलीन और डायोसजेजेन की मात्रा के आधार पर भारत के विभिन्न पादप-भौगोलिक क्षेत्रों से *हेमीडेस्मस इंडिकस* और *कोस्टस स्पेशिओसस* के विशिष्ट कीमोटाइपों की पहचान करना था। विभिन्न क्षेत्रों से *कोस्टस स्पेशिओसस* के कुल 85 नमूने और *हेमीडेस्मस इंडिकस* के 52 नमूने एकत्र किए गए थे। एक ही पादप-भौगोलिक क्षेत्र के साथ-साथ विभिन्न क्षेत्रों के नमूनों में जर्मप्लाज्म के बीच एक महत्वपूर्ण रासायनिक भिन्नता देखी गई। *हेमीडेस्मस इंडिकस* में, जर्मप्लाज्म के बीच महत्वपूर्ण रासायनिक भिन्नता मिली और अधिकतम मात्रा एनबीएच-35 (गया, बिहार) में देखी गई। इसके अलावा दोनों प्रजातियों के बहुस्तरीय ट्रायल अध्ययन प्रगति पर हैं।

आइसोक्विनोलाइन एल्केलोइड के लिए चिकित्सीय रूप से महत्वपूर्ण जीन के लिए *बर्बेरिस* का उपापचय विश्लेषण

इस अध्ययन में *बर्बेरिस* के जैव संसाधनों की मैपिंग और भारत के विभिन्न पादप-भौगोलिक क्षेत्रों में अनुकूलित उसके मेटाबोलाइटों का विश्लेषण किया जा रहा है। पश्चिमी हिमालय से 668 से 8743 फीट की ऊंचाई के बीच से *बर्बरिस* के बीस नमूने एकत्र किए गए। इन प्रजातियों को *ब. लाइसियम, ब. एरिस्टेटा, ब. जाइस्चेकना* एवं *ब. जलाकोकार्पी* आदि के रूप मे पहचाना गया। मानकों के आधार पर विभिन्न भौतिक-रासायनिक मापदंडों जैसे निष्कर्षण मूल्य, कुल फेनोल की मात्रा, कुल फ्लेवोनोइड मात्रा, कुल टैनिन मात्रा, शर्करा, स्टार्च मात्रा आदि का आंकलन किया गया।

सेंटेल्ला एशियाटिका के विशेष कीमोटाइपों की खोज एवं पारिस्थितिक-भौगोलिकी से संबंध

भारत के विभिन्न पादप-भौगोलिक क्षेत्रों से *सेंटेल्ला एशियाटिका* के 150 नमूने एकत्र किए गए। भेषज मापदंड स्थापित किए गए और एचपीटीएलसी का उपयोग करके मेथनॉलिक अर्क से मेटाबोलाइट्स (एशियाटिकोसाइड, मेडकासोसाइड, एशियाटिक अम्ल और मेडेकैसिक अम्ल) का मात्रात्मक विश्लेषण किया गया।

पादप आधारित सहक्रियात्मक प्राकृतिक पूरकों का विकास एवं गठिया के स्थिति में सुधार के लिए इनका फार्माकोलोजिकल सत्यापन

इस अध्ययन का उद्देश्य गठिया की स्थिति में सुधार हेतु एक सहक्रियात्मक प्राकृतिक पूरक का विकास करना है। उपलब्ध जानकारियों के आधार पर संभावित गठिया रोधी क्रिया हेतु पौधों के नमूनों की छंटनी की गई। फार्माकोग्नोस्टिक मानकों के लिए तेरह नमूनों (एनबीएजी-1 से एनबीएजी-13) का मूल्यांकन किया गया। मानक प्रोटोकॉल के अनुसार वानस्पतिक और भौतिक-रसायनिक परीक्षण किए गए। मार्कर यौगिकों के लिए एचपीटीएलसी प्रोटोकॉल विकसित किया गया। एनबीजीए-7 के जलीय अर्क में संभावित गतिविधि देखी गई जबकि न्यूनतम गतिविधि एनबीजीए-2 के हाइड्रोअल्कोहलिक अर्क में दर्ज की गई।

भारत के विभिन्न पादप-भौगोलिक क्षेत्रों से एकत्रित चित्रक (*प्लंबैगो ज़ेलेनिका*) के विशिष्ट कीमोटाइप की पहचान और विशिष्ट जर्मप्लाज्म की जैविक क्षमता का मूल्यांकन

आयुर्वेदिक दवा की मांग दुनिया भर में बढ़ रही है लेकिन गुणवत्तापूर्ण कच्चे माल का उत्पादन बहुत ही सीमित है। इसलिए, न केवल वैज्ञानिक सत्यापन के लिए, बल्कि गुणवत्ता मानकों के लिए भी औषधीय पौधों के हिस्सों को पहचानने और प्रमाणित करने की प्रमुख आवश्यकता

है। भारत के विभिन्न पादप-भौगोलिक क्षेत्रों से *प्लंबैगो ज़ेलेनिका* के कुल 36 जर्मप्लाज्म को एकत्र किया गया। *प्लंबैगो ज़ेलेनिका* के विशिष्ट कीमोटाइपों का चयन करने के लिए एकत्रित जर्मप्लाज्म का उनके प्रमुख जैविक रूप से सक्रिय यौगिकों के लिए मूल्यांकन किया जाएगा। *प्लंबैगो ज़ेलेनिका* के चयनित पादप नमूनों की खेती हर्बल उद्योग को वाणिज्यिक प्रसंस्करण के लिए प्रमाणित और गुणवत्तापूर्ण पौधों की सामग्री प्रदान करने में मदद करेगी।

पूर्वोत्तर भारत के सुगंधित चावल के उपज प्रबंधन में सूक्ष्म जीवों की भूमिका

काले चावल की 10 किस्मों की एंटीऑक्सीडेंट क्षमता की जांच करने के लिए जड़ों और तनों में उनकी कुल फेनोलिक मात्रा, कुल फ्लैवोनॉयड मात्रा और एंटीऑक्सीडेंट गतिविधि का अध्ययन किया गया।

संजीवनी पौधे *सेलेजिनेला ब्रायोप्टेरिस* से अलग किए गए पॉलीफेनॉल के पादप-रासायनिक एवं फार्माकोलॉजिकल अध्ययन

सेलेजिनेला ब्रायोप्टेरिस एक टेरिडोफाइट पौधा है जिसे इसकी उल्लेखनीय पुनरुत्थान क्षमताओं के लिए जाना जाता है। इसके औषधीय उपयोग जैसेः (i) तनाव एवं गैस्ट्रिक अल्सर से आराम; (ii) घाव भरने की क्षमता एवं (iii) पीलिया का उपचार शामिल हैं। वांछित फार्माकोलॉजिकल गतिविधियों के लिए संभावित चिकित्सीय अणुओं की पहचान की गई जिनमें प्रमुख हैंः हेवेयाफ्लैवोन, सिरिंजारेसिनोल एवं एमेंटोफ्लावोन।

अन्य सीएसआईआर-समर्थित परियोजनाएं

सीएसआईआर-एरोमा मिशन

सीएसआईआर-एनबीआरआई की टीम ने हल्दी की किस्म 'केसरी' की खेती को बढ़ावा देने के लिए विभिन्न राज्यों के संस्थानों और उत्तर प्रदेश के कई जिलों के किसानों से संपर्क किया है। अगले सीजन में क्षेत्र विस्तार के लिए उत्तर प्रदेश, मध्य प्रदेश, बिहार, ओडिशा, उत्तराखंड और मेघालय में किसानों और सहयोगियों की पहचान की गई है। 31 जनवरी 2018 को सीएसआईआर-सीमैप द्वारा आयोजित किसान मेले में भाग लेने वाले दो राज्यों के सात जिलों के 34 किसानों के बीच केसरी के बीज को वितरित किया गया और सीएसआईआर-एनबीआरआई के अरोमा मिशन और प्रौद्योगिकियों/उत्पादों से संबन्धित गतिविधियों का प्रदर्शन किया गया। कुल 77 किसानों ने हल्दी की केसरी किस्म के बीज के लिए पंजीकरण कराया। किसानों को अतिरिक्त आय प्राप्त करने के लिए हल्दी की अपशिष्ट पत्तियों से आवश्यक तेल के निष्कर्षण के बारे में बताया गया। संस्थान द्वारा विकसित हर्बल संयोजन ''हैंड सैनिटाइजर'', जिसमें हर्बल सामग्री के रूप में आवश्यक तेल इमल्शन शामिल हैं, को मैसर्स सतगुरु बायोलॉजिकल प्रा. लिमिटेड, बाराबंकी, उत्तर प्रदेश को स्थानांतरित कर दिया गया है। सीएसआईआर- सीमैप के सहयोग से हर्बल कवक रोधी फॉर्मूलेशन के विकास का कार्य प्रगति पर है।

मेगा लैब परियोजना 022

77 बैक्टीरियल आइसोलेट की 16S rRNA पर आधारित पहचान एवं उनका वंशावली विश्लेषण

सभी 77 आइसोलेटों को आंशिक 16S rRNA क्रम के माध्यम से पहचाना गया जिससे पता चला कि अधिकांश आइसोलेट (67) *बैसिलस* वंश से संबंधित हैं। *बैसिलस* प्रजातियों में अधिकांश *बैसिलस मेगाटेरियम* (24) एवं *बैसिलस मारिसफ्लावी* (24) से संबंधित थीं। शेष आइसोलेट क्रमशः *बैसिलस फ्लेक्सस* (01), *बैसिलस एंडोफाइटिकस* (01), *बैसिलस नियासिनी* (01), *बैसिलस फर्मस* (02), *बैसिलस ओसिनीसेडिमिनिस* (02), *बैसिलस सबटिलिस* (05), *बैसिलस टेक्विलेन्सिस* (01), *बैसिलस स्ट्रेटोस्फेरियस* (02), *बैसिलस सैफेन्सिस* (01), *बैसिलस गिब्सोनाइ* (02) एवं *बैसिलस सीरिअस* (01) आदि से संबंधित पाए गए। सभी अनुक्रमों को >95% विश्वसनीयता के साथ प्रजाति स्तर तक वर्गीकृत किया गया।

चुनिंदा बैक्टीरियल आइसोलेटों द्वारा ACC डीएमिनेज क्रिया का मात्रात्मक आंकलन एवं इनका *इन-विट्रो* धान के अंकुरों के जैव भार एवं एथीलीन उत्सर्जन पर प्रभाव

प्रत्येक कृषि-जलवायु क्षेत्र का प्रतिनिधित्व करने वाले एवं सर्वश्रेष्ठ प्रदर्शन करने वाले कुल 15 बैक्टेरियल आइसोलेटों को उनके उच्च बीज अंकुरण दर, पीजीपी और अजैविक तनाव सहनशीलता क्षमता के आधार पर छांटा गया। चयनित आइसोलेटों का एसीसी डीएमिनेज क्रिया का मात्रात्मक आंकलन किया गया एवं लवण तनाव के तहत बैक्टीरिया लेपित चावल के अंकुरों के जैव भार और ईथिलीन उत्सर्जन का आंकलन किया गया। विशेष रूप से *बैसिलस मेगाटेरियम* को सभी कृषि-जलवायु क्षेत्रों में पाया गया। इसके अतिरिक्त दक्षिण-पश्चिमी अर्ध शुष्क क्षेत्र के NBRI 20M (*बैसिलस मेगाटेरियम*) में अधिकतम ACC डीएमिनेज क्रिया को देखा गया। दूसरी ओर चयनित 15 आइसोलेटों में से बुंदेलखंड क्षेत्र के NBRI 2Q (*एल. फ्यूसीफोर्मीस*) ने न्यूनतम मात्रात्मक मूल्य प्रदर्शित किया। लवण तनाव की स्थिति में नियंत्रित नमूने की तुलना में NBRI 16E ने अंकुर जैव-भार को 262% बढ़ाया जबकि NBRI 6I ने 76% बढ़त प्रदर्शित की। साथ ही बिना लवण तनाव की स्थिति में NBRI 16E (बैसिलस मेगाटेरियम) ने नियंत्रित नमूने की तुलना में अधिकतम अंकुर जैवभार प्रदर्शित किया। लवण तनाव के संकेतक के रूप में एथीलीन उत्सर्जन के मामले में NBRI 20M (*बैसिलस मेगाटेरियम*) लेपित धान अंकुरों ने न्यूनतम एथीलिन सांद्रता प्रदर्शित की। आश्चर्यजनक रूप से, 2Q लेपित धान अंकुरों में, नियंत्रित नमूने की तुलना में अधिक एथीलीन सांद्रता देखी गई। बिना लवण तनाव की स्थिति में NBRI 9N लेपित अंकुरों ने नियंत्रित नमूने की तुलना में अधिक एथीलीन उत्सर्जित की। विभिन्न कृषि-जलवायु क्षेत्रों से संबंधित कुछ चुनिंदा आइसोलेट NBRI 21E, 16E, 16I, 33N, 53L, 20M, 69D एवं 12M बिना लवण तनाव की स्थितियों में एथीलीन उत्सर्जन को कम करते पाए गए।

1-अमीनोसाइक्लोप्रोपेन-1-कार्बोक्सिलिक अम्ल (ACC) डीएमिनेज पैदा करने वाले लवण सहिष्णु, देशज, पादप वृद्धि प्रेरक राइजोबैक्टीरिया के चयन हेतु कृषि-जलवायु पर्यावरण का उपयोग

धान की फसल में लवणता के प्रभाव को कम करने के लिए उत्तर प्रदेश (भारत) के 9 कृषि-जलवायु क्षेत्रों की मिटटी से लवणता सहिष्णु 1-अमीनोसाइक्लोप्रोपेन-1-कार्बोक्सिलिक अम्ल (एसीसी) डीएमिनेज युक्त पादप वृद्धि वर्धक जीवाणुओं को निकाल कर उनकी पहचान की गयी। यहां 1M NaCl लवणता को सहन कर सकने वाले 1125 जीवाणुओं को निकाल कर, ACC को एकमात्र नाइट्रोजन स्रोत के रूप में उपयोग करने की क्षमता के लिए, छांटा गया। परिणामस्वरूप 77 आइसोलेटों का बीज अंकुरण परीक्षण, पीजीपी एवं अजैविक तनाव सहनशीलता के लिए *इन-विट्रो* मूल्यांकन किया गया। इस मूल्यांकन से प्रत्येक कृषि-जलवायु क्षेत्र का प्रतिनिधित्व और लवणता कम करने वाले 15 सक्षम राइजोबैक्टेरिया का पता चला है। विशेष रूप से, जीवाणु शोधित धान के बीजों से प्राप्त अधिक पादप जैवभार, उन्ही जीवाणुओं द्वारा उत्पादित इंडोल एसीटिक अम्ल (IAA) के साथ समतुल्यता प्रदर्शित करता है। आश्चर्यजनक रूप से, 16S rRNA पर आधारित बहुत से विशिष्ट आइसोलेट एक ही प्रजाति से संबंधित थे किन्तु विशेषताओं में भिन्नता प्रदर्शित कर रहे थे। कुल मिलाकर, *बैसिलस* प्रजातियों को प्रभावी कुल के रूप में पाया गया जोकि सबसे ज्यादा पश्चिमी क्षेत्र में और उसके बाद मध्य क्षेत्र में वितरित पाया गया।

यह अध्ययन कृषि-जलवायु क्षेत्रों के आधार पर बहुआयामी पादप वृद्धि प्रेरणा एवं जैविक तनाव सहनशीलता के लिए देशज सूक्ष्मजीवों के चयन हेतु दृष्टिकोण उपलब्ध कराता है ताकि स्थानीय तनाव युक्त वातावरण में कृषि में उपयोग हेतु अधिक उपयोगी इनोकूलेंट की स्थापना एवं विकास को और क्षमता प्रदान की जा सके।

Research and 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 Institute has been in the forefront of plant sciences research in the country for past six decades and is an institution of national importance. As globally recognized advance center 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, systematic and database for lower and higher plant groups.
- Bio-prospection and development of nutraceutical, cosmeceutical and health care products.
- Botanic garden, plant conservation and development of new varieties of floriculture plants.
- Microbes for enhanced plant productivity.
- 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.

Botanic Garden and Distant Research Centres

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BOTANIC GARDEN AND DISTANT RESEARCH CENTRES

In-House Projects

Enrichment and Maintenance of the Germplasm 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. A wide range of germplasm comprising of five thousand taxa has been maintained under *ex-situ* conservation in the arboretum and different plant houses. These live germplasm collections serve as unique material for botanical studies and research, besides their use in landscaping for recreation purposes. The botanic garden, with their vast genetic resource, is an out of school education centre for the students, researchers and the public as a whole.

Enrichment of Germplasm Collection

Around 20 rare and interesting species were introduced in the Botanic Garden viz. *Aeschynanthus hookeri, Asclepias curassavica, Camellia sinensis, Dietes grandiflora, Elaeocarpus angustifolius, E. floribundus, Ephedra saxatilis, Eurayle ferox, Hoya longifolia, H. pandurata, Iris hookeriana, I. kemaonensis, Nepenthes mirabilis, Parkia roxburghii, Renanthera imschootiana, Rhynchostylis retusa, Salvinia cucullata, Vanda coerulea, Wisteria sinensis* and *Zanthoxylum armatum*. Few succulent plants were also introduced namely, *Kalanchoe thyrsiflora, Pereskia aculeata* 'Godseffiana' and *Sedum morganarium*. Four species of orchids (*Dendrobium aphyllum, D. herbaceum, D. moschatum, D. pachyanthum*) were propagated through keiki (vegetative method). Seed germination was successfully carried in some important species viz. *Nepenthes khasiana* (Pitcher Plant), *Adansonia digitata* (Baobab Tree), *Parkia timoriana* (Tree Bean), *Sterculia foetida* (Wild almond tree) and *Hylocereus undatus* (Dragon Fruit).

About 500 plants belonging to over 80 species of Orchids (*Arundina graminifolia, Bulbophyllum* spp., *Dendrobium nobile, D. tesellata, D. williamsonii, Gastrochilus* spp., *Luisia* spp., *Oberonia* spp., *Pholiodota imbricata, Thunia alba, Vanda coerulea, V. cristata, etc.*), Zingibers (*Alpinia* spp., *Globba* spp., *Hedychium* spp., etc.), *Begonia* spp., *Calathea* sp., *Cycas pectinata, Hoya* spp., ferns, palms and hydrophytes were collected for *ex-situ* conservation at the botanic garden (Fig. 1).

The live germplasm are being conserved in RET Propagation House and Orchid House. Cuttings of ornamentally important *Mussaenda glabra* were collected and introduced in the botanic garden. Seeds of *Coix lacryma-jobi, Elaeocarpus floribundus, Juglans regia, Sapindus mukorossi* and *Spondias pinnata* were collected for germination studies and conservation.

Fig. 1(a-f): New plants introduced for *ex-situ* conservation - a. *Arundina graminifolia*, b. *Dendrobium williamsonii*, c. *Hoya pandurata*, d. *Vanda cristata*, e. *Bulbophyllum forrestii*, f. *Hoya longifolia*

For the enrichment of germplasm in Bambusetum, four species of bamboos were collected from Manipur. Saplings of *Dendrocalamus giganteus*, a species of the giant bamboo, were also collected. Efforts are being made to enrich Bambusetum with addition of more species from different phyto-geographical zones.

Following species of flowering plants of ornamental, conservation, and other economic interests were successfully introduced in CSIR-NBRI Botanic Garden for *ex-situ* conservation: *Adenocalymma comosum*

(Cham.) DC., *Aristolochia acuminata* Lam., *Ayapana triplinervius* (Vahl) R.M. King & H. Rob., *Baccaurea courtallensis* (Wight) Muell.-Arg., *Cinnamomum verum* Presl., *Cleisostoma racemiferum* (Londl.) Garay, *Coptis teeta* Wall., *Cullenia exarillata* Robyns, *Elettaria cardamomum* (L.) Maton, *Embelia ribes* Burm. f., *Eryngium foetidum* L., *Garcinia gummi-gutta* (L.) Robs., *Garcinia indica* (Thouars) Choisy, *Hemigraphis alternata* (Burm.f.) T. Anderson, *Hopea parviflora* Bedd., *Nepenthes mirabilis* (Lour.) Druce, *Pimenta dioica* (L.) Merr., *Plectranthus verticillatus* (L.f.) Druce, *Polyalthia coffeoides* (Thw. ex Hook. f. & Thoms.) Hook. f. & Thoms., *Ruta chalepensis* L., *Syzygium aromaticum* (L.) Merr. & L.M. Perry, *Syzygium stocksii* (Duthie) Gamble, *Tristellateia australis* A. Rich., *Turpinia malabarica* Gamble, *Vateria indica* L. and *Vetiveria zizanioides* (L.) Nash.

House of Spice and Medicinal Plants of India

A new 'Plant House of Spice and Medicinal Plants' was created in the botanic garden of the institute. This unique plant house is meant for display and conservation of two economically important plant groups viz. spice and medicinal plants. The house covers an area of 680 m^2 with two tier-raised planting beds. Currently, 67 taxa are conserved in the plant house, including *Crocus sativus* (Kesar), *Cinnamomum camphora* (Camphor), *C. verum* (Cinnamon), *Myristica fragrans* (Jaiphal), *Coffea arabica* (Coffee), *Piper nigrum* (Kali Mirch), *Aloe vera*, *Withania somnifera* (Ashwagandha), *Ephedra foliata* (Somlata), *Hypericum gaitii* and Capsicum varieties (Fig. 2).

Socio-economic development through enhancing production of agricultural systems, skill development and outreach programmes

Evaluation of non-traditional economic plants for sodic soil

Collection and conservation of Tuberose (*Polianthes tuberosa*), Ashwagandha (*Withania somnifera*) and Isabgol (*Plantago ovata*) were taken up for evaluation in sodic soils. Number of varieties/accessions of Tuberose (18), Ashwagandha (08) and Isabgol (07) were grown under partially reclaimed sodic soil condition for their commercial cultivation and income generation for the farmers.

Safe utilization of industrial waste viz., fly ash and press mud, to reclaim the sodic waste land and its response on growth and flowering attributes of Tuberose was studied in a field experiment. Response of Plant Growth Promoting Rhizobacteria (PGPR) on improving root growth and alkaloid content of Ashwagandha was studied.

Shankhpushpi (*Convolvulus microphyllous* Sieb. ex Spreng; Syn. *C. pleuricaulis* Choisy) was evaluated under different levels of sodicity to determine the optimum yield and quality. Increasing sodicity levels increased the maturity days and also reduced the biomass yield of the plant (Fig. 3).

Fig. 2. House of Spice and Medicinal Plants at the Botanic Garden

Fig. 3. Performance evaluation of Shankhpushpi in sodic soil

Field experiments were continued to study the effect of different sources and levels of organic matter on biomass yield and quality of Kalmegh (*Andrographis paniculata*). The plant height, number of branches, stem diameter, plant canopy, fresh and dry biomass of the plant increased with increasing doses of Farm Yard Manure (FYM), press mud and vermi-compost.

Other collaborative field experiments

Bacterial and fungal consortia are being evaluated for growth and yield of paddy varieties (NDR 359, Samba mahsuri, Sarjoo 52, Indrasan) in partially reclaimed sodic land.

Evaluation of microbial strains for *ex-situ* and *in-situ* decomposition of paddy-straw and investigation of the response of decomposed material on physio-chemical properties of sodic land and growth and yield of wheat was also carried out.

Cytological studies on *Chrysanthemum morifolium*

Cytological studies have been initiated in *Chrysanthemum morifolium* to reveal chromosome numbers in its different varieties and occurrence of polyploidy within the germplasm (Fig. 4).

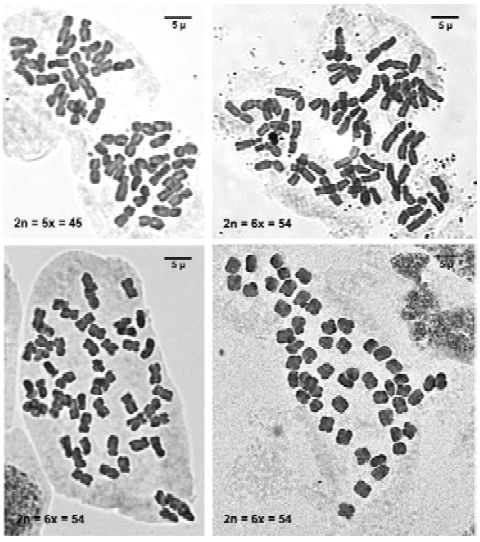

Fig. 4(a-d): Chromosome metaphase spreads showing polyploidy in *Chrysanthemum morifolium* germplasm. a. Pentaploid state (2n=5x=45), b-d. Different varieties with Hexaploid state (2n=6x=54).

New Variety Released

Chrysanthemum 'NBRI-HIM JYOTI'

'NBRI-Him Jyoti' is a new dwarf, 'no-pinch', 'anemone' type, floriferous Chrysanthemum variety which bears cream coloured (pale greenish yellow; RHS Fan-1-Yellow Group 2-D) flowers that bloom during late-November to early January. The new variety has been developed by gamma irradiation of the parent variety 'Himanshu'.

The plant attains a height up to ~30 cm; spreads evenly like dome with numerous branches bearing buds and cream coloured flowers (capitula) radiating out of the dome. The maximum capitulum size (diameter across) is up to 8.5 cm. The ray florets are semi-tubular with open strap shaped lamina at the ends. It is excellent for pots as well as for borders and beds (Fig. 5).

Fig. 5. Chrysanthemum 'NBRI-HIM JYOTI'

Grant-in-Aid Projects

Revalidation of Good Agricultural Practices – GAPs, to develop agro-technology for the cultivation of medicinal plants

Germplasm of *Phyllanthus amarus* and *Cyperus rotundus* was collected and field trials for evaluation of agriculture practices are being conducted.

Coptis teeta, a RET species, was collected from Mishmi hills of Arunachal Pradesh, and trials for its domestication and propagation through tissue culture and vegetative methods from rhizome cuttings are made.

Viola pilosa, was also collected from ICAR-National Bureau of Plant Genetic Resources (NBPGR), Bhowali, Uttarakhand, and its domestication trials are in progress.

Plant Diversity, Systematics and Herbarium

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PLANT DIVERSITY, SYSTEMATICS AND HERBARIUM

In House Project

Bio-resource Inventory, Systematics and Conservation of Diverse Plant Groups

Suhelwa Wildlife Sanctuary is located along the Indo-Nepal international boarder, spreaded over three districts of Uttar Pradesh – Shrawasti, Balrampur and Gonda. The sanctuary, declared as a protected area in the year 1988, has an area of 452 km^2. The sanctuary has not been fully explored and assessed for its floristic diversity, traditional knowledge and bioresource utilization. Therefore, the project was initiated to comprehensively assess the plant resources and associated traditional knowledge of Suhelwa for their systematic documentation, conservation and utilization.

A plant collection tour was conducted to the sanctuary and 12 sites were explored. A total of 422 specimen comprising eight algal, 200 lichen, 42 bryophyte, 22 pteridophyte and 150 angiosperm specimens were collected. Identification of the collected samples is in progress. The algal samples resulted in 21 algal taxa under 16 genera and 4 classes. The lichens represented 70 species. *Arthonia, Arthothelium, Bacidia, Caloplaca, Cryptothecia, Dirinaria, Graphis, Lecanora, Parmotrema, Pertusaria, Pyrenula* & *Pyxine* are the common genera, while *Arthothelium chiodectoides* (Nyl.) Zahlbr., *Caloplaca bassiae* (Willd. ex Ach.) Zahlbr., and *Pyxine cocoes* (Sw.) Nyl. are some of the common species of lichens in the sanctuary. The presence of rich lichen diversity indicates that forest in the sanctuary area is undisturbed, humid and tropical.

Eight species of bryophytes and nine species of pteridophytes identified so far from the sanctuary. The common bryophytes recorded from the study area included the liverworts viz., *Marchantia papillata* ssp. *grossibarba* (Steph.) Bischl., *Plagiochasma appendiculatum* Lehm. & Lindenb., and *Riccia* spp., mosses viz., *Barbula indica* (Hook.) Spreng., *Erpodium mangiferae* C. Muell., *Hyophila* sp. and *Fissidens* sp. The common pteridophytes species are *Adiantum incisum* Forssk., *A. philippense* L., *Ampelopteris prolifera* (Retz.) Copel., *Christella dentata* (Forssk.) Brownsey & Jermy, *Diplazium esculentum* (Retz.) Sw., *Helminthostachys zeylanica* L., *Lygodium flexuosum* (L.) Sw., *Pteris vittata* L., and *Selaginella ciliaris* (Retz.) Spring.

About 69 species of angiosperms in 29 families has been identified so far. The dominant families are

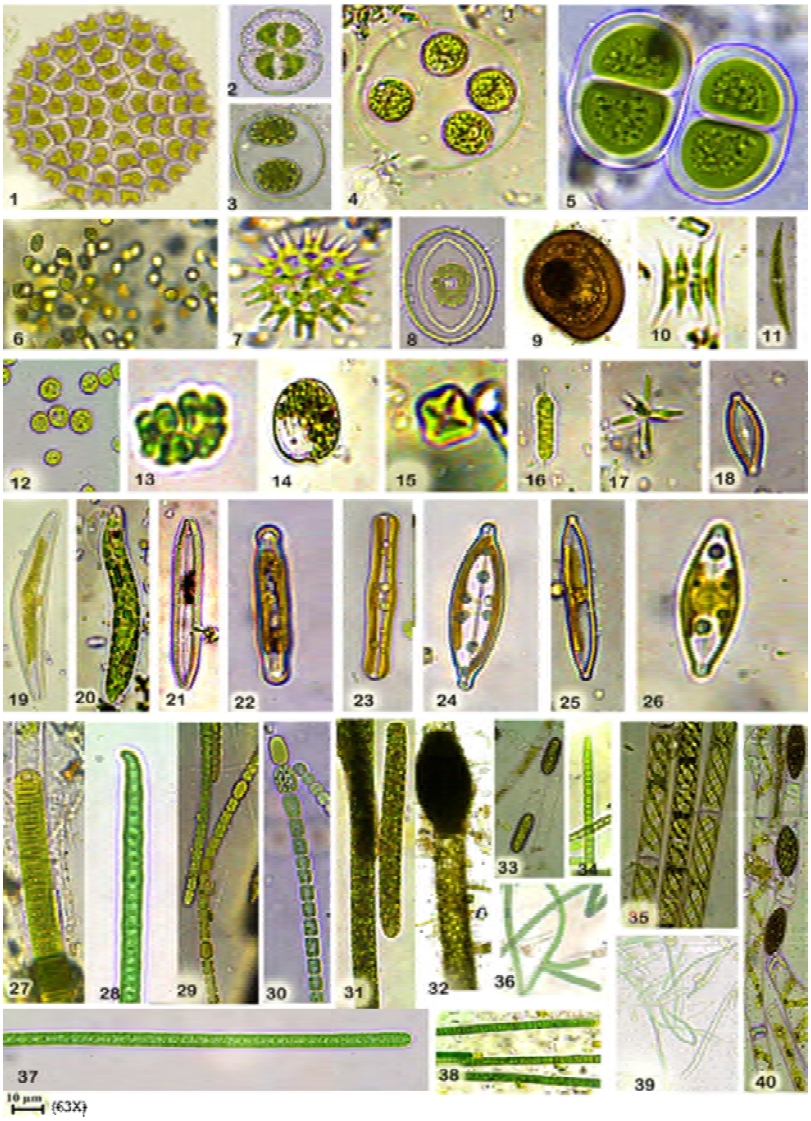

Fig. 1: Microphotographs (magnification of 63X) of (1) *Pediastrum duplex;* (2) *Cosmarium angulosum;* (3) *Oocystis gigas*; (4) *Gonium sociale;* (5) *Chroococcus turgidus*; (6) *Aphanothece saxicola*; (7) *Pediastrum biradiatum*; (8) *Diploneis finnica;* (9) *Spicaticribra kodaikanaliana;* (10) *Scenedesmus obliquus*; (11) *Closterium acerosum;* (12) *Chlorella vulgaris*; (13) *Botryococcus braunii*; (14) *Phacus pleuronects;* (15) *Crucigenia tetrapedia;* (16) *Rhizosolenia* Brightwell*;* (17) *Actinastrum hantzschii;* (18) *Gamphonema parvulum;* (19) *Cymbella vulgate*; (20) *Euglena ehrenbergii;* (21) *Tryblionella hungarica;* (22) *Pinnularia acrosphaeria;* (23) *Navicula germainii;* (24) *Pinnularia amabilis;* (25) *Nitzschia umbonata*; (26) *Navicula rostellata;* (27) *Lyngbya birgei;* (28) *Oscillatoria curviceps;* (29) *Anabaena constricta;* (30) *Cylindrospermum stagnale;* (31) *Oscillatoria peronata* (32) *Pithophora mooreana* (33) *Mougeotia scalaris;* (34) *Oscillatoria okeni;* (35) *Spirogyra elliptica*; (36) *Scytonema pseudoguyanense;* (37) *Oscillatoria chalybea;* (38) *Oscillatoria subbrevis;* (39) *Phormidium mucosum*; (40) *Spirogyra teodoresci.*

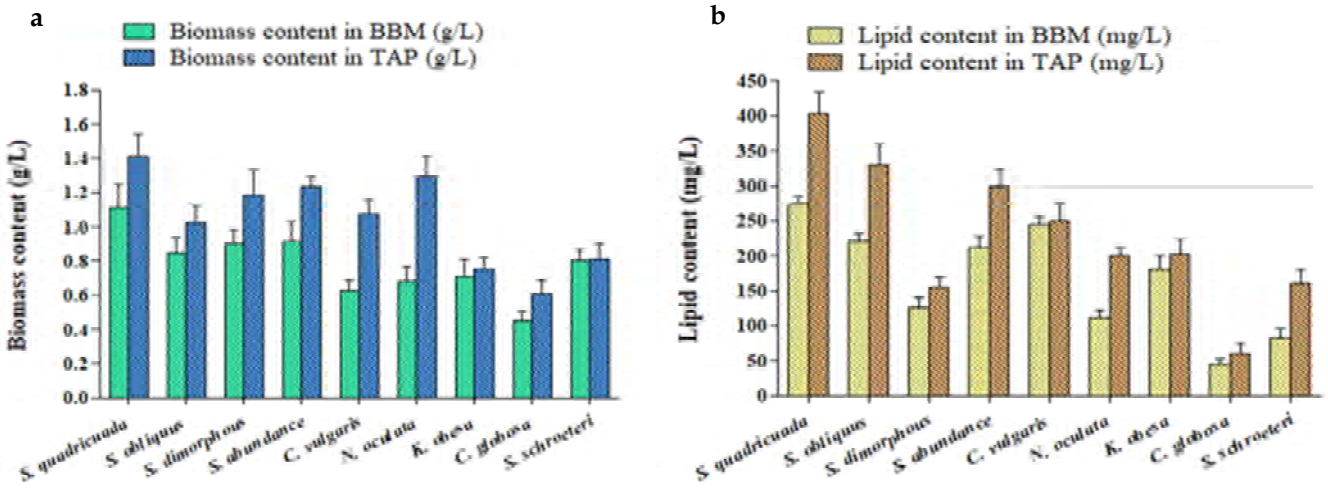

Fig.2 (a-b): (a) Biomass content of algal isolates (g/L) and (b) Lipid content of algal isolates (mg/L).

Euphorbiaceae, Asteraceae, Acanthaceae and Leguminosae. The common species of flowering plants found in the sanctuary are *Murraya koenigii* (L.) Spreng., *Clerodendrum tomentosum* (Vent.) R. Br., *Curculigo orchioides* Gaertn., *Hemidesmus indicus* (L.) R. Br. ex Schult., *Lantana camara* L., *Parthenium hysterophorus* L., *Oxalis corniculata* L., *Evolvulus nummularius* L. and *Tridax procumbens* (L.) L.

Grant in Aid Projects

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

Diversity and species composition of 11 sites of sub-urban water bodies of Lucknow revealed the presence of 40 taxa belonging to 32 genera (Fig.1). *Centritractus belonophorus* of Xanthophyta has been reported for the first time from Uttar Pradesh. Thirteen microalgae were isolated and maintained in NBRI. Among them *Scenedesmus quadricauda* LWG002611 was found to be the most efficient strain for biomass (1.41±0.13 g/L) and lipid production (404±30 mg/L) under both autotrophic (BBM) and mixotrophic growth conditions (TAP medium) (Fig.2). The fuel properties of fatty acid methyl ester (FAME) mix of *S. quadricauda* LWG002611 were found within the limits of European standard EN14214 and EN 590:2013 (Table1).

The whole genome of *Scenedesmus quadricauda* LWG002611 was sequenced (using Ion Torrent) and a total of 13514 genes were predicted de novo and 16739 genes from reference sequences. Reference assembly of whole genome sequence was submitted to NCBI BioProject and assigned an accession number NNCB00000000. Gene expression analysis of *S. quadricauda* genome revealed that 6167 genes were involved in cellular processes, 6558 in biological processes, 8348 in molecular functions and 283 genes in lipid metabolism. Among them some genes were found common in all the above processes. Small subunit

Table 1: Fuel properties of *S. quadricauda* LWG002611

Biodiesel properties	*S. quadricauda* LWG 002611 biodiesel	Biodiesel specifications (EN14214)	Petro-diesel (EN 590:2013)
Saturated Fatty Acid (SFA) (%)	44.825	-	-
Mono Unsaturated Fatty Acid (MUFA) (%)	16.461	-	-
Poly Unsaturated Fatty Acid (PUFA) (%)	22.250	-	-
Degree of Unsaturation (DU)	60.961	<137	-
Sapnification Value (SV) (mg/g)	175.371	-	-
Iodine Value (IV)	65.651	>51	>51
Cetane number (CN)	62.651	>51	>51
Long Chain Saturated Factor (LCSF)	5.669	-	-
Cold Filter Plugging Point (CFPP) (^{0}C)	1.334	Varies	-5^{0}C to -15^{0}C
Cloud Point (CP) (oC)	17.025	Varies	-
Pour Point (PP) (^{0}C)	11.661	Varies	-
Allylic Position Equivalent (APE)	56.876	-	-
Bis-Allylic Position Equivalent (BAPE)	33.208	-	-
Oxidation Stability (OS) (g/m3)	7.891	>6	<25
Higher Heating Value (HHV) (MJ/kg)	32.816	-	<25
Kinematic Viscosity (u) (mm2/s) at 40^{0}C	2.937	3.5-5.0	2.0-4.5
Density (p) (kg/m3) at 15^{0}C	731	860-900	820-845

ribosomal RNA gene (18S rRNA) was sequenced to establish phylogenetic relationships of *S. quadricauda* with other algae and also to establish its correct taxonomic identity (Fig. 3). The 18S rDNA sequence was submitted to NCBI Gen bank (Accession no. KY654954.1.)

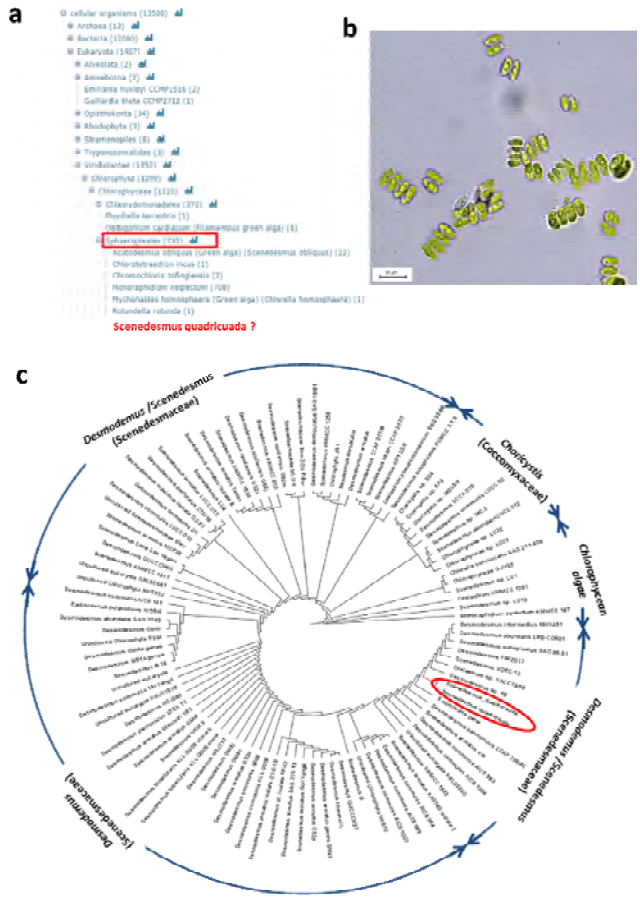

Fig. 3 (a-c): (a) Phylogenetic tree constructed from *de novo* genome sequence annotation of *Scenedesmus quadricauda* and related microalgae. (b) Photomicrograph of *S. quadricauda* LWG 002611 under light microscope (63X). (c) Phylogenetic analysis based on 18S rDNA sequences using NR database of NCBI blast.

International consortium for renewable and advanced fuel technologies (i-CRAFT)

The micro algae, *Nannochloropsis* and *Scenedesmus*, were identified as potential candidates for biomass and lipid production. These two isolates were inoculated in the raceway pond-1 and 2, respectively, for biomass production (Fig 4a). They were grown in each pond containing 15000 liters of tap water with total 500g of urea (250gm of urea supplemented twice in the gap of 10-15 days) and 170g of phosphate (supplemented during inoculation). Although, monoculture of *Nannochloropsis* and *Scenedesmus* was inoculated initially in the raceway ponds, the presence of *Chlorella* and some other algae were noticed subsequently amongst the mono cultured microalgae (Fig. 5). Algal biomass was routinely harvested after 30-45 days depending on the growth of algae. The highest biomass yield 4.56 kg was found in pond-2 in the month of July 2017 dominated by *Scenedesmus*, *Nannochloropsis* and *Chlorella* (Fig. 6b). The percentage of lipid, protein and carbohydrate was estimated from sundried algae powder. The highest lipid percentage 21.09% (w/w) was obtained in pond-2 in the month of September 2017 dominated by *Scenedesmus* and *Chlorella* (Fig. 6b). A total of 36.09 kg of dry algal biomass has been sent to the coordinator of the i-CRAFT project for further study.

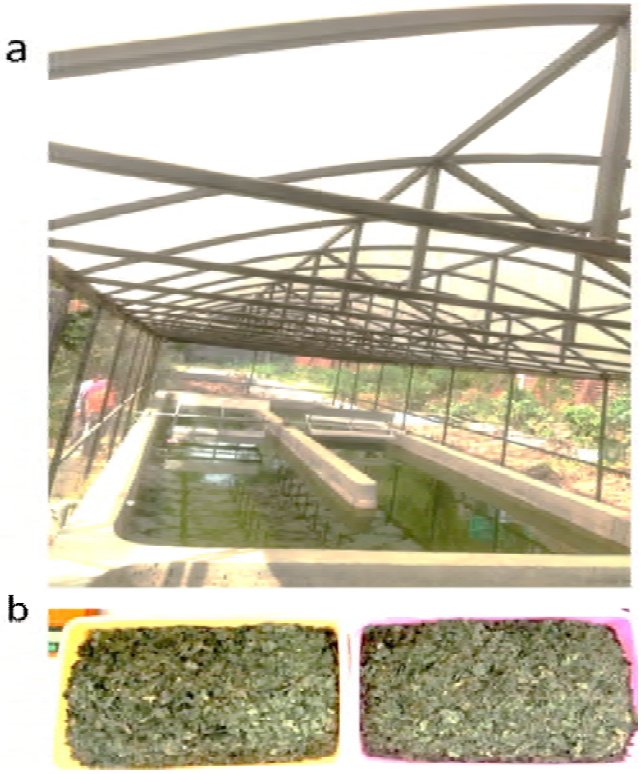

Fig.4 (a-b): (a) Raceway Ponds (each 15,000 litre) (b) Harvested dry algal biomass

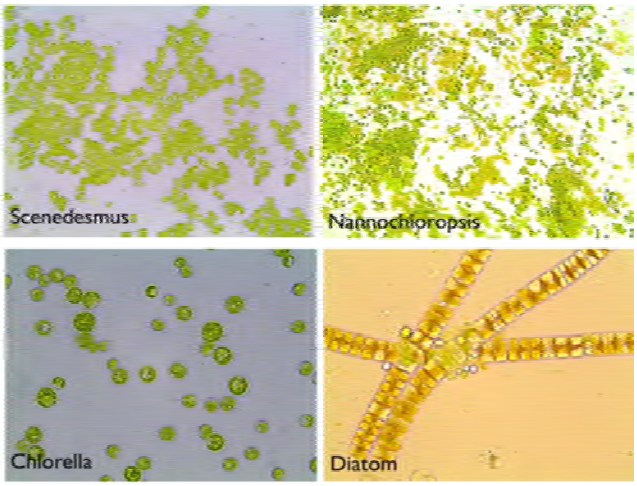

Fig. 5: Microphotographs of algal strains cultured for biomass production.

Lipid extraction, transesterification and fatty acid profiling of harvested biomass of *Scenedesmus quadricauda* was carried out (Fig. 7). The fatty acid profile of *S.*

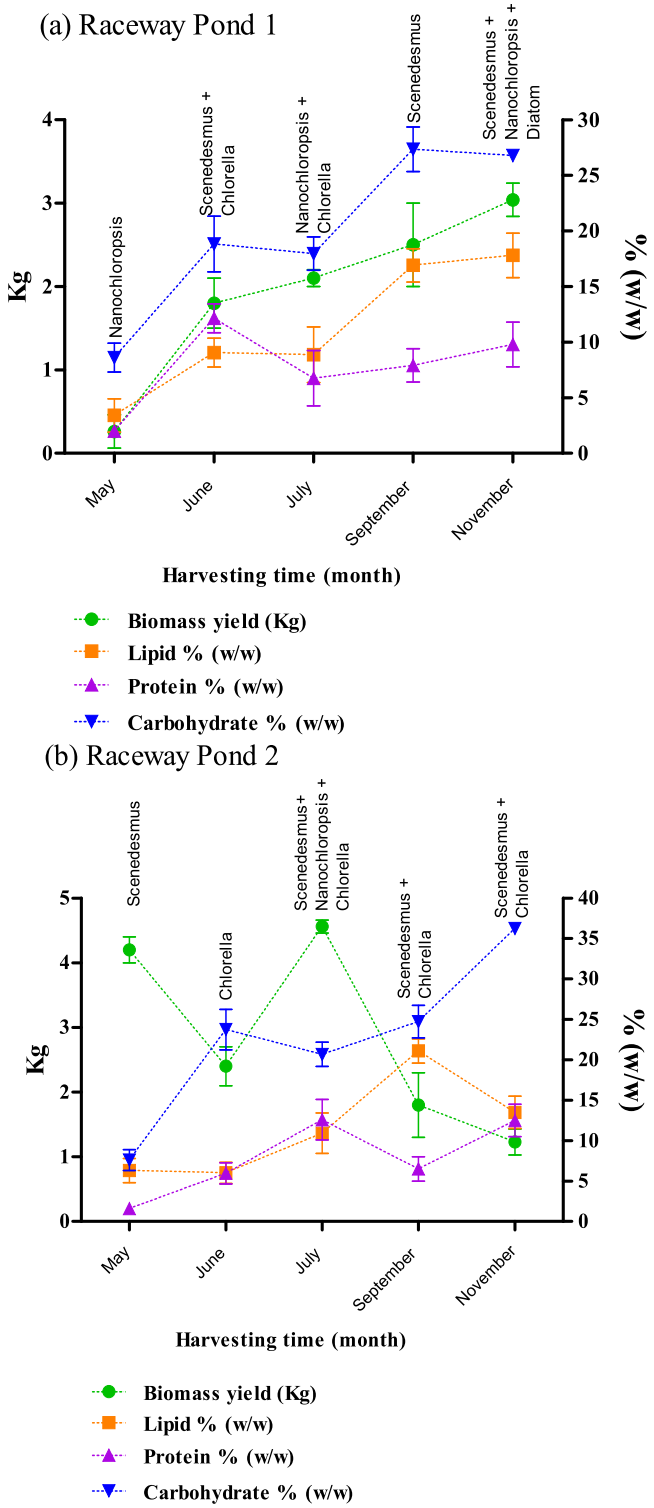

Fig. 6(a-b): The yield of Biomass, lipid, protein and carbohydrate from microalgae in the different month of cultivation. (a) Raceway pond-1, (b) Raceway pond-2.

quadricauda showed only six fatty acids of carbon chain length of C16 to C18, of which Palmitic acid (16:0) 44.466%, oleic acid (18:1) 12.376%, linoleic acid (18:2) 11.292% and linolenic acid (18:3) 10.958% were the major components. Other fatty acids were present in very negligible quantity.

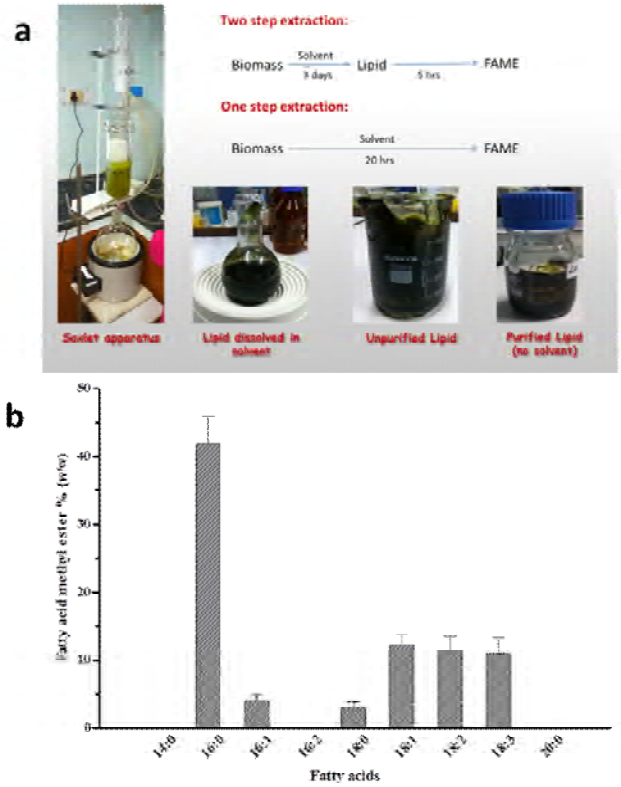

Fig. 7 (a-b): (a) Lipid Extractions and Transesterification, (b) Fatty acid methyl ester (FAME) proûle of *Scenedesmus*

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

The revisionary study carried out on Teloschistacean lichens, resulted in the discovery of a new genus *Upretia* S. Y. Kondr. & A. Thell, and a new species, *Gallowayella awasthiana* S. Y. Kondr. & D. K. Upreti (Fig. 8)

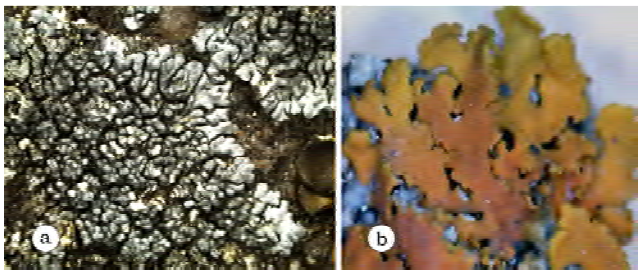

Fig. 8 (a-b): New taxa of Teloschistacean lichens - A. *Upretia* S. Y. Kondr. & A. Thell; B. *Gallowayella awasthiana* S. Y. Kondr. & D. K. Upreti;

A three gene (ITS1/ITS2 nrDNA, 12S mt SSU and RPB2) phylogeny tree was applied for the first time in the classification of the Indian Teloschistaceae. More than 15 species of *Caloplaca* were collected from Patni Top in Jammu & Kashmir. The St. Mary's Islands (Karnataka) was surveyed for lichens for the first time and *Caloplaca subpoliotera* was reported from the area. A fruticose lichen, *Teloschistes flavicans* (Sw.) Norman was

collected from a sacred grove in Shivamoga district of Karnataka. An updated inventory of genera *Caloplaca*, *Ioplaca*, *Rusavaskia* and *Xanthoria* in India has been prepared.

Ecology, phylogeny and computational approach of lichenized and lichenicolous fungi in India with emphasis on family Arthoniaceae (Ascomycota: Arthoniales)

The objective of the project is to study the history, diversity, molecular systematics and ecology of the family Arthoniaceae in India along with the development of web-based applications and manuals for the identification of lichens. In the course of the study, several type specimens were procured on loan from the following foreign herbaria: H, USA, L and G. Two field tours were conducted to Jammu district (Jammu & Kashmir) and Uttara Kannada district (Karnataka). About 100 lichen specimens including 15 Arthonialean members were collected from Jammu and about 250 specimens including 40 Arthonialean members were collected from Uttara Kannada. A non-profit YouTube Channel named "Lichens of India" (www.youtube.com/lichensofindia) has been created for public awareness and disseminating knowledge about lichens. The channel includes nine videos featuring different aspects of lichenology in India and it has received more than 4000 views and 207 subscribers from all over the world.

Diversity, ecology and conservation of the lichen biota of fragile forest ecosystem in central Western Ghats, Karnataka

This project aims to study the diversity and ecology of lichens in relation to different fragile forest habitats of central Western Ghats in Karnataka, assess impacts of anthropogenic factors on lichen biota, and to develop conservation strategies for threatened lichens. The field trips carried out during the reporting year resulted in collection of more than 500 lichen specimens, and identification of 100 specimens collected in Uttara Kannada and Shivamoga districts in Karnataka. Among all the study sites, Hosagunda '*kan*' in Shivamoga district with rejuvenated sacred forest patch, harbours more than 40 species of lichens, which is highest number of species recorded so far from a scared grove in the study area.

Revisionary studies on lichen genera *Buellia sensu lato* and *Rinodina* (Caliciales) from India

Buellia and *Rinodina* are two closely related tropical lichen genera. *Buellia* was recently splitted into eight smaller genera. According to old concept, *Buellia s. l.* is represented by ca. 73 species, while *Rinodina* is represented by ca. 11 species. The major objective of the project is to undertake a detailed taxonomic revision of *Buellia* and *Rinodina* in India, using morpholoical, chemical and molecular data. The specimens of *Buellia* and *Rinodina* housed in LWG were examined and segregated into 186 specimens under *Buellia,* 18 under *Diplotomma,* 21 under *Amandinea,* two under *Baculifera,* five under *Hafellia,* and 393 under *Rinodina.* Additionally, specimens in ASSAM and BSHC were also examined.

Assessment of bryophyte diversity, species richness and composition in Darjeeling Hills with special reference to climate change and its conservation strategies.

A total of 316 bryophytes of Darjeeling hills have been recorded from the three sets of secondary data viz. Set 1 (1965), set 2 (1981, 1983) and Set 3 (2002, 2003). These sets comprised 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.

The previous collections were assorted in to three groups, based on altitudinal zonation: Lower Altitudinal Zone (1000-1500 m); Middle Altitudinal Zone (1501-2000 m) and Higher Altitudinal Zone (2001-2500 m).

During the present assessment of the bryoflora of Darjeeling, 48 species under 36 genera and 22 families from Tiger hill and 63 species under 46 genera and 31 families in Senchal Wildlife Sanctuary were documented. So far, 20 species under 16 genera and 11 families have been recorded from all six selected habitats viz., soil, soil covered rocks, wet rocks, dry rocks, epiphytic and on stony walls/ brick walls, which is to be used as the primary data Set- 4.

A study has also been carried out on the genus *Hypnum* Hedw. that explicates the distribution and diversity of eight taxa viz. *H. aduncoides* (Brid.) Müll. Hal., *H. cupressiforme* Hedw., *H. cupressiforme* sp. *imponens, H. macrogynum* Besch., *H. sikkimense* Ando, *H. subimponens* Lesq., *H. submoluscum* Besch. and *H. subimponens* subsp. *ulophyllum* (Müll. Hal.) Ando, occurring in Darjeeling hill region of the eastern Himalaya. It is noteworthy to mention that these eight species are known to represent the genus from the entire east Himalayan region. The distribution of the taxa has been studied across the altitudinal gradient and at five different habitats viz., soil, rocks, soil covered rocks, stony walls/ brick walls (terricolous habitats) and epiphytic. During the assessment, the maximum number of species was found between 2001 to 2500 m, with all the eight species of *Hypnum* being distributed over this altitude (Fig. 9). Rocks and bark provide the most suitable habitat for

this genus with maximum distribution (Fig. 10). Soil also furnished a favorable habitat for some species (Fig. 10).

During the study two species viz., *Frullania ornithocephala* (Reinw. et al.) Nees and *Marchantia subgeminata* Steph. were recorded as new to India, whereas four species viz., *Gollania ruginosa* (Mitt.) Broth., *Trichostomum hyalinoblastum* (Broth.) Broth., *Fissidens zollingerii* Mont. and *Brachythecium garhwalense* Vohra as new to eastern Himalaya.

Ex-situ propagation of three species viz., *Lunularia cruciata* (L.) Dum., *Anthoceros bharadwajii* Udar & Asthana, and *Rhynchostegiella scabriseta* (Schwägr.) Broth. has been done for their conservation.

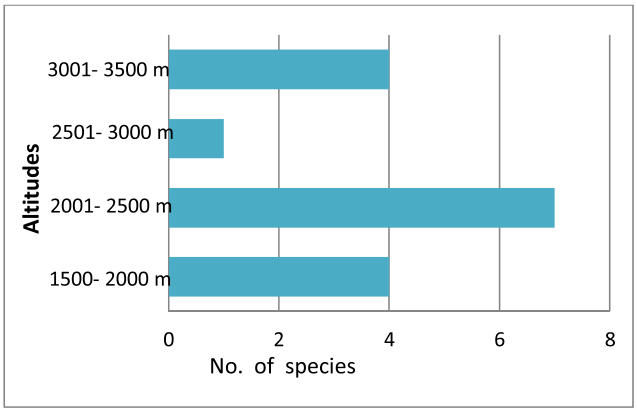

Fig. 9: Distribution of species of *Hypnum* at different altitudinal gradients of Darjeeling hills

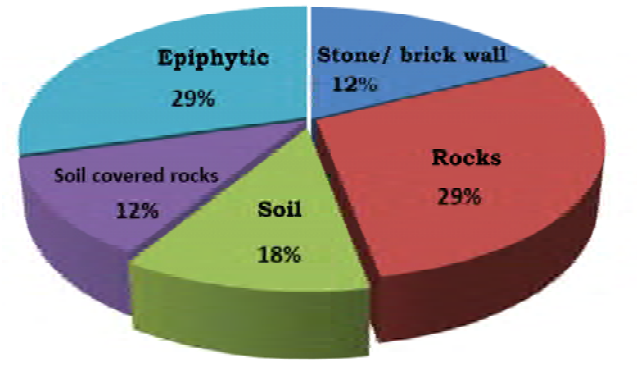

Fig. 10: Distribution of species of *Hypnum* at various habitats of Darjeeling hills

Study of Bryophyte Diversity in Eastern Ghats

A morpho-taxonomical study was carried out to document the diversity of bryophyte rich areas of Eastern Ghats in Tamil Nadu, Andhra Pradesh and Odisha. The study documented 109 species of mosses, 46 species of liverworts, and one species of hornwort. Among mosses, high species diversity was found in the families Pottiaceae, Bryaceae, Thuidiaceae and Hypnaceae while in case of liverworts, high numbers of species were in the families Lejeuneaceae and Aytoniaceae. The study revealed several new geographic distributional records of bryophytes to India (*Riccia boliviensis* Jovet-Ast and *Weissia parajaponica* Y. Inoue & H. Tsubota), southern peninsular India (12 species), and Eastern Ghats (58 species).

Exploration of plant diversity in un/underexplored areas of Manipur and Nagaland: Inventory, conservation of threatened and endemic plants, field germplasm bank and bio-prospection of selected taxa for using as bio-resources

Extensive field surveys were taken to unexplored or underexplored areas of Manipur (Ukhrul, Kamjong, Siruhi hills and Tamenglong) and Nagaland (Dzukou Valley, kiphire, Pungro, Mt. Saramati). A total of 4022 specimens comprising 1870 angiosperms, 30 gymnosperms, 110 pteridophytes, 182 bryophytes, 1800 lichens and 15 algal samples were collected. Out of which, 315 species of angiosperms, three gymnosperms, 102 bryophytes, 110 lichens and 79 species of algae have been identified till date. Some rare, endemic and threatened species such as *Vanda coerulea, Renanthera imschootiana, Hoya pandurata, Cycas pectinata* and *Lilium chitangada* were also collected. *Hoya pandurata*, a globally threatened species, was recorded from India for the first time from Kamjong district of Manipur, bordering Myanmar (Fig. 11)

Approximately, 600 live plants belonging to over 70 species of orchids, ferns and hydrophytes have been introduced in the CSIR-NBRI Botanic Garden. These included cuttings of ornamentally important *Mussaenda glabra* and seeds of *Spondias pinnata, Elaeocarpus floribundus, Juglans regia* and *Coix lacryma-jobi* for seed germination study. Ethnomedicinally important species,

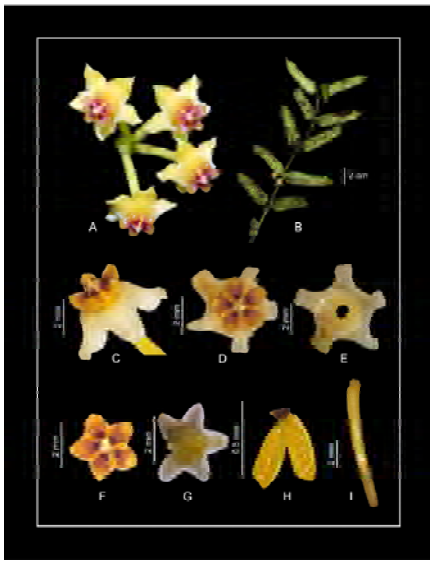

Fig. 11: *Hoya pandurata* Tsiang, A. Flowers, B. Leaves, C. Side view of flower, D. Upper view of flower, E. Corolla, F. Corona, G. Calyx, H. Pollinia, I. Pedicel. (Source: Khuraijam *et. al.*, 2017, Pleione. 11. 501-504)

such as *Zanthoxylum armatum, Cinnamomum zeylanicum, Costus speciosus* and *Curcuma* spp. were collected for bio-prospection. Essential oil of (NE-NBRI1) has been tested for analgesic properties and against human skin pathogen - *Streptococcus aureus*; MIC- 0.5%- 1.0%, *Tricho*phyton; MIC- 0.5%- 1.0%. The essential oil of (NE-NBRI2) has been tested for anti-microbial activity against human skin and oral pathogen; MIC- 1% and anti-inflammatory activity; MIC- 0.25%.

The following bryophytes, *Lejeunea pallide-virens* S. Hatt., *Campylopus fragilis* subsp. *zollingerianus* (Mull. Hatt.) J. P. Frahm, *Lindbergia duthei* (Broth.) Broth., *Leucobryum aduncum* Dozy and Molk., *Physcomitrium eurystomum* Schiffn., *Oxystegus uncinifolius* (Dixon) Aziz et Vohra and *Thuidium sparsifolium* (Mitt.) A. Jaeger were identified as new to Eastern Himalaya, while 31 species of mosses and three species of liverworts were identified for the first time from Manipur.

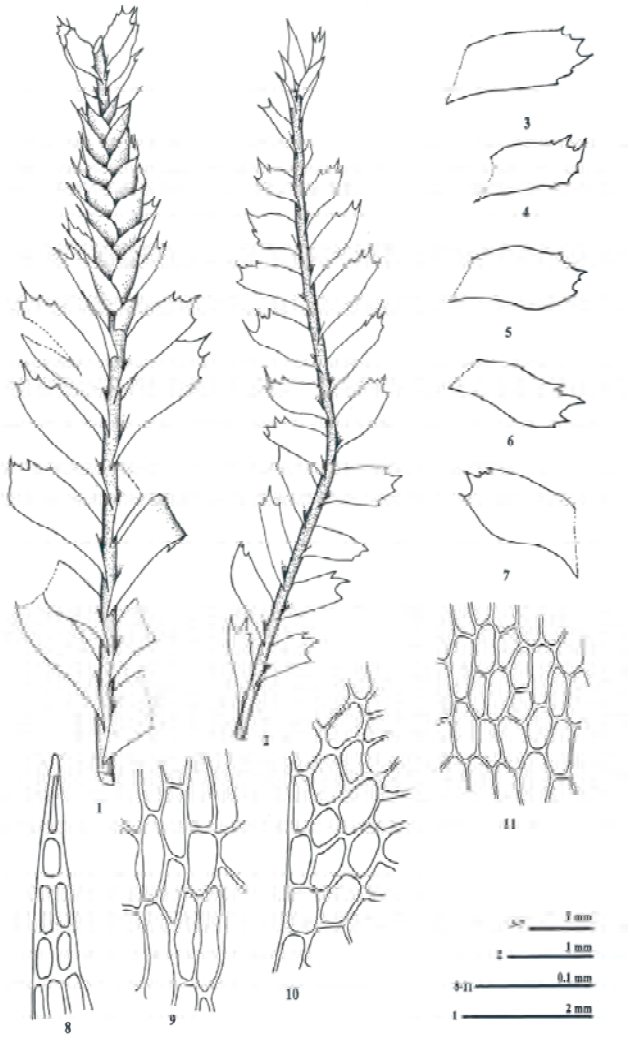

Fig. 12: *Plagiochila trabeculata* Stephani; 1. Male plant; 2. Vegetative plant; 3-7. Leaves; 8. Leaf apical cells; 9. Basal leaf cells; 10. Marginal leaf cells; 11. Median leaf cells.

Similarly, 89 species of bryophytes have been identified from Nagaland. *Plagiochila trabeculata* Stephani (Fig. 12) and *Atrichum crispulum* Schimp ex Besch. have been recorded as new to India, while 40 species of mosses and 13 species of liverworts have been identified for the first time from Nagaland.

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

The forest of KWLS comes under the tropical moist deciduous type. Based on the physiognomy, the entire area is chiefly dominated by Sal (*Shorea robusta* Gaertn. f.) forest, mixed Sal forest, Teak (*Tectona grandis* L. f.) and Semal (*Bombax ceiba* L.) plantation.

About 470 species under 260 genera and 58 families were collected from KWLS during different seasons. The family Fabaceae was dominated followed by Poaceae, Asteraceae, Malvaceae, Rubiaceae, Tiliaceae, Euphorbiaceae and Lamiaceae (Fig. 13). *Bauhinia vahlii* Wight & Arn. and *Millettia extensa* (Benth.) Baker are the two dominant woody climbers in the sanctuary area.The empty niches are well occupied by invasive alien species, such as *Lantana camara* L., *Argemone mexicana* L., *Parthenium hysterophorus* L., *Ageratum conyzoides* (L.) L., etc.The savannah grasslands are also present in some pockets in the forest and mainly represented by the members of Poaceae such as *Desmostachya bipinnata* (L.) Stapf., *Dendrocalamus strictus* (Roxb.) Nees, and *Saccharum spontaneum* L. Shrubs, mainly associated with the grasslands, near agricultural fields, road sides and forest patches are represented by *Helicteres isora* L., *Senna occidentalis* (L.) Link, *Tamarix dioica* Roxb. ex Roth, *Grewia asiatica* L., *Xanthium indicum* DC., *Datura metel* L., *Breynia vitis-idaea* (Burm. f.) C.E.C.Fisch., *Ipomoea carnea* Jacq., *Glycosmis pentaphylla* (Retz.) DC., etc.

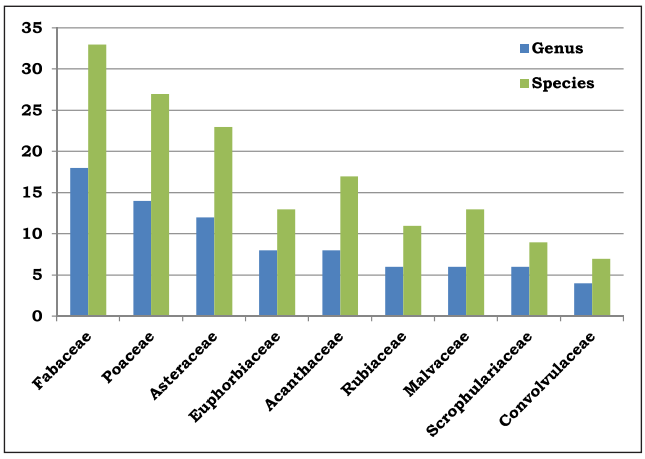

Fig. 13: Family wise plant diversity in Kishanpur Wildlife Sanctuary

Patches of herbs, found under forest in moist habitats, forest edges, road sides and near water bodies

are reperesented by mainly *Helminthostachys zeylanica* (L.) Hook., *Zingiber capitatum* Roxb., *Commelina attenuata* K.D.Koenig ex Vahl, *Exacum tetragonum* Roxb., *Peperomia pellucida* L., *Polygonum glabrum* Willd., *Barleria cristata* L. and *Persicaria limbata* (Meisn.) H. Hara.

Inventorisation of plant diversity of Nawab Wazid Ali Shah Zoological Garden, Lucknow (UP)

The Lucknow Zoo (26º 50'44.28" N and 80º 57' 17.18" E) was established in 1921 and it is now known as Nawab Wazid Ali Shah Zoological Garden, Lucknow. An enumeration of trees and shrubs found in the zoo was made. A total of 92 species have been recorded from the area under 70 genera and 32 families. Of these, 62 species are native to India while 30 species are exotic. Fabaceae represented the dominant family followed by Moraceae, Arecaceae, Apocynaceae, Myrtaceae, Malvaceae and Bignoniaceae. In terms of their uses, the species enumerated from the zoo included 43 ornamentals, 19 timber, 13 medicinal, 12 edible and 5 religiously important plants.

Plant Diversity Assessment of Dima Haso District in Assam

Six field tours were conducted to different regions of Dima Haso district for the collection of plant materials and habitat study. More than 1200 specimens have been collected and systematically documented along with GPS data. The initial scrutiny of the collected specimens resulted about 600 species, of which about 272 species comprising 169 herbs and shrubs, 20 climbers, and 83 trees have been identified and listed with their currently accepted name, habit, habitat, flower colour, flowering and fruiting period and reference to the specimens examined. The herbarium at Forest Research Institute, Dehradun (DD) was consulted for identification of the specimens collected from Dima Haso and to examine previous collections from this area.

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

So far, a total of 971 specimens of 29 species of *Henckelia* and 407 specimens of 17 species of *Didymocarpus* were critically studied in 10 Indian and eight foreign herbaria: BM, BSD, BSHC, BSI, CAL, CALI, DD, E, FRC, G-DC, K, L, LWG, MH, P, S, TBGT and W.

The field surveys during the year covered 31 localities in 11 districts of five states (Kerala and Tamil Nadu: Western Ghats; Uttarakhand: West Himalaya; Sikkim: East Himalaya; and Meghalaya: NE India). Fresh samples of 77 accessions of 12 species of *Henckelia* and 39 accessions of 10 species of *Didymocarpus* were collected for morpho-taxonomic and molecular phylogenetic studies. Young leaf tissues of 108 accessions (70 *Henckelia* + 38 *Didymocarpus*) were collected for DNA isolation.

PCR amplification of 108 DNA samples was performed using nrDNA ITS and two cpDNA loci- *trnL-F* and *matK*. Sequencing resulted in 69 ITS, 39 *trnL-F*, and 47 *matK* sequences from multiple accessions. All the sequences were analysed, edited and contigs were made using the Bioedit Sequence Alignment Editor (version 7.1.9). The average trimmed lengths of the sequences are ITS P4&P5: 652 bp, ITS 5P & 8P: 754 bp, *trnL-F*: 854 bp and *matK*: 860 bp.

Molecular systematics of genus *Betula* L. (Betulaceae) in India

More than 400 specimens and images of four taxa of Indian *Betula (B. alnoides, B. cylindrostachya, Betula utilis* subsp. *utilis* and *B. utilis* subsp. *jacquemontii*) were critically studied at different herbaria such as ARUN, ASSAM, BSD, BSHC, CAL, DD and LWG. Five field tours were conducted in different localities in seven states of the Indian Himalayan and North East Indian regions: Himachal Pradesh, Jammu & Kashmir, Uttarakhand, Arunachal Pradesh, Sikkim and Meghalaya, and 400 accessions of the four target taxa of *Betula* were collected and documented for molecular systematic studies.

Studies on diversity and systematics of the genus *Sonneratia* L.f. (Lythraceae) in India using molecular markers

So far, 120 specimens of five species of *Sonneratia* (*S. alba, S. apetala, S. caseolaris, S. griffithii* and *S. ovata*) were critically studied in CAL and PBL. Field surveys were carried out in the major mangrove areas of the east coast (Sundarban, West Bengal; Bhitarkanika, Odisha; Krishna and Godavari delta, Andhra Pradesh; Pichavaram, Tamil Nadu); west coast (Kochi, Kerala) and Andaman Islands (South, North and Middle Andaman Islands). Leaf samples of 170 accessions of the above five species of *Sonneratia* were collected for DNA isolation. PCR amplification and sequencing are in progress. The geographical distribution of *S. griffithii* and *S. alba* was revisited and it was found that all previous reports on the occurrence of *S. griffithii*, a critically endangered species, in West Bengal and Odisha, were erroneous. *Sonneratia griffithii* is restricted to Andaman Islands whereas the materials reported earlier as *S. griffithii* from West Bengal and Odisha represented *S. alba*.

Meta-genomic and transcriptomic studies on Termitomyces growing fungal combs of termites found in Assam for bio-prospection

Hydroalcoholic extracts (70%) were prepared from 11 samples of *Termitomyces* species, collected from Assam, and these samples were analysed for their antioxidant attributes such as total antioxidant activity, total phenolic content (TPC), total flavonoid content (TFC) and radical scavenging activity using DPPH free radicals. All samples were also examined for their nutritional components, including total carbohydrate and protein contents. The highest total antioxidant activity was detected in M22, TPC in M02, and TFC and DPPH radical scavenging activity in M20. The extract, M32 showed the highest total carbohydrate content while M21 showed the maximum total protein content. Anti-quorum sensing analysis using *Chromobacterium violaceum* ATCC 12472 as the bioindicator strain did not show anti-quorum sensing activity in the 11 extracts assayed.

Monographic studies on the genus *Geranium* with special emphasis on the phyto-sociological and conservation status

Primary data on morphology, geographic distribution and flowering and fruiting periods of 27 species of Geranium were collected by consulting flora and herbaria (BSD, BM, CAL, DD, LWG, E, K, L, NY, P). In all, 520 specimens of Indian *Geranium* were examined. Four field tours were conducted to West Himalayas (Kashmir and Himachal Pradesh) and Central Himalayas (Garhwal, Uttarakhand). About 32 localities in 16 districts of these three states were covered during the field survey. Geo-coordinates (latitude/longitude/altitude) of each specimen were recorded. A total of 420 specimens were collected and detailed morphological studies of the following 12 species were completed: *Geranium clarkeii*, *G. himalayense*, *G. lucidum*, *G. mascatense*, *G. ocellatum*, *G. nepalense*, *G. polyanthes*, *G. pretense*, *G. pusillum*, *G. robertianum*, *G. sibricum* and *G. wallichianum* (Fig. 14).

Other Research Achievements:

In-vitro propagation of a saprophytic moss *Splachnum sphaericum* Hedw.

Splachnum sphaericum was reported for the first time in India from Arunachal Pradesh (Fig. 15). The species was found growing on Yak dung. *In-vitro* propagation of this rare and interesting moss was achieved by developing a new protocol (Sahu et al, 2017, International Journal of Plant and Environment, 3(2): 47-50) (Fig. 16). The protocol will be useful for mass propagation and

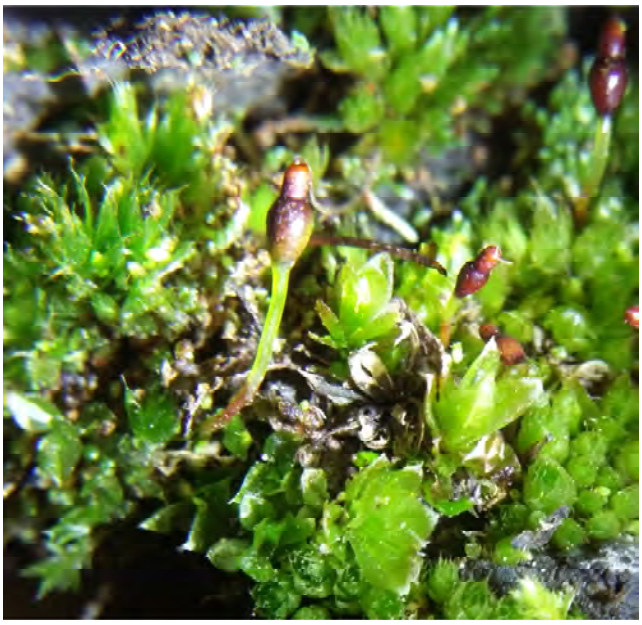

Fig. 15: *Splachnum sphaericum* in nature (source: Sahu et al, 2017, International Journal of Plant and Environment, 3(2): 47-50).

Fig. 14. a. *Geranium himalayense* Klotzsch, b. *Geranium wallichianum* D. Don ex Sweet

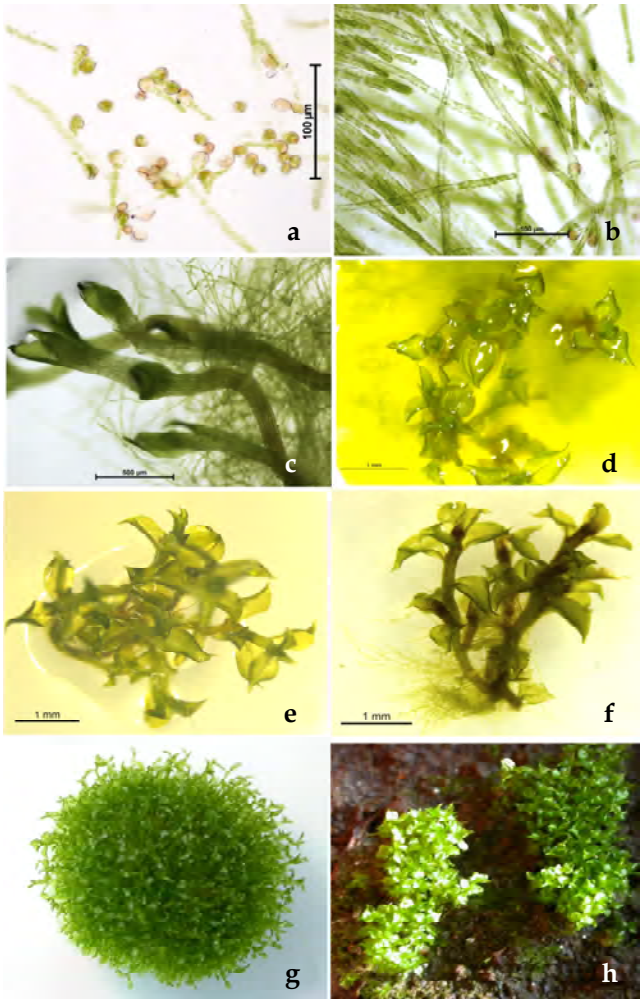

Fig. 16 (a-h): *In vitro* growth and multiplication of *Splachnum sphaericum* a: Germinating spores; b: Protonema. stage; c: Young gametophores produced from caulonema after 30 days; d-f: Development of erect leafy gametophores; g: Dense population of erect plants; h: Plants after transferring on soil in pots (source: Sahu et al, 2017, *International Journal of Plant and Environment*, 3(2): 47-50).

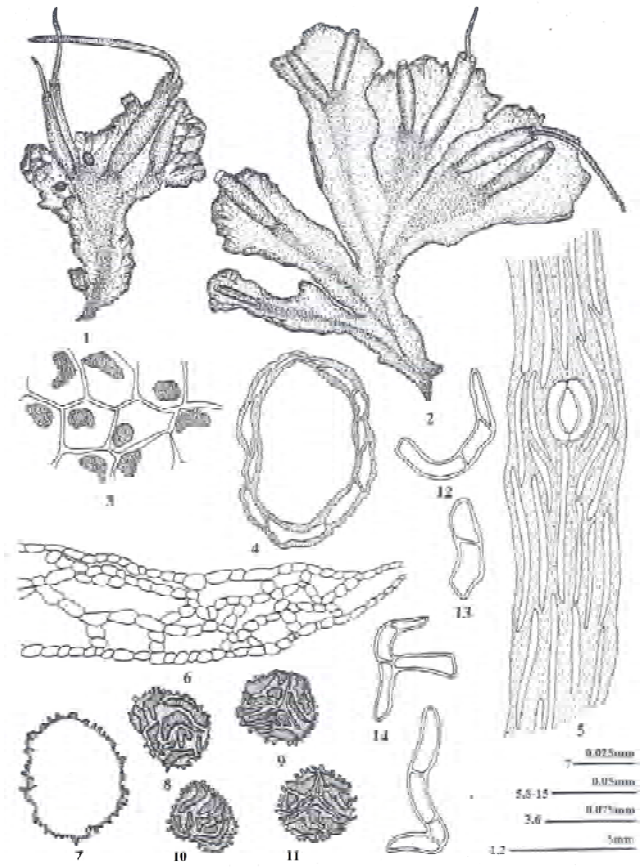

Fig. 17: *Anthoceros macrosporus* Steph. 1-2. Thalli with sporophytes. 3. Epidermal layer of thallus showing chloroplasts. 4. Cross section of involucre. 5. Epidermal layer of capsule wall showing stoma. 6. Cross section of thallus showing mucilage chambers.7. Equatorial view of spore. 8, 10. Distal face of spores. 9, 11. Proximal face of spores with triradiate mark. (Asthana *et al.*, 2017, *Current Science* 113:1830-32)

multiplication of this rare moss, besides aiding study on its growth pattern and morphogenetic attributes.

Conservation status of *Anthoceros macrosporus* Steph. (Anthocerotophyta) *Anthoceros macrosporus* is an endemic and threatened hornwort, known to occur in only a few localities at Borghat and Kasara Ghat in Maharashtra and Saputara and Amba in Gujarat. The conservation status of *A. macrosporus* was assessed using the IUCN Red list criteria. The rarity of this taxon could also be explained from the fact that taxon could not be collected in spite of several plant surveys. As such, the species is presently known from severely fragmented populations at only five inferred sites spread across Maharashtra and Gujarat with an 'extent of occurrence' of less than 5000 km^2 and a highly restricted 'area of occupancy'. Therefore, as per the IUCN Red List categories and criteria version 3.1 (2001), *A. macrosporus* belongs to endangered Category at global level. (Fig. 17).

Reproductive Biology of *Microlepia speluncae* (Dennstaedtiaceae)

Reproductive biology of *Microlepia speluncae* was carried out (Fig. 18). The study revealed that protonema with single rhizoidal initial appears on 10th day of spore sowing. The 4-5 celled filamentous gametophytes develop on 16th day. The semi-spathulate gametophytes develop on 21st day. Spathulate gametophyte develops on 31st day. Semi-cordate gametophyte develop on 42nd day. Cordate gametophyte was formed on 48th day. Female gametangia (archegonia) appeared first below the apical notch region on 54th day. Male gametangia (antheridia) appear on 70th day. Both the gametangia were present on different gametophytes showing dioecious sexuality. As a result of intergametophytic selfing sporophytes developed on 90th day. The gap in sexual expression could be one of the reasons for the population decline of the fern (Fig. 18).

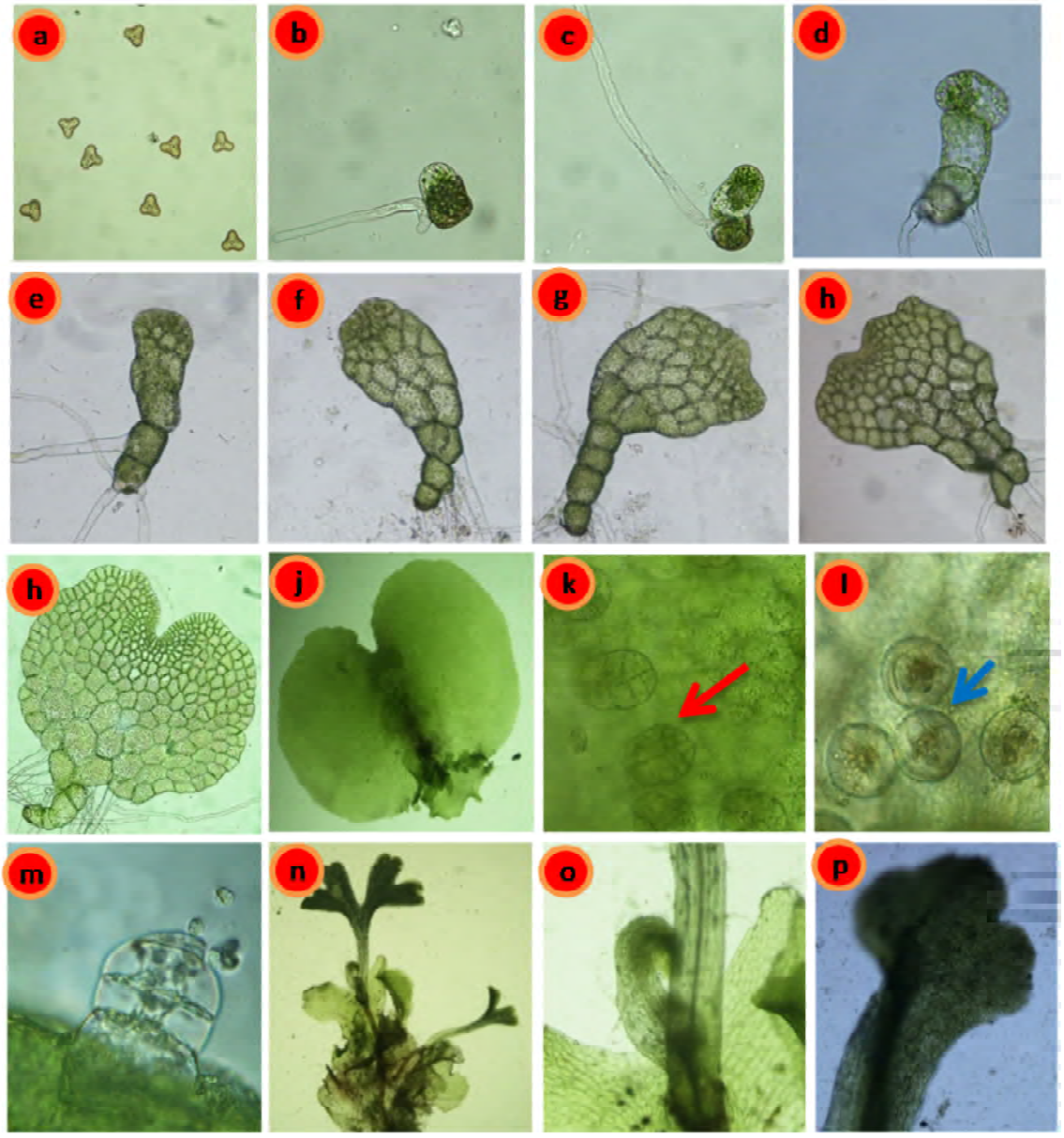

Fig. 18 (a-p): *Developmental stages of Microlepia speluncae: a. Spore; b-c. First Protonemal Initial; d. Filamentous gametophyte (2-4 celled); e. 2-dimensional gametophyte; f-g. Spathulate gametophyte; h. Semi-cordate Gametophyte; i-j. Cordate Gametophyte; k. Archegonia; l. Antheridia; m.Enlarged view of antheridia; n. Sporophyte; o. Initiation of sporophyte; p. Sporophyte.*

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 recognized herbaria of the country and abroad. The herbarium was enriched by incorporating fresh voucher specimens from different phyto-geographic zones and states such as Jammu and Kashmir, Himachal Pradesh, Odisha, Sikkim, Tamil Nadu, Uttarakhand, Uttar Pradesh and West Bengal.

The new additions included 216 specimens of seed plants, 2696 specimens of cryptogamic plants (Pteridophytes-201, Bryophytes-475, Algae-20 and 2000 lichens).

Herbarium Holdings	
Seed plants (Angiosperms and Gymnosperms)	1,03,078
Pteridophytes	6,339
Bryophytes	17,617
Lichens	1,53,500
Algae	2695
Carpological collections	16,000
TOTAL HERBARIUM HOLDINGS	**2,99,229**

Plant Ecology and Environmental Sciences

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PLANT ECOLOGY AND ENVIRONMENTAL SCIENCES

In-House Projects

Monitoring and assessment of pollution and its mitigation through bioremediation

Comparative assessment of PAHs degradation by growing *Zea mays* L. augmented with microbial consortia and fertilizer: modulation in uptake and antioxidant defense response

In order to assess whether the degradation and uptake of polycyclic aromatic hydrocarbon is influenced by growing plants augmented with organic fertilizer and hydrocarbon degrading microbes, Maize plants were grown on PAH contaminated soil under three regimes i.e. i) plants alone, ii) with organic fertilizer, and iii) fertilizer and microbes.

Seed germination in Maize was reduced to 26% when grown in soil contaminated with 1000 ppm PAHs i.e. cocktail of 300µg g^{-1} phenanthrene (PHN), 300µg g^{-1} anthracene (ANT), 200µg g^{-1} pyrene (PYR) and 200µg g^{-1} fluoranthene (FLU) (Fig. 1).

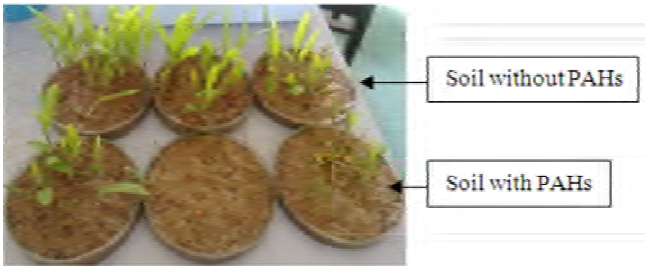

Fig. 1. Maize (n=30 in each Petri dish) germination in petri-dishes having soil supplemented with 1000 µg PAHs g^{-1} soil; (300 µg g^{-1} PHE, 300 µg g^{-1} ANT, 200 µg g^{-1} FLU and 200 µg g^{-1} PYR).

When maize plants were grown in soil contaminated with 1000 ppm PAHs, with / without fertilizer and hydrocarbon degrading microbial combination (MC) (*Pseudomonas* sp. BP10 and *Penicillium* sp. PS10) either in isolation or combination, the maximum reduction in soil PAHs was observed in Soil+PAH+Fertilizer+MC+Plant (PAH-SPFM), i.e., 99.4%, followed by Soil+PAH+Fertilizer+MC (PAH-SFM) (90.8%) and in Soil+PAH+Plant+MC (PAH-SPF)

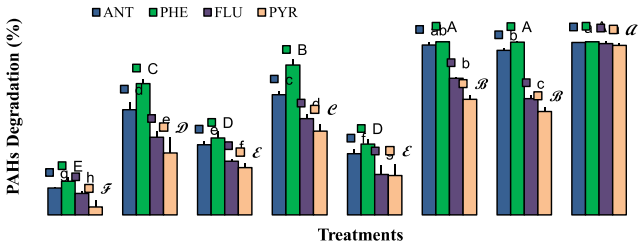

Fig. 2. PAHs degradation (%) in soil. Values marked with same alphabet are not significantly different ($p<0.05$).

(87.1%) while natural degradation of PAHs in soil in the abscence of plant was only 31% (PAH-S) (Fig. 2). The application of both fertilizer (F) and microbes (M) had complementary effect in reducing the soil PAHs (PAH-SPFM) along with plant.

Lipid layer of the root cell wall facilitates the uptake of hydrophobic petroleum hydrocarbons. The lowest PAHs level (µg g^{-1} FW) accumulation in plant tissues were observed in the order of 11.4, 1.2 and ND, in root, shoot and leaves, respectively, when it was grown with combined application of fertilizer and MC (PAH-SPFM). Among the different parts of the plant, highest accumulation of ANT, PHN, FLU and PYR was observed in the roots (22.2, 47.5, 19.4 and 10.3 µg g^{-1}, respectively), followed by shoot (15.4, 29.7, 11.1 and 7.3µg g^{-1}, respectively), while the least was observed in the leaves (8.3, 20.5, 9.7 and 5 µg g^{-1} respectively) in Soil+PAH+Plant (PAH-SP) (Fig. 3).

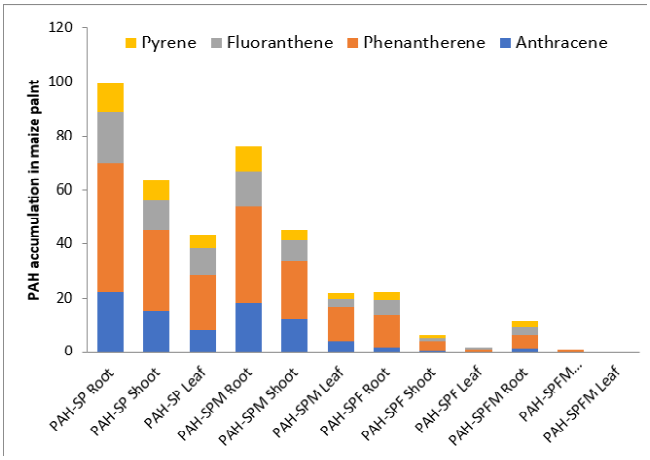

Fig. 3. PAHs accumulation (µg g-1 of FW) in Maize plants parts (root, shoot and leaves) in presence of fertilizer and MC in both isolation

Forest carbon stock assessment and plants for mitigating urban air pollution

Air pollution in urban areas is a major problem. Cumulative exposure to several pollutants enhances toxicity of the air. Green plants are known for their role in attenuation of certain air pollutants and are widely recommended in the form of green belts and urban green spaces for air pollution mitigation.

Nine commonly growing plant species viz., *Azadirachta indica, Bougainvillea spectabilis, Ficus benghalensis, Ficus religiosa, Nerium indicum, Plumeria rubra, Polyalthia longifolia, Tabernaemontana divaricata, Terminalia arjuna* were exposed to ambient ozone (AO_3) and ambient +20 ppb ozone (EO_3) for three months under the FACE facility.

The following parameters were studied in these nine species, namely, air pollution tolerance index (APTI); dust loading capacity; stomatal density, and size and gas exchange parameters.

The average ozone concentrations for experimental periods were 48.59 ppb ozone in AO_3 rings and 69.62 ppb in ozone in EO_3 rings, resulting in approximately 1.4 times higher O_3 levels in ozone treatment. APTI is used to evaluate the susceptibility or resistance level of plants for air pollutants. It uses four parameters, namely ascorbic acid content, total chlorophyll content, relative water content, and leaf-extract pH. These parameters are determined and computed together to obtain the APTI of the plant.

APTI was calculated in all the nine trees grown under ambient and elevated ozone conditions. It was, observed that *Ficus benghalensis*, *Nerium indicum*, *Plumeria rubra*, *Polyalthia longifolia* and *Tabernaemontana divaricata* had higher APTI under elevated O_3 condition (Table 1). In addition, *F. beghalensis* and *Nerium indicum* had maximum dust loading capacity (Table 2).

The stomatal traits under elevated ozone concentration showed that the stomatal density decreased in *Azadirachta indica, Plumeria rubra, Polyalthia longifolia, and Tabernaemontana divaricata* under EO (Table 3), while the guard cell length increased in these species (Table 4). The increase in the guard cell length was probably to compensate the reduction in the stomatal density, to maintain the net photosynthesis rates (Table 5). Our results show that *Ficus benghalensis*, *Nerium indicum*, *Plumeria rubra*, *Polyalthia longifolia* have promising potential for mitigating ozone pollution. Further studies are ongoing.

Table 1. Air Pollution Tolerance index (APTI) values of plants in ambient (A) and elevated (E) ozone

Species	Condition	APTI
Azadirachta indica	A	20.88±4.60
	E	16.70±5.49
Bougainvillea spectabilis	A	16.0±2.00
	E	11.0±0.48
Ficus benghalensis	A	26.32±0.41
	E	29.34±0.24
Ficus religiosa	A	27.07±1.43
	E	25.02±1.40
Nerium indicum	A	16.0±1.15
	E	18.0±0.48
Plumeria rubra	A	24.0±0.88
	E	25.0±0.18
Polyalthia longifolia	A	18.97±3.83
	E	21.52±4.01
Tabernaemontana divaricata	A	19.30±0.79
	E	20.88±0.43
Terminalia arjuna		
	A	15.26±0.77
	E	15.29±0.25

Table 2. Leaf area and dust holding capacity of selected plant leaves

Species	Leaf Area (cm^2)	Dust Holding Capacity ($\mu g\ cm^{-2}\ month^{-1}$)
Azadirachta indica	7.50±0.58	0.93
Bougainvillea spectabilis	14.75±0.96	0.54
Ficus benghalensis	191.83±25.1	1.00
Ficus religiosa	55.50±1.06	0.80
Nerium indicum	14.7±2.06	2.18
Plumeria rubra	102.77±26.3	0.62
Polyalthia longifolia	31.88±4.87	0.30
Tabernaemontana divaricata	12.13±1.03	0.55
Terminalia arjuna	43.50±6.76	0.51

Table 3. Stomatal density (mm^{-2}) of plant species under elevated O_3

Plant species	Ambient O_3		Elevated O_3	
	Abaxial	Adaxial	Abaxial	Adaxial
Azadirachta indica	542±56	-	351±23***	-
Bougainvillea spectabilis	290±29	113±12	270±18*	90±16***
Ficus benghalensis	716±43	-	818±78***	-
Ficus religiosa	240±29	-	250±36^{ns}	-
Plumeria rubra	542±38	90±24	340±30***	54±17***
Polyalthia longifolia	454±46	-	305±31***	-
Tabernaemontana divaricata	303±61	-	200±30***	-
Terminalia arjuna	552±55	-	657±139*	-

P<0.05*, <0.001***

Evaluating effect of ambient ozone on wheat using ethylene diurea

Ozone is a powerful oxidant causing oxidative stress, low stomatal conductance and photosynthesis, accelerated senescence, and a general decrease in plant productivity. An aromatic compound ethylenediurea (N-[2-(2-oxo-l-imidazolidinyl) ethyl]-N-phenyl urea) commonly abbreviated as EDU is used as ozone protectant for plants and tree under open field conditions. As EDU specifically protect plants against ambient O_3, it is very useful to ascertain O_3 effects on field grown plants.

Impact of EDU on growth, physiology, yield and proteome of two wheat varieties differing in O_3 sensitivity was studied. The objective was to gain better insight in to EDU induced changes on leaf protein expression in wheat varieties and their possible biological significance. Two wheat (*Triticum aestivum* L.) varieties Kundan and PBW-343 were selected for the experiments which are widely grown varieties of north-eastern plains of Indo-Gangetic plains. After 15 days of germination plants were sprayed with 200 and 300 ppm EDU till harvesting stage.

Table 4. Guard cell length (µm) in plant species under elevated O_3

Plant species	Ambient O_3	Elevated O_3	Ambient O_3	Elevated O_3
	Abaxial	Adaxial	Abaxial	Adaxial
Azadirachta indica	24.31±0.43	absent	28.81±0.45***	absent
Bougainvillea spectabilis	26.53±0.38	25.46±0.95	28.94±0.52***	27.19±0.99***
Ficus benghalensis	25.48±0.65	absent	22.09±0.55***	absent
Ficus religiosa	24.94±0.67	absent	22.03±0.62***	absent
Plumeria rubra	21.00±0.95	25.06±0.98	25.00±0.82***	26.73±0.78***
Polyalthia longifolia	23.47±0.35	absent	28.59±0.49***	absent
Tabernaemontana divaricata	24.10±0.52	absent	27.41±0.51***	absent
Terminalia arjuna	22.54±0.32	absent	19.98±0.47***	absent

P<0.001***

Table 5. Gas-exchange studies in selected species

Plant Species	Net CO_2 assimilation (µmol m^{-2} s^{-1})		Rate of transpiration (mmol m^{-2} s^{-1})		Stomatal conductance (mmol m^{-2} s^{-1})	
	Ambient O_3	Elevated O_3	Ambient O_3	Elevated O_3	Ambient O_3	Elevated O_3
Azadirachta indica	19.10 ± 0.93	6.70 ± 0.72***	4.03 ± 0.64	6.83 ± 0.93	248 ± 39	462 ± 56
Ficus benghalensis	17.19 ± 0.24	13.98 ± 0.67***	6.11 ± .44	2.23 ± 0.22	327 ± 28	139 ± 13
Ficus religiosa	15.72 ± 0.53	11.76 ± 0.95**	7.44 ± 1.14	5.13 ± 1.03	576 ± 72	268 ± 70
Nerium indicum	13.48 ± 2.17	10.54 ± 0.80^{NS}	4.91 ± 0.60	7.29 ± 0.88	280 ± 27	431 ± 91
Plumeria rubra	12.91 ± 0.70	16.20 ± 0.79**	6.63 ± 0.95	6.36 ± 0.54	373 ± 59	390 ± 38
Polyalthia longifolia	8.94 ± 0.63	4.63 ± 0.34***	5.88 ± 1.38	1.93 ± 0.37	290 ± 79	102 ± 17
Terminalia arjuna	19.45 ± 0.68	16.59 ± 0.72**	6.00 ± 0.78	4.95 ± 0.71	433 ± 35	275 ± 43

P<0.01**, <0.001***

Average ambient ozone concentration during the experiment was 60 ppb. It ranged from 15 to 100 ppb during experimental period (Fig. 4).Foliar injuries in terms of interveinal chlorosis and chlorotic stippling were first observed on adaxial surface of non-EDU treated leaves of Kundan (Fig. 5). Photosynthesis, fluorescence and chlorophyll content did not show any significant change due to EDU treatment in both the varieties. The extent of lipid peroxidation (measured as MDA equivalents) was lower in both the EDU treated varieties than non-treated ones. All the antioxidative enzymes showed significant variation due to EDU treatment in both the varieties at both the stages. There were variety specific variations in yield parameters, while EDU treatment only impacted 1000 grain weight. Significant increase in 1000 grain weight was observed in K1 and K2 (Table 6). One way ANOVA analysis showed increase in spike length in P1 and P2 at harvest stage.

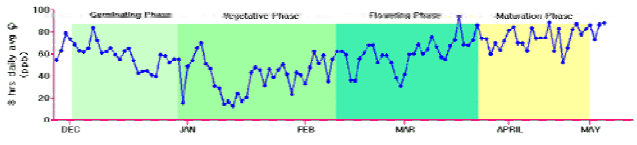

Fig. 4. Daily ozone concentrations (8 hrs daily average) during the study period. The different phases for wheat growth shown in coloured boxes, and dots denote the date of the month.

It was interesting to note that Kundan showed massive protein changes (more at vegetative stage) than PBW 343 at both EDU treatments. In Kundan (among 92 identified proteins) about 50% proteins were more in abundance and 20% less in abundance at vegetative

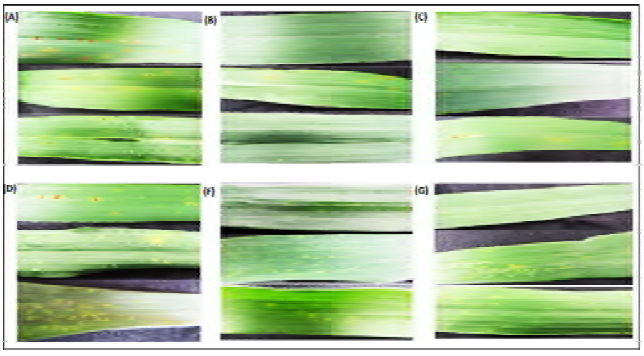

Fig. 5. Injury profile in leaves of wheat (*Triticum aestivum* L.) at 70 DAG

stage while at flowering stage (among 92 identified proteins) the percent increase/decrease was 25%/18%, while in PBW 343 (99 proteins-vegetative and 87 proteins-flowering), only about 15% proteins were more in abundance and 20% proteins were less in abundance at both the stages. In photosynthesis category seven proteins were identified and these proteins showed variable response, e.g., Rubisco LSU was both up and down regulated in response to EDU. Moreover, Oxygen evolving enhancer (OEE) protein was more abundant in Kundan at vegetative stage while it was more abundant in PBW 343 at flowering stage. Cyt b6f protein was more in Kundan while less abundant in PBW. Out of 14 proteins related to carbon metabolism, Fructose bis phosphate aldolase (FBPase), hydrolase, Rubisco activase and glyceraldehyde-3 phosphate dehydrogenase (GAPDH) were differentially expressed. In energy metabolism, ATP synthase beta subunit was less abundant in Kundan while more abundant in PBW.

In antioxidant defense, germin like protein was more in Kundan and less in PBW.

The above results clearly showed that prevailing O_3 concentrations around Lucknow unfavorably impacted both wheat varieties and that EDU is a good research tool to assess ozone toxicity in crops under natural field conditions.

Table 6. Mixed model annova results for harvest and yield parameters

S.No.	Parameters	(Cv)	(Trt)	(Cv*Trt)
1	Shoot weight	0.02 (*)	0.22 (ns)	0.39 (ns)
2	Spike Length	0.000 (***)	0.17 (ns)	0.12 (ns)
3	Spikelet No.-Spike^{-1}	0.000 (***)	0.01 (**)	0.30 (ns)
4	Inflorescence wt Pt^{-1}	0.02 (*)	0.17 (ns)	0.22 (ns)
5	Grain No. Pt^{-1}	0.000 (***)	0.13 (ns)	0.18 (ns)
6	Grain wt Pt^{-1}	0.002 (**)	0.30 (ns)	0.37 (ns)
7	1000 Grain wt	0.000 (***)	0.000 (***)	0.08 (ns)
8	Harvest Index	0.008 (**)	0.85 (ns)	0.82 (ns)

P<0.05*, <0.01**, <0.001***

Optical properties and pigment concentration as an indicator of drought stress in Guar (*Cyamopsis tetragonoloba* (L.) Taub.)

The aim of the study was to evaluate the responses of guar varieties to changes in leaf reflectance spectroscopy under drought and watered condition. These were then, simultaneously analysed to detect possible physiological and pigment alterations in water-stressed leaves of guar.

Three varieties of Guar namely RGC-1002, RGC-936 and RGC-1066, were subjected to eight days of water stress. The physiological characteristics of gas exchange, pigments and, the spectral properties of the leaves were monitored and assessed.

Leaf optical properties

The guar leaf showed major changes in visible and near infrared regions of the spectra on different days of desiccation in the RGC-1002, RGC-936 and RGC-1066, varieties of guar. The reflectance and scattering coefficient increased in the visible range between 500 and 750nm of spectra under drought stress (Fig. 6). Transmittance also showed increasing pattern under water stress condition (Fig. 6a, b, c). From these spectral studies, further observations such as scattering and absorbance coefficient were also calculated which provides the physiological state of the plant under stress. The scattering coefficient increased (Fig. 6d, e, f), due to shrinking and loss of water content of the cells. While, absorption coefficient becomes narrower and decreases with increase in days of desiccation in the visible spectrum (Fig. 6g, h, i).

From the reflectance spectra, we also calculated different spectral reflectance indices such as Photochemical reflectance index (PRI), Plant senescence

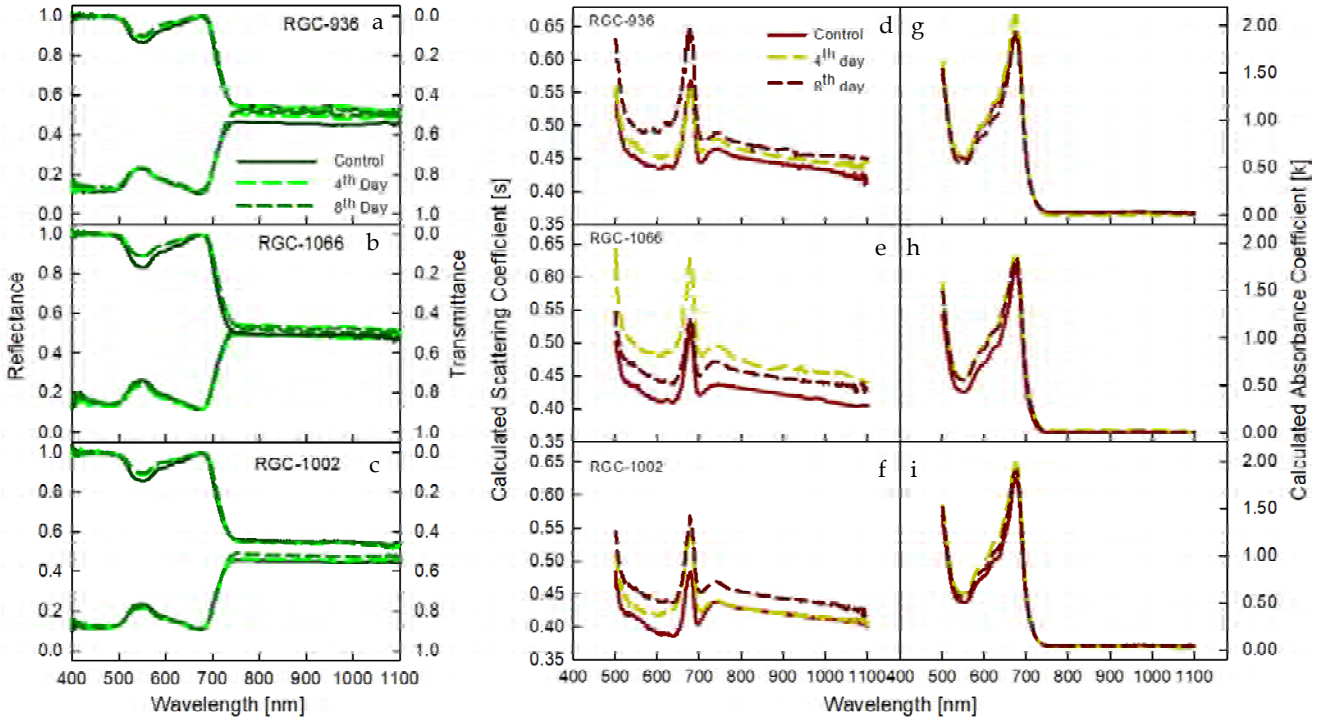

Fig. 6 (a-i): Variations in reflectance and transmittance due to drought of the adaxial surface in leaves of Guar varieties, RGC-936 (*a*), RGC-1066 (*b*), and RGC-1002 (*c*). The Changes in Scattering coefficient, s (*d–f*), and variation in absorption coefficient, k (*g–i*), in the three varieties of Guar under water stress. Each trace is average of five independent leaves.

reflectance index (PSRI), Normalized Difference Vegetation Index (NDVI), and modified red edge normalized difference vegetation index (mNDVI). These provide information about the functional and pigment changes in the leaves during drought stress. These narrowband, greenness vegetation indexes are a combination of reflectance measurements sensitive to the combined effects of foliage chlorophyll concentration, canopy leaf area, etc. These are, designed to provide a measure of the overall amount and quality of photosynthetic material in vegetation, which is essential for understanding the state of vegetation. All varieties showed an increase in NDVI and mNDVI under drought stress, but RGC-1002 showed maximum increase by a fold of 1.21 and 1.26 respectively in both the indices (Fig. 7*a*, *b*). The PRI showed a significant increase of 1.24 fold in RGC-1002 and 1.17 fold in RGC-936 while in RGC-1066 it showed no significant change

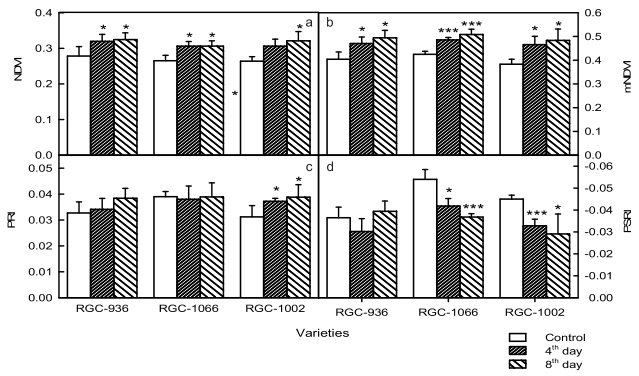

Fig. 7. Variations in reflectance indices due to drought. normalized difference vegetative index, NDVI (a), modified normalized difference vegetative index, mNDVI (b), Photosynthetic reflectance index, PRI (c), and plant senescence reflectance index PSRI (d). Data represent the means ± SD of five separate measurements. Statistical significance are indicated as (* P<0.05) and (*** P<0.0001).

under drought stress (Fig. 7*c*). RGC-936 showed enhancement in PSRI under drought condition due to chlorophyll degradation and drought induced senescence (Fig. 7*d*). The Plant Senescence Reflectance Index (PSRI) is, designed to maximize the sensitivity of the index to the ratio of bulk carotenoids to chlorophyll.

The physiological attributes and optical studies, showed, RGC-1002 to be drought tolerant among the three varieties studied. RGC-1002 exhibited higher photosynthesis and stomatal conductance rates, a higher percentage of RWC, and lesser membrane damage. A significant correlation was, found between spectral reflectance and pigment concentration of the three varieties of guar. The study suggests that leaf spectral measurements along with the photosynthetic characteristics, can be used as, a tool for screening large populations to review the physiological status of the plants more easily, rapidly and in a non-destructive way.

Grant-In-Aid Projects

Development of bio-augmentation based safe cultivation practice for remediating arsenic contamination to paddy crop.

Reconnaissance of highly arsenic contaminated sites in the state of West Bengal has been done and three sites viz., Gotera and Ghetugachhi in Chakdah Block of Nadia District and Pipligram in Gaighata Block of North 24 Parganas have been selected for conducting multilocation trials. Detailed soil characterization for physico-chemical properties and enzyme analysis along with soil arsenic fractionation has been done.

The compatibility assay among four novel arsenic remediating soil fungal strains *Westerdykella* sp. (FNBR_3, MTCC 10845, NCBI gb# JN118571), *Trichoderma* sp. (FNBR_6, MTCC 10846, NCBI gb# JN102303), *Lasiodiplodia* sp. (FNBR_13, MTCC 10847, NCBI gb# JN118572), and *Rhizopus* sp. (FNBR_19, MTCC 10848, NCBI gb# JN118573) has been done for preparing their consortium.

These four soil fungal strains exhibited different plant growth promotion traits viz., phosphate solubilization (FNBR_19), siderophore production (FNBR_3), ACC deaminase activity (FNBR_6 and FNBR_13), auxin (FNBR_3).

Carriers and additives have been screened for ensuring viability of fungal strains in consortium.

In the Boro- and Aman- Rice trials for the year 2017, three treatments were given viz., the control (without any treatment) T_1 fungal consortium application to paddy crop T_2 fungal consortium to paddy crop along with soil treatment T_3. Four locally-grown rice varieties were selected for the trials viz., IR-36, Triguna, Khitiz and Lalat, which were found to be arsenic accumulating in our earlier studies.

In the context of rice growth promotion, length (cm) of root, shoot, panicle and flag leaf were increased and ranged 22-25%, 4-5%, 11-23% and 12-32%, respectively in T3 compared to T1 at three sites. Numbers of tillers, panicles and spikelets were also enhanced and ranged 13-17, 15-20 and 19-27, respectively in T3 compared to T1 at three sites. Yield parameters viz., weight (g) of 1000 seeds (filled+unfilled), weight of filled seeds (with husk) and weight of grains (without husk) significantly increased and ranged 10-17, 16-35, 18-36, respectively. Rice yield per sq. m. enhanced with a range of 2-3% in the case of T3 compared to T1.

The rhizospheric cfu enhanced with a range of 7-15% in T3 compared to the control and confirmed the effect of treatment. Ergosterol estimation in the

rhizospheric soil samples was done for detailed confirmation of fungal live biomass increase upon treatment. The ergosterol in samples of T3 found 140% higher compared to T1. The arsenic content (mg/kg) in rice grains reduced with a range of 24-54% upon T3 compared to T1, whereas reduction observed in husk by 26-36%, in tillers by 39-64% and in roots 41-58%. The bioavailable soil arsenic fraction in the rhizosphere soils was also reduced with a range of 30-41% at three sites under the trials.

Monitoring and assessment of arsenic pollution in arsenic prone districts of Uttar Pradesh.

The official reports available with Uttar Pradesh Jal Nigam (potable water), Central Groundwater Board (piezometric heads) and Geological Survey of India (India Mark-II handpumps) were consulted for the identification of Arsenic hot-spot areas in 20 districts in U.P (Fig. 8).

The project staff were trained for field sampling, standard methods of analysis of samples, and Q-GIS for developing administrative block-wise map of each districts and overlaid grid of 2x2 km for geo-tagging of field sampling sites. RSAC, Govt. of U.P. has been contacted to provide geo-portal for tagging of project data of arsenic mapping, which will be available for Dept. of Agriculture, Govt. of U.P. Field survey has been done at 20 project districts covering 264 blocks during the rabi cropping season.

Sampling of the standing crops such as food crops, vegetables, spices in the rabi cropping season has been done. Field survey at 20 project districts for sampling of groundwater and agriculture soil samples irrigated by the same water was carried out. Sampling of feed-water and feedstock has also been done.

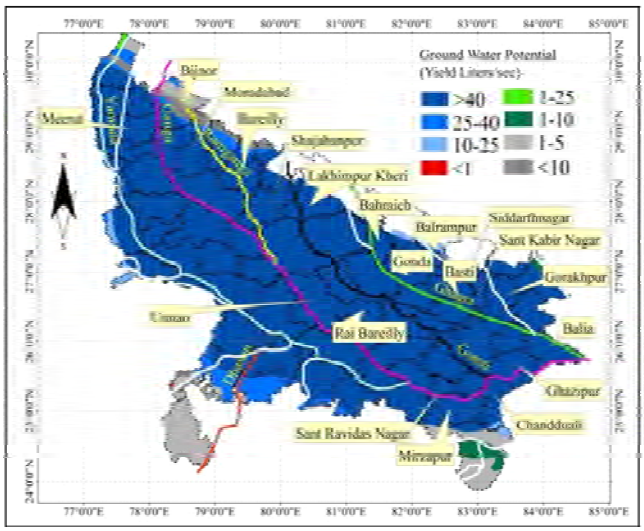

Fig. 8. Twenty districts of Uttar Pradesh undertaken for arsenic mapping.

Analysis of key soil parameters (physico-chemical, microbiological and enzyme affecting arsenic loading in soils) and arsenic contents in the sampled groundwater, agriculture soils and crop/ vegetable samples was done.

Low arsenic rice grain variety for safer human consumption

The low grain rice cultivar (CN1794-2-NBRI-Muktashree) jointly developed by CSIR-NBRI and RRS, Chuchura, was cultivated in West Bengal across a concentration gradient of arsenic contamination. The low contaminated site was selected in Khamargachi, (Dist: Hoogly), Medium in Birnagar (Dist: Nadia) and highest in Gaighata (Dist: 24 parganas) for *Aus* (pre kharif) and *Aman* (Kharif) season (Fig. 9).

Fig. 9: Field trials of the rice cultivar CN1794-2-NBRI across the arsenic contamination gradient

The cultivation and harvest of the three rice cultivars (Muktashree, Gotra bidhan-1 and Shatabdi) for the *Aus* and *Aman* season was completed (Fig. 10). There was an overall variation between the two seasons and between the different locations. The grain arsenic level (µg kg^{-1}) in CN1794-2-NBRI (Muktashree) was higher (251.65±5.81) than Gaighata (Dist: 24-pargonas) than the Birnagar (48.38±0.15) (Dist: Nadia) and Khamargachi (113.49±1.74) (Dist: Hoogly) during Aus season. During Aman season the level in CN1794-2-NBRI (Muktashree) at Gaighata, Birnagar and Khamargachi was 73.45±0.18, 38.28±2.46 and 80.62±0.14, respectively.

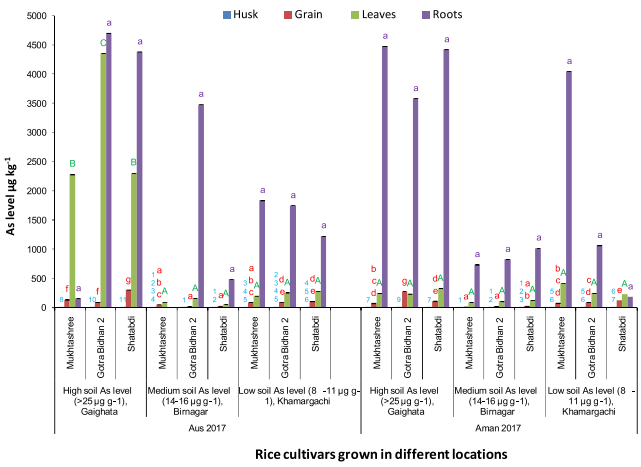

Fig. 10. Arsenic content in the different parts of rice plants, grown at three different locations during Aus and Aman 2017

Table 7. Grain yeild of the three cultivars, viz CN-1794-2-NBRI (*Muktashree*), *Gotra Bidhan*-1 and *Shatabdi* cultivated in high, medium and low soil as contamination location of West-Bengal for *Aus* and *Aman* seasons

		Aus 2017			*Aman* 2017		
		Muktashree (CN-1794-2-NBRI)	Gotra Bidhan-2	Shatabdi	Muktashree (CN-1794-2-NBRI)	Gotra Bidhan-2	Shatabdi
High soil As level (>25 µg g^{-1}) Gaighata	Area (sq. m)	350	350	280	300	300	450
	Yield (tons/ha)	**3.0**	**3.25**	**2.5**	**3.6**	**4.5**	**2.7**
Medium soil As level (14-16 µg g^{-1}) Birnagar	Area (sq. m)	600	400	400	400	400	300
	Yield (tons/ha)	**2.8**	**3.0**	**2.4**	**2.4**	**4.5**	**3.0**
Low soil As level (8-11 µg g^{-1}) Khamargachi	Area (sq. m)	300	300	350	300	400	300
	Yield (tons/ha)	**2.9**	**3.5**	**3.0**	**3.6**	**3.5**	**3.0**

For *Boro* season, beginning January 2018, additional trial sites were included by RRS for multi-location trials using seeds of CN-1794-2-NBRI grown in non-arsenic areas.

The yield of Muktashree in Khamargachi for the Aman season (3.6 t ha^{-1}) was higher than that of Aus (2.9 t/ha) (Table 7).

In order to verify, whether the trait of the cultivar accumulating low arsenic, is due to the environmental pressure or inherent character, seeds of *Muktashree* obtained from cultivation in the non-arsenic contaminated area of North Bengal (*Boro* season 2018), will be grown in a gradient of As contamination from low to high arsenic contaminated region (*Aman* season 2018).

We would be able to validate, whether the ability to accumulate lesser amount of arsenic in the seeds of *Muktashree* growing in the As contaminated region has developed under selection pressure or it has inherent capability to accumulate lesser arsenic in the grains.

Biofortification of essential metal nutrients (Fe, Zn) in *Oryza sativa* L. through microbes

Zn solubilizing microbial strains were isolated from soil samples collected from various places, on the basis of qualitative and quantitative assay along with growth on soluble Zn source. Selected strains were also characterized for siderophore, P solubilization and auxin production (Table 8). Strains having common characteristics along with plant growth promotion in soil conditions were selected (Ban 9, P2.21, D2.8, D2.1, D1.4, D1.20, D1.16, D1.17, D1.2 and D2.16).

Table 8

Sites	P soluluzation (%)	Auxin (%)	Siderophore (%)
Bulandshehr	58.13	41.86	27.90
Haryana	-	100	-
Devkhera	96.77	96.77	74.19
Punjab	33.33	66.66	-
Banthara	-	100	66.66
Imphal	-	100	-
Shillong	100	100	-

Selected strains were characterized for Zn solubilization ability using $ZnPO_4$ as insoluble source of Zn. The metal estimation was performed in the supernatant after 3rd, 5th, 7th and 10th day of inoculation of strains through atomic absorption spectrometer, that showed different levels of Zn solubilization in the supernatant (Fig. 11 a).

Among the nine strains obtained, three strains namely, D2.16, D1.20, D1.2 exhibited high Zn solublization (185.73 µg ml^{-1} to 228.55µg ml^{-1}) followed by D2.1, D1.16 and D2.8 as moderate Zn solublization (204.13 µg ml^{-1} to 155.07 µg ml^{-1}) and Ban 9, D1.17 and P2.21 as lowest (131.73 to 31.6 µg ml^{-1}).

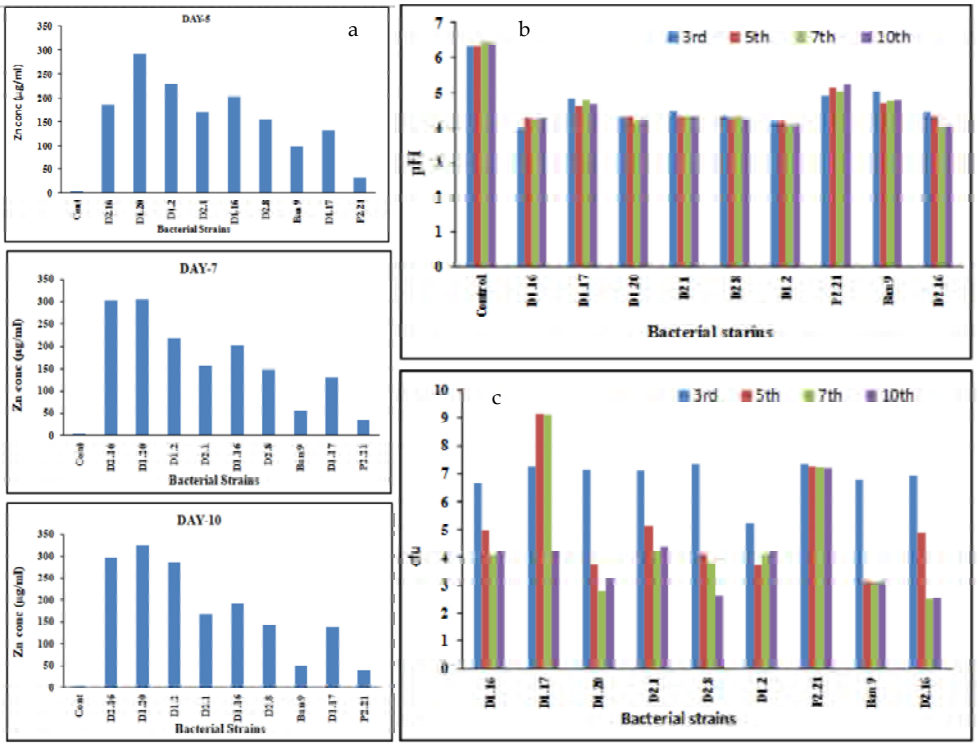

Fig. 11. (a) Solubilized Zn in the medium supernatant, (b) pH of the supernatant, (c) growth of the selected strains in the medium supplemented with insoluble source of Zn as $Zn(PO_4)_3$.

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

In the environment, the chemicals interact simultaneously with the plant through air or water. The plant-chemical interactions of a chemical generally represent the partitioning of organic compounds between a cuticular matrix of the plant, and either air or water. In the atmosphere, if a compound can find their way into vegetation, they can pass from there into the human food chain. In view of the large number of chemicals being manufactured and used today, it is an extremely difficult task to measure the experimental partition coefficient values for all of them and for the new chemicals added every day to the list, thus necessitating for some reliable alternative methods. The multivariate random forest (mvRF) algorithm offers an opportunity for the multi-target (mt) quantitative structure activity relationship (QSAR) analysis and establishes relationships between multiple predictors and dependent variables, and can accommodate multiple outcomes simultaneously.

Multi-target data set of 63 volatile organic chemicals (VOCs) were collected from literature and considered here for mt-QSAR analysis. The collected experimental data considered were, water-plant cuticular polymer matrix membrane partitioning (log K_{MXw}), air-plant cuticular polymer matrix membrane partitioning (log K_{MXa}), in *Lycopersicon esculentum* Mill. and gas-water partition coefficients (K_{aw})values of VOCs. One and two dimensional (n=3839) molecular descriptors were calculated for all the VOCs. The relevant descriptors for the mt-QSAR modeling were selected from the pool of calculated molecular descriptor using the model-fitting approach. For mt-QSAR modeling, the data were split into the training and test subsets using random distribution approach.

In mvRF dealing with multiple response output, the multivariate node cost is calculated as the difference between a sample point and the multivariate mean distribution. The multivariate node cost can be calculated as the sum of the squares of the Mahalanobis distances. Mahalanobis distance captures the distance of the sample point from the mean of the node along the principal component axes. The selection of the node splitting feature from a random set of features decreases the correlation between different trees and thus, the average response of multiple regression trees is expected to have lower variance than individual regression trees. A conceptual diagram of mvRF is shown below (Fig. 12).

From our results the mt-QSAR model successfully predicted the plant-chemical interaction of diverse chemicals, simultaneously covering with wide chemical classes with different functional groups (Allylic/Vinyl Nitriles, Epoxides, Esters, Neutral Organics, Phenols, Vinyl/Allyl Halides). The proposed mt-QSAR model developed here would help to generate data on plant-chemical interactions, which are required for the risk/safety assessment of the chemicals with highly reduced efforts, time and computational costs.

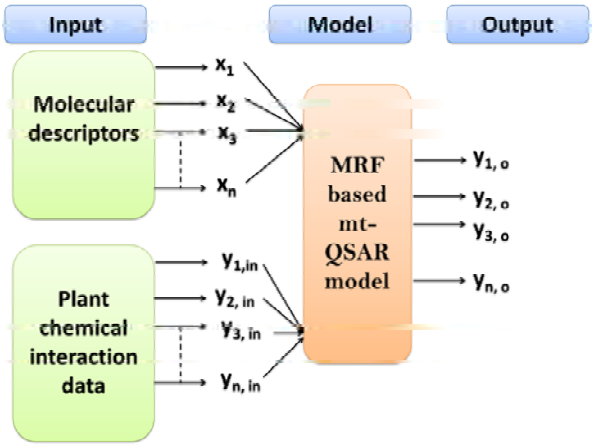

Fig. 12: Conceptual diagram of the mvRF based mt-QSAR modeling approach

Assessment of Fluorine and Chromium in soil, plants and water in and around the Unnao region of UP

Fluorine is an essential element required in trace amounts but becomes toxic for human beings by consuming drinking water having more than 1.0 mg F^- L^{-1}. Fluoride (F^-) is widely distributed in all components of environment, air, soils, rocks, and plant and water. The problem of fluoride contamination in Unnao region has been earlier reported by many researchers but they mostly found it confined to the underground water. The study area was within the Unnao Distrct (Fig. 13). Fluoride level of surface water in study area was found below the threshold limit (1.0 mg F^- L^{-1}) (Fig. 14). It was also observed that the F^- content in the ground water was directly influenced by the pH value, as the water samples having pH value more than 7.9 also showed F^- content in it. However, the high concentration of F^- i.e., beyond the maximum permissible limit, may cause fluorosis disease if used for drinking purposes without treatment. It has been observed that in Jajmau and Jargaon village the concentration of F^- in the ground water is below the minimum desirable limit 0.6 mg L^{-1} which may cause dental caries while ground water of other sites i.e., Pathakpur, Sarsakheda and Methi Tikur contain more than permissible limits (1 mg L^{-1}). In case of surface water, highest F^- content was observed in Sarsakheda (0.84 µg g^{-1}) followed by Jajmau (0.81 µg ml^{-1}). Highest F^- content in soil was also reported for Sarsakheda (1.7) followed by Jajmau (0.9 µg g^{-1}).

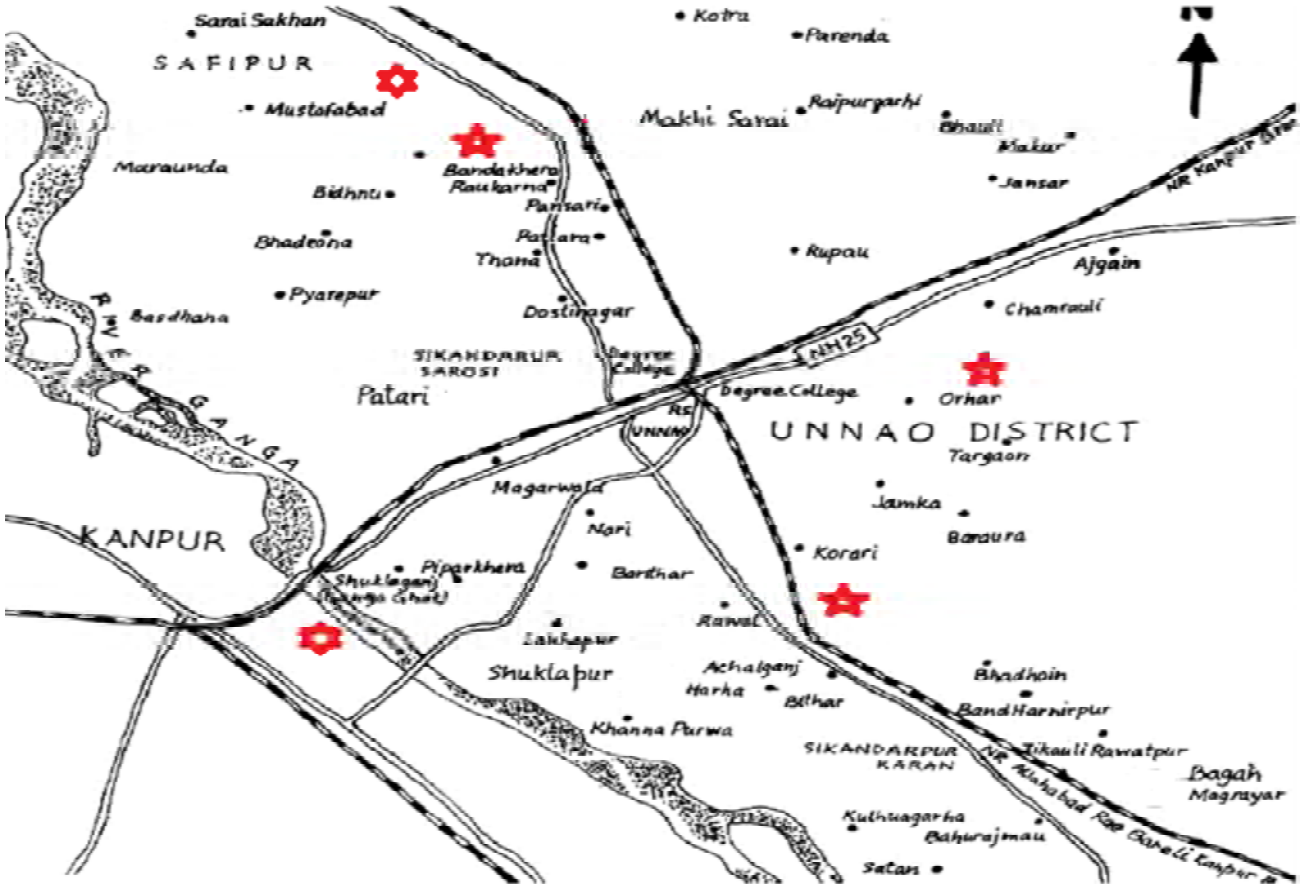

Fig. 13. Schematic map showing the locations of sampling within the Unnao district

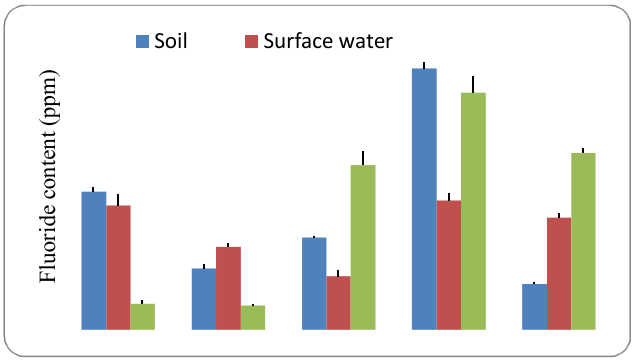

Fig. 14. Level of F^- in the different matrices of environment samples from different locations of Unnao.

Role of micro-climate in soil carbon sequestration in two Pulses in Indo-Gangetic Plains of Uttar Pradesh

Field trial for 8 varieties of Chickpeas (*Cicer arietinum)* (HK94-134, JG -11, PANTG -186, Radhey, Avrodhi, Shubhra, Ujjawal and DCP-92-3) were conducted at farmers field at Ujaresta village, Banda district of Uttar Pradesh during 2016-2017.

Leaf Area Index (LAI)

Maximum Leaf Area Index (LAI) was observed in Radhey variety with an average value of 1.43 (ranged between 1.28 - 1.58), followed by Avarodhi with an average value of 1.38 (ranged between 1.02 - 1.44).

Above ground biomass

Above ground biomass (AGB) was highest in the variety Radhey (39.76 ± 3.88 g/plant), followed by Avrodhi (30.33 ± 2.64 g/plant), Shubhra (25.83 ± 3.07 g/plant) and DCP-92 (24.66 ± 1.68 g/plant), respectively.

Physiological efficiency measurements

Out of the 8 *Cicer* varieties screened for physiological efficiency, highest CO_2 assimilation rates were observed in variety Radhey (23.71 ± 1.52 µmol m^{-2} s^{-1}) and lowest rates in PANTG-186 (13.39 ± 1.36 µmol m^{-2} s^{-1}). Avarodhi (23.21 ± 1.23 µmol m^{-2} s^{-1}) and Shubhra (19.71 ± 2.89 µmol m^{-2} s^{-1}) *Cicer* varieties were second and third in terms of carboxylation rates.

Leaf stomatal conductance (G) which are tightly linked to assimilation rates were also highest (0.21 ± 0.006 mol H_2O $m^{-2}s^{-1}$) for Radhey while PANTG variety had lowest G (0.11 ± 0.003 mol H_2O $m^{-2}s^{-1}$) which also matched their low assimilation rates. Leaf transpiration values were highest for Avarodhi (7.4 ± 0.41 mmol $m^{-2}s^{-1}$) variety of *Cicer arietinum*.

Seed yield was maximum in Radhey (23.5 q/ha) followed by Avrodhi (20.3 q/ha) and Shubhra (17.8 q/ha).

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GENETICS AND MOLECULAR BIOLOGY

In-House Projects

A novel *OsDHN-FKBP* complex triggers ABA responsive signalling to impart drought tolerance in rice

Dehydrins (DHNs) have been reported to act as chaperones to combat drought stress. In this study, we explored a novel nuclear complex of *Oryza sativa FKBP* and SK2 type dehydrin (*OsDhn-Rab16D*), associated with ABA signalling to impart drought stress tolerance. The transcript levels of *OsDhn-Rab16D* in rice seedlings were induced in response to drought, abscisic acid (ABA) and H_2O_2 exposure. Ectopic expression of *OsDhn-Rab16D* in transgenic lines showed enhanced tolerance to drought stress (Fig. 1). Using the yeast two-hybrid (Y2H) assay, *O. sativa FKBP* (a prolyl cis-trans isomerase) was identified as an interacting partner of *OsDhn-Rab16D*. qRT-PCR of drought and ABA-responsive genes reveals the higher transcript abundance in PEG-treated transgenic lines. Moreover, under drought conditions, transgenic lines maintain membrane integrity and increase the lignification in adventitious rice roots (Fig. 2) due to the higher expression level of catalase and lignin biosynthesis enzyme, respectively, as compared to the wild-type. Overall, our findings suggest that *OsDhn-Rab16D* and *OsFKBP* complex is involved in ABA-mediated drought stress signalling in rice and probably act as a positive transcriptional co-regulator, in addition, to act as chaperones.

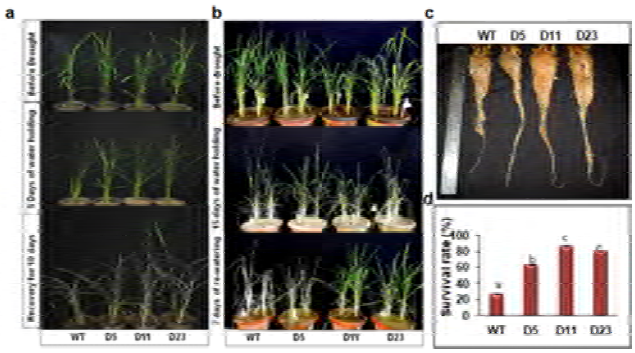

Fig. 1. *OsDhn-Rab16D* over-expressing plants cope up under drought stress in simulated pot experiments: Transgenic lines over-expressing of *OsDhn-Rab16D* and wild-type plants grown under controlled conditions for 30 days - **(a).** 5 days of water, withholding and plants are recovered for ten days **(b).** 15 days of water, withholding and plants are recovered for seven days **(c).** Change in root morphology of wild type and dehydrin over-expressing lines after survival from drought stress **(d).** The survival rate of wild type and *OsDhn-Rab16D* lines after revival for seven days in a simulated pot experiment.

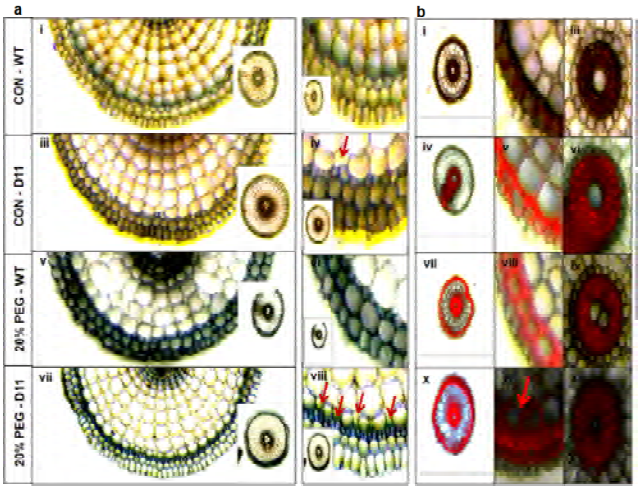

Fig. 2. *Oryza sativa* class III peroxidase (*OsPRX38*) overexpression in *Arabidopsis thaliana* reduces arsenic accumulation due to apoplastic lignifications Effect of PEG-6000 on the anatomy of the root architecture of *OsDhn-Rab16D* expressing lines and wild-type in hydroponic condition: **(a).** Influence of 20% PEG on the anatomy of root cross section of WT and highest over-expressing line D11 within 24 hours. Presence of passage cell beneath the sclerenchyma layer is marked with red arrow **(b).** Lignification of sclerenchyma layer and stele region of adventitious rice roots of plants grown in nutrient solution without PEG and with 20%PEG. Lignification in cortex cells is marked with red arrow. Scale bars=400µm.

Oryza sativa class III peroxidase (*OsPRX38*) overexpression in *Arabidopsis thaliana* reduces arsenic accumulation due to apoplastic lignifications

Class III peroxidases are multigenic plant-specific peroxidase enzymes. They are involved in various physiological and developmental processes like cell elongation, auxin catabolism, cell metabolism, various biotic, abiotic stresses and lignification. In the present study, we identified a class III peroxidase (*OsPRX38*) from rice, which excessively increases its expression under arsenic (As) stress. The over-expression of *OsPRX38* in *Arabidopsis thaliana* significantly enhances As tolerance by improving root biomass, increasing antioxidant activity and decreased ROS accumulation leading to more viable cells (Fig.3). *OsPRX38* overexpression also affects the plant growth by increasing total biomass and seeds production in transgenics than WT under As stress. Transgenics lines showed less As accumulation than WT when treated with As. In addition, lignification was positively correlated with an increase in cell-wall-associated peroxidase activities in transgenic plants, indicating the role of *OsPRX38* in lignin biosynthesis. The reason behind low As accumulation in transgenic lines is due to the accumulation of lignin in the apoplastic region of root cell (Fig. 4). The study indicates that overexpression of *OsPRX38* in *Arabidopsis thaliana* activates the

signalling network of different antioxidant systems under As stress condition, enhancing the plant tolerance by reducing As accumulation due to high lignifications.

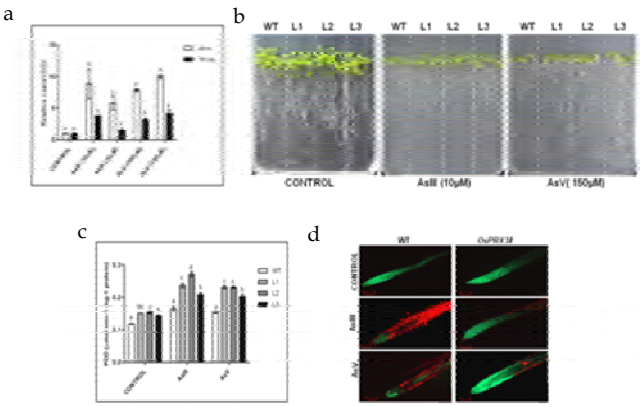

Fig. 3. Increased As tolerance due to high antioxidant activity and low ROS (Reactive oxygen species): **(a)**. qRT-PCR expression analysis of *OsPRX38* gene under control and As (AsIII and AsV) stress in root of *O. sativa* cv. Nipponbare hydroponics on 24 hrs and 7th day; **(b).** 12days old seedling phenotype of WT and *OsPRX38* transgenic lines grown on ½ Murashige and Skoog (MS) medium with AsIII (10μm) and AsV (150μm) respectively; **(a)**. Peroxidase activity (POD) performed from total protein extracted from 12 days old seedlings of WT and *OsPRX38* transgenic lines; **(d)**. Visualisation of viable (green) and non-viable (red) cells in roots of 12 days old seedlings using confocal microscopy. Scale bar =100μm. Data are mean ± SE (n = 3). Different letters above bars represent significant difference at P < 0.05 according to Duncan's test.

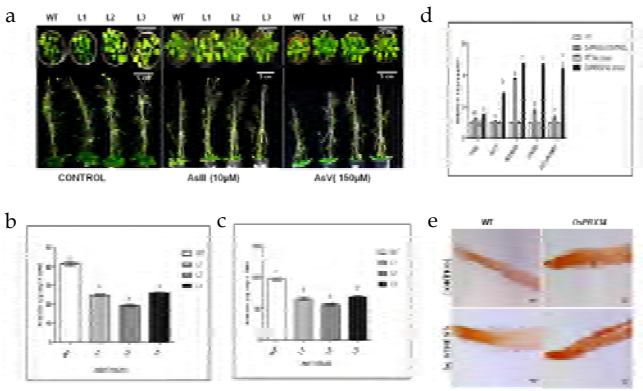

Fig. 4. Low As accumulation due to high apoplastic lignifications: (a). Plant morphology of six weeks old WT and OsPRX38 transgenic after As [AsIII (10μm) and AsV (150μm)] stress; (b and c). Arsenic accumulation in six weeks old WT and OsPRX38 transgenic lines treated under AsIII (10μm) and AsV (100μm) respectively; (d). Expression profiles of phenylpropanoid pathway genes in WT and transgenic under control and arsenic stress; (e). Phloroglucinol staining for detection of lignin in roots of 12 days old seedlings. Scale bar = 200μm. Data are mean ± SE (n = 3). Different letters above bars represent significant difference at P < 0.05 according to Duncan's test.

Plant improvement through transgenic and modern breeding approaches

Thebaine-rich opium poppy lines for suitable cultivation through Narcotics Department

Among the diverse array of alkaloids in opium latex, thebaine is one of the non-narcotic alkaloids which is industrially converted into a number of compounds like oxycodone, naloxone, buprenorphine, oxymorphone, nalbuphine, naltrexone and etorphine. These are extensively used in synthesis of pharmaceutical drugs. The production of thebaine in India is quite less in comparison to its demand due to lack of thebaine rich varieties. The international demand for thebaine is 260 tons. CSIR-NBRI has developed breeding lines with thebaine content up to 10% in latex for the first time. The developed thebaine rich line(s) can substantially fulfil the demand of thebaine for pharmaceutical industries and can uplift socio-economic condition of opium cultivators improving Indian economy. Thebaine has $500 to $600 million market in Canada and a multibillion-dollar market in the United States. Therefore, if cultivated in large scale using the developed line, India will not only reduce the import of thebaine and its derivatives for its requirements but would also be an exporter of Thebaine. Two thebaine rich lines NBIHT-1 and NBIHT-3 have been tested in different agro climatic zones of Madhya Pradesh and Rajasthan in crop year 2016-17 and large quantity of seeds were produced. The passport data on 11 thebaine rich lines along with two checks collected on morphological features, opium, seeds, and specific alkaloids along with thebaine content has been compiled. Seeds of thebaine rich line (NBIHT-3) have been deposited at NBPGR, New Delhi along with the requisite application and necessary documents for registration. Seeds of two lines NBIHT-1 and NBIHT-3 are under possession of Narcotics Department for suitable cultivation to explore the possibilities of its commercialization.

Altering fatty acid profile of linseed through mutagenesis for edible purpose, association mapping in linseed to identify molecular markers for major fatty acids and identification and validation of molecular markers for narcotine and papaverine in opium poppy for MAS

A high yielding variety "Neelam" of linseed was subjected to physical mutagenesis (Gamma Rays 10, 20, 30, 40 and 50kR, respectively).

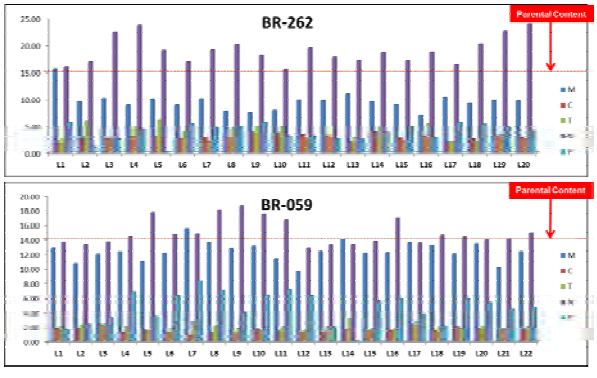

Fig. 5. Recurrent selection of BR-262 and BR-059.

Table 1: Performance of opium and seed yield in thebaine rich lines of opium poppy in advance breeding trials during 2009-10 to 2016-17.

Line Name/ Year	Opium yield dry (Kg/ha)								Seed yield (q/ha)							
	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
NBIHT-1	19.67	17.18	32.52	37.40	37.70	32.19	32.48	34.61	13.63	12.75	8.06	8.82	11.13	9.50	10.36	8.54
NBIHT-2	15.56	15.00	18.16	24.07	28.65	27.87	28.83	28.24	14.44	15.38	9.95	9.61	10.27	9.11	10.07	8.85
NBIHT-3	22.19	21.79	30.79	31.80	36.10	33.95	32.42	33.86	18.72	18.78	7.69	10.06	9.24	9.34	9.26	8.04
NBIHT-4	19.28	17.63	21.30	21.38	32.33	31.87	32.17	30.19	18.37	18.06	11.49	9.96	13.66	10.55	9.31	8.92
NBIHT-5	14.22	14.05	31.85	29.01	30.53	29.09	28.84	34.04	14.68	15.25	9.90	10.64	11.04	10.78	7.88	7.66
NBIHT-6	15.76	15.37	19.82	21.91	27.50	25.32	27.89	33.09	17.58	17.60	5.75	9.66	7.83	9.13	9.25	8.11
NBIHT-7	16.07	14.85	14.36	23.20	25.35	26.93	29.04	31.58	12.64	11.95	7.59	10.53	8.99	9.92	9.37	8.67
NBIHT-8	21.10	21.16	22.08	24.90	21.28	21.95	24.85	31.24	11.18	10.88	8.21	9.66	8.67	8.87	9.83	6.55
NBIHT-9	16.27	16.12	21.24	25.13	30.65	28.35	20.26	30.79	10.84	11.91	6.93	9.01	7.93	8.25	9.38	8.33
NBIHT-10	21.10	21.64	29.33	25.76	31.60	30.64	29.64	30.34	11.67	10.32	8.54	9.64	8.99	9.26	8.95	7.50
NBIHT-11	22.10	23.28	17.76	24.09	47.35	28.98	29.88	26.80	10.99	11.43	8.41	8.63	9.61	7.90	8.53	7.56
NBMHT-1	35.15	31.82	32.27	31.87	42.38	35.42	34.73	33.50	12.33	14.10	10.21	10.63	9.80	10.28	9.79	10.11
NBMHT-2	34.11	32.28	31.33	31.69	39.80	36.02	35.52	34.66	13.37	14.56	10.64	10.32	10.26	10.50	9.72	9.54
NBMHT-3	35.20	31.09	32.58	32.21	41.20	38.29	37.54	34.81	13.76	14.31	11.34	10.07	9.05	9.77	10.51	8.83
NBMHT-4	34.64	34.92	34.02	34.13	46.25	38.45	37.31	34.52	13.16	14.36	10.67	10.86	9.65	9.61	10.96	9.13
NBRI-5*	39.47	39.28	37.63	35.97	46.10	40.81	39.72	38.45	12.74	13.94	12.94	12.57	12.14	10.31	11.51	10.81
BROP-1*	38.20	39.92	37.75	37.62	40.57	39.88	37.75	35.25	12.94	12.72	12.70	12.62	13.05	12.68	10.96	11.16
Mean	24.71	23.96	27.34	28.95	35.61	32.12	31.70	32.70	13.71	14.02	9.47	10.19	10.08	9.75	9.74	8.72
SE	1.58	1.58	1.94	1.34	1.91	1.32	1.24	0.70	0.78	0.65	0.73	0.27	0.40	0.27	0.22	0.29
C.D. 5%	3.22	3.22	3.96	2.85	4.06	2.81	2.63	0.617	1.59	1.32	1.49	0.57	0.86	0.57	0.48	0.617
C.D. 1%	4.32	4.33	5.32	3.94	5.61	3.89	3.64	0.855	2.13	1.77	2.00	0.79	1.19	0.78	0.66	0.855
CV	7.82	8.08	8.71	19.04	22.06	16.93	16.07	8.79	6.96	5.65	9.45	10.84	16.51	11.25	9.49	13.70

*Checks

Table 2: Performance of thebaine and morphine in thebaine rich lines of opium poppy in advance breeding trials during 2009-10 to 2016-17.

Line Name/ Year	Thebaine (%)								Morphine (%)							
	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
NBIHT-1	18.54	15.05	15.35	9.60	10.39	10.57	9.90	10.51	17.93	14.00	15.60	16.73	17.15	17.69	12.56	11.73
NBIHT-2	13.26	12.29	12.06	12.54	10.87	11.78	13.01	7.48	23.03	14.95	15.33	17.45	16.21	16.29	13.27	9.27
NBIHT-3	13.27	14.99	12.89	16.81	11.94	13.30	25.45	19.07	20.71	18.68	15.34	16.31	17.48	15.42	12.80	11.73
NBIHT-4	12.87	9.52	7.70	9.98	5.39	9.80	7.85	5.33	19.37	17.09	14.96	15.61	16.67	17.81	12.56	11.73
NBIHT-5	14.53	11.54	12.96	12.85	10.86	11.92	17.96	14.81	21.19	20.06	16.79	12.58	18.20	16.79	10.82	7.40
NBIHT-6	14.63	4.67	9.31	7.08	5.71	6.45	9.62	6.12	15.73	13.36	15.45	12.64	16.85	17.54	13.15	8.26
NBIHT-7	13.60	10.79	9.39	8.28	7.43	8.84	9.40	9.46	17.84	13.42	21.92	17.94	20.87	14.99	9.60	11.73
NBIHT-8	10.84	15.65	10.43	10.66	6.49	8.89	11.30	12.95	18.00	12.79	19.95	13.67	22.26	17.61	19.12	11.73
NBIHT-9	10.30	18.83	10.29	11.82	13.56	15.55	17.05	17.27	19.08	14.99	16.26	13.08	15.11	14.17	12.56	8.56
NBIHT-10	12.99	16.59	11.69	12.94	7.70	9.75	8.71	9.51	14.91	16.35	17.47	12.20	16.11	15.55	13.44	10.19
NBIHT-11	14.14	13.66	5.92	7.58	5.74	8.56	13.78	6.32	15.93	14.70	14.59	10.00	12.86	14.83	15.44	11.73
NBMHT-1	4.96	6.06	4.48	7.25	4.25	8.44	7.15	5.20	13.50	16.89	14.30	10.68	15.16	15.54	10.49	11.73
NBMHT-2	8.48	5.53	4.76	5.40	5.12	6.76	7.25	6.12	14.40	12.21	16.32	12.72	15.60	15.74	12.89	8.61
NBMHT-3	7.42	6.94	6.62	3.70	4.49	7.35	7.05	3.90	21.07	10.05	16.11	13.20	17.75	12.61	12.56	10.11
NBMHT-4	8.10	11.25	11.94	11.82	12.72	9.76	18.18	11.77	13.73	14.35	13.32	10.59	14.06	11.80	13.12	11.73
NBRI-5*	1.85	2.57	2.79	2.36	1.78	0.66	2.38	1.58	15.18	19.60	10.43	12.49	18.24	17.53	8.02	9.69
BROP-1*	1.06	2.82	1.96	2.37	1.35	0.95	1.58	2.27	12.98	12.38	16.14	15.11	10.55	10.25	9.69	13.78
Mean	10.69	10.52	8.86	9.00	7.40	8.73	11.04	8.80	17.33	15.05	15.90	13.71	16.54	15.42	12.48	10.57
SE	0.77	0.88	0.41	0.98	0.90	0.92	1.47	1.23	1.68	1.78	0.76	0.59	0.67	0.53	0.60	0.42
C.D. 5%	1.57	1.79	0.84	2.09	1.93	1.96	3.13	0.62	3.43	3.62	1.54	1.25	1.42	1.14	1.28	0.62
C.D. 1%	2.11	2.41	1.12	2.89	2.66	2.71	4.32	0.86	4.61	4.87	2.07	1.73	1.96	1.57	1.77	0.86
CV	8.84	10.26	5.67	44.97	50.36	43.37	54.83	57.46	11.90	14.48	5.81	17.67	16.61	14.24	19.86	16.24

*Checks

M_1 mutant plants raised in field from 50 physically mutagenized seeds of each treatment. Seeds of 183 M_1 plants were irradiated with gamma rays for developing M_2 generation.

One hundred and nintyfive germplasm lines of opium poppy were characterized, and two lines (BR 059 and BR 262) rich in narcotine (14.2% and 15.3%, respectively) were identified from the indigenous germplasm (Fig. 5).

We also identified contrasting lines of narcotine and papaverine for the development of alkaloid specific markers.

Molecular characterization of genes/transcription factors responsible for biosynthesis of proanthocyanidin in underutilized winged bean (*Psophocarpus tetragonolobus*)

Heavy deposition of Proanthocyanidin (condensed tannin) on the seed coat of *P. tetragonolobus* (a tropical

Table 3: Percentage of codeine and narcotine in thebaine rich lines of opium poppy in advance breeding trials during 2009-10 to 2016-17

Line Name/ Year	Codeine (%)								Narcotine (%)							
	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
NBIHT-1	3.46	4.72	2.97	2.47	1.33	3.85	3.20	3.47	0.00	2.85	0.32	3.23	3.21	4.74	4.62	2.78
NBIHT-2	3.26	3.65	2.37	1.88	1.26	3.52	3.72	3.47	0.00	0.00	0.00	0.00	0.00	3.49	0.00	0.44
NBIHT-3	2.39	5.38	1.70	1.45	1.09	3.49	7.64	6.13	0.00	0.00	1.37	0.00	0.00	1.28	0.00	0.00
NBIHT-4	2.95	3.38	2.95	2.05	2.40	2.84	3.20	3.47	0.00	1.74	3.24	2.84	2.92	0.22	6.50	0.58
NBIHT-5	2.63	5.26	1.70	1.70	1.43	4.94	4.58	3.33	0.00	0.88	2.48	0.00	0.00	3.17	0.00	0.00
NBIHT-6	2.42	2.78	2.46	1.72	1.49	2.07	3.05	3.47	0.00	1.55	3.88	6.30	7.02	11.66	11.65	0.52
NBIHT-7	2.64	3.19	1.93	1.71	1.16	4.45	3.28	3.01	0.00	1.84	0.56	0.00	0.00	4.26	12.06	5.09
NBIHT-8	3.07	2.65	3.32	2.16	1.75	3.76	3.70	3.47	0.00	0.24	0.00	0.00	0.00	0.55	0.00	0.00
NBIHT-9	2.34	3.52	2.42	1.58	1.26	4.65	3.20	4.17	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00
NBIHT-10	2.31	4.65	2.29	1.76	1.65	1.43	2.63	3.47	0.00	0.95	0.00	0.00	5.17	6.47	8.46	6.25
NBIHT-11	3.36	3.28	2.76	1.55	2.21	1.12	4.92	2.42	0.00	1.42	5.71	8.59	7.28	9.54	4.85	11.36
NBMHT-1	4.52	3.99	3.14	1.59	2.09	2.22	31.82	3.47	8.13	5.92	7.03	7.95	7.62	9.74	12.40	12.36
NBMHT-2	3.11	2.68	2.42	1.52	1.83	2.28	2.59	2.53	8.44	7.42	5.58	8.39	7.95	8.12	11.95	10.04
NBMHT-3	2.47	4.15	2.36	2.72	1.70	3.89	3.20	3.47	6.08	6.95	7.30	8.81	8.10	5.19	9.10	12.45
NBMHT-4	3.26	2.91	2.68	1.36	1.72	3.83	6.60	4.32	0.00	1.41	0.99	0.00	0.00	1.21	0.00	0.00
NBRI-5*	2.12	2.64	2.32	2.96	2.83	1.01	1.85	1.65	6.18	11.49	5.64	8.23	6.02	10.94	14.85	14.24
BROP-1*	1.86	2.12	2.88	1.05	1.87	1.63	1.65	2.45	7.66	7.88	7.84	6.67	12.46	13.17	14.24	20.25
Mean	2.83	3.59	2.51	1.84	1.71	3.00	5.34	3.40	2.15	3.09	3.06	3.59	3.99	5.53	6.51	5.67
SE	0.40	0.66	0.12	0.12	0.11	0.31	1.70	0.23	0.42	1.33	0.33	0.93	0.97	1.04	1.39	1.58
C.D. 5%	0.82	1.34	0.25	0.26	0.24	0.66	3.61	0.62	0.86	2.70	0.67	1.99	2.07	2.22	2.95	0.62
C.D. 1%	1.10	1.80	0.33	0.36	0.34	0.91	5.00	0.86	1.16	3.63	0.90	2.75	2.86	3.07	4.08	0.86
CV	17.34	22.47	5.86	27.13	27.39	42.29	130.94	28.25	24.09	52.53	13.14	107.10	100.41	77.74	87.73	114.80

underutilized legume) is a potential problem for human consumption. Studies are reported that increased condensed tannin-content beyond a certain value reduces the seed-protein quality significantly and disturbs the digestive system of monogastrics like human. Condensed tannins are the oligomers or polymers of flavan-3-ol units. The questions concerning synthesis of condensed tannins from chemical, biochemical and molecular genetic perspectives were investigated.

A comparative transcriptome analysis of diverse condensed tannin containing lines (HCTW and LCTW) of *P. tetragonolobus* (Fig.6a) was carried out. Qualitative analysis was done through DMACA staining (Fig. 6b). Quantitative estimation through Vanillin-HCl assay and on HPLC platform (Fig. 6c and d) suggested the presence of monomeric Pelargonidin, Delphinidin and cyanidin in different concentrations.

Gene ontology study of unigenes from transcriptomic analysis and further mapping of the identified transcripts on the phenylpropanoid biosynthetic pathway identified some unique transcripts responsible for biosynthesis of condensed tannin in *P. tetragonolobus* (Fig. 7). Further studies are under progress.

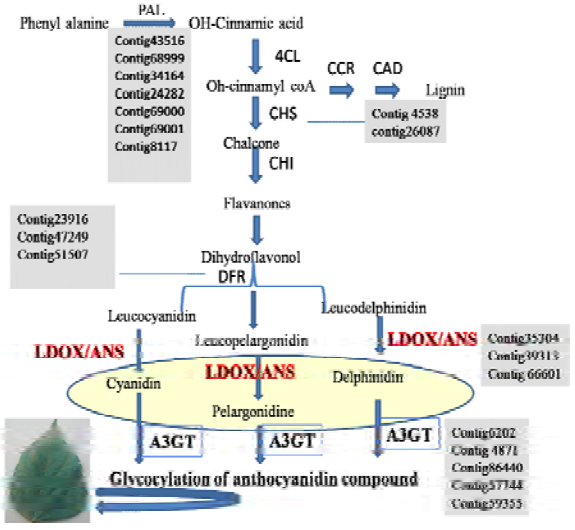

Fig.7. Expression of different transcripts involved in condensed tannin biosynthesis

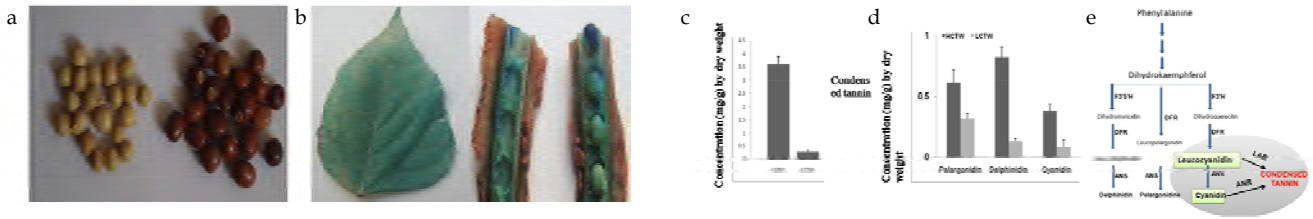

Fig.6. (a). Low condensed tannin winged bean (LCTW) and high condensed tannin winged bean (HCTW) seeds; (b). Localization of condensed tannin in leaf, pod and seed of HCTW plant; (c). Estimation of condensed tannin by vanillin assay; (d). Estimation of major metabolites of condensed tannin through HPLC of both HCTW and LCTW plant; (e). Flavonoid pathway showing the major compound and gene responsible for condensed tannin biosynthesis.

Medicinal plant functional genomics: elucidation and exploitation of complex pathways for enhanced synthesis of pharmaceutically important molecules

A detailed molecular information about genes catalysing key regulatory steps from *Withania somnifera* has been established. The full-length sequences of genes encoding enzymes for intermediate steps of terpenoid backbone biosynthesis and their paralogs have been identified for their functional and structural properties as well as phylogeny using bioinformatics approach. The expression analysis suggests that these genes are differentially expressed in different tissues (with maximal expression in young leaf), chemotypes and in response to salicylic acid (SA) and methyl jasmonate (MJ) treatments. Sub-cellular localization studies suggest that paralogs of Sterol "-7 reductase (WsDWF5-1 and WsDWF5-2) are localized in the endoplasmic reticulum (ER) thus supporting their indispensable role in withanolide biosynthesis. In addition, method for VIGS has been established to analyse role of these genes in withanolide biosynthesis. Analysis of some of these genes through VIGS suggests their role in plant development and withanolide biosynthesis (Fig. 8).

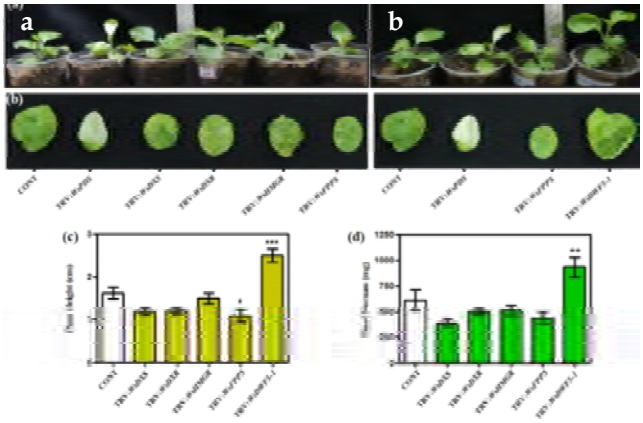

Fig. 8. Plant height and leaf phenotype in different TRV silenced lines: Down-regulation of *WsDXS*, *WsDXR*, *WsHMGR*, *WsFPPS* and *WsDWF5-1* of *W. somnifera* significantly affects the height **(a & c)** and shoot biomass **(b & d)** of the plants. Individual plants are representative of silenced lines of specific genes **(a & b)**. Plant height and shoot biomass data are means ± SE (SEM) of six biological replicate (n=6) and three technical replicate.

For alkaloid biosynthesis in opium poppy, a number of genes involved in biosynthesis of specific alkaloids were identified. Involvement of some of the genes is being studied through VIGS approach. Suppression of Ps3'OMT through VIGS caused a significant reduction in the level of papaverine in comparison to control plants. The characterization of the functionally unique Ps3'OMT involved in benzylisoquinoline alkaloid metabolism highlights NH pathway as the primary course to papaverine biosynthesis.

Our previous studies suggested involvement of miR858a in plant growth and development and flavonoid biosynthesis. To understand regulation of miR858a, we carried out in-depth studies and showed that *Arabidopsis thaliana* pri-miR858a encodes a small peptide (miPEP858a) which regulates the expression of pri-miR858a leading to modulation in the expression of target genes involved in the phenylpropanoid pathway as well as plant growth and development. Exogenous application of synthetic miPEP858a resulted in enhanced miR858a expression along with substantial down-regulation of target genes. To study the effect of miPEP858a on miR858a activity, we developed knock-out mutants of miPEP858a along with miR858 family members using the CRISPR/Cas9 system. miPEP858a-edited plants developed phenotypes similar to that of mature miR858-edited plants including enhanced anthocyanin accumulation (Fig. 9). Exogenous treatment of synthetic miPEP858a to the miPEP858a-edited plants complemented their phenotypes and the gene function suggesting a significantly important role of miPEP858a in controlling the miR858 function.

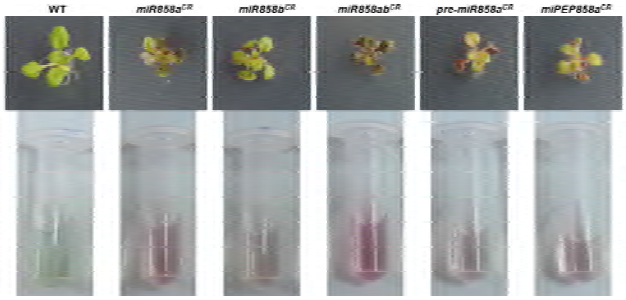

Fig. 9. Enhanced anthocyanin accumulation in CRISPR/Cas9 derived knockout mutants of miR858a and associated miPEP. Accumulation of anthocyanin in 10-day old WT and CRISPR edited miR858 and miPEP858a seedlings (upper panel). Illustrative picture of the anthocyanin accumulation in WT and CRISPR edited plants (bottom panel).

Our studies related to regulatory aspects of flavonoid biosynthesis also suggest strict requirement of light for the low temperature-enhanced flavonol biosynthesis. Low temperature-induced expression of biosynthetic genes as well as flavonol accumulation was hampered in ELONGATED HYPOCOTYL (*hy5)* and *myb11myb111myb12* triple mutants as compared to wild-type (WT) in *Arabidopsis*. Over-expression of *AtHY5* in the *hy5* mutant restored induction of gene expression and flavonol accumulation in response to low-temperature in light. Metabolite and gene expression analysis also suggests negative role of constitutive photomorphogenic1 (COP1) in accumulation of flavonols in response to low temperature. Over-expression of *AtMYB12* enhanced accumulation of flavonols under low-temperature in a light-dependent

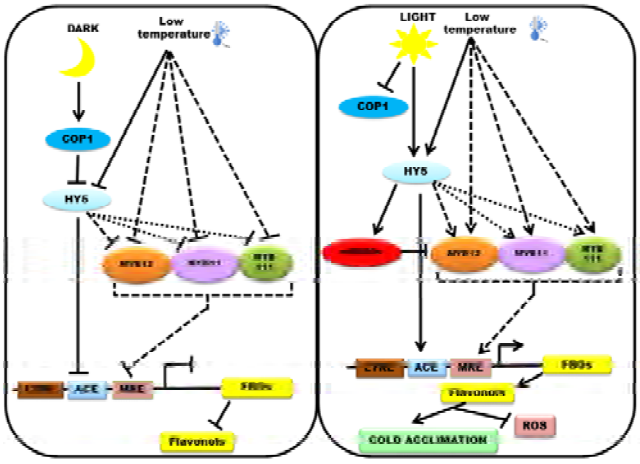

Fig. 10. Hypothetical working model for the roles of HY5 and PFGs in regulating the expression of flavonol pathway genes during low temperature exposure. In this work, we proposed a signalling cascade wherein HY5 acts as the upstream regulatory factor and relays the light and low temperature signal to the promoters of PFGs resulting in enhanced flavonol biosynthesis.

manner. We developed a model which suggests requirement of HY5 and flavonol-specific MYB regulatory factors for low temperature-induced flavonol synthesis (Fig. 10).

Prickleless mutant of *Solanum viarum* Dunal (Solanaceae)

Solanum viarum Dunal (Syn: *Solanum khasianum* C. B. Clarke var. *chatterjeeanum* Sen Gupta), commonly known as tropical soda apple, is a medicinal plant having high contents of medicinally important steroidal alkaloids. Although steroidal alkaloids are also found in other members of *Solanaceae, S. viarum* is a promising source for commercial production of solasodine in India. Several steroidal alkaloids such as solasodine, α-solanine, solamargine, solasonine, solanidine, khasianine etc. are found in *S. viarum,* which exhibit a variety of biological activities, including anti-cancerous, anti-fungal, anti-microbial, anti-viral, anti-biotic, insecticidal, anti-inflammatory, anthelmintic and anti-herpes activities. These alkaloids are also major raw materials for commercial production of pharmaceutically important contraceptive steroids.

S. viarum is a shrub of South American origin and widely distributed in the Asian subcontinent. It is reported from Khasi hills, Naga hills, West Bengal, Nilgiris, Orissa, Sikkim, and the Upper Gangetic plains in India. It is also found in China, Myanmar and Nepal. The aerial parts of *S. viarum* (wild type, WT), including the calyx are packed with sharp prickles which renders harvesting of fruits difficult and expensive (Figs. 11a, 12). Due to nonsynchronous maturity of berries, mechanized harvesting is not possible. Therefore, the harvesting is done by hand plucking which is very

Fig. 11. Mature plants of *Solanum viarum* in the field: (a). Prickly WT and (b). Prickleless mutant

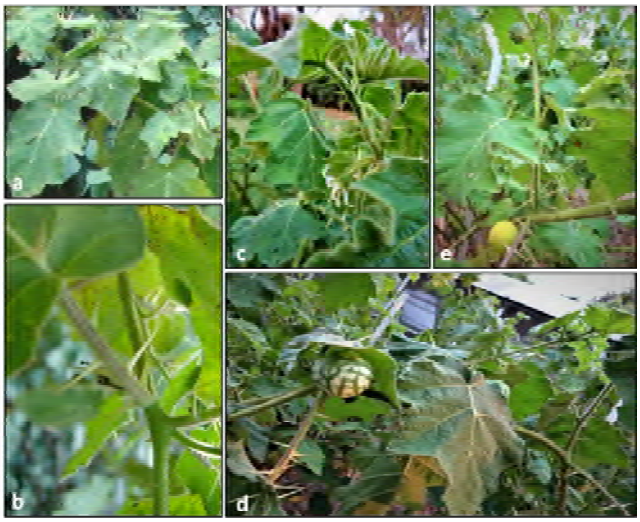

Fig. 12. Close-up view of prickly *S. viarum*; (a). Apical portion; (b). Stem and petiole; (c). Flowering; (d). Green berries; (e). berries at different stages of maturity.

difficult due to large and hard prickles (Fig. 12). CSIR-NBRI, Lucknow, has obtained a prickleless spontaneous mutant under *S. viarum* breeding program and named as NBRI-Sel. The mutant was later christened as 'Nishkantak' (Fig. 11b, 13). Earlier the terms spiny and spineless were used for the WT and mutant, respectively.

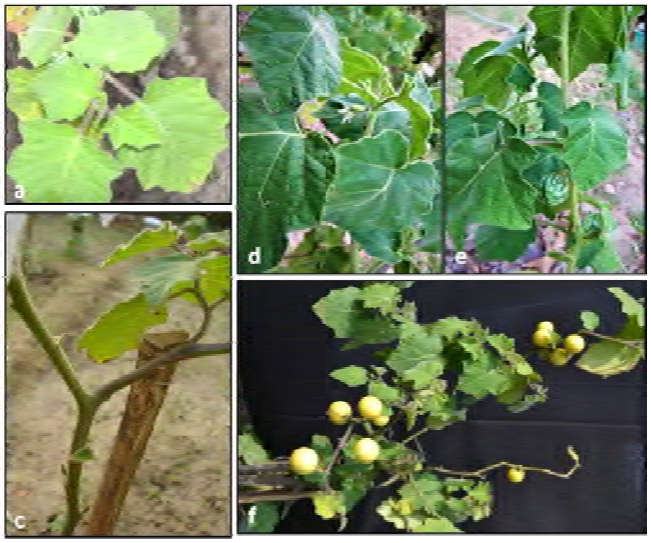

Fig. 13. Close-up view of prickleless *S. viarum* in the field: (a). apical portion; (b). stem and petiole; (c). flowering; (d). green berries (e). yellow ripened berries.

Our studies, however suggested that these structures prickles as these are of epidermal origin and lack vascular connection. The prickleless genotype, therefore, becomes very important. It is important not only for being devoid of prickles but also for better yield and alkaloid contents. The highest alkaloid content is reported in the berries as compared to any of the other plant parts, eg. leaf, stem or root. The yellowish green berries, at a particular ripening stage, contain the highest alkaloid contents.

Germplasms of both the prickly and prickleless mutant of *S. viarum* have been conserved under *in vitro* condition in the form of *in vitro* shoot cultures as well as excised root cultures at CSIR-NBRI. Nodal segments of both the genotypes are being subcultured at interval of every 6-8 weeks for last ~35 years maintaining their prickly/prickleless nature under *in vitro* conditions (Fig. 14). The prickleless plants are stable under field conditions for last 35 years.

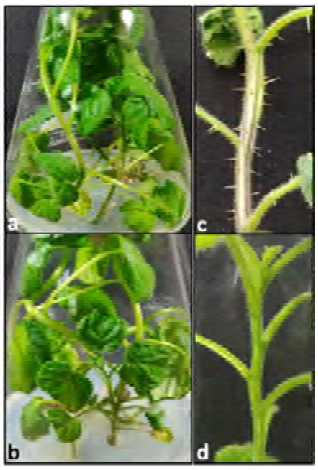

Fig. 14. *In-vitro* cultures of *S. viarum* (a). Prickly and (b). Prickleless; Magnified view of (c). Prickly stem; (d). prickleless stem.

The appearance of prickles is greatly influenced by the environment. As has been seen in WT *S. viarum*, the development of prickles is profuse in winters as compared to summers. The prickleless mutant, 'Nishkantak' has no prickles on the stem throughout the year, but 2-4 prickles appeared on mature leaves during winter months. By suitably manipulating the sowing time, it has been possible to get the mature crop in May when winter leaves would have fallen off and new leaves would develop prickleless. The finding to develop prickleless mutant is novel in overcoming the constraint for adapting high density planting, easy harvesting and there by getting high yield. The berries yield is 1.29 tonnes/ hectare in prickly WT and 1.57 tonnes/ hectare in prickleless mutant.

SNP analysis for genetic relatedness of prickly and prickleless *S. viarum*

After a long-term conservation of prickly and prickleless genotype of *S. viarum* under *in vitro* condition, we performed single-nucleotide polymorphisms (SNPs) analysis to measure the genetic relatedness between these genotypes. Transcriptome sequences (developed through Illumina sequencing HiSeq 2500 of both the genotypes were used for SNPs analysis. In order to identify the putative SNPs in the transcript assembly, we separately mapped all of the high quality short reads from each library using Tophat. Next, Samtools were used to identify SNPs positions from the consensus-assembled data. Only those SNPs were considered which possess the minimal mapping quality (-Q) and coverage (-d) of 20 bp. Our analysis showed that the prickly and prickleless genotypes were 99.92% genetically similar. At the stringency level, we have found 150 bi-allelic SNPs in 95 contigs, which represent only 0.086% of the total contigs. Furthermore, the 26 contigs have two or more SNPs. The SNPs analysis thus revealed that both the genotypes used in the study are genetically related with probably minor difference which may reflect their prickliness trait.

Phenotypic evaluation of agri-traits and alkaloid profiling of field and *in vitro*-grown plantlets of prickly (WT) and prickless mutant of *S. viarum*

The growth and alkaloid production kinetics under *in vitro* established shoot cultures, was performed as a function of varying harvesting schedule. Shoots from cultures were harvested after 5 days interval over seventy days of culture cycle. Further the tissues were oven dried for their dry weight (DW) determination and chemical extraction of alkaloids. Growth was recorded in terms of growth index (GI) that was calculated as percent increase of fresh/dry biomass over the initial inoculum weight (Fig. 15a and 15b) taking three replicates. Extraction of alkaloids was done by methanol extraction method and the crude extracts thus obtained were used further for HPLC analysis. For comparative analysis of solasodine, solanidine and α-solanine contents in two important prickly and prickleless *S. viarum*, different tissues i.e. leaves, stems and roots were chemically extracted for HPLC analysis (Fig. 15c and 15d; Table 4).

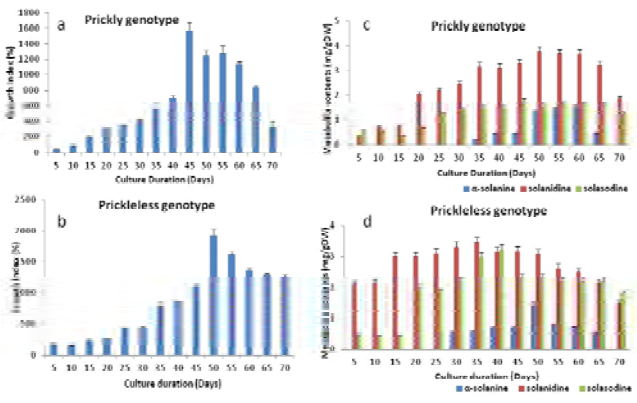

Fig. 15(a-d). Growth and alkaloid profiling in *in vitro* shoot cultures of prickly and prickleless *S. viarum*

Table 4. Alkaloid contents (solasodine, solanidine, and α-solanine) in various plant parts of field and *in vitro*-grown prickly and prickleless genotypes of *S. viarum*

Type of Material	Alkaloids analysed (mg/g DW)	Prickly (WT) *Avg±S.E.			Prickleless (Mutant) *Avg±S.E.		
		2016	2017	2018	2016	2017	2018
Field-grown L+S+R[2]	Solasodine	1.71±0.14	1.89±0.12	1.88±0.11	2.22±0.42	2.34±0.33	2.32±0.25
	Solanidine	2.96±0.41	2.94±0.35	2.99±0.33	2.48±0.47	2.59±0.25	2.44±0.34
	α-solanine	3.96±0.25	3.99±0.28	3.84±0.31	4.09±0.31	4.12±0.53	4.21±0.22
	Total	**8.64**	**8.82**	**8.71**	**8.81**	**9.05**	**8.97**
Field-grown Berries[3]	Solasodine	1.00±0.13	1.10±0.11	1.08±0.05	1.17±0.37	1.18±0.28	1.15±0.22
	Solanidine	1.02±0.04	1.04±0.08	1.06±0.12	0.76±0.01	0.87±0.05	0.92±0.08
	α-solanine	4.91±1.23	4.99±0.09	4.88±1.22	5.61±0.87	5.66±0.12	5.45±0.99
	Total	**6.93**	**7.13**	**7.02**	**7.44**	**7.71**	**7.52**
[4]*In vitro*-grown L+S+R	Solasodine	1.34±0.07	1.31±0.05	1.25±0.03	1.90±0.24	2.01±0.33	1.98±0.21
	Solanidine	2.30±0.13	2.64±0.22	2.48±0.11	2.41±0.21	2.49±0.22	2.78±0.36
	α-solanine	1.19±0.02	1.04±0.04	1.18±0.09	2.31±0.09	2.22±0.06	2.28±0.02
	Total	**4.83**	**4.99**	**4.91**	**6.62**	**6.72**	**6.74**

*Average of 3 replicates ± Standard Error;

[2] L+S+R = Leaf + Stem + Roots in total

[3] Second stage of berries, i.e. yellowish green

[4] Culture incubation: 45 days

All Alkaloid content data presented in mg/g DW

The various morphological characters of field-grown mature plants and *in vitro*-grown shoot cultures were recorded with five and three replicates, respectively, for consecutive three years, i.e. 2016, 2017 and 2018. The different parameters of field-grown plants including the yield/plant were taken into consideration and presented in Table 5. For alkaloid profiling different plant parts (leaf, stem and roots) of field-grown mature plants, in vitro-grown shoot cultures and yellowish coloured berries (II stage of ripening) were used following the procedure mentioned above (Table 4). The morphological parameters of *in vitro*-shoot cultures of prickly and prickleless genotypes are presented in Table 6.

Functional analysis and characterization of Phosphomevalonate kinase (*PMK*) gene from mango fruit

Mango aroma develops during fruit ripening and is derived from various chemical groups including terpene, hydrocarbons, esters, lactones, ketones, alcohols, aldehydes, acids and other groups. There are 578 volatile compounds identified from mango fruit in various

Table 5. Agri-traits of field-grown plants of prickly and prickleless genotypes of *S. viarum*

Parameters studied	Prickly (WT) *Avg±S.E.			Prickleless (Mutant) *Avg±S.E.		
	2016	2017	2018	2016	2017	2018
Plant height (cm)	119±2.81	125±1.73	132.52±1.29	103±2.19	104.6±2.49	115±1.71
Plant spread (m^2)	1.16±0.03	1.19±0.04	1.35±0.08	1.0±0.06	1.17±0.09	1.12±0.02
No. of branches/plant	17±1.14	20.6±1.20	23.6±1.80	14.2±1.28	16±1.58	14.4±0.88
No. of leaves/branch*	35.8±0.86	39±2.12	33±1.79	29±0.71	35±1.14	35.8±1.16
No. of nodes/branch*	38.4±0.68	43.4±1.64	34.8±0.86	34±1.14	35±0.70	34.4±1.21
No. of prickles/young leaf *	13.6±0.68	14.6±1.08	17.6±0.68	nil	nil	nil
No.of prickles/mature leaf*	23.6±1.08	26.4±0.93	26±1.00	nil	nil	3.2±0.83
No. of prickles/ petiole of young leaf*	10.2±0.75	8.8±0.97	9.6±1.08	nil	nil	nil
No. of prickles/ petiole of mature leaf *	7.6±0.37	10.4±1.7	11±0.71	nil	nil	nil
No. of prickle/ Internode*	21.2± 0.11	20.4±1.44	18. 4±0.82	nil	nil	nil
Leaf surface index of young leaf	5.4±0.16	5.53±0.15	7.45±0.24	6±0.19	6.08 ±0.04	6.47±0.21
Leaf surface index of mature leaf	37.71±0.26	45.75±0.59	48.30±0.64	43.07±0.91	43.77±0.77	43.24±0.87
Stem diameter (cm)	1.84±0.06	2.12±0.19	1.87±0.04	1.71±0.12	1.74±0.11	1.77±0.09
Days to flower	127.00±4.35	133.20±2.54	131.60±3.54	129.80±3.15	130.80±1.93	135.00±3.86
Days to maturity (initiation of fruit)	151.60±3.17	163.80±2.56	155.00±2.92	156.40±3.31	159.80±3.23	162.40±3.98
Days to fruit ripening (yellowing of berries)	214.20±2.69	221.80±2.76	216.80±4.49	219.00±3.18	218.00±2.37	222.60±3.74
Berries diameter (cm)	2.50±0.19	2.72±0.21	2.65±0.33	2.32±0.16	2.54±0.18	2.33±0.18
Berries weight (g)	2.26±0.10	2.38±0.12	2.28±0.19	2.35±0.12	2.48±0.07	2.47±0.17
No. of berries per plant	57.20±3.47	52.80±3.15	54.00±3.39	63.20±0.28	64.20±2.97	65.60±1.96
Yield/plant (g)	129.04±7.83	125.56±7.50	123.01±5.98	148.27±5.11	159.34±7.38	162.03±4.85

*Average of 5 replicates ± Standard Error

Table 6. Morphological parameters of *in vitro*-shoot cultures of prickly and prickleless

Parameters studied in *in vitro*-shoots	Prickly (WT)			Prickleless (Mutant)		
	*Avg±S.E.			*Avg±S.E.		
	2016	2017	2018	2016	2017	2018
Shoots height (cm)	8.07±0.29	8.16±0.25	8.08 ±0.30	6.2±0.30	6.22±0.14	6.11±0.93
No. of nodes/plant	9.33±0.88	9.63±0.41	8.78±0.62	11.00±2.64	10.91±2.31	10.22±2.22
No. of leaves /plant	9.33±0.88	9.63±0.41	8.78±0.62	11.00±2.64	10.91±2.31	10.22±2.22
No. of prickles /leaf	32.00±1.25	35.00±1.58	31.00±1.21	NIL	NIL	NIL
No. of prickles/internode	28.33±1.64	29.12±0.97	30.23±1.22	NIL	NIL	NIL
No. of prickles on petioles	15.63±1.35	18.59±1.30	17.84±1.88	NIL	NIL	NIL
Leaf area (cm^2)	4.68±0.19	4.52±0.24	4.89±0.33	3.82±0.65	3.49±0.25	3.14±0.32

cultivars. Isopentenyl diphosphate (IPP) and its isomer dimethylallyl diphosphate (DMAPP) are the universal precursors of terpenoid biosynthesis and are produced by the cytosolic enzymatic MVA (mevalonic acid) pathway or by plastidic 2-*C*-methylerythritol-4-phosphate (MEP) pathway. Phosphomevalonate kinase (PMK) is a key enzyme in the isoprenoid/sterol biosynthesis, which catalyses the mevalonate 5-phosphate and ATP to mevalonate 5-diphosphate and ADP. Comparative mRNA expression analysis of *MiPMK* in Dashehari Mango showed a 1.5 folds expression in the midripe stage as compared to the unripe stage in inner zone. In the outer zone (which ripens later in Dashehari compared to the inner zone) transcript levels increased gradually from midripe to ripe stage (Fig. 16). Tissue and developmental expression of *MiPMK* was also analysed in Dashehari mango. The study revealed maximum transcript abundance of *MiPMK* in pulp and early developmental stages. Real time analysis of *MiPMK* was also performed in different mango varieties (Banganpalli, Ratna, Mallika and Alphonso) and revealed its differential expression in zonal and varietal specific manners.

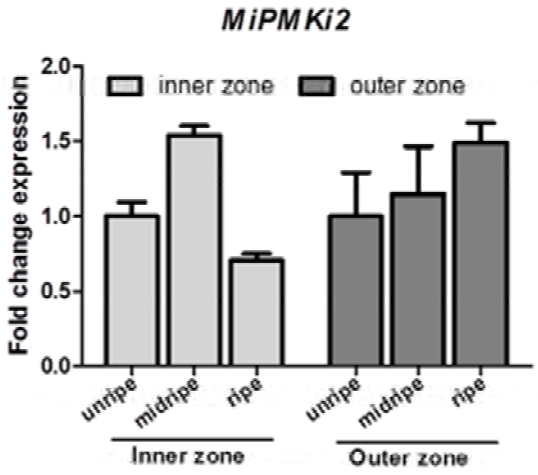

Fig. 16. Differential Expression of *MiPMK* in *Dashehari* fruit: Relative fold change was calculated using ÄÄCt method taking the transcript of the unripe stage as 1. *MiActin* was used as endogenous control for normalization. Each graph point represents the mean ± standard error (SE)

To expedite functional characterization of mango PMK, recombinant protein was expressed in *E.coli*, (Bl21DE3) and purified using Ni-NTA column, the purified protein has MW of 54.8KD (Fig. 17). MiPMK was silenced in mango fruit by VIGS. Further studies are in progress.

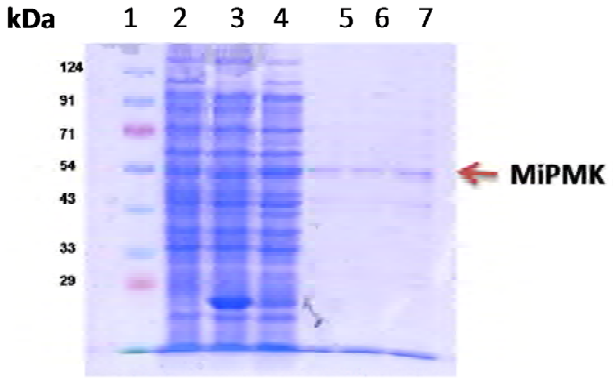

Fig. 17. Expression of *MiPMK* protein *in E.coli* Lane1-marker, Lane2-Empty vector, Lane3- uninduced, Lane4-induced, Lane5-7-Purified PMK protein

Grant in Aid Projects

Identification characterization of genes for oil biosynthetic pathway

Oils and fats are stored in endosperm during seed development in the form of triacylglycerols. Three acyltransferases: glycerol-3-phosphate acyltransferase (GPAT), lysophosphatidyl acyltransferase (LPAT) and diacylglycerol acyltransferase (DGAT) are involved in the storage lipid biosynthesis and catalyze the stepwise acylation of glycerol backbone. In a previous study we characterised JcDGAT involved in oil biosynthetic (Kennedy Pathway) pathway. In this study two members of GPAT gene family (JcGPAT1 and JcGPAT2) from Jatropha seeds were identified. Sequence analysis suggested that JcGPAT1 and JcGPAT2 are different from each other and the sub-cellular localization studies of these two GPATs showed that JcGPAT1 localizes into plastid whereas JcGPAT2 localizes in to endoplasmic reticulum (Fig. 18). JcGPAT1 and JcGPAT2 expressed throughout the seed development. The transcript levels

Table 7: Total seed oil content in control and transgenic Arabidopsis lines.

Genotypes	Total seed oil (mg/100 mg dry seed)
Control (Col0)	33.3±0.6
CaMV35S::JcGPAT1	37.6±1.9
AtPER::JcGPAT1	39.8±2.2
CaMV35S::AsJcGPAT1(Antisense)	29.4±1.0
CaMV35S::JcGPAT2	47.3±1.7
AtPER::JcGPAT2	53.5±2.2

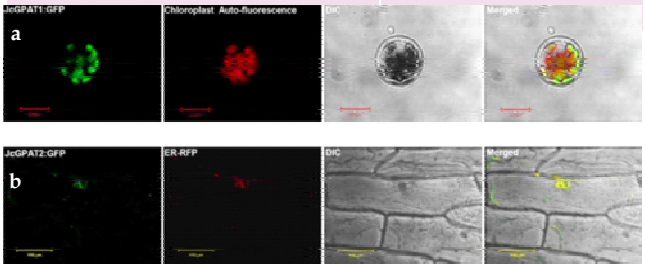

Fig. 18. Sub-cellular localization of the JcGPAT1 and JcGPAT2. (a). The fusion construct (JcGPAT1: GFP) was used for developing transgenic Arabidopsis lines. Protoplast isolated from leaves of the transgenic lines expressing JcGPAT1: GFP fusion protein were used for confocal microscopy. (b). For JcGPAT2 localization, the fusion construct CaMV35S:JcGPAT2:GFP was co-transfected with an ER specific fluorescent marker (ER-rk) in to onion epidermal cells. The GFP fluorescence was observed at excitation wavelength of 495 nm and emission wavelength of 530 nm. The auto fluorescence of chloroplasts was observed at excitation wavelength of 540 nm and emission wavelength of 600 nm while the ER-rk was observed at excitation wavelength of 590 nm and emission wavelength of 610 nm. Bar=20µm.

of JcGPAT2 were higher with respect to JcGPAT1 in different stages of developing seed. Heterologous expression of JcGPAT1 and JcGPAT2 under constitutive and seed specific promoter in *Arabidopsis thaliana* increased total oil content (Table 7). Transgenic seeds of JcGPAT2-OE lines accumulated 43–60% more oil than control seeds whereas seeds of Arabidopsis lines overexpressing plastidial GPAT lead to only 13–20% increase in oil content.

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

Sequencing of sRNA of the epidermal layer of the prickly and prickleless strains was performed to identify the potential miRNA associated with prickle development. The Blast hits showing similarity with known miRNA from virdi plantae were reported as known miRNA with the precursor sequence. The unaligned miRNA have been considered as novel miRNA. Targets of the miRNA were predicted using transcriptome data generated by mRNA sequencing of *S. viarum*.

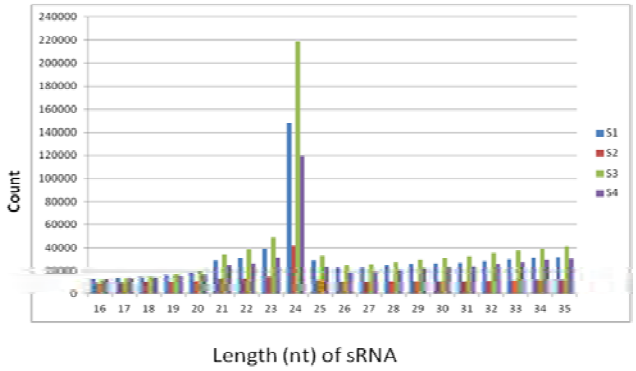

Fig. 19. Sequence length distribution of small RNAs expressed in epidermis of prickly and prickleless strains.

Table 8: Summary of the miRNA sequencing, prediction of

	Prickly		Prickleless	
	S1	S2	S3	S4
Total Reads	16414758	8983830	12867569	17858223
Trimmed Unique Reads	794584	321492	994028	714101
rRNA	110	82	189	173
snoRNA	28	12	36	29
snRNA	37	15	39	21
tRNA	4	6	6	9
Clustered Reads	368075	133727	467650	309498
Known miRNA miRBase	203	128	220	209
Known miRNA from Transcriptome	6	5	10	13
Novel miRNA predicted	59	18	39	108

Differential expression analysis was also performed to identify the differentially expressed miRNA. Statistics of the computational analysis is given in the Table 8 and Fig. 19. Further analysis and validation is under progress.

Exploring a novel role of SkMSM1 and SkR2R3-Myb315-like transcriptional regulators in the development of prickle in *Solanum viarum*

One gene *Sk*MSM1 (MADS box like transcription factor) and another *Sk*R2R3 (MYB315-like TFs) of *S. khasianum* were selected from transcriptomic data. To know the role of both of these genes in prickle development, we are developing the transgenic lines of prickly *S. khasianum*, using RNAi technology. Full length of *Sk*MSM1 (MADS box like) and *Sk*R2R3–MYB315-like TFs were cloned in pTZ57R/T vector, and were confirmed by sequencing, and also checked by colony PCR where 518 bp and 484 bp bands, respectively, were observed. RNAi construct were transformed in pFGC 1008 expression vector. For the development of

transgenic RNAi lines, we have transformed RNAi construct into *A. tumifacience* (LBA 4404 strain). *Agrobacterium* mediated plant transformation in *S. viarum* for transgenic development is under progress. In order to clone the promoter sequence of *Sk*MSM1(MAD-box like) and *Sk*R2R3-MYB315-like TFs, we have developed four separate Genome Walker libraries using genomic DNA of *S. viarum* [EcoRV (DL-1), DraI (DL-2), PvuII (DL-3), StuI (DL-4)]. Gene specific primers and adapter sequences (AP1 and AP2) were used for primary PCR reaction followed by secondary (Nested) PCR. Promoter of *Sk*R2R3-MYB315-like TFs in vector pCR3.9 has been successfully cloned and sequenced, while cloning of promoter sequence of *Sk*MSM1 TF is under progress. To test promoter activity, the sequenced fragment of *Sk*R2R3-MYB315-like TF promoter has been cloned into expression vector.

Enhancement of solasodine content in shoot cultures of *Solanum viarum* Clarke through biotic elicitors and expression analysis of the genes associated with solasodine biosynthesis

The shoot cultures of *S. viarum* established in liquid medium were used for various elicitation experiments. The cultures were subjected to different doses of biotic elicitors which were isolated from the rhizospheric soil of different medicinal plants. The strains used in the present study were selected on the basis of higher IAA, phosphatase and asparaginase activities observed in different medicinal plants.

Six different biotic elicitors (four bacterial isolates i.e. PB-1, PB-2, PB-3, PB-4 and two fungal culture filtrates i.e. TP-5, THF were tested at four different doses (1, 3, 5 and 7%) and two different stages i.e. 25 day and 35 day of culture cycle. All the treated shoot cultures were harvested for monitoring biomass in terms of growth index (Percent increase of final fresh weigh over initial fresh weight) and metabolite content by HPLC (Fig. 20).

Out of the all the screened elicitors, the two elicitors (THF and PB-1) showed most promising effect on the growth of *S. viarum*. Addition of THF at 5% and PB-1 at 3% levels resulted in significant enhancement of growth index by 3.36 and 4.96 folds, respectively over the untreated control (Fig. 20).

Real time expression analysis of the four different glycosyltransferase gene involved in the biosynthesis of glycoalkaloid, the major metabolites of *S. viarum* revealed the differential expression of SGTs in different plant parts of prickly and prickleless.

The three SGT's i.e. SGT-2, 3 and 5 were found to be the major glycosyltransferase expressed in the aerial parts of mutant lines i.e. prickleless *S. viarum* while SGT1 was predominantly expressed in the roots of both prickly and prickleless *S. viarum*.

The expression of other pathway and defence related genes viz. MVA, HMG, FLS, CYP4, CHS, COMT were also analyzed in both prickly and prickleless *S. viarum*. These genes expressed differentially in tissue specific manner.

Out of six different elicitors (TP-5, THF, PB-1, PB-2, PB-3 and PB-4) screened, the two elicitors (THF and PB-1) were successfully recognized for achieving enhanced growth in the shoot cultures of *S. viarum*. Implementation and identification of the suitable elicitor(s) will be helpful for generating higher biomass of the suitable material with high solasodine content.

Real time expression analysis identified the differential expression of potent glycosyltransferase and metabolite pathway genes in tissue specific manner that can contributes for the biosynthesis of *S. viarum* alkaloid and glycoalkaloids and can be further used for correlating the study of the accumulation of different metabolites in the selected tissue.

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

Previous studies from constitutive over-expression of *SlERF6* in tobacco had shown suppression of several ABA responses in different processes. Over-expression and suppression lines of *SlERF6* under the CaMV35S promoter were also developed in tomato and confirmed these findings. Transgenic tomato lines with reduced expression of *SlERF6* showed delayed seed germination (indicative of ABA hypersensitivity) while over-expression lines showed early seed germination (indicative of reduced ABA sensitivity). The germination phenotypes were also seen on ABA (Fig. 21). When an estimation of ABA was carried out, suppression lines were found to have 2-4 fold higher ABA levels while sense lines showed much reduced ABA (down to 14% of control, Fig. 22). Gene expression analysis revealed an increase in transcript levels of *CYP707A3* (encoding an enzymes that degrades ABA) in sense lines but a decrease in suppression lines. Early germination in sense lines was also associated with increase in expression of GA3and GA20 oxidases and a few ABA signaling components like SnRKs and ABFs.

The effects of *SlERF6* manipulation were not restricted to seed germination but also seen at later stages of growth. They affected leaf senescence (which was increased in hypersensitive lines and reduced in over-expression lines) as well as stomatal closure (which showed reduced sensitivity to ABA in over-expression lines and was hypersensitive to ABA in suppression

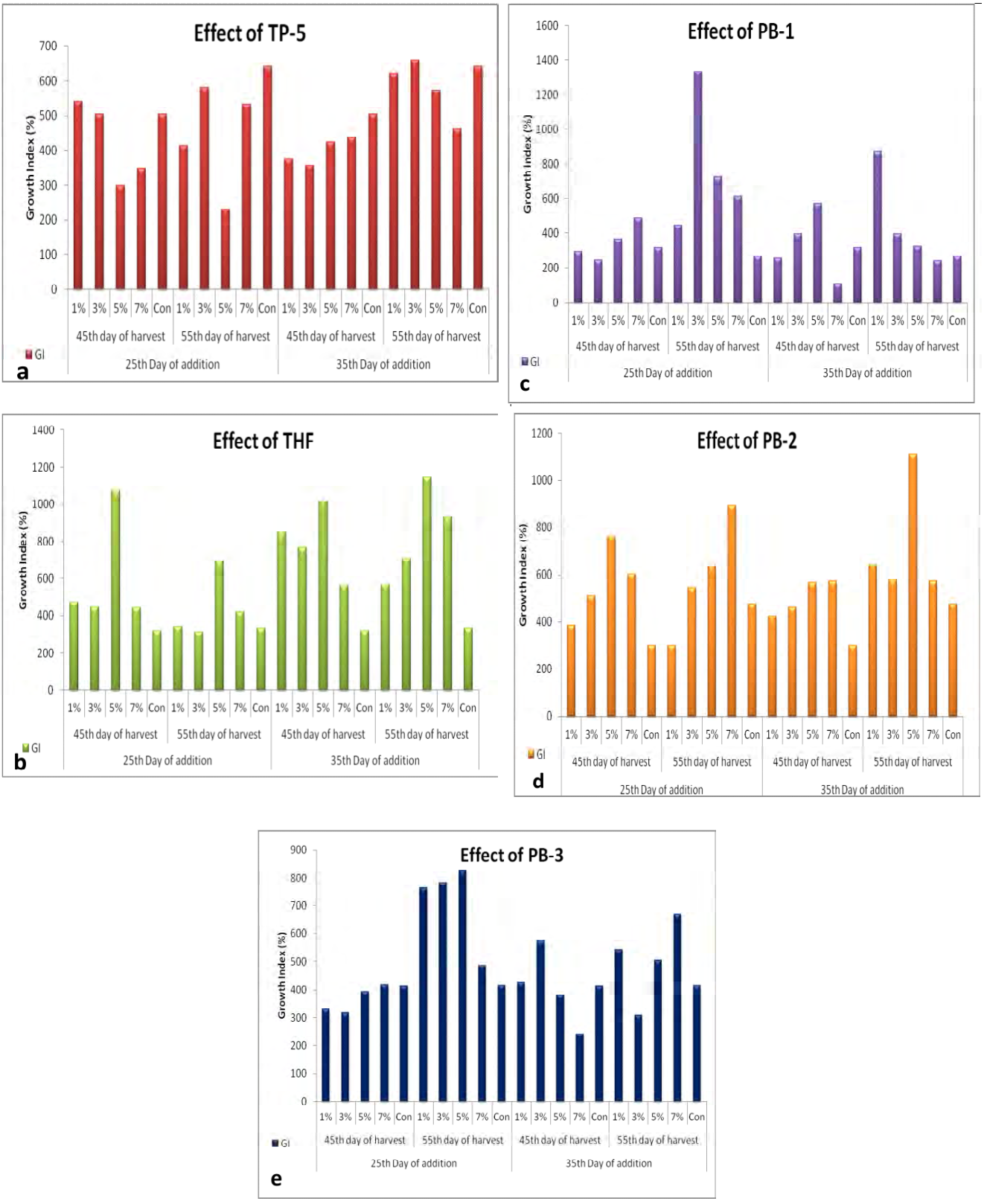

Fig. 20. Effect of TP-5(a), THF (b), PB-1 (c), PB-2 (d) and PB-3 (e) at 1, 3.5 and 7% (w/v) doses on growth index in shoot cultures of *S. khasianum*

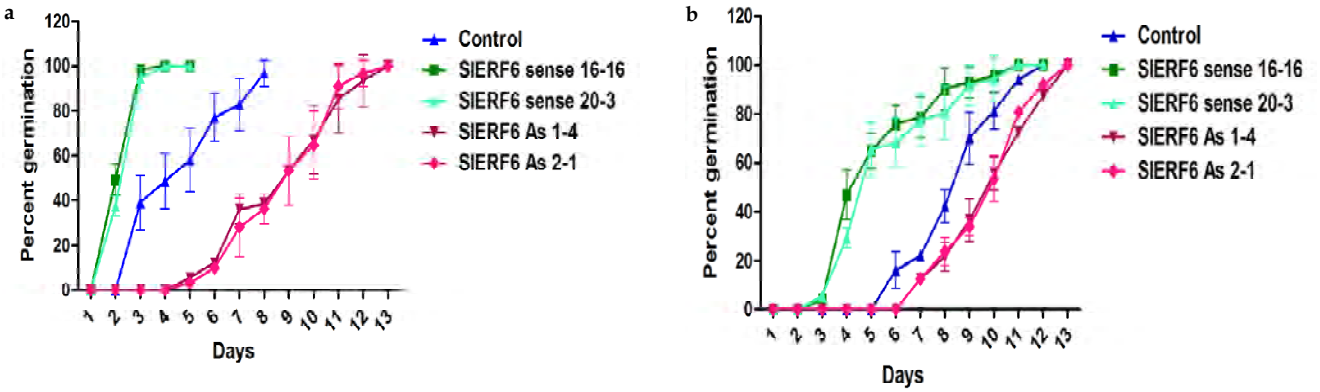

Fig. 21. *SlERF6* regulates seed germination: (a). Germination percentage of seeds of control, sense and antisense lines on ½ MS (-ABA). (b). Germination percentage of seeds of control, sense and antisense lines on ½ MS supplemented with 1µM ABA. Germination was monitored based on radical emergence. Days were counted after stratification for 2 days. Data are means ± SD (n= 30).

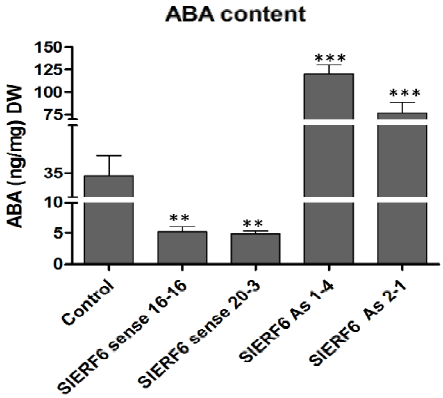

Fig. 22. Estimation of endogenous ABA level in dry seeds of control, *SlERF6* sense and *SlERF6* antisense plants ABA was estimated using the Phytodetek ABA estimation kit. Each bar represents the mean of three replications, (±SD) and **, indicates P <0.01, ***, indicates P <0.001 (Student's t-test).

lines). *SlERF6* thus seemed to negatively regulate ABA responses in tomato across tissues and processes. In all cases the expression of *Le25,* a marker of ABA levels was up-regulated in ABA hypersensitive lines and down regulated in ABA insensitive lines (Fig. 23).

Our study suggests that *SlERF6* regulates seed germination and plant development through regulation of ABA levels and responses.

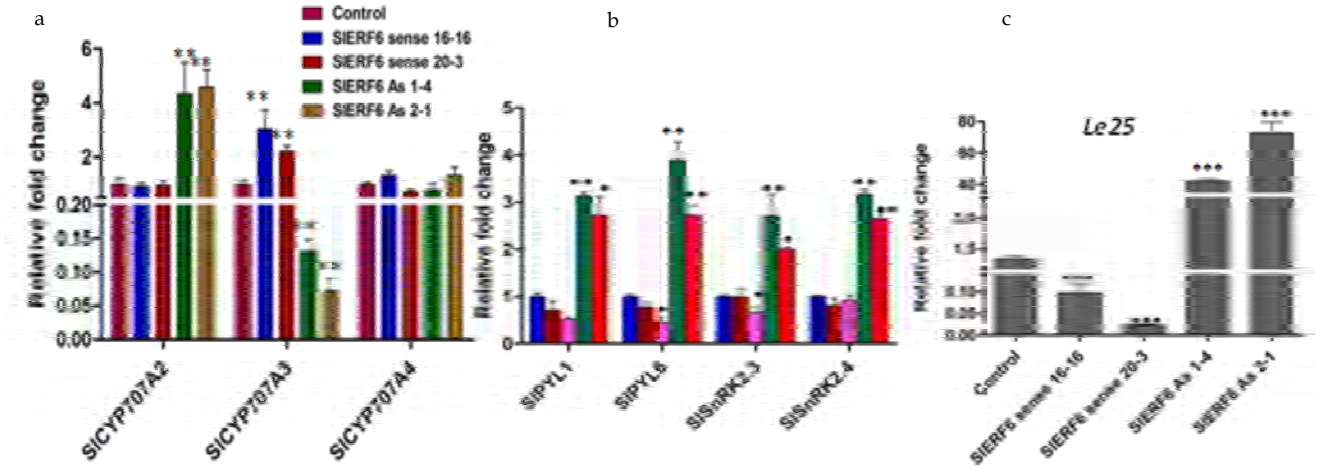

Fig. 23. Quantitative real time PCR analysis of relative transcript levels of genes associated with ABA catabolism and signalling in seeds of control, transgenic sense and antisense plants 3 days post-imbibition. (a). Relative change in transcript levels of members of *SlCYP707A* family in control and transgenic seeds; (b). Relative fold change in transcript levels of *SlPYL1*, *SlPYL6*, *SlSnRK2.3* and *SlSnRK2.4* in control and transgenic seeds; (c). Relative fold change in transcript levels of *Le25* in control and transgenic seeds. Values were normalized against SlSAND and represent means of three biological replicates. Error bars represent SE, *, indicates P < 0.05, **, indicates P < 0.01, ***, indicates P < 0.001 (Student's t-test).

The Calmodulin-Binding Transcription activator 5 (CAMTA5) link calcium import to root development in *Arabidopsis thaliana*

Calcium ion is an imperative ubiquitous intracellular messenger molecule, acting as a lead cue in signal transduction pathways. Interaction of calcium with calmodulin leads to conformational changes, which eventually results in many downstream signalling cascades. Calmodulin in a calcium dependent manner regulates several transcription factors implicated in various molecular, physiological and biochemical functions in the cell. CAMTA (Calmodulin binding Transcription Activator) is one such calcium loaded calmodulin dependent basic helix-loop-helix transcription factor that demands detailed investigation for its molecular function in plant development and physiology. We identified the role of *Arabidopsis thaliana* CAMTA5 in root development. The relative expression of CAMTA5 was greater in the root tissue as compared to other tissues of *Arabidopsis thaliana* (Fig. 24). Two independent T-DNA insertion mutants of CAMTA5 showed modified primary and lateral root development indicating a probable role of CAMTA5 in root architecture (Fig. 25). The transcriptome analyses of mutant further strengthened the hypothesis since expression of several genes critical for calcium transport and root development was perturbed in the mutant. In crux, the study establishes the role of CAMTA5 in root development.

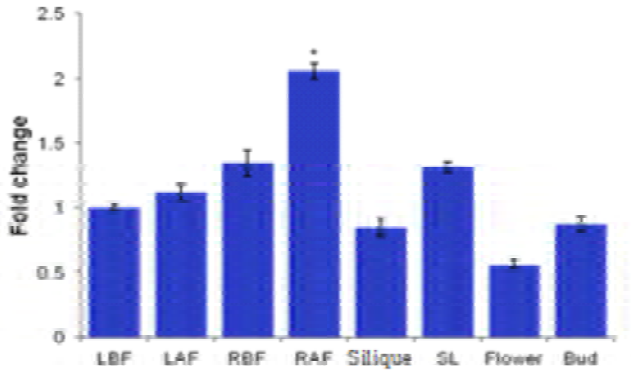

Fig. 24. Relative Expression of CAMTA5 in various tissues of *Arabidopsis thaliana* (LBF- Leaf before flowering, LAF- Leaf After Flowering, RBF- Root Before Flowering, RAF- Root After Flowering, SL- Senescent Leaf).

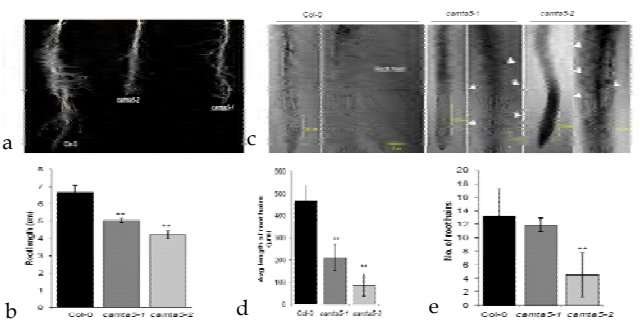

Fig. 25. CAMTA5 modulates root architecture: (a). Root morphology of *camta5-1*, *camta5-2* and Col-0. Bar = 10mm; (b). The root lengths (cm) of *camta5-1*, *camta5-2* and Col-0. Data are the mean ± SE of five different biological replicates and asterisk indicates significant difference from values of Col-0 at $P < 0.05$ (*) $P < 0.01$ (**) by t-test; (c). Confocal microscopy DIC images of *camta5-1*, *camta5-2* and Col-0 roots post 10 das (days after stratification). White arrows indicate deformed root hair initials. Bar = 200µm and 50µm; (d). & (e). Average length in µm and number of root hairs. Data are the means of ± SE of five different biological replicates and asterisk indicates significant difference from values of Col-0 at $P < 0.05$ (*) $P < 0.01$ (**) by t-test.

Genome-wide comparative and evolutionary analysis of Calmodulin-binding Transcription Activator (CAMTA) family in *Gossypium* species

The Calmodulin-binding transcription activator (CAMTA) family with amphipathic α-helical property represents one of the well-characterized Calmodulin (CaM) binding transcription factors that are reported to be evolutionarily conserved from plants to animals. This gene family selected because of its role in abiotic and biotic stresses as well as in plant growth and development. Cotton (*Gossypium* spp.), is the world's most valuable fibre producing crop, yet no substantial research is reported on cotton CAMTAs. To obtain an integrated image of the evolutionary characteristics and probable role of CAMTA family in cotton, we characterized this family in *G. arboreum*, *G. raimondii*, and *G. hirsutum*. Genome-wide screening of A-genome (*G. arboreum*), D-genome (*G. raimondii*), and AD-genome (*G. hirsutum*) for CAMTA family genes resulted into

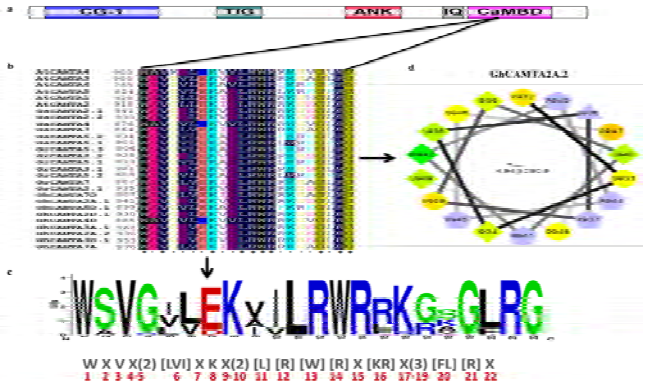

Fig. 26. Conservation of CaMBD in all cotton CAMTA proteins: (a). Functionally proved motif in *Arabidopsis* CAMTAs; (b). Alignment of conserved CaMBD of cotton CAMTAs with 6 AtCAMTAs; (c). Sequence logo of the CaMBD of 22 putative cotton CAMTAs and 6 AtCAMTAs. In the square brackets "[..]" are the amino acids allowed in this position of the motif; "X" represents any amino acid and the round brackets "(..)" indicate the number of amino acids; (d). Amphipathic á-helix structure in the predicted CaMBD of GhCAMTA2A.2 amino acid residues (Val^{932}-Leu^{949}). Circles, diamonds, triangles and pentagons represent hydrophilic residues, hydrophobic residues, potentially negatively charged and potentially positively charged residues respectively.

identification of six, seven and nine CAMTA genes, respectively. The results showed that all cotton CAMTAs were localized in the nucleus and possessed calmodulin-binding domain (CaMBD) (Fig. 26).

To understand the evolutionary origin and phylogeny of cotton CAMTA genes, CAMTA protein sequences; from various plant species known to have publicly available complete genome sequences; were extracted. As shown in Fig. 27 Plant CAMTAs were clustered into five major groups (I to V) while cotton CAMTA proteins into four (except group III). Group II CAMTAs experienced higher evolutionary pressure, leading to a faster evolution in diploid cotton.

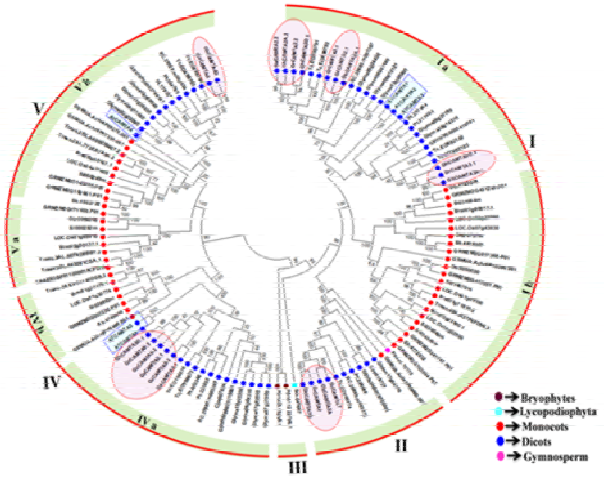

Fig. 27. Phylogenetic relationships of cotton CAMTAs from Arabidopsis and other plant species: The unrooted phylogenetic ML tree was constructed using MEGA 5.2 software with 1000 bootstrap value. The numbers beside the branches indicate the bootstrap values that support the adjacent nodes. Different colors of dots represented the different species (Brown, Bryophytes; Sky blue, Lycopodiophytes; Red, Monocots; Blue, dicots; Pink, Gymnosperms). Cotton CAMTAs and AtCAMTAs represented by pink and sky blue color, respectively.

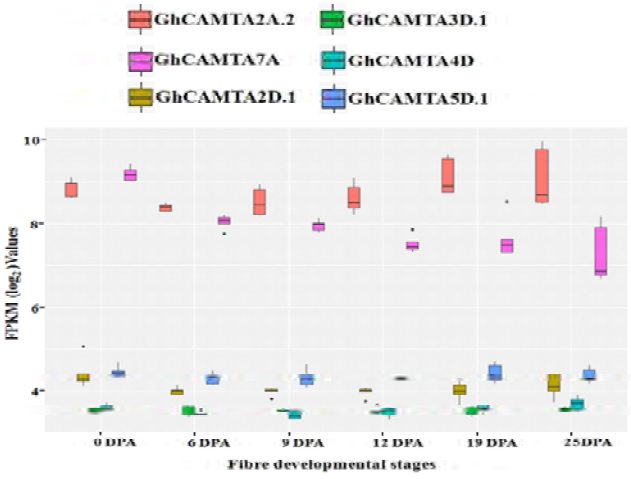

Fig. 28. Expression profiles of 6GhCAMTAs present in Affymetrix cotton chip at different fiber developmental stages: Variation in expression of six GhCAMTAs in different fiber developmental stages were visualized by box plot. Each GhCAMTAs in box plot were represented with different colors. The vertical axis represents expression values, while the horizontal axis corresponds to the different cotton fiber developmental stages. The central line for each box plot indicated median. The top and bottom edges of the box indicated the 25th and 75th percentiles.

In the present study, expression of different CAMTAs in microarray data of *G. hirsutum* at various fibre developmental stages was analyzed to retrieve the putative role and functions of various CAMTAs. Expression profiles of GhCAMTAs revealed that GhCAMTA2A.2 and GhCAMTA7A express profoundly in different stages of cotton fibre development (Fig. 28). Positive correlation between expression of these two CAMTAs and fibre strength confirmed their functional relevance in fibre development. The promoter region of co-expressing genes network of GhCAMTA2A.2 and GhCAMTA7A showed a higher frequency of occurrence of CAMTA binding motifs. This work will lead to significant refinements in understanding the functional roles and evolutionary history of CAMTA family in cotton and their potential role in cotton fibre development.

Role of GhHDA5 in H3K9 deacetylation and fibre initiation in *Gossypium hirsutum*

GhHDA5 is a class II histone deacetylase expressed significantly at the time of fibre initiation (-1 and 0 DPA). The RNAi cotton transgenic lines were generated to assess the role of GhHDA5. These RNAi transgenic lines showed the smaller boll size, lower boll and seed number (Fig. 29a) as well as suppression

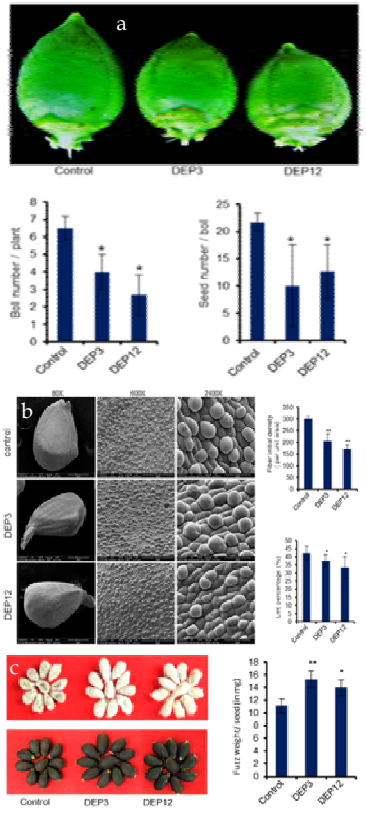

Fig. 29. Down-regulation of *GhHDA5* affects the fibre initiation and fibre yield: (a). RNAi-lines showing smaller ball size, lower Boll and Seed numbers compared to control plants; (b). SEM images of Control, DEP3 and DEP12 ovules at 0DPA. Bar=500µm [80X magnification], 100µm [600X magnification] and 20µm [2400X magnification]. Lower fiber initial density and Lint percent in RNAi lines compared to control plants; (c). Delinted seeds of control and RNAi transgenic lines, showing higher fuzz fibres, bigger seed size and higher fuzz fibre content per mg of seed weight in RNAi-lines. Error bars represent the standard deviation of three replicates. Asterisks represent Student's t-test: * $P < 0.05$; ** $P < 0.01$.

of fibre initiation in 0DPA ovules which leads to the reduction of total lint yield (Fig. 29b). Furthermore, the phenotypic analysis also revealed the larger seeds containing more fuzz fibres (shorter fibre) in the *GhHDA5* RNAi lines (Fig. 29c). The detailed molecular and genomics analysis suggested that GhHDA5 primarily acts via modulation of H3K9ac histone marks regulating expression of many hormones, stress and development-related genes involved in fibre development. Overall our results showed that the GhHDA5 is important for the fibre initiation but further more detailed investigation is needed to validate the results via generation of overexpressing lines of GhHDA5.

Inhibition of Heat Shock proteins HSP90 and HSP70 induce oxidative stress, suppressing cotton fibre development

Cotton fibre is a specialized unicellular structure useful for the study of cellular differentiation and development. Heat shock proteins (HSPs) have been shown to be involved in various developmental processes. In the present work, we assessed the effect of inhibition of HSP90 and HSP70 in *in-vitro* ovule culture to study its impact on fibre development. Microarray data analysis of five *Gossypium hirsutum* genotypes revealed high transcript levels of GhHSP90 and GhHSP70 genes at different stages of fibre development, indicating their importance in the process. Further, we identified 26 and 55 members of HSP90 and HSP70 gene families in *G. hirsutum*. Novobiocin and Pifithrin are reported inhibitors for HSP90 and HSP70 classes of proteins, respectively. We assessed the role of HSP90 and HSP70 in cotton fibre development by treating developing cotton ovules with Nov and Pif respectively in *in-vitro* ovule culture. The treatment of specific inhibitors novobiocin (Nov; HSP90) and pifithrin/2-phenylethyne- sulfonamide (Pif; HSP70) in *in-vitro* cultured ovules resulted in a fewer number of fibre initials and retardation in fibre elongation (Fig. 30a). Decline of fibre growth on the epidermal layer of the inhibitor treated ovule can be clearly seen in the Scanning electron microscopy (SEM) images (Fig. 30b). Quantitative estimation of fibre growth in initiation, elongation and secondary cell wall stage at different concentration of Pif and Nov inhibitors treated ovules further confirmed declination of growth (Fig. 30 C). Our results suggest a

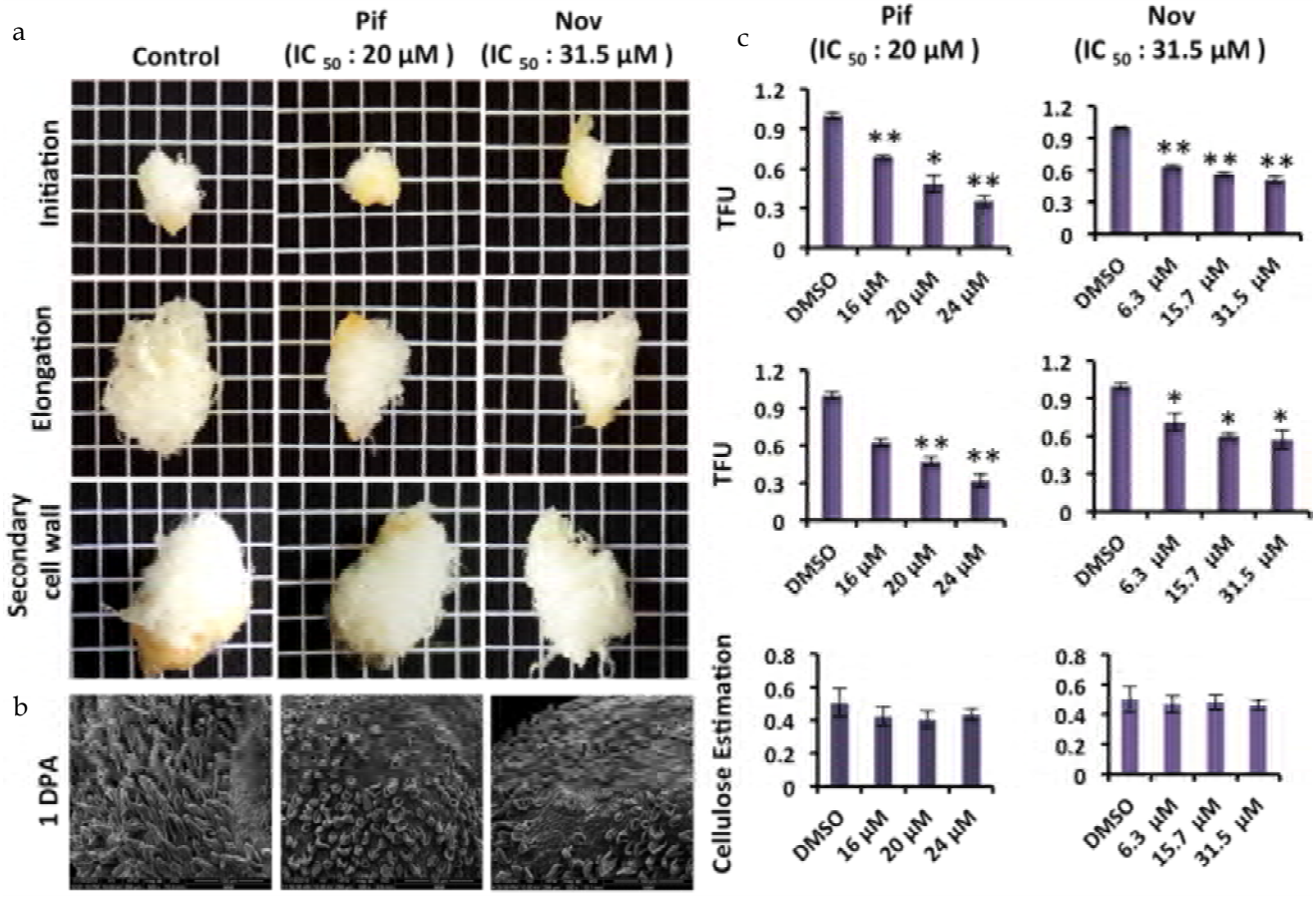

Fig. 30. Effects of different HSP inhibitors on in-vitro ovule culture at different stages of cotton fibre development; (a). Photographs of *in-vitro* cultured ovules in initiation, elongation and SCW stage showing the effect of Pif (HSP70) and Nov (HSP90) inhibitors; (b). SEM of control and treated ovules at 1 DPA shows clear decline in fiber growth; (c). Quantitative estimation of fiber growth in initiation, elongation and SCW stage at different concentration of Pif and Nov inhibitors (X-axis and Y-axis designates O.D. and concentration of inhibitors, respectively). The asterisks represent statistical significance between three biological and three technical replicates (*p-value d" 0.05, **p value d" 0.01)

significant role of HSP70 and HSP90 in maintaining homeostasis during fibre initiation and elongation.

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

NPR1 (Nonexpressor of pathogenesis-related gene) is a transcription co-activator and central regulator of Systemic Acquired Resistance (SAR) pathway. It controls wide range of pathogenesis associated genes contributing to various defense responses; stimulates by sensing SAR signal molecule, Salicylic acid (SA). A mutation in NPR1 renders increased susceptibility to pathogen derived infection thereby changing the expression landscape of pathogenic genes. Erstwhile studies have confirmed correlation between global nucleosome positioning and SA-mediated transcriptional regulation in Arabidopsis. However, role of NPR1 in SA-mediated nucleosome remodeling remains ambiguous hitherto. The current examination aims to identify role of NPR1 in nucleosome remodelling. For this, MNase-seq and transcriptomic sequencing was done in *Arabidopsis thaliana* in response to Salicylic acid in *npr1-1* and Col-0 to identify global changes in nucleosomal positioning and modulation in gene expression. Primarily, we identified remodeled nucleosomes in Col-0 and *npr1-1* post 12h SA stimulation. The remodelled nucleosomes were classified into 3 categories – Occupancies change, Positional shifts and Fuzziness change. In Col-0 before and after salicylic acid condition (C vs CS), the gap between the occupancy change of Enriched Nucleosomes as opposed to depleted nucleosomes is noticeably larger, corresponding to case in *npr1-1* before and after salicylic acid induction (N vs NS). The results of Positional shifts as well as fuzziness change in C vs CS as compared to N vs NS have an akin impression (Table 9).

Additionally, transcriptome analysis were executed for C vs CS and N vs NS samples, which highlights the important role of NPR1 in changing the global expression profile after SA treatment (Table 10) .

Table 9: Two Fold Differential change in Nucleosomal remodelling in samples (P.S positional shifts were ascertained on the basis of 30 bps threshold.) (a) Differential change in Nucleosomes in C vs CS samples (b) Differential change in Nucleosomes in N vs NS samples.

(a)	Enriched Nucleosomes	Depleted Nucleosomes
Occupancy change	21617	3960
Positional shifts	1926	687
Fuzzineess change	1898	2260
(b)	**Enriched Nucleosomes**	**Depleted Nucleosomes**
Occupancy change	17397	16615
Positional shifts	960	2884
Fuzzineess change	3291	5571

Table 10: Classification of genes into different categories

Category	Number of genes
Salicylic acid Induced(SI)	2109
Salicylic acid Repressed(SR)	1702
Salicylic acid Induced NPR1 depnedent (SI-ND)	1645
Salicylic acid Induced NPR1 independent (SI-NI)	464
Salicylic acid Repressed NPR1 dependent (SR-ND)	1316
Salicylic acid Repressed NPR1 independent SR-NI	386

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

A total of 285 guar accessions have been evaluated for 16 quantitative traits viz, Days to 50% flowering, Plant height, Days to maturity, Branches/plant, Fruiting branches/plants, Number of fruiting nodes/main stem, Number of clusters/plant, Number of pods/cluster, Number of pods/plant, Fruit yield/plant (g), Pod length (mm), Pod width (mm), Number of seeds/pod, 1000 seed weight (g), Seed yield/plant (g), and Protein content (%). The preliminary data analysis revealed significant level of variability for various traits in the evaluated accessions. Further, for SNP discovery in guar, the genomic DNA of 220 accessions were used for preparation of ddRAD libraries and sequenced on Illumina platform. A total of 7.87 billion raw sequence reads (100bp length) were generated from ddRAD sequencing platform. The mean read quality (phred score) among accessions ranged from 33.59 to 35.59. The number of reads was found to be maximum upto 6184497 and minimum was 183046, while 46.85% GC was found to be the highest among accessions. The number of bases ranged with a maximum of 618.45MB to a minimum of 18.3MB. The average read length for all the genotypes was found to be 100bp. The average homozygote rate was approximately 98.5% (maximum 99.88 and minimum 96.53) and the average heterozygote rate was found to be approximately 1.47% (maximum 3.465 and minimum 0.117). A total of 43052 SNP have been identified across 220 accessions of guar with major allele frequency <0.05.

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

For linkage analysis and mapping in linseed, total 2001 SSRs were screened between parental lines JRF-4 and Chambal. Out of 2001, 191 polymorphic SSRs were used for linkage map construction and QTL identification for *Alternaria* blight and other agronomic traits. A total of 10 QTLs have been identified: 4 QTLs for capsule/plant, 2 QTLs each for capsule weight/plant, seed weight/plant and *Alternaria* blight resistance. Three QTLs each found on LG 14 and LG 9, 2 QTLs on LG9 and 1 each on LG 6 and LG2. The percentage phenotypic variability varied from 1.0 (QTL for seed weight/plant) to 10.5 (capsule weight/plant).

Plant Microbe Interaction, Pharmacognosy and Phytochemistry

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PLANT MICROBE INTERACTION, PHARMACOGNOSY AND PHYTOCHEMISTRY

PLANT MIRCOBE INTERACTION

In-House Projects

Plant Molecular Virology Studies

Ageratum enation virus infection induces programmed cell death and alters metabolite biosynthesis in *Papaver somniferum*

A previously unknown disease which causes severe vein thickening and inward leaf curl was observed in a number of opium poppy (*Papaver somniferum* L.) plants (Fig. 1 a-c). The sequence analysis of full-length viral genome and associated betasatellite revealed the occurrence of *Ageratum enation virus* (AEV) and Ageratum leaf curl betasatellite (ALCB), respectively. Co-infiltration of cloned agroinfectious DNAs of AEV and ALCB induces the leaf curl and vein thickening symptoms as observed naturally. Infectivity assay confirmed this complex as the cause of disease and also satisfied the Koch's postulates. In the AEV infected poppy sample, the production of stress biomolecules like sugar and proline was elevated by two-fold. Moreover, the production of scavenging enzymes, APX, LPX, SOD, and CAT, was also elevated to cope with the elevated ROS. Microscopic analysis of infiltrated plants revealed severe structural anomalies in leaf and stem tissues represented by unorganized cell architecture and vascular bundles. The characteristic blebs and membranous vesicles formed due to the virus-induced disintegration of the plasma membrane and intracellular organelles were also present (Fig. 1 d-f). An accelerated nuclear DNA fragmentation was observed by Comet assay and confirmed by TUNEL and Hoechst dye staining assays, suggesting virus-induced programmed cell death. The biosynthesis potential of morphine, thebaine, codeine, and papaverine alkaloids reduced significantly in infected plants except for noscapine whose biosynthesis was comparatively enhanced (Fig. 2). The expression analysis of corresponding alkaloid pathway genes by real time-PCR corroborated well with the results of HPLC analysis for alkaloid perturbations. Virus-infection altered the biosynthesis of several important metabolites. The GC-MS study of AEV infected poppy leaves and stem tissues demonstrated 1.5-fold upregulation in sugar derivatives, which suggested that infected plants divert their carbohydrate flux metabolic activities to sensing the stress. This study and that AEV infection causes reduction in the metabolite contents resulting in decrease in the commercial value of the crop.

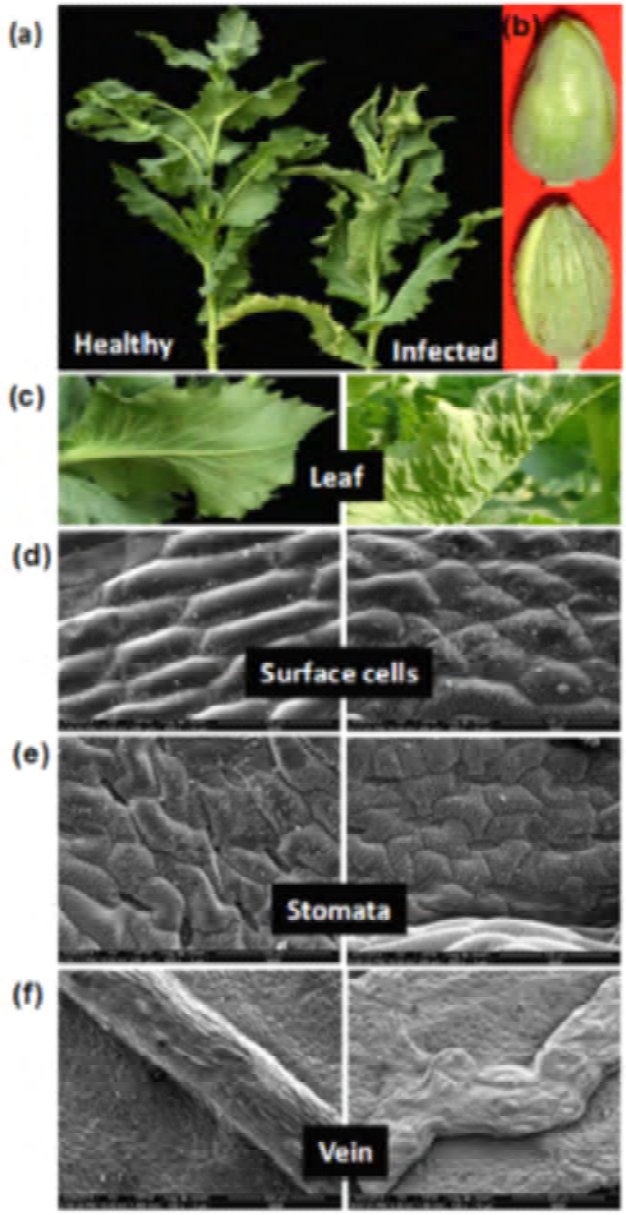

Fig. 1: Symptoms and anatomical alterations in naturally infected *Papaver somniferum* plant. (a) Infected poppy plant exhibiting typical upward leaf curling, rolling, and stunting symptoms. (b) Capsule from same infected plant exhibiting enations. A healthy plant and capsule are shown for comparison. (c) Close view of healthy with no symptom and infected leaf showing upward leaf curling with enation symptoms. (d–f) Micrographs showing alterations in the surface cell, stomata and veins in infected leaves (right panels). (d) SEM of abaxial side of the leaf showing alterations in the surface cells. (e) Stomata are sunken. (f) Veins are irregularly thickened. The images on the left panels are shown as control (healthy leaves).

Full length genome sequence of *Cyrtanthuselatus virus-A* isolated from *Narcissus tazetta* in India

Narcissus tazetta L. is a bulbous ornamental plant popular for its notable fragrant flowers, which make it a plant of high economic value. *Narcissus* is found to be susceptible for a number of diseases borne by fungi, bacteria, nematodes, and viruses. A potyvirus, *Cyrtanthuselatus virus-A* isolate NBRI16 (CEVA-NBRI16), associated with leaf chlorotic stripe disease of *N. tazetta* cv. Paperwhite was reported for first time in India from virology laboratory of CSIR-NBRI, based on the partial coat protein gene sequence. A randomly chosen sample was used for full-length genome amplification taking the advantage of available degenerate primer pairs targeting different conserved motifs of potyvirus genome. The 32 UTR to partial nuclear inclusion B (Nlb) region of ~1.6 kb was amplified using Pot-I/ Pot-II primers which target the polyadenylated 32 end and -GNNS- motif in Nlb region of CEVA isolate, respectively. The results of sequence analysis showed that the genome of CEVA-NBRI16 isolate is 9942 nucleotides long and contain 5'UTR, a single large predicted ORF (nucleotide positions 460-9769) encoding large polyprotein (387.12 kDa) of 3100 amino acids and 3'UTR (Fig. 3a). The polyprotein further yields the predicted ten mature proteins identified as P1, HC-Pro, P3, 6K1, CI, 6K2, VPg (viral protein genome-linked), Nla-Pro (nuclear inclusion protein a protease), Nlb, and CP having the amino acid number/ molecular weight (kDa) of 317/38.0, 457/54.8, 382/45.8, 52/6.2, 635/76.2, 52/6.2, 185/22.2, 241/28.9, 520/62.4, and 259/31.0, respectively (Fig. 3a). The complete nucleotide and deduced large polyprotein sequence of NBRI16 isolate when compared to previously reported potyviruses shared only 93 and 94% identities, respectively, with the only available full-length sequences of CEVA-Marijiniup7-1 and

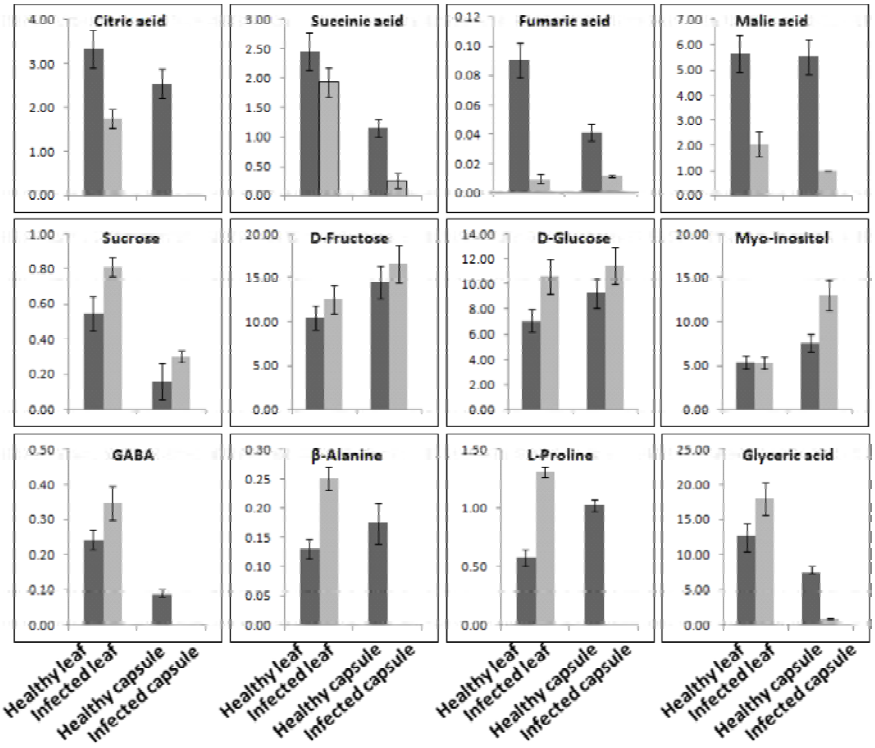

Fig. 2: *Ageratum enation virus* infection altered the alkaloid contents and perturbs the respected pathway genes in infected poppy sample. HPLC analysis revealed the alterations in major alkaloids, morphine, codeine, thebaine, narcotine, and papaverine in infected plant. Values are given as the mean—SD of three independent experiments.

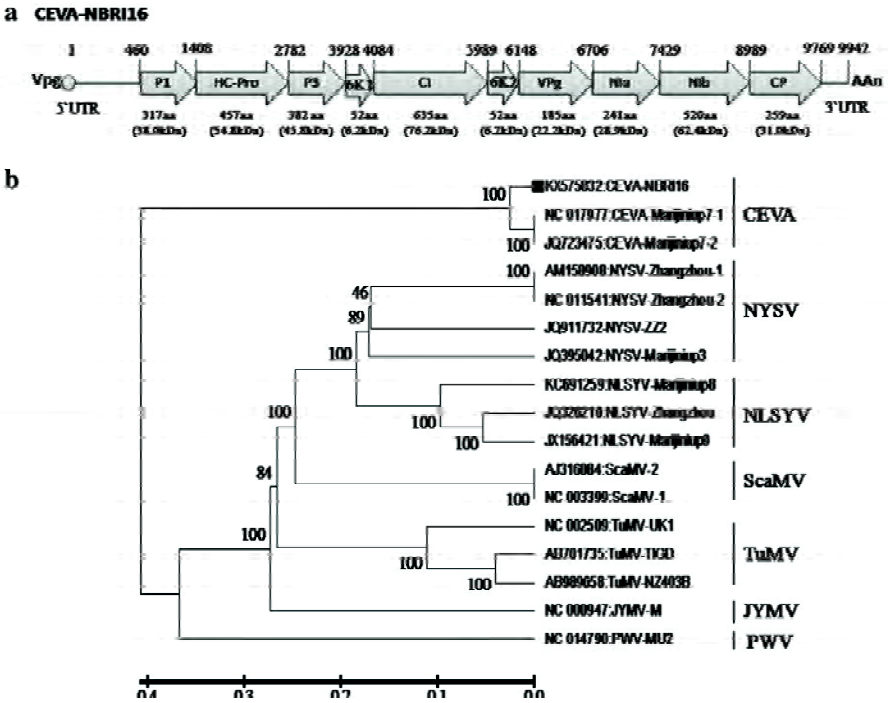

Fig. 3: a. Schematic representation of full length genome of narcissus isolate CEVA-NBRI16. Arrow represents the orientation of ORFs present in virus genome. The numbers above the ORF indicate their starting site, while the length (amino acids) and predicted molecular weight (in kDa) of ORF are shown below. 3b. Phylogenetic tree showing closest relationship of CEVA-NBRI16 isolates with CEVA-Marijiniup7- 1 and Marijiniup7-2.

CEVAMarijiniup7- 2 isolates (Fig. 3). Tree was constructed employing MEGA v6.1 tool using Maximum-likelihood method based on the Tamura–Nei model with 1000 bootstrap replicates (Fig. 3b). The full-length genomic sequence of CEVA from narcissus plant is being reported for the first time from India.

Microbial intervention for amelioration of abiotic and biotic stresses in plants

Studies on the synergistic activity of plant growth promoting rhizobacteria and *Chlorella vulgaris* to enhance plant growth under arsenic and phosphate stress conditions

A study was conducted to elucidate the potential role of microalgae, *Chlorella vulgaris (CHL),* and plant growth promoting rhizobacteria, *Pseudomonas putida* (PAR) on rice plant grown under excess As and phosphate (P) conditions. Synergistic activity of *P. putida* and *C. vulgaris* was found to enhance plant growth under both arsenic and arsenic with phosphate stress conditions (Fig. 4a). Interaction of *P. putida* and *C. vulgaris* impeded arsenic uptake in rice plant (Fig. 4b) by improving the detoxification mechanism of the plant (Fig. 4c). The CHL and PAR combination also modulated the phosphate trafficking in rice in order to mitigate arsenic uptake by modulating P:As and As:biomass ratio.

Understanding the role of Bacillus amyloliquefaciens in abiotic stress tolerance and phytohormones response in rice

Role of plant growth promoting strain of *Bacillus amyloliquefaciens* SN13 in ameliorating various abiotic stresses such as salt, drought, desiccation, heat, cold, and freezing on a popular rice cv. Saryu-52 was investigated. Studies were carried under hydroponic growth conditions with and without SN13 inoculation, and subjected to various abiotic stresses and also exogenously supplied with phytohormones such as abscisic acid (ABA), salicylic acid (SA), jasmonic acid (JA) and ethephon (ET) for 1, 3, 10, and 24h.

Proline and TSS content of inoculated rice plants showed significant time-dependent increase as compared to the non-inoculated seedlings under all stresses.

In our findings lipid peroxidation (LP) was significantly lower at all durations of short-term salt, drought, and desiccation stresses upon SN13 inoculation except at late stress, i.e., 24 h. It may be possible that initially layer of mucilage around root protects plant by direct exposure to stress but later bacterial adherence to root or root cortex changes membrane permeability to some extent and leads to slight increase in membrane damage.

Further two representative abiotic stresses i.e. salt and heat, and two representative phytohormone treatments i.e. ABA and JA were selected for gene expression analysis. The selected genes *DHN, GST, LEA, NAM, GRAM*, and *NRAMP6* were found to be differentially expressed and generally followed the similar pattern in biochemical assays under all stresses and phytohormone treatments (Fig. 5).

Based on differential responses of rice seedlings to abiotic stresses and phytohormones, PCA analysis confirmed basis for a holistic view on SN13 inoculation

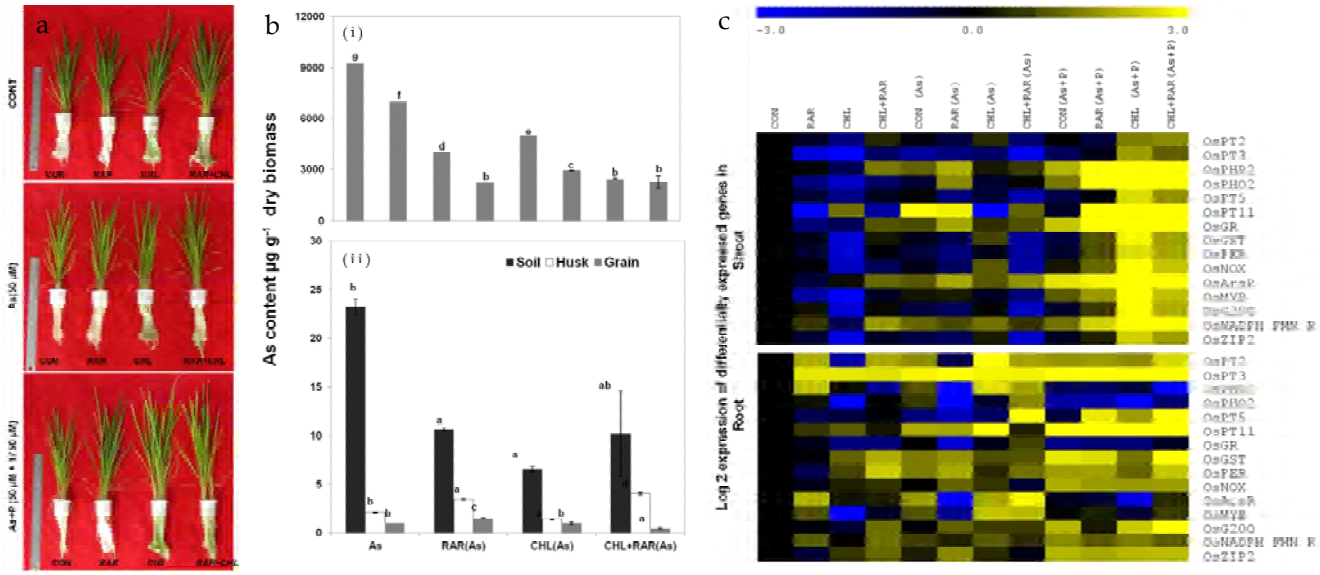

Fig. 4: Effect of *Pseudomonas putida* (PAR) and *Chlorella vulgaris*(*CHL*) inoculations (alone and combination) on (a) the growth of rice plant in presence and absence of arsenate (AsV) and phosphate stress; (b) arsenic uptake of rice in hydroponic (i) and live soil conditions (ii); (c) Heat map showing expression profiling of differentially expressed genes of phosphate transporters, defence response and other stress responsive genes in hydroponically grown rice root and leaf tissues.

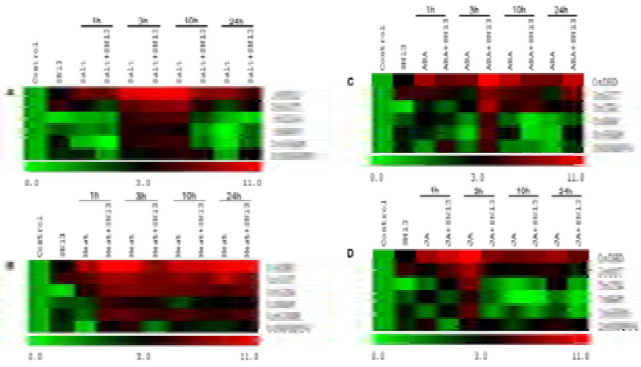

Fig. 5: Differential expression of genes in rice exposed to salt (A), heat (B), ABA (C), and JA (D) stress at 1, 3, 10, and 24 h in the presence or absence of SN13. The heat map has been generated based on the fold-change values in the treated sample when compared with its unstressed control sample.

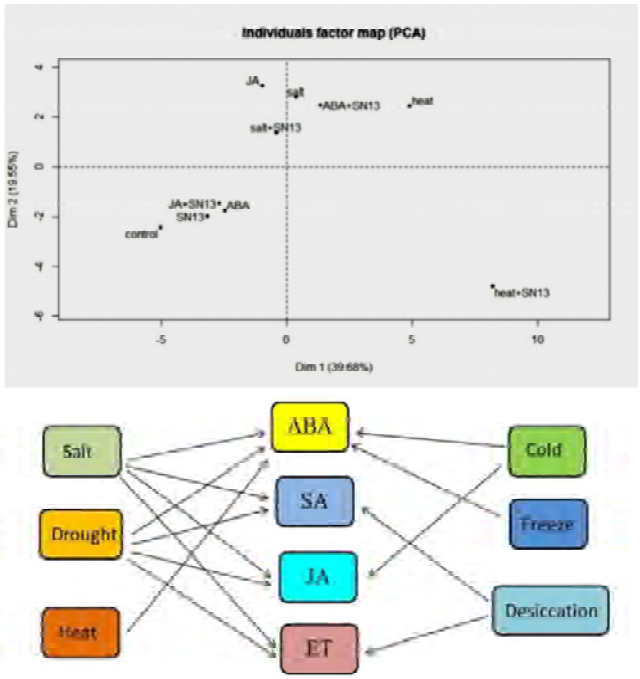

Fig. 6: 6a. Principal component analysis biplot of biochemical traits and gene expression of rice under abiotic stresses and phytohormone treatments in the presence or absence of SN13 (A model of the SN13 responsive cross-talk among various abiotic stresses and 6b. Phytohormones operating in rice is created based on biochemical analyses and gene expression profiling

effects on rice response to different abiotic stresses and phytohormone treatments (Fig. 6a) based on which a model for cross-talk was also generated (Fig. 6b).

Assessment of availability and soil application potential of surplus rice straw residue for improving soil productivity using microbial intervention

Intensive cropping has depleted soil organic carbon (SOC) leading to soil infertility and land degradation. To restore depleted SOC, renewable sources of organic amendments are required.

We assessed the prospective of surplus crop residue (CR) for soil recarbonization and nutrient sequestration to restore SOC and promote ecosystem services for sustainable agriculture. The magnitude of CR generated and its fertilization potential using the derived conversion factors and crop production data from 2002-2016 were extrapolated. The extrapolations shows availability of surplus rice straw residue left after secondary use in most of the states in Indo-Gangetic Region. (Fig. 7). The application of rice straw residue will be helpful in regaining soil organic carbon and could partially fulfil the need of nutrients such as potassium and phosphorus to improve soil fertility. The group is prospecting microbial application to ensure judicious use of the agricultural residues.

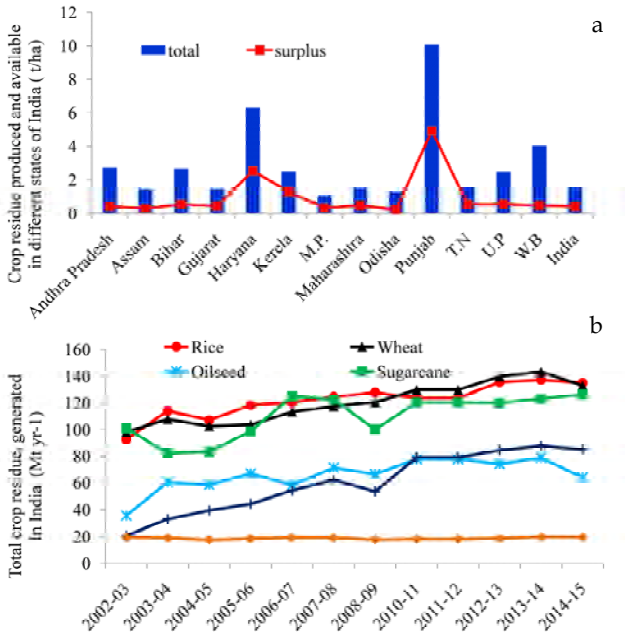

Fig. 7: Total and surplus crop residue abundance per hectare, generated in different states of India (a) CR_{Sab} = CR_S /A. All India residues generated from major crops cultivated during 2002-15 (b) CR = P x R_f x DM_f

Endophyte-mediated modulation of defense-responsive genes and systemic resistance in *Withania somnifera* (L.) Dunal under *Alternaria alternata* stress

Endophytes have been explored to perform an important role in plant health. However, their effects on the host physiological function and disease management remains elusive. Study was carried out to assess the potential of endophytes singly as well as in combination on various physiological parameters and systemic defense mechanism against *Alternaria alternata* in *Withania somnifera*. Seed priming with endophytic *Bacillus amyloliquefaciens* and *Pseudomonas fluorescens*, individually and in combination, demonstrated enhanced vigour index and germination rate. Plants treated with the microbial combination showed remarkably reduced plant mortality (71.40%) under *A.*

alternata stress. Physiological profiling of treated plants showed improved photosynthesis, respiration, transpiration and stomatal conductance under pathogenic stress. Additionally, these endophytes not only augmented defense enzymes and antioxidant activity in treated plants but also enhanced the expression of salicylic-and jasmonic acid-responsive genes in the stressed plants. Reduction in reactive oxygen and nitrogen species along with enhanced callose deposition in host plant leaves corroborated well with the above findings. Altogether, the study provides novel insights into the underlying mechanisms behind the tripartite interaction of endophyte- *A. alternata*- *W. somnifera* and underscores their ability to boost up plant health under pathogen stress.

Bacterial endophytes modulates the withanolide biosynthetic pathway and physiological performance in *Withania somnifera* under biotic stress

Despite the vast exploration of endophytic microbes for growth enhancement in various crops, knowledge about their impact on the production of therapeutically important secondary metabolites is scarce. In the current investigation, chitinolytic bacterial endophytes were isolated from selected medicinal plants and assessed for their mycolytic as well as plant growth promoting potentials. Among them the two most efficient bacterial endophytes namely, *Bacillus amyloliquefaciens* (MPE20) and *Pseudomonas fluorescens* (MPE115) individually as well as in combination were able to modulate withanolide biosynthetic pathway and tolerance against *Alternaria alternata* in *Withania somnifera*. Interestingly, the expression level of withanolide biosynthetic pathway genes (3-hydroxy-3-methylglutaryl co-enzyme A reductase, 1-deoxy-D-xylulose-5-phosphate reductase, farnesyl di-phosphate synthase, squalene synthase, cytochrome p450, sterol desaturase, sterol Ä-7 reductase and sterol glycosyl transferases) were upregulated in plants treated with the microbial consortium under *A. alternata* stress. In addition, application of microbes not only augmented withaferin A, withanolide A and withanolide B content (1.52–1.96, 3.32–5.96 and 12.49–21.47 fold, respectively) during *A. alternata* pathogenicity but also strengthened host resistance *via* improved photochemical efficiency, normalizing the oxidized and non-oxidized fraction, accelerating photochemical and non-photochemical quantum yield, and electron transport rate. Moreover, reduction in the passively dissipated energy of PSI and PSII in microbial combination treated plants corroborate well with the above findings. Altogether, the above finding highlights novel insights into the underlying mechanisms in application of endophytes and emphasizes their capability to accelerate biosynthesis of withanolides in *W. somnifera* under biotic stress caused by *A. alternata*.

Effect of biosynthesized silver nanoparticles on native soil microflora via plant transport during plant - pathogen -nanoparticles –interaction

In this study, the interaction of biosynthesized silver nanoparticles (BSNP) with native soil *via* plant transport was assessed in model pathosystem of *Arabidopsis thaliana* and *Alternaria brassicicola*. Foliar application of 5 ìg/mL of BSNP reduced number of spores of fungi to 2.2×10^5 from 7×10^5, while numbers of lesions got reduced to 0.9/leaf in treated plants compared to 2.9/leaf in pathogen-infected plant without altering soil pH, electric conductivity, soil organic carbon and soil microbial biomass carbon. Soil enzyme activities including dehydrogenase, acid and alkaline phosphatase, urease, β-glucosidase and protease did not alter significantly in BSNP-treated plants compared to control plants. Application of BSNP did not alter the number of cultivable bacteria, fungi and actinomycetes. Effect of BSNP on uncultured bacterial diversity was measured by DGGE analysis which revealed similar banding pattern in all different treatments except in *A. brassicicola*-infected (AB) and *A. brassicicola*-infected plants treated with silver nanoparticles (AB + BSNP) after 120 days. Although AB-infected plants exhibited a decrease in bacterial diversity, treatment of AB + BSNP after 120 days demonstrated maximum bacterial diversity. McIntosh, Shannon, and Simpson diversity indices were calculated based on carbon source utilization pattern by BIOLOG analysis, revealing no significant difference among all treatments in different time intervals. BSNPs have the potential to act as strong antimicrobial agent for plant disease management without altering the native soil microflora.

Finding a facile way for the bacterial DNA transformation by biosynthesized gold nanoparticles

To overcome the problem of transformation of bacteria due to their natural non-competency during genetic manipulations, a cost-effective method was developed by combining the properties of gold nanoparticles (GNPs) and the Yoshida effect. Various parameters, including GNP:plasmid ratio, pH and time, were optimized for stability of the GNP–plasmid conjugate. With non-competent Gram-negative cells, the efficiency ranged between 0.1 and 0.45×10^4 transformants ìg^{-1}, while the range was $(0.02–0.2) \times 10^4$ transformants ìg^{-1} with Gram-positive bacteria. The

results showed that GNPs could serve efficiently as a vehicle for better transformation in bacteria.

Protective role of biosynthesized silver nanoparticles against early blight disease in *Solanum lycopersicum*

Tomato suffers a huge loss every year because of early blight disease. This study focuses on efficient inhibition of *Alternaria solani,* the causative agent of early blight disease in tomato *in vitro* and *in vivo.* Foliar spray of 5 ìg/mL of biosynthesized silver nanoparticles in *A. solani* infected plants resulted in significant increase of 32.58% in fresh weight and 23.52% in total chlorophyll content of tomato as compared to *A. solani* infected plants. A decrease of 48.57, 30, 39.59 and 28.57% was observed in fungal spore count, lipid peroxidation, proline content and superoxide dismutase respectively in infected tomato plants after treatment with synthesized silver nanoparticles as compared to *A. solani* infected plants. No significant variation in terms of soil pH, cultured population, carbon source utilization pattern and soil enzymes including dehydrogenase, urease, protenase and β-glucosidase were observed after foliar spray of nanoparticles. It was revealed that direct killing of pathogens, increased photosynthetic efficiencies, increased plant resistance and decrease in stress parameters and stress enzymes are the mechanisms employed by plants and nanoparticles simultaneously to combat the biotic stress. Biosynthesized silver nanoparticles bear the potential to revolutionize plant disease management, though the molecular aspects of increased resistance must be looked upon.

A novel Trichoderma fusant for enhancing nutritional value and defence activity in chickpea

In recent years, due to the rise in food consumption, much of the attention has been focused to increase the yield of the agricultural crops, which resulted in compromised nutritional quality. Efforts have to be undertaken to enhance the nutritional attributes of legumes, cereals and staple food crops by increasing amino acids and mineral content. In the present study, we evaluated a protoplast fusant (*Hypocrea lixii* MTCC 5659) for its ability to enhance nutritional value and defence activity in chickpea. Essential amino acids: methionine (9.82 mg kg^{-1} dw), cysteine (2.61 mg kg^{-1} dw), glycine (11.34 mg kg^{-1} dw), valine (9.26 mg kg-1 dw), and non-essential amino acids: aspartic acid (39.19 mg kg^{-1} dw) and serine (17.53 mg kg^{-1} dw) were significantly higher in seeds of fusant inoculated chickpea. Fusant significantly improved accumulation of mineral nutrients i.e. Cu (157.73 mg kg^{-1} dw), Co (0.06 mg kg^{-1} dw), Ni (1.85 mg kg^{-1} dw), Zn (157.73 mg kg^{-1} dw) and S (16.29 mg kg^{-1} dw) in seeds. Biocontrol and defence activities of chickpea increased from 20 to 35% in fusant inoculated plants suggesting its potential to ameliorate biotic stress. To the best of our knowledge, this is the first report of an increase in amino acids and mineral content of chickpea by fusant inoculation.

Grant-in-Aid Projects

A comparison of microsatellites in phytopathogenic *Aspergillus* species in order to develop markers for the assessment of genetic diversity among their isolates

The occurrence of Microsatellites (SSRs) has been witnessed in most of the fungal genomes however, its abundance varies across species. The frequency of SSRs in the whole genome and transcripts of *Aspergillus* strains were analyzed and compared between two phyto-pathogenic strains (*A. niger* and A. *terreus*) and two non-pathogenic strains (*A. nidulans* and *A. oryzae*). Higher relative abundance and relative density of SSRs were observed in the whole genome and transcript sequences of the pathogenic *Aspergillus* when compared to the non-pathogenic. The relative abundance and density of SSRs were positively correlated with the G+C content of transcripts. Among the different classes of SSR, the percentage of tetra-nucleotide SSRs were maximum in *A. niger* (36.7%) and *A. oryzae* (35.9%) whereas *A. nidulans* and *A. terreus* preferred tri-nucleotide SSRs (38.2 and 42.1%) in whole genome sequences. In transcripts, tri-nucleotide SSRs were the most abundant whereas di-nucleotide SSRs were the least favored. Motif conservation study among the transcripts revealed conservation of only 27% motif within *Aspergillus* species. Furthermore, a similar relationship among the *Ascomycetes* was obtained on the basis of motif conservation and conserved genes (rDNA). To analyze the diversity present within the Indian isolates of *Aspergillus*, primers were successfully designed for 692 motifs in *A. niger* and *A. terreus,* of which 20 were selected for diversity analysis. Among all the markers amplified, 10 markers (83.3%) were polymorphic, whereas remaining two markers (16.6%) were monomorphic. Ten polymorphic markers acquired in this investigation showed the utility of recently created SSR markers in the assessment of genetic diversity among various isolates of *Aspergillus*.

Deciphering plant responses to elevated CO_2 and its implication for root-soil-microbe interaction

Effect of biofertilizer *Trichoderma reesei* MTCC5659 (BF) on paddy crop was studied under elevated CO_2 condition (eCO_2). The results show that percent change of yield was minimum in the BF treated variety, which

indicated the efficiency of Trichoderma MTCC5659 in ameliorating CO_2 stress. SEM analysis of root micrographs revealed intact sections in eCO_2 condition with treatment whereas distorted morphology of sections was obtained in non-treated plants. This might have ensured proper transport of water and nutrients required for combating stress more efficiently under CO_2 stress. Additionally, the numbers of meta xylem were also increased from four to five due to various adaptation strategies induced by BF under elevated conditions. The antioxidant activity was found increased in the treatment under elevated CO_2 condition, which indicated the increased stress resistance in rice.

Screening of pearl millet genotypes at germination and early seedling growth stages

Six pearl millet genotypes namely, PRLT2/89-33, H77/833-2, PPMI 69, PPMI 301, 863B-P2 and TT-1 were subjected to drought stress at different level of osmotic stress at early- and late-seedling growth stages. To analyze the effect of PEG induced osmotic stress at early seedling stage for different agronomic traits, ANOVA was performed that showed significant difference in all traits in both treatment and genotypes. Among all genotypes, TT-1 and H77/833-2 had maximum relative decrease (RD) in germination percentage (G%), root length (RL), root weight (RW) and shoot weight (SW) while PRLT2/89-33 showed no change in G% and minimum decline was recorded in almost all traits. At early seedling stage, proline content was estimated, that showed more than 1.5 fold increase in TT-1, PPMI301 and PPMI69 while 2.4 fold or more increase was observed in 863BP2, 2.6 fold in PRLT2/89-33 and 2.8 fold fold H77/833-2 (Fig. 8a).

At late seedling growth stage at 24 h, PPMI69 showed a 6-fold increase in proline accumulation followed by PRLT2/89-33 and TT-1 (~5 fold), 863BP2 (3.8 fold), H77/833-2 (2.8 fold), and PPMI301 (2.5 fold) (Fig. 8B).

All six pearl millet genotypes showed differential expression patterns for three antioxidative genes under study, namely APX, GlutR and SOD. Based on various morphological, biochemical and molecular parameters, this study indicated PRLT2/89-33 to be more drought tolerant, while TT-1 and H77/833-2 were found to be drought sensitive genotypes.

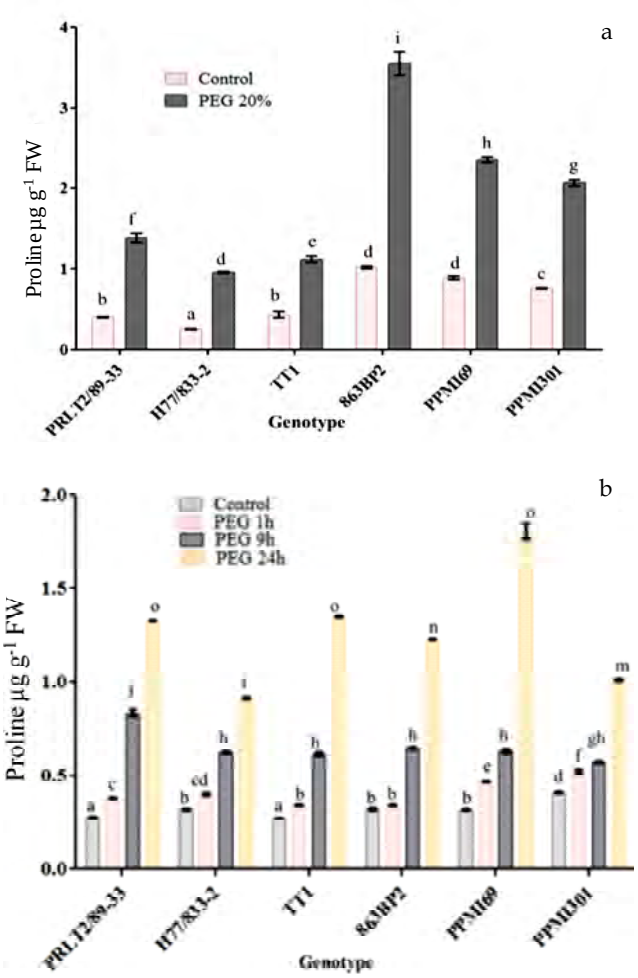

Fig. 8: Changes in proline content level of different pearl millet genotypes under (a) 20% PEG treatment at early growth stage and (b) 30% PEG treatment at late growth stage. Data represent the means ± SD of three independent experiments.

Expression analysis of miRNAs and their respective target genes to understand their role in RA-mediated abiotic stress tolerance in chickpea

This study was carried out to understand the role of *Pseudomonas putida* RA in modulating the expression of miRNAs and their target genes in response to drought and salt stresses in chickpea.

A drought tolerant '*desi*' chickpea cv. BG-362 was selected to investigate the effects of RA-inoculation on the expression profiles of nine conserved miRNAs, namely,miR159, miR160, miR166, miR167, miR169, miR171, miR172, miR393 and miR396 and their respective target genes namely, gibberellin- and abscisic acid-regulated MYB-like (*GAMYB-like*), auxin response factor 16-like (*ARF16*), homeobox-leucine zipper protein-15 (*ATHB-15*), ABSCISIC ACID-INSENSITIVE 5-like protein 5 (*ABI5*), nuclear transcription factor Y subunit A-1 (*NF-YA1*), nodulation-signalling pathway-2 protein-like (*NSP2*), ethylene-responsive transcription factor RAP2-7-like (*RAP2-7*), AUXIN SIGNALING F-BOX 2 (*AFB2*), and cysteine protease29 (*CP29*) under different durations of drought and salt stresses. All miRNAs and their target genes were amplified and resolved on agarose gels, and the presence of a unique product was verified for each primer pair (Fig. 9a-b).

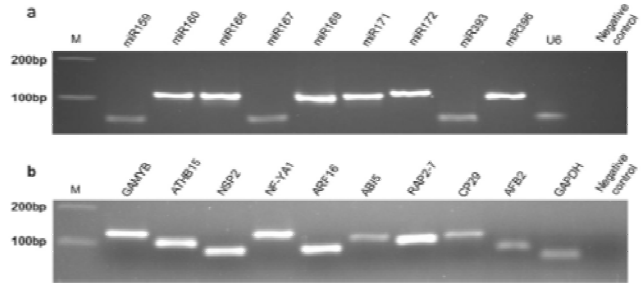

Fig. 9: Amplification products by PCR. a selected miRNAs. b Target genes

All the chosen conserved miRNAs and their targets showed differential expression under drought (Fig. 10a and 10b) and salt stresses (Fig. 11a and 11b) in chickpea and were also found to be involved in the regulation of stress response.

The study showed significant alterations in the expression patterns of miR159, miR160, miR166, miR167, miR169, miR171, miR172, miR393 and miR396 at atleast one time-point in drought and salt-stressed plants exposed or not to RA inoculation suggesting them to be the key players of abiotic stress alleviation in chickpea.

Characterization of gene(s) responsible for tyloses formation in chickpea during *Fusarium oxysporum* infection

Study is under progress to characterize gene(s) responsible for tyloses formation in chickpea during *Fusarium oxysporum* infection. Contrasting wilt resistance varieties of chickpea were planted and infected with

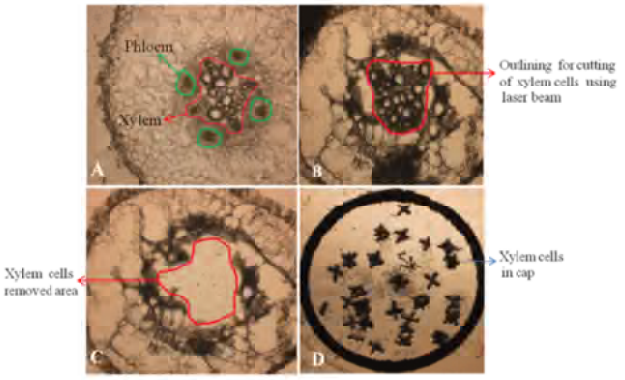

Fig. 12: Cryo-sectioning and capturing of xylem cells from chickpea roots: a-Root section of 10 µm size showing xylem and phloem cells; b-Outlining of xylem cells using laser beam for cutting and capturing; c-Section after catapulting xylem cells; d-Adhesive cap containing catapulted xylem cells.

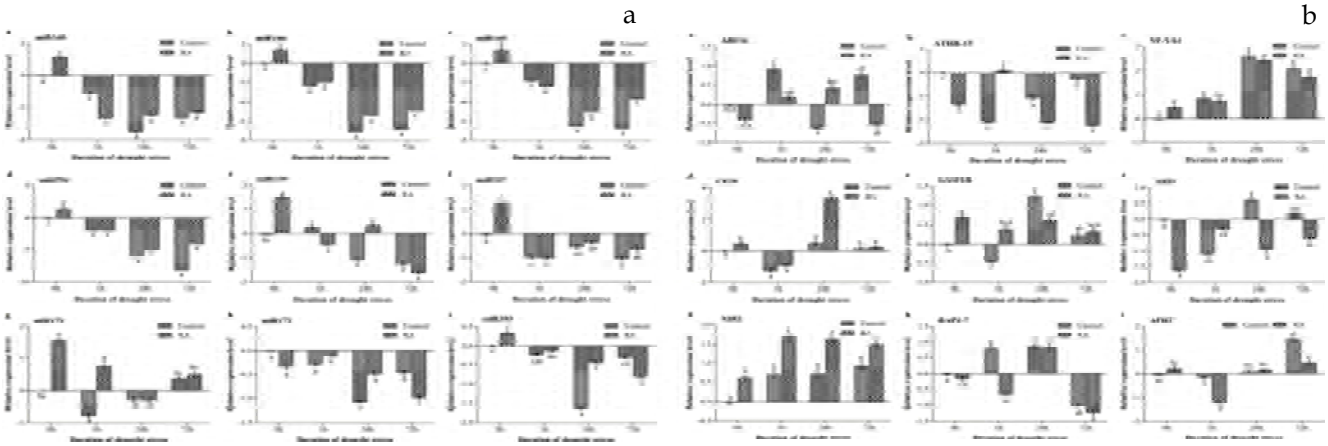

Fig. 10: Expression analysis of nine conserved miRNAs (a) and target genes (b) by qRT-PCR in chickpea cultivar cv. BG-362 exposed to drought stress at 0 h, 1 h, 24 h and 72 h in the presence or absence of RA.

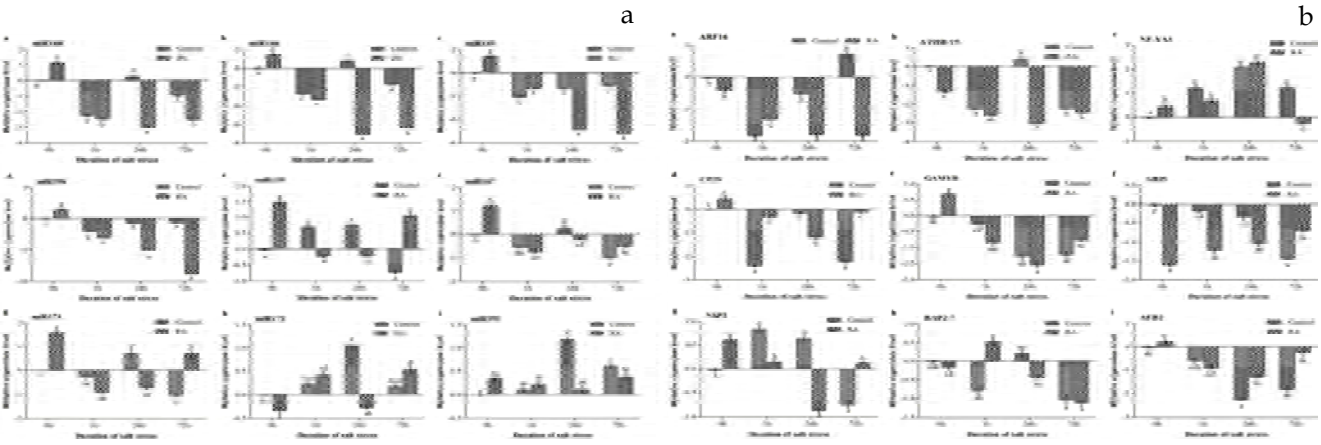

Fig. 11: Expression analysis of nine conserved miRNAs (a) and target genes (b) by qRT-PCR in chickpea cv. BG-362 exposed to salt stress at 0 h, 1 h, 24 h and 72 h in the presence or absence of RA.

Fusarium oxysporum. Laser capture micro dissection (LCM) of the section were made to take out the xylem parenchyma cells for isolation of RNA from xylem cells. Fig. 12 shows cryosectioning and capturing of xylem cells from chickpea roots.

Exploration of native endophytic fungi from *Bacopa monnieri* involved in bacoside production

Studies were made to isolate and identify endophytic fungal strains capable of producing medicinally important bacoside. Saponins producing indigenous endophytic fungal strains were isolated from *Bacopa monnieri* leaves. The fungal crude extracts were prepared and analyzed for production of bacosides and withanolides using HPLC. Three best isolates (SUBL33, SUBL51 and SUBL206) were further characterized for morphological and biochemical traits (phytochemical, extracellular enzymes and antimicrobial) and plant growth promoting features. The isolates were identified by the ITS1 sequence analysis, which were submitted to Genbank under the accession numbers MH071153, MH071155 and MH071154, respectively. This is the first report of production of bacosides and withanolides content through endophytes.

PHYTOCHEMISTRY

In-House Projects

Bio-prospection of *Diospyros cordifolia*

Essential oil of *Diospyros cordifolia* leaves: *D. cordifolia* leaves were analysed for the first time for their essential oil content. Nine compounds were quantified which represented 71.28% of the oil. The main class of compounds were terpenoids, diterpene, and fatty acid. The identified compounds in the essential oil were hexadecane (1.24%), caryophyllene oxide (3.84%), tau-cadinol (3.48%), á-cadinol (8.63%), isopropyl myristate (6.07%), hexahydrofarnesyl acetone (30.58%), phthalic acid (6.73%), phytol (2.30%) and phytol acetate (8.41%). The major compound in essential oil was hexahydrofarnesyl acetone, which is used as a flavor and fragrance. It is used as a fragrance in jasmine compositions. Another major compound, phytol acetate is used as a food additive. Isopropyl myristate is a polar emollient and is used in cosmetic and topical medicinal preparations.

Identification of bio-molecules from *D. cordifolia* by UPLC-ESI-QTOF/MS: Eight compounds namely isorhmnetin, myricetin, 3,5-O-cyclodiospyrin, chromenone ester, chromenone acid, kaempferol glucoside, epicatechin and 1-hexacosanol were detected in UPLC-ESI-QTOF/MS. The molecular mass of the compounds was obtained from their positive and negative ion electrospray mass spectra (ESI-MS), which described the corresponding protonated and deprotonated pseudomolecular ions. The peaks of identified compounds are shown in Fig.13. Substitution products at á-and gamma- positions of benzopyronyl ring of 7- methyljuglonechromenone ester and chromenone acids were reported.In the positive ion mode five phytochemicals yielded with their protonated molecule $[M+H]^+$ were tentatively identified based on their mass. Peaks corresponding to the molecular species of isorhamnetin (m/z 317), myricetin (m/z 319), and chromenone ester (407), epicatechin (m/z 291) and 1-hexacosanol (m/z 383) were identified. In the negative ion mode three phytochemicals yielded with their deprotonated molecule $[M-H]^-$ tentatively identified based on their mass. Peaks corresponding to the molecular species of 3, 5-o-cyclodiospyrin (m/z 371), chromenone acid (m/z 377) and kaempferoldiglucoside (m/z 609) were detected by UPLC-ESI-QTOF/MS., Chromenone ester, epicatechin and 1-hexacosanol reported in other species of *Diospyros*, were also reported for the first time in *D. cordifolia* (Table 1).

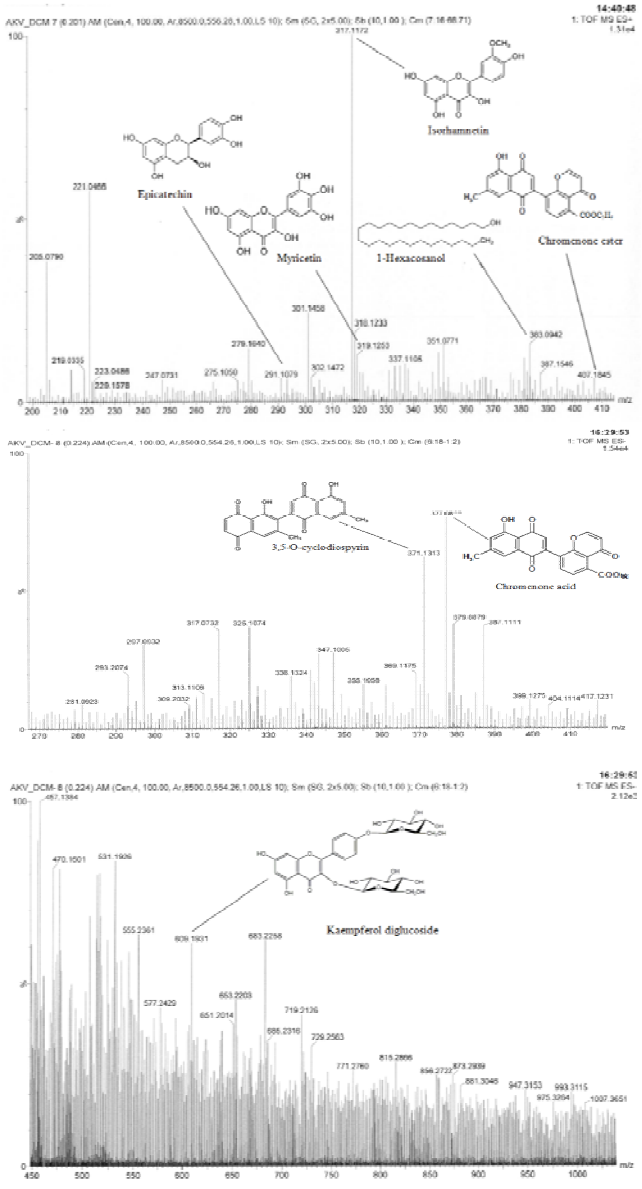

Fig. 13: UPLC-ESI/MS spectra and structures of methanol extract of *D. cordifolia* leave

Anti-termite activity of *Punica granatum*

Bioactive components of plant extracts may provide natural biodegradable alternative to crop pest control and resolve problems associated with synthetic pesticides. Different polarity fractions (hexane, ethyl acetate, chloroform and water) of methanolic extract of *Punica granatum* fruit rind (Fig. 14) were evaluated for anti-termite activity against *Microcerotermes beesoni*. A partially purified column fraction (PGR) was found to be significantly effective among different fractions.

Five compounds namely, gallic acid, ellagic acid, kaempferol, quinic acid, quiricetin acid identified from *P. granatum* were evaluated for termite mortality using chlorpyrifos 20% TC as control. Quercetin enriched

Table 1. UPLC-ESI/MS spectra and identified compounds in methanol extract of *D. cordifolia* leaves

Compounds	Observed $[M+H]^+$ (m/z)	Observed $[M-H]^-$ (m/z)	Molecular formula
Isorhmnetin	317	-	$C_{28}H_{44}O_5$
Myricetin	319	-	$C_{16}H_{12}O_7$
3,5-O-Cyclodiospyrin	-	371	$C_{15}H_{14}O_5$
Chromenone ester	407	-	$C_{16}H_{18}O_9$
Chromenone acid	-	377	$C_{20}H_{26}O_9$
Kaempferoldiglucoside	-	609	$C_{27}H_{40}O_3$
Epicatechin	291	-	$C_{27}H_{40}O_4$
1-Hexacosanol	383	-	$C_{29}H_{46}O_5$

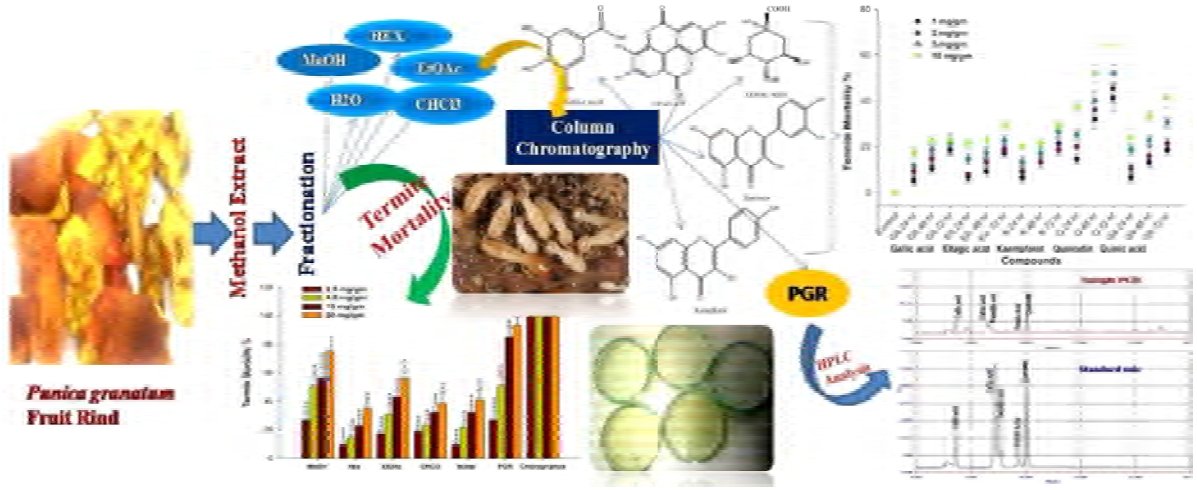

Fig. 14: Anti-termite activity of purified and crude extract of *Punica granatum* fruit rind

fraction showed significant anti-termite activity as compared to that of chlorpyrifos. The significant activity of enriched fraction may be attributed to the high concentration of quercetin present in the fraction.

Phytochemical investigation of *Commiphora agallocha* for bioprospection

Metabolite profiliig resulted in identifying germacrone as a major secondary metabolite in leaves, thin branches and latex of *C. agallocha*. *C. agallocha* was identified as a rich bio-resource of germacrone, a potential anti-cancer and anti-viral agent. Germacrone was isolated, purified and structure was determined by NMR spectroscopy. Qualitative and quantitative estimation of germacrone content among different accessions of *C. agallocha* was carried out using reverse phase analytical HPLC. Germacrone content varied significantly among different accessions of *C. agallocha* (Fig. 15). High germacrone yielding accessions of *C. agallocha* were identified and multiplied through macro-propagation technique under controlled environmental conditions.

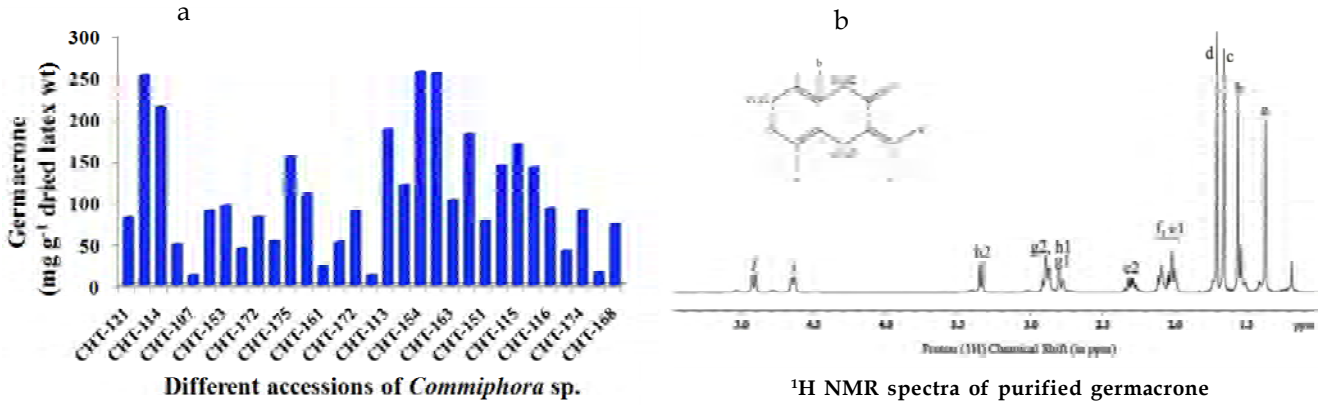

Fig. 15 (a-b): Variations in germacrone content among different accessions of *C. agallocha*.

Phytochemical studies of some medicinal, aromatic and ornamentally important plants

Extraction and phytochemical studies of some medicinal, aromatic and ornamentally important plants was carried out for development of novel nutraceutical, pharmaceutical, formulations and other commercially viable products. Characterization of the extracts, biomarkers and potential bioactive components was carried out using HPLC, HPTLC, FTIR, GC-MS, LC-MS and NMR. Economically useful phytochemicals, gums, resins, natural additives, formulations and biodegradable natural products were studied in *Cassia fistula, Cassia siamea, Acacia nilotica, Leucena leucocephela, Sesbania sesban, Sesbania grandiflora, Trigonella foenumgraecum, Cyamopsis tetragonoloba, Tamarindus indica, Sterculia urens, Lepidium sativum, Rosa indica, Tagetes erecta, Bixa orelana, Bougenvillea, Thevetia peruviana,* and *Erythrina* spp. Chemical profiling of more than twenty separated/isolated plant gums, resins, mucilage, medicinal plant extracts and modified films was carried out for identification of sugar/starch, volatile/ phenolic compounds, functional groups, and development of chemomarkers and compared with commercial reference standards. Five leguminous seeds and their separated parts i.e. seed coat, endosperm, meal were characterized for specific utilization, based on yield and quality parameters. Seeds from two species of *Sesbania viz. S. sesban* and *S. grandiflora* were explored as new alternative sources of commercially known gum additive materials. The yield of each seed parts in the two *Sesbania* species varied from 11.16-13.14% in seed coat, 17.64-26.163% in endosperm and 40-42% in gum. Significant variations among nutritional and antinutritional parameters viz. sugar/starch, protein, phenolics, flavanoids and tannins of the whole seed of each species and different separated parts was detected in the extracts (Fig. 16).

Isolation and purification of endospermic gum and extraction for oil potential was accomplished. Constituent sugars in seed gum and fatty acids along with total saponins were estimated to identify major chemo markers *viz*. Sucrose, D-pinitol and arachidonic acid to ascertain real potential of the two seeds (Fig. 17). *S. grandiflora* is characterized by galactomannan and arachidonic acid as major chemical markers. Isolation and purification of galactomannan along with solution mechanical properties is in process for standard materials and formulation prospects (Fig. 18).

Quantification of aloe emodin in the leaves of *Cassia* species viz. *C. siamea, C. fistula, C. javanica and C. suratense* was carried out, which ranged from 0.43mg/100g to 0.21mg/100g. Extraction protocol for the highest solvent extract yield was established. Extraction from other plant parts for bioactivity testing is in progress. High yielding

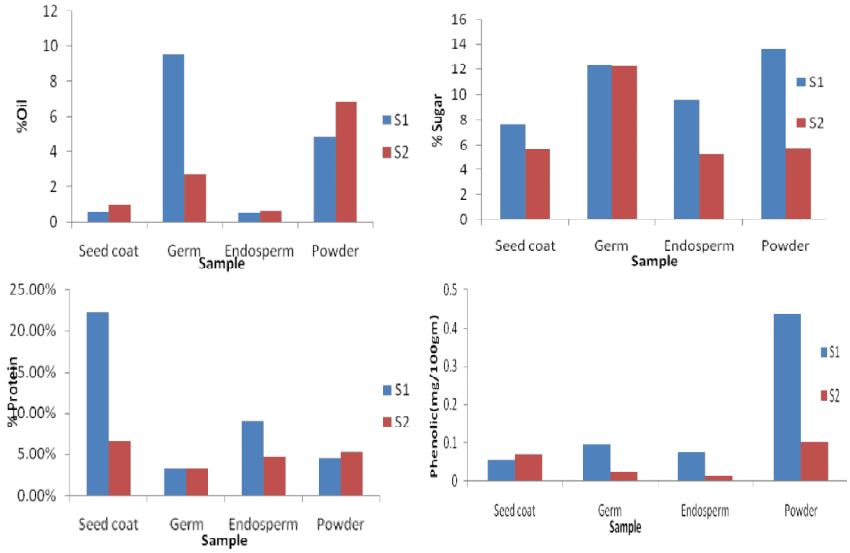

Fig. 16: Nutritional and anti-nutritional estimations in *Sesbania* seed spp.

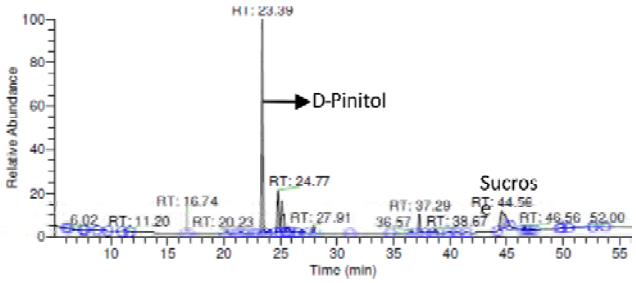

Fig. 17: Identification of markers in *Sesbania* seed spp. through GC-MS

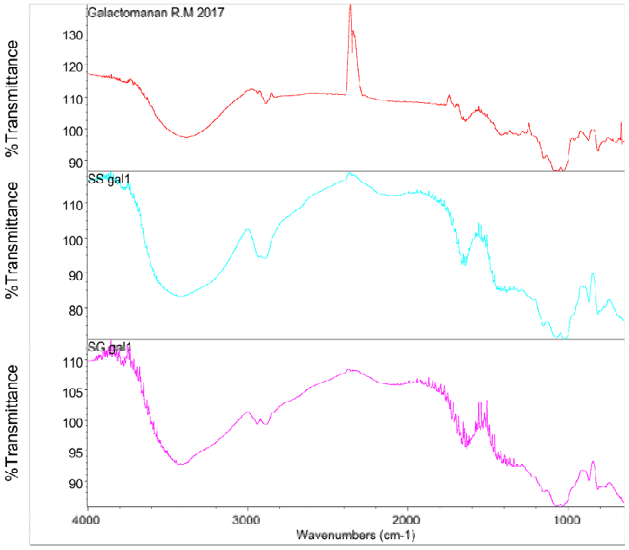

Fig. 18: Characterization of galactomannan in *Sesbania* seed spp. through FTIR

specific solvent extracts and two major markers aloe emodin and sennosides are in process of identification, isolation, purification and characterization as/for reference material and anticancer activity on breast cancer cell lines.

Extraction, and quantification of phytochemicals in Dammar resins and its characterization for chemomarkers was carried out. Physicochemical properties were also determined for prospection.

Modification and value addition of gum/gum additives, biodegradable and glassy films for substitution/ replacement of synthetic and plastic materials.

Two plant based stable synergistic functional combinants in different forms and sizes were studied to substitute and replace harmful cleansing chemical, sodium lauryl sulphate. Five saponin rich plants out of ten explored bioresources were exploited and characterized at laboratory scale. Studies are in progress to determine effective dose, delivery forms and upscaling for large scale and cost effective production for technology development.

Developed protocol for simple, rapid, cost-effective, and sensitive high-performance thin-layer chromatography (HPTLC) method for the simultaneous determination of six phenolic compounds, *viz.*, gallic (phenolic acid), *p*-coumaric, caffeic acid (hydroxycinnamic acid), chlorogenic acid (cinnamic acid derivative), quercetin and kaempferol (flavonols) in flowers, pods, leaves, twigs, and seeds of *Moringa oleifera*.

Explored the *in vivo* antioxidant and anti-aging potentials of Juniper berry essential oil (JBEO) by using *Caenorhabditis elegans* as a model organism and investigated the impact of different doses (0, 10, 50, 100ppm) on life span and health span of *C. elegans*. The screening studies on mutants of *C.elegans* for prediction of mechanism demonstrated the involvement of major conserved transcription factors *(DAF-16, SKN-1,* and *HSF-1)* which coordinate in the stress-induced transcription and extend.

Grant-in-Aid Projects

Evaluation of Medicinal plants for cultivation in sodic waste land of U.P.

Effect of different soil conditions i.e., soil sodicity and use of organic manure, was studied on the extractive yield and quantity of bioactive phytoconstituents of medicinal plant *Andrographis paniculata*. An ultra performance liquid chromatography-triple quadrupole-linear ion trap mass spectrometry method in multiple-reaction monitoring mode was developed for the rapid determination of 12 bioactive compounds in the leaf and stem of *A. paniculata* (Fig. 19). A good linear regression relationship (r^2, 0.9988–0.9999), intra-day precision (RSD, 0.17–3.22%), inter-day precision (RSD, 0.31–3.44%), stability (RSD, 1.19–3.09%), and recovery (RSD, 1.03–3.20%) were obtained for all the analytes. The results showed significant quantitative differences in diterpenoids, flavonoids, phenolics and triterpenoid of *A. paniculata*. The highest quantity (187.5 mg/g and 109.0 mg/g) of andrographolide and neoandrographolide was detected in the leaves of *A. paniculata* grown in salty clay loam soil with addition of 3.5% organic manure.

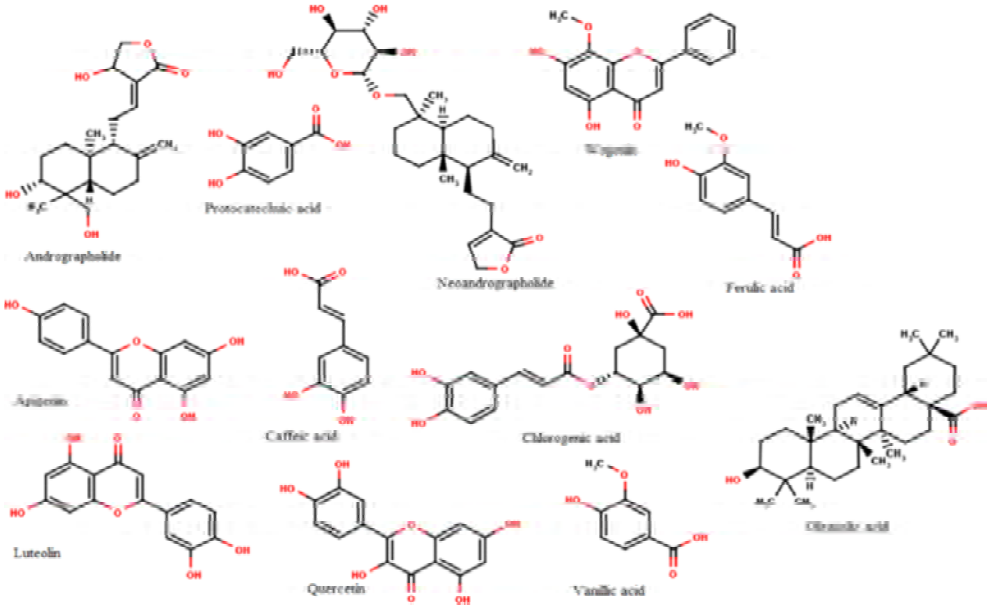

Fig. 19: Twelve bioactive compounds of leaf and stem of *A. paniculata*

PHARMACOGNOSY

In-House Projects

Herbal product development for industrial application

Comparative pharmacognostical and pharmacological evaluation of two *Achyranthes* species

Achyranthes is a well-known herb used in folk lore and traditional systems of medicine for its therapeutic value. The two species *Achyranthes aspera* and *A. bidentata* are used interchangeably by people and by herbal industries due to their resemblance in appearance. Therefore, the present study was undertaken to evaluate the comparative pharmacognostic and pharmacological properties of both species (Fig. 20). Pharmacognostic characters were evaluated as per the guidelines of Ayurvedic Pharmacopoeia of India. A quantitative HPTLC method was developed for quantification of linoleic acid and oleanolic acid using toluene: ethyl acetate: formic acid (6: 4: 0.5 v/v/v) as a mobile phase. Quantification was performed using linear regression analysis by plotting the peak area *vs* concentration curve with 2000-5000 ng/band (R^2 = 0.998) for oleanolic acid and 2000-5000 ng/band (R^2 = 0.994) for linoleic acid. The developed method was validated in terms of accuracy, recovery and inter and intraday study as per ICH guidelines. Antioxidant activity of methanolic extracts was estimated by five different models *viz*. DPPH free radical scavenging assay, total anti-oxidant capacity, reducing power assay, total flavonoid and phenol content. Anti-diabetic activity was analyzed by α-amylase inhibition assay using 3, 5 di nitro salicylic acid and iodine starch model. The limit of detection (LOD) and limit of quantification (LOQ) of oleanolic acid and linoleic acid were determined, respectively, as 0.426, 1.29 and 0.427, 1.29 ìg mL^{-1}. Inhibition of free radicals increases with concentration and IC_{50} of *A. aspera* and *A. bidendata* was obtained at 1.35 ± 0.173 mg/ml and 1.28 ± 0.169 mg/ml respectively. *In vitro* antidiabetic activity, IC_{50} value shows that *A. bidentata* exhibits better activity than *A. aspera*. The present study generates data for the

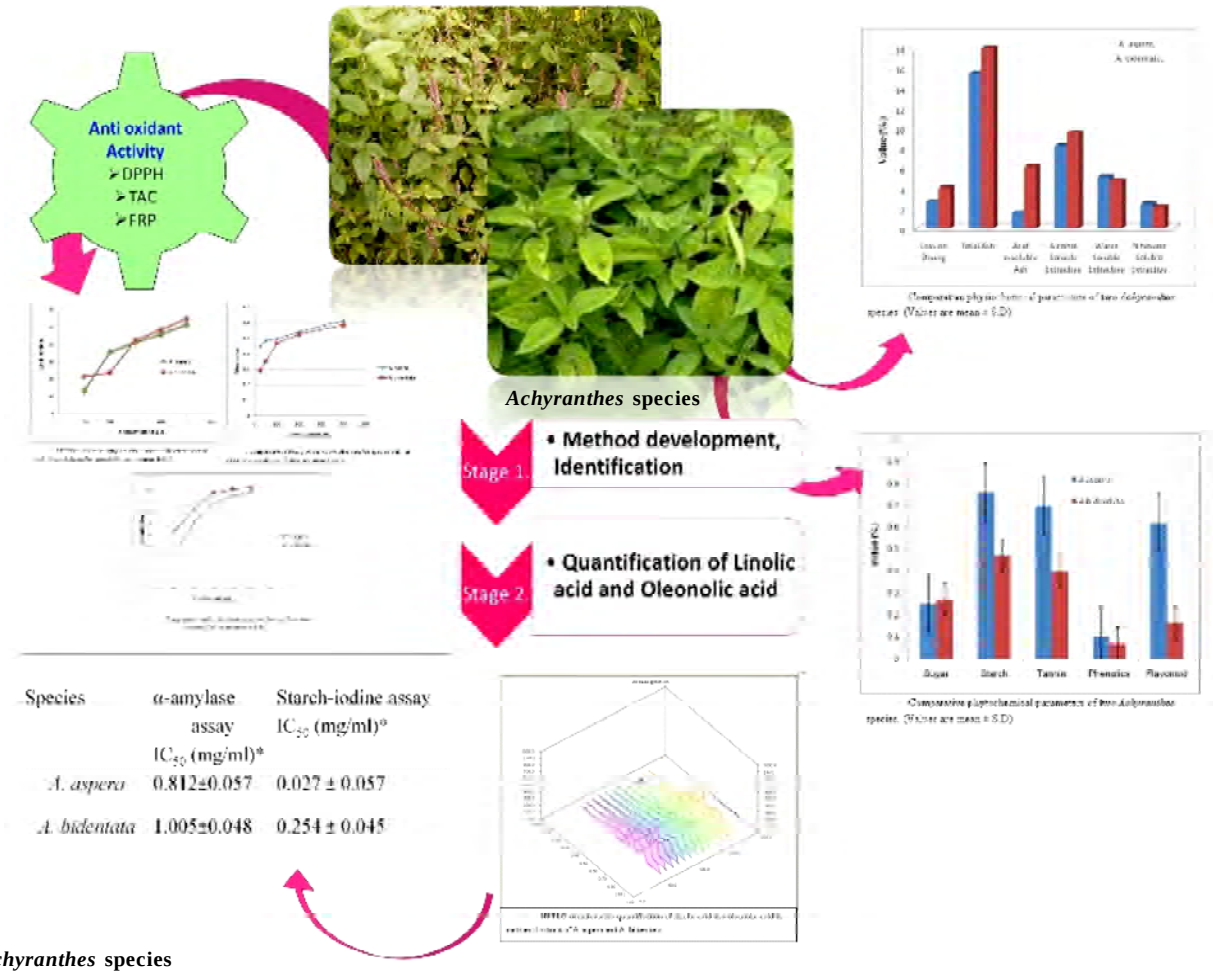

Fig. 20: Comparative pharmacognostical and pharmacological evaluation of two *Achyranthes aspera* and *A. bidentata*

proper establishment of quality control standards of the crude drug.

Identification of elite chemotypes of *Gloriosa superba L.* collected from Sikkim Himalayas (India)

Gloriosa superba L. (Colchicaceae) is used as an adjuvant therapy in gout for its potential antimitotic activity of high colchicine(s) alkaloids present in the plant. (Fig. 21). The HPTLC chromatographic method was developed to detect the bioactive alkaloids in *G. superba* using mobile phase of chloroform: acetone: diethyl amine (5:4:1) at λ_{max} of 350 nm. Five germplasms were collected from Sikkim region, and on morpho-anatomical inspection, no significant variation was observed among them. Quantification data revealed that the amount of colchicine (*Rf*: 0.72) and gloriosine (*Rf*: 0.61) varied from 0.035%–0.150% to 0.006%–0.032% (dry wt. basis). Linearity of method was obtained in the concentration range of 100–400 ng/spot of marker(s), exhibiting regression coefficient of 0.9987 (colchicine) and 0.9983 (gloriosine). Limit of detection and limit of quantification were analyzed, respectively, as 6.245, 18.926 and 8.024, 24.316 (ng). Two germplasms, namely NBG-27 and NBG26, were found to be elite chemotypes of both the markers. The developed method is validated in terms of accuracy, recovery, and precision studies as per the ICH guidelines (2005) and can be adopted for the simultaneous quantification of colchicine and gloriosine in phytopharmaceuticals. In addition, this study is relevant to explore the chemotypic variability in metabolite content for commercial and medicinal purposes.

Pharmacognostic studies of *Acorus calamus* L.

Acorus calamus Linn. (Araceae), commonly known as ''Sweet flag'' or ''Vacha'', is a well known medicinal plant, the rhizomes and leaves of which are used in traditional medicine. Rhizome is spongy, pale to dark brown or occasionally orange-brown in colour. Physico-chemical parameters in *A. calamus* were studied and the essential oil, Asarone was found to be its major constituent.

HPTLC densitometric method for simultaneous quantification of phenolic and terpenoid markers in the plants attributed to 'Shankhpushpi'

'Shankhpushpi' is a known nervine tonic prescribed by Ayurvedic practitioners since ancient times. But the drug faces the problem of adulteration/ substitution that affects its quality and efficacy. HPTLC densitometric method (Fig. 22) was developed for simultaneous quantification of phenolic (ferulic acid and caffeic acid) and terpenoid (β-sitosterol and lupeol) markers in the plants attributed to 'Shankhpushpi' *viz. Clitoria ternatea, Convolvulus pluricaulis, Evolvulus alsinoides, Evolvulus nummularius* and *Tephrosia purpurea.* The developed method will help to maintain batch to

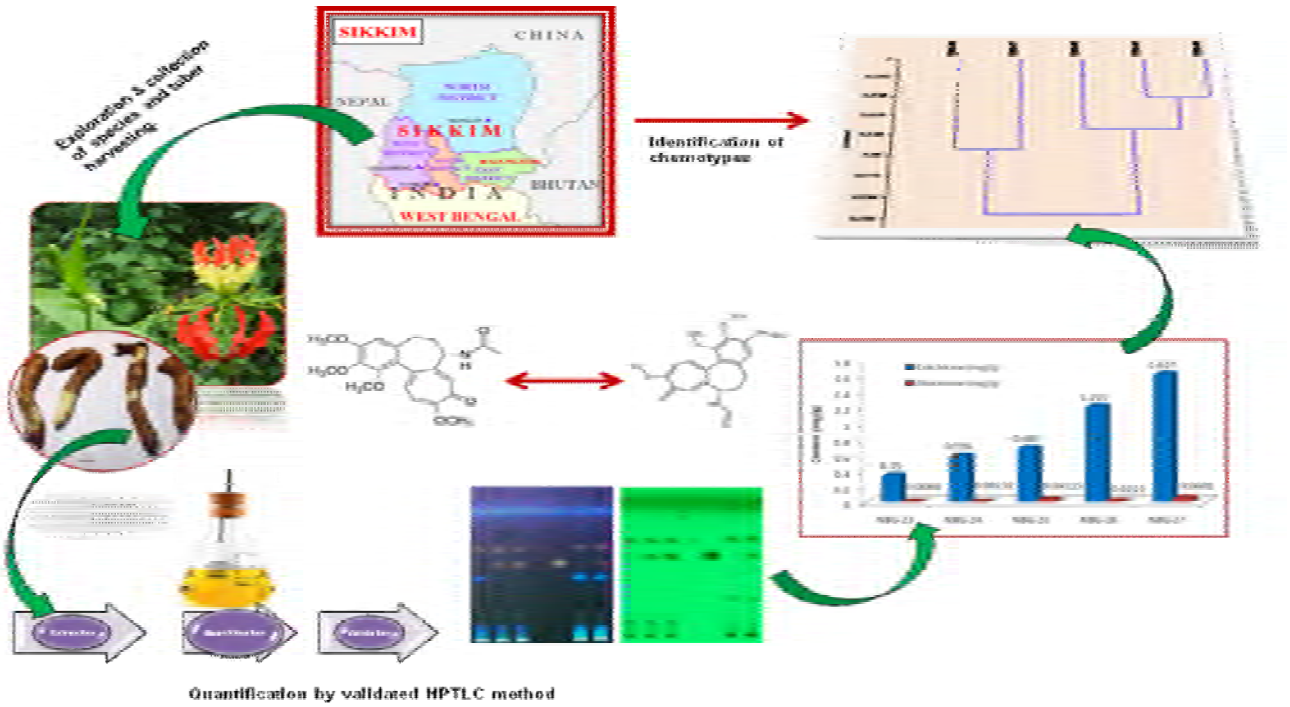

Fig. 21: Simultaneous densitometric quantification and optimum recovery of colchicine and glorisine for identification of elite chemotype of *Gloriosa superba* L. from Sikkim Himalayas

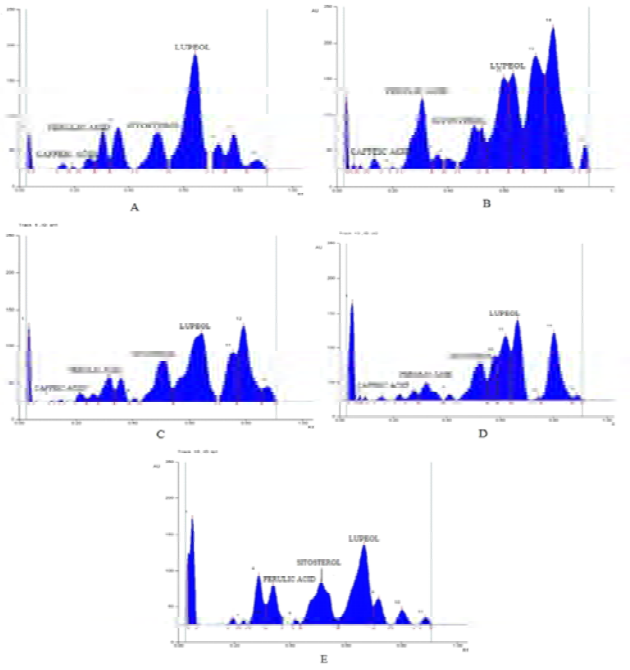

Fig. 22: Densitometric chromatogram of methanolic extract of samples A, *Convolvulus pluricaulis*; B, *Evolvulus alsinoides*; C, *Evolvulus nummularius*; D, *Clitoria ternatea*; E, *Tephrosia pupurea*

batch consistency and identification of adulterant/ substituent in raw material during production of drug in the pharmaceutical units.

Development of Herbal Products:

A potential herbal combination for alleviating urolithiasis, nephrolithiasis and post lithotripsy conditions (ESWL)

A herbal formulation was developed to alleviate urolithiasis and nephrolithiasis (Fig. 23). This product is efficacious and cost effective than existing herbal brands against urolithiasis and nephrolithiasis.

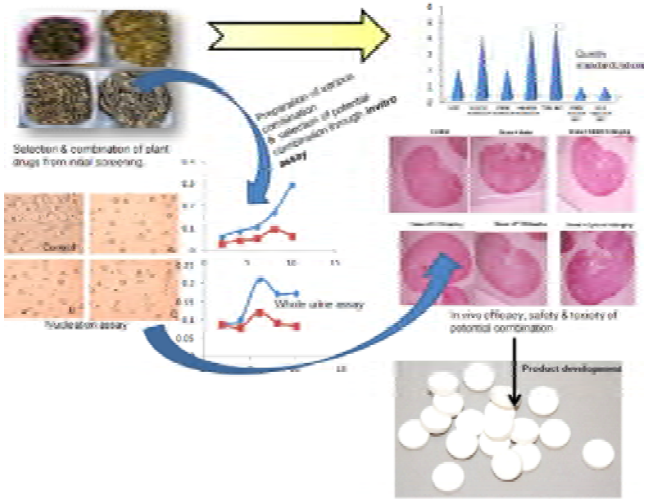

Fig. 23: Graphical representation of the work done for development of formulation of urolithiasis

Novel Herbal Acaricide

To overcome the issues related to health hazards in cattle, two novel herbal acaricides were developed to control cattle ticks, jointly with ICAR-Indian Veterinary Research Institute, Izatnagar - Bareilly (UP) under NAIP scheme of ICAR (Fig. 24 and 25).

Fig. 24: Herbal Acaricide formulation

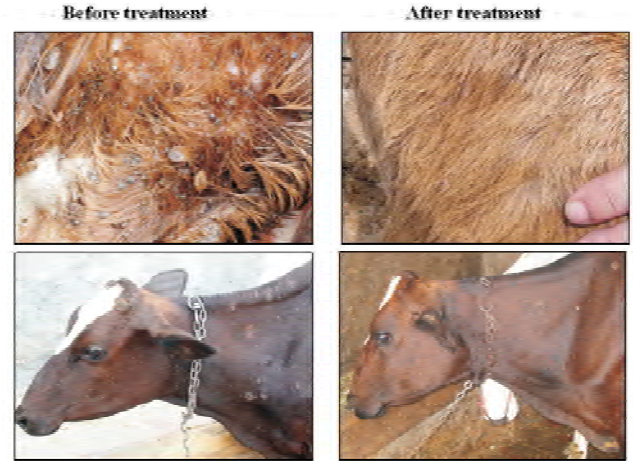

Fig. 25: Treatment of cattle with Herbal Acaricide formulations

Grant-In-Aid Projects

Studies on role of endophytes in variation of acaricidal properties of two acaricide producing plant species NBA/22/F1 and NBA/18/D1 from North Eastern states

Two identified acaricidal plants *Argemone mexicana* (NEA, earlier coded as NBA22/F1) and *Datura metel* (NED, earlier coded as NBA/18/D1) were collected along with rhizospheric soil samples from six agro-climatic zones of Assam. Acaricidal activity of ethanolic extracts of the shade dried and powdered plant samples were analysed *in vitro* and *in vivo*. n-propanol:water: formic acid (9:0.8:0.04, v/v/v) was found to be the best suited solvent system for separation of secondary metabolites of *A. mexicana* (Fig. 26) and chloroform:acetone: diethylamine (5: 4: 1, v/v/v) for *Datura metel* (Fig. 27). Absorption spectra of berberine

and sanguinarine were obtained at λ_{max} 340 nm after scanning the UV range of 200-400 nm. The λ_{max} for *Datura* was in the visible range i.e., 530 nm. Maximum content of berberine (0.159%) and sanguinarine (0.036%) was recorded in NEA-04. Maximum atropine content was found in NED-07 (0.891%) and scopolamine (1.00%) in NED-04.

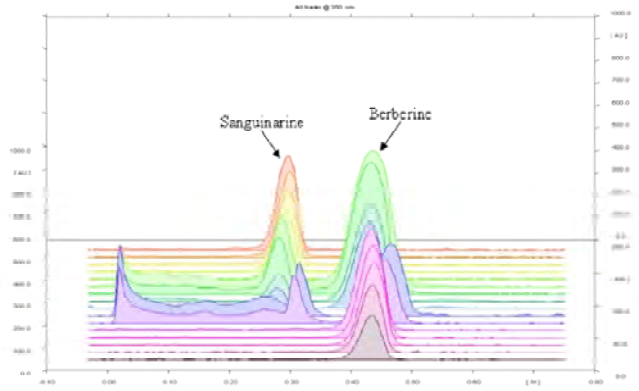

Fig. 26: HPTLC densitometric profile of *A. mexicana* samples at 340 nm.

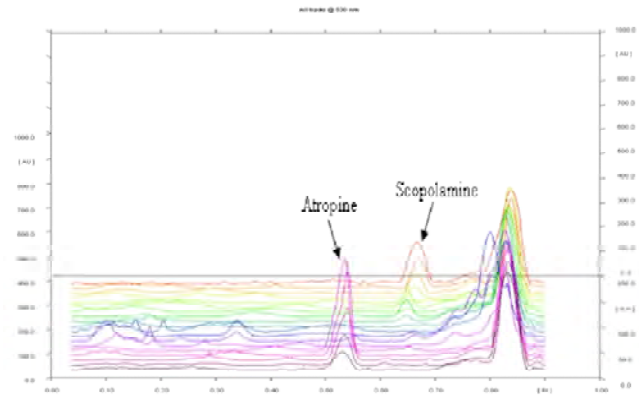

Fig. 27: HPTLC densitometric scanning of *D. metel* at 530 nm.

Chemical structural and functional characterization of identified anti-tick phytochemical and optimization of delivery matrix for effective application of natural formulation for control of acaricide resistant ticks

The objective of the study was to evaluate phytochemical variations and anti tick activity of *Ageratum conyzoides* L. (NAC-01) and *Blumea lacera (*Burm.f.*) DC.* (CPV-05) collected from different geographical zones of India (previously identified leads). Qualitative and quantitative estimation of Precocene-I and precocene-II was carried out using HPTLC. Precocene I and II content varied from 0.001 to 0.15 % in *A. conyzoides* and 0.023 to 0.053 % in *B. lacera*, respectively. The caryophyllene oxide content in *A. conyzoides* varied from 0.001 to 0.111 %.

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

The aim of the study was to identify elite chemotypes of *Hemidesmus indicus* and *Costus speciosus* from different phytogeographical zones of India, based on major metabolite vanillin and diosgenin content, respectively. A total of 85 samples of *Costus speciosus* and 52 samples of *Hemidesmus indicus* were collected from different localities. Significant chemical variation was observed among the germplasms within and among phytogeographical zones. The maximum content of diosgenin (0.3678%) was detected in NBCS-37 (Ramgarh, Jharkhand), however, it was not detected in NBCS-16 (Chandigarh, Punjab) and NBCS-59 (BHU, Varanasi, Uttar Pradesh). Vanillin was quantified at 320 nm in binary solvent system of n-hexane: diethyl ether (4:6) in *H. indicus*. Chemical variation was significant among the germplasm, and the maximum content of vanillin was detected in NBH-35 (Gaya, Bihar), 0.0127% per dry weight. Multilocation trails of both the species are in progress.

Metabolic analysis for Isoquinoline alkaloids from therapeutically important genus *Berberis* L.

The project activity includes bioresource mapping of *Berberis* and species characterization of their metabolites adapted to different phyto-geographical regions of India. Twenty samples of *Berberis* were collected from Western Himalayas from altitudinal variation of 668 to 8743 ft. The species were identified as *B. lycium*, *B. aristata*, *B. jaeschkeana* and *B. jlaucocarpa*. Passport datasheet was prepared and herbarium specimens were deposited at LWG. Various physico-chemical parameters viz., extractive values, total phenol content, total flavonoid content, total tannin content, sugar, starch content of *Berberis* were estimated as per standards.

Search for Elite Chemotype(s) of *Centella asiatica* (L) Urban and their Relationship with Ecogeography

One hundred and fifty nine samples of *Centella asiatica* were collected from different phyto-geographical zones of India. Passport data sheets of collected samples were prepared with GPS co-ordinates and other relevant information. Pharmacognostical parameters were established and metabolites (asiaticoside, madecassocide, asiatic acid and madecassic acid) were quantified from methanolic extracts using HPTLC. High concentration of madecassoside (4.8%) and asiaticoside (4.3%) was found in CA109 (Palaghat, Kerala).

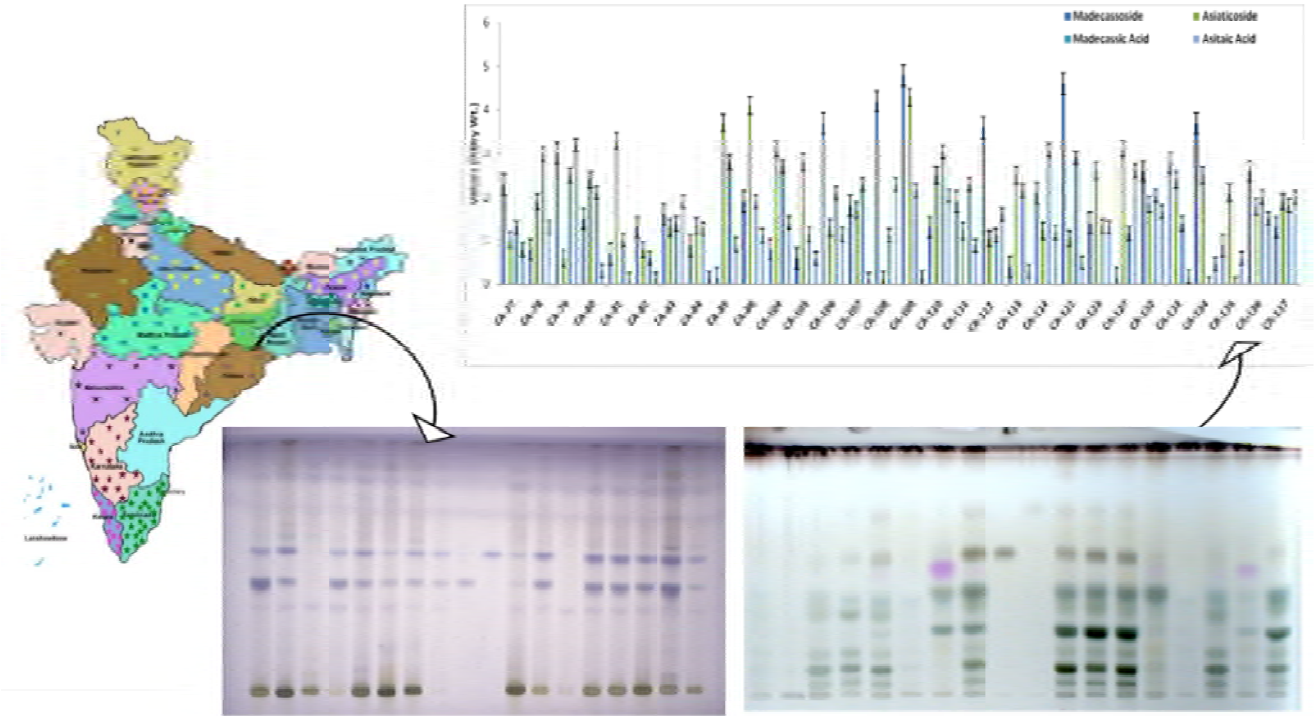

Fig. 28: Map showing locations of *Centella asiatica* collection and respective HPTLC chromatogram

Madecassic acid (3.06%) was observed in CA114 (B.R. Hills, Karnataka) and asitaic acid (3.2%) was found to be higher in CA79 germplasms collected from Ooty, Tamil Nadu (Fig. 28).

Development of plant based synergistic natural supplement and its pharmacological validation to alleviate gouty arthritic conditions

The study was aimed at development of a synergistic natural supplement to alleviate gouty arthritic conditions. Plant samples were screened for promising anti gout/arthritic activity from available leads. Thirteen samples (NBAG-1 to NBAG-13) were evaluated for pharmacognostical standards i.e. botanical (macroscopy and microscopy) and physicochemical (ash values and extractive values) were carried out as per standard protocols. HPTLC protocol was developed for marker compounds. *In vitro* anti-gout activity was initiated in hydroalcoholic (50% aqueous) and aqueous extracts for each sample. The activity was tested by inhibition of protein denaturation method using bovine serum albumin model. IC_{50} was determined in 8 samples. Promising activity was observed in aqueous extract of NBGA-7 and least activity was recorded in hydroalcoholic extract of NBGA-2 (Fig. 29).

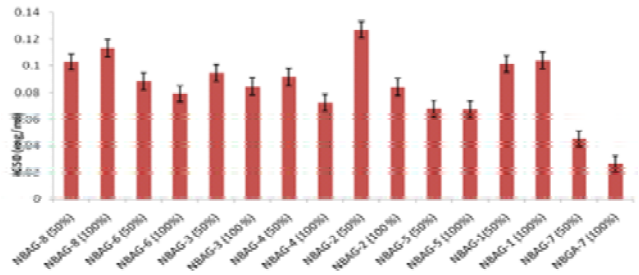

Fig. 29: IC_{50} value of 8 samples in two different solvents (n=3), values are mean ± S.D.

Identification of elite chemotype(s) of *Plumbago zeylancia* Linn. collected from different phyto-geographical zones of India and evaluation of biological potential of elite germplasm

The demand of Ayurvedic drugs is increasing world-wide but there is limited production of quality raw material. Therefore, it is the prime need to identify and authenticate the medicinal plant parts not only for the scientific validation but also for the quality standards. A total of 36 germplasm of *Plumbago zeylanica* (4 from central India, 4 from Eastern Ghats, 13 from Gangetic Plain, 09 from Western Himalaya and 06 from other locations) were collected from different phyto-geographycal regions of India. Collected germplasm are to be evaluated for their major biologically active compounds to select elite chemotypes of *P. zeylanica*. Cultivation of selected plant accession of *P. zeylanica* will help to provide authenticated and qualitative plant material to the herbal industry for commercial prospection.

Role of microbes in yield management of scented rice of North East India

To investigate antioxidant potential of 10 varieties of black rice, shoot and roots were studied for their total phenolic contents (TPC), total flavonoid content (TFC) and antioxidant activity (AOA) (Table 2). TPC varied widely from 31.81 in Khothachakhao to 46.78 in Chakhao portion tall 2 µg gallic acid equivalent (GAE)/g of dry extract, TFC ranged from 13.60 (Chettamachakhao) to 23.19 (Chakhao portion tall 2) µg quercetin equivalent (QE)/g of extract) and AOA, measured by auto-oxidation of β-carotene and linoleic acid coupled reaction, ranged from 20.59% (Chakhaosumpak) to 46.17% (Chakhao portion tall 2) in shoot extracts of different rice varieties. The shoot samples were further subjected to free radical scavenging activity (FRSA), assayed by DPPH free radical, that easily accepts an electron or hydrogen radical to become a stable diamagnetic molecule and activity was expressed (Table 2) in terms of IC_{50} (inhibitory concentration) that ranged from 0.10 (Chakhao portion tall 2) to 0.58 (Chakhaosumpak) mg/ml.

In roots of rice samples, TPC, TFC, AOA and DPPH varied from 10.37 to 35.83, 3.30 to 14.19, 1.47 to 14.67% and 2.92 to 0.78, respectively. Highest reducing power (RP) has recorded in shoot of Chakhao portion tall 2 and roots of Chakhaosumpak. The grains of two black rice varieties, Chakhaoamubi and Chakhaoporeiton were assessed for their antioxidant activity (Table 3).

Table 3. Antioxidant activity of grain of two scented rice varieties

Sample	TPC	TFC	FRSA	AOA	RP
Chakhaoamubi	61.51	51.84	0.21	70.42	0.602
Chakhaoporeiton	50.36	45.21	0.29	62.68	0.482

Chakhaoamubi was found to be superior than Chakhaoporeiton in terms of TPC, TFC, AOA, FRSA and RP with the values of 61.51, 51.84, 70.42%, 0.2, and 0.602 OD, respectively.

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

Selaginella bryopteris is a pteridophytic plant which is known for its remarkable resurrection capabilities. The medicinal uses of *S. bryopteris* include: (i) relief from stress and gastric ulcer; (ii) wound healing activity; and (iii) for curing jaundice. The potential therapeutic molecules responsible for desired pharmacological activities were identified *viz* heveaflavone, syringaresinol, amentoflavone. The bioactive fraction of *Selaginella bryopteris* was subjected for acute and sub-acute toxicity studies. The *S. bryopteris* fractions showed no significant change on body weight, biochemical and histopathological changes after treatment. However, the potential wound healing and free radical scavenging of the isolated 2", 3"-dihydrohinokiflavone was quantified for desired pharmacological activity.

Table 2. Antioxidant activity of different parts of scented rice plants

Sample	Shoot					Root				
	TPC	TFC	FRSA	AOA	RP	TPC	TFC	FRSA	AOA	RP
Wahongchakhao	40.29	17.30	0.40	21.05	0.31	12.14	3.30	2.15	2.84	0.125
Chakhao portion vyumpok	39.21	18.16	0.53	24.01	0.25	10.37	ND	ND	ND	0.139
Chakhao portion leimaran	43.13	16.67	0.46	23.14	0.305	28.86	3.52	0.94	3.42	0.187
Wairechakhao	40.97	24.37	0.31	42.67	0.352	22.02	4.43	1.59	2.85	0.134
Chakhao portion tall 2	46.78	23.19	0.10	46.17	0.388	26.85	7.08	1.10	5.02	0.139
Khothachakhao	31.81	14.86	0.54	28.95	0.203	12.76	2.92	2.92	1.47	0.104
Chettamachakhao	34.65	13.60	0.54	18.20	0.182	26.85	7.08	1.30	4.76	0.139
Chakhao portion	45.64	15.88	0.19	31.89	0.321	32.21	4.72	1.25	4.59	0.166
Chakhaosumpak	35.11	19.34	0.58	20.59	0.205	35.83	13.19	0.78	14.67	0.262
Chakhaoambui	41.54	18.55	0.46	24.18	0.242	29.38	8.12	1.01	6.98	0.158

OTHER CSIR SUPPORTED PROJECTS

CSIR-Aroma Mission

The Mission has the major objective of catalyzing rural empowerment through cultivation, processing, value addition and marketing of aromatic plants.

Objectives

- Development of superior varieties and their agro-technologies and assessment of their suitability for specific agro-climatic regions
- Promotion of cultivation and processing of aromatic crops, enhancing area under selected aromatic crops along with enabling interventions including setting up of distillation units and catalyzing setting up of cooperatives for marketing of the produce
- Value-addition of aromatic crops (High-end aroma chemicals and products)
- Making public aware of Mission activities and achievements using appropriate interface

Highlights

- Development of Herbal anti-fungal formulation in collaboration with CSIR-CIMAP is in progress.
- The farmers and partners have been identified in Uttar Pradesh., Madhya Pradesh., Bihar, Odisha, Uttarakhand and Meghalaya for area expansion in next season (2018-19). The promising turmeric variety Kesari has been distributed among 34 farmers of seven districts and two states.
- Technology intervention to extract the highest quantity and best quality leaf essential oil, leaves of the turmeric variety Kesari were harvested at three stages; viz. green, partially senesced and fully senesced. The leaves were processed for hydro-distillation. Minimum amount of oil (0.88%) is obtained from green leaves whereas fully senesced leaves yielded 1.405% oil. The highest amount of leaf essential oil (1.702%) was obtained from partially senesced leaves.

Fig. 1: Green, partially senesced and fully senesced leaves of Kesari processed for essential oil extraction

Mega Lab Project

Development of microbial formulations to serve as stress buster and biofertilizer for improving crop productivity in stressed agriculture

Nodal Laboratory: CSIR-IHBT

Participating Laboratories: CSIR-NBRI, CSIR-NEIST and CSIR-NIIST

Objectives:

- Evaluation of ACC deaminase producing PGPR for plant growth performance under stressed environments in controlled condition and fields
- Scale up of inoculums production for promising PGPR

Highlights

16S rRNA based identification of 77 bacterial isolates and their phylogenetic analysis

Seventy seven rhizobacterial isolates were identified by partial 16S rRNA sequences (~ 1400 bp amplicon) which revealed most of the bacterial isolates belonged to *Bacillus* genera (67 nos.). Among *Bacillus* spp., most of them were related to *B. megaterium* (24 nos.) and *B. marisflavi* (24 nos.) (Fig. 2). Rest of the rhizobacillus isolates belonged to *B. flexus* (1 no.), *B. endophyticus* (1 no.), *B. niacini* (1 no.), *B. firmus* (2 nos.), *B. oceanisediminis* (2 nos.), *B. subtilis* (5 nos.), *B. tequilensis* (1 no.), *B. stratosphericus* (2 nos.), *B. safensis* (1 no.), *B. gibsonii* (2 nos.) and *B. cereus* (1 no.) (Fig. 2). Apart from *Bacillus* spp., the remaining rhizobacterial ones were pertinent to *Oceanobacillus picturae* (2 nos.), *Lysinibacillus fusiformis* (1 no.), *J. huakuii* (2 nos.), *S. cohnii* (3 nos.), *Ac. lwoffii* (1 no.) and *Arthrobacter defluvii* (1 no.) (Fig. 2). All the sequences were classified up to species level with >95% confidence.

Quantitative estimation of ACC deaminase activity by select bacterial isolates and their effect on *in vitro* rice seedling biomass and ethylene emission

A total of 15 best performing bacterial isolates representing each agro-climatic zone (Fig. 3) were

screened based on their high seed germination rate, PGP and abiotic stress tolerance ability. The select isolates were subjected to quantitative estimation of ACC deaminase activity, and ethylene emission and biomass of bacteria coated rice seedlings under salt stress (100 mM NaCl) (Table 1). Specifically, *Bacillus megaterium* was found in most of the agro-climatic zones. Besides this, we also observed NBRI 20M (*B. megaterium*) of South Western Semi-Arid zone exhibited maximum ACC deaminase activity. On the other hand, NBRI 2Q (*Lysinibacillus. fusiformis*) of Bundelkhand zone demonstrated lowest quantitative value for ACC deaminase activity among selected 15 isolates (Table 1). In comparison to control, NBRI 16E enhanced seedling biomass by 262% whereas, NBRI 6I showed 76% increment under salinity stress. Also, NBRI 16E (*B. megaterium*) showed maximum rice seedling biomass under no salinity stress when compared with its respective control. About ethylene emission as salinity stress indicator, NBRI 20M (*B. megaterium*) coated rice seedlings demonstrated lowest ethylene concentration.

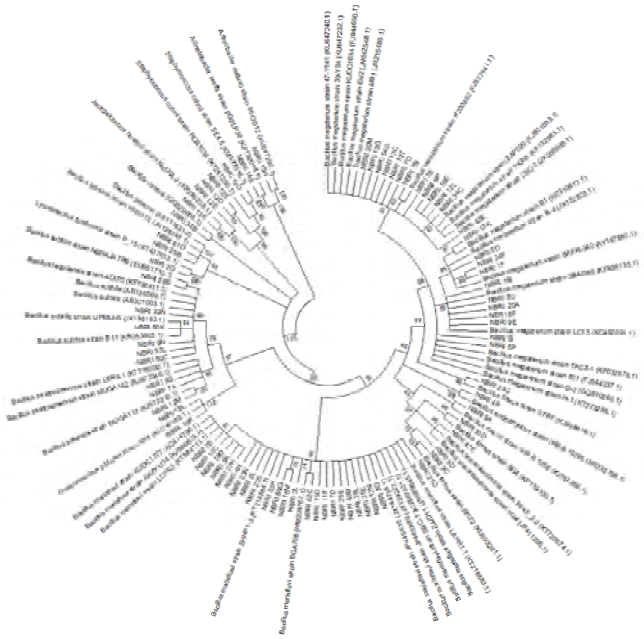

Fig. 2: Molecular phylogenetic analysis by maximum likelihood method

Table 1. Screened salt tolerant bacterial isolates with their 16S rRNA based binomial nomenclature, ACC deaminase activity along with biomass and effect on ethylene biosynthesis in rice seedlings under salt stress.

Isolates	Identification by 16S rRNA	ACC deaminase activity[a]	Biomass[b]		Ethylene emission[c]	
			No Salt stress	Salt stress	No Salt stress	Salt stress
Bhabhar and Tarai zone						
NBRI 6I	*Bacillus megaterium*	9.86±0.02	0.32±0.01	0.23±0.02	6.44±0.25	4.26±0.61
Bundelkhand zone						
NBRI 54O	*Bacillus megaterium*	4.25±0.01	0.33±0.01	0.31±0.02	5.46±0.48	4.46±0.21
NBRI 2Q	*Lysinibacillus fusiformis*	0.29±0.00	0.52±0.03	0.37±0.03	4.95±0.23	6.89±0.52
Central zone						
NBRI 13E	*Jeotgalicoccus huakuii*	0.75±0.00	0.56±0.05	0.46±0.06	3.02±0.32	3.69±0.62
NBRI 9N	*Bacillus tequilensis*	12.91±0.05	0.53±0.02	0.42±0.03	7.79±1.08	5.62±0.63
Eastern Plain zone						
NBRI 21D	*Bacillus marisflavi*	1.08±0.00	0.44±0.07	0.31±0.04	1.67±0.51	1.86±0.31
Mid-Western Plain zone						
NBRI 16E	*Bacillus megaterium*	12.19±0.04	0.59±0.05	0.47±0.04	2.21±0.24	3.33±0.61
NBRI 16I	*Bacillus megaterium*	1.97±0.00	0.52±0.04	0.39±0.02	2.47±0.18	3.19±0.11
North Eastern Plain zone						
NBRI 33N	*Bacillus subtilis*	3.07±0.01	0.33±0.01	0.25±0.01	2.02±0.21	2.21±0.25
NBRI 53L	*Bacillus subtilis*	9.63±0.03	0.52±0.12	0.39±0.03	2.44±0.73	2.08±0.29
South Western Semi-Arid zone						
NBRI 28B	*Bacillus subtilis*	2.75±0.01	0.35±0.01	0.26±0.01	5.77±0.79	4.63±0.16
NBRI 20M	*Bacillus megaterium*	54.08±0.11	0.49±0.04	0.38±0.01	1.66±0.13	1.60±0.22
Vindhyan zone						
NBRI 69D	*Bacillus marisflavi*	5.71±0.02	0.35±0.02	0.26±0.02	2.16±0.40	2.28±0.19
Western Plain zone						
NBRI 12M	*Bacillus safensis*	3.80±0.01	0.36±0.01	0.30±0.02	2.57±0.05	2.19±0.48
NBRI 5K	*Bacillus marisflavi*	29.17±0.06	0.46±0.03	0.37±0.05	3.27±0.12	2.19±0.13
Control			0.30±0.02	0.13±0.01	2.84±0.53	6.19±0.31
LSD (P=0.05)		0.03	0.02		0.07	

Values are means±SE of three replications. Least squared differences (LSD=0.05).

[a]ACC deaminase activity is expressed as nmol α-Ketobutyrate mg protein^{-1} h^{-1}.

[a]Biomass is represented in g weight of fresh seeds.

[c]Ethylene emission is expressed as pmol ethylene g FW^{-1} h^{-1}.

Astonishingly, NBRI 2Q (*L. fusiformis*) coated rice seedlings was observed with ethylene concentration higher than its respective control (Table 1). In no-salinity stress, NBRI 9N (*B. tequilensis*; Central zone) coated rice seedlings increased the ethylene emission than control. Some of the select isolates namely, NBRI 21E, 16E, 16I, 33N, 53L, 20M, 69D and 12M belonging to various agro-climate zones were found to reduce the ethylene emission under no-salinity stress condition (Table 1).

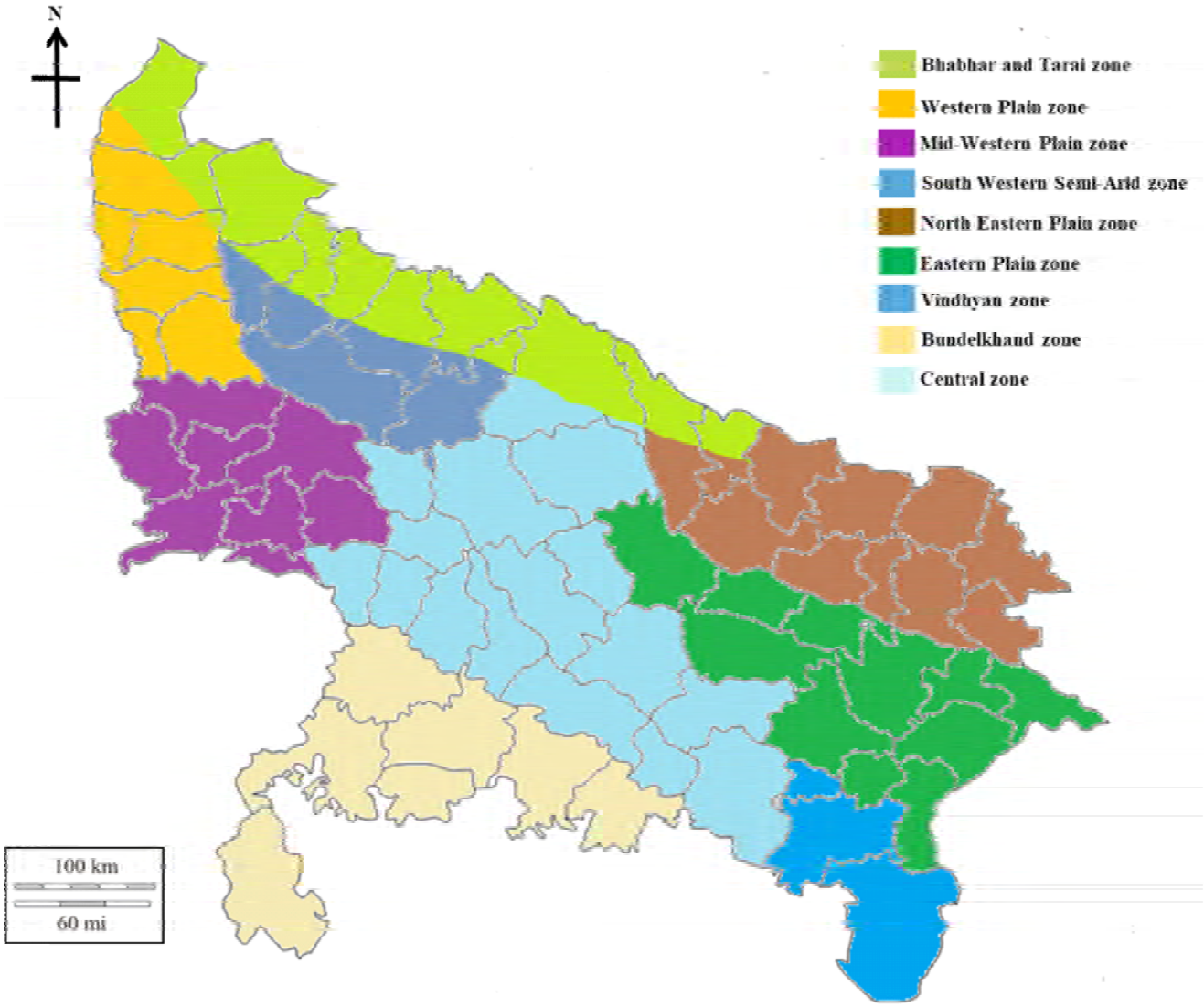

Fig. 3: Geographic map representing soil sampling sites from arable fields of 9 agro-climatic zones of state of Uttar Pradesh in India.

R&D outputs

PUBLICATIONS

Research Papers

1. Agarwal A.V., Gupta P., Singh D., Dhar Y.V., Chandra D. and Trivedi P.K. (2017). Comprehensive assessment of the genes involved in withanolide biosynthesis from *Withania somnifera*: chemotype-specific and elicitor-responsive expression. ***Functional and Integrative Genomics***, 17 (4): 477-490.
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1. Chaudhary L.B. (2018). A revision of the genus *Astragalus* L. (Leguminosae-Papilionoideae) in India. *Siya Publishing House, New Delhi*: 236 pp.

2. Nair K.N. (2017). The Genus *Syzygium: Syzygium cumini* and Other Underutilized Species. (Ed. K.N. Nair), *CRC Press*: 270 pp.

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1. *In*: The Genus *Syzygium: Syzygium cumini* and Other Underutilized Species, (Ed. K.N. Nair), *CRC Press*, (2017).
   i. Nair K.N. and Rana T.S.–Phylogeny of *Syzygium*. 07-14.
   ii. Kushwaha A. and Chaudhary L.B. - Diversity, Distribution and Life History of *Syzygium cumini*. 57-61.
   iii. Pandey M.M. and Rawat A.K.S. - Pharcognosy and pharmacoepeal standards for *Syzygium cumini*. 119-132.
   iv. Tewari S.K., Nainwal R.C. and Singh D. - Potential of *Syzygium cumini* for Biocontrol and Phytoremediation. 237-254.
   v. Tewari S.K., Singh D. and Nainwal R.C. - Horticultural Management of *Syzygium cumini*. 215-236.
2. Singh A. Chauhan P.S. (2017). Ecological significance of soil-associated plant growth–promoting biofilm-forming microbes for stress management. *In*: Biofilms in Plant and Soil Health, *John Wiley & Sons*, 291-318.
3. *In*: Green Pesticides Handbook: Essential Oils for Pest Control, (Eds Leo M.L. Nollet and H.S. Rathore), *CRC Press,* (2017).
   i. Niranjan A., Lehri A., and Tewari S.K. - Essential Oil of *Cinnamomum cassia* for Pest Control, **13**: 309-18.
   ii. Niranjan A., Lehri A., and Tewari S.K. - Essential Oil of Thymus vulgaris L. for Pest Control, **13**: 319-32.
4. Lata C. and Shivhare R. (2017). Genetic Determinants of Abiotic Stress Tolerance in Foxtail Millet. *In*: The Foxtail Millet Genome. (Ed. M. Prasad), *Springer*, 85-104.
5. Misra S., Pandey S., Dixit V., Mishra S.K., Khan M.H., Agarwal L. and Chauhan P.S. (2017). Microbiome for enhanced crop productivity. *In*: Mining of microbial wealth and metagenomics. (Eds. V.C. Kalia, Y. Shouche, H.J. and P.Rahi). *Springer Nature Singapore*, 227-247.
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8. In: Current Advances in Fern Research. Springer, Cham, Switzerland, (Eds. Fernández H.), *Springer, Cham, Switzerland.* (2018).
   i. Johari D. and Singh A.P. - Biotechnology in Clone Gametophytes: Future Perspectives in Homosporous Ferns: 75-97.
   ii. Singh A.P. and Johari D. - Scope of Ferns in Horticulture and Economic Development: 153-175.
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   i. Shukla S., Mishra T., Nahar S. A. and Pal M. - Antimicrobial Potential of Bio-molecules Originated from Terrestrial and Marine Medicinal Plants: 283-299.
   ii. Verma A., Upreti D.K., Pande V. and Pal M. - Nutritional and Medicinal values of Fruits in Diabetes: 225-240.
10. Srivastava S. and Misra A. (2018). Quality Control of Herbal Drugs: Advancements and Challenges. In: New Age Herbals: Resource, Quality and Pharmacognosy, (Eds. B.Singh, K.V. Peter), *Springer Nature Singapore*: 189-209.
11. Khatoon S. and Irshad S. (2017). Alzheimer's and age related Dementias: Ethnomedicine, Modern researches and future prospects. *In*: Alzheimer's and age related Dementias: Ethnomedicine, Modern researches and future prospects. *Aviskar Publishers, Jaipur*: 41- 68.
12. Singh H. and Khatoon S. (2017). Ethnobotany and Phytochemistry of Sacred Plant Species *Betula utilis* (bhojpatra) and *Quercus oblongata* (banj) from Uttarakhand Himalaya, India. In: Ethnobotany - A Phytochemical Perspective. First Edition. (Eds. B.M. Schmidt and D.M. Klaser Cheng). *John Wiley & Sons Ltd*: 278-284.

13. Sharma M. Dwivedi J., Kumar B., Singh B.N. and Rawat A.K.S. (2018). Plant Based Secondary Metabolites for Health Regulation: Classification, Processing and Potential Therapeutic Effects. *In:* Plant Products and Health Promoting Potential. *Apple Academic Press, CRC Press.*

Popular Articles

1. मीना बी. एल., मीना आर. के. एवं नागर डी. (2017)। कृषि में ग्रामीण महिलायों का योगदान। *हरित क्रांति,* जून, 10: 5।
2. मीना आर. के., कुमार आर., एवं मीना बी. एल. (2017). नीम्बू जातीय फलों में कीटों का प्रबंधन, *हरित क्रांति,* जून, 10: 7।
3. मीना आर. के., कुमार आर., एवं मीना बी. एल. (2017)। सब्जियों में जैव-उर्वरकों का उपयोग, *कृषि गोल्ड लाइन,* 9 (20): 6।
4. शर्मा एस.के. एव तिवारी एस.के. (2017)। औषधीय फसल केवांच, *कहार,* 4 (3), जुलाई-सितम्बरः 06-07।
5. सिंह पी.के., तिवारी ए.के., एवं ओझा एस.के. (2017)। बुद्धि व स्मरण शक्तिवर्धक आयुर्वेदिक औषधि - शंखपुष्पी, *अनुसंधान* (वैज्ञानिक शोध पत्रिका), 5 (1): 161-164।
6. मिश्रा एस. एवं द्विवेदी एस.के. (2018)। स्टेफन हाकिंग्सः एक कालजयी वैज्ञानिक, *कहार,* 5(1-2): 39-40।
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8. मिश्रा एस. एवं द्विवेदी एस.के. (2017)। गर्म होती हवाएं, कही पानी को न तरस जाए, *कहार,* 4 (4): 4-6।
9. मिश्रा एस. एवं द्विवेदी एस.के. (2017)। दीपावली का पर्व और प्रदूषण, *कहार,* 4 (3): 17-20।
10. मिश्रा एस. एवं द्विवेदी एस.के. (2017)। होली के रंग हर्बल गुलाल के संग, *कहार,* 4 (1-2): 42-43।
11. Mishra S., Dwivedi S., Verma R., Tripathi R.D. (2017). Drinking water arsenic contamination in India and available removal techniques. *Kahaar*, 4 (1-2), 53-54.

Bulletins

1. Misra A., Srivastava S., Shukla P., Agrawal P.K. and Barik S.K. (2017). Chemotaxonomy and its relevance to Industrial consummation of colchicine, a commercially known metabolite of *Gloriosa superba* (L). *CSIR-NBRI*, 2017.
2. Shukla P., Srivastava S., Misra A., Agrawal P.K. and Barik S.K. (2018). Analysis of chemotaxonomic variation in *Coleus forskohlii* samples collected from different phyto-geographical zones of India. *CSIR-NBRI*, 2018.

विज्ञान वाणी 2017 अंक 23

1. शिव नारायण, कोमल पाण्डेय एवं प्रमोद अरविन्द शिर्के-ग्वारः एक आर्थिक कृषि फसलः 1-4।
2. रेखा कनौजिया एवं विवेक पाण्डेय-गेहूँ की वृद्धि एवं उपज पर वातावरणीय ओजोन का प्रभाव तथा एथिलीन डाई यूरिया आधारित उपचार का मूल्यांकनः 5-11।
3. मिन्हाज अख्तर उसमानी, किरन टोप्पो एवं संजीवा नायक-स्पाइरूलीना-रोजी और रोटीः 12-14।
4. रेखा कनौजिया, लाल बहादुर एवं डी.के. श्रीवास्तव-पान की व्यावसायिक खेतीः 15-18।
5. प्रेमनाथ शुक्ल, विनय कुमार एवं हेमन्त कुमार यादव-औषधीय पादप चन्द्रशूरः 19-21।
6. अतुल बत्रा एवं आर. एस. कटियार शोभाकारी पौधेः औषधीय गुणों का भण्डारः 22-24।
7. प्रतिभा मिश्रा, धर्मेन्द्र कुमार पुरूषोत्तम एवं चन्द्र शेखर नौटियाल-टिश्यूकल्चर विधि द्वारा कैना का प्रोपेगेशनः 25-26।
8. दया शंकर-*हेमरोकैलिसः* एक शोभाकारी पुष्पीय पौधाः 27-29।
9. सुषमा वर्मा, किरन टोप्पो एवं संजीवा नायका-ऐस्टाजैनथीनः एक अद्वितीय प्रति उपचायकः 30-31।
10. रणजीत कुमार यादव एवं आनन्द प्रकाश - लोक वानस्पतिक पादप डिलेनिया पेन्टागाइना के फल का मधुमेह के रोगोपचार में परीक्षणः 32-36।
11. भगवान दास- कतीराः एक औषधीय वृक्षः 37-39।
12. विनय साहू- बेल एक गुणकारी पौधाः 40-41।
13. आनन्द प्रकाश- उत्तर प्रदेश की आदिवासी जनजातियों में माँ व शिशु रोग उपचार हेतु कुछ कारगर औषधीय वनस्पतियाः 42-47।
14. ग्यासुद्दीन-कलौंजी का औषधीय उपयोगः 48-50।
15. नीरज सिंह एवं टी. एस. राणा- अखरोटः एक बहु उपयोगी वृक्षः 51-53।
16. आलोक कुमार एवं आनन्द प्रकाश- गाजर घासः घातक खरपतवार, उपयोग व नियन्त्रणः 54-56।
17. श्रवण पासवान, प्रीति वर्मा, रामेश्वर प्रसाद, किरन टोप्पो एवं सी. एच.वी.राव- चिकनगुनियाः 57-58 ।
18. सुरेश उजाला- जल प्रदूषणः समस्या और समाधानः 59-61।
19. जयेन्द्र कुमार जौहरी- पान का ऐतिहासिक विवरण एवं किंवदंतियाः 62-63।
20. अर्चना विन्द्रा- पर्यावरण संरक्षणः 64-67।
21. भरत लाल मीना, विवेक श्रीवास्तव, ए. के. गौनियाल एवं स्वाति शर्मा- उत्तर प्रदेश राज्य में महिलाओं के विकास व सशक्तीकरण के लिए कार्यान्वित योजनाएंः 68-74।
22. अनिल कुमार राठौर-वैचारिक एवं बौद्धिक समुदायों में अस्पृश्यता के नवीन प्रतिमानः 75-76।
23. संध्या श्रीवास्तव-स्वच्छ भारत अभियानः 77-78।
24. स्वाति शर्मा एवं मेघा-मंजिलेंः 79।
25. शुभम टण्डन- मेरी व्यथा- गोल है दवात, नम्बर भी गोल हैः 80।
26. सूर्यकान्त सिंह- लखनऊ में वायु प्रदूषणः समस्या और समाधान के कुछ प्रयासः 81-83।
27. सचिन मेहरोत्रा-गजल-जबां पर आज भी ताले नहीं हैः 84।
28. राम चरन-सीमा के पहरे पर वीर जवान चलेः 85।

PATENTS GRANTED / FILED

PATENTS GRANTED

Abroad

Sr. No.	Title	Inventors	Application No.	Country and Grant Date	Patent No.
1.	*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 K, Tuli R	201280070840	CN/17/05/2017	104302769
2.	A process for preparation of a novel insecticidal chitinase toxic against whiteflies, it"s encoding nucleotides and application there off	Singh PK, Upadhyay SK, Chandrashekhar K, Sharad S, Singh R, Preeti R, Singh H, Mishra M, Singh AP, Verma PC, Nair KM, Tuli R	12824781.4	EP/03/05/2017 GB/17/06/2014	2798061
3.	A method for production of transgenic cotton plants	Sawant SV, Tripathi RK, Idris A	2014333405	AU/11/04/2016	2014333405

India

Sr. No.	Title	Inventors	Application No.	Grant Date	Patent No.
1.	A novel soil improving synergistic composition useful for the reclamation of degraded land/soil	Behl HM, Sinha A, Singh N, Chandrashekhar K, Sidhu OP, Kumar V, Shukla VK	1827DEL2006	28/06/2017	284657
2.	Method of enhancing antioxidants activity in functional foods by plant growth promoting rhizobacteria	Nautiyal CS, Lavania M, Raghvan G, Rawat AKS, Phushpangadan P	0904DEL2006	05/07/2017	284932
3.	A biologically pure bacterial strain of *Bacillus pantothenticus* and novel bicontrol composition	Behl HM, Tewari K, Singh N, Sidhu OP, Kumar V, Chandrashekhar K and Tuli R	2194DEL2006	23/03/2018	294818

PATENTS FILED

Abroad

Sr. No.	Title	Inventors	Country	Filing Date/NF No.
1.	A wound inducible expression construct and a method of its preparation	Sane AP, Pandey SP, Singh AP	US (USA)	22/06/2017/0061NF2014/US
2.	A novel formulation for improving the yield and quality of fiber in cotton plants	Sawant SV, Singh SK, Singh Babita, Bhattacharya P	US (USA)	28/07/2017/ 0240NF2014/US
3.	Novel reversible expression system for transgene expression in plants	Sawant SV, Singh SP	US (USA)	16/10/2017/0174NF2014/US

TECHNOLOGIES TRANSFERRED

SI. No.	Details	Client	Date
1.	Supplementary Licensing Agreement for technology / know how of Herbal Sindoor stick	M/S Vedic Biocare Private Limited, Lucknow	May 11, 2017
2.	Licensing Agreement for technology / know how of Alcohol Free Herbal Hand Sanitizer	M/S Satguru Biologicals Private Limited, Barabanki	June 27, 2017
3.	Licensing Agreement for technology / knowhow of Dental Cream (Jointly developed by CSIR-NBRI & CSIR-CIMAP)	M/S Herbal Ayurveda and Research Centre, Noida	September 27, 2017
4.	Licensing Agreement for technology / knowhow of Nutri-Jam and Anti-cough herbal formulation		
5.	Licensing Agreement signed for knowhow of Dental Cream (Jointly developed by CSIR-NBRI & CSIR-CIMAP technology)	M/s Medes Consultancy Services, Medas House 6/2, Meera Complex Zone -2 M. P. Nagar, Bhopal (M.P.)	October 06, 2017
6.	Licensing Agreement signed for technology / know how of Herbal Gulal	M/s Radha Kishan Bishan Dass Rang Rasayan Pvt. Ltd., Hathras	January 31, 2018

HUMAN RESOURCE DEVELOPMENT

CSIR-NBRI Participation in Trainings/Exhibition/Flower Shows/Seminars

Sr. No.	Event Name	Venue	Date	Participating Division
1.	CSIR Mega Exhibition	CSIR-CCMB, Hyderabad	September 01-05, 2017	TTBD
2.	Closing Ceremony of CSIR Platinum Jubilee Celebrations	Vigyan Bhawan, New Delhi	September 26, 2017	Botanic Garden and TTBD
3.	Indian International Science Festival 2017	CSIR-IITR, Lucknow	September 07, 2017	Botanic Garden and TTBD
4.	North East Calling Programme	India Gate, New Delhi	September 9-10, 2017	TTBD
5.	CSIR Platinum Jubilee Ceremony	Vigyan Bhawan, New Delhi	September 26, 2017	TTBD and Botanic Garden
6.	Swadeshi Mela and Exhibition	Varanasi, UP	October 8-17, 2017	TTBD
7.	3rd International Toxicology Conclave, ITC-2017	CSIR-IITR, Lucknow	November 05-06, 2017	TTBD and Botanic Garden
8.	Science & Technology Exhibition	Simauni Dham, Baberu, Banda, UP	December 15-17, 2017	TTBD
9.	Kisan Mela 2018	CSIR-CIMAP, Lucknow	January 31, 2018	TTBD, Botanic Garden
10.	State Exhibition	UP Governor House, Lucknow	February 24-25, 2018	TTBD and Botanic Garden
11.	Flower Show 2018	Lucknow Nagar Nigam, E-park, Mahanagar, Lucknow	February 24-25, 2018	Plant Ecology and Environment Science Division (*Awarded First Prize under Shri Raj Narayan Shashtri Chal Baijanti Trophy*)
12.	Indian Science Congress	Manipur University, Imphal	March 16-20, 2018	TTBD and Botanic Garden
13.	8th Science Expo 2018	Regional Science City, Lucknow	March 26-28, 2018	TTBD

Individual Training/Workshop Attended

Sr. No.	Name of Person (s)	Subject of Training Course	Organizer/ Place	Date/ Period
1.	Dr. TS Rahi	Intellectual Property Rights and Related Issues	CSIR-HRDC, Ghaziabad	April 19-21, 2017
2.	Dr. SK Behera	Capacity Building Programme for Technical Officers	CSIR-HRDC, Ghaziabad	April 24-28, 2017
3.	Dr. Aradhana Mishra	Evaluation of uncertainty and ISO-17025	CSIR-HRDC, Ghaziabad	July 25-28, 2017
4.	Dr. Poonam C Singh & Dr. Suchi Srivastava	Workshop on Science and technology for women	Science and Technology council, Shimla, Himachal Pradesh,	September 8-9, 2017
5.	Ms. Rekha Kannaujia,	Laboratory Quality Management System and Internal Audit	CIPET, Lucknow	October 10-13, 2017
6.	Mr. SK Sharma, Drs. Poonam C. Singh and Suchi Srivastava	Creativity and Innovation for Rural Societies	CSIR-HRDG, Ghaziabad	October 04-06, 2017
7.	Dr. Lal Bahadur	Phenotyping for drought adaptable physiological traits in different crops	University of Agricultural Sciences, Bengaluru	October 25 to November 11, 2017
8.	Drs. M Pal, PK Singh, Vivek Pandey, KN Nair and Mr. Vivek Srivastava	CSIR-Leadership Development Programme	By CSIR-HRDC at CSIR-NBRI, Lucknow	November 13-17, 2018
9.	Dr. Poonam C Singh and Dr. Suchi Srivastava	Creativity and innovation for Rural Societies	CSIR-HRDC, Ghaziabad	December 4-6, 2017
10.	Dr. AP Singh	Management of Scientific Research for Value Creation	CSIR-HRDC, Ghaziabad	January 17-19, 2018

Group Training Imparted

Sr. No.	Name of the Organization/Group	Subject of Training	No. of Participants	Date/Period
1.	General Public (Housewives, students, garden lovers, etc.)	Bonsai Technique	39	April 5-7, 2017
2.	ITBP Staff	Gardening	80 (in 4 batches)	May 22 – June 23, 2017, November 06, 2017 to December 04, 2017 and December 12, 2017 to January 10, 2018, January 23, 2018 to February 21, 2018.
3.	General Public (Housewives, students, garden lovers etc.)	Home Gardening	35	August 22-24, 2017
4.	CPWD Horticulture Officers	Gardening	16	August 29 – September 01, 2017
5.	Farmers, Floriculturist and general public	PPV&FRA Awareness Programme	200	December 09, 2017
6.	Farmers from different districts	Betelvine Cultivation	50	December 14, 2017 and March 14, 2018

Student Training Imparted

One hundred and three post-graduate students of different universities/institutes were imparted training on various topics of their interest, during April 2017 to March 2018. A sum of Rs. 17, 98,680/- were realized from them as training fee.

Skill Development Programmes

Fully Industry/Govt. Sponsored Skill/Training Programmes*:

S.No	Sponsoring Industry/ Govt Agency	Skill/Training programme	Duration		No. of candidates trained	Fee/sponsorship collected (In Rs.)
			From	To		
1.	Indo-Tibetan Border Police Force, Govt. of India	Training Programme on Garden Maintenance	22.05.2017	23.06.2017	15	2,25,000/-
2.	Indo-Tibetan Border Police Force, Govt. of India	Training Programme on Garden Maintenance	06.11.2017	04.12.2017	22	3,30,000/-
3.	Indo-Tibetan Border Police Force, Govt. of India	Training Programme on Garden Maintenance	12.12.2017	10.01.2018	22	3,30,000/-
4.	Indo-Tibetan Border Police Force, Govt. of India	Training Programme on Garden Maintenance	23.01.2018	21.02.2018	22	3,30,000/-

(*Skill/Training programs sponsored by particular Industry/Govt. agency to train their manpower exclusively)

Semi Sponsored Skill/Training Programmes*: (Individual/Departmental fee based)

S. No	Skill/Training programme	Duration		No. of candidates trained	No. of candidates placed in industry, if any	Fee/sponsorship collected (In Rs.)	Remarks, if any
		From	To				
1.	Soil & Water Testing Lab Analyst	9 Feb 2018	20 Mar 2018	3	One in-service candidate	40000	ASCI
2.	Plant Tissue Culture Technician	8 Jan 18	9 Feb 18	2	01	20,000	ASCI
3	Developing a Cadre of "Quality Analyst" for Herbal Industry	30 Oct 17	28 Nov 17	6	01 self employed	60,000	CSIR-NBRI

ASCI= Agriculture Skill Council of India

HONORS/AWARDS/DISTINCTIONS

Individual Honours/Awards/Recognitions

Sr. No.	Name of the Person	Award (s)
1.	Smita Kumar	INSA Young Scientist Medal -2017
2.	Bhattacharya Arpita, Pandey Shipra and Kumar S	Won the award of Rs one lakh each, project grant at BIRAC - Society for Research and Initiatives for Sustainable Technologies and Institutions (SRISTI) BIIS (Biotech Innovation Ignition School).
3.	Prasad MG	IAPT Research Grant Award for the year 2017, by the International Association for Plant Taxonomy, Bratislava, Slovakia.

Member/Editor, Referee, Expert, Reviewer, Judge, etc. (selected, recognized, enrolled, empaneled, nominated)

Sr. No.	Name of Person	Details
1.	Agnihotri Priyanka	Full member of Organization for Women in Science for the Developing World (OWSD), a programme unit of UNESCO, Trieste, Italy
2.	Asthana AK	• Recognized as reviewer for International Journals *Taiwania* (Taiwan), *Lindbergia* (The Netherlands), *Plant Science Today,* Cryptogam Biodiversity and Assessment, *International Journal of plant and Environment* • Empaneled as Judge to select best paper for Cryptogam Biodiversity and Assessment
3.	Lata Charu	Life member of the International Society of Environmental Botanists (ISEB), Lucknow
4.	Mishra A	Reviewer of *Genetics and Molecular Biology Research* and *American Journal of Clinical Microbiology and Antimicrobials*
5.	Nair KN	Reviewer Panel of *Current Science*
6.	Rao ChV	• Selected as CPCSEA Nominee Ministry of Environment and Forest, New Delhi. • Selected as Research Council Member of Amity University, Integral University and Dr. APJ Abdul Kala technical University, lucknow
7.	Trivedi PK	• Member, Editorial Board of PLoS one, Scientific Reports, Physiology and Molecular Biology of Plants, International Journal of Plant and Environment • Member of Advisory Committee for Biotechnology, UPCST
8.	Sahu V	Elected as Fellow of Indian Botanical Society
9.	Singh BN	• Editorial board member of the journals *Frontiers in Cellular and Infectious Microbiology, Frontiers in Microbiology, PLOS ONE, Biotechnology Journal, BMC Complementary and Alternative Medicine, International Journal of Agriculture, Environment and Biotechnology, EC Nutrition, Pharmacology-ContROL, Journal of Nutrition and Metabolism Research, Journal of Plant Science and Horticulture, SF Journal of Biotechnology and Biomedical Engineering, Journal of Nutrition and Food Science Forecast, Food and Drug Research, Annals of Short Reports, Preventive Medicine Research, The Open Biology Journal, Annals of Pediatrics & Adolescent Medicine, Cell and Cellular Life Sciences Journal, Journal of Biomedical Engineering Research*) • Reviewer of the journals *Microbome, Scientific Report, Biotechnology Journal, Frontiers in Cellular and Infectious Microbiology, Frontiers in Microbiology, PLOS ONE, Biomaterials, Journal of Ethnopharmacology, Phytomedicine, Mycologia, Frontiers in Plant Science, Food and Chemical Toxicology, Current Science, Journal of Complementary Medicine Research*)

PH.D. AWARDED/SUBMITTED

Ph.D. Theses Awarded

Sr. No.	Name of the Student	Title of Thesis	Guides	University
1.	**Ms. Ameena Siddiqui**	Diversity analysis, gene interactions and association among different traits in Linseed (*Linum usitatissimum* L.)	**Dr. S Shukla**, Senior Principal Scientist, CSIR-NBRI, Lucknow	Academy of Scientific and Innovative Research (AcSIR), New Delhi
2.	**Ms. Ankita Misra**	Chemotaxonomic studies on *Gloriosa superba* (L.) from different phytogeographical zones of India and their pharmacological validation	**Dr. S Srivastava**, Principal Scientist, CSIR-NBRI, Lucknow and **Dr. Ponam Kushwaha**, Department of Pharmacy, Integral University, Lucknow	Integral University, Lucknow
3.	**Ms. Ankita Srivastava**	Studies on Moss Flora of Khasi hills, Meghalaya (North-East India)	**Dr. AK Asthana**, Principal Scientist, CSIR-NBRI, Lucknow	Academy of Scientific and Innovative Research (AcSIR), New Delhi
4.	**Ms. Archana Bhardwaj**	Design and development of plant specific model based SNP pipeline	**Dr. SK Bag**, Senior Scientist, CSIR-NBRI, Lucknow	Academy of Scientific and Innovative Research (AcSIR), New Delhi
5.	**Ms. Asmita Gupta**	Functional analysis of SIERF6 during Tomato Plant growth and Ripening	**Dr. AP Sane**, Senior Principal Scientist, CSIR-NBRI, Lucknow	Academy of Scientific and Innovative Research (AcSIR), New Delhi
6.	**Ms. Astha Gupta**	Mapping quantitative trait loci for traits related to biomass in *Arabidopsis thaliana*	**Dr. HK Yadav**, Senior Scientist, CSIR-NBRI, Lucknow	Academy of Scientific and Innovative Research (AcSIR), New Delhi
7.	**Mr. Baleshwar**	Studies on the Systematics of the genus *Ephedra* L. (Ephedraceae) in India, using PCR-based methods	**Dr. TS Rana**, Senior Principal Scientist, CSIR-NBRI, Lucknow and **Dr. YK Sharma,** Professor, Department of Botany, Lucknow University, Lucknow	Lucknow University, Lucknow
8.	**Ms. Chandrawati**	Genetic diversity analysis and QTL mapping in linseed (*Linum usitatissimum* L.)	**Dr. HK Yadav**, Senior Scientist, CSIR-NBRI, Lucknow	Academy of Scientific and Innovative Research (AcSIR), New Delhi
9.	**Ms. Deepali Johari**	*In-vitro* studies on mating system and colonization potential of some threatened Pteridophytes	**Prof. LN Tiwari**, Kumaun University, **Dr. PB Khare**, Retd. Chief Scientist and **Dr. AP Singh**, Senior Scientist, CSIR-NBRI, Lucknow	Kumaun University, Nainital
10.	**Ms. Deepika Lakhwani**	Integrating bioinformatics approaches to identify genes and networks regulating fruit ripening in Banana	**Dr. MH Asif**, Senior Scientist, CSIR-NBRI, Lucknow	Academy of Scientific and Innovative Research (AcSIR), New Delhi
11.	**Ms. Mrinalini Srivastava**	Enhancement of secondary metabolites with the use of biotic and abiotic elicitors in hairy root cultures of *Rauwolfia serpentina* L., *Glycyrrhiza glabra* L., and *Solanum khasianum* C. B. Clark.	**Dr. P Misra**, Principal Scientist, CSIR-NBRI, Lucknow and **Dr. Swati Sharma**, Integral University, Lucknow	Integral University, Lucknow
12.	**Ms. Namita Gupta**	Studies on lichen diversity in relation with air pollution monitoring around some selected thermal power plants of Uttar Pradesh, India	**Dr. DK Upreti**, Chief Scientist, CSIR-NBRI, Lucknow and **Prof. SK Dwivedi,** Department of Environmental Sciences, BBAU, Lucknow	Babasaheb Bhimrao Ambedkar Univeristy, Lucknow
13.	**Mr. Pankaj K Verma**	Functional characterization of arsenic-responsive glutaredoxin genes of rice (*Oryza sativa* L.)	**Dr. D Chakrabarty**, Senior Scientist, CSIR-NBRI, Lucknow and **Dr. Veena Pande,** Head, Department of Biotechnology, Kumaun University	Kumaun University, Nainital

14.	**Ms. Parul Agarwal**	Papaverine biosynthesis in *Papaver somniferum* L.: Analysis of regulatory and structural genes	**Dr. PK Trivedi**, Senior Principal Scientist, CSIR-NBRI, Lucknow	Academy of Scientific and Innovative Research (AcSIR), New Delhi
15.	**Ms. Priya**	Functional Studies of cis Element in the Gene Promoter Involved in Petal Abscission in Rose (*Rosa bourboniana*)	**Dr. AP Sane**, Senior Principal Scientist, CSIR-NBRI, Lucknow	Academy of Scientific and Innovative Research (AcSIR), New Delhi
16.	**Ms. Ridhi Goel**	Bioinformatics of WRKY gene family: Evolution, Expression and Neofunctionalization in higher plant	**Dr. MH Asif**, Senior Scientist, CSIR-NBRI, Lucknow	Academy of Scientific and Innovative Research (AcSIR), New Delhi
17.	**Mr. SK Mishra**	Physiological and molecular characterization of stress tolerant biofilm forming plant growth promoting rhizobacteria	**Dr. PS Chauhan**, Senior Scientist, CSIR-NBRI, Lucknow	Academy of Scientific and Innovative Research (AcSIR), New Delhi
18.	**Ms. Shikha Verma**	Identification and characterization of a novel arsenic methyltransferase from *Westerdykella aurantiaca* isolated from arsenic contaminated agricultural soil	**Dr. D Chakrabarty**, Senior Scientist, CSIR-NBRI, Lucknow and **Dr. Veena Pande,** Head, Department of Biotechnology, Kumaun University, Nainital	Kumaun University, Nainital
19.	**Mr. Shyam S Gupta**	Isolation and biological evaluation of selected medicinal plants against Gastro-esophageal reflux disease (GERD) in rats	**Prof. PK Mohapatra**, Ravenshaw University, Cuttack and **Dr. ChV Rao**, Principal Scientist. CSIR-NBRI, Lucknow	Ravenshaw University, Cuttack
20.	**Ms. Smrati Srivastava**	Spatial and Temporal Regulation of Ripening in Two Indian Varieties of Mango (*Mangifera indica*)	**Dr. Vidhu Sane**, Principal Scientist, CSIR-NBRI, Lucknow	Academy of Scientific and Innovative Research (AcSIR), New Delhi
21.	**Ms. Sujata Mishra**	Taxonomic reappraisal and genetic diversity assessment in Indian *Luffa* Mill. (Cucurbitaceae) through morphological and PCR-based DNA marker analyses	**Dr. KN Nair,** Senior Principal Scientist. CSIR-NBRI, Lucknow and **Prof. SS Bargali**, Kumaun University, Nainital	Kumaun University, Nainital
22.	**Mr. Sunil Kumar Yadav**	Characterization of whitefly toxic protein (Tma12) and aphid toxic protein(Dhi31)	**Dr. PK Singh**, Principal Scientist. CSIR-NBRI, Lucknow	Academy of Scientific and Innovative Research (AcSIR), New Delhi
23.	**Mr. Sumit Yadav**	Physiological and Molecular Characterization of Stress Tolerant Biofilm Forming Plant Growth Promoting Rhizobacteria	**Prof. Vinod Singh**, Barkatullah University, Bhopal, MP and **Dr. CS Nautiyal,** Ex-Director, CSIR-NBRI, Lucknow	Barkatullah University, Bhopal, MP
24.	**Mr. Surendra Pratap Singh**	Novel strategy for developing male sterile plants and fertility restoration of F1 hybrid through regulated expression system	**Dr. RR Singh**, Department of Botany, Lucknow University and **Dr. SV Sawant**, Senior Principal Scientist, CSIR-NBRI, Lucknow	Lucknow University, Lucknow
25.	**Ms. Sweta Bhambani**	Identification and Characterization of genes involved in tetranortriterpenoid biosynthesis pathway from *Azadirachta indica A. Juss*	**Dr. PK Trivedi**, Senior Principal Scientist, CSIR-NBRI, Lucknow	Academy of Scientific and Innovative Research (AcSIR), New Delhi
26.	**Ms. Tapsi Shukla**	Understanding arsenic stress responses using natural variation in Arabidopsis thaliana	**Dr. PK Trivedi**, Senior Principal Scientist, CSIR-NBRI, Lucknow	Academy of Scientific and Innovative Research (AcSIR), New Delhi
27.	**Ms. Tripti Mishra**	Isolation and Identification of bioactive compounds from selected medicinal plants for their biological activity	**Dr. M Pal,** Principal Scientist. CSIR-NBRI, Lucknow and **Prof. P Joshi**, Kumaun University, Nainital	Kumaun University, Nainital
28.	**Mr. Verendra Kumar**	To explore the role of histone deacetylases in epigenetic regulation of fiber development in *Gossypium hirsutum*	**Dr. Gauri Saxena**, Department of Botany, Lucknow University and **Dr. SV Sawant**, Senior Principal Scientist, CSIR-NBRI, Lucknow	Lucknow University, Lucknow

29.	**Mr. Vikash K Yadav**	Identification and characterization of long-range chromatin interactions involved in regulation of gene expression in *Arabidopsis thaliana*	**Dr. SV Sawant**, Senior Principal Scientist, CSIR-NBRI, Lucknow	Academy of Scientific and Innovative Research (AcSIR), New Delhi
30.	**Mr. Vrijesh Kumar Yadav**	Identification And Molecular Characterization of fibre specific promoters in cotton	**Dr. SV Sawant**, Senior Principal Scientist, CSIR-NBRI, Lucknow	Academy of Scientific and Innovative Research (AcSIR), New Delhi

Ph.D. Theses Submitted

Sr. No.	Name of the Student	Title of Thesis	Guides	University
1.	**Mr. Aditya V Agarwal**	Molecular characterization of genes involved in biosynthesis of specific withanolides from *Withania somnifera*	**Dr. PK Trivedi,** Senior Principal Scientist, CSIR-NBRI, Lucknow and **Prof. Deepak Chandra,** Lucknow University	Lucknow University, Lucknow, U.P.
2.	**Mrs. Anjali Verma**	Phytochemical screening of antihyperglycemic activity of some medicinal plants	**Dr. M Pal,** Principal Scientist. CSIR-NBRI, Lucknow and **Prof. V Pande,** Kumaun University, Nainital	Kumaun University, Nainital
3.	**Ms. Ansulika Sable**	Exploring the role of heat shock proteins in cotton fiber development	**Dr. SK Agarwal,** Department of Biochemistry, Lucknow University and **Dr. SV Sawant,** Senior Principal Scientist, CSIR-NBRI, Lucknow	Lucknow University, Lucknow, U.P.
4.	**Ms. Aradhana Lucky Hans**	Development of stable transgenic lines of cotton (*Gossypium hirsutum* L.) cv. Coker 312 for resistance against sap sucking pests	**Dr. PK Singh,** Principal Scientist, CSIR-NBRI, Lucknow	Academy of Scientific and Innovative Research (AcSIR), New Delhi
5.	**Mr. Ashish Praveen**	Phytoremediation of arsenic contaminated soil and water for arsenic-safe crop yield	**Dr. Nandita Singh,** Ex-Principal Scientist, CSIR-NBRI	Academy of Scientific and Innovative Research (AcSIR), New Delhi
6.	**Mr. Ashutosh Kumar Singh**	Study of climatic influence on soil carbon pools and fluxes in a tropical dry forest	**Dr. Nandita Singh,** Ex-Principal Scientist, CSIR-NBRI	Academy of Scientific and Innovative Research (AcSIR), New Delhi
7.	**Mr. Devesh Mishra**	Identification and validation of wound inducible promoter from Arabidopsis thaliana characterization of long range chromatin interactions involved in regulation of gene expression in Arabidopsis thaliana	**Dr. SV Sawant,** Senior Principal Scientist, CSIR-NBRI, Lucknow	Academy of Scientific and Innovative Research (AcSIR), New Delhi
8.	**Ms. Garima Dixit**	Exploring the role of phenolics for management of chewing pests in *Gossypium hirsutum* L.	**Dr. PC Verma,** Senior Scientist, CSIR-NBRI, Lucknow	Academy of Scientific and Innovative Research (AcSIR), New Delhi
9.	**Mr. Navin Kumar**	Study on the role of Gamma aminobutyric acid in imparting stress tolerance towards arsenite induced oxidative stress by nitric oxide and polyamines synthesis in *Oryza sativa*	**Dr. Saripella Srikrishna,** Dept. of Biochemistry, Institute of science, Banaras Hindu University, Varanasi and **Dr. Shekhar Mallick,** Senior Scientist, CSIR-NBRI, Lucknow	Banaras Hindu University, Varanasi

10.	**Ms. Poonam Pant**	Computational analysis of Calmodulin-binding Transcription Activator (CAMTA) gene family in *Gossypium* species: identification, evolutionary analysis and transcriptional gene regulatory networks	**Dr. SV Sawant**, Senior Principal Scientist, CSIR-NBRI, Lucknow	Academy of Scientific and Innovative Research (AcSIR), New Delhi
11.	**Mrs. Shipra Shukla**	Phytochemical Studies of Selected Medicinal Plants for their Biological Activity	**Dr. M Pal,** Principal Scientist. CSIR-NBRI, Lucknow and **Prof. G Chaudhary**, Mangalayatan University Aligarh	Mangalayatan University, Aligarh
12.	**Ms. Shiksha Mishra**	Studies on lichen flora at the tarai region of Kumaun Himalaya with special reference to pollution monitoring	**Dr. DK Upreti,** Chief Scientist. CSIR-NBRI, Lucknow and **Dr. AK Srivastava,** Government PG College, Dwarahat, Almora	Kumaun University, Nainital
13.	**Mr. Sunil Kumar Gupta**	Use of Ethylenediurea (EDU) to assess impact of tropospheric ozone in Wheat and Maize	**Dr. Vivek Pandey,** Senior Principal Scientist. CSIR-NBRI, Lucknow	Academy of Scientific and Innovative Research (AcSIR), New Delhi
14.	**Mr. Sunil Kumar Jaiswal**	Phytopharmacological evaluation of selected medicinal plants in the treatment of gastric ulcer	**Dr. Ch. V. Rao**, Principal Scientist, CSIR-NBRI, Lucknow	Dr. A.P.J. Abdul Kalam Technical University, Lucknow
15.	**Ms. Vandana Tiwari**	Studies on Diversity and Systematics of the Genus *Bergenia Moench* (Saxifragaceae) Using Molecular Markers	**Dr. TS Rana,** Senior Principal Scientist. CSIR-NBRI, Lucknow and **Prof. Sushma Tamta**, Kumaun University, Nainital	Kumaun University, Nainital
16.	**Ms. Varsha Srivastava**	Cytotaxonomic studies on some threatened and medicinally important plants from the Indian Himalayan Regions	**Dr. P Agnihotri**, Scientist, CSIR-NBRI, Lucknow and **Dr. K Mishra**, Professor, Lucknow University, Lucknow	Lucknow University, Lucknow

S & T Support

Information, Publication and Library
Dr. PA Shirke, Dr. KN Nair, Dr. CS Mohanty, Mr. Yogendra Nath, Mr. ML Kain, Mr. Rajat R Rastogi

Planning, Monitoring & Evolution
Dr. AK Gauniyal, Dr. RN Gupta, Mr. VK Gupta

Technology Transfer & Business Development
Dr. AK Gauniyal, Mr. Vivek Srivastava, Mrs. Swati Sharma, Mr. BL Meena

ICT
Dr. PK Trivedi, Mr. Surjit Kumar, Mrs. Leena Wahi Gupta, Mr. Prashant Srivastava, Mr. Devranjan

Essential and Civil Services
Mr. VD Tripathi, Mr. LK Srivastava, Mr. Harendra Pal, Mr. Somnath 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 2017-2018:

i) CSIR-NBRI Newsletter, 2017, Vol. 44, Nos. 2-4

ii) Educational Material (Calendar) for the year 2018 was designed and produced, on the theme "Unique Plants In India".

iii) CSIR-NBRI Annual Report: Annual Report 2016-2017 was compiled and brought out. It was released on the occasion of Annual Day of the Institute on October 25, 2017 by Prof. LMS Palni, Vice-chancellor, Graphic Era University, Dehradun, Prof. Manoj Dixit, Vice-Chancellor, Dr. RML Awadh University, Faizabad and Prof. PK Seth, Former CEO, Biotech Park 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 2016-2017.

Sale of Publications : Rs 23,414/-

Parliament Questions: 48 parliament questions received from CSIR HQ were answered.

Knowledge Resource Centre (KRC)

Knowledge Resource Centre (Library) acts as the main knowledge resource center of the Institute and provides services and facilities to meet the S & T knowledge requirements of the Institute's R & D activities. The library 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.

KRC has subscribed a total of 566 journals including 494 online journals. KRC also subscribed four databases : Grammarly, iThenticate plagiarism checker, Web of science and TAIR (The Arabidopsis Information Resource) that are important resources for the scientists and researchers of the institute.

A Botanical Archive that contains rare and hand-written manuscripts in Persian and Arabic, illustrations of plants dating back to 18th century, besides a host of other botanical literature of original value, is also maintained in the library.

Inter Library Loan facility is provided by KRC to share the resources of libraries of other research organizations and universities. CSIR-NBRI Library also provides Document Delivery Service by sending documents through emails against Document Delivery Requests (DDR) received from various laboratories of CSIR and DST through J-Gate database and through emails.

Library Holdings (As on 31.3.2018)

Books & Journals	
1. Number of books and journals added During 2017-2018	
(i) Books Purchased	69
(ii) Books received on gratis/ exchange	03
(iii) FAO's Books received	16
(iv) Bound Journals	06
Total number of books added during 2017-18	**94**
2. Number of books and bound journals as on 31.3.2018	60997
Current Periodicals	
(i) Print only	50
(ii) Print + Online	03
(iii) Online only	19
(iv) Online received through CSIR consortium (NKRC) on share basis	475
(v) Complimentary/Exchange	19
Total number of Periodicals (titles) received during 2017-2018	**566**
Database received through CSIR Consortium (NKRC) on share basis	03
Reprography Service	
Total number of photocopies of documents and scientific publications provided to the scientists of the Institute during 2017-2018	01 5800

Planning, Monitoring & Evaluation

The Planning, Monitoring and Evaluation Division of the Institute 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 range from scrutiny and coordinating in the evaluation of new research proposals, assist in monitoring the progress of research projects, maintenance of repository of R&D projects in both physical documents and as well as electronic databases.

During 2017-18, forty-seven Grant-in-Aid/ consultancy/network OLP projects were populated in the R&D module as a part of ERP solutions for quick online accessibility and usability of complete accurate information. The necessary project receipts of the FY 2017-18 of ongoing projects were processed in the Centralized Valuable Receipt (CVR).

The major activities carried out during the year were:

- Evaluations of new research project proposals
- Evaluation, examination and processing of proposals the various national and international fellowships.
- Formulation of Facility Creation Project Proposals.
- Mapping of new Contract R&D Projects in R&D Project Module
- Technical manpower planning and human resource development.
- Coordination between various agencies with respect to R & D activities
- The necessary project receipts of the FY 2017-18 of ongoing projects were processed in the CVR
- Database maintenance for R&D projects (in-house, sponsored, Grant-in-aid, Consultancy, Plan Projects & Network Projects)
- Organization of 47th Research Council (RC) meetings held during December 28-19, 2017.
- 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
- Processing of foreign deputation cases of researchers for various R & D purposes.

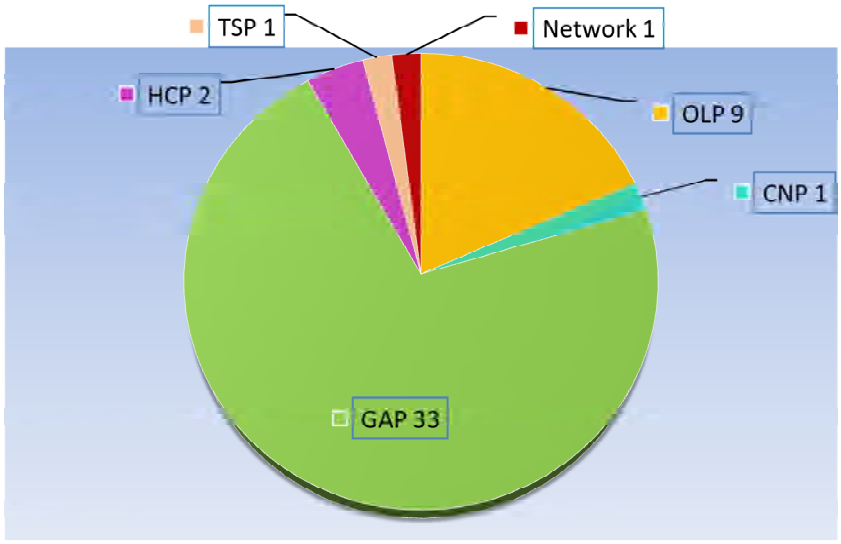
Projects Initiated During 2017-18

Sr. No.	Project Number	Project title	Funding Agency	Principal Investigator/ Co-ordinator	Duration Details
1.	NWP 100	CSIR Integrated Skill Initiative program : Vision, Mission & Roadmap of CSIR-NBRI Skill Development Programmes	CSIR, New Delhi	PC: Prof. SK Barik NO: Dr. SK Tewari	03 Months w.e.f. December 5, 2017
2.	HCP 007	CSIR Aroma Mission: Catalyzing rural empowerment through cultivation processing, value addition and marketing of aromatic plants	CSIR, New Delhi	PI: Dr. SK Tewari	32 Months w.e.f. July 17, 2017
3.	HCP 010	CSIR Phytopharmaceutical Mission: Catalyzing Phytopharmaceutical drug discovery as per global standards for unmet medical needs from indigenous medicinal plants under captive cultivation	CSIR, New Delhi	PI: Dr. TS Rana	27 Months w.e.f. December 8, 2017
4.	TSP 0003	Training on Tissue Culture Techniques	Govt. Tissue Culture Laboratory, Horticulture & Food Processing Department, Lucknow	PI: Dr. Pratibha Misra	05 days w.e.f. Oct 30, 2017 - Nov 3, 2017
5.	CNP 3044	Advise on feasibility study for the programme 'Forest and Biodiversity Management of the Himalayas' in Nagaland	KfW (Kreditianstalt fur Wiederaufbau, Franfurt, Germany	PI: Dr. SK Barik	01 Month w.e.f. July 21, 2017
6.	OLP 0099	Plant conservation, botanical garden, plant houses and development of new varieties of ornamental and floricultural crops	CSIR-NBRI	PC: Dr. RS Katiyar	36 Months w.e.f. April 1, 2017
7.	OLP 0100	Socio-economic development through enhancing production of agricultural systems, skill development and outreach programmes	CSIR-NBRI	PC: Dr. SK Tewari	36 Months w.e.f. April 1, 2017
8.	OLP 0101	Bioresource Inventory, Systematics and conservation of diverse plant groups of Suhelwa Wildlife Sanctuary, (SWLS) Uttar Pradesh	CSIR-NBRI	PC: Dr. TS Rana	36 Months w.e.f. April 1, 2017
9.	OLP 0102	Monitoring and assessment of pollution and its mitigation through bioremediation	CSIR-NBRI	PC: Dr. Pankaj K Srivastava	36 Months w.e.f. April 1, 2017
10.	OLP 0103	Forest carbon stock assessment and plants for mitigating urban air pollution	CSIR-NBRI	PC: Dr. PA Shirke	36 Months w.e.f. April 1, 2017
11.	OLP 0104	Plant improvement through transgenic and modern breeding approaches	CSIR-NBRI	PC: Dr. Sudhir Shukla	36 Months w.e.f. April 1, 2017
12.	OLP 0105	Microbial intervention for amelioration of abiotic and biotic stresses in plants	CSIR-NBRI	PC: Dr. Suchi Srivastava	36 Months w.e.f. April 1, 2017
13.	OLP 0106	Herbal product development for industrial application	CSIR-NBRI	PC: Dr. Alok Lehri	36 Months w.e.f. April 1, 2017
14.	OLP 0107	Facility creation for bio-prospection, development of herbal products and green technologies	CSIR-NBRI	PC: Dr. TS Rana	04 Months w.e.f. December 5, 2017
15.	GAP 3414	Understanding molecular mechanisms to heavy metal stress response using natural variations in *Arabidopsis thaliana*	DST, New Delhi	PC: Dr. PK Trivedi PI: Dr. Smita Kumar	26 Months w.e.f. April 1, 2017
16.	GAP 3410	Identification, expression and network analysis of non- coding RNAs (ncRNAs) to understand their role in the regulation of fruit ripening in *Musa accuminata*	SERB, New Delhi	PC: Dr. MH Asif PI: Dr. Sanchita	24 Months w.e.f. April 5, 2017

17.	GAP 3415	Reducing cold temperature induced damages and biotic stress in betelvine involving humic acid rich vermicompost and ACC deaminase containing microbes	SERB, New Delhi	PC: Dr. SK Tewari PI: Dr. Deepamala Maji	24 Months w.e.f. April 17, 2017
18.	GAP 3411	Molecular basis of differential phase change in Arabidopsis natural variation	SERB, New Delhi	PC: Dr. P.K. Trivedi PI: Dr. Nivedita Singh	24 Months w.e.f. May 1, 2017
19.	GAP 3413	Ecology, Phylogeny and Computational approach of Lichenized and Lichenicolous Fungi in India with emphasis on family Arthoniaceae (*Ascomycota: Arthoniales*)	SERB, New Delhi	PC: Dr. Sanjeeva Nayaka PI:Dr. Siljo Joseph	24 Months w.e.f. May 1, 2017
20.	GAP 3406	Recombinant expression and characterization of new insecticidal protein isolated from lower plant biodiversity	SERB, New Delhi	PC: Dr. PK Singh PI: Dr. Mohd. Kashif	24 Months w.e.f. May 4, 2017
21.	GAP 3407	*In-vitro* studies on reproductive behaviour, regeneration and conservation of threatened and economically important Pteridophytes of Niyamgiri Hill, Odisha	SERB, New Delhi	PI: Dr. Sandeep K Behera	48 Months w.e.f. May 11, 2017
22.	GAP 3412	Studies on diversity and systematics of the genus *Sonneratia* in India using molecular markers	SERB, New Delhi	PC: Dr. TS Rana PI: Dr. Ragavan P	24 Months w.e.f. June 1, 2017
23.	GAP 3408	Characterization of gene(s) responsible for tyloses formation in chickpea during *Fusarium oxysporum* infection	SERB, New Delhi	PI: Dr. Manoj Kumar	36 Months w.e.f. June 8, 2017
24.	GAP 3417	Diversity, ecology and conservation of the lichen biota of fragile forest ecosystem in central Western Ghats, Karnataka	SERB, New Delhi	PC: Dr. Sanjeeva Nayaka PI: Dr. Sumesh N Dudani	24 Months w.e.f. June 12, 2017
25.	GAP 3409	Technology development, management, and long-term monitoring of shifting cultivation and coal mining in north-eastern India	GB Pant Institute of Himalayan Environment and Development, Almora, Uttarakhand	PC: Prof. SK Barik PI: Dr. SK Tewari	20 Months w.e.f. Jul 15, 2017
26.	GAP 3416	Revisionary studies on lichen genera *Buellia sensu* lato and *Rinodina* (Caliciales) from India	SERB, New Delhi	PI: Dr. Sanjeeva Nayaka	36 Months w.e.f. September 12, 2017
27.	GAP 3418	Epigenetical effect of *Arabidopsis thaliana* of West Himalayan populations in response to elevated CO_2 for adaptive advantage	SERB, New Delhi	PI: Dr. Sribash Roy	36 Months w.e.f. September 28, 2017
28.	GAP 3422	Soil carbon sequestration in tropical deciduous forests of India and it's functional relationship with community structural variables.	DST, New Delhi	PC: Dr. SK Behera PI: Ms. Shruti Mishra	36 Months w.e.f. October 23, 2017
29.	GAP 3419	Mitigation of greenhouse gases in rice fields by using *Trichoderma* based biofertilizer	DST, New Delhi	PC: Dr. Aradhana Mishra PI: Mrs Afroj Ali	36 Months w.e.f. November 1, 2017
30.	GAP 3420	Monitoring and assessment of Arsenic pollution in Arsenic prone districts of Uttar Pradesh	Directorate of Agriculture, Govt. of UP	PI: Dr. Pankaj K Srivastava	36 Months w.e.f. November 17, 2017
31.	GAP 3421	Carrying out tree falling risk assessment study on 50 trees on pilot basis at GSPL Bongaigaon of Indian Oil Corporation Limited (IOCL), Eastern Region Pipelines (ERPL)	Indian Oil Corporation Limited, Kolkata	PI: Dr. SK Tewari	12 Months w.e.f. November 21, 2017
32.	GAP 3424	Identification of elite chemoytpe of *Plumbago zeylanica* Linn. collected from different phyto-geographical zones of India and evaluation of biological potential of elite germplasm	DST, New Delhi	PC: Dr. Sharad Srivastava PI: Mr. Pushpendra Kumar Shukla	36 Months w.e.f. December 5, 2017

33.	GAP 3425	Unraveling the role of plant growth promoting rhizobacteria-responsive microRNA(s) in Arabidopsis	INSA, New Delhi	PI: Dr. Charu Lata	36 Months w.e.f. December 22, 2017
34.	GAP 3433	Invasive alien plants in Himalayas: Status, ecological impact and management Sub-Project :"Distribution and population growth of invasive alien plants in Sikkim and Darjeeing Himalaya in different ecosysytems along the altitudinal gradient and their impact	GB Pant Institute of Himalayan Environment and Development, Almora, Uttarakhand	PI: Dr. LB Chaudhary	24 Months w.e.f. Jan 01, 2018
35.	GAP 3432	Evaluation of seasonal effect on anti-hypertensive indole alkaloid of *Rauvolfia* sp. from Nothern India and development and validation of physicochemical and molecular markers	UPCST, Lucknow	PC: Dr. S. Khatoon PI: Dr. Saba Irshad	36 Months w.e.f. March 13, 2018
36.	GAP 3428	Adaptation strategies of rice varieties of Indo-Gangetic Plains to climate change	DST, New Delhi	PI: Dr. Vivek Pandey	36 Months w.e.f. March 16, 2018
37.	GAP 3427	Identification of targets of the cotton GhNAC2 involved in root growth and abiotic stress tolerance	SERB, New Delhi	PI: Dr. VA Sane	36 Months w.e.f. March 17, 2018
38.	GAP 3430	A combining approach of GBS and ECOTILLING based GWAS study for expediting trait-associated genes /QTLs / molecular tags for thebaine content in Opium Poppy	SERB, New Delhi	PI: Dr. SN Jena	36 Months w.e.f. March 17, 2018
39.	GAP 3438	Bioresource and sustainable livelihoods in North East India: Component 3 & Sub-project 2 "Assess the economic value of bio-resources and their role in meeting the societal needs and sustainable development goals "	DBT, New Delhi	PC: Dr. KN Nair PI: Dr. CS Mohanty	36 Months w.e.f. March 17, 2018
40.	GAP 3434	To correlate the micro-structures of natural populations *Arabidopsis thaliana* along the altitudinal range with environmental conditions	DBT, New Delhi	PI: Dr. Sribash Roy	12 Months w.e.f. March 20, 2018
41.	GAP 3436	Contained field studies on distribution and abundance of whitefly larvae on transgenic cotton plants	DBT, New Delhi	PI: Dr. PC Verma	12 Months w.e.f. March 20, 2018
42.	GAP 3435	Genome characterization of Banana/Plantain genetic resources of North-eastern region and their utilization in multicentre planning for commercial improvement	DBT, New Delhi	PI: Dr. SN Jena	36 Months w.e.f. March 22, 2018
43.	GAP 3441	Biotechnological interventions through RNAi approach for management of banana bunchy top virus (BBTV) in Northeast region of India	DBT, New Delhi	PI: Dr. PK Trivedi	36 Months w.e.f. March 22, 2018
44.	GAP 3429	Remediation and reclamation of Hexachlorocyclohexane (HCH) dumpsite by using microbial bioremediation technology	DBT, New Delhi	PC: Dr. SK Barik PI: Dr. Pankaj K Srivastava	24 Months w.e.f. March 28, 2018
45.	GAP 3431	Bioresource and sustainable livelihoods in North East India: Component 2 & Sub-project 3 "Integrative taxonomic analysis for assessment of diversity and phylogenetic relationships among *Quercus* and *Citrus* from Northeast Region"	DBT, New Delhi	PC & PI: Dr. KN Nair	36 Months w.e.f. March 29, 2018

46.	GAP 3437	Bioresource and sustainable livelihoods in North East India: Component 1 & Sub-project 11 "Quantitative assessment and mapping of the diversity of non-flowering plants (Lichen, bryophytes, fungi, pteridophytes) of Northeast India"	DBT, New Delhi	PC: Dr. KN Nair PI: Dr. Sanjeeva Nayaka	36 Months w.e.f. March 29, 2018
47.	GAP 3439	Bioresource and sustainable livelihoods in North East India: Component 4 & Sub-project 1 "Product development and partner support for demonstration farming and value addition "	DBT, New Delhi	PC: Dr. KN Nair PI: BN Singh	36 Months w.e.f. March 29, 2018



Deputation of NBRI Scientists Abroad during 2017-18

S.N.	Scientist Name	Country Visited	Deputation Period	Purpose of Visit
1	Prof. SK Barik	Bangladesh Poribesh Andolon (BAPA), Dhaka, Bangladesh and Faculty of Biological Sciences Jahangirnagar University, Bangladesh	April 25-27, 2017	To participate and deliver a lecture in the workshop on "Methodology of River Basin, Cumulative Impact Assessment (CIA) and Carrying Capacity Assessment"
2	Dr. PK Trivedi	Botanical Institute and Cluster of Excellence on Plant Science, University of Cologne, Germany	May 15-28, 2017	To work on the joint research project entitled "Light dependent flavonol biosynthesis by MYB transcriptions factors: Identification of interacting Factors" between CSIR-NBRI and CEPLAS, University of Cologne, Germany
3	Dr. DK Upreti	MG Kholodny Institute of Botany of the National Academy of Sciences, Ukraine	June 15-20, 2017	To work on the Indo-Ukrainian project entitled "Phylogenetic Grouping of South Asian Lichen of the Teloschistaneae (Ascomycota) for Biotechnological Purposes" funded by DST, New Delhi within the framework of Ukrainian-Indian joining bilateral exchange programme
4	Dr. Charu Lata	University of Queensland, Brisbain, Australia	June 21- September 20, 2017	Indo-Australia Early & Mid Career Researcher Fellowship 2016-17 for carrying out work on the project entitled "Analysis of Heat Stress Response Genes in the Developing Wheat using IsoSeq Transcripts"
5	Dr. Sanjay Dwivedi	Deutsches Elektronen-Synchrotron (Desy), Hamburg, Germany	June 29-July 10, 2017	To carry out the experiment on DESY, Germany on the project proposal "Changes in metal (loid) compartmentation at the sub-cellular level induced by Arsenic toxicity
6	Dr. PK Singh	International Institute of Tropical Agriculture Office, Nairobi, Kenya	September 25-28, 2017	To discuss the future collaboration for Whitefly control in Cassava
7	Dr. TS Rana	Kuwait Institute for Scientific Centre (KISR), Kuwait	November 20-23, 2017	For participating in the International Symposium and Workshop on "Native Seeds in Restoration of Dry land Ecosystem"
8	Dr. PK Singh	Ronda/Malaga, Spain	November 26-29, 2017	For participation in the 3rd Annual Meeting of "African Cassava Whitefly: Outbreak and Sustainable Solutions"

Technology Transfer and Business Development, Patent and Training Cell

- Technology Transfer & Business Development (TTBD) division made efforts to take R&D to stakeholders. Major activities undertaken by the division are:
- Interaction with industries, agencies for increasing business opportunities for the Institute.
- Facilitating agreements (MoU, MoA, Secrecy Agreement, Technology Transfer Agreement) for smooth business and R&D 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/ knowhow 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.
- For igniting young minds of students of kendriya Vidyalaya (KV) organizes interaction with scientists, lab visits and lectures.
- Management of visits of students of various schools / colleges for dissemination of science.

MoAs/MoUs/Mta Signed

Sl. No.	Details	Client	Date
1.	An agreement signed for collaborative research for "molecular characterization and documentation of genetic diversity in selected native plants of Kuwait (Project -1) and Bioprospecting of native plants for bioactive compounds (Project – 2)	Kuwait Institute for Science Research (KISR) Shuwaith, Al-Jahidh street, P.O. Box 24885, 13109 Safat, Kuwait	April 01, 2017
2.	MoU for together work for research of new genes and markers suitable for improvement on cotton yield	Tierra Seed Science Pvt. Ltd., Hyderabad	April 17, 2017
3.	MoA for Project 'Revalidation of good Agricultural Practices (GAPs) to develop Agro-technology for the cultivation of medicinal plants'	National Medicinal Plants Board (NMPB), Ministry of AYUSH, New Delhi	April 24, 2017
4.	MoA for Project 'Molecular genetics of guar (*Cyamopsis tetragonoloba*) using SNP markes'	DBT, New Delhi	May 05, 2017
5.	Secrecy Agreement for Evaluation of Nutri-jam and Herbal Soft Drink	Aven Drinks, Volg Hotel Building, Arya Samaj Marg, Haldwani, Nainital	May 24, 2017
6.	MTA for procurement of plant material (*Viola pilosa*)	NBPGR (ICAR), New Delhi	May 24, 2017
7.	MoA for conduct R&D activities 'Standardization of agro-practices for cultivation of *Cannabis sativa*'	Govind Ballab Pant National Institute of Himalayan Environment and Sustainable Development (GBPNIHESD), Almora	May 30, 2017
8.	MoA for project 'Meta-genomics and transcriptomic studies on Termitomyces growing fungal comds of termites found in Assam for bioprospection'	DBT, New Delhi	May 30, 2017
9.	Secrecy Agreement for Evaluation of Herbal Sindoor stick and Herbal Hand Sanitizer	KTC PRODUCTS, Baddi, Himachal Pradesh	May 31, 2017
10.	MTA for procurement of 'Drought sensitive chickpea cultivar (ICC 1882)'	ICRISAT, HYDERABAD	June 08, 2017
11.	MTA for procurement of *Fusarium oxysporum* f.sp. ciceri race 2 material for research purpose	Indian Institute of Pulses Research (IIPR), Kanpur U.P.	July 17, 2017
12.	MoA for collaborative work on farm trials with rice cultivar	Nadia Zilla Farmers, A.T.C., Dakshinpara, Nadia, West Bengal	August 14, 2017
13.	MoA for collaborative work in the area of development of herbal formulations	AROGYADHAM, Deendayal Research Institute, Chitrakoot, Satna, MP	August 22, 2017
14.	For Research and Academic Activities	Dr. RML Avadh University, Faizabad	October 25, 2017
		DDU Gorakhpur University, Gorakhpur	November 06, 2017
15.	To Conduct Collaborative Activities to Establish and Promote a Mutually Beneficial Relationship	Agriculture Skill Council of India (ASCI), Gurugram, Haryana	November 10, 2017
16.	For Collaborative Work	Bio Resource Development Centre, Shillong (Meghalaya)	November 16, 2017
17.	For Procurement of Maize Seeds	ICAR-Vivekananda Parvatiya krishi Anusandhan Sansthan, Almora	November 23, 2017
18.	Evaluation of Herbal Soft Drink and Herbal Fermented Health Drink	M/s. Bitchem Asphalt Technologies Ltd., Guwahati, Assam	November 22, 2017
19.	For Procurement of Pure Line of Cotton var. Coker 312 and 310 seeds	ICAR-Central Institute for Cotton Research, Nagpur	December 08, 2017
20.	Microbial roles in yield management of scented rice of North – East India	DBT, New Delhi	December 26, 2017
21.	Lichenometry studies in IHR as part of NMSHE Task Force – IV	Wildlife Institute of India (WII), Dehradun	January 29, 2018
22.	Tissue culture and plant transformation	DBT, New Delhi	March 13, 2018
23.	Bioaccumulation and Bio-magnification study on flora and fauna of surrounding the ash filled south balanda mine void	NTPC limited, NTPC bhawan, Scope Complex, 7, Institutional area Lodi road, New Delhi – 110003 and Talcher Thermal Power station at Talcher site, Dist. Angul, Odisha	March 19, 2018
24.	Establishment of World Class Botanical Garden at Chandrapur	Governor and the State of Maharashtra, Chandrapur Distt. Chandrapur, Maharashtra	March 21, 2018
25.	A MoC (Cooperation) signed for "Setting up Thematic Environmental Information System"	Ministry of Environment, Forest & Climate Change, Govt. of India on	March 23, 2018

Central Instrumentation Facility of the Institute (CIF)

Technical Services provided and Achievements

Central Instrumentation Facility of the institute, maintaining all the equipments (GCMS, IRMS, TD-NMR, HPLC, HPTLC, LC/MS, GLC, AAS, Flash Chromatography, Microwave Digestion system, Stereo Microscope, Refractometer, Tintometer, and SCFE etc.) has provided analytical services to various industries/ organization/entrepreneurs/individuals (External samples) and various scientists/staff of the institute (Internal samples). The details of external and internal samples analyzed are given below:

Analytical testing services provided (1st April 2017 to 31st March 2018)	
No. of external samples analysed for industries/institutes/organization	**100**
Total revenue generated (**testing)**	**Rs. 2,42,880.00**
No. of internal samples analysed	**4755**
Participated in International and National PT/ILC programme	**2**
Entrepreneurs/ individuals benefited	**18**
Maintenance and repairing of instruments (1st April 2017 to 31st March 2018)	
Total number of job (internal equipments repairing) completed	**103**
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 2017 and the report suggested continuation of NABL-accreditation of the Institute up to October 2018. The NABL Certificate No. T-1381and the area of scope is Herbal drugs, Essential oils, Vegetable oils & Soil	

Plant and Plant Art Sales

A total revenue of Rs. 10, 47,230/- was generated from April 2017 to March 2018 from the sale of plants, seeds, dried flower, dehydrated artefacts etc., by sale section of Botanic Garden.

Exposition

CSIR-NBRI Exposition displays all recent scientific, research and developmental activities of the Institute. About three thousands visitors from different scientific and non- scientific organizations including common public, school children, college and university students, teachers, scientists, researchers, foresters, policymakers, planners, ITBP personals and other professionals from the country and abroad have visited the Exposition during this year. Some of the distinguished visitors like Dr. Amita Prasad, IAS, Additional Secretary, Ministry of Environment, Forest and Climate Change, Government of India, Mr. Anurag Srivastava, Indian Ambassador to Ethiopia, Dr. Deepak Pental, Ex-Vice Chancellor, Delhi University and Chairman of Research Council of CSIR-NBRI who, appreciated the Ethnobotanical Gallery and CSIR-NBRI Exposition of the Institute.

The Exposition was open on various open days like National Science day, National Technology day, World Environment Day, CSIR Foundation day, CSIR-NBRI Annual day and on other special occasions. The visitors were got acquainted and inspired with the research and developmental activities and programmes being carried out by the scientists of the Institute. To inspire and influence the visitors at the Institute, day-to-day thoughts and inspiring words of wisdom are regularly displayed at the reception of the Institute.

Environmental Information System (ENVIS) at National Botanical Research Institute (NBRI)

Activities done during 2017-18

- Four quarterly Newsletters entitled "आतंरिक्ष परिवेशी (इंडोर) प्रदूषण"; Lichens: Tool for assessing climate change and ambient air quality"; "Hyperaccumulator Plants"; and "Greenbelt to mitigate air pollution" have been published.
- A smart phone APP, "Green Planner" has been developed on iOS platform, now available in Tunes Store. This APP provides comprehensive database with illustrations of 70 air pollution- mitigant plants.
- Database of 34 different pollutants has been updated with respective numeric references and abstracts.
- Website of ENVIS-NBRI has regularly been updated.

Events Organized by ENVIS-NBRI

- **World Environment Day on 5th June 2017:** An Awareness Programme was organized on the World Environment Day on June 5th 2017 by ENVIS-NBRI on different sub-themes of Plants & Pollution using educational displays at CSIR-NBRI. About 100 students of educational institutions viz., Saarthak Foundation, Ehsaas Organization, Integral University, Amity University, Rani Laxmi Bai School, and City Montessori School of Lucknow participated in the programme.
- **Outreach Programme during the NBRI Flower Show:** During Rose and Gladiolus Flower Show of CSIR-NBRI on January 20-21, 2018, ENVIS-RP NBRI has displayed its quarterly newsletters, case studies, bibliography and 14 educational posters on different sub-themes of Plants & Pollution. A total of 250 visitors were imparted knowledge and their queries about mitigating the environmental pollution using plants were answered. Visitors appreciated the efforts of ENVIS RP-NBRI in developing the user-friendly Green Planner Android App.
- **International Day for Preservation of Ozone Layer:** An event was organized at University of Lucknow on 11th September 2017 on the occasion of the World Ozone Day awareness week (11-16 Sep. 2017). About 61 students and all the faculty members from the Departments of Botany, Plant Sciences, Environmental Sciences and Microbiology participated in the event. The programme started with the presentation on ENVIS RP-NBRI and ENVIS Programme of MoEF & CC, GoI.
- **Workshop at Loreto Convent Intermediate College, Lucknow:** A orientation workshop was organized by ENVIS RP-NBRI at Loreto Convent Intermediate College, Lucknow on 2nd August 2017 for the benefit of the students and faculty members. The programme covered presentation on the activities of ENVIS and ENVIS NBRI. A detailed overview of Green Planner Android App was also given. The ENVIS-NBRI coordinator made a presentation on "Vermicomposting" followed by hands-on demonstration of techniques for preparing vermicompost. Educational displays were explained to students by the team ENVIS-NBRI.

राजभाषा यूनिट

संस्थान में राजभाषा कार्यान्वयन समिति के अंतर्गत संस्थान के राजभाषा यूनिट द्वारा वर्ष 2017-18 के मध्य किये गए कार्यक्रम एवं गतिविधियाँ निम्नलिखित हैं

1. राजभाषा कार्यान्वयन समिति बैठक

राजभाषा विभाग, गृह मंत्रालय, भारत सरकार द्वारा जारी दिशा निर्देशों के अनुसार निर्धारित समय पर संस्थान की राजभाषा कार्यान्वयन समिति की चार तिमाही बैठकों का आयोजन किया गया।

2. हिंदी प्रयोग हेतु प्रयास

संस्थान में हिंदी के प्रगामी प्रयोग हेतु समय समय पर कार्यालय ज्ञापन एवं आदेश जारी किये गए। संस्थान के अधिकारियों एवं कर्मचारियों को हिंदी में कार्य करने हेतु प्रोत्साहित किया गया।

3. हिंदी कार्यशालाएं

वर्ष 2017-18 में कुल चार हिंदी कार्यशालाएं आयोजित करी गयी जिनका विवरण निम्नलिखित हैं

दिनांक 18.05.2017 को वित्तीय वर्ष 2017-18 की प्रथम हिन्दी कार्यशाला का आयोजन किया गया। इस अवसर पर डॉ. विजय नारायण तिवारी, वरिष्ठ हिन्दी अधिकारी सीएसआईआर-सी.डी.आर.आई., लखनऊ को मुख्य अतिथि के रूप में आमंत्रित किया गया जिन्होंने 'राजभाषा नीति तथा कम्प्यूटर पर हिन्दी में कार्य करने की तकनीक' विषयक व्याख्यान प्रस्तुत किया।

डॉ. विजय नारायण तिवारी व्याख्यान देते हुए

दिनांक 14.09.2017 को वित्तीय वर्ष 2017-18 की द्वितीय हिन्दी कार्यशाला का आयोजन किया गया। इस अवसर पर संस्थान के प्रधान वैज्ञानिक डॉ. संजीव कुमार ओझा जी ने 'हिन्दी का उद्भव एवं विकास' विषयक व्याख्यान प्रस्तुत किया।

द्वितीय हिन्दी कार्यशाला

दिनांक 27.12.2017 को वित्तीय वर्ष 2017-18 की तृतीय हिन्दी कार्यशाला का आयोजन किया गया। इस अवसर पर संस्थान के वरिष्ठ प्रधान वैज्ञानिक डॉ. आनन्द प्रकाश जी ने 'उत्तर प्रदेश की अधोपयोगी खाद्य वनस्पतियों की उपयोगिता' विषयक व्याख्यान प्रस्तुत किया।

दिनांक 28.03.2018 को वित्तीय वर्ष 2017-18 की चतुर्थ हिन्दी कार्यशाला का आयोजन किया गया। इस अवसर पर प्रो. ए.के.त्रिपाठी, विभागाध्यक्ष, हिमैटोलॉजी विभाग, किंग जार्ज चिकित्सा विश्वविद्यालय, लखनऊ को मुख्य अतिथि के रूप में आमंत्रित किया गया। जिन्होंने 'एनीमिया एक चुनौती' विषयक व्याख्यान प्रस्तुत किया।

प्रो. ए.के.त्रिपाठी व्याख्यान देते हुए

4. राजभाषा पत्रिका विज्ञानवाणी का संपादन

संस्थान से प्रकाशित होने वाली राजभाषा गृह पत्रिका 'विज्ञानवाणी' के 23वें अंक का सफल सम्पादन किया गया। जिसमें संस्थान में होने वाले क्रिया कलापों से सम्बंधित वैज्ञानिक, तकनीकी तथा जनप्रिय लेखों को प्रकाशित किया गया। इस अंक में कुल 28 लेख प्रकाशित हुए जिनमे वैज्ञानिक लेखों के अतिरिक्त कुछ सामाजिक जानकारियों पर आधारित लेख एवं गजले व कवितायें शामिल हैं।

5. हिंदी पखवाड़े का आयोजन

दिनांक 1-14 सितम्बर 2017 के अंतर्गत हिन्दी पखवाड़ा का सफल आयोजन किया गया। जिसमें विभिन्न प्रतियोगिताओं द्वारा हिन्दी में दक्षता बढ़ाने का प्रयास किया गया। संस्थान के पुस्तकालय में उपलब्ध हिन्दी पुस्तकों की प्रदर्शनी का उदघाटन संस्थान के निदशक प्रो.एस.के. बारिक द्वारा किया गया। जिसमें संस्थान के अधिकारी व कर्मचारी उपस्थित हुए। इसके अतिरिक्त हिन्दी में कार्य करने वाले कर्मचारियों को हिन्दी में उत्तरोत्तर और वृद्धि लाने हेतु हिन्दी प्रोत्साहन पुरस्कार योजना के अंतर्गत पुरस्ेत किया गया। पखवाड़े के उद्घाटन समारोह में प्रो. सूर्यप्रसाद दीक्षित, प्रोफेसर तथा पूर्व अध्यक्ष, हिन्दी विभाग, लखनऊ विश्वविद्यालय को मुख्य अतिथि के रूप में आमंत्रित किया गया जिन्होंने हिन्दी के प्रयोग संबंधी विस्तृत व्याख्यान प्रस्तुत किया।




हिंदी पखवाड़े की कुछ झलकियाँ

EVENTS

Sl. No.	Date	Salient Feature
1.	April 5-7, 2017	Bonsai Training Programme for General Public. A total of 39 candidates participated in the programme.
2.	May 11, 2017	CSIR-NBRI celebrated National Technology Day on May 11, 2017. Dr. Madhu Dikshit, Director, CSIR-CDRI, Lucknow was the Chief Guest and she delivered the Technology Day Lecture on 'Phytochemical Drug Discovery and Development in India'. On this occasion, an alcohol free Herbal Hand Sanitizer developed by CSIR-NBRI was launched and the know-how technology for Herbal Sindoor Stick was also transferred to M/s Vedic Biocare Pvt. Ltd., Lucknow, by the Chief Guest in the presence of Director, CSIR-NBRI.
3.	17 मई, 2017	दिनांक 17.05.2017 को वित्तीय वर्ष 2017–18 की प्रथम हिन्दी कार्यशाला का आयोजन किया गया। इस अवसर पर डॉ. विजय नारायण तिवारी, वरिष्ठ हिन्दी अधिकारी सीएसआईआर–सी.डी.आर.आई., लखनऊ को मुख्य अतिथि के रूप में आमंत्रित किया गया जिन्होंने 'राजभाषा नीति तथा कम्प्यूटर पर हिन्दी में कार्य करने की तकनीक' विषयक व्याख्यान प्रस्तुत किया।
4.	May 22 – June 23, 2017	One Month Training programme on Gardening for Indo-Tibetan Border Police Staff.
5.	May 22 – 24, 2017	CSIR-NBRI organized a three-day training programme on 'Aloe species cultivation and its product processing for farmers and entrepreneurs' during May 22-24, 2017. A total of 26 farmers from different states and various districts of Uttar Pradesh, participated the training programme.
6.	June 5, 2017	CSIR-NBRI, Lucknow celebrated World Environment Day on June 05, 2017. Dr. Dinesh Sharma, Hon'ble Deputy Chief Minister, UP and Dr. PK Seth, Ex-Director, CSIR-IITR and Ex-CEO, Biotech Park, Lucknow, was the Chief Guest and Guest of Honour of the celebration, respectively.
7.	June 14-16, 2017	A three day Scientist Student Connect Programme: Jigyasa 2017 was organized during June 14-16, 2017. A total of 65 students along with 10 teachers from four Kendriya Vidyalayas of Lucknow participated in the programme.
8.	June 21, 2017	CSIR-NBRI, Lucknow, in collaboration with Uttar Pradesh Government, organized a Yoga Session to commemorate the 3rd International Yoga Divas, on June 21, 2017. A large number of participants including regular morning walkers, scientists, students and staff members participated actively in the yoga session.
9.	July 17, 2017	CSIR-NBRI organized a tree plantation program on July 17, 2017. About 100 tree species were planted in the Botanic Garden's Arboretum. Padma Shri Dr. Nitya Anand, Former Director, CSIR-CDRI, initiated the plantation drive by planting a tree sapling.
10.	August 15, 2017	**INDEPENDENCE DAY**
11.	August 22-24, 2017	Training programme on Home Gardening for General Public.
12.	August 29 – September 01, 2017	One Month Training programme on Gardening for CPWD Horticulture Officers. Sixteen candidates participated in the training.
13.	सितंबर 1–14, 2017	दिनांक 1–14 सितम्बर 2017 के अंतर्गत हिन्दी पखवाड़ा का सफल आयोजन किया गया। जिसमें विभिन्न प्रतियोगिताओं द्वारा हिन्दी में दक्षता बढ़ाने का प्रयास किया गया। संस्थान के पुस्तकालय में उपलब्ध हिन्दी पुस्तकों की प्रदर्शनी का उदघाटन संस्थान के निदशक प्रो.एस.के. बारिक द्वारा किया गया। जिसमें संस्थान के अधिकारी व कर्मचारी उपस्थित हुए। इसके अतिरिक्त हिन्दी में कार्य करने वाले कर्मचारियों को हिन्दी में उत्तरोत्तर और वृद्धि लाने हेतु हिन्दी प्रोत्साहन पुरस्कार योजना के अंतर्गत पुरस्कृत किया गया। पखवाड़े के उद्घाटन समारोह में प्रो. सूर्यप्रसाद दीक्षित, प्रोफेसर तथा पूर्व अध्यक्ष, हिन्दी विभाग, लखनऊ विश्वविद्यालय को मुख्य अतिथि के रूप में आमंत्रित किया गया जिन्होंने हिन्दी के प्रयोग संबंधी विस्तृत व्याख्यान प्रस्तुत किया।
14.	September 5-7, 2017	A CSIR Platinum Jubilee Techno fest under Platinum Jubilee Celebration of the Council of Scientific and Industrial Research (CSIR) was organized jointly by CSIR-NBRI and CSIR-IITR at CSIR-IITR, Lucknow during 5-7 September 2017. The three-day exhibition showcased CSIR's contribution in areas of Aerospace and Strategic sector, Agriculture and Floriculture, Chemical and Petrochemical, Energy, Ecology and Environment, Food and Nutrition, Generics and Healthcare, Materials/Minerals/Mining, etc.
15.	14 सितम्बर, 2017	दिनांक 14.09.2017 को वित्तीय वर्ष 2017–18 की द्वितीय हिन्दी कार्यशाला का आयोजन किया गया। इस अवसर पर संस्थान के प्रधान वैज्ञानिक डॉ. संजीव कुमार ओझा जी ने 'हिन्दी का उद्भव एवं विकास' विषयक व्याख्यान प्रस्तुत किया।

16.	September 26, 2017	The CSIR-NBRI celebrated the 75th Foundation Day of Council of Scientific & Industrial Research, New Delhi on September 26, 2017 Mr. G Pattanaik, Chairman, Uttar Pradesh Jal Nigam, Lucknow, was the Chief Guest of the function. Mr. Pattanaik, while addressing the audience congratulated the staff on this occasion. He said "CSIR is not only an institute but also an organization to which the nation looks upon as it has a long historical connection with the development of the nation".
17.	October 5, 2017	First SA Ranade Memorial Lecture 2017 Dr. Rajeev Varshney, Research Programme Director, Genetic Gains, ICRISAT, Hyderabad was the chief guest and delivered the lecture on '4G in Crop Breeding for Enhancing Precision, Efficiency, and Effectiveness'.
18.	October 25, 2017	CSIR- National Botanical Research Institute, Lucknow celebrated its 64th Annual Day on October 25, 2017. Prof. LMS Palni, Vice-Chancellor, Graphic Era University, Dehradun, was the Chief Guest, and Prof Manoj Dixit, Vice-Chancellor, Dr. RML Avadh University, Faizabad and Prof. PK Seth, Former CEO, Biotech Park, Lucknow, were the Guest of Honours. On this occasion, the dignitaries released the institute's Annual Report. Prof. SK Barik, Director, CSIR-NBRI presented the annual progress made by the institute during 2016-17. On this occasion, the Know-How Technology of three recently developed products by the institute were transferred to M/s Herbal Canada and Ayurveda Research Centre, Noida. The products are Nutri Jam – An Herbal Jam rich in nutrition, Anti-Cough Herbal Formulation and Polyherbal Dental Cream (Jointly Developed by CSIR-NBRI and CSIR-CIMAP). A Memorandum of Understanding between CSIR-NBRI and Dr. RML Avadh University, Faizabad was also exchanged for Academic and R&D coordination/activities. In his address Prof. Manoj Dixit, VC, Dr. RML Avadh University, Faizabad mentioned the need for strategic plan for better coordination between the university and institutes. Prof. Palni delivered the annual day lecture on "Biodiversity under Global Change Scenerio Focussing on Evidence from Himalaya". Prof. P.K. Seth complements the Team CSIR-NBRI for the outstanding achievement of the Institute in high end research and technology development.
19.	October 31, 2017	**National Unity Day**
20.	November 06 – December 04, 2017	Training Programme on Garden Management.
21.	November 13-17, 2017	CSIR-NBRI organized a CSIR-HRDC Leadership Development Programme during November 13 – 17, 2017.
22.	December 09-10, 2017	CSIR-NBRI organized its two-day Annual Chrysanthemum & Coleus – 2017 show at the Central Lawn, Botanic Garden during December 09-10, 2017. Mr. Brajesh Pathak, Hon'ble Minister, Law and Justice Department, Department of Additional Resources of Energy and Political Pension, Government of UP, was the Chief Guest and inaugurated the show on December 09, 2017. On this occasion, Mr. Brajesh Pathak, Hon'ble Minister, released a new variety of Chrysanthemum, 'NBRI Him-Jyoti' developed by CSIR-NBRI. It is a new dwarf floriferous chrysanthemum variety, with cream-colored flowers. A total of 109 exhibitors with 996 exhibits participated in the flower show. A one-day awareness programme on Protection of Plant Varieties and Farmers' Rights was also organized by CSIR-NBRI jointly with Protection of Plant Varieties and Farmers' Rights Authority (PPV&FRA), New Delhi, on the sidelines of the flower show.
23.	December 14, 2017	CSIR-NBRI organized a one-day training programme on Betelvine Cultivation on December 14, 2017 at its Distant Research Centre, Banthra. About 50 farmers from Barabanki, Lucknow, Sitapur, Raebareli and Unnao districts participated in the programme.
24.	दिसम्बर 27, 2018	दिनांक 27.12.2017 को वित्तीय वर्ष 2017–18 की तृतीय हिन्दी कार्यशाला का आयोजन किया गया। इस अवसर पर संस्थान के वरिष्ठ प्रधान वैज्ञानिक डॉ. आनन्द प्रकाश जी ने 'उत्तर प्रदेश की अधोपयोगी खाद्य वनस्पतियों की उपयोगिता' विषयक व्याख्यान प्रस्तुत किया।

25.	December 30, 2017	Lecture on Legacy and Life of Dr. APJ Abdul Kalam by Prof. Arun Tiwari, Director, Astra Microwave Products Limited, Hyderabad, Ex-Chief Scientist, Defence Research and Development Organization, New Delhi
26.	January 05-06, 2018	CSIR-NBRI organized two days Faculty Training programme during January 05-06, 2018 for science teachers/ lecturers from different schools/colleges. The objective of the programme was to create awareness towards new technologies of science and motivate teaching faculty. Dr. Sunil Bajpai, Director, BSIP, Lucknow was the Chief Guest and inaugurated the programme. Dr. CM Nautiyal, former senior scientist, BSIP, Lucknow, delivered a lecture on "Evolutionary Development of Plants".
27.	January 20-21, 2018	A two-day Rose and Gladiolus Show was organized during January 20-21, 2018 in the central lawn of the Institute. Dr. Rupak De, Principal Chief Conservator of Forest and Head of Forest Force, UP Forest Department, Lucknow, inaugurated the show on January 20, 2018. The Chief Guest also inaugurated a newly developed 'Spice and Herb Garden' at the botanic garden. This special garden is meant for conservation of two economically important plant groups' viz. spice and medicinal plants. On this occasion, Herbal Products (Herbal toothpaste and Nutri-Jam) developed by CSIR-NBRI, were commercially launched by M/s Herbal Canada, Noida. The Herbal Toothpaste is now available in the market with the trade name 'Natural Toothpaste' and Nutri-Jam with the trade name 'Mix Fruit-Jam'.
28.	January 23-February 21, 2018	Training Programme on Garden Management
29.	जनवरी 25, 2018	राष्ट्रीय मतदाता दिवस
30.	January 27-28, 2018	National Conference on Current Development and Next Generation Lichenology held at CSIR-NBRI during January 27-28, 2018
31.	January 26, 2017	**REPUBLIC DAY**
32.	February 19, 2018	CSIR-National Botanical Research Institute, Lucknow remembered it's Founder Padma Bhushan Professor Kailash Nath Kaul by organizing a special Memorial Lecture on February 19, 2018. On this occasion Dr. AK Koul, Former Professor, Jammu University, Jammu was the Chief Guest of the function. Prof. AK Koul delivered the Memorial Lecture on 'Revisiting the Failed Experiments of Evolution'.
33.	February 28, 2017	CSIR-NBRI celebrated National Science Day on February 28, 2018. The theme for this year's science day was 'Science and Technology for a Sustainable Future'. On this occasion, Prof. Surya Kant Tripathi, Head, Department of Respiratory Medicine, King George's Medical University, Lucknow, was the Chief Guest and delivered the National Science Day Lecture on 'Tobacco: A Threat to Human Health'.
34.	मार्च 28, 2018	सीएसआईआर–एनबीआरआई द्वारा दिनांक 28 मार्च, 2018 को एक हिंदी कार्यशाला का आयोजन किया गया। इस कार्यशाला में किंग जॉर्ज चिकित्सा विश्वविद्यालय, लखनऊ के हिमैटोलॉजी विभाग के विभागाध्यक्ष प्रो. ए के त्रिपाठी मुख्य अतिथि के रूप में उपस्थित रहे। प्रो. त्रिपाठी ने 'एनीमियारू एक चुनौती' विषय पर अपना व्याख्यान प्रस्तुत किया।

Glimpses of CSIR-NBRI Events


Bonsai Training Programme




National Technology Day Celebration


हिन्दी कार्यशाला का आयोजन

Glimpses of CSIR-NBRI Events

Training programme on Gardening for ITBP Staff

World Environment Day Celebration

Glimpses of CSIR-NBRI Events

Scientist Student Connect Programme: Jigyasa 2017

Glimpses of CSIR-NBRI Events




3rd International Yoga Divas




Plantation Drive

Glimpses of CSIR-NBRI Events

Independence Day

Training programme on Home Gardening

Glimpses of CSIR-NBRI Events

हिन्दी पखवाड़ा का आयोजन

CSIR Platinum Jubilee Techno fest

Glimpses of CSIR-NBRI Events

75th Foundation Day of Council of Scientific & Industrial Research, New Delhi

Glimpses of CSIR-NBRI Events

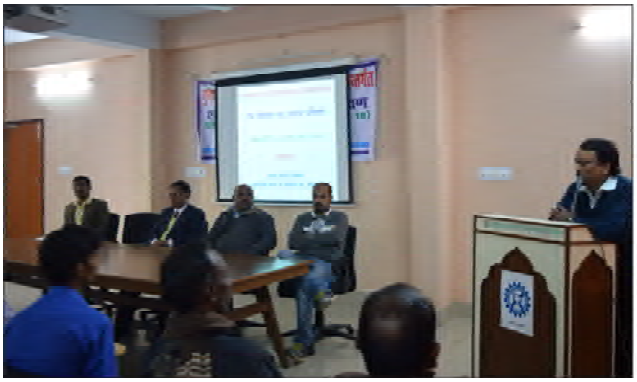
64th Annual Day Celebration of CSIR-NBRI

CSIR-HRDC Leadership Development Programme

Glimpses of CSIR-NBRI Events

Annual Chrysanthemum & Coleus – 2017 show

Glimpses of CSIR-NBRI Events




Training Programme on Betelvine Cultivation

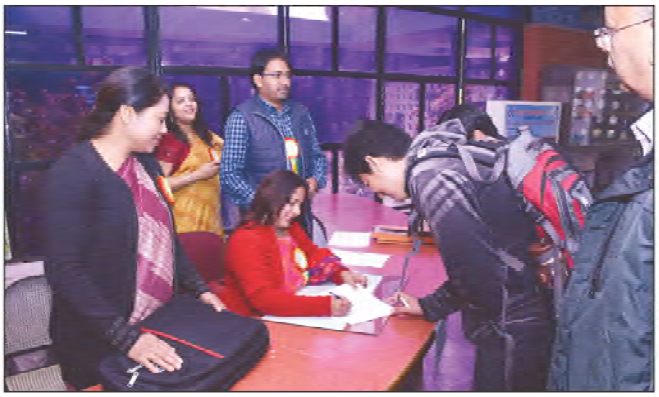


Two days Faculty Training programme

Glimpses of CSIR-NBRI Events

Two-day Rose and Gladiolus Show

Glimpses of CSIR-NBRI Events



National Conference on Current Development and Next Generation Lichenology

Glimpses of CSIR-NBRI Events

प्रो. के एन कॉल स्मृति व्याख्यान - २०१८

National Science Day

Glimpses of CSIR-NBRI Events

हिंदी कार्यशाला का आयोजन

ACADEMY OF SCIENTIFIC AND INNOVATIVE RESEARCH (AcSIR)

Coordinator: Dr. Debasis Chakrabarty

The **Academy of Scientific and Innovative Research** or **AcSIR** is an Indian institute of national importance, currently head quartered in CSIR Campus, Taramani, Chennai. The Academy was established for the purpose of granting doctoral and post-doctoral degrees, through a centralized institution to manage research and development in CSIR laboratories. It was established in 2010 (Government of India resolution of June 17, 2010 and the Academy of Scientific and Innovative Research Act, 2011 notified on April 3, 2012), as an 'Institution of National Importance', with an aim of furtherance of advancement of learning and research in the field of Science & Technology and their interfaces in association with Council of Scientific and Industrial Research (CSIR), India.

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.

National Research Professor Prof. RA Mashelkar took charge as the first Chairperson of AcSIR, from Prof. SK Brahmachari (former Acting Chairperson of interim AcSIR) and Director General, CSIR. The Academy has received recognition from Department of Scientific and Industrial Research (DSIR), Ministry of Science & Technology, as a Scientific and Industrial Research Organization (SIRO).

Number of students enrolled for Ph.D. until 31 March 2018	**95**
Ph.Ds. awarded during 2017-18	**17**
Ph.D. theses submitted during 2017-18	**07**

Courses offered at AcSIR-NBRI

S.No	Subject	Code	Status
1.	Computation/Bioinformatics	1-002	Compulsory
2.	Basic Chemistry	1-003	Compulsory
3.	Bio-techniques and Instrumentation	2-001	Compulsory
4.	Plant Microbe Interaction	2-009	optional
5.	Cell Signaling	2-012	optional
6.	Molecular Breeding of Plants	2-021	optional
7.	Biodiversity	2-025	optional
8.	Environmental Biochemistry and Biotechnology	3-488	optional
9.	Phylogenomics	3-493	optional
10.	Taxonomy and speciation	3-489	optional
11.	Development biology- plants	2-016	optional
12.	Genomics: Information flow in Biological System	2-005	optional
13.	Plant Environment Interaction	2-010	optional
14.	Epigenetics and Chromatin Organization	2-017	optional
15.	Climate change and Plants	3-486	optional
16.	Cell and Tissue Engineering	3-003	optional
17.	Research Methodology, Communication /ethics/safety	1-004	Compulsory
18.	Biostatistics	1-001	Compulsory
19.	Seminar course	3-001	Compulsory
20.	Cell Signaling	2-012	optional
21.	Biology of Inheritance	602	optional
22.	Reproductive Biology	707	optional
23.	Plant Morphogenesis & Regeneration	611	optional
24.	Bioremediation	704	optional

RESEARCH COUNCIL (As on 31.03.2018)

Dr. Deepak Pental INSA Senior Scientist, Centre for Genetic Manipulation Crop Plants (CGMCP), Delhi University, South Campus, New Delhi	Chairman	**Dr. RK Kohli** Vice-Chancellor, Central University of Punjab, Punjab	Member
Prof. SR Yadav Department of Botany Shivaji University, Kolhapur	Member	**Dr. Ram A. Vishwakarma** Director, CSIR-Indian Institute of Integrative Medicine, Jammu	Member
Shri Anand Chordia Director (Technical), M/s Pravin Masalewale, Pune	Member	**Dr. Ram Rajasekharan** Director CSIR-Central Food Technological Research Institute, Mysore	Member
Dr. Anil Prakash Joshi Founder, Himalayan Environmental Studies and Conservation Organization (Hesco), Dehradun	Member	**DG, CSIR or his nominee**	Member
Dr. Shree Kumar Apte JC bose National Fellow, DST Emritus Professor, HBNI Raja Rammana Fellow, DAE Room 1-156-H, Modular Labs Bhabha Atomic Research Centre, Mumbai	Member	**Prof. SK Barik** Director CSIR-National Botanical Research Institute, Rana Pratap Marg, Lucknow	Member
Prof. R Uma Shaanker Department of Crop Physiology, University of Agricultural Sciences, GKVK, Bellary Road, Bengaluru	Member	**Dr. SK Tewari** Senior Principal Scientist CSIR-National Botanical Research Institute Rana Pratap Marg, Lucknow	Member-Secretary

MANAGEMENT COUNCIL (As on 31.03.2018)

Prof. SK Barik Director CSIR-National Botanical Research Institute **LUCKNOW - 226 001**	Chairman
Dr. TS Rana Senior Principal Scientist CSIR-National Botanical Research Institute **Lucknow - 226 001**	Member
Dr. VA Sane Principal Scienist CSIR-National Botanical Research Institute **Lucknow - 226 001**	Member
Dr. MH Asif Senior Scientist CSIR-National Botanical Research Institute **Lucknow - 226 001**	Member
Dr. RC Nainwal Scientist CSIR-National Botanical Research Institute **Lucknow - 226 001**	Member
Mr. Lalit K Srivastava Executive Engineer CSIR-National Botanical Research Institute **Lucknow - 226 001**	Member
Dr. AK Tripathi Director CSIR-Central Institute of Medicinal and Aromatic Plants **Lucknow – 226 015**	Member
Dr. AK Gauniyal Senior Principal Scientist CSIR-National Botanical Research Institute **Lucknow - 226 001**	Member
Mr. Sanjeev Shekhar Finance & Accounts Officer CSIR-National Botanical Research Institute **Lucknow - 226 001**	Member
Mr. Mukund Sahai Controller of Administration CSIR-National Botanical Research Institute **Lucknow - 226 001**	Member Secretary

EXPENDITURES AND EARNINGS 2017-18 (As on 31.03.2018)

I. EXPENDITURE	Figure in Lakhs of Rupees
A. Revenue	
1. Salary & Sal. Linked Allowances	3251.380
2. Other Allowances	
a. Re-imburs. of Med.Exp./CGHS/Med.charges	79.743
b. Overtime Allowance	
c. Honorarium	1.000
d. Leave Travel Concession	19.425
e. T.A. (India)	15.000
f. T.A. (Foreign)	
g. Professional Update Allowance	115.168
h. Total Other Allowances (a to g)	106.209
3. Total Salaries (1+2h)	**3366.548**
4. P-04 Contingencies	938.000
5. P-05 H.R.D.	
6. P-06 Lab. Maintenance	365.000
7. P-701 Staff Qrs. Maintenance	86.000
8. P07 Chemical/Consum.& Other Res.Exp.	449.000
9. Total Revenue (3 to 8)	**5204.548**
B. Capital	
a) P-50 Land Cost	
a) P-50 Land Cost	
b) (i) P-50 Works & Services/Elec. Installations (Lumpsum)	93.000
b) (ii) P-50 Works & Services/Elec. Installations (Other)	
c) P-50 App. & Equip./Computer Equipments	613.398
d) P-50 Workshop Machinery	
e) P-50 Office Equipments	
f) P-50 Furniture & Fittings	2.847
g) P-50 Library (Books/ Journals/ e-Journal)	71.566
h) P-50 Model & Exhibits	
i) P-50 Vehicles	
j) P-50 Tools & Plants	
k) P-50 Software development/procurement/LAN/WAN	
l) P-26 -ICT	
m) (i) P-702 Staff Qrs.(Construction) (Lumpsum)	25.982
m) (ii) P-702 Staff Qrs.(Construction) (Other)	
Total Capital (a to m)	**806.793**
Total A+B	**6011.341**

C. Special Proj. SIP/NWP/FAC/IAP/RSP/HCP/12th Plan Proj.	
1. Revenue	
(i) T. A. (India)	4.158
(ii) T.A. (Foreign)	
(iii) Contingencies	2.918
(iv) Maintenance	2.000
(v) Chemical, Consum.& Other Res.Exp.	70.509
Total Rev.(C1)	**79.585**
2. Capital	
(i) Work's & Services	10.000
(ii) Appartus & Equipment	
(iii) Other Capitals	
Total Capital(C2)	**10.000**
C. Total allocation SIP/NWP/FAC/IAP/RSP/HCP/12th Plan (C1+C2)	**89.585**
Total National Labs. (A+B+C)	**6100.926**
D. CENTRAL ADMINISTRATION	
P-804 Pension & Other retirement benefits	3466.300
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	3.284
(ii) House Building Advance	
(iii) Others	
Total Central Admin.	**3469.584**

II. Earnings	
RECEIPTS	
R04 DONATION	
R05 CONTRIBUTION	
R06 MISC RECEIPTS	166.763
R906 RECOV. OF ADV.	3.450
TOTAL R06+R906	**170.213**
R071 LAB RESERVE	
a) Royality Premia	
b) Testing & Analytical Charges	2.766
c) Other Technical Service	
d) Job Work	32.194
e) Rest of R 071 heads	55.569
Total Lab Reserve(R-071)	**90.529**
R909 EXTERNAL CASH FLOW	
a) Govt deptt./PSU's	1874.845
b) Private agencies	2.119
c) Foreign govt/agencies	6.503
TOTAL ECF (a+b+c)	**1883.467**
Royalty & Premia for distribution (R907)	**31.743**

PERSONNEL (As on 31.03.18)

Director
SK Barik

Chief Scientist
RS Katiyar

Sr. Principal Scientists
T Husain
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
Samir V Sawant
A P Sane

Principal Scientists
Talewar Singh
Pratibha Misra
Vidhu A Sane
Alok Lehri
ChV Rao
Sayyada Khatoon
P K Singh
Mahesh Pal
Sharad K Srivastava
Sanjeeva Nayaka
Ashish K Asthana
S K Ojha
O P Sidhu
Indraneel Sanyal
Subha Rastogi

Senior Scientists
Arvind Jain
Vivek Srivastava
C S Mohanty
H K Yadav
Mehar H Asif
Debasis Chakrabarty
Shekhar Mallick
Pankaj K Srivastava
S 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
RC Nainwal
Brahmanand Singh
Manoj Kumar
V V Wagh
Charu Lata

Pr. Technical Officers
Yogendra Nath
M L Kain
V D Tripathi

Sr. Tech. Officers (3)
A C Little
R K Tripathi
D K Purshottam
Alok Kumar
Shankar Verma

Sr. Tech. Officers (2)
Lalit 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
SK Behera
Vinay Sahu
Anil Kumar
MK Shukla
Kiran Toppo
MM Pandey
Surjit Kumar

Technical Officers
Swati Sharma
Leena Wahi Gupta
SK Sharma
KN Maurya
Babita Kumari
GG Sinam
Sumit Yadav
KK Rawat
Somanath Swain
Satish Kumar
Prashant Srivastava
Jai Chand

Technical Assistants
Shweta Singh
Rameshwar Prasad
Rekha Kannaujia
Shashank K Mishra
Komal K Ingle
Bharat Lal Meena
Vivek Kumar Gupta
RR Rastogi
Devranjan
Vandana Tiwari
MG Prasad

Administration
Mukund Sahai, CoA
Rajhans Gautam, CoF&A
Sanjeev Shekhar, F&AO
Dinesh Kumar, F&AO
Dinesh Kumar, SPO
RS Chaudhary, SPO
Prasoon Misra, SO
Ram Badal, SO
Sachin Mehrotra, SO
RK Verma, SO
SK Singh, SO
Prabha Tirkey, SO
BP Pande, PS
Bijendra Singh, Hindi Officer
SK Pandey, Security Officer

NOTES

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