

वार्षिक प्रतिवेदन ANNUAL REPORT

2020-2021



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

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Front Cover :

1. Inauguration of 'Advanced Virology Laboratory' for Covid-19 testing by Mr. RK Tiwari, Chief Secretary, Government of UP & Prof. MLB Bhatt, VC, KGMU, Lucknow
2. Grain Amaranth Accession 'IC42334'
3. Herbal products developed by CSIR-NBRI (UR05 & Inhale Easy)
4. Probe distribution of '*AtHMGB15*' (*Arabidopsis* HMG-box protein) with NGS plot & Circos plot
5. A *Cannabis* breeding line selected for high THC content.
6. Sanitizers developed by CSIR-NBRI
7. Leaves of *Leucaena leucocephala* showing injury symptoms after 24 months of continual exposure of eO₃.
8. *Henckelia umbellata* Karthraj & K. Narayanan, a new species described from India
9. Kamal (*Nelumbo nucifera*) flower
10. *Cycas divyadarshini* Khurajam & Rita Singh, a new species of *Cycas* discovered from North-East India

वार्षिक प्रतिवेदन Annual Report

2020-2021

With best compliments from
Director
CSIR-NBRI, Lucknow

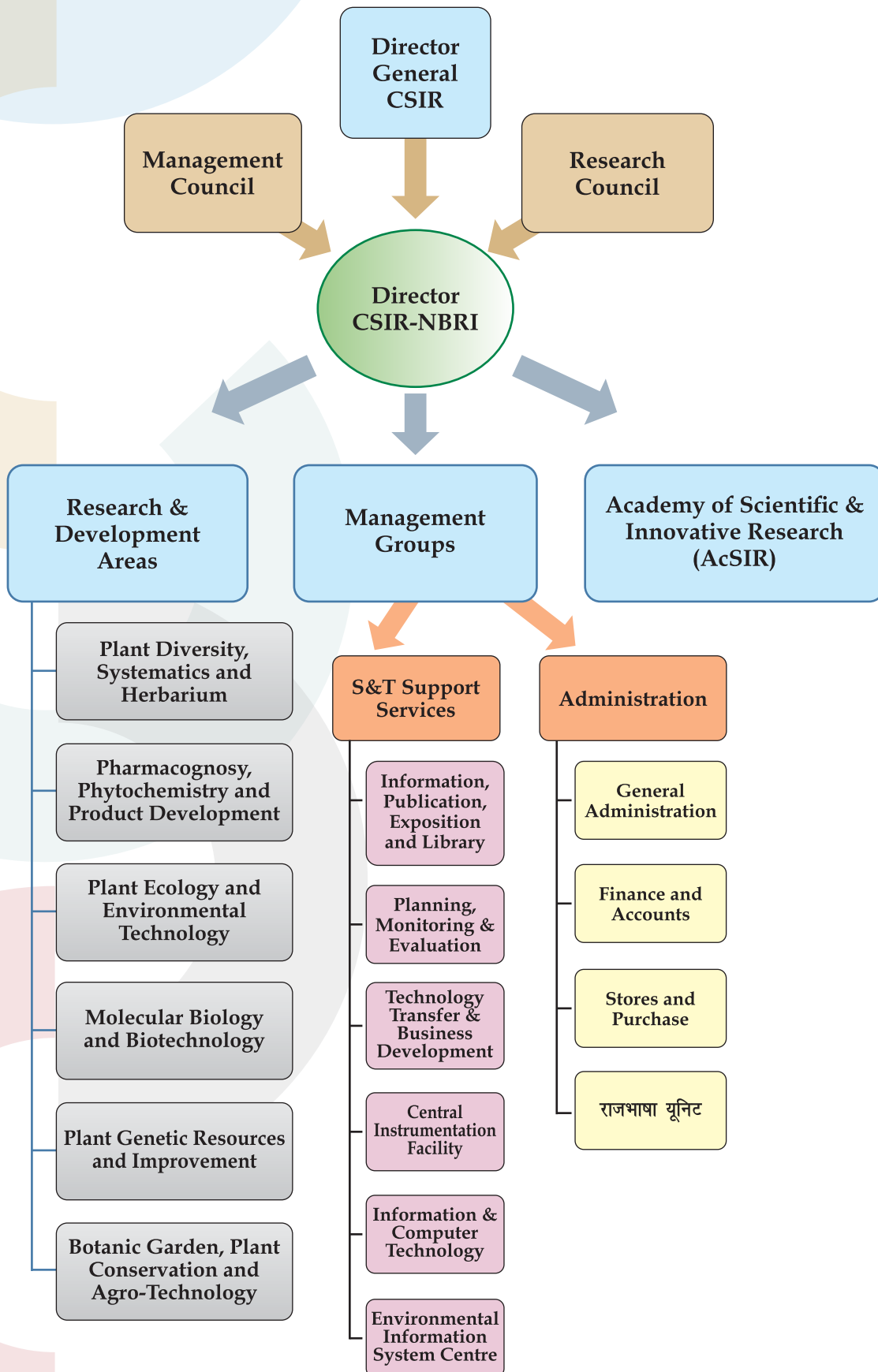


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Organizational Set-Up



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Annual Progress At A Glance

Publications

SCI Journals	157
Average IF Per Paper	3.562
Total IF Per Scientist	9.582



Patents Granted

National	03
International	01



Technologies Transferred

- Alcohol based Herbal Hand Sanitizer
- Floor Mop
- Herbal formulation useful in Urolithiasis
- Traditional Kadha
- Mask Stress Reducer



HRD

Ph.D Awarded/Submitted	17/13
Training Programmes Organized	19
Skill Development Programmes	05
No. of Individuals Trained	1627
PG Students Trained	42



Extra Budgetary Resources (Rupees in lakh)

Total ECF	2425.015
EBR	3540.201



Plant Inventory

New Species Discovered	09
New Geographical Records to India	26



Projects Undertaken

New Projects Initiated	52
Projects Under Implementation	132



Staff Strength

Group IV	57
Group III	46
Group II	29
Group I	16
Administration	63
Research Scholars	355





CSIR-NBRI INITIATIVES FOR COVID-19 PANDEMIC



COVID19 affected the globe. To combat the Covid19 pandemic CSIR-National Botanical Research Institute, Lucknow took several initiatives and worked on the following verticals:



Health Care Products



Covid19 Testing Facility

Health Care Products

- Under the CSIR social responsibility program, CSIR-NBRI developed a range of low cost hand sanitizers which are easily manufactured at small scales. NBRI developed both alcohol free and alcohol based herbal hand sanitizers. Over 1200 liters of hand sanitizers were distributed to the frontline warriors across Lucknow during the first and second waves.
- CSIR-NBRI also developed an innovative herbal product, 'Mask Stress Reducer: NITYA', which reduces breathing discomforts (congestion, excessive humidification of the nostrils, dizziness, etc.) due to long hours of wearing face masks. NITYA is purely an herbal product prepared by blending three essential oils and base oil, known traditionally.



Herbal Hand Sanitizers



Mask Stress Reducer

Technologies of both the products were transferred to various startups and health companies for marketing.

Covid19 Testing Facility

Seeing the demand for rapid testing, CSIR-NBRI despite being plant based Institute, established a BSL3 level facility (Advance Virology Laboratory) with Negative Pressure" for Covid-19 testing. The facility was developed under the guidelines as given by ICMR, WHO, and Ministry of Health & Family Welfare, Government of India. The facility was inaugurated by Mr. RK Tiwari, Chief Secretary, Government of UP and Prof. MLB Bhatt, VC, KGMU, Lucknow on June 30, 2020.



Sample Tested till 31 March, 2021

 **1,46,251**

Sanitizer & Other Products Distributed

 **To Over 10,000 Frontliners**

Team CSIR-NBRI

Coordinators- Dr. SV Sawant/ Dr. PK Singh

Members- Drs. Sumit Bag, AP Sane, Vidhu Sane, Praveen C Verma and Indraneel Sanyal, and research scholars of the institute as volunteers.

निदेशक की कलम से

मुझे वर्ष 2020-21 के लिए सीएसआईआर-एनबीआरआई की वार्षिक रिपोर्ट प्रस्तुत करते हुए खुशी हो रही है। कई अन्य लोगों की तरह, हमारे लिए कोविड-19 महामारी के बीच अपनी गतिविधियों को बनाए रखने के लिए यह एक चुनौतीपूर्ण वर्ष रहा है। कोविड-19 की अभूतपूर्व चुनौतियों के बावजूद, हमने अपने कर्मचारियों और हमारे आसपास के लोगों को महामारी से सुरक्षा प्रदान करने के लिए अपनी प्राथमिकताएं निर्धारित कीं, हमारे पादप संग्रह एवं भंडार की रक्षा की, और सावधानीपूर्वक वित्तीय प्रबंधन के साथ हमारे चल रहे अनुसंधान और विकास कार्यक्रमों का प्रबंधन किया। कोविड-19 महामारी से निपटने के लिए हमने कई पहल की हैं। हमने अल्कोहल-मुक्त और अल्कोहल-आधारित दोनों ही प्रकार के हर्बल हैंड सैनिटाइजर विकसित किए हैं। पहली और दूसरी लहर के दौरान पूरे लखनऊ में फ्रंटलाइन योद्धाओं को 1200 लीटर से अधिक हैंड सैनिटाइजर वितरित किया गया। हमने एक अभिनव हर्बल उत्पाद, 'मास्क स्ट्रेस रिड्यूसर: नित्या' भी विकसित किया है, जो लंबे समय तक फेस मास्क पहनने के कारण सांस लेने में होने वाली तकलीफ को कम करता है। इन दोनों उत्पादों की तकनीकों को मार्केटिंग के लिए विभिन्न स्टार्टअप और स्वास्थ्य कंपनियों को हस्तांतरित किया गया है। परीक्षणों में तेजी की मांग को देखते हुए, हमने आईसीएमआर, डब्ल्यूएचओ तथा स्वास्थ्य एवं परिवार कल्याण मंत्रालय, भारत सरकार द्वारा दिए गए दिशानिर्देशों के तहत, सीएसआईआर-एनबीआरआई में कोविड-19 परीक्षण के लिए "नकारात्मक दबाव के साथ बीएसएल३ स्तर की सुविधा (उन्नत विषाणुविज्ञान प्रयोगशाला)" की स्थापना की। इस सुविधा में 31 मार्च, 2021 तक कुल 1,46,251 नमूनों का परीक्षण किया गया।



2020-21 में, सीएसआईआर-एनबीआरआई ने पादप विज्ञान के प्राथमिकता वाले क्षेत्रों में 132 अनुसंधान और विकास परियोजनाओं पर काम किया। हमारी प्रमुख प्राथमिकता सबसे चुनौतीपूर्ण और महत्वाकांक्षी कार्यक्रमों को शुरू करना था जो पादप विज्ञान में प्रगति के लिए नया ज्ञान प्रदान करने, नई प्रजातियों, जीनों और जैव अणुओं की खोज करने और मानव स्वास्थ्य देखभाल, भोजन, पोषण, आजीविका सुरक्षा, पर्यावरण संरक्षण और अन्य सामाजिक लाभों के लिए सस्ती हरित प्रौद्योगिकियों का विकास करने में सक्षम हों। हमने इस साल 46 नई परियोजनाएं शुरू कीं, जिनमें सीएसआईआर द्वारा वित्तपोषित 31 इन-हाउस परियोजनाएं और अन्य अनुदान एजेंसियों द्वारा प्रायोजित 14 अनुदान सहायता परियोजनाएं शामिल हैं। इन सभी परियोजनाओं में बहुत सारी संभावनाएं निहित हैं। कपास और फूलों की खेती पर नई मिशन परियोजनाएं, और भारत के संकटग्रस्त पौधों के संरक्षण, भांग और पॉपी में मेटाबोलाइट आनुवंशिकी, भारतीय लोटस (कमल) के संरक्षण, कृषि विज्ञान, चयापचय और जीनोमिक्स पर नई बहु-प्रयोगशाला परियोजनाएं (एमएलपी), और कई अन्य अनुदानित तथा इन-हाउस परियोजनाओं में एक संश्लेषात्मक एवं ट्रांस-डिसिप्लिनेरी ढांचा है। इसके अलावा, संस्थान ने कई जनसम्पर्क, प्रशिक्षण और कौशल विकास कार्यक्रमों के माध्यम से विभिन्न उपयोगकर्ताओं को सेवाएं प्रदान करना जारी रखा।

प्रौद्योगिकी विकास के मोर्चे पर, हर्बल हैंड सैनिटाइजर और मास्क स्ट्रेस रिड्यूसर के अलावा, हमने तीन और पादप आधारित उत्पाद - फ्लोरमॉप (हल्दी की पत्ती के आवश्यक तेल पर आधारित), यूरोलिथियासिस में उपयोगी हर्बल फॉर्मूलेशन, और पारंपरिक काढ़ा विकसित किए। इन उत्पादों की जानकारी उद्योगों को हस्तांतरित की गई।

हमें यह घोषणा करते हुए खुशी हो रही है कि सीएसआईआर-एनबीआरआई को औषधीय और सुगंधित यौगिकों के एनएबीएल-मान्यता प्राप्त संदर्भ सामग्री उत्पादक के रूप में मान्यता दी गई है। इस वर्ष हमने आईएसओ-17034-2016 की आवश्यकता के अनुसार तीन प्रमाणित संदर्भ सामग्री (सीआरएम) (यूजेनॉल (+), लिमोनीन, और जेरेनियोल) और एक संदर्भ सामग्री (आरएम) (मिथाइल शैविकोल) को तैयार किया। कई अन्य सीआरएम और आरएम तैयार किए जा रहे हैं।

एक शोधन प्रोटोकॉल विकसित किया गया और पारंपरिक फॉर्मूलेशन एवं उनके एसओपी तैयार किए गए तथा *कैनबिस सैटाईवा* की पत्तियों के आवश्यक तेल के पादप-रासायनिक एवं जैविक अध्ययनों के माध्यम से मूल्यांकन किया गया। खाद्य और औद्योगिक अनुप्रयोगों के लिए पौधों से चार

खाद्य रंग (पीला, लाल, हरा और गहरा भूरा) विकसित किए गए। व्यापक कीमोप्रोफाइलिंग और जैविक अध्ययनों ने औषधीय और सुगंधित पौधों जैसे कि *बर्बेरिस लाइसियम*, *कोस्टस स्पेशियोसस*, *हेमेडेस्मस इंडिकस*, *मोमोर्डिका डायोका*, और क्षुद्र कीटनाशक पौधों, *आर्जीमोन मेक्सिकाना* और *धतूरा मेटेल* से कई आशाजनक कीमोटाइप की पहचान की है। नैनोजैवप्रौद्योगिकी अध्ययनों से एक संभावित संकेत भी प्राप्त किया गया है जिसमें जैव संश्लेषित सिल्वर (Pg-AgNPs) और जिंक ऑक्साइड नैनोकणों (Pg-ZnONPs) ने *सीडियम गुआजावा* की पत्तियों के अर्क का उपयोग करते हुए, *स्यूडोमोनास एरुजिनोसा* PAO1 में एलएएस-आरएचएल रेगुलोन के माध्यम से बेहतर एंटी-कोरम सेंसिंग और एंटी-बायोफिल्म गतिविधियों को प्रदर्शित किया।

कोविड-19 महामारी के प्रभाव के बावजूद हमारे पादप विविधता समूह के वैज्ञानिकों और शोधकर्ताओं ने विविधता विश्लेषण, वर्गीकी, संरक्षण और जैव पूर्वेक्षण अध्ययन हेतु भारत के कई पादप-भौगोलिक क्षेत्रों में खोज जारी रखी। इसके परिणामस्वरूप विज्ञान के लिए नवीन 09 पादप एवं शैक प्रजातियों और 26 प्रजातियों को भारत में नए भौगोलिक रिकॉर्ड के रूप में खोजा गया है। संस्थान के पादपालय (LWG) को इस वर्ष मौजूदा संग्रह में पुष्पीय पौधों के 2570 नमूनों को शामिल करके समृद्ध किया गया, और इस तरह पादपालय का कुल संग्रह 3 लाख से अधिक पादप एवं शैक नमूनों तक पहुंच गया। इसके अलावा, आठ विभिन्न संगठनों से प्राप्त 22 पादप प्रजातियों की पहचान/प्रमाणीकरण किया गया और उन्हें प्रमाण पत्र जारी किए गए।

हम पर्यावरण और सूक्ष्मजैविक प्रौद्योगिकियों के विकास और पादप आधारित उपचार, स्वच्छ पर्यावरण, जैविक नियंत्रण, खाद्य सुरक्षा और कृषि उत्पादकता के समाधान की दिशा में महत्वपूर्ण लीड पैदा करने में भी सफल रहे। इन संभावित सुरागों में शामिल हैं: उच्च फॉस्फेट संचय क्षमता वाले *स्यूडोमोनास पुटिडा* (Δppx) के एक एक्सोपॉलीफास्फेट म्यूटेंट की पहचान; चावल की किस्मों में आयरन और जिंक बायोफोर्टिफिकेशन के लिए चार सूक्ष्म-जीव; जैव-कवकनाशी *बेसिलस सबटिलिस* NBRI-W9 (W9); मक्के में जल तनाव को कम करने वाले गुण के साथ मक्के की वृद्धि को बढ़ावा देने वाला जीवाणु *ओक्रोबैक्ट्रम* प्रजाति (NBRISH6); टमाटर में अर्ली ब्लाइट बीमारी के प्रबंधन हेतु पेपरमिंट तेल पर आधारित नैनोइमल्शन (पीएनई); और चावल के भूसे के त्वरित अपघटन के लिए एक सूक्ष्मजीवी फोर्मूलेशन।

हमने उत्तर प्रदेश के आर्सेनिक-संदूषित जिलों में आर्सेनिक प्रदूषण का आंकलन और निगरानी और उत्तर प्रदेश में सूक्ष्मजैविक उपचार तकनीक का उपयोग करते हुए हेक्साक्लोरोसाइक्लोहेक्सेन (एचसीएच) डंप स्थलों का सुधार करने के अपने प्रयासों में महत्वपूर्ण प्रगति हासिल की है।

जीन-खनन, ट्रांसजेनिक पौधों के विकास और जीनोम-संपादन प्रौद्योगिकियों में अंतःविषयी अध्ययनों ने कई संभावित पादप जीनों की पहचान की और उनकी भूमिकाओं जैसे कि रेशों का विकास, नर बंध्यता-उर्वरता बहाली और कपास में कीट प्रतिरोध, चना में सूखा सहिष्णुता, चावल में आर्सेनिक तनाव, गुलाब में पंखुड़ी का विलगन और घाव भरना, टमाटर में फल का पकना, तंबाकू में लवण तनाव, और एराबिडोप्सिस में वृद्धि और विकास आदि की व्याख्या की है। इस वर्ष हमारे संस्थान में नर बंध्यता-उर्वरता बहाली अनुसंधान के संदर्भ में की गयी एक खोज “पौधों में ट्रांसजीन अभिव्यक्ति के लिए नवीन प्रतिवर्ती अभिव्यक्ति प्रणाली” के लिए एक अंतरराष्ट्रीय पेटेंट प्रदान किया गया।

औद्योगिक रूप से महत्वपूर्ण फसलों जैसे भांग, पॉपी, अलसी, एमरेन्थ और विंगड बीन जैसी फसलों में सुधार के लिए आनुवंशिक और जीनोमिक संसाधनों को विकसित करने में महत्वपूर्ण सुराग प्राप्त हुए। अफीम पोस्ट में सटीक ओपीओयड आंकलन के साथ जीनोम-वाइड एसोसिएशन स्टडी (जीडब्ल्यूएस) ने थीबेन पाथवे में प्रमुख एसएनपी और उनके संबंधित जीनों को पहचाना। कम THC और उच्च CBD के लिए भांग के सुधार के लिए एक प्रमुख पहल प्रगति पर है। जीडब्ल्यूएस ने विंगड-बीन में 54 एसएनपी की पहचान की, जो बीज-प्रोटीन लक्षणों से महत्वपूर्ण रूप से जुड़े हुए हैं और 88 एसएनपी जो बीज-तेल लक्षणों के साथ जुड़े हैं। अलसी का संदर्भ जीनोम (आईसी 0526166) तैयार किया गया और 10,000 बीपी से अधिक आकार वाले कुल 671 कोण्टिग्स की पहचान की गई। एक जंगली स्टोन ओक के पेड़ (*लिथोकार्पस डीलबैटस*) के 161,476 बीपी आकार के क्लोरोप्लास्ट जीनोम को संकलित किया गया और प्लास्टिड जीनोम में 134 जीनों की पहचान की गई थी, जिसमें 87 प्रोटीन-कोडिंग जीन, 39 टीआरएनए और 8 आरआरएनए शामिल थे।

वनस्पति उद्यान और इसकी कई संबद्ध इकाइयों एवं प्रायोगिक अनुसंधान केन्द्रों ने पौधों की विविधता के संवर्धन तथा पौधों के विविध समूहों के संरक्षण एवं अनुसंधान, सौंदर्यशास्त्र, शिक्षा, जागरूकता निर्माण और जनसम्पर्क के लिए उनके प्रबंधन से संबंधित गतिविधियों को जारी रखा। कोविड-19 महामारी के दौरान लॉक डाउन ने नियमित बागवानी संचालन, फूलों के शो और प्रदर्शनियों, पौधों के भंडार के प्रबंधन और वनस्पति उद्यान के प्रयोगात्मक क्षेत्र/प्रयोगशाला कार्यों को काफी प्रभावित किया। इसने आगंतुकों की संख्या और वनस्पति उद्यान संसाधनों तथा जनसम्पर्क गतिविधियों तक सार्वजनिक पहुंच को कम कर दिया। हालांकि, लोगों और कर्मचारियों को महामारी से बचाने के लिए सभी एहतियाती और निवारक

तरीकों को अपनाते हुए, हमने अपने पौधों के संग्रह को बगीचे, संरक्षण गृहों और फील्ड जीन बैंकों में प्रबंधित किया और उन्हें जारी एवं नवीन शोध गतिविधियों के लिए उपयोग किया।

इस वर्ष साइकस गार्डन को भारतीय प्रजातियों के लिए एक राष्ट्रीय संदर्भ केंद्र बनाने के लिए समृद्ध किया गया और संकट ग्रस्त साइकस प्रजातियों के एक्स-सीटू संरक्षण हेतु उनके बचाव, पुनर्प्राप्ति और पुनर्वास के लिए एक मॉडल बनाया गया। कैना, ग्लैडियोलस, आइरिस और निम्फिया जैसी फूलों की फसलों के विकास के लिए विभिन्न प्रयोगों को डिजाइन किया गया था। ग्लैडियोलस, कैना, निम्फिया, रेनवर्डिया इंडिका जैसे सजावटी पौधों के सुधार के लिए संकरण और उत्परिवर्तन प्रजनन को चुना गया। वनस्पति उद्यान में विषयगत उद्यानों, पादप गृहों, वृक्षस्थलों और सार्वजनिक स्थानों में संरक्षित पेड़ों और झाड़ियों का एक डेटाबेस विकसित किया गया।

सोडिक भूमि के लिए आर्थिक रूप से महत्वपूर्ण पौधों के संभावित जर्मप्लाज्म की पहचान करने और उनकी कृषि-प्रौद्योगिकी विकसित करने के लिए, क्विनोआ (चेनोपोडियम क्विनोआ), या इसबगोल (प्लाटैगो ओवाटा), नटग्रास या नागरमोथा (साइपेरस स्केरियोसस), ट्यूबरोज (पॉलीएंथेस ट्यूबरोसा), अलसी (लाइनम यूसीटैटीसीमम), ऐमारैथस प्रजाति (ए. हाइपोकोन्ड्रियस, ए. क्रुएंटस, ए. कॉडैटस), और कालमेघ (एंड्रोग्राफिस पैनिकुलेटा) का मूल्यांकन बंधरा में फील्ड जीन बैंक में किया गया। भारतीय गांगेय मैदानों की प्रमुख पारंपरिक चावल-गेहूं फसल प्रणाली के विकास और उपज प्रदर्शन पर जिओलाइट्स की प्रतिक्रिया का अध्ययन करने के लिए नए क्षेत्र प्रयोग शुरू किए गए।

जनसम्पर्क कार्यक्रमों के तहत, ओडिशा के नबरंगपुर जिले के किसानों के लिए तीन तकनीकी हस्तक्षेप किए गए। किसानों को वितरण के लिए सीएसआईआर-एनबीआरआई की हल्दी की किस्म 'केसरी' का सौ किलोग्राम प्रकंद और 30 किलोग्राम ट्यूबरोज बल्ब प्रदान किए गए। नबरंगपुर जिले में जैव-उर्वरक को बढ़ावा देने के उद्देश्य से कृषि अधिकारियों के लिए एक प्रशिक्षण कार्यक्रम आयोजित किया गया और किसानों को वितरण के लिए जैव उर्वरक के 200 पैकेट प्रदान किए गए। इसके बाद छह गांवों में किसानों के खेतों में प्रशिक्षण कार्यक्रम भी आयोजित किया गया।

सीएसआईआर-एनबीआरआई वनस्पति उद्यान में 13 अगस्त 2020 को "हल्दी की खेती और अन्य वनस्पति पौधों के क्षेत्र में उद्यमिता के लिए संभावनाएं" विषय पर एक ऑनलाइन उद्यमिता विकास कार्यक्रम आयोजित किया गया।

सीएसआईआर कौशल विकास पहल के तहत कौशल विकास कार्यक्रमों का समन्वयन किया गया। इन कार्यक्रमों की अवधि 3 दिनों से लेकर 29 दिनों तक थी, जिसके माध्यम से कुल 845 उम्मीदवारों को 12 प्रशिक्षण पाठ्यक्रमों के तहत प्रशिक्षित किया गया है। इसके अलावा, 194 किसानों, महिलाओं, छात्रों, शिक्षकों और गैर सरकारी संगठनों को विभिन्न तकनीकों जैसे कि हर्बल गुलाल बनाने के लिए रंग निकालने के लिए मंदिर के फूलों के कचरे का उपयोग, पान की बेल की खेती और उद्यान प्रबंधन पर समूह प्रशिक्षण दिया गया। अरुणाचल प्रदेश, झारखंड, बिहार और उत्तर प्रदेश के 11 गांवों के लगभग 298 किसानों को हल्दी की खेती और हल्दी के पत्तों से आवश्यक तेल निकालने का प्रशिक्षण दिया गया।

पादप विज्ञान के विभिन्न विषयों में कुल 42 छात्रों को अनुसंधान प्रशिक्षण दिया गया। वर्ष के दौरान प्रशिक्षण शुल्क के रूप में 7,43,000/- रुपये का राजस्व अर्जित किया गया। कोविड-19 की वर्तमान महामारी की स्थिति के कारण अनुसंधान विद्वानों, छात्रों, किसानों सहित आम जनता के लिए हमारी विभिन्न सुविधाओं, प्रयोगशालाओं, वनस्पति उद्यान और अभिदर्शन के भ्रमण को प्रतिबंधित कर दिया गया था। इस वर्ष हमने कोविड-19 प्रोटोकॉल और दिशानिर्देशों के अनुसार तीन स्कूलों के मात्र 137 विद्यार्थियों के भ्रमण का समन्वयन किया। विज्ञान मंथन यात्रा-2020 के तहत मध्यप्रदेश के विद्यार्थियों के लिए आभासी भ्रमण का भी आयोजन किया गया।

सीएसआईआर-एनबीआरआई ने सीएसआईआर-निस्केयर के सहयोग से एक आभासी मंच पर 23-24 दिसंबर, 2020 को जैव विविधता सम्मेलन का समन्वय किया। यह कार्यक्रम भारत सरकार और विज्ञान भारती द्वारा समर्थित और आयोजित छठे भारत अंतर्राष्ट्रीय विज्ञान महोत्सव (IISF-2020) के हिस्से के रूप में आयोजित किया गया था। दो दिवसीय कार्यक्रम में विश्व स्तर पर मान्यता प्राप्त विशेषज्ञों से आमंत्रित वार्ता, ई-पोस्टर गैलरी, जैव विविधता नवाचार एक्सपो, स्वदेशी समुदाय-विज्ञान एवं तकनीकी विशेषज्ञों की बैठक, उद्यमी-उद्योग बैठक और लघु फिल्म एवं प्रकृति वन्यजीव फोटो प्रदर्शनी शामिल थी।

रिपोर्टिंग वर्ष के दौरान संस्थान ने एससीआई पत्रिकाओं में 157 शोध पत्र प्रकाशित किए, जिनका संचयी प्रभाव कारक 555.756 (3.562 प्रति पेपर) था। भारत में दो पेटेंट दायर किए गए, जबकि में तीन पेटेंट भारत में और एक विदेश में हासिल किए गए। वैज्ञानिक और अभिनव अनुसंधान अकादमी (AcSIR) और भारत के अन्य विश्वविद्यालयों द्वारा सत्रह छात्रों को पीएचडी से सम्मानित किया गया। हमें खुशी है कि हमारे एक वैज्ञानिक डॉ. पी. के. सिंह को 2020 में भारतीय राष्ट्रीय विज्ञान अकादमी (INSA) का फेलो चुना गया।

मैं अपने सभी वैज्ञानिक, तकनीकी और प्रशासनिक कर्मचारियों और छात्रों को कोविड-19 महामारी के इस चुनौतीपूर्ण समय में हमारी संस्थागत गतिविधियों को बनाए रखने में आपकी प्रतिबद्धता, उत्साह और समर्पण के लिए धन्यवाद देना चाहता हूँ। इसके लिए हम आपके आभारी हैं और सीएसआईआर-एनबीआरआई को पादप विज्ञान अनुसंधान के लिए एक विश्वस्तरीय संस्थान के रूप में आगे बढ़ाने के आपके निरंतर प्रयासों के लिए आशान्वित हैं। मैं इस अवसर पर हमारे संस्थान के समग्र विज्ञान एवं प्रौद्योगिकी प्रबंधन में हमें बहुमूल्य समर्थन, प्रोत्साहन और मार्गदर्शन प्रदान करने के लिए डॉ. शेखर सी मांडे, महानिदेशक, सीएसआईआर के प्रति अपनी कृतज्ञता व्यक्त करता हूँ। हम अपने अनुसंधान एवं विकास और प्रबंधन एजेंडा को तैयार करने तथा संस्थागत प्रदर्शन और प्रगति की निगरानी में हमारा मार्गदर्शन करने के लिए सीएसआईआर-एनबीआरआई के अनुसंधान परिषद के अध्यक्ष प्रोफेसर (डॉ.) परमजीत खुराना और प्रबन्ध परिषद के माननीय सदस्यों को धन्यवाद देना चाहते हैं। हम अपने सभी प्रायोजकों, अनुदान प्रदाताओं, उद्योग भागीदारों, सहभागियों, साथियों, शिक्षाविदों, अन्य समर्थकों और जनता के लिए बहुत आभारी हैं कि उन्होंने हमें कई तरह से अपना उदार समर्थन और सहयोग दिया। हम आपके समर्थन की सराहना करते हैं और हमारे भविष्य के सभी प्रयासों में भी आपके निरंतर समर्थन की आशा करते हैं।

सरोज बारिक

(सरोज के बारिक)

निदेशक

From the Director's Desk

I am delighted to present the Annual Report of CSIR-NBRI for the year 2020–21. Like many others, it has been a challenging year for us to sustain our activities amidst the COVID–19 pandemic. Despite the unprecedented challenges presented by COVID-19, we set our priorities to provide safety to our staff and people around us from the pandemic, safeguard our plant collections and repositories, and manage our ongoing research and development programs with careful fiscal management. To combat the COVID–19 pandemic we took several initiatives. We developed both alcohol-free and alcohol-based herbal hand sanitizers. Over 1200 liters of the hand sanitizers were distributed to the frontline warriors across Lucknow during the first and second wave. We also developed an innovative herbal product, 'Mask Stress Reducer: NITYA', which reduces breathing discomforts due to long hours of wearing face masks. Technologies of both these products were transferred to various startups and health companies for marketing. Seeing the demand for rapid testing, we established a “BSL3 level facility (Advance Virology Laboratory) with Negative Pressure” at CSIR-NBRI for Covid-19 testing, under the guidelines as given by ICMR, WHO, and Ministry of Health & Family Welfare, Government of India. A total of 1, 46, 251 samples were tested at this facility till March 31, 2021.



In 2020–21, CSIR-NBRI worked on 132 research and development projects in the prioritized areas of plant sciences. Our overriding priority was to take up the most challenging and ambitious programmes capable of delivering new knowledge for advancements in plant science, discovering new species, genes and biomolecules, and developing affordable green technologies for human healthcare, food, nutrition, livelihood security, environmental protection and other societal benefits. We initiated 46 new projects this year, which included 31 In-house projects funded by CSIR and 14 Grant-in Aid Projects (GAP) sponsored by other funding agencies. All of these projects hold lot of promises and prospects. The new mission projects on Cotton and Floriculture, and the new multi-laboratory projects (MLP) on conservation of threatened plants of India, metabolite genetics in cannabis and poppy, conservation, agronomics, metabolomics and genomics of Indian Lotus (KAMAL), and many other GAP and In-house projects have a translational and trans-disciplinary framework. Besides, the institute continued to provide services to various end users through several outreach, training and skill development programmes.

In the technology development front, besides the herbal hand sanitizers and mask stress reducer, we developed three more plant-based products – Floormop (Turmeric leaf essential oil based), Herbal formulation useful in Urolithiasis, and Traditional Kadha. The know-how for these products was transferred to industry.

We are glad to announce that CSIR-NBRI has been recognized as a NABL-Accredited reference material producer of medicinal and aromatic compounds. This year we prepared three Certified Reference Materials (CRMs) (Eugenol, (+) Limonene, and Geraniol) and one Reference Materials (RM) (Methyl Chavicol) as per requirement of ISO-17034-2016. Preparation of several more CRMs and RMs is in progress.

A shodhan protocol was developed and classical formulations and their SOPs were prepared and evaluated through phytochemical and biological studies of *Cannabis sativa* leaf essential oil. Four food colours (yellow, red, green and dark brown) were developed from plants for food and industrial applications. Comprehensive chemoprofiling and biological studies have identified several promising chemotypes from medicinal and aromatic plants such as *Berberis lycium*, *Costus speciosus*, *Hemidesmus indicus*, *Momordica dioica*, and acaricidal plants, *Argemon mexicana* and *Datura metel*. A potential lead has also been obtained from nanobiotechnological studies in which the biosynthesized silver (Pg-AgNPs) and zinc oxide nanoparticles (Pg-ZnONPs) using leaf extract of *Psidium guajava*, showed superior anti-quorum sensing and anti-biofilm activities in *Pseudomonas aeruginosa* PAO1 via las-rhlRegulons.

Despite the impact of COVID-19 pandemic, scientists and researchers of our plant diversity Group continued to explore several phytogeographical regions of India for diversity analysis, systematic, conservation and bioprospecting studies. This has resulted in the discovery of nine plant and lichen species as new to science and 26 species as new geographical records to India. The herbarium of the institute (LWG) was enriched this year with an addition of 2570 specimens of angiosperms to the existing collections, and thereby making the total holding of the herbarium to over 3 lakh plant and lichen specimens. Besides, 22 plant species received from eight different organizations were identified/ authenticated and certificates were issued to them.

We also succeeded in generating significant leads toward developing environmental and microbial technologies and solutions for phytoremediation, clean environment, biological control, food safety and agricultural productivity. These potential leads included identification of an exopolyphosphatase mutant of *Pseudomonas putida* (Δ ppx) having high phosphate accumulating potential; four microbes for Fe and Zn biofortification in rice cultivars; Bio-fungicide, *Bacillus subtilis* NBRI-W9 (W9); *Ochrobactrum* sp. (NBRISH6), a growth promoting bacteria with water stress alleviating property in maize; a peppermint oil-based nanoemulsion (PNE) for early blight disease management in tomato; and a microbial formulation for hastened decomposition of rice straw.

We achieved significant progress in our efforts to assess and monitor arsenic pollution in arsenic-prone districts of Uttar Pradesh, and reclamation of Hexachlorocyclohexane (HCH) dumpsites in Uttar Pradesh using microbial remediation technology.

The interdisciplinary studies in gene-mining, transgenic plant development and genome-editing technologies identified several potential plant genes and elucidation of their roles such as fibre development, male sterility-fertility restoration and insect resistance in cotton, drought tolerance in chickpea, arsenic stress in rice, petal abscission and wound healing in rose, fruit ripening in tomato, salt stress in tobacco, and growth and development in *Arabidopsis*. An international patent was granted this year to an invention “novel reversible expression system for transgene expression in plants”, which was made in the context of male sterility-fertility restoration research carried out at our institute.

Significant leads were obtained in developing genetic and genomic resources for improvement in industrially important crops such as cannabis, poppy, linseed, amaranths and orphan crops like the winged bean. Genome-wide association study (GWAS) in opium poppy, with precise opioid estimation, identified key SNPs and their associated genes involved in thebaine pathways. A major initiative for improvement of Cannabis for low THC and high CBD is in progress. GWAS identified 54 SNPs significantly associated with seed-protein traits and 88 SNPs with seed-oil traits in winged-bean. The reference genome of linseed (IC 0526166) was prepared and a total of 671 contigs with more than 10000 bp size were identified. The chloroplast genome of a wild stone oak tree (*Lithocarpus dealbatus*) was assembled of 161,476 bp size and 134 genes were identified in the plastid genome, including 87 protein-coding genes, 39 tRNAs, and 8 rRNAs.

The Botanic Garden and several of its associated units and experimental research stations continued with activities related to enrichment of plant diversity and conservation of diverse groups of plants and their management for research, aesthetics, education, awareness creation, and outreach. Like in the preceding year, the lock down during covid-19 pandemic considerably affected the routine horticultural operations, flower shows and exhibitions, and management of plant repositories and experimental field/lab works of the botanic garden. It has also slowed down the visitors and public access to the botanic garden resources and the outreach activities. However, while taking all precautionary and preventive methods to protect people and staff from the pandemic, we managed our plant collections in the garden, conservatories and field gene banks and put them to use for the ongoing and new research activities.

This year the Cycas Garden was enriched to make it a national reference centre for Indian species and a model for ex-situ conservation of threatened *Cycas* species for their rescue, recovery and rehabilitation. The experiments were designed for varietal development of floricultural crops such as *Canna*, *Gladiolus*, *Iris*, and *Nymphaea*. Hybridization and mutation breeding of ornamental plants such as *Gladiolus*, *Canna*, *Nymphaea*, *Reinwardtia indica* were taken up for their improvement. A database of trees and shrubs conserved in thematic gardens, plant houses, arboretum and public places in Botanic Garden was developed.

In order to identify potential germplasm of economically important plants for sodic lands and to develop their agro-technology, evaluation of quinoa (*Chenopodium quinoa*), or isabgol (*Plantago ovata*), nutgrass or nagarmotha (*Cyperus scariosus*), tuberose (*Polyanthes tuberosa*), Linseed (*Linum usitatissimum*), *Amaranthus* spp. (*A. hypochondriacus*, *A. cruentus*, *A. caudatus*), and Kalmegh (*Andrographis paniculata*) was carried out at Field Gene

Bank at Banthra. New field experiments were initiated to study the response of Zeolites on growth and yield performance of dominant traditional rice-wheat cropping system of Indo-Gangetic plains.

Under outreach programmes, three technological interventions were made for the farmers of the aspirational district, Nabarangpur in Odisha. Hundred kilogram rhizome of CSIR-NBRI turmeric variety 'Kesari' and 30 kg tuberosa bulb were provided for distribution to farmers. With the aim to promote the bio-fertilizer in Nabarangpur district, a training programme was organized for agriculture officers and provided 200 packets of Biofertilizers (PSB) for distribution to the farmers. Subsequently, training programme at the farmers' fields was also conducted in six villages.

An online entrepreneurship development Programme on "Scope for entrepreneurship in the field of turmeric cultivation and other botanical plants" was organized on 13th August 2020 at CSIR-NBRI Botanic Garden.

Skill development programmes were coordinated under the CSIR Skill Development Initiative. The duration of these programmes ranged from 3 days to 29 days through which total 845 candidates have been trained under 12 training courses. Besides, 194 farmers, women, students, teachers and NGOs, were given group training on different techniques, such as utilization of temple flower waste by extraction of colour for making herbal gual, betel vine cultivation, and garden management. About 298 farmers from 11 villages of Arunachal Pradesh, Jharkhand, Bihar and Uttar Pradesh were trained in cultivation of turmeric and extraction of essential oil from turmeric leaves.

A total of 42 students were imparted research trainings in different disciplines of the plant science. A revenue of Rs 7, 43,000/- was generated as training fee during the year. Due to current pandemic conditions of Covid-19, physical visits to our various facilities, laboratories, botanic garden and exposition were restricted for individuals, including research scholars, students, farmers, general public. This year we coordinated physical visits of only 137 students from three schools as per the Covid-19 protocols and guidelines. A virtual tour was also organized for the students from Madhya Pradesh under Vigyan Manthan Yatra – 2020.

CSIR-NBRI, in association with CSIR-NISCAIR (CSIR-NIScPR), coordinated a Biodiversity Conclave during 23-24 December, 2020 on a virtual platform. This event was conducted as part of the 6th India International Science Festival (IISF-2020), supported and organized by the Government of India and VIBHA. The two-day event included invited talks from globally recognized experts, E-poster gallery, Biodiversity Innovation Expo, Indigenous Communities- S & T Experts Meet, Entrepreneurs- Industry Meet and Short films and nature wildlife photo exhibition.

During the reporting year the institute published 157 research papers in SCI journals, with a cumulative impact factor of 555.756 (IF 3.562 per paper). Two patents were filed in India, while the number patents granted included three in India and one abroad. Seventeen students were awarded PhD by the Academy of Scientific and Innovative Research (AcSIR) and other universities of India. We are delighted that one of our scientists, Dr. P. K. Singh was elected as a Fellow of the Indian National Science Academy (INSA) in 2020.

I would like to thank all my scientific, technical and administrative staff and students for your commitment, enthusiasm and dedication in sustaining our institutional activities in this challenging time of COVID-19 pandemic. We are grateful to you for this and look forward to your continued efforts to propel CSIR-NBRI in the trajectory of a world-class institute for plant science research. I also take this opportunity to extend our sincere gratitude to Dr. Shekhar C Mande, Director General, CSIR for rendering us valuable support, encouragement and guidance in the overall S & T management of our institute. We would like to thank Prof. (Dr) Paramjit Khurana, Chairperson and honorable members of the Research and Management Councils of CSIR-NBRI for guiding us in formulating our R&D and management agenda and monitoring the institutional performance and progress. We are extremely grateful to all our sponsors, funders, industry partners, collaborators, peers, academia, other supporters and the public for the generous support and cooperation extended to us in many ways. We appreciate your kind gestures and look forward to your unstinted support in all our future endeavors.



Saroj K Barik
Director

कृषि विज्ञान

वर्ष 2020-21 के दौरान सीएसआईआर-एनबीआरआई ने पादप विविधता मूल्यांकन, वर्गिकी, संरक्षण, जीनोमिक्स, आनुवंशिक सुधार, अजैविक और जैविक तनावों के लिए ट्रांसजेनिक पौधों के विकास, जलवायु परिवर्तन, पारिस्थितिकी-शरीर क्रिया विज्ञान, पादप-सूक्ष्मजीव संबंध, पादप उपचार, बागवानी, कृषि प्रौद्योगिकी, सूक्ष्मजीव विज्ञान, औषध विज्ञान, पादप रसायन, भेषज विज्ञान और हर्बल अथवा प्राकृतिक उत्पाद विकास के चिन्हित क्षेत्रों में कई अनुसंधान और विकास परियोजनाओं पर काम किया है। यह अध्ययन नए ज्ञान के सृजन, जैव पूर्वक्षण के माध्यम से नवीन प्रजातियों, जीनों और जैव रसायनों की खोज, और सस्ती स्वास्थ्य देखभाल, पोषण, आजीविका सुरक्षा, पर्यावरण संरक्षण और अन्य सामाजिक लाभों के लिए हरित प्रौद्योगिकियों के विकास पर लक्षित थे। इसके अलावा संस्थान ने कोविड-19 महामारी के बावजूद जनसम्पर्क कार्यक्रम, प्रशिक्षण और कौशल विकास के माध्यम से बागवानी, उद्यान प्रबंधन, कृषि प्रौद्योगिकी, जैव-उपचार, ऊतक संवर्धन और अन्य जैवप्रौद्योगिकी तरीकों में विभिन्न उपयोगकर्ताओं को सेवाएं प्रदान कीं। इस वर्ष की गई प्रमुख उपलब्धियों का सारांश छह अनुसंधान एवं विकास क्षेत्रों के तहत निम्नवत है।

कृषि विज्ञान, आणुविक विज्ञान, जैव पूर्वक्षण, और भारत के पौधों एवं शैक संसाधनों के संरक्षण को केन्द्रित करते हुए बहुविषयक दृष्टिकोण से पादप विविधता अनुसंधान किया गया है। संस्थान का पादपालय, पादप वर्गीकरण एवं संबंधित पहलुओं में अनुसंधान का मुख्य केंद्र है, और यह उद्योगों, शोधकर्ताओं, छात्रों, शिक्षकों सहित अन्य विभिन्न उपयोगकर्ताओं के लिए पौधों की पहचान तथा पौधों और शैक के प्रमाणीकरण की सेवाएं प्रदान करके भारत की वनस्पतियों के राष्ट्रीय भंडार के रूप में कार्य करता है। दुर्भाग्य से, कोविड-19 महामारी ने इस वर्ष हमारी पौधों की खोज, वाह्य एवं प्रयोगशाला प्रयोगों की नियोजित गतिविधियों को धीमा कर दिया। इसके बावजूद,

संस्थान में वर्गिकी, पुष्प विज्ञान, नृवंशविज्ञान, आणुविक विज्ञान, जैव पूर्वक्षण और भारत के पौधों एवं शैक संसाधनों के संरक्षण को केन्द्रित करते हुए बहुविषयक दृष्टिकोण से पादप विविधता अनुसंधान किया गया है। संस्थान का पादपालय, पादप वर्गीकरण एवं संबंधित पहलुओं में अनुसंधान का मुख्य केंद्र है, और यह उद्योगों, शोधकर्ताओं, छात्रों, शिक्षकों सहित अन्य विभिन्न उपयोगकर्ताओं के लिए पौधों की पहचान तथा पौधों और शैक के प्रमाणीकरण की सेवाएं प्रदान करके भारत की वनस्पतियों के राष्ट्रीय भंडार के रूप में कार्य करता है। दुर्भाग्य से, कोविड-19 महामारी ने इस वर्ष हमारी पौधों की खोज, वाह्य एवं प्रयोगशाला प्रयोगों की नियोजित गतिविधियों को धीमा कर दिया। इसके बावजूद,

शोधकर्ताओं के निरंतर प्रयासों ने कुछ हद तक इस प्रभाव को दूर करने और निम्नलिखित क्षेत्रों में उल्लेखनीय प्रगति हासिल करने में मदद की:

कृषि विज्ञान, आणुविक विज्ञान, जैव पूर्वक्षण, और भारत के पौधों एवं शैक संसाधनों के संरक्षण को केन्द्रित करते हुए बहुविषयक दृष्टिकोण से पादप विविधता अनुसंधान किया गया है। संस्थान का पादपालय, पादप वर्गीकरण एवं संबंधित पहलुओं में अनुसंधान का मुख्य केंद्र है, और यह उद्योगों, शोधकर्ताओं, छात्रों, शिक्षकों सहित अन्य विभिन्न उपयोगकर्ताओं के लिए पौधों की पहचान तथा पौधों और शैक के प्रमाणीकरण की सेवाएं प्रदान करके भारत की वनस्पतियों के राष्ट्रीय भंडार के रूप में कार्य करता है। दुर्भाग्य से, कोविड-19 महामारी ने इस वर्ष हमारी पौधों की खोज, वाह्य एवं प्रयोगशाला प्रयोगों की नियोजित गतिविधियों को धीमा कर दिया। इसके बावजूद,

कोविड-19 महामारी से खोज की हमारी प्राथमिकताएं काफी प्रभावित हुईं, जिसने हमें केरल, तमिलनाडु, महाराष्ट्र, मध्य प्रदेश, उत्तर प्रदेश, उत्तराखंड, हिमाचल प्रदेश, असम और मेघालय में केवल कुछ पौधों और शैकों के सर्वेक्षण तक सीमित कर दिया गया। केरल और तमिलनाडु के पश्चिमी घाट के भागों में अन्वेषण हेतु सर्वेक्षण किए गए और 15 स्थानिक प्रजातियों सहित 189 पौधों की प्रजातियों को एकत्र किया गया। महाराष्ट्र में विदर्भ क्षेत्र की पादप विविधता का व्यवस्थित प्रलेखन जारी रखा गया और इस क्षेत्र से 244 जातियों और 79 परिवारों के तहत पुष्पीय पौधों की लगभग 334 प्रजातियों की पहचान की गई। मध्य प्रदेश के चंबल और मालवा पारिस्थितिक-क्षेत्र का सर्वेक्षण किया गया और दो अत्यधिक शोषित गोंद-उत्पादक पौधों, *कमिफोरा वाइटाई* और *बोसवेलिया सेराटा* के लिए संकट की स्थिति का आंकलन किया गया। रबी फसलों की खर-पतवारों के व्यवस्थित प्रलेखन के लिए उत्तर प्रदेश के कई जिलों का सर्वेक्षण किया गया और 185 खर-पतवार प्रजातियों की स्थानीय वितरण सीमा, परिवार, अद्यतन नामकरण, फलोद्गदिकी, उपयोग और हानियों की जानकारी के साथ एक अद्यतन सूची तैयार की गई। वहीं उत्तर प्रदेश के 11 जिलों में किए गए एक सर्वेक्षण में एस्टेरेसी परिवार के 19 जातियों के तहत लगभग 41 प्रजातियां दर्ज की गईं। उत्तर प्रदेश के यूफोरबिएसी परिवार के एक विस्तृत व्यवस्थित अध्ययन से परिवार में 31 जातियों से संबंधित लगभग 121 प्रजातियों का पता चला। पश्चिमी हिमालय में हिमाचल प्रदेश की पांगी घाटी में एक खोज के दौरान इस क्षेत्र से 140 प्रजातियों की पहचान की गई। इस वर्ष के दौरान वानस्पतिक आंकड़ों के अलावा, उत्तर प्रदेश में सुहेलवा वन्य जीव अभयारण्य के आदिवासी समुदायों द्वारा उपयोग किए जाने वाले लगभग 34 संभावित पौधों की नृवंशविज्ञान संबंधी जानकारी का भी दस्तावेजीकरण किया गया।



असम के साथ-साथ हिमाचल प्रदेश के मंडी जिले के कई इलाकों में किए गए शैक सर्वेक्षणों के परिणामस्वरूप क्रमशः 85 और 70 प्रजातियों का संग्रह किया गया। इस बीच, पहले से एकत्रित शैकों के नमूनों के आधार पर असम के पांच जिलों से 138 प्रजातियां, मेघालय से 337 प्रजातियां और उत्तर प्रदेश के सुहेलवा वन्यजीव अभयारण्य से 53 प्रजातियां दर्ज की गईं। दार्जिलिंग हिमालय में संचल वन्यजीव अभयारण्य और घूम में वानस्पतिक सर्वेक्षण, और हिमाचल प्रदेश में कुल्लू एवं मनाली में क्रमशः 106, 48 और 74 ब्रायोफाइट टैक्सा की पहचान की गईं। इसी तरह, टेरीडोफाइट्स के सर्वेक्षण के परिणामस्वरूप मध्य प्रदेश के पचमढ़ी जैवमण्डल रिजर्व से 59 प्रजातियों, मेघालय से 67 प्रजातियों और सुहेलवा वन्यजीव अभयारण्य, उत्तर प्रदेश से छह प्रजातियों की पहचान हुई। सुहेलवा वन्यजीव अभयारण्य से एकत्र किए गए शैवाल के नमूनों की सूक्ष्म-छायांकन और रूपात्मक पहचान के परिणामस्वरूप बैसिलेरियोफाइसी परिवार के 25 जातियों से संबंधित 43 टैक्सा प्राप्त हुए। उत्तराखंड में जिम कॉर्बेट नेशनल पार्क का सर्वेक्षण किया गया और 130 से अधिक शैवाल के नमूने एकत्र किए गए। इन शैवालीय नमूनों की पहचान के परिणामस्वरूप सायनोफाइसी वर्ग के चार गणों में 22 जातियों और 13 परिवारों से संबंधित 74 टैक्सा प्राप्त हुए।

भारत में कई महत्वपूर्ण पौधों और शैक टैक्सा के वर्गीकीकरण संशोधन की दिशा में महत्वपूर्ण प्रगति हुई है, जैसे कि *डेस्मोडियम* और संबन्धित जातियाँ, *यूरेरिया* (लेगुमिनोसी), *एनीमोन* (रेननकुलेसी), *जिरेनियम* (जिरेनिएसी), *डिडिमोकार्पस-हेन्केलिया* जातीय समूह (जिरेनिएसी), जनजाति *बोहेमरिया* जनजाति (अर्टिकेसी), उप-परिवार पोओइडी (पोएसी), *जुनिपेरस* (क्यूप्रेसेसी) और शैक समूह, जिसमें आर्थोनिएल्स गण, टेलोसिस्टेसी परिवार, और *बुएलिया* (वृहद अर्थ में) एवं और *रिनोडिना* जाति (फिसीएसी) शामिल हैं। भारतीय आर्थोनियल्स के ई-प्रबंध के डेटाबेस को 41 जातियों और 276 प्रजातियों के विवरण के साथ अद्यतन किया गया। इस वर्ष पुष्पीय पौधों की जातियों की चयनित प्रजातियों के समूह पर वर्गीकी एवं विविधता अध्ययन भी शुरू किया गया है, जैसे

कि *जिम्नोस्पोरिया* (सेलेस्ट्रेसी), *कैम्पैनुला* (कैम्पानुलेसी) और *इम्पेशेंस* (बाल्समिनेसी)।

आणुविक वर्गीकी अध्ययनों के हिस्से के रूप में *बरजेनिया* की तीन भारतीय प्रजातियों के वर्गीकरण और वंशानुक्रम को आईटीएस और आरबीसीएल अनुक्रम विश्लेषण के माध्यम से हल किया गया। अध्ययन ने *बरजेनिया सिलियाटा*, *बी. पर्पुरासेंस*, और *बी. स्ट्रैकियाई* को स्पष्ट प्रजातियों के रूप में मान्यता दी एवं *बी. लिगुलाटा* को *बी. सिलियाटा* का सजातीय माना।

साइट्रस मेडिका, *एनसेट ग्लॉकम*, *ए. सुपर्बम* और *यूरेरिया पिक्टा* में आनुवंशिक विविधता पर अध्ययन जारी रखा गया जिनमें *डी. नोवो* आरएनए अनुक्रमण के माध्यम से जीनोटाइपिंग के लिए एसएसआर मार्करों की पहचान और जनसंख्या आनुवंशिकी एवं वंशानुक्रम-भौगोलिकी के लिए परमाणुविक और प्लास्टिड जीनों या स्पेसरो के लिए अनुक्रम डेटा के निर्माण में प्रगति की गई। वंशानुक्रम-भौगोलिकी अध्ययन के भाग के रूप में भारत में *जिम्नेमा सिल्वेस्टर*, *एनसेट ग्लॉकम*, और *ए. सुपर्बम* के आवास की उपयुक्तता और वर्तमान वितरण का अंदाजा लगाने के लिए मैक्सएंट मॉडलिंग की गई।

रिपोर्टिंग अवधि के दौरान, पुष्पी पौधों के 2570 नमूनों को संस्थान के पादपालय में शामिल किया गया। आठ विभिन्न संगठनों से प्राप्त लगभग 22 पादप प्रजातियों की पहचान/प्रमाणीकरण किया गया और उन्हें प्रमाण पत्र जारी किए गए।

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वानस्पतिक एवं वर्गीकी अध्ययनों ने विज्ञान के लिए आठ नई प्रजातियों की खोज की, जिसमें पुष्पीय पौधों की पांच प्रजातियां, साइकेड की एक प्रजाति और शैक की तीन प्रजातियां शामिल थीं। पुष्पीय पौधों में वर्णित नवीन प्रजातियाँ हैं: *जेरेनियम एडोनियानम* इम्तियाज हुर्रा एवं विजय वाघ, *जेरेनियम जैनिआई* इम्तियाज हुर्रा एवं विजय वाघ, *जेरेनियम लाहुलेंसे* विजय वाघ और इम्तियाज हुर्रा (जेरेनिएसी), *हेन्केलिया अंबेलाटा* कांथराज और के नारायणन (जेस्नेरिएसी), और *एग्रोस्टिस बारिकाई* पी.

अग्निहोत्री और डी. प्रसाद (पोएसी), साईकेड की नई प्रजाति: *साइकस दिव्यदर्शिनी* खुराईजम और रीता सिंह। लाइकेन में नई प्रजातियां हैं: *हुरिएला उप्रेतियाना* एस.वाई. कोंद्र. एवं अन्य (टेलोसिस्टेसी), *मायरियोस्पोरा हिमालयेंसिस* जी.के. मिश्रा एवं अन्य (एकारोस्पोरेसी), और *क्रेटरिया रुब्रम* आर. नगंगोम एवं अन्य (कैलिसिएसी)।

वानस्पतिक अन्वेषणों से भारत में पौधों और शैकों के कई नवीन वितरण संबंधी रिकॉर्ड भी सामने आए। विशेषकर पुष्पीय पौधे की एक प्रजाति, ब्रायोफाइट्स की तीन प्रजातियां और शैक की 22 प्रजातियों को भारत में नए भौगोलिक वितरण रिकॉर्ड के रूप में सूचित किया गया था।

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हिमाचल प्रदेश से एकत्र किए गए *जुनिपेरस कम्युनिस* किस्म *सैक्सटिलिस*, *जु. इंडिका* एवं *जु. सेमीग्लोबोसा* के आवश्यक तेल के अर्कों की डीपीपीएच मुक्त रेडिकल स्केवेंजिंग एसे के माध्यम से, एस्कॉर्बिक एसिड को कंट्रोल की भांति उपयोग करते हुए, एंटीऑक्सिडेंट गतिविधि के लिए जांच की गई। डीपीपीएच एसे ने *जु. सेमीग्लोबोसा* की बेरी में उत्कृष्ट स्केवेंजिंग गतिविधि (IC₅₀ 369.13 माइक्रोग्रा/ग्रा) का खुलासा किया जिसका भविष्य में चिकित्सीय उद्देश्यों के लिए उपयोग किया जा सकता है। पांच शैक प्रजातियों (*क्लैडोनिया रेंजिफेराईना*, *परमोट्रेमा नीलघेरेंसे*, *रैमालाइना कंडुप्लिकेन्स*, *स्टीरियोकॉलोन फोलियोलोसम* और *अस्निया लॉन्गिसिमा*) के विभिन्न विलायकों में कच्चे अर्क के सूक्ष्मजीवरोधी और एंटीऑक्सिडेंट अध्ययन ने *अस्निया लॉन्गिसिमा* अर्क में क्रमशः 0.5 और 0.7 मिलीग्राम/मिली की न्यूनतम निरोधात्मक सांद्रता पर महत्वपूर्ण निरोधात्मक गतिविधि प्रदर्शित की।

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‘भारत के संकटग्रस्त पौधों के संरक्षण’ पर शुरू की गई नई बहु-संस्थागत परियोजना के तहत सीएसआईआर-एनबीआरआई ने पश्चिमी घाट के तमिलनाडु और केरल के हिस्सों में खोज और संग्रह हेतु दौरा किया और संकटग्रस्त पौधों की 10 प्रजातियों को एकत्र किया। संकटग्रस्त पौधों की 100 लक्षित प्रजातियों के संरक्षण

मूल्यांकन, डीएनए-बारकोडिंग, सूक्ष्म और स्थूल प्रसार तकनीक, पारिस्थितिक निश मॉडलिंग (ईएनएम) और आईयूसीएन आंकलन के लिए मानक संचालन प्रक्रियाएं (एसओपी) तैयार की गई हैं। इसके अतिरिक्त, संकटग्रस्त पौधों की सभी लक्षित प्रजातियों के लिए द्वितीयक डेटा संग्रह कार्य को पूरा कर लिया गया है। *इफेड्रा फोलिएटा* (400 स्टेम कटिंग), *क्लिस्टेन्थस कॉलिनस* (100 स्टेम कटिंग), *इंडोपिप्टाडेनिया ओडेन्सिस* (100 स्टेम कटिंग), *साइकस सेशाचलमेंसिस* (30 बीज), *साइकस स्फेरिका* (30 बीज), *साइकस बेडोमी* (30 बीज) जैसे संकटग्रस्त पौधों को स्थूल-प्रसार तकनीकों का उपयोग करके गुणित किया गया। टेरेडोफाइट और ब्रायोफाइट की संभावित प्रजातियों के लिए भी संरक्षण और प्रसार के तरीके विकसित किए गए। प्राकृतिक आवास में बहाली के लिए *साइथिया स्पाइनुलोसा* के लगभग 50 बीजाणुदिभदों के बड़े पैमाने पर इन-विट्रो गुणन के लिए प्रोटोकॉल बनाया गया। *साइथिया जाइगोटिया* में बीजाणु जीवन क्षमता, अंकुरण प्रतिशत और युग्मकोदिभद के विकासात्मक स्वरूप पर इन विट्रो अध्ययन शुरू किया गया। बड़े पैमाने पर *टेरेडोफाइट्स* की 13 सजावटी प्रजातियों के 1100 पौधों का प्रसार किया गया। कीटनाशक प्रोटीन के लिए एक संभावित स्रोत *टेक्टेरिया कोडुनाटा* का भी बड़े पैमाने पर प्रसार किया गया। फर्न हाउस में लुप्तप्राय प्रजातियों सहित फर्न की लगभग 67 प्रजातियों को संरक्षित किया गया है। एक संभावित औषधीय मॉस प्रजाति, *रोडोब्रायम रोसियम* के बड़े पैमाने पर प्रसार के लिए पौधे के तने के शीर्षस्थ भागों के इन विट्रो संवर्धन के माध्यम से एक प्रोटोकॉल मानकीकृत किया गया।

v k k foKku] i kni j l k u , oamRi kn fodk

प्रमुख अनुसंधान एवं विकास गतिविधियों में पारंपरिक और नैनो-जैवप्रौद्योगिकी दृष्टिकोणों के माध्यम से औषधीय, सुगंधित और अन्य आर्थिक हितों के संभावित पादप संसाधनों के जैव रासायनिक, औषधीय और भेषज पूर्वक्षण और मूल्यांकन शामिल थे। इस तरह के अनुसंधान एवं विकास का मुख्य उद्देश्य देशज पौधों और उनसे संबद्ध पारंपरिक ज्ञान से वैज्ञानिक रूप से मान्य हर्बल/प्राकृतिक उत्पादों और प्रौद्योगिकियों का विकास करना है। अन्य सेवाओं के



रूप में औषधीय पौधों के लिए फार्माकोपिया मानकों का विकास और आईएसओ-17034-2016 की आवश्यकताओं के अनुसार प्रमाणित संदर्भ सामग्री (सीआरएम) और संदर्भ सामग्री (आरएम) को तैयार किया जाता है। इस क्षेत्र में उपलब्धियों के मुख्य अंश निम्नलिखित हैं:

m | kxk ds fy, l hvkj, e@v kj, e dk fodkl , oa D; w kj, e dh igpku

तीन सीआरएम (यूजेनोल, (+) लिमोनीन एवं जेरेनिओल) तथा एक आरएम (मेथिल शेविकोल) को ISO-17034-2016 की आवश्यकता के अनुरूप तैयार किया गया। एक संदर्भ सामग्री निर्माता के रूप में संस्थान के एनएबीएल-प्रत्यायन को सक्षम करने हेतु गुणवत्ता प्रणाली के प्रलेखन और कार्यान्वयन से संबंधित सभी आवश्यक गतिविधियों का किया गया।

i kskal s [k] , oavk kxd j t d

पीले, लाल, हरे और गहरे भूरे खाद्य रंगों को क्रमशः टैगेटस इरेक्टा (फूल), हिबिस्कस रोजा-साईनेंसिस (फूल), इकोर्निया क्रैसिपस (पत्तियाँ) और एलियम सेपा (लाल बाहरी त्वचा) से विकसित किया गया।

Hskt eW; kdu v k v k k r v / ; ; u

भारत में स्वदेशी चिकित्सा पद्धतियों में उपयोग किए जाने वाले एक महत्वपूर्ण औषधीय पौधे, बर्बरिस लाइसियम (जड़) में बर्बरिन और पामेटीन की चयापचय भिन्नता का विश्लेषण एचपीटीएलसी-यूवी पद्धति के माध्यम से किया गया। शुष्क भार के आधार पर पामेटीन और बर्बरिन क्रमशः 0.117 से 0.739% और 0.203 से 1.134% तक भिन्न पाए गए। चयापचय सामग्री(ओं) के क्लस्टर विश्लेषण के आधार पर, एक विशिष्ट नमूने NB-03 को औद्योगिक अनुप्रयोगों के लिए सर्वोत्तम गुणवत्ता वाले कच्चे माल (क्यूआरएम) के स्रोत के रूप में पहचाना गया।

भारत में विभिन्न पादप-भौगोलिक क्षेत्रों से एकत्र किए गए कॉस्टस स्पेशियोसस और हेमेडिस्मस इंडिकस के नमूनों की रासायनिक रूपरेखा के अध्ययन के परिणामस्वरूप दो विशिष्ट रसायन-प्ररूपों: कॉस्टस स्पेशियोसस से डायोसजेनिन (2.405%, सूखे वजन के आधार पर) की

अधिकतम मात्रा युक्त एनबीसीएस-88, और हेमेडिस्मस इंडिकस से वैनिलिन (0.0127%, सूखे वजन पर) की अधिकतम मात्रा युक्त एनबीएच-35 की पहचान हुई।

मोमोर्डिका डायोका के फलों के अर्क की डेंसिटोमेट्रिक हाई परफोर्मेस थिन लेयर क्रोमैटोग्राफी (एचपीटीएलसी) द्वारा मात्रात्मक विश्लेषण आरएफ मूल्य 0.44 ± 0.04 पर कैफिक एसिड की उपस्थिति दर्शाता है।

इन-विट्रो आंकड़ों ने एम. डायोका के सृजन रोधी, एंटी-ऑक्सीडेंट और मधुमेहरोधी गुणों को दिखाया और विभिन्न फार्मूलों में प्रजाति के उपयोग की संभावना को इंगित किया।

असम के छह कृषि-जलवायु क्षेत्रों से एकत्र किए गए क्षुद्र कीटनाशक पौधों, आर्जीमोन मेक्सिकाना (एनबीए22/एफ1) और धतूरा मेटेल (एनबीए/18/डी1) में एचपीटीएलसी मात्रात्मक विश्लेषण किया गया। आर्जीमोन मेक्सिकाना में जैव-अणु, बर्बरिन और सेंग्युनारिन, और डी. मेटेल में एट्रोपिन और स्कोपोलामाइन की मात्रा निर्धारित की गई।

टेरोस्पर्मम लैसीफोलियम के अर्क (पीएलई) को चूहों में एन-नाइट्रोसो डाईएथिल एमीन (एनईडीए) प्रेरित लीवर विषाक्तता में सीरम जैव रासायनिक मार्करों जैसे एएलटी, एएसटी, जीजीटी, एएलपी के संभावित अवरोधक के रूप में दिखाया गया।

मैंगिफेरा इंडिका, लीची चिनेंसिस, साइट्रस रेटिकुलाटा, एगल मार्मेलोस और मूसा पैराडिसियाका से चयनित कृषि अपशिष्टों की एंटीऑक्सीडेंट क्षमता का प्रायोगिक मॉडल में अध्ययन किया गया।

ekudh-r Hkx ds ' ksku c k w k l y dk fodkl

एक शोधन प्रोटोकॉल विकसित किया गया और पारंपरिक फॉर्मूलेशन और उनके एसओपी तैयार किए गए और कैनाबिस सैटाईवा की पत्तियों के आवश्यक तेलों के पादप-रासायनिक और जैविक अध्ययनों के माध्यम से मूल्यांकन किया गया। आवश्यक तेल में मौजूद मुख्य घटक हैं: हुमुलीन, β -सेलीनीन, β -बिसाबोलीन, ट्रांस- α -बिसाबोलीन, कैरियोफिलीन ऑक्साइड, हुमुलीन एपोक्साइड 2, बिसाबोलोल एवं नैपथलीन। एचपीएलसी-पीडीए का उपयोग करके कैनाबिनोइड्स के

मात्रात्मक विश्लेषण के लिए विधि को अनुकूलित और स्थापित किया गया।

gcZy uSik t S&ckS kfxdh

चांदी के जैव संश्लेषित नैनोकणों और जिंक ऑक्साइड नैनोकणों ने सीडियम गुआजावा की पत्तियों के अर्क का उपयोग करते हुए एलएएस-आरएचएल रेगुलोन के माध्यम से स्यूडोमोनास एरुगिनोसा पीएओ1 में बेहतर एंटी-कोरम सेंसिंग और एंटी-बायोफिल्म गतिविधियों का प्रदर्शन किया।

fodfl r gcZy mRi kn

gcZy gM l SltWbt j

सीएसआईआर के सामाजिक उत्तरदायित्व कार्यक्रम के तहत, सीएसआईआर-एनबीआरआई ने कम लागत वाले हैंड सैनिटाइजर की एक श्रृंखला विकसित की है जो आसानी से छोटे पैमाने पर निर्मित होते हैं। एनबीआरआई ने अल्कोहल मुक्त और अल्कोहल आधारित दोनों ही प्रकार के हर्बल हैंड सैनिटाइजर विकसित किए। कोविड-19 की पहली और दूसरी लहर के दौरान पूरे लखनऊ में फ्रंटलाइन योद्धाओं को 1200 लीटर से अधिक हैंड सैनिटाइजर वितरित किया गया।

gcZy eKd LV1 fjMi Wj&fuR k

‘नित्या’ एक अभिनव हर्बल उत्पाद ‘मास्क स्ट्रेस रिड्यूसर’ है जो लंबे समय तक फेस मास्क पहनने के कारण सांस लेने में तकलीफ (जकड़न, नाक में अत्यधिक नमी, चक्कर आना) को कम करता है। नित्या को पारंपरिक रूप से ज्ञात तीन आवश्यक तेलों और बेस ऑयल को मिलाकर तैयार किया गया।

दोनों उत्पादों की प्रौद्योगिकियों को बाजार में व्यापक उपलब्धता के लिए विभिन्न स्टार्टअप और स्वास्थ्य कंपनियों को हस्तांतरित किया गया है।

ikjáfjd dk<k

इस पॉलीहर्बल उत्पाद को आयुष के दिशा-निर्देशों के तहत विकसित किया गया था। इसमें गले में खराश, खांसी और छींकने के शुरुआती लक्षणों को कम करने

की क्षमता है। यह शरीर को डिटॉक्सिफाईड, स्वस्थ और तरोताजा रखने के लिए भारतीय पारंपरिक चिकित्सा पर आधारित एक शक्तिशाली फोर्मूलेशन है। इस उत्पाद को एक कप दूध/चाय/गुनगुने पानी में 1-2 बूंद डाल कर आसानी से उपयोग कर सकते हैं।

ikni ikjflFkrdh , oai ; kZj. kx rduhd

इस अनुसंधान एवं विकास क्षेत्र में पारिस्थितिकी, पर्यावरण, पादप-सूक्ष्मजीव संबंधों और जलवायु परिवर्तन से संबंधित निम्नलिखित विषयगत क्षेत्रों पर अनुसंधान केंद्रित है:

ikni ikjflFkrdh , oai ; kZj. kx rduhd

अनुसंधान के व्यापक क्षेत्रों में शामिल हैं: वायु प्रदूषण और जलवायु परिवर्तन की प्रतिक्रिया में पादप पारिस्थितिकी-शारीरिक और जैव रासायनिक प्रक्रियाएं; वन पारिस्थितिकी तंत्र का संरचनात्मक और कार्यात्मक विश्लेषण, वन जैवभार एवं वन कार्बन पृथक्करण; बिगड़े हुए पारिस्थितिक तंत्रों और संकटग्रस्त पौधों की बहाली/पुनर्वास; ईआईए/सीआईए, पारिस्थितिक और जलवायु परिवर्तन मॉडलिंग, जैव संसाधन मानचित्रण और जीआईएस के लिए नई विधियों का विकास करना; जैविक और अजैविक एजेंटों को नियोजित करते हुए चावल में आर्सेनिक विषहरण तंत्र; तथा पर्यावरणीय मैट्रिक्स में जहरीले और रोगजनक एजेंटों की निगरानी और मूल्यांकन। वर्ष के दौरान प्रमुख शोध एवं विकास गतिविधियां इस प्रकार हैं:

ok q çnWk k , oa t yok q ifjorZi ds çfr ikni çfrfØ; k

एक मुक्त वायु ओजोन सांद्रता संवर्धन (O₃-एफएसीई) में ल्यूसेना ल्यूकोसेफला के प्रकाश संश्लेषक लक्षणों और एंटी-ऑक्सीडेटिव रक्षा प्रणाली पर उच्च ओजोन (सामान्य परिवेश से 20 पीपीबी अधिक) के दीर्घकालिक जोखिम के प्रभाव का अध्ययन किया गया। ल्यूसेना ल्यूकोसेफला ने प्रारंभिक अनावृत्ति (12 महीने तक) के दौरान O₃ के प्रति अधिक संवेदनशीलता प्रदर्शित की, लेकिन दूसरे वर्ष के अंत तक मध्यम सहनशीलता दिखाई। eO₃ स्थितियों के तहत उगाई जाने वाली ल्यूसेना ल्यूकोसेफला पत्तियों में दृश्यमान O₃ चोटें पाई गईं। उच्च ओजोन के संपर्क



में आने के बाद कुल प्रकाश संश्लेषण, प्रकाश संश्लेषक रंजक और लिपिड पेरोक्सीडेशन काफी कम हो गए थे, जबकि उच्च ओजोन के संपर्क के 12 महीनों के बाद रंध्र संवाहकता और वाष्पोत्सर्जन दर में काफी कमी आई। उच्च ओजोन के संपर्क में आने के बाद एंटीऑक्सिडेंट एंजाइमेटिक गतिविधियों (कैटालेस, एस्कॉर्बेट पेरोक्सीडेज और ग्लूटाथियोन रिडक्टेस), और एस्कॉर्बेट में काफी वृद्धि हुई।

इसी तरह के एक अध्ययन में, जब गेहूं की सहिष्णु और संवेदनशील किस्मों को O₃, CO₂ और उच्च तापमान की सामान्य परिवेश और भविष्य की संभावित सांद्रताओं के संपर्क में लाया गया था, तो यह अनुमान लगाया गया था कि भविष्य में O₃, CO₂ और उच्च तापमान की सांद्रता में गेहूं की एचडी 2967 किस्म की खेती सबसे अधिक प्रभावित होगी जबकि डीबीडबल्यू 184 किस्म सबसे कम प्रभावित होगी।

Xokj dh 'kjdrrk ruko t foch

ग्वार (सायमोप्सिस टेद्रागोनालोबा) में सूखे की स्थितियों के तहत कार्बन और नाइट्रोजन चयापचय एंजाइमों के नियमन का अध्ययन किया गया। अध्ययनों से पता चलता है कि सूखे के दौरान ग्वार की किस्मों में ग्लूकोज के स्तर में काफी वृद्धि हुई। ग्वार में एसिटाइलटास्फेरेज की जीन अभिव्यक्ति उच्च-नियंत्रित थी, जिससे जो पीईपी-सी द्वारा ट्राइकार्बॉक्सिलिक अम्ल (टीसीए) चक्र में पाइरुवेट के माध्यम से ग्लाइकोलाइटिक मार्ग से कार्बन के स्थानांतरण का संकेत प्राप्त होता है। अध्ययन से यह भी पता चला है कि टीसीए चक्र का एक प्रमुख नियामक एंजाइम आइसोसाइट्रेट डिहाइड्रोजनेज (आईसीडीएच) सूखे के तनाव के दौरान निम्न-नियंत्रित रहा। ग्लूटामाइन सिंथेटेज (जीएस), ग्लूटामेट सिंथेज (जीओजीएटी) और नाइट्रेट रिडक्टेस (एनआर) के जीन अभिव्यक्ति स्तर को सूखे के दौरान ग्वार में निम्न-नियंत्रित रहे, जिससे नाइट्रोजन चयापचय के लिए ऊर्जा प्रवाह सीमित हो गया।

ou ikjflfkrdh ræ dk ljpukred vls dk kred fo'yšk k

सिमिलीपाल बायोस्फीयर रिजर्व, ओडिशा के सूखे, पर्णपाती

और नम पर्णपाती वन प्रकारों में पादप-सामाजिक विश्लेषण पर एक अध्ययन शुरू किया गया था। तीन प्रकार के वनों में 37 परिवारों की 78 जातियों से संबंधित कुल 95 वृक्ष प्रजातियों को दर्ज किया गया था। नम सिमिलीपाल बाघ अभयारण्य क्षेत्र का लगभग 35-40% क्षेत्र पर्णपाती वन में शामिल है और खुली से लेकर बहुत घनी वृक्ष कैनोपी के लिए एलएआई मूल्यों की अधिकतम सीमा को दर्शाता है।

i ; kbj.kt çHko vkdyu ds rjhd

इस वर्ष “हिमालयी नदियों में व्यापक हस्तक्षेपों के लिए संचयी प्रभाव मूल्यांकन” के विकास पर एक नया अध्ययन शुरू किया गया। संचयी प्रभाव मूल्यांकन कार्यप्रणालियाँ शोधकर्ताओं, योजनाकारों और प्रशासकों को नदियों में हस्तक्षेपों के संचयी प्रभाव मूल्यांकन के लिए कल्पना करने, समझने, विश्लेषण करने और निर्णय लेने में मदद करेगी।

सेलेनियम (Se), जो पौधों में आर्सेनिक (As) विषाक्तता का एक ज्ञात विरोधी है, आर्सेनिक तनाव में सुधार करता है और चावल के पौधों में कोशिका भित्ति और झिल्लियों के विघटन की मरम्मत करता है। सेलेनियम चावल में आर्सेनिक तनाव का मुकाबला करने के लिए आर्सेनिक ट्रांसपोर्टर जीन के साथ-साथ सल्फेट ट्रांसपोर्टर्स, SULTR3; 1 और SULTR3; 6 की अति-अभिव्यक्ति द्वारा आर्सेनिक संचय को कम करता है।

प्रयागराज (इलाहाबाद) में महा-कुंभ 2013 के दौरान, गंगा जल के भौतिक-रासायनिक मापदंडों में गिरावट आई, सूक्ष्मजैविक विविधता कुंभ पूर्व मौजूद 27 जातियों से संबंधित 40 जीवाणु प्रजातियों से बढ़कर 43 जातियों से संबंधित 112 जीवाणु प्रजातियां हो गईं।

l fet foch rduld

यह समूह व्यावसायिक रूप से मूल्यवान फसलों के रोग प्रबंधन और पर्यावरण के अनुकूल स्थायी उपचार विकसित करनेय जैविक नियंत्रण, पादप सूक्ष्मजीव संबंध और सॉडिक मृदा सुधारय कृषि भूमि और तनावग्रस्त मृदा दोनों ही के लिए किफायती और कुशल जैव-इनोक्यूलेंट फॉर्मूलेशन के विकास के माध्यम से खाद्य सुरक्षा और पर्यावरण की सुरक्षा; और विभिन्न फसली पौधों में सूक्ष्म जीव की मध्यस्थता वाले अजैविक और जैविक तनाव सहिष्णुता के

आणविक तंत्र/तंत्रों की व्याख्या पर ध्यान केंद्रित करता है। प्रमुख अनुसंधान एवं विकास कार्य निम्नलिखित हैं:

स्यूडोमोनास पुटिडा (Δppx) के एक्सोपॉलीफॉस्फेटस म्यूटेंट जिसमें उच्च फॉस्फेट संचय क्षमता होती है, को नॉकआउट म्यूटेजेनेसिस के माध्यम से उत्पन्न किया गया। फॉस्फेट की अत्यधिक कमी की स्थिति में *एरबिडोप्सिस थैलियाना* में Δppx के टीकाकरण ने जंगली प्रभेद और असंक्रमित पौधों की तुलना में काफी अधिक फली निर्माण एवं और शुष्क वजन प्रदर्शित किया।

चावल में आर्सेनिक तनाव में सुधार करने वाले जीवाणुओं में सिलिकॉन (Si) की भूमिका का पता लगाया गया। चावल में सिलिकॉन की मध्यस्थता से आर्सेनिक विषहरण के दौरान भूसी और दानों में कम आर्सेनिक ग्रहण, और पौधों की वृद्धि में सुधार देखा गया।

चावल के भूसे के त्वरित अपघटन के लिए एक सूक्ष्मजीवी फार्मूलेशन विकसित किया गया। परिणामों से पता चला कि नियंत्रण उपचार की तुलना में इनोकुलेशन उपरांत 20–30 दिनों के भीतर संरचनात्मक क्षति शुरू हुई एवं तीन महीने के बाद पूर्ण विघटन हुआ।

Zn घुलनशीलता, सिडेरोफोर और कार्बनिक अम्ल उत्पादन के आधार पर, चार सूक्ष्मजीवों *बैसिलस प्यूमिलस*, *स्यूडोमोनास पुटिडा*, *स्यूडोमोनास* प्रजाति और *स्यूडोमोनास फ्लोरेसेंस* की पहचान की गई है, और चावल की विभिन्न किस्मों में आयरन और जिंक बायोफोर्टिफिकेशन के लिए मूल्यांकन किया गया।

जैव-कवकनाशी, *बैसिलस सबटिलिस* NBRI-W9 (W9) टीकाकरण ने अपनी अन्तः पादपीय विविधता में सुधार करके, रासायनिक कवकनाशी प्रोपियोकोनाजोल (PCZ) उपचारित टमाटर के पौधों की तुलना में आशाजनक प्रभाव दिखाया।

पेपरमिंट के तेल पर आधारित एक नैनोइमल्शन (पीएनई) को संश्लेषित किया गया, जो टमाटर में अर्ली ब्लाइट रोग प्रबंधन के लिए रासायनिक कवकनाशी की तुलना में अधिक प्रभावी पाया गया।

ओक्रोबैक्ट्रम प्रजाति (NBRI6) का *जिया मेज* में इनोकुलेशन जल तनाव की स्थिति में होमोस्टैसिस को

बनाए रखने में कई भूमिकाएँ निभाता है और सूखे के हानिकारक प्रभाव को कम करता है एवं विकास को बढ़ावा देता है।

आर्थिक महत्वपूर्ण फसलों को संक्रमित करने वाले नए विषाणुओं की पहचान, लक्षण वर्णन और विविधता विश्लेषण तथा पादप विषाणुओं का शीघ्र पता लगाने के लिए कुशल, तीव्र ऑन-साइट नैदानिक उपकरणों के विकास के लिए कार्य शुरू किया गया है।

i ; k; .k; rduhd

समूह के अनुसंधान एवं विकास के प्रमुख क्षेत्रों में शामिल हैं: कृषि के जल-मृदा-फसल निरंतरता के संबंध में मृदा प्रदूषकों/संदूषकों की निगरानी और मूल्यांकन; फसलों/सब्जियों में प्रदूषकों के संदूषण को दूर करने के लिए प्रौद्योगिकियों का विकास; मृदा में सूक्ष्मप्लास्टिक अलगाव और लक्षण वर्णन; धातु उपचार और फसल उत्पादकता बढ़ाने हेतु बायोचार। वर्ष के दौरान की प्रमुख उपलब्धियों इस प्रकार हैं:

गंगा-मेघना-ब्रह्मपुत्र बेसिन में उत्तर प्रदेश के आर्सेनिक-प्रवण जिलों में आर्सेनिक प्रदूषण की निगरानी और मूल्यांकन, तथा सिंचाई भूजल के नमूनों, कृषि मिट्टी के नमूनों और विभिन्न खाद्य फसलों और सब्जियों की फसल उपज में आर्सेनिक का आंकलन जारी है। उत्तर प्रदेश के बाराबंकी जिले के औद्योगिक क्षेत्र में सूक्ष्मजैविक उपचार प्रौद्योगिकी का उपयोग कर हेक्साक्लोरोसायक्लोहेक्सेन (एचसीएच) डंपसाइट के सुधार पर अध्ययन प्रगति पर है।

कृषि/आसवन अपशिष्ट से पाइरोलाइज्ड बायोचार के उत्पादन और मिट्टी से आर्सेनिक और अन्य जहरीली धातुओं जैसे दूषित पदार्थों को सोखने के संभावित अनुप्रयोग के लिए इसके लक्षण वर्णन पर कार्य प्रगति पर है।

vk k;pd t ;odh , oat ;k;S k;fxdh

आणविक जैविकी और जैवप्रौद्योगिकी में अनुसंधान और विकास का मुख्य ध्यान उपज और गुणवत्ता के लिए विभिन्न आनुवंशिक निर्धारकों को समझना एवं किसानों और उपभोक्ताओं के लाभ के लिए पौधों के जींस का उपयोग करके उन्नत उपज और गुणवत्ता के लिए बेहतर पौधों की



किस्मों को विकसित करना है। इन उद्देश्यों को पूरा करने के लिए विभिन्न फसलों पर जीन-खनन, ट्रांसजेनिक पौधों के विकास और जीनोम-संपादन प्रौद्योगिकियों का उपयोग किया जा रहा है। वर्ष के दौरान की प्रमुख उपलब्धियां निम्नलिखित हैं:

दिलचस्प बात यह देखी गई कि GhHDA5 के साथ सकारात्मक रूप से सह-व्यक्त जीन ने HDA6 और SUVH1 के साथ एक प्रोटीन इंटरैक्शन तंत्र प्रदर्शित किया।

पिछले अध्ययनों में कपास रेशों के विकास के आरंभ में एचडीए5 की भूमिका स्थापित की गई थी। दिलचस्प बात यह देखी गई कि GhHDA5 के साथ सकारात्मक रूप से सह-व्यक्त जीन ने HDA6 और SUVH1 के साथ एक प्रोटीन इंटरैक्शन तंत्र प्रदर्शित किया।

कपास के रेशों के विकास में SUVH1 जीन की भूमिका का पता लगाने के लिए सभी अति-व्यक्त, एंटीसेंस और मिर्क-टैग ट्रांसजेनिक लाइनों के आणुविक लक्षण वर्णन की प्रक्रिया चल रही है।

दो प्रमुख जीनों, सेल्फ-प्रुनिंग (GhSP) और सिंगल फलावर ट्रांस (GhSFT), ने *गॉसिपियम हिर्सुटम* में क्रमशः कायिक वृद्धि (अनिर्धारित) और पुष्पन अवस्था में संक्रमणकाल (निर्धारित अवस्था) को प्रेरित किया। निर्धारित/अर्ध-निर्धारित वृद्धियों और तुल्यकालिक पुष्पन प्राप्त करने के लिए, कोकर 312 (*गॉसिपियम हिर्सुटम*) से दोनों जीनों (ए और डी उप-जीनोम दोनों) के जीन और प्रमोटर को क्लोन और अनुक्रमित किया गया है और आगे के अध्ययन के लिए उपयोग किया जाएगा।

कॉटन MYB1 ट्रांसक्रिप्शन फैक्टर (TF) ने एंथेसिस के 19 दिनों (DPA) पर द्वितीयक कोशिका भित्ति जैव संश्लेषण अवस्था के दौरान उच्च अभिव्यक्ति दिखाई। रेशों की कोशिकाओं में CRISPR/Cas9-आधारित संपादन के प्रभाव का अध्ययन करने के लिए कपास के पौधों का स्थिर परिवर्तन किया जाएगा। माइक्रोआरएनए 828 ए-एन्कोडेड पेप्टाइड्स (miPEP828a1 एवं miPEP828a2) ने कपास बीजांड संवर्धन में रेशों के विकास को प्रभावित किया।

पूर्ण नर बंध्यता प्राप्त करने और F1 संकर कपास में पुरुष बंध्यता को उलटने के लिए, एराबिडोप्सिस BECLIN1 और COP1 जीन को कपास के पौधों के परागकोष के टेपेटम में

व्यक्त किया गया। इस शोध का उद्देश्य मार्कर-असिस्टेड बैकक्रॉसिंग (एमएबीसी) के माध्यम से ट्रांसजेनिक कपास से व्यावसायिक कपास संकरों के एलीट पैतृक लाइन्स तक पुरुष बंध्यता के स्थानांतरण के लिए एक प्रणाली स्थापित करना है ताकि इसके आर्थिक लाभों का फायदा उठाया जा सके।

पराग परिवर्तन के माध्यम से ट्रांसजेनिक कपास का विकास प्रगति पर है। कृत्रिम आहार पर *पेक्टिनोफोरा गोसीपियेल्ला* संवर्धन स्थापित किया गया। एफिड टॉलरेंस के लिए पीसीडी प्रमोटर के नियमन के तहत कीटनाशक प्रोटीन Dhi31 को व्यक्त करने वाली छह पुटेटिव ट्रांसजेनिक कपास लाइनों का विकास प्रगति पर है।

GhNAC2 जीन को व्यक्त करने वाले कपास के पौधों (पांचवीं पीढ़ी) ने नियंत्रित पौधों की तुलना में बढ़े हुए आकार, वजन और संख्या के साथ अधिक मजबूत वृद्धि और अधिक फलन दिखाया। रोमिल जड़ों में प्रमोटर अध्ययन विभिन्न हार्मोनों के नियंत्रण में विनियमन के साथ जड़ों की नोकों, बढ़त क्षेत्र और पार्श्व जड़ प्रिमोर्डिया में अभिव्यक्ति प्रदर्शित की।

पेक्टिन मिथाइलएस्टरेज (PME) पेक्टिन को एस्ट्रिफाइड करते हैं और इस प्रक्रिया में मेथनॉल छोड़ते हैं जो कि कीटों के लिए विषाक्त है। *विथानिया सोमिफेरा* से पृथक एक PME जीन WsPME29 जैविक तनाव के दौरान शीघ्र प्रेरित और अत्यधिक जैव सक्रिय पाया गया। रचनात्मक और प्रेरक प्रमोटरों के तहत WsPME29 को व्यक्त करने वाले ट्रांसजेनिक कपास के पौधों ने, क्रमशः चौथे दिन और छठे दिन, चबाने वाले (*स्प्योडोप्टेरा लिटुरा* और *हेलिकोवर्पा आर्मिजेरा*) और रस चूसने वाले (एफिड और व्हाइटपलाई) कीटों के खिलाफ 75–85% मृत्यु दर प्रदर्शित की।

जड़ वृद्धि और ओज संबंधी पादप तनाव प्रतिक्रियाओं में सुधार करने के लिए, जड़ों में व्यक्त होने वाले दो ट्रांसक्रिप्शन फैक्टरों HSF और WRKY की CRISPR लाइनों को सिंगल और डबल गाइड आरएनए का उपयोग करके विकसित किया गया है और अनुक्रमण के माध्यम से पुष्टि की गई। आगे की पीढ़ियों में जड़ों से जुड़े फेनोटाइप पर ध्यान देने के साथ पौधे की सम्पूर्ण वृद्धि के लिए पौधों का अध्ययन किया जा रहा है।

iKkadsfodkl , oavt Sod vls t Sod rulo ea 'lfey t hula dh igpku vls y{k k o. kzi

टमाटर से SIERF6 जीन को ABA-एथिलीन इंटरैक्शन को बदलता पाया गया और इस तरह फल पकने वाले प्रमुख नियामकों की अभिव्यक्ति को बदलता हुआ पाया गया। SIERF6 की अभिव्यक्ति और एंटीसेंस लाइनों पर किए गए अध्ययनों से पता चला है कि SIERF6 फलों के सेट के साथ-साथ फलों के विकास/पकने को नियंत्रित कर सकता है।

चावल में GSTU5 की अति-अभिव्यक्ति और नॉक-डाउन लाइनों ने OsABCC1 वेक्यूलर ट्रांसपोर्टर्स का उपयोग करते हुए जड़ में आर्सेनिक जब्तीकरण में इस जीन की भागीदारी को दिखाया।

OsHsp20 के कार्यात्मक लक्षण वर्णन ने आर्सेनिक तनाव को कम करने में इसकी भागीदारी भी दिखाई।

काबुली चने *CaCYP*, *CaMTD* और *CaWAT1* की अति-अभिव्यक्त लाइनों ने दिखाया कि *CaCYP* और *CaMTD* संभवतः सूखे के दौरान तनाव से संबंधित जीन की अभिव्यक्ति को विनियमित करके सूखा तनाव सहिष्णुता में शामिल होते हैं। हालांकि, *CaWAT1* जाहिर तौर पर सूखे के लिए पौधों की प्रतिक्रिया में शामिल नहीं था। *एराबिडोप्सिस* में सूखा और भारी धातु सहिष्णुता के लिए काबुली चने के मेटेलोथायोनिन (MT) और ग्लूटारेडॉक्सिन (*CaGrx*) जीन की पुष्टि की गई।

miR775 एक गैर-संरक्षित miRNA है जिसे केवल *एराबिडोप्सिस थैलियाना* में पहचाना गया है। miR775 की अति-अभिव्यक्त और नॉकआउट लाइनों ने दिखाया कि यह पर्णवृत्त की लंबाई बढ़ाकर और पत्ती के क्षेत्र को बढ़ाकर रोसेट के आकार को नियंत्रित करता है और पोस्ट ट्रांसक्रिप्शनल स्तर पर एक संभावित β -(1,3)-गैलेक्टोसिलट्रांसफेरेज जीन को लक्षित करता है। miR775 को UV-B और हाइपोक्सिया की प्रतिक्रिया के जवाब में अप-रेगुलेटेड भी पाया गया। यह निष्कर्ष *एराबिडोप्सिस थैलियाना* में वृद्धि और विकास को विनियमित करने में miR775 की भूमिका स्थापित करते हैं।

गुलाब में पंखुड़ी का झड़ना जैस्मोनिक एसिड (JA) और एथिलीन पथों के बीच परस्पर क्रिया द्वारा नियंत्रित होता पाया गया है जो एथिलीन के प्रति संवेदनशीलता को बदल देता है। अध्ययनों से पता चला है कि एथिलीन के प्रति संवेदनशीलता बढ़ाने के लिए जेए पाथवे जीनों में कमी आवश्यक थी जिसने गुलाब में फूलों के खुलने और पंखुड़ी के विच्छेदन को बढ़ावा दिया। JA से फूलों का उपचार करने से फूलों के खुलने के साथ-साथ विच्छेदन में भी देरी हुई जिससे JA या JA एनालॉग्स के उपयोग के साथ सुगंधित गुलाब के फूलों में विलंबित विच्छेदन हेतु रणनीतियों के संकेत मिले। RbPCD1pro में घाव प्रेरण को MYB प्रोटीन, जो गुलाब और अरेबिडोप्सिस के मध्य संरक्षित है, के द्वारा एक JA-स्वतंत्र तरीके से विनियमित किया गया।

CRISPR/Cas9 दृष्टिकोण का उपयोग करते हुए अति-अभिव्यक्त और संपादित लाइनों को विकसित करके द्वितीयक पादप उत्पादों के नियमन में शामिल प्रकाश नियामक घटकों (HY5 और COP) का कार्यात्मक विश्लेषण किया गया। miPEP (माइक्रोआरएनए एन्कोडेड पेप्टाइड) और पौधे की वृद्धि और विकास के नियमन में शामिल एक छोटे पेप्टाइड को *एराबिडोप्सिस थैलियाना* में विभिन्न पृष्ठभूमि में कई ट्रांसजेनिक लाइनों को विकसित करके कार्यात्मक लक्षण वर्णन किया गया।

HPT जीन परिवार का विकास बेसल यूडार्डकोट प्रतिनिधियों के माध्यम से मध्यस्थ कुछ द्विबीजपत्री और एकबीजपत्री HPT हस्ताक्षरों के समानांतर विकास की ओर संकेत करता है।

क्लाइमेक्टेरिक और नॉन-क्लाइमेक्टेरिक फलों में द्विघटक तंत्र मॉड्यूल के कामकाज ने दिखाया कि टीसीएस मॉड्यूल क्लाइमेक्टेरिक और नॉन-क्लाइमेक्टेरिक फलों के पकने के दौरान अलग-अलग काम करता है।

कपास के TLP जीन की पहचान की गई तथा लवण एवं सूखे के तनाव में उनकी भूमिका का अध्ययन किया गया, यह दिखाया गया कि GhTLP11A और GhTLP12A-1 ने इस बात का पुख्ता सबूत दिया कि सूखे और लवण तनाव के दौरान इन जीनों की प्रमुख भूमिका हो सकती है। लवण



तनाव में *निकोटियाना* के bHLH जीन पर एक अध्ययन में, पांच NtbHLH ने द्रुतशीतन तनाव प्रतिक्रियाओं के दौरान महत्वपूर्ण उच्च अभिव्यक्ति दिखाई। द्रुतशीतन तनाव की स्थिति के दौरान इन जीनों की महत्वपूर्ण भूमिका संभव हो सकती है।

कपास में कैलमोडुलिन बाइंडिंग ट्रांसक्रिप्शन एक्टिवेटर्स (CAMTAs) पर अध्ययन ने एम्प्लिकॉन डेटा से तीन CAMTA1 वेरिएंट (VS, V2, और VL) की पहचान की। जीनोमिक डीएनए पर वेरिएंट की मैपिंग से CAMTA1_VS और VL दोनों वेरिएंट में इंट्रोन रिटेंशन का पता चला। Col-0-VS ट्रांसजेनिक लाइनों के विश्लेषण ने उच्च रूट लेटरल के साथ-साथ उच्च एलआर घनत्व को दिखाया, जिससे यह संकेत मिले कि रूट लेटरल तनाव सहिष्णुता के दौरान महत्वपूर्ण हो सकते हैं।

हेटेरोसिस पर अन्तःपुनर्दुहराव के दौरान उप-जीनोम प्रभुत्व के प्रभाव को समझने के लिए, माता-पिता और उनके पारस्परिक F1 संकर में संपूर्ण-जीनोम अनुक्रमण किए गए। परिणाम इंगित करता है कि एक अंतःचक्र के दौरान, Col-0 का दोहराव C24 उप-जीनोम के दोहराव पर हावी हो जाता है।

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यह समूह औद्योगिक रूप से महत्वपूर्ण और ओर्फन फसलों में किस्मों के विकास के लिए आणुविक मार्करों, आनुवंशिक संसाधनों के निर्माण, लिंकेज विश्लेषण, एसोसिएशन मैपिंग और जीनोमिक्स असिस्टेड ब्रीडिंग के क्षेत्र में काम कर रहा है। इन पादप संसाधनों में सुधार, मुख्यधारा में लाना, घरेलू स्थितियों में पालन और सतत उपयोग पर इस समूह का प्रमुख बल है। इस वर्ष के प्रमुख अनुसंधान मुख्य अंश निम्नलिखित हैं:।

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द्वितीयक मेटाबोलाइट्स के आधार पर ओर्फन फली युक्त विंग्ड बीन (*सोफोकार्पस टेट्रागोनोलोबस*) की विभिन्न लाइनों के लिए छंटनी और चयन का कार्य जारी है। *सोफोकार्पस टेट्रागोनोलोबस* के परिपक्व बीजों में सोयाबीन के समान

15–18% तेल होता है। बीजों के आटे की अमीनो अम्ल संरचना में अपेक्षाकृत अधिक मात्रा में लाइसिन, एस्पार्टिक अम्ल, ग्लूटामिक अम्ल और ल्यूसीन और अपेक्षाकृत कम मात्रा में सल्फर युक्त अमीनो अम्ल पाया गया, जो सोयाबीन के समान एक पैटर्न है।

जनसंख्या संरचना और पारिवारिक संबंध विश्लेषण के लिए जीनोटाइपिंग बाय सीक्वेंसिंग (GBS) के माध्यम से विंग्ड बीन के जीनोम-वाइड एसोसिएशन स्टडीज (GWAS) किए गए। कुल 167845 टैग-युग्म (335690 टैग) उत्पन्न किए गए, और 80941 SNP की पहचान की गई। विश्लेषण के परिणामस्वरूप *सोफोकार्पस टेट्रागोनोलोबस* में बीज-प्रोटीन लक्षणों के साथ महत्वपूर्ण रूप से जुड़े 54 SNP और बीज-तेल लक्षणों के साथ 88 SNP की खोज हुई।

सटीक ओपियोड अनुमान के साथ अफीम में GWAS अध्ययन किए गए और इसके परिणामस्वरूप थीबेन पाथवे के साथ कुछ प्रमुख SNP और उनके संबंधित जीन प्राप्त हुए। कम THC और उच्च CBD के लिए भांग के सुधार हेतु एक प्रमुख पहल जारी है।

लिथोकार्पस डीअलबैटस के क्लोरोप्लास्ट जीनोम (161,476 बीपी) को संकलित किया गया है। जीनोम में एक बड़ा एकल-प्रतिलिपि क्षेत्र (90,732 बीपी) और एक छोटा एकल-प्रतिलिपि क्षेत्र (18,987 बीपी) होता है, जो दो उल्टे पुनरावृत्ति क्षेत्रों (25,879 बीपी) से अलग होता है। क्लोरोप्लास्ट जीनोम में 134 जीन होते हैं जिनमें 87 प्रोटीन-कोडिंग जीन, 39 टीआरएनए और 8 आरआरएनए शामिल हैं।

अलसी के संदर्भ जीनोम (IC 0526166) को ऑक्सफोर्ड नैनोपोरप्रोमेथियन और इलुमिना प्लेटफॉर्म का उपयोग करके तैयार किया गया। स्मार्ट डी नोवो असेंबली ने 10000 बीपी से अधिक आकार के कुल 671 कंटिग्स बनाए। उत्कृष्ट मात्रात्मक लक्षणों के लिए तीन द्वि-अभिभावकीय मानचित्रण आबादी को भी विकसित किया गया है और आरआईएल के गठन की ओर अग्रसर F3 पीढ़ी तक प्रगति की गई। आरआईएल के अलावा, MAGIC आबादी की पीढ़ी आगे बढ़ाई गई है।

गॉसिपियम हर्बेसियम की वागड किस्म में एथिल मीथेन सल्फोनेट (ईएमएस) मध्यस्थ TILLING (टार्गेटेड इन्ड्युस्ड लोकल लेसन इन जीनोम्स) आबादी को द्विगुणित कपास में कार्यात्मक जीनोमिक्स अध्ययन के लिए विकसित किया गया। न्यूक्लियोटाइड विविधता के मूल्यांकन के लिए टिलिंग आबादी से चुने गए 95 विविध एम 3 पौधों की नियंत्रण पौधों के साथ जीनोटाइपिंग-बाय-सीक्वेंसिंग की गई।

सीएसआईआर-एनबीआरआई, लखनऊ में फसल सुधार कार्यक्रमों के तहत उपयोग के लिए ग्रेन अमरन्थ (रामदाना) में आनुवंशिक और जीनोमिक संसाधनों को विकसित करने का प्रयास किया गया। भाकृअनुप-एनबीपीजीआर के विभिन्न केंद्रों से कुल 1165 पौध नमूने प्राप्त किए गए और सीएसआईआर-एनबीआरआई उद्यान क्षेत्र और बंधरा अनुसंधान स्टेशन में उगाए गए।

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वनस्पति उद्यान और इसकी कई संबद्ध इकाइयों और प्रायोगिक अनुसंधान केंद्र मुख्य रूप से पौधों की विविधता के संवर्धन और पौधों के विविध समूहों के संरक्षण तथा अनुसंधान, सौंदर्यशास्त्र, शिक्षा, जागरूकता और जनसम्पर्क गतिविधियों के लिए उनके प्रबंधन में लगे हुए हैं। इन गतिविधियों के प्रमुख उद्देश्यों में शामिल हैं: फूलों की लोकप्रिय फसलों की नई किस्मों का विकास; पौधों की विविधता का संवर्धन और विशिष्ट गृहों और क्षेत्र संरक्षण गृहों में पौधों के विविध समूहों का संरक्षण, उनका प्रसार और लक्षण वर्णन, जर्मप्लाज्म का डीयूएस परीक्षण; अनुकूलनीय पौधों और वृक्षों के माध्यम से सोडिक बंजर भूमि का विकास, उनका संरक्षण और परस्पर प्रतिक्रिया; सोडिक मिट्टी के लिए गैर-पारंपरिक आर्थिक पौधों का मूल्यांकन; सोडिक बंजर भूमि के सतत उपयोग के लिए विभिन्न औषधीय और सुगंधित पौधों की कृषि-प्रौद्योगिकी का मानकीकरण; जनन दृव्य के संरक्षण और बैकअप, पादप प्रसार प्रोटोकॉलों द्वारा अनुसंधान एवं विकास सहायता सेवाएं प्रदान करना; और कौशल विकास/जनसम्पर्क कार्यक्रम/विस्तार गतिविधियां।

पिछले वर्ष की तरह, कोविड-19 महामारी के दौरान लॉक डाउन ने नियमित बागवानी संचालन, पुष्प प्रदर्शनियों, और पौधों के भंडार के प्रबंधन और वनस्पति उद्यान के प्रायोगिक क्षेत्र/प्रयोगशाला कार्यों को काफी प्रभावित किया। इसने आगंतुकों की संख्या के साथ वनस्पति उद्यान संसाधनों एवं जनसम्पर्क गतिविधियों तक सार्वजनिक पहुंच को भी धीमा कर दिया है। हालांकि, लोगों और कर्मचारियों को महामारी से बचाने के लिए सभी एहतियाती और निवारक तरीके अपनाते हुए, बगीचे और संरक्षण गृहों में पौधों के संग्रह को अच्छी तरह से प्रबंधित किया गया और जारी तथा नवीन शोध गतिविधियों के लिए उपयोग किया गया। वर्ष के दौरान उपलब्धियां नीचे निम्नलिखित हैं:

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साइकस उद्यान को भारतीय प्रजातियों के लिए एक राष्ट्रीय संदर्भ केंद्र बनाने और संकटग्रस्त साइकस प्रजातियों के बचाव, पुनर्प्राप्ति और पुनर्वास के लिए एक्स-सीटू संरक्षण के लिए एक मॉडल बनाने हेतु समृद्ध किया गया।

कैना, ग्लेडियोलस, आइरिस और निम्फिया जैसी फूलों की फसलों की किस्मों के विकास के लिए प्रयोगों को डिजाइन किया गया है। पीपीवी एंड एफआरए के डीयूएस परीक्षण दिशानिर्देशों के आधार पर ग्लेडियोलस की 70 किस्मों, कैना की 20 किस्मों और बोगनविलिया की 10 किस्मों का रूपात्मक लक्षण वर्णन किया गया। ग्लेडियोलस, कैना, निम्फिया, रेनवर्डिया इंडिका जैसे सजावटी पौधों के सुधार के लिए संकरण और उत्परिवर्तन प्रजनन कार्य किया जा रहा है। कोलकाता की विभिन्न प्रामाणिक नर्सरीयों से गुलाब की 85 किस्मों को लाकर सीएसआईआर-एनबीआरआई रोज गार्डन में लगाया गया है। आंध्र प्रदेश के विभिन्न स्थानों से एकत्रित सजावटी, आर्थिक, संरक्षण महत्व की लगभग 16 प्रजातियों को सीएसआईआर-एनबीआरआई वनस्पति उद्यान में लगाया गया है और उनका रखरखाव किया गया है।

कुछ संकटग्रस्त पौधों जैसे टेरोकार्पस सैंटालाईनस, टेरोकार्पस मार्सुपियम, इंडोपिप्ताडेनिया अवधेन्सिस, हार्डविकिया बाईनाटा, एफेड्रा फोलिएटा, बैलियोस्पर्मम मोंटेनम, कमिफोरा कॉडाटा, कमिफोरा वाइटी, सराका



असोका, हिल्डेगार्डिया पोपुलीफोलिया, बोस्वेलिया ओवैलीओफोलिओलेटा, एडनैन्थेरा पावोनिया के बीज अंकुरण अध्ययन सफलतापूर्वक किए गए।

वनस्पति उद्यान में विषयगत उद्यानों, पौध गृहों, वृक्ष गृहों सार्वजनिक स्थलों में संरक्षित पेड़ों और झाड़ियों का एक डेटाबेस तैयार किया गया। प्रत्येक पेड़ और झाड़ी को जियो-टैग किया गया है और इस जानकारी का उपयोग सीएसआईआर वनस्पति उद्यान के वनस्पतियों के क्यूआर एम्बेडेड प्लान्ट लेबल के माध्यम से मूल्यांकन योग्य ऑनलाइन डेटाबेस की तैयारी के लिए किया जाएगा।

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सोडिक भूमि के लिए आर्थिक रूप से महत्वपूर्ण पौधों के संभावित जननदृव्य की पहचान करने और उनकी कृषि-प्रौद्योगिकी विकसित करने के लिए, क्विनोआ (चीनोपोडियम क्विनोआ) के 15 नमूनों, साइलियम या इसबगोल (प्लांटगो ओवाटा) के 27 नमूनों और नटग्रास या नागरमोथा (साइपरस स्कारियोसस) के 13 नमूनों का मूल्यांकन बंधरा में फील्ड जीन बैंक में किया गया। मूल्यांकन किए गए क्विनोआ जननदृव्य में PQ 5 को सबसे लंबा (123 सेमी), और PQ 11 को बड़े पुष्पक्रम (34 सेमी) और उच्च अनाज उपज (41.96 ग्राम/पौधा) युक्त पाया गया।

नीम की चार किस्मों के लिए ऊतक संवर्धन और क्लोनल प्रवर्धन तकनीकों का मानकीकरण किया गया। मुख्य फसल के रूप में नीम के साथ अंतर-फसली मॉडल को प्रदर्शन भूखंडों के रूप में विकसित किया गया था।

बंधरा रिसर्च स्टेशन पर ऐमारैथ जनन दृव्य संग्रह को ऐमारैथ (ए. हाइपोकोन्ड्रिआकस, ए. क्रुएंत्स, ए. कॉडैटस) के 1223 नमूनों से समृद्ध किया गया और कृषि संबंधी विभिन्न महत्वपूर्ण गुणवत्ता लक्षणों और लक्षण विशिष्ट लाइनों की पहचान के लिए उनका मूल्यांकन किया गया।

बंधरा में एकल और दोहरे प्रकार के फूलों सहित ट्यूबरोस (पोलिएन्थेस ट्यूबरोसा) की लगभग 30 किस्मों को एकत्र किया गया है और लगाया गया है। नई उत्परिवर्ती

किस्म प्राप्त करने के लिए ट्यूबरोस की कुछ किस्मों को उत्परिवर्तन प्रजनन के लिए गामा प्रेरित विकिरण के संपर्क में भी लाया गया।

लवण सहिष्णुता, उच्च तेल सामग्री और रेशों की गुणवत्ता की जांच के लिए बंधरा में आंशिक रूप से सॉडिक भूमि पर अलसी (लाईनम यूसीटैटीसिमम) नमूनों का मूल्यांकन किया गया।

कालमेघ (एंद्रोग्राफिस पैनिकुलेटा) की खेती के लिए जैविक स्रोत के रूप में एफवाईएम के मानकीकरण के लिए क्षेत्र प्रयोग किए गए। FYM के बढ़ते स्तर के साथ ताजा और सूखा जैवभार 60.0 टन प्रति हेक्टेयर तक बढ़ गया। जैविक खेती के तहत ए. पैनिकुलेटा के पोषक तत्वों की रूपरेखा भी तैयार की गई। नाइट्रोजन (N), जिंक (Zn), आयरन (Fe), कॉपर (Cu), मैंगनीज (Mn), मोलिब्डेनम (Mo), निकल (Ni), क्रोमियम (Cr), सेलेनियम (Se), आर्सेनिक (As), लेड (Pb), कोबाल्ट (Co) और कैडमियम (Cd) के लिए प्रोफाइलिंग की गई। फसल की कटाई के बाद मिट्टी के गुणों (मृदा पीएच, विद्युत चालकता, कार्बनिक कार्बन, सूक्ष्मजीव आबादी और मृदा एंजाइम गतिविधि) में परिवर्तन का भी अध्ययन किया गया है।

भारतीय-गंगा के मैदानों की प्रमुख पारंपरिक चावल-गेहूं फसल प्रणाली के विकास और उपज प्रदर्शन पर जिओलाइट्स की प्रतिक्रिया का अध्ययन करने के लिए क्षेत्र प्रयोग शुरू किए गए।

t ul Ei dZ@çf' kfk k@dSkY fodk

आकांक्षी जिले, ओडिशा के नबरंगपुर के किसानों के लिए तीन तकनीकी हस्तक्षेप किए गए। किसानों को वितरण के लिए सीएसआईआर-एनबीआरआई की हल्दी की किस्म 'केसरी' का सौ किलोग्राम प्रकन्द और 30 किलोग्राम ट्यूबरोज बल्ब प्रदान किया गया। पुराने पत्तों से प्राप्त आवश्यक तेल से 34.16% α -फेलेन्ड्रीन प्राप्त हुआ, जो तेल के आर्थिक मूल्य के लिए विशिष्ट यौगिक है। नबरंगपुर जिले में जैव-उर्वरक को बढ़ावा देने के उद्देश्य से कृषि अधिकारियों के लिए एक प्रशिक्षण कार्यक्रम आयोजित किया गया और किसानों को वितरण के लिए जैव उर्वरक (PSB)

के 200 पैकेट प्रदान किए गए। इसके बाद छह गांवों में किसानों के खेतों में प्रशिक्षण कार्यक्रम भी आयोजित किया गया।

13 अगस्त 2020 को सीएसआईआर-एनबीआरआई वनस्पति उद्यान में "हल्दी की खेती और अन्य वनस्पति पौधों के क्षेत्र में उद्यमिता के लिए गुंजाइश" पर एक

ऑनलाइन उद्यमिता विकास कार्यक्रम आयोजित किया गया।

एनडब्ल्यूपी100 परियोजना के तहत कौशल विकास कार्यक्रमों का समन्वयन किया गया। इन कार्यक्रमों की अवधि 3 दिनों से लेकर 29 दिनों तक थी, जिसके माध्यम से कुल 845 उम्मीदवारों को 12 प्रशिक्षण पाठ्यक्रमों के तहत प्रशिक्षित किया गया।



EXECUTIVE SUMMARY

In 2020-21, CSIR-NBRI worked on several research and development projects in the identified areas of plant diversity assessment, systematics, conservation, genomics, genetic improvement, transgenic plant development for abiotic and biotic stresses, climate change, ecophysiology, plant-microbe interactions, phytoremediation, horticulture, agrotechnology, pharmacognosy, phytochemistry, pharmacology, and herbal or natural product development. These studies were aimed at generating new knowledge and advancement in plant sciences, discovering new species, genes and biomolecules through bioprospecting, and development of affordable green technologies for human healthcare, food, nutrition, livelihood security, environmental protection and other societal benefits. Besides, the institute, despite the covid-19 pandemic, provided services to various end users through several outreach programmes, training and skill development in horticulture, garden management, agrotechnology, phytoremediation, tissue culture and other biotechnological tools. A summary of the key achievements made during the year under the six R& D Areas is presented below.

PLANT DIVERSITY, SYSTEMATICS AND HERBARIUM

The plant diversity research at the institute has been organized with a strong focus on taxonomy, floristics, ethnobotany, molecular systematics, bioprospecting and conservation of plant and lichen resources of India from a multidisciplinary perspective. The herbarium of the institute is the main centre of research in plant taxonomy and related aspects, and it serves as a national repository of flora of India by way of providing services of taxonomic identification and authentication of plants and lichens for various end users, including industry, researchers, students, teachers and others. Unfortunately, the covid-19 pandemic slowed down the planned activities of our plant explorations, field and lab experiments this year. Despite this, the sustained efforts by the researchers helped overcome the impact to a greater extent and achieve appreciable progress in the following areas:

Plant diversity assessment and systematic studies

Our priorities of field explorations were significantly

affected by the Covid-19 pandemic, limiting us to conduct only a few plant and lichen surveys in Kerala, Tamil Nadu, Maharashtra, Madhya Pradesh, Uttar Pradesh, Uttarakhand, Himachal Pradesh, Assam and Meghalaya. Exploration surveys were conducted to southern Western Ghats of Kerala and Tamil Nadu, and collected 189 plant species, including 15 endemic species. Systematic documentation of plant diversity of Vidarbha region in Maharashtra was continued, and about 334 species of flowering plants under 244 genera and 79 families were identified from the region. Chambal and Malwa eco-region of Madhya Pradesh was surveyed and the threat status of two highly exploited gum-yielding plants, *Commiphora wightii* and *Boswellia serrata*, was assessed. Several districts of Uttar Pradesh were surveyed for systematic documentation of weeds of Rabi crops and an updated list of 185 weed species was prepared with information on their native range, family, updated nomenclature, phenology, uses and harms. While field survey conducted in 11 districts of Uttar Pradesh recorded about 41 species under 19 genera of Asteraceae. A detailed systematic study of the family Euphorbiaceae of Uttar Pradesh revealed the occurrence of about 121 species belonging to 31 genera in the family. From an exploration in Pangi Valley in the West Himalaya of Himachal Pradesh, 140 species were identified from the region. Besides floristic data, ethnobotanical information on about 34 potential plants used by tribal communities of Suhelwa Wild life Sanctuary in Uttar Pradesh was also documented during this year.

Lichen surveys made in several localities in Assam as well as Mandi District of Himachal Pradesh resulted in collection of 85 and 70 species, respectively. Meanwhile, based on previously collected lichen materials, 138 species were recorded from five districts of Assam, 337 species from Meghalaya, and 53 species from Suhelwa Wildlife Sanctuary of Uttar Pradesh. Floristic surveys in Senchal Wildlife Sanctuary (SWLS) and Ghoom in Darjeeling Himalayas, and Kullu and Manali in Himachal Pradesh, identified 106, 48 and 74 bryophyte taxa, respectively. Similarly, survey of pteridophytes resulted in identification of 59 species from Pachmarhi Biosphere Reserve of Madhya Pradesh, 67 species from Meghalaya, and six species from Suhelwa Wildlife Sanctuary, Uttar Pradesh. The

microphotography and morphological identification of algal samples collected from Suhelwa Wildlife Sanctuary resulted in 43 taxa belonging to 25 genera of the family Bacillariophyceae. Jim Corbett National Park in Uttarakhand was surveyed and more than 130 algal samples were collected. Identification of these algal samples resulted in 74 taxa belonging to 22 genera and 13 families in four orders of the class Cyanophyceae.

Significant progress was made towards taxonomic revision of several important plant and lichen taxa in India, such as *Desmodium* and allied genera, *Uraria* (Leguminosae), *Anemone* (Ranunculaceae), *Geranium* (Geraniaceae), *Didymocarpus-Henckelia* generic complex (Gesneriaceae), tribe *Boehmerieae* (Urticaceae), subfamily Pooideae (Poaceae), *Juniperus* (Cupressaceae) and lichen groups, including the order Arthoniales, family Teloschistaceae, and genera *Buellia s.l.* and *Rinodina* (Physciaceae). The database for the e-monograph of Indian Arthoniales was updated with details of 41 genera and 276 species. During the year systematic and diversity studies have also been initiated on selected species complexes in the flowering plant genera, such as *Gymnosporia* (Celastraceae), *Campanula* (Campanulaceae) and *Impatiens* (Balsaminaceae).

As part of molecular systematic studies the taxonomy and phylogeny of the three Indian species of *Bergenia* was resolved through ITS and *rbcL* sequence analyses. The study inferred recognition of *Bergenia ciliata*, *B. purpurascens*, and *B. stracheyi* as distinct species, and *B. ligulata* as conspecific to *B. ciliata*. Studies on genetic diversity in *Citrus medica*, *Ensete glaucum*, *E. superbum* and *Uraria picta* was continued with progress made in identification of SSR markers for genotyping through *de novo* RNA sequencing and generation of sequence data for nuclear and plastid genes or spacers for population genetic and phylogeographic analyses. As part of phylogeographic studies MaxEnt modeling was performed for predicting habitat suitability and current distribution of *Gymnema sylvestre*, *Ensete galucum* and *E. superbum* in India.

During the reporting period, 2570 specimens of angiosperms were accessioned and incorporated in the institute's herbarium (LWG). About 22 plant species received from eight different organizations were identified/authenticated and certificates were issued to them.

New species discovery and new distribution records to India

The floristic and systematic studies enabled discovery of eight new species to science, which included five species of flowering plants, one cycad, and three species of lichens. The novelties described in flowering plants are *Geranium aedonianum* Imtiyaz Hurrah & Vijay Wagh, *Geranium jainii* Imtiyaz Hurrah & Vijay Wagh, *Geranium lahulense* Vijay Wagh & Imtiyaz Hurrah (Geraniaceae), *Henckelia umbellata* Kanthraj & K Narayanan (Gesneriaceae), and *Agrostis barikii* P. Agnihotri & D. Prasad (Poaceae), *Cycas divoyadarshanii* Khuraijam & Rita Singh is the new cycad described. The new species in lichens are *Huriella upre tiana* S.Y. Kondr. et al. (Teloschistaceae), *Myriospora himalayensis* G.K. Mishra et al. (Acarosporaceae), and *Cratiria rubrum* R. Ngangom et al. (Caliciaceae). The floristic explorations also brought to light several new distributional records of plants and lichens to India. Notably, one species of a flowering plant, three species of bryophytes and 22 species of lichens were reported as new geographic distributional record to India.

Bioprospecting Studies

The essential oil extracts of *Juniperus communis* var. *saxatilis*, *J. indica*, *J. semiglobosa* collected from Himachal Pradesh were examined for antioxidant activity through DPPH free radical scavenging assay using ascorbic acid as control. The DPPH assay revealed excellent scavenging activity (IC₅₀ 369.13 µg/g) in *J. semiglobosa* berry which can be exploited for further therapeutic purposes. Antimicrobial and antioxidant study of the crude extracts in different solvents of five lichen species (*Cladonia rangiferina*, *Parmotrema neilgherrense*, *Ramalina conduplicans*, *Stereocaulon foliolosum* and *Usnea longissima*) showed significant inhibitory activity at minimal inhibitory concentrations of 0.5 and 0.7 mg/ml, respectively in *Usnea longissima* extracts.

Conservation of threatened plants

Under the newly initiated multi-institutional project on 'Conservation of Threatened Plants of India', CSIR-NBRI conducted field exploration and collection tour to Tamil Nadu and Kerala parts of Western Ghats and collected 10 threatened plant species. Standard Operating Procedures (SOPs) have been prepared for conservation assessment, DNA-barcoding, micro



and macro propagation techniques, Ecological Niche Modelling (ENM) and IUCN Assessment of the 100 target species of threatened plants. Besides, secondary data collection has been completed for all the target species of threatened plants. The threatened plants such as *Ephedra foliata* (stem cuttings: 400 nos.), *Cleistanthus collinus* (stem cuttings: 100 nos.), *Indopiptadenia oudhensis* (stem cuttings: 100 nos.), *Cycas seshachalamensis* (seeds: 30 nos.), *Cycas sphaerica* (seeds: 30 nos.), *Cycas beddomei* (seeds: 30 nos.), were multiplied using macro-propagation techniques.

Conservation and propagation methods were also developed for potential pteridophyte and bryophyte species. Protocol for mass *In-vitro* multiplication of about 50 sporophytes of *Cyathea spinulosa* was made for restoration in the natural habitat. *In vitro* studies on spore viability, germination percentage and gametophyte developmental pattern in *Cyathea gigantea* have been initiated. Mass propagation of 1100 individuals of 13 ornamental species of pteridophytes was made. *Tectaria coadunata*, a potential source for insecticidal protein, was also propagated in large scale. About 67 species of ferns, including threatened species, have been conserved in the fern house. A protocol for mass propagation of a potential medicinal moss species, *Rhodobryum roseum*, was standardized through *in vitro* culture of apical stem portions.

PHARMACOGNOSY, PHYTOCHEMISTRY AND PRODUCT DEVELOPMENT

The major R&D activities involved phytochemical, pharmacognostical, and pharmacological prospecting and evaluation of potential plant resources of medicinal, aromatic and other economic interests through traditional and nanobiotechnological approaches. The principal aim of such R& D is to develop scientifically validated herbal/natural products and technologies from indigenous plants and associated traditional knowledge. Developing pharmacopeia standards for medicinal plants and preparation of Certified Reference Materials (CRMs) and Reference Materials (RMs) as per the requirements of ISO-17034-2016 are other services provided. The following are the highlights of achievements in this area:

Development of CRMs/RMs and identification of QRM for industry

Three CRMs (Eugenol, (+) Limonene, and Geraniol) and one RM (Methyl Chavicol) were prepared as per requirement of ISO-17034-2016. All required activities related to documentation and implementation of quality system were performed to enable NABL-Accreditation of the institute as a reference material producer.

Edible and industrial dyes from plants

Food colours *viz.* yellow, red, green and dark brown were developed from *Tagetes erecta* (flowers), *Hibiscus rosa-sinensis* (flowers), *Eichhornia crassipes* (leaves) and *Allium cepa* (red outer skin), respectively.

Pharmacognostical evaluation and Pharmacological studies

Metabolic variation of berberine and palmatine in *Berberis lycium* (roots), an important medicinal plant used in indigenous systems of medicine in India, was analyzed through HPTLC-UV method. Palmatine and berberine varied from 0.117 to 0.739 % and 0.203 to 1.134 %, respectively, on dry weight basis. Based on cluster analysis of metabolic content(s), an elite accession NB-03 was identified as source of the best quality raw material (QRM) for industrial applications.

Chemoprofiling of *Costus speciosus* and *Hemidesmus indicus* samples, collected from different phytoecographic zones in India, resulted in identification of two elite chemotypes *viz.* NB-CS-88 with maximum content of Diosgenin (2.405%, on dry weight basis) from *Costus speciosus*, and NBH-35 with maximum content of Vanillin (0.0127%, on dry weight) from *Hemidesmus indicus*.

Densitometric High Performance Thin Layer Chromatography (HPTLC) quantification of *Momordica dioica* fruit extract showed presence of caffeic acid at R_f value 0.44 ± 0.04 . The *in-vitro* data showed anti-inflammatory, anti-oxidant and anti-diabetic properties of *M. dioica* and suggest the possibility of using the species in various formulations.

HPTLC quantification was performed in acaricidal plants, *Argemone mexicana* (NBA22/F1) and *Datura metel* (NBA/18/D1), collected from six agro-climatic zones of Assam. The biomolecules, berberine and

sanguinarine in *A. mexicana*, and atropine and scopolamine in *D. metel* were quantified.

Pterospermum lanceifolium extract (PLE) was shown to be a potential inhibitor of serum biochemical markers viz ALT, AST, GGT, ALP in N-nitroso diethyl amine (NDEA) induced liver toxicity in rats. The antioxidant potential of selected agro wastes from *Mangifera indica*, *Litchi chinensis*, *Citrus reticulata*, *Aegle marmelous* and *Musa paradisiaca* was studied in experimental models.

Development of Shodhan protocol of standardized cannabis

A shodhan protocol was developed and classical formulations and their SOPs were prepared and evaluated through phytochemical and biological studies of *Cannabis sativa* leaf essential oil. The main components present in the essential oil are Humulene, β -Selinene, β -Bisabolene, trans- α -Bisabolene, Caryophyllene oxide, Humulene epoxide 2, Bisabolol, Naphthalene. The method was optimized and established for the quantification of Cannabinoids using HPLC-PDA.

Herbal Nanobiotechnology

Biosynthesized silver nanoparticles (Pg-AgNPs) and zinc oxide nanoparticles (Pg-ZnONPs) using the leaf extract of *Psidium guajava* demonstrated superior anti-quorum sensing and anti-biofilm activities in *Pseudomonas aeruginosa* PAO1 via las-rhlRegulons.

HERBAL PRODUCTS DEVELOPED

Herbal Hand sanitizers

Under the CSIR social responsibility program, CSIR-NBRI developed a range of low cost hand sanitizers which are easily manufactured at small scales. NBRI developed both alcohol free and alcohol based herbal hand sanitizers. Over 1200 liters of hand sanitizers were distributed to the frontline warriors across Lucknow during the Covid-19 first and second wave.

Herbal Mask Stress Reducer -NITYA

NITYA is an innovative herbal product 'Mask Stress Reducer' which reduces breathing discomforts (congestion, excessive humidification of the nostrils, dizziness) due to long hours of wearing face masks. NITYA was prepared by blending three essential oils and base oil, known traditionally.

Technologies of both the products are transferred to various startups and health companies for wider range of availability in the market.

Traditional Kadha

This polyherbal product was developed under the guidelines of AYUSH. It has capability to reduce the initial symptoms of sore throat, coughing and sneezing. It is a potent formulation based on Indian traditional medicine to keep the body detoxified, healthy and fresh. The product is easy to use just by adding 1-2 drops in a cup of milk/tea/lukewarm water.

PLANT ECOLOGY AND ENVIRONMENTAL TECHNOLOGY

The research in this R& D Area is centered on the following thematic areas related to ecology, environment, plant-microbe interactions, and climate change:

Plant Ecology and Environmental Technology

The broad areas of research include: Plant eco-physiological and biochemical processes in response to air pollution and climate change; Forest ecosystem structural and functional analysis, forest biomass, and forest Carbon sequestration; Restoration/rehabilitation of degraded ecosystems and threatened plants; developing new methods for EIA/CIA, ecological and climate change modeling, bioresource mapping & GIS; Arsenic detoxification mechanism in rice employing biotic and abiotic agents; and monitoring and assessment of toxic and pathogenic agents in environmental matrices. The major R&D highlights during the year are:

Plant responses to air pollution and climate change

Impact of long-term exposure of elevated ozone (+20 ppb above ambient) was studied on photosynthetic traits and anti-oxidative defense system of *Leucaena leucocephala* in a Free Air Ozone Concentration Enrichment (O_3 -FACE). *L. leucocephala* exhibited greater sensitivity to O_3 during initial exposure (up to 12 months), but showed moderate tolerance by the end of the 2nd year. Visible O_3 injuries were found in *L. leucocephala* leaves grown under e O_3 conditions. Net photosynthesis, photosynthetic pigments and lipid peroxidation were significantly reduced after



exposure to elevated ozone (eO_3), whereas stomatal conductance and transpiration rate were significantly decreased after 12 months of exposure to eO_3 . Antioxidant enzymatic activities (catalase, ascorbate peroxidase and glutathione reductase), and ascorbate were significantly increased after exposure to eO_3 .

In a similar study, when tolerant and sensitive cultivars of wheat were exposed to ambient and futuristic concentrations of O_3 , CO_2 and high temperature, it was inferred that the wheat cultivar HD 2967 will be most affected in future concentrations of O_3 , CO_2 and higher temperature, while DBW 184 will be least affected.

Drought stress biology of guar

The regulation of carbon and nitrogen metabolic enzymes was studied under drought in guar (*Cyamopsis tetragonoloba* (L.) Taub.). Studies suggest that the levels of glucose increased significantly in guar varieties during drought stress. The gene expression of acetyltransferase was upregulated in guar, suggesting the translocation of carbon from glycolytic pathway through pyruvate by PeP-C to the tricarboxylic acid (TCA) cycle. The study also showed that the enzyme isocitrate dehydrogenase (ICDH), a key regulator of the TCA cycle, was down regulated during drought stress. The gene expression level of glutamine synthetase (GS), glutamate synthase (GOGAT) and nitrate reductase (NR) were down regulated in guar during drought, limiting the energy flux for nitrogen metabolism.

Forest ecosystem structural and functional analysis

A study on phytosociological analysis in dry, deciduous and moist deciduous forest types of Similipal Biosphere Reserve, Odisha, was initiated. A total of 95 tree species belonging to 78 genera and 37 families were recorded in the three forest types. Moist deciduous forest comprises about 35-40% of the Similipal tiger reserve area and showed maximum range of LAI values forming fairly open to very dense canopy.

Environmental impact assessment methods

A new study on development of "Cumulative impact assessment for cascading interventions in Himalayan Rivers" was initiated this year. CIA methodologies will help researchers, planners and administrators

for visualizing, understanding, analyzing and taking decisions for CIA of river interventions.

Selenium (Se), a known antagonist of Arsenic (As) toxicity in plants, ameliorates As stress and repairs disintegration of cell wall and membranes in rice plants. Se reduces the As accumulation, in rice by over-expression of As transporter genes as well as sulfate transporters, SULTR3;1 and SULTR3;6 for countering the stress.

During Maha-Kumbh 2013 at Prayagraj (Allahabad), the physico-chemical parameters of Ganga water deteriorated, the microbial diversity increased from the core structure of 40 bacterial species belonging to 27 genera present during pre-Kumbh to 112 species of bacteria belonging to 43 genera.

Microbial Technology

The group focuses on disease management of commercially valuable crops and developing sustainable eco-friendly remedies; biological control, Plant microbe interactions and sodic soil reclamation; food safety and protection of the environment through development of economical and efficient bio-inoculants formulations both for agricultural lands and stressed soils; and elucidation of molecular mechanism(s) of microbe mediated abiotic and biotic stress tolerance in different crop plants. Following are the major R&D highlights:

Exopolyphosphatase mutant of *Pseudomonas putida* (Δppx) having high phosphate accumulating potential was generated through knockout mutagenesis. Further inoculation of Δppx in *Arabidopsis thaliana* under phosphate starvation condition showed significantly higher silique formation and dry weight as compared to wild type strain and uninoculated plants.

The role of silicon (Si) solubilizing bacteria in arsenic (AsIII) stress amelioration in rice was explored. Reduced arsenic uptake in husk and grain, and improved plant growth during silicon mediated arsenic detoxification was observed in rice.

A microbial formulation for hastened decomposition of rice straw was developed. The results showed that the structural damage initiated within 20-30 days post inoculation in comparison to control treatment followed by its complete disintegration after three months.

On the basis of Zn solubilization, siderophore and organic acid production, four microbes *Bacillus pumilus*, *Pseudomonas putida*, *Pseudomonas sp.* and *Pseudomonas fluorescens* have been identified, and assessed for Fe and Zn biofortification in different rice cultivars.

The Bio-fungicide, *Bacillus subtilis* NBRI-W9 (W9) inoculation showed promising effect against chemical fungicide Propiconazole (PCZ) treated tomato plants, by improving its endophytic diversity.

A peppermint oil based nanoemulsion (PNE) was synthesized, which has been found more efficacious than chemical fungicide for early blight disease management in tomato.

Inoculation of *Ochrobactrum sp.* (NBRISH6) in *Zea mays* L. performs multiple roles in maintaining the homeostasis under water stress conditions and mitigates the deleterious effect of drought and promotes growth.

Work has been initiated for identification, characterization and diversity analysis of novel viruses infecting economic important crops, and development of efficient, rapid on-site diagnostic tools for early detection of plant viruses

Environmental Technology

The focal areas R&D of the Group include: Monitoring and assessment of soil pollutant(s)/ contaminant(s) in respect of the water-soil-crop continuum of agriculture; development of technologies for remediation of pollutant(s) contamination in crops/vegetables; microplastic isolation and characterization in soil; biochar for metal remediation and enhancing crop productivity. The major achievements made during the year are highlighted.

The monitoring and assessment of arsenic pollution in arsenic-prone districts of Uttar Pradesh in the Ganga-Meghna-Brahmaputra basin, and the arsenic estimation in the irrigation groundwater samples, agricultural soil samples, and crop produce of different food crops and vegetables is on-going. Studies on reclamation of Hexachlorocyclohexane (HCH) dumpsites at industrial area in Barabanki district of Uttar Pradesh using microbial remediation technology is in progress.

Work is in progress on production of pyrolysed biochar from agricultural/distillation waste and its characterization for potential application for

adsorbing contaminants like arsenic and other toxic metals from the soil.

MOLECULAR BIOLOGY AND BIOTECHNOLOGY

The main focus of R&D pursued in Molecular Biology and Biotechnology is on understanding various genetic determinants for yield and quality and developing superior plant varieties for enhanced yield and quality using plant genes for the benefits of farmers and consumers. To fulfill these objectives, gene-mining, transgenic plant development and genome-editing technologies are being used on various crops. Following are the key achievements made during the year:

Cotton genomics: Fibre development, male sterility-fertility restoration system, and insect resistance

In previous studies the role of *HDA5* in cotton fiber initiation was established. Interestingly, positively co-expressed genes with *GhHDA5* exhibited a protein interaction network with *HDA6* and *SUVH1*. The molecular characterization of all the transgenic lines over-expressing, antisense and myc-tag are under process to explore the role of the *SUVH1* gene in cotton fiber development.

Two key genes, SELF-PRUNING (*GhSP*) and SINGLE FLOWER TRUSS (*GhSFT*), induced vegetative growth (indeterminate) and transition to flowering (determinate state), respectively, in *Gossypium hirsutum*. To achieve determinate/semi-determinate growth habits and synchronous flowering, the gene and promoter of both genes (both A and D sub-genome) from Coker 312 (*Gossypium hirsutum*) have been cloned and sequenced and will be used for further studies.

Cotton MYB1 transcription factor (TF) showed higher expression during the secondary cell wall biosynthesis stage at 19 days post-anthesis (DPA). To study the effect(s) of CRISPR/Cas9-based editing in fiber cells, the stable transformation of cotton plants will be carried out. The microRNA828a-encoded peptides (miPEP828a¹ and miPEP828a²) affected fibre growth in cotton ovule culture.

To achieve complete male sterility and reverse the male sterility in F1 hybrid cotton, Arabidopsis *BECLIN1* and *COP1* genes were expressed in anther



tapetum of cotton plants. The research aims to establish a system to introgress male sterility from transgenic cotton to elite parental lines of commercial cotton hybrid through marker-assisted backcrossing (MABC) to exploit its economic benefits.

Development of transgenic cotton through pollen transformation is under progress. Culture of *Pectinophora gossypiella* on artificial diet was established. Development of six putative transgenic cotton lines expressing insecticidal protein Dhi31 under regulation of PCD promoter for aphid tolerance is in progress.

The *GhNAC2* gene expressing cotton plants (5th generation) showed sturdier growth and more fruiting as compared to control plants, with increased boll size, weight and number. Promoter studies in hairy roots show expression in the root tips, elongation zone and lateral root primordia with regulation under control of different hormones.

Pectin methylesterases (PME) esterify the pectin and in the process release methanol which is toxic to insect pests. WsPME29, a PME gene isolated from *Withania somnifera*, was found to be induced early and highly bioactive during biotic stress. Transgenic cotton plants expressing WsPME29 under constitutive and inducible promoters have shown 75-85% mortality against both the chewing (*Spodopteralitura* & *Helicoverpa armigera*) and sap sucking (Aphid and Whitefly) insect pests on the 4th day and 6th day, respectively.

In order to improve root growth and vigour plant stress responses, CRISPR lines of two root expressed transcription factors HSF and WRKY have been developed using single and double guide RNAs and validated through sequencing. The plants are being studied for whole plant growth with a focus on root associated phenotypes in subsequent generations.

Identification and characterization of genes involved in plant development and abiotic and biotic stress

The *SIERF6* gene from tomato was found to alter ABA-ethylene interactions and thereby the expression of key ripening regulators. The studies on the overexpressing and antisense lines of *SIERF6* showed that *SIERF6* may govern fruit set as well as fruit growth/ripening.

The over-expression and knocked-down lines of *GSTU5* in rice showed the involvement of this gene in As sequestration in root by utilizing *OsABCC1* vacuolar transporters. The functional characterisation of *OsHsp20* also showed its involvement is alleviating As stress.

The chickpea over-expressing lines of *CaCYP*, *CaMTD* and *CaWAT1* showed that *CaCYP* and *CaMTD* are probably involved in drought stress tolerance by regulating the expression of the stress-related genes during drought. However, *CaWAT1* was apparently not involved in the response of plants to drought. The chickpea metallothionein (*MT*) and glutaredoxin (*CaGrx*) genes were validated for drought and heavy metal tolerance in *Arabidopsis*.

miR775 is a non-conserved miRNA identified only in *Arabidopsis thaliana*. Over-expression and knockout lines of miR775 showed it regulates rosette size by elongating petiole length and increasing leaf area and targets a probable β -(1,3)-galactosyltransferase gene at post transcriptional level. miR775 was also found to be up-regulated in response to UV-B and hypoxia. The findings establish the role of miR775 in regulating growth and development in *A. thaliana*.

The petal abscission in rose was found to be governed by an interaction between the jasmonic acid and ethylene pathways that alters sensitivity to ethylene. Studies showed that reduction in JA pathway genes were necessary to increase sensitivity to ethylene which promoted flower opening and petal abscission in rose. Treatment of flowers with JA delayed flower opening as well as abscission suggesting strategies for delaying abscission in fragrant rose flowers with the use of JA or JA analogues.

Wound induction in *RbPCD1pro* was found to be regulated in a JA-independent manner by a MYB protein that is conserved between rose and *Arabidopsis*.

Light regulatory components (HY5 and COP) involved in regulation of secondary plant products has been functionally characterized by developing overexpression and edited lines using CRISPR/Cas9 approach. miPEP (microRNA encoded peptide) and a small peptide involved in the regulation of plant growth and development have been functionally characterized in *Arabidopsis thaliana* by developing several transgenic lines in various backgrounds.

The evolution of the HPT gene family indicated towards the parallel evolution of some dicot and monocot HPT signatures mediated through basal eudicot representatives. The functioning of the two component system module in climacteric and non-climacteric fruits showed that the TCS module functions differentially during ripening of climacteric and non-climacteric fruits.

The cotton TLP genes were identified and their role in salt and drought stress was studied, it was shown that GhTLP11A and GhTLP12A.1 provided strong evidence that these genes might have prominent role during drought and salt stress. In a study on bHLH genes of *Nicotiana* in salt stress, five NtbHLHs showed significant higher expression during chilling stress responses. These genes might have important role during chilling stress condition.

Studies on Calmodulin binding transcription activators (CAMTAs) in cotton identified three *CAMTA1* variants (*VS*, *V₂*, and *VL*) from amplicon data. Mapping of variants on genomic DNA showed that both the *CAMTA1_VS* and *VL* variants possess intron retention. Analysis of Col-0- *VS* transgenic lines showed enhanced root laterals as well as higher LR density, suggesting root laterals might be crucial during stress tolerance.

To understand the impact of sub-genome dominance during endoreduplication on heterosis, whole-genome sequencing in parents and their reciprocal F1 hybrids performed. The result indicates that during an endocycle, the replication of Col-0 dominates the replication of the C24 sub-genome.

PLANT GENETIC RESOURCES AND IMPROVEMENT

The group is working in the area of molecular markers, creation of genetic resources, linkage analysis, association mapping and genomics assisted breeding for varietal development in industrially important and orphan crops. Improvement, mainstreaming, domestication and sustainable utilization of these plant resources are the major thrust of this group. The major research highlights of the reporting year are summarized below.

Development of genetic and genomics resources for varietal development

Screening and selection for different lines of the underutilized orphan legume winged bean

(*Psophocarpus tetragonolobus*) on the basis of secondary metabolites, is underway. Mature seeds of *P. tetragonolobus* contain 15-18% oil, similar to that of soybean. The amino acid composition of the flour from the seeds reported relatively high amounts of lysine, aspartic acid, glutamic acid and leucine and relatively low amounts of the sulphur-containing amino acids, a pattern similar to that of soybean.

Genome-wide association studies (GWAS) of winged bean was carried out through Genotyping By Sequencing (GBS) for population structure and familial relatedness analysis. A total of 167845 tag-pairs (335690 tags) were generated, and 80941 SNPs were identified. The analysis resulted in the discovery of 54 SNPs significantly associated with seed-protein traits and 88 SNPs with seed-oil traits in *P. tetragonolobus*.

GWAS study was conducted in opium poppy with precise Opioid estimation and resulted in few key SNPs and their associated genes with thebaine pathways. A major initiative for improvement of *Cannabis* for low THC and high CBD is in progress.

The chloroplast genome (161,476 bp) of *Lithocarpus dealbatus* has been assembled. The genome consists of a large single-copy region (90,732 bp) and a small single-copy region (18,987 bp), separated by two inverted repeat regions (25,879 bp). The chloroplast genome contains 134 genes including 87 protein-coding genes, 39 tRNAs, and 8 rRNAs.

The reference genome of linseed (IC 0526166) was prepared using Oxford Nanopore PromethION and Illumina platform. The SMART *de novo* assembly generated a total of 671 contigs with more than 10000 bp size. Three bi-parental mapping populations for elite quantitative traits have also been developed and progressed to F₃ generation leading towards formation of RILs. In addition to RILs, the generation advancement of MAGIC population had been made.

Ethyl methane sulfonate (EMS) mediated TILLING (Targeting Induced Local Lesions IN Genomes) population of the cv. WAGAD of *Gossypium herbaceum* was developed for the functional genomics studies in diploid cotton. Genotyping-by-sequencing of 95 diverse M₃ plants selected from the TILLING population along with control was done for evaluation of nucleotide diversity.

An attempt had been made to develop genetic and genomic resources in grain Amaranth at CSIR-NBRI,



Lucknow for utilization under its crop improvement programmes. A total of 1165 accessions of grain amaranths were obtained from different centers of ICAR-NBPGR and have been grown at CSIR-NBRI garden field and Banthra Research Station.

BOTANIC GARDEN AND PLANT CONSERVATION & AGRO-TECHNOLOGY

The Botanic Garden and several of its associated units and experimental research stations are engaged primarily in enrichment of plant diversity and conservation of diverse groups of plants and their management for research, aesthetics, education, awareness creation, and outreach activities. The major objectives of these activities include development of new varieties of popular floricultural crops; enrichment of plant diversity and conservation of diverse groups of plants in specialized houses and field conservatories, their propagation and characterization, DUS testing of germplasm; development of sodic waste land through adaptable plants and trees, their conservation and interactive response; evaluation of non-traditional economic plants for sodic soil; standardization of agro-technology of different medicinal and aromatic plants, for sustainable utilization of sodic wastelands; providing R & D support services by conservation and back-up of germplasms, plant propagation protocols; and skill development/Outreach programmes/extension activities.

Like the preceding year, the lock down during covid-19 pandemic considerably affected the routine horticultural operations, flower shows and exhibitions, and management of plant repositories and experimental field/lab works of the botanic garden. It has also slowed down the visitors and public access to the botanic garden resources and the outreach activities. However, while taking all precautionary and preventive methods to protect people and staff from the pandemic, the plant collections in the garden and conservatories were managed well and put to use for the ongoing and new research activities. The achievements during the year under report are highlighted below:

Botanic Garden: New initiatives and development

Cycas Garden was enriched to make it a national

reference centre for Indian species and a model for *ex-situ* conservation of threatened *Cycas* species for their rescue, recovery and rehabilitation.

The experiments have been designed for varietal development of floricultural crops such as *Canna*, *Gladiolus*, *Iris*, and *Nymphaea*. Morphological characterization of 70 varieties of *gladiolus*, 20 varieties of *Canna* and 10 varieties of *Bougainvillea* were carried out based on DUS Test guidelines of PPV&FRA. Hybridization and mutation breeding of ornamental plants such as *Gladiolus*, *Canna*, *Nymphaea*, *Reinwardtia indica* are taken up for their improvement. Eighty five Rose varieties from different authentic nurseries of Kolkata have been introduced to CSIR-NBRI Rose Garden. About 16 species of ornamental/economic/conservation importance collected from different locations of Andhra Pradesh have been introduced and maintained at CSIR-NBRI Botanic Garden.

Seed germination studies of some threatened plants like *Pterocarpus santalinus*, *Pterocarpus marsupium*, *Indoptadeni aoudhensis*, *Hardwickia binata*, *Ephedra foliata*, *Baliospermum montanum*, *Commiphora caudata*, *Commiphora wightii*, *Saracaasoca*, *Hildegardia populifolia*, *Boswellia ovalifoliolata*, *Adenantha pavoninal*, etc. were done successfully.

A database of trees and shrubs conserved in thematic gardens, plant houses, arboretum and public places in Botanic Garden was prepared. Each tree and shrubs are geo-tagged and this information will be used for preparation of online database of flora of CSIR Botanic Garden assessable through QR embedded plant labels.

Plant Conservation and Agro-technology

In order to identify potential germplasm of economically important plants for sodic lands and to develop their agro-technology, evaluation of 15 accessions of quinoa (*Chenopodium quinoa*), 27 accessions of psyllium or isabgol (*Plantago ovata*) and 13 accessions of nutgrass or nagarmotha (*Cyperus scariosus*) was carried out at Field Gene Bank at Banthra. Among the evaluated quinoa germplasm, PQ 5 was found to be the tallest (123 cm), and PQ 11 with larger inflorescence (34 cm) and high grain yield(41.96 g/plant).

Tissue culture and clonal propagation techniques were standardized for four cultivars of neem.

The inter-cropping models were developed as demonstration plots with neem as main crop.

The amaranth germplasm repository at Banthra Research Station was enriched with 1223 accessions of Amaranth (*A. hypochondriacus*, *A. cruentus*, *A. caudatus*) and evaluated them for various agronomically important quality traits and identification of traits specific lines.

Around 30 varieties of tuberose (*Polygonum tuberosum* L.), including single and double type flowers, have been collected and planted at Banthra. Some varieties of tuberose were also exposed to gamma induced radiation for mutation breeding to obtain the new mutant variety.

Linseed (*Linum usitatissimum*) accessions were evaluated on partially sodic land at Banthra for screening of salt tolerance and high oil content and fiber quality.

Field experiments were conducted for standardization of FYM as organic source for cultivation of Kalmegh (*Andrographis paniculata*). The fresh and dry biomass significantly increased with increasing levels of FYM up to 60.0 t ha⁻¹. Nutrients profiling of *A. paniculata* under organic farming has also been done. The profiling has been done for Nitrogen (N), Zinc (Zn), Iron (Fe), Copper (Cu), Manganese (Mn), Molybdenum (Mo), Nickel (Ni), Chromium (Cr), Selenium (Se), Arsenic (As), Lead (Pb), Cobalt (Co) and Cadmium (Cd). The changes in soil properties (Soil pH, electrical conductivity, organic carbon, microbial population and soil enzymes activity after

harvest of the crop has also been studied.

Field experiments were initiated to study the response of Zeolites on growth and yield performance of dominant traditional rice-wheat cropping system of Indo-Gangetic plains.

Out-reach/Training/Skill development

Three technological interventions were made for the farmers of the aspirational district, Nabarangpur in Odisha. Hundred kilogram rhizome of CSIR-NBRI turmeric variety 'Kesari' and 30 kg tuberose bulb were provided for distribution to farmers. The essential oil from senesced leaves yielded 34.16% α -Phellandrene, the characteristic compound for the economic value of oil. With the aim to promote the bio-fertilizer in Nabarangpur district, a training programme was organized for agriculture officers and provided 200 packets of Biofertilizers (PSB) for distribution to the farmers. Subsequently, training programme at farmers fields was also conducted in six villages.

An online entrepreneurship development Programme on "Scope for entrepreneurship in the field of turmeric cultivation and other botanical plants" was organized on 13th August 2020 at CSIR-NBRI Botanic Garden.

Skill development programmes were coordinated under NWP100 project. The duration of these programmes ranged from 3 days to 29 days through which total 845 candidates have been trained under 12 training courses.

Research & Development



वै.ओ.अ.प.—राष्ट्रीय वनस्पति अनुसंधान संस्थान, लखनऊ की स्थापना वर्ष 1953 में हुई थी। यह वैज्ञानिक एवं औद्योगिक अनुसंधान परिषद, वैज्ञानिक एवं औद्योगिक अनुसंधान विभाग, विज्ञान एवं प्रौद्योगिकी मंत्रालय, भारत सरकार के 37 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 केन्द्र 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, वर्गीकी, प्रलेखन, पूर्वक्षण एवं आनुवांशिक सुधार आदि पर बुनियादी एवं प्रायोगिक अनुसंधान करना है। संस्थान निम्न क्षेत्रों के प्रमुख सामर्थ्य रखता है।

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

संस्थान नये ज्ञान का सृजन करने और मानव स्वास्थ्य, कृषि और पर्यावरण संरक्षण के लिए सस्ती प्रौद्योगिकियों के निर्माण हेतु देश की गैर-अन्वेषिक पादप विविधता की अप्रयुक्त क्षमता की खोज करने के लक्ष्य के साथ आगे बढ़ रहा है।

CSIR-NBRI: Mission and Mandate

The Council of Scientific and Industrial Research-National Botanical Research Institute (CSIR-NBRI), Lucknow was established in the year 1953. It 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, CSIR-NBRI 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 sciences, including conservation, systematics, documentation, prospection and genetic improvement with particular emphasis on under-exploited, non-traditional and wild plant genetic resources of the country for the sustainable development and human welfare. The institute has core strength in the following areas:

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

The institute is surging ahead with its envisioned goals of exploring the untapped potential of the underexplored and unexplored plant diversity of the country for generating new knowledge, and affordable technologies for human health care, agriculture and environmental protection.

Plant Diversity, Systematics and Herbarium



PLANT DIVERSITY, SYSTEMATICS & HERBARIUM (PDSH)

Area Co-ordinator

Dr. TS Rana, Chief Scientist

Scientists

- Dr. KN Nair, Chief Scientist
- Mr. Anand Prakash, Senior Principal Scientist
- Dr. LB Chaudhary, Senior Principal Scientist
- Dr. Sanjeeva Nayaka, Senior Principal Scientist
- Dr. AK Asthana, Senior Principal Scientist
- Dr. AP Singh, Principal Scientist
- Dr. Baleshwar, Principal Scientist
- Dr. Priyanka Agnihotri, Principal Scientist
- Dr. SK Rath, Principal Scientist
- Dr. VV Wagh, Senior Scientist
- Dr. KM Prabhukumar, Senior Scientist
- Dr. GK Mishra, Scientist

Technical and Support Staff

- Dr. Sandeep Kumar Behera, Senior Technical Officer
- Dr. Kiran Toppo, Senior Technical Officer
- Dr. Sushma Verma, Senior Technical Officer
- Dr. Vinay Sahu, Senior Technical Officer
- Dr. KK Rawat, Senior Technical Officer
- Mr. Rameshwar Prasad, Technical Assistant
- Dr. KK Ingle, Technical Assistant
- Dr. Vandana Tiwari, Technical Assistant
- Mr. MK Srivastava, Senior Technician
- Smt. Gomta Devi, Lab Assistant
- Mr. Mohan Lal, MTS
- Mr. Mauje Lal, Lab Assistant

R&D Area Scholars Statistics

Sr. No.	Position Name	Numbers
1.	NPDF	01
2.	INSPIRE Faculty	01
3.	Research Associate	02
4.	JRF/SRF/INSPIRE	34
5.	Project Staff	27
6.	CSIR-TWAS and TARE Fellow	02

Broad Areas of R&D

Taxonomy of Algae, Fungi (Lichens), Bryophytes, Pteridophytes, Gymnosperms and Angiosperms, Molecular Systematics, Conservation of Threatened plants, and Herbarium

Aims and Objectives

- Diversity assessment of plants and lichens of under-explored/un-explored areas of India.
- Revisionary and monographic studies of Algae, Lichens, Bryophytes, Pteridophytes, Gymnosperms and Angiosperms.
- Molecular systematics of plants.
- Conservation of threatened plants of India.
- Enrichment and maintenance of the herbarium (LWG).
- Digital databases of plant resources.

R&D Highlights

- The scientists of the division are presently working on 11 grant-in-aid projects (GAP) sponsored by different funding agencies like SERB-DST, New Delhi; DBT, New Delhi; MOEF&CC, New Delhi, Government of Maharashtra; and CSIR, New Delhi.
- The group also significantly contributes towards bio-prospecting plant resources for the development of new varieties, process and technologies. During the year, the scientists of the division have published 36 research papers, 3 book chapters, 7 new species to science, 22 new records and 7 general articles in Hindi. Besides, scientists of the division are also teaching various courses to AcSIR students.
- Herbarium (LWG) of the institute is a recognized 'National Repository' of Indian flora by the National Biodiversity Authority (NBA) of India. The scientist of the PDSH division are significantly contributing towards the growth and development of the herbarium, and have added ca 2570 specimens collected from different parts of the country during the period under report.



Future prospects

- Plants and Lichens exploration in under/un-explored areas like Suhelwa Wildlife Sanctuary, Terai region (Uttar Pradesh); Pachmari Biosphere Reserve; North Eastern States, the Himalayas, peninsular India, and Chambal Ravines.
- Revisionary and monographic studies on Arthoniales, *Buellia*, *Pyrenocarpus*, *Rinodina* (Lichens); Mniaceae, Marchantiales (Bryophytes), *Anemone*, *Desmodium*, and *Geranium* (Angiosperms).
- Molecular systematics, phylogeny and phylogeography of *Betula*, *Ephedra*, *Citrus*, *Ensete*, *Gymnema*, *Gymnosporia*, *Campanula* and *Uraria*.
- Recovery, rescue and rehabilitation of threatened plants of India.

HERBARIUM: A NATIONAL FACILITY

Curator

Dr. Lal Babu Chaudhary, Senior Principal Scientist

The herbarium plays an important role in biodiversity assessment including ecology, conservation and climate change other than classical taxonomic and systematic studies. The herbarium of CSIR-National Botanical Research Institute (LWG) is a designated 'National Repository of Indian Flora' by National Biodiversity Authority, Govt. of India. Following are the major activities conducted in the herbarium:

Plant Collection

Plants are collected from different parts of the country under various research projects handled by scientists of the Plant Diversity, Systematics and Herbarium Division. The collected specimens are processed and herbarium specimens are prepared and ultimately deposited to the institute's herbarium. Due to Covid-19 pandemic not many field tours were conducted during 2020-21, except some collections made from Uttar Pradesh, Maharashtra and the Himalayas. Presently LWG houses 1,09,751 specimens alone in angiosperms, including 2,570 specimens incorporated during reporting period.

Floristic Study

The Group is involved in the floristic study of different areas of the country, such as Chambal Ravines, Chandrapur District and its surrounding areas (Maharashtra), Suhelwa Wildlife Sanctuary and Pilibhit Tiger Reserve (Uttar Pradesh). Studies on some specific groups of plants, such as Acanthaceae, Lamiaceae, Euphorbiaceae and Asteraceae of Uttar Pradesh, herbaceous flora of Lucknow and its adjoining districts, cultivated legumes of Uttar Pradesh, floristic study of Pangi Valley and grasses of the Himalaya are in progress.

Revisionary Study

Revisionary studies on different groups of plants such as *Desmodium* and its allied genera (70 spp.), *Didymocarpus* (22 spp.), *Geranium* (27 spp.), *Henckelia* (37 spp.), *Uraria* (11 spp.), *Anemone* (26 spp.), etc. are also under way with significant contribution.

Training Course

Training courses are conducted at various occasions for young researchers and amateur faculties of different institutions and universities to give them exposure on various recent taxonomic advances through theoretical and practical classes.

Visit of Students and Researchers to the Herbarium

The students from different schools, colleges, universities and research organisations are visiting CSIR-NBRI Herbarium to know about the plant diversity, techniques of herbarium preparation and identification and authentication of plant materials. During the reporting period, although we were in lock down for most of the time, students from eight organisations visited the herbarium for various purposes at different occasions.

Plant Specimen Identification/Authentication and Certification: The herbarium provides services to general public and researchers in plant identification and authentication and preserving their voucher specimens for future records. During this period, the plant specimens received from different organisations/research personnel such as AMITY University, Lucknow; HYGIA, Lucknow; BBD University, Lucknow; CSJM University, Kanpur; HNB Garhwal University, Uttarakhand; GLA University, Mathura and Motherhood University, Roorkee were identified and certificates were issued to them.



Tikam Singh Rana

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Assessment of genetic diversity and population genetics, phylogeny, phylogeography, DNA barcoding and bioprospecting of plant resources

Phylogeny of *Bergenia* Moench (Saxifragaceae)

The genus *Bergenia* comprises of 10 species worldwide, distributed mainly in the temperate and subtropical regions in South, Central and East Asia. In India, the genus is represented by four species (*Bergenia ciliata* (Haw.) Sternb., *B. ligulata* (Wall.) Engl., *B. stracheyi* (Hook. and Thoms.) Engl., and *B. purpurascens* (Hook. and Thoms.) Engl.) It is commonly known as “Pashanbheda” indicating their rocky habitat and therapeutic uses in dissolving kidney and urinary calculi.

Phylogenetic relationships amongst Indian species of *Bergenia* were examined through DNA sequencing analysis of nrDNA ITS and cpDNA *rbcL* loci using universal primers. Twelve accessions of *Bergenia*, representing *B. stracheyi* (5), *B. ciliata* (2), *B. ligulata* (2) and *B. purpurascens* (3) were included in the analysis along with one accession of a closely related species, *Saxifraga oppositifolia*, as an out group. The amplicon size for ITS and *rbcL* in *Bergenia* was identified around 700 and 714 base pairs, respectively. The ITS and *rbcL* sequences were edited manually and the aligned sequence data were analyzed individually for phylogenetic inference using neighbor joining (NJ), maximum parsimony (MP) and maximum likelihood (ML) methods in MEGA7, with the bootstrap values for the node support set to 1000 replicates. The NJ, MP and ML trees generated from ITS and *rbcL* sequences resolved all the three species of *Bergenia* (*B. purpurascens*, *B. ciliata* (including *B. ligulata* accessions), and *B. stracheyi*), with high bootstrap support. All the trees from both the data sets presented similar topology.

Distribution modeling of *Gymnema sylvestre* (Retz.) R. Br. ex Schult (Apocynaceae)

Gymnema sylvestre, commonly known as ‘Gudmar’ in ‘Hindi’, is a woody climber. It is a popular and important medicinal plant species known since centuries for the treatment of Diabetes (Madhu), and is also known as ‘Madhunashini’. Gymnemic acid (triterpene saponin) is the main chemical constituent which attributes the medicinal properties of *G. sylvestre*. Although *G. sylvestre* is reasonably well-distributed over Indian Peninsular region, the current unsustainable destructive harvesting practices and fragmentation of natural forests and climate change has lead to depletion of the wild populations of the species. In order to predict the current habitat suitability and distribution of the wild populations in India, and to find out the major environmental variables affecting the growth and distribution of *G. sylvestre*, species distribution modeling was carried out using MaxEnt model.

A total of 308 geo-coordinates of *G. sylvestre* were obtained from India from GBIF database (Global Biodiversity Information Facility- <https://www.gbif.org/>), published literature, herbarium consultation, and fresh field surveys conducted to several locations of India covering different bio-geographical regions like Semi-arid, Deccan Peninsula, Coasts and Western Ghats. All the geo-coordinates were subjected to spatial filtration (one occurrence record per ~4.6 km²) using QGIS v3.14 “Pi” (QGIS Development Team 2020). Finally, 125 valid, non-replicate occurrence data were obtained which were used for modeling the current distribution of the species. The basic 19

bioclimatic variables and 3 topographic variables (aspect, elevation and slope), downloaded from WorldClim dataset (<https://www.worldclim.org/>), were included in the model, with a 2.5 minutes (~4.6 km²) spatial resolution. MaxEnt programme was run with 5 replicates and 5000 iterations, keeping all other values as default. After a pilot run of MaxEnt with five replicates, seven variables having negligible contribution to the model prediction were eliminated. Further, five highly correlated variables having the Pearson correlation coefficient value ≥ 0.8 were also eliminated. This removal of variables led to the selection of 10 predictor variables out of 22 environmental variables, based on which MaxEnt model was run for the current distribution prediction of *G. sylvestre*. Four classes of habitat suitability were regrouped: unsuitable (0-0.25); less suitable (0.25-0.50); moderately suitable (0.50-0.75) and highly suitable (0.75-1).

MaxEnt analysis predicted highly suitable areas of *G. sylvestre* in the entire Western Ghats and Western Coasts (starting from Maharashtra, Goa, Karnataka to Kerala), some parts of the states of Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Telangana, Karnataka, Andhra Pradesh, Tamil Nadu and Andaman and Nicobar Islands. Moderately suitable areas were found in Central and Eastern parts of Madhya Pradesh, Western Ghat region of Maharashtra, Central and Southern Karnataka and some parts of Telangana, Andhra Pradesh and Tamil Nadu. Less suitable areas were found in the entire Indian Peninsular region also extending to some parts of Gangetic Plain (Uttar Pradesh and Jharkhand) and Mizoram. The Northern parts (Trans-Himalaya, Himalaya and most of the North-East India) of the country were shown to be unsuitable for the distribution of *G. sylvestre*.

The Jackknife test showed that, among the 10 selected predictor variables, the current potential distribution of *G. sylvestre* was influenced majorly by Temperature Seasonality (Bio 4, 47.5%), followed by Precipitation of Wettest Month (Bio 13, 11%), Precipitation of Warmest Quarter (Bio 18, 7.4%), Precipitation of Wettest Quarter (Bio 16, 7%) and Elevation (Bio 21, 6.1%). The cumulative contribution of these five factors is 79%. Temperature Seasonality (Bio 4) has the most useful information by itself because it increased the gain the most when it is used in isolation. Precipitation of Warmest Quarter (Bio 18) has the most information that isn't present in

the other variables because it decreased the gain the most when it is omitted. Besides, Ecological Niche Modelling (ENM), population genetic structure and genetic diversity studies on *G. sylvestre* are underway.

Systematics and phylogeny of *Uraria* Desv. (Leguminosae)

Work on taxonomic revision, molecular systematics of Indian *Uraria* and DNA-marker based assessment of genetic diversity in the high value medicinal plant, *Uraria picta*, was continued this year. Scanning electron microscopy of nine species was carried out for leaf surface, pod surface and pollen grains. DNA sequencing of 42 samples of nine species of *Uraria* and four species of *Desmodium* (outgroup) was carried out using four loci, i.e., ITS, *trnL*, *psbA-trnH* and *matK*. The generated sequences will be used further for phylogenetic studies.

Transcriptome of leaf samples of *Uraria picta* was sequenced using Illumina platform through outsourcing (Eurofins Genomics India Pvt. Ltd, Bengaluru, India). From the assembled transcripts, simple sequence repeats (SSRs) were identified using MISA (v1.0, <http://pgrc.ipk-gatersleben.de/misa/misa.html>) (Table 1). A total of 28,223 primer pairs of SSR were designed using Primer3 (ver 2.3.5, <https://primer3.org>). Out of these, around 100 primers were selected randomly and synthesized, to do the genotyping of *Uraria picta*. Furthermore, highly polymorphic SSR primers will be selected and utilized for the assessment of genetic diversity and related aspects of *Uraria picta*. The work is in progress.

Table 1. Summary statistics of SSRs mined from transcriptome data of *Uraria picta*

1	Total number of sequences examined	70518
2	Total size of examined sequences (bp)	98925278
3	Total number of identified SSRs	30213
4	Number of SSR containing sequences	22594
5	Number of sequences containing more than 1 SSR	5780
6	Number of SSRs present in compound formation	1992
7	Number of mono-nucleotide repeats	18614



8	Number of di-nucleotide repeats	5689
9	Number of tri-nucleotide repeats	5367
10	Number of tetra-nucleotide repeats	430
11	Number of penta-nucleotide repeats	91
12	Number of hexa-nucleotide repeats	22

Conservation of Threatened Plants of India

India is considered as one of the 12 centers of origin for several cultivated plant species in the world. Besides that, India is experiencing a series of environmental problems, viz. climate change, habitat modification, landuse and landcover change, environmental pollution, overexploitation of biological resources and invasion of alien species. It is estimated that in India about 1052 species are Red-listed, which also include several hundreds medicinal plants. Among these, eight species are already extinct and 77 plant species are critically endangered. For many of these threatened plant species, the major threat is their extremely small population size, over exploitation and degradation of natural habitats. Thus unless urgent conservation action is taken up in terms of recovering these species, many of them may be completely lost. The multi-institutional project on 'Conservation of Threatened Plants of India' was initiated by three CSIR institutes namely CSIR-NBRI (Nodal Lab.), CSIR-IHBT and CSIR-NEIST. The present project aims to (1) assess the conservation status of 200 threatened plant species occurring in different bio-geographic regions of India using IUCN ver. 3.1, (2) estimate the genetic variability in Critically Endangered (CR) species, (3) develop DNA bar-code for threatened plant species, (4) develop agro-technologies and mass multiplication of threatened plant species using macro as well as micro-propagation, and (5) develop

of threatened plant species conservatory at all the three locations (CSIR-NBRI, Lucknow, CSIR-IHBT, Palampur and CSIR-NEIST, Jhohrat).

During the period under report, CSIR-NBRI conducted field exploration and collection tour to Tamil Nadu and Kerala parts of Western Ghats and collected 10 threatened plant species. Standard Operating Procedures (SOPs) have been prepared for conservation assessment, DNA-barcoding, micro and macro propagation techniques, Ecological Niche Modelling (ENM) and IUCN Assessment of the target threatened plant species. Besides, secondary data collection has been completed for all the 100 target species of threatened plants. Genomic DNA has been isolated from all the collected plant species and stored for further analyses. The threatened plants such as *Ephedra foliata* (stem cuttings: 400 nos.), *Cleistanthus collinus* (stem cuttings: 100 nos.), *Indopiptadenia oudhensis* (stem cuttings: 100 nos.), *Cycas seshachalamensis* (seeds: 30 nos.), *Cycas sphaerica* (seeds: 30 nos.), and *Cycas beddomei* (seeds: 30 nos.), were multiplied using macro-propagation techniques. The work is in progress.

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Plant molecular systematics, phylogeography and genetic diversity assessment

Phylogeny and phylogeography of Indian *Citrus* L. (Rutaceae)

As part of an ongoing study on integrative taxonomic analysis for assessment of diversity and phylogenetic relationships among native and wild species of *Citrus*, *C. medica* L. and *C. indica* Tanaka, were selected for phylogeographic studies. These two species are found wild in Northeast India and considered as primitive among all the *Citrus* species. Phylogeographic approach was made to study the pattern of gene flow, population genetic structure and historical processes that may be responsible for the current pattern of distribution of these two species in the complex topography of Northeast India.

Sequencing of two cp DNA loci, *trnL-F* and *rps-16*, was done for 77 individuals of *Citrus medica* sampled from different populations. Sequence data were analyzed for genetic diversity and phylogeographic inferences, including haplotype diversity, nucleotide diversity, AMOVA, neutrality test (Tajima D and Fu'Fs), mismatch distribution analysis (MDA), principal coordinate analysis (PCoA), geographical distribution of haplotypes and Bayesian haplotype network. The preliminary data showed the following pattern in *C. medica*. High nucleotide diversity ($\pi = 0.738$) and haplotype diversity ($Hd = 0.66 \times 10^{-3}$) was detected. AMOVA revealed partition of 85.64% genetic variation within populations and 14.36% among the populations. The F_{st} value indicated a low but significant genetic differentiation among the populations ($F_{st} = 0.14$, $p \leq 0.001$). A total of 15 haplotypes were identified, of which Hap2 and Hap4 were widely distributed among the populations. Bayesian analyses of haplotype network formed a

star like pattern and Hap2 represented the ancestral haplotype. PCoA based on pair-wise genetic distance between the populations identified two weak genetic clusters. Neutrality test with Tajima D (-0.33902 , $p \leq 0.44$) and Fu'Fs (-0.001 , $p \leq 0.33$) was negative although not significant, suggesting range expansion. Unimodal graph under the growth-decline model in MDA revealed historical demographic expansion in *C. medica*.

Phylogeographic analysis of *C. medica* and *C. indica* is in progress with SSR markers and addition of more number of plant samples and cp DNA and ITS sequences to the dataset.

Phylogeography of *Ensete Bruce ex Horan.* (Musaceae) in India

The group has been working on phylogeography of two species of *Ensete* in India, i.e., *Ensete glaucum* and *Ensete superbum*. The objectives are estimation of genetic diversity and population genetic structure, determination of age and divergence of *Ensete* populations in India, and *ex-situ* conservation of *Ensete* germplasm at CSIR-NBRI.

Ensete glaucum is distributed in the Northeast India while *E. superbum* is found throughout Western Ghats, some parts of Aravalli, Satpura and Vindhya mountain ranges. Sampling has been done from all the known localities of both the species of *Ensete*. The samples included leaf materials for DNA isolation (*E. glaucum*- 64 and *E. superbum*-84), voucher specimens for herbarium preparation representing all the populations (*E. glaucum*-10 and *E. superbum*- 14), and fresh seeds and seedlings for *ex-situ* conservation. A total of 7 (≈ 3500 seeds) and 12

(≈1400 seeds) accessions of seeds were collected for *E. glaucum* and *E. superbum*, respectively. The number of seedlings which are successfully established included seven accessions of *E. glaucum*, and 10 accessions of *E. superbum*. Distribution maps for *E. glaucum* and *E. superbum* were prepared using geo-referenced occurrence records and Q-GIS software.

PCR amplification of selected samples of both the species for cpDNA (*psbA-trnH* and *rps-16*) was optimized. Successfully amplified sequences (*E. glaucum* -36 and *E. superbum* -84) were sequenced for the two loci. These sequences will be used for phylogeographic analysis of *E. glaucum* and *E. superbum*. Further, RNA sequencing of *E. glaucum* was done using an Illumina platform by outsourcing to Eurofin Pvt Ltd. (Bengaluru, India) and 8670 SSRs were identified from the assembled transcripts using MISA version 1.0 (<http://pgrc.ipk-gatersleben.de/misa/misa.html>). The primers for the identified SSR regions were designed using Primer3 version 0.4.0 (<https://primer3.org>). Out of the identified SSRs, 77 dinucleotide and 79 trinucleotide repeats were selected for primer synthesis. In the first lot, 52 SSR primer pairs from de novo data (37 dinucleotide and 15 trinucleotide repeats) and 44 SSR primer pairs from the published literature were synthesized for genotyping of *Ensete* accessions.

A plot was set up at NBRI garden for the maintenance of live plants of *E. glaucum*, *E. superbum* and *Musa* species as part of *ex-situ* conservation. The present collection includes seven accessions of *E. glaucum*, 10 accessions of *E. superbum* and six accessions of *Musa* species.

Maxent modelling was done in both *E. superbum* and *E. glaucum* to predict the potential suitable habitat for future exploration and to prioritize the area for conservation. The final data on the population structure, genetic diversity and ecological niche modeling will help

in the conservation and utilization of these crop wild relatives.

Systematic studies on *Henckelia-Didymocarpus* generic complex (Gesneriaceae) in India

During the year under report, a new species in *Henckelia*, along with a new geographic record, recollection and lectotypification of some Indian species of *Didymocarpus* was reported.

Henckelia umbellata Kanthraj & K Narayanan, *Rheedea* 30 (1): 143-149.2020 (Fig 1 A & B).

The new species was described from Arunachal Pradesh, India. *H. umbellata* can be easily distinguished by its umbellate flowers from other congeners. Although *H. umbellata* superficially resembles *H. longisepala* (H.W.Li) D.J. Middleton & Mich.Möller in having large paired involucre bracts enclosing the flowers, it differs from the latter in having 4–6-flowered umbellate inflorescences (vs. 3–9-flowered umbel-like cymes); fused, narrowly triangular, acuminate sepals (vs. free, spatulate-linear, obtuse sepals); and anther connective without any appendage (vs. connective with one appendage abaxially). The species is known so far only from Kra Daadi, Kurung Kumey and Lower Subansiri districts of Arunachal Pradesh, where it grows on muddy slopes and shady places along moist tropical forest margins at elevation of 770 to 1700 m.



Fig. 1: *Henckelia umbellata* Kanthraj & K. Narayanan: A. Habit, B. Closer view of the flowers

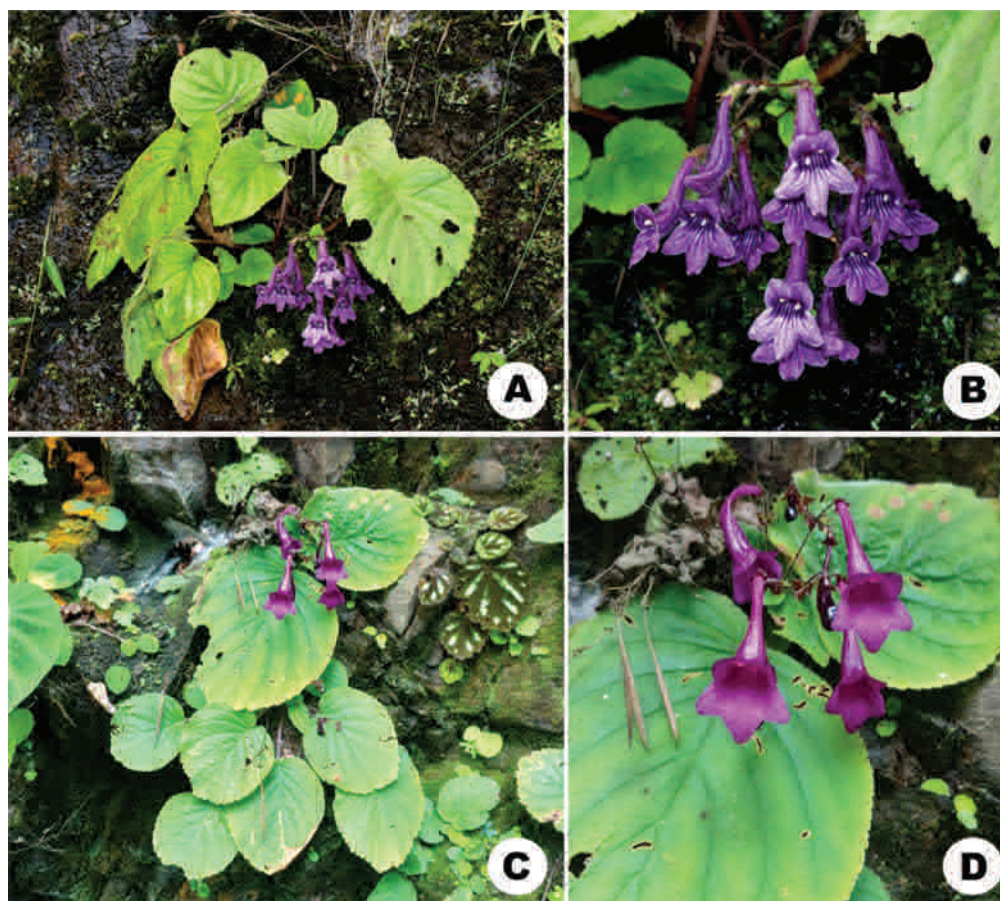


Fig. 2. *Didymocarpus cinereus* D. Don [A-B]: A. Habit, B. Closer view of the flowers; *Didymocarpus triplotrichus* Hilliard [C-D]: C. Habit, D. Closer view of the flowers

Didymocarpus cinereus D. Don, previously known only from Nepal and Bhutan, was recorded for the first time in India from Arunachal Pradesh (Fig. 2 A, B). *D. cinereus* has been often misidentified with *D. triplotrichus* Hilliard (Fig. 2 C, D), a closely related narrow endemic species of the Darjeeling Himalayas. *D. cinereus* differs from *D. triplotrichus* in having longer (8-21 cm) petiole (vs. shorter (2-8 cm) petiole), long spreading hairs absent on both surfaces of leaf (vs. long spreading hairs present on upper surface and only along the nerves on lower surface), corolla purple or bluish-purple with prominent white striations on the lobes, glandular hairy outside (vs. corolla purple without white striations on the lobes, glabrous outside), and stamen with filaments sparsely glandular puberulent and anthers bearded (vs. filaments and anthers bearded). *D. cinereus* was recorded from moist tropical and wet montane temperate forests of Tawang area in Arunachal Pradesh at an elevation ranging from 900 to 2400

m. *Didymocarpus triplotrichus* was recollected from its type locality (Pankhabari, Darjeeling District, West Bengal) after a collection gap of 138 years. The collections of *D. triplotrichus* were made at two locations along the Pankhabari road at an elevation of 950-1065 m.

Additionally, lectotypes for two species of *Didymocarpus*, *D. cinereus* D. Don and *D. albicalyx* C. B. Clarke, were also designated.

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Ethnobotany and floristics of angiosperms

Bioresources Inventory of Suhelwa Wildlife Sanctuary, Uttar Pradesh

Ethnobotanical information on about 34 potential plants used by tribal communities of Suhelwa Wild Life Sanctuary was documented. Information about local names, locality, phenology, and uses on plants were provided. Voucher specimens of underutilized wild edible plant species were also collected, processed, identified, accessioned and deposited in the herbarium of the institute (LWG). The useful plant species documented include: *Allium cepa* L. (Liliaceae), *Amaranthus spinosus* L., *A. viridis* L. (Amaranthaceae), *Amorphophallus paeonifolius* Dennst. (Araceae), *Anthocephalus chinensis* (Lamk.) A. Rich. ex Walp. (Rubiaceae), *Artocarpus lakucha* Ham. (Moraceae), *Asparagus racemosus* Willd. (Liliaceae), *Bauhinia variegata* L. (Caesalpinaceae), *Bridelia squamosa* Gehr. (Euphorbiaceae), *Commelina*

benghalensis L. (Commelinaceae), *Costus speciosus* (Koenig) Smith (Zingiberaceae), *Crotolaria juncea* L. (Fabaceae), *Dendrocalamus strictus* (Roxb.) Nees (Poaceae), *Ficus hispida* L.f. (Moraceae), *F. racemosa* L. (Moraceae), *F. virens* Ait. (Moraceae), *Flacourtia indica* (Burm.f.) Merr. (Flacourtiaceae), *Grewia hainesiana* Hole (Tiliaceae), *Luffa cylindrica* (L.) Roem. (Cucurbitaceae), *Miliusa velutina* (Dunal) Hook.f. (Annonaceae), *Moringa olerifera* Lam. (Moringaceae), *Morus alba* L. (Moraceae), *Portulaca oleracea* L., *P. quadrifida* L. (Portulacaceae), *Pueraria tuberosa* (Roxb. ex Willd.) DC. (Fabaceae), *Rumex dentatus* L. (Polygoniaceae), *Solanum nigrum* L. (Solanaceae), *Syzygium cerasoides* (Roxb.) Chatt. & Kanjilal, *S. heyneanum* Wall. ex Duthie (Myrtaceae), *Tamarindus indica* L. (Caesalpinaceae), *Trianthum portulacastrum* L. (Aizoaceae), (Rubiaceae), *Ziziphus mauritiana* Lam., *Z. oenoplia* (L.) Mill., and *Z. rugosa* Lamk. (Rhamnaceae).

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Plant diversity assessment, floristic analysis, taxonomic revision, plant survey and collection, herbarium curation

An assessment of weed flora in Rabi crops in Uttar Pradesh

Area wise Uttar Pradesh is the 4th largest state in India, which is dominated by plain fertile agriculture lands throughout. Due to large agriculture lands it is considered as the first major crop producing state in the country. Agriculture alone contributes to 24% of State's GDP. Being open agriculture land area, the State also provides a suitable environment for weeds to grow here along agriculture lands. Therefore, the State has been selected to survey and document the weed species growing along with rabi crops which are dominantly cultivated here. In rabi crop season wheat, barley, mustard, gram, linseed, groundnut, pearl millet, rapeseed and important vegetables like pea, cauliflower, cabbage, potato, carrot, etc. are grown.

Weeds are the plants which pose major hazard to vegetation and compete with the crops for the same resources like light, carbon dioxide, water, nutrients and space. Weeds have enormous adaptability, subsistence and aggressive nature. They increase irrigation requirement which in turn reduces the percentage of total crop production. Furthermore, they interfere in harvesting and are alternate hosts for crop pests and pathogens. In addition to this they cause various harmful effects like skin allergies (rashes, itching), respiratory dysfunctions (asthma, bronchitis), etc. Milch animals when eat some weeds like *Cleome viscosa* L., will produce an undesirable odour in milk. Still, some of them are beneficial in various medicinal aspects. In the present study a comprehensive and updated list of 185 weed species belonging to 63 families have been documented

along with their native range, family, updated nomenclature, phenology, uses and harms. It was also observed that among them, 73 species are of alien nature. Families which possess majority of weeds are Poaceae, Fabaceae, Asteraceae, Amaranthaceae, Cyperaceae and Euphorbiaceae. For authenticating the work, the secondary data along with the study of a large number of herbarium specimens housed at LWG, BSA and CDRI were also analysed. The current work will be very useful for weed scientists, agricultural professionals and farmers in the proper management and utilization of weeds. Some of the prominent weed species growing among the rabi crops are as follows:

- Wheat: (*Asphodelus tenuifolius* Cav., *Avena fatua* L., *Carthamus oxyacantha* M. Bieb., *Chenopodium album* L., *Cirsium arvense* (L.) Scop., *Convolvulus arvensis* L., *Cynodon dactylon* (L.) Pers., *Cyperus rotundus* L., *Fumaria indica* (Hausskn.) Pugsley, *Galium aparine* L., *Lysimachia arvensis* (L.) U. Manns & Anderb., *Phalaris minor* Retz.).
- Barley: (*Avena fatua* L., *Carthamus oxyacantha* M. Bieb., *Chenopodium album* L., *Convolvulus arvensis*

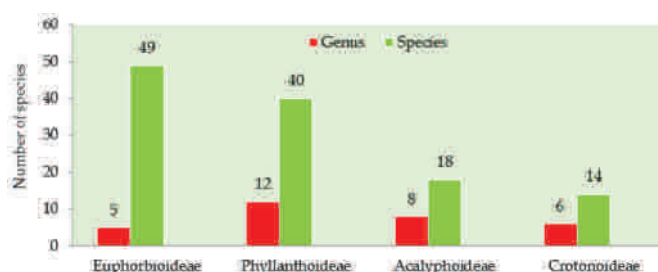


Fig. 1: Distribution of species in Subfamilies of Euphorbiaceae in Uttar Pradesh.

L., *Cyperus rotundus* L., *Galium aparine* L., *Lysimachia arvensis* (L.) U. Manns & Anderb.).

- Chickpea: (*Asphodelus tenuifolius* Cav., *Carthamus oxyacantha* M. Bieb., *Convolvulus arvensis* L., *Cynodon dactylon* (L.) Pers., *Lysimachia arvensis* (L.)U. Manns & Anderb.).
- Onion: (*Chenopodium album* L., *Carthamus oxyacantha* M. Bieb., *Convolvulus arvensis* L., *Fumaria indica* (Hausskn.) Pugsley, *Lysimachia arvensis* (L.)U.Manns & Anderb.).
- Rapeseed and Mustard: (*Carthamus oxyacantha* M. Bieb., *Chenopodium album* L., *Convolvulus arvensis* L., *Alhagi maurorum* Medik.).
- Other seasonal vegetables: (*Euphorbia helioscopia* L., *Chenopodium album* L., *Convolvulus arvensis* L., *Lysimachia arvensis* (L.) U. Manns & Anderb., *Rumex crispus* L.).
- Fodders: (*Carthamus oxyacantha* M. Bieb., *Convolvulus arvensis* L., *Lysimachia arvensis* (L.) U. Manns & Anderb.).

Diversity Assessment of Asteraceae in Uttar Pradesh

Uttar Pradesh, mostly occupied by agriculture lands, provides a better environment for the growth of herbaceous and weedy plants. Most of the members of the family Asteraceae are herbaceous (about 93%) followed by few climbers and shrubs which are found in open areas along agriculture fields, forest fringes and waste and fallow lands. During the reporting period some districts of Uttar Pradesh such as Balrampur, Barabanki, Hardoi, Farrukhabad, Kannauj, Kanpur, Lakhimpur, Lucknow, Sitapur, Shravasti and Unnao were surveyed to assess the diversity of Asteraceae. About 41 species under 19 genera have been collected so far, and identification and preparation of herbarium specimens of collected specimens are in progress. In addition to field surveys, plant specimens housed at CSIR-National Botanical Research Institute, Lucknow (LWG) and CSIR-Central Drug Research Institute, Lucknow (CDRI) were also examined. With the help of critical assessment of previously published literature, collections housed at different herbaria and personal field visits, a list of all expected taxa of Asteraceae in Uttar Pradesh was prepared. The list contains about 182 species (including 36 cultivated species) under

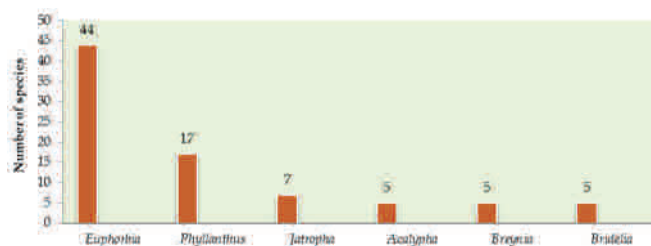


Fig. 2: Some dominant genera of Euphorbiaceae in Uttar Pradesh

109 genera. The species/taxa found in Uttar Pradesh can be distributed among 21 different tribes in which Inuleae with 32 taxa is the largest tribe, followed by Heliantheae, Astereae, Anthemideae and Cichorieae. *Blumea* with 15 species is the largest genus in the family in Uttar Pradesh, followed by *Artemisia*, *Acmella*, *Launaea*, *Sonchus*, etc. Some of the tribes like Arctotideae, Calenduleae, Dicomeae, Mutiseae and Pertyeae are represented by single genus and species, and about 72 genera are represented by only one species in the study area which need proper conservation strategy to protect them on priority basis. The family is of enormous economic potential as most of the members are utilized as the source of food, oil, medicines, drugs, dye and for the ornamental purposes.

Taxonomic study of the family Euphorbiaceae in Uttar Pradesh

Euphorbiaceae, usually called spurge family, is one of the sixth largest families among angiosperms with 340 genera and 8000–9000 species in the world. The plants of this family occur everywhere, except in arctic and cool temperate regions of northern hemisphere. In India, Euphorbiaceae consist of 410 species under 70 genera. All life forms such as herbs, shrubs, trees and rarely climbers are found in the family. A detailed systematic study of the family Euphorbiaceae occurring in the current political boundaries of Uttar Pradesh has been carried out. Based on the extensive literature survey, herbarium study, and field visits conducted during 2018–2020, about 121 species belonging to 31 genera have been recognized from the study area in the family. These species are distributed in four subfamilies viz., Acalyphoideae (18 species under 8 genera), Crotonoideae (14 species under 6 genera), Euphorbioideae (49 species under 5 genera) and Phyllanthoideae (40 species under 12 genera) (Fig. 1). According to their life forms, 43

species are herbs, 35 species are shrubs, 23 species are either shrubs or small trees, 19 species are trees, and only one species is a climber. Among all species of Euphorbiaceae occurring in Uttar Pradesh, 10 species are abundant, 22 species are frequent, 15 species are occasional, 35 species are infrequent and 20 species are rare. The cultivated species constitute about 17% (approximately 19 species) of the total species. The study revealed that *Euphorbia* is the largest genus in the family with 44 species (36.36%), followed by *Phyllanthus* with 17 species (14.04%) and *Jatropha* with 7 species (5.8%)(Fig. 2). The family has high economic importance as ornamental, food, oil, rubber, medicine, timber and dye yielding plants. The flowering and fruiting generally take place during January to March and may extend up to June. In some of the species the flowering and fruiting occur throughout the year.

Herbarium curatorial work

During the reporting period, 2570 specimens of angiosperms were accessioned and incorporated in the herbarium. About 22 plant species received from eight different organizations were identified/ authenticated and certificates were issued to them.

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Diversity, floristic, revisionary and phylogenetic studies on lichens, taxonomical studies on lichenicolous fungi, bioprospection studies on lichens and endolichenic fungi

New species discovered

1. *Cratiria rubrum* R. Ngangom, Nayaka & R. Gogoi, *Plant Science Today* 7(4): 584 (2020). Fig. 1.

The new species *Cratiria rubrum* is characterized by brick red pigmented thallus, convexly bulged areoles with pale margin, sessile, black apothecia, smaller, *Buellia*-type ascospores and by the presence of norstictic acid.

Species reported as new record for India

1. *Amandinea efflorescens* (Mull. Arg.) Marbach. – This species was earlier reported from North Atlantic, Thailand, Singapore, Puerto Rico, Guyana, Brazil, Australia, Madagascar and Seychelles.
2. *Amandinea incrustans* (J. Steiner) Marbach. – This species was earlier reported from Namid desert in South Africa.
3. *Bacidia pycnidiata* C. zarnota & Coppins. – Previously this species was known from Belgium, Czech Republic, Estonia, Finland, Lithuania, Mordovia, North Caucasus, Poland, and Ukraine.
4. *Baculifera orosa* Marbach. – This species was earlier reported from Central America and Mexico.
5. *Chapsa cinchonarum* (Fée) Frisch. – Previously, this species was known from tropical Africa and the Neotropics.

6. *Chapsa farinose* Lücking & Sipman. – This species was previously known from Costa Rica.
7. *Diorygma sticticum* Sutjar., Kalb & Lücking. – Earlier, this species was known from Thailand.
8. *Fissurina albocinerea* (Vain.) Staiger. – This species was earlier known from the Philippines.
9. *Graphis bungartzii* A.B. Peña, Lücking, Herrera-Camp. & R. Miranda – Previously, this species was known from Mexico.
10. *Graphis discarpa* A.W. Archer – This species was previously known from Papua New Guinea.
11. *Graphis nigririmis* (Nyl.) Müll. Arg. – This species was earlier known from Australia.

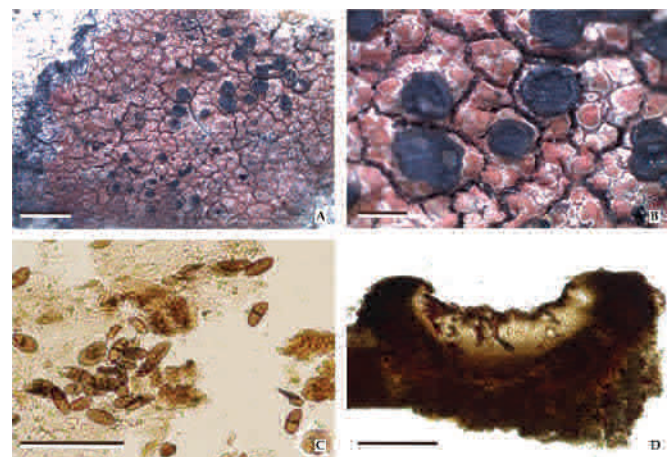


Fig. 1: *Cratiria rubrum*- (A–B). Thallus with ascوماتа, (C). Sections showing ascospores, (D). Sections through apothecia. (Scale bars: A = 2 mm; B = 0.5 mm; C = 50 μ m; D = 100 μ m.)

12. *Hafellia dissa* (Stirt.) H. Mayrhofer & Sheard – Earlier this species was reported from cool temperate regions of Tasmania, Southern Australia, Brazil, Philippines and South Africa.
13. *Hafellia reagens* Pusswald – This species was earlier known from subtropical Australia.
14. *Malmidea nigromarginata* (Malme) Lücking & Breuss – This species was previously reported from Nicaragua and Puerto Rico.
15. *Ocellularia alba* (Fée) Müll. Arg. – Previously, this species was known from Australia, Brazil, the Philippines.
16. *Phaeographis pseudostromatica* Seavey & J. Seavey – This species was earlier known from Florida.
17. *Porina malmei* P.M. McCarthy – This species was earlier known from Brazil, north-eastern Australia.
18. *Porina nuculastrum* (Müll. Arg.) R.C. Harris – Earlier, this species was known from Neotropics, Madagascar, Philippines, Hong Kong and Vietnam.
19. *Pyrenula laetior* Müll. Arg. – This species was earlier reported from Neotropics and Vietnam.
20. *Pyrenula wrightii* (Müll. Arg.) R.C. Harris – This species was earlier known only from Cuba.
21. *Sarcographa verrucosa* (Vain.) Zahlbr. – Previously this species was known from Australia, Indonesia, and the Philippines.
22. *Thelotrema crassisporum* Mangold – This species was previously known from Australia.

Lichen study in Assam, Meghalaya, Kerala and Uttar Pradesh

An account of lichens growing in five districts of Assam was published with 138 species of which 37 were new to the state. In another study, six species of crustose lichens were recorded as new to India from Assam.

From Meghalaya, based on previous reports and our recent explorations, 337 species under 40 families and 102 genera have been compiled, including 93 species as new records to the State. The lichen biota in Meghalaya is dominated by crustose lichens (226 spp.), with maximum representation of graphidaceous forms (66 spp.).

In another field tour to Pathanamthitta District in Kerala, 11 species of lichens were recorded as new to the State.

The identification of lichens collected from Suhelwa Wildlife Sanctuary in Uttar Pradesh resulted in 53 species belonging to 23 genera and 16 families. The crust forming lichen exhibited their dominance in this area with 43 species, followed by foliose and leprose lichens with eight and one species, respectively. Out of 16 families, Graphidaceae exhibited 11 species, followed by Pyrenulaceae and Ramalinaceae with eight and seven species, respectively. The genera *Bacidia* and *Pyrenula* were the largest genera with seven species each, followed by *Diorygma* with five and *Dirinaria*, *Graphis*, *Lecanora*, *Pertusaria* and *Pyxine* with three species each.

Lichenicolous fungi

The lichenicolous fungi are the fungi which grow on lichens as saprophytes or parasites. About 1400 specimens of parmelioid lichens deposited in CSIR-NBRI herbarium (LWG) were examined under microscope for the presence of lichenicolous fungi. Out of these 1400, only 124 specimens were found infected by lichenicolous fungi which were then subjected to detailed taxonomic studies. The study so far resulted in 19 species under 16 genera.

Endolichenic fungi

The study of secondary data indicates that ca. 500 endolichenic fungi have been isolated so far in the world, of which only 135 have been identified up to species level. These endolichenic fungi belong to 32 orders, 70 families and 112 genera. In our ongoing study, a total of 60 endolichenic fungi have been isolated from eight species of *Parmotrema*. The endolichenic fungi were identified through microscopy and molecular techniques.

Revisionary and phylogenetic study of Arthoniales

During the revision of *Bactrospora*, the study of type specimens confirmed that *B. lamprospora* (Nyl.) Lendemer is conspecific with *B. metabola* (Nyl.) Egea & Torrente. Further, world key for 16 known species of the genus *Crypthonia* was prepared, and their distribution mapping was carried out. The database for the e-monograph of Indian Arthoniales is updated with details of 41 genera and 276 species.



Lichen genera *Buellia s.l.* and *Rinodina*

The genera *Buellia sensu lato* and *Rinodina* belonging to order Caliciales are being revised. So far, a total of 556 specimens belonging to *Buellia s.l.* were studied which resulted in identification of 80 species under 10 genera. The genus *Buellia sensu stricto* alone represented 37 species. The study also resulted in one new species (*Cratiria rubrum* R. Ngangom, Nayaka & R. Gogoi) and five new distributional records to India (*Amandinea efflorescens*, *A. incrustans*, *Baculifera orosa*, *Hafellia dissa* and *H. reagens*). Further, 527 specimens of *Rinodina* were studied in detail, which resulted in identification of 21 species. The description of several interesting *Rinodina* specimens as new species or new distributional records is under progress. A key to all genera and species of *Buellia s.l.* and *Rinodina* was prepared. DNA was extracted from 11 freshly collected specimens of *Amandinea errata*, *A. extenuata*, *Baculifera xylophila*, *Buellia confusa*, *B. proximata*, *Cratiria obscurior*, *Rinodina intermedia* and *Rinodina pyrina* and ITS loci were sequenced for phylogenetic study.

Antimicrobial and antioxidant activities of some potential lichens from Himalaya

A total of five lichen species, *Cladonia rangiferina*, *Parmotrema neilgherrense*, *Ramalina conduplicans*, *Stereocaulon foliolosum* and *Usnea longissima* occurring in the Himalaya were selected for antimicrobial and antioxidant study. These lichens have shown significant antimicrobial activity in the previous study. Further, 2 mg crude extracts in different solvents (acetone, ethyl acetate, chloroform and methanol) of these lichens are utilized for estimating the minimal inhibitory concentration (MIC). The MIC test was carried out by 96 well plate method against pathogenic bacteria (*Acinetobacter baumannii*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*) and fungi (*Aspergillus niger*, *Candida albicans*, *Fusarium oxysporum*). The sensitivity of the tested microorganisms to lichen extracts ranged from

0.5mg/ml to 1.5mg/ml. Among five lichens species, *U. longissima* showed significant inhibitory activity at minimal concentrations of 0.5 and 0.7 mg/ml.

The endolichenic fungi isolated from lichen genus *Parmotrema* were screened for antimicrobial activity against microbes *Acinetobacter baumannii*, *Bacillus subtilis*, *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *Streptococcus mutans*. The ethyl extract of endolichenic fungi *Daldinia eschscholtzii* showed significant antimicrobial activities with inhibition zone ranging from 15.4 to 25.2 mm against tested microbes, which is higher than the standard streptomycin. *Daldinia eschscholtzii* was further screened for its chemical constituents through gas chromatography-mass spectrometry (GC-MS) which resulted in detection of a total of 20 compounds.

Antioxidant activities of methanolic extract of lichens were studied in comparison to standard ascorbic acid. The lichens exhibited concentration dependent antioxidant activity by scavenging DPPH⁺ free radical and converting them into DPPHH. Over 50% scavenging activities were observed in all the concentrations of the extracts. The lichens *R. conduplicans*, *U. longissima* and *P. nilgherrense* showed the maximum antioxidant activities at 1 mg concentration among all five species. However, the radical scavenging activities of lichens are lesser in comparison to the standard.

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Diversity assessment, floristic analysis, morphotaxonomy, *in vitro* studies and conservation of Bryophytes

Assessment of Bryophyte diversity in Senchal Wildlife Sanctuary

Senchal Wildlife Sanctuary (SWLS), Darjeeling was surveyed and about 106 taxa of bryophytes were recorded, of which mosses represented 74%. Among mosses, the acrocarpous mosses with nearly 2/3rd representation, were dominant than the pleurocarpous mosses. The short turfs form is the most frequently occurring growth form among acrocarpous mosses whereas liverworts tend to form mats covering the substratum. Six habitats viz., soil, soil covered rocks, wet rocks, dry rocks, stone/ brick walls and tree barks (epiphytic) have been identified for study of distribution of bryophytes in selected habitats. The distribution pattern highlights the dominance of some forms, particularly the epiphytic ones preferring rocks as their favored habitat. The similarity index values were less than 20 for most habitat combinations, indicating a good diversity in the study area. Maximum similarity was observed among bryophytes growing on soil with those on dry rocks as well as stony/brick walls (25% & 22.2%), respectively. Two species, *Marchantia subgeminata* Stephani and *Frullania ornithocephala* (Reinw. et al.) Nees were recorded for the first time from India.

Floristic analysis in Kullu and Manali (Himachal Pradesh) and Ghoom (Darjeeling)

A floristic survey made for Bryophytes in Kullu and Manali (Himachal Pradesh) recorded 74 taxa that included 25 taxa of liverworts, 48 taxa of mosses, and one species of hornwort. The moss species *Syntrichia fragilis* (Tayl.) Ochyra was recorded as new to the Himalaya and *Trichostomum minusculum* Dixon &

P. Verd. as new to the western Himalaya. Among liverworts, *Lejeunea obscura* Mitt. and *Lejeunea minutiloba* A. Evans were identified as new to the western Himalaya. In addition, 16 species of mosses viz., *Hymenostylium aurantiacum* Mitt., *Hymenostylium dicranelloides* Broth. ex Dixon, *Hyophila spathulata* (Harv.) A. Jaeger., *Timmiella diminuta* (Mull. Hal.) P. C. Chen., *Physcomitrium pulchellum* (Griff.) Mitt., *Philonotis mollis* (Dozy and Molk.) Mitt., *Pohlia cruda* (Hedwig) Lindberg., *Homaliodendron microdendron* (Mont.) M. Fleisch., *Brachythecium plumosum* (Hedw.) Schimp., *B. procumbens* (Mitt.) A. Jaeger, *B. velutinum* (Hedw.) Schimp., *Rhynchostegium celebicum* (Lac.) A. Jaeger, *R. herbaceum* (Mitt.) A. Jaeger, *R. planiusculum* (Mitt.) A. Jaeger., *Gollania ruginosa* (Mitt.) Broth., *Clastobryum capillaceum* (Griff.) Broth., and one species of liverwort *Porella perrottetiana* (Mont.) Trev. were recorded for the first time from Himachal Pradesh.

Ghoom area of Darjeeling was also surveyed and 48 bryophyte taxa belonging to 25 families were identified. Families Pottiaceae, Bryaceae and Marchantiaceae were found dominant in this region. *Marchantia subgeminata* Steph. was found as a new record for India, while *Anoetangium aestivum* (Hedw.) Mitt. was recorded for the first time from the eastern Himalaya

In-vitro studies

Rhodobryum roseum (Hedw.) Limpr. is a medicinally potential moss which is used to treat nervous prostration and cardio-vascular diseases. It was grown *in-vitro* with an objective to standardize the protocol for its mass propagation under controlled conditions. Apical stem portions were used as

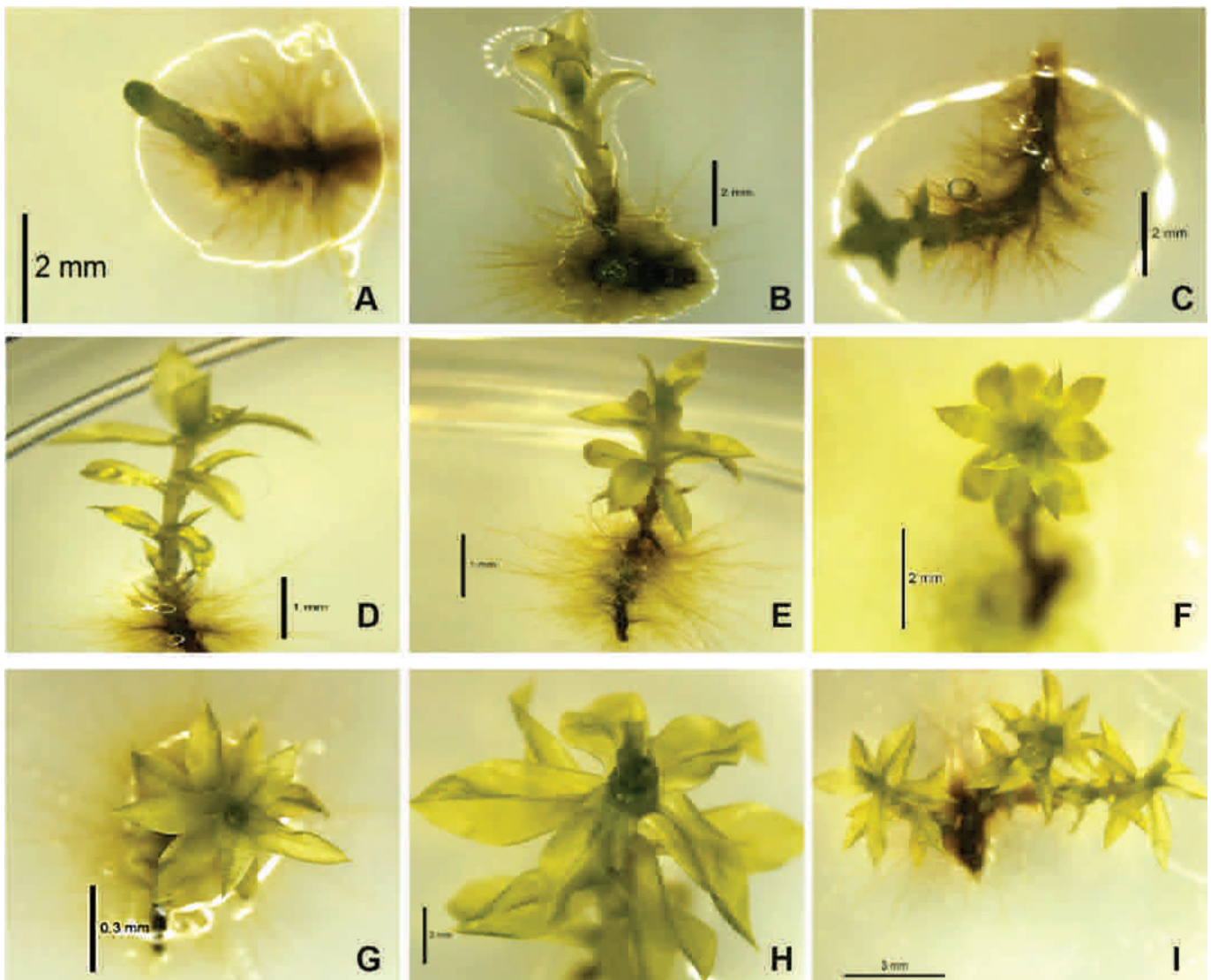


Fig. 1: *In-vitro* propagation of *Rhodobryum roseum* (Hedw.) Limpr. (A-C): Initiation of rhizoids with small leaves during 1-3 weeks. (D-F): Plant and leaf size enhanced with high density of protonemata during 3-6 weeks. (G-I): Leaf size increased at apex forming a rosette during 6-9 weeks.

explants and cultured on Knop's, Knop's + vitamins B_1 , Knop's + 2,4D and Knop's + 2,4D + Vit. B_1 media. Well-developed plants were obtained forming a good population in Knop's + 2,4D + Vit. B_1 medium in 16 weeks (Fig. 1).

New plant distributional records

Plagiomnium insigne (Mitt.) T. J. Kop. known as Badge moss has been reported for the first time from Asia (Gulmarg, India). It was earlier known from North America (California, USA and Canada). The species

is characterized by its dioecious sexuality, elliptical leaves with small \pm pitted isodiametric cells and more number of two celled teeth on leaf margin.

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Floristic survey, diversity assessment, reproductive biology, mass-multiplication, conservation and bioprospection of Indian Pteridophytes.

Floristic Survey & Diversity Assessment

Identified 59 species of pteridophytes belonging to 40 genera under 28 families from Pachmarhi Biosphere Reserve, Madhya Pradesh. Some of the common species among them are: *Ampelopteris proliferata*, *Lygodium flexuosum*, *Dryopteris cochleata*, *D. sparsa*, *Adiantum incisum*, *Equisetum ramosissimum*, *Diplazium esculentum*, *Paraleptochilus decurrens*, *Tectaria coadunata*, *Christella dentata*, *Athyrium pectinatum*, *Cyclosorus cylindrothrix*, *Dicranopteris linearis*, and *Cyathea gigantea* (Fig. 1 A-H). A few species were encountered only at one or two locations with a few individuals (e. g. *Azolla pinnata*, *Botrychium lanuginosum*, *Deparia* sp., *Isoetes coromandeliana*, *Hymenophyllum javanicum*, *Marsilea quadrifolia*, *Pleopeltis nudus*, *Psilotum nudum*, *Salvinia cucullata*, *Lycopodium cerenum*, and *Bolbitis* sp.). Some new records for India in the family *Athyriaceae* have also been observed, and further study on this is in progress.

Similarly, 67 species of pteridophytes under 52 genera and 28 families were identified from Meghalaya. Six species (*Adiantum incisum*, *A. philippense*, *Ampelopteris proliferata*, *Cheilanthes farrinosa* and *Equisetum ramosissimum*) have also been identified from Suhelwa Wildlife Sanctuary (SWLS), Uttar Pradesh.

Micropropagation of *Cyathea spinulosa*

In-vitro multiplication of about 50 sporophytes of *Cyathea spinulosa* was made for restoration in the natural habitat (Fig. 2 A-B).

Reproductive Biology of *Cyathea gigantea*

Studies on spore viability, germination percentage

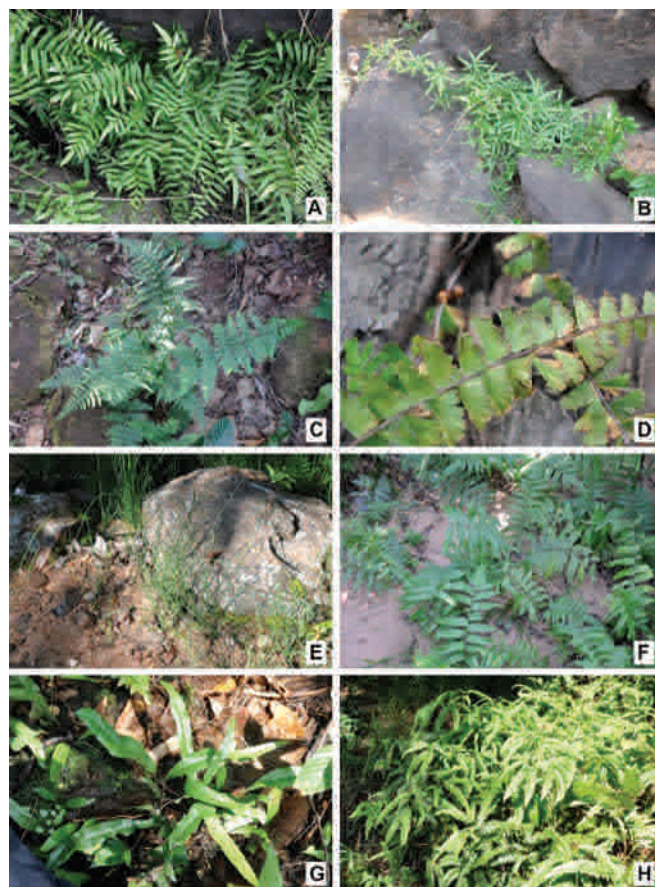


Fig. 1: Some of the common pteridophytes of Pachmarhi Biosphere Reserve, Madhya Pradesh. (A). *Ampelopteris proliferata*, (B). *Lygodium flexuosum*, (C). *Dryopteris cochleata*, (D). *Adiantum incisum*, (E). *Equisetum ramosissimum*, (F). *Diplazium esculentum*, (G). *Paraleptochilus decurrens*(H). *Dicranopteris linearis*.

and gametophyte developmental pattern in *Cyathea gigantea* have been initiated. *In-vitro* study showed 17.42% spore germination on 67th day, with subsequent

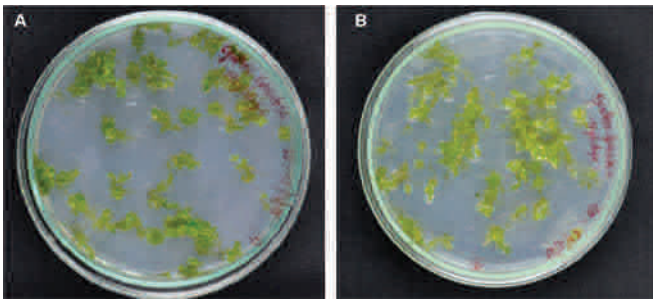


Fig. 2: (A-B). *In-vitro* multiplication of *Cyathea spinulosa* sporophytes

gametophytic development from 3-6-celled, 9-11 celled filamentous to two-dimensional gametophyte (2-D) spatulate stage on 72nd, 79th and 93rd day, respectively. The spore germination at the above stages was recorded as 28.22%, 31.88% and 40.24%, respectively. The spatulate 2-D gametophytes reached semi-cordate and cordate stages on 107th

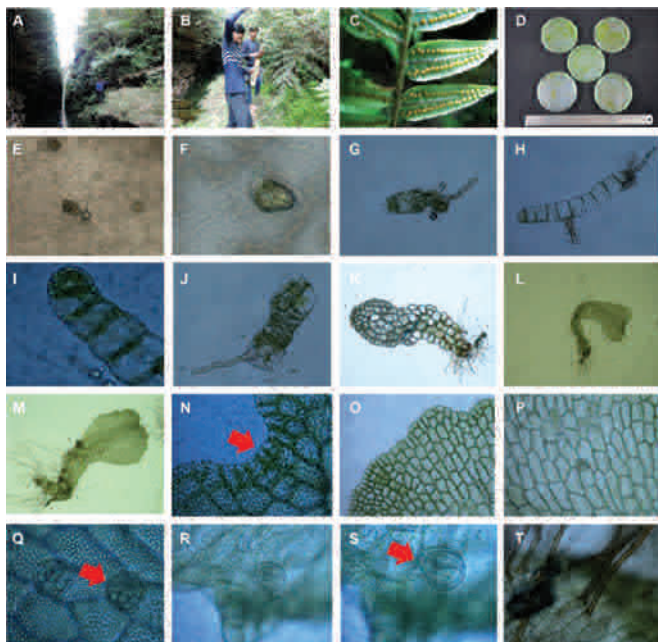


Fig. 3: *In-vitro* study on *Cyathea gigantea*. (A-B). Spore collection in Pachmarhi, (C). Spore containing pinnae, (D). *In-vitro* culture of spore (in replicates), (E). Spores, (F). Germinating spore on 67th day, (G). 2-3-celled stage with 1-2 rhizoid, (H). 9-10-celled uniseriate or branched gametophyte, (I-J). Meristem in apical cell and 2-D stage, (K). Spatulate stage, (L). Semi-cordate stage, (M). Cordate stage, (N). Apical notch, (O). Marginal cells, (P). Median cells, (Q-S). Antheridium & antherozoids, (T). Rhizoids on ventral side.

and 119th day respectively, with 46.89% and 53.44% spore germination. Small, sessile, globose antheridia appeared at ventral side of the gametophyte on 142nd day, with 57.96% germination. The average number of antheridia observed was 10.60. Multiflagellate antherozoids were released from the antheridia on 149th day and spore germination recorded at this stage was 58.65%. The composite cultures containing the gametophytes showed 60.53% spore germination on 163rd day. The germination percentage reached up to 61.60% on 177th day and no archegonia appeared on the gametophyte at this stage. The germination pattern of spore is *Cyathea* type and the prothallial development is *Adiantum* type. Further study is in progress (Fig. 3 A-T).

Mass Propagation of plants

Mass propagation of 1100 individuals (replicates) of 13 ornamental species of pteridophytes was made. In addition, *Tectaria coadunata* (Fig. 4A) was also propagated in large scale for prospecting for potential molecules.

Ex-situ Conservation of plants in Fern House

About 67 species of ferns, including threatened species, have been conserved in the fern house.

In-vitro multiplication and new introduction of plants

The plantlets of *Christella dentata* were produced through *in-vitro* spore culture and introduced in the fern house of the institute (Fig. 4 A & B).

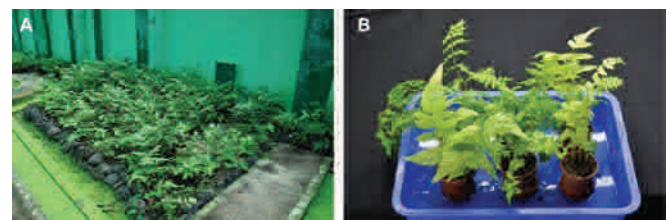


Fig. 4: (A). Large scale multiplication of *Tectaria coadunata*, (B). *Christella dentata* plantlets produced from *in vitro* spore culture

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Plant diversity assessment and molecular systematic studies

Floristic studies of Vidarbha region of Maharashtra

Systematic collection, herbarium preparation and documentation of plant diversity of Vidarbha region continued as part of establishing a Herbarium at Botanical Garden, Chanda, Chandrapur. Vidarbha region is characterized by mixed dry deciduous vegetation dominated by species of *Terminalia*, *Pongamia*, *Butea*, *Tamarindus*, *Mallotus*, *Ficus*, *Tectona*, *Zizyphus*, *Phyllanthus*, *Lagerstroemia*, *Acacia*, *Dalbergia*, *Emblica*, *Nyctanthes*, *Calotropis*, *Combretum* and *Bauhinia*. Plant materials collected from different forest parts of the region were critically studied and identified. Approximately 1332 herbarium specimens have been prepared, which on critical examination revealed 334 species under 244 genera and 79 families. Leguminosae with 50 species was found to be the most dominant family followed by Poaceae (32), Euphorbiaceae (21), Malvaceae (15), Cyperaceae (13) and Asteraceae (11); while within genera *Ficus*

L. with six species was the most dominant, followed by *Acacia* and *Terminalia* having five species each. Analysis of life form diversity revealed dominance of herbaceous elements (45%), followed by trees (26%), shrubs (18%) and climbers (11%) (Fig. 1). Further work on identification and documentation of specimens of monocots is in progress.

Molecular systematics and phytochemical studies in *Juniperus* L. (Cupressaceae)

Juniperus L., a highly diverse genus among conifers, comprising ca. 70 species and 40 varieties, is distributed widely over Northern Hemisphere from the Arctic to the mountains of East Tropical Africa, Himalaya and far-east. At high altitudes (1800–4600 m) *Juniperus* species are one of the important elements of the forest vegetation in the Indian Himalayan Region (IHR) and serve as source of food, spice and flavour, wood, fuelwood and medicine. Juniper essential oils obtained from leaves, shoots and berries possess diuretic, antiseptic, antimicrobial, anti-inflammatory, antirheumatic and stomachic properties.

The plant materials of four *Juniperus* taxa namely *J. communis* L. var. *saxatilis* Pall., *J. indica* Bertol., *J. semiglobosa* Regel and *J. recurva* Buch.-Ham ex D. Don were collected from Lahul valley, Himachal Pradesh and West Kameng District, Arunachal Pradesh and identified. Genomic DNA was extracted from the collected samples. Quantitative and qualitative analyses of 53 genomic DNAs representing the four species were carried out. Thirteen nuclear ribosomal and chloroplast DNA markers for phylogenetic studies have been identified and commercially synthesized. Furthermore, optimization of PCR

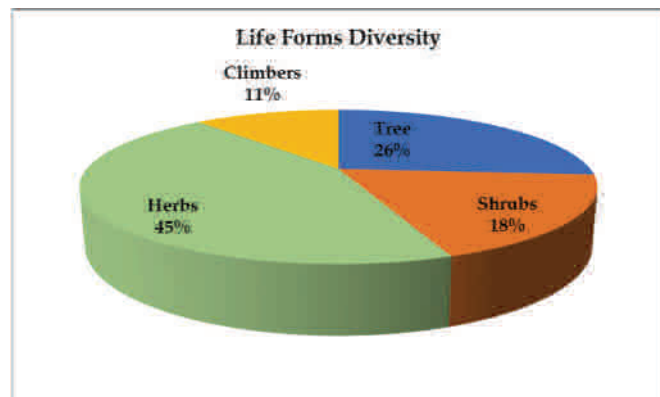


Fig. 1: Representation of life form diversity of angiosperms documented from Vidarbha region

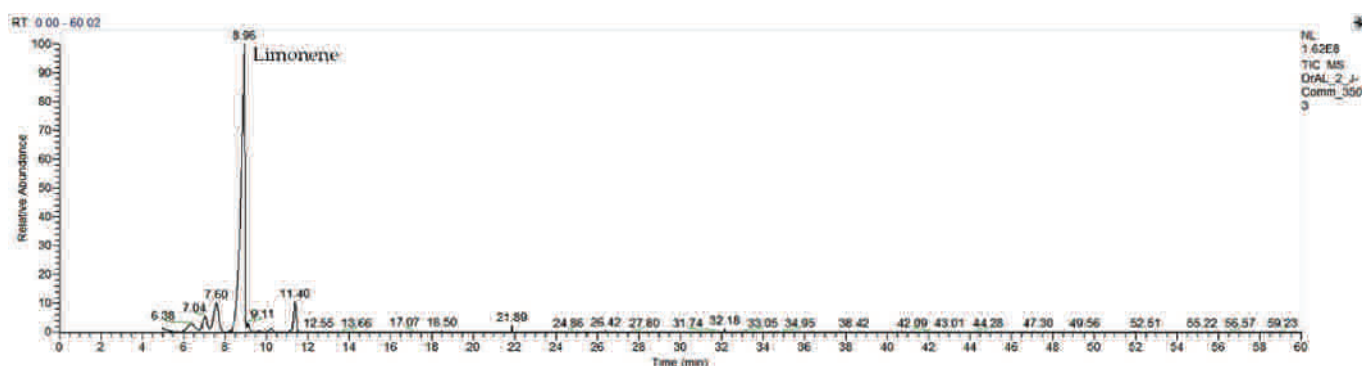


Fig. 2: GC/MS profile of *Juniperus communis* var. *saxatilis* Pall. showing higher limonene content

amplification conditions, screening and selection of ISSR and DAMD for genetic diversity analysis, and ITS markers for sequencing of *Juniperus* species were carried out.

Four essential oils, hydro-distilled from three species (*J. communis* var. *saxatilis*., *J. indica*, *J. semiglobosa*), collected from Himachal Pradesh, were investigated for qualitative and quantitative chemical variability using GC/MS. Populations from Lahaul valley were found to contain high quantities of limonene (66.66%) and sabinene (61.79%). Estimates of total phenolic and total flavonoid contents and antioxidant capacity of the four oils were examined using standard protocols and these were found very significant in comparison to the control (Fig. 2).

The scavenging activity of four essential oils samples (*J. communis*, *J. indica*, *J. semiglobosa*, and *J. semiglobosa* (berry)) was evaluated using DPPH free radical assay with ascorbic acid as a control. The extent of scavenging activity in EOs of *Juniperus* species varies among different species and also depends on bioclimatic conditions of their habitats. Significant radical scavenging IC_{50} value was found in sample 4 (*J. semiglobosa* berry), followed by sample 3 (*J. semiglobosa* leaf), whereas IC_{50} value in sample 1 (*J. communis*) was comparatively low. However, the overall levels of IC_{50} 125.90 $\mu\text{g}/\text{ml}$, 170.48 $\mu\text{g}/\text{ml}$ and 206.28 $\mu\text{g}/\text{ml}$ in sample 1, sample 2 and sample 3 respectively, were significantly higher than the control (IC_{50} 8.15 $\mu\text{g}/\text{ml}$). However, sample 4 revealed high scavenging activity (IC_{50} 369.13 $\mu\text{g}/\text{g}$) and can

be exploited for further therapeutic purposes (Fig. 3).

Conservation of threatened plant species

Under conservation of threatened plant species of India review of literature to collate and synthesise the

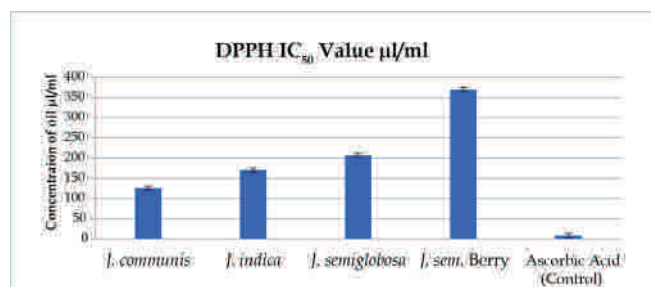


Fig. 3: Scavenging activity in four species of *Juniperus* L.

secondary information available on botanical names, synonyms, etymology, vernacular names, description, taxonomic notes, phenology, distribution, ecology, associate species, threat status, uses and trade was carried out. Information on 16 species has been documented using different published resources and web databases, and further work on other 10 species is in progress. To map the natural range of distribution of selected threatened taxa voucher specimens housed at NBRI, CIMAP, CDRI, and CAL were also studied and documented.

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Diversity and floristic studies of algae

Diversity and floristic studies

During the period under report algal diversity in following areas was documented:

Suhelwa Wildlife Sanctuary, Uttar Pradesh

The microphotography and morphological identification of algal samples collected from Suhelwa Wildlife Sanctuary resulted in 43 taxa belonging to 25 genera, namely *Anomoeoneis*, *Benetorus*, *Brachysira*, *Caloneis*, *Craticula*, *Cymbella*, *Diadesmis*, *Dorofeyukea*, *Encyonopsis*, *Fallacia*, *Epithemia*, *Fragilariforma*, *Geissleria*, *Gomphonema*, *Gyrosigma*, *Hantzschia*, *Navicula*, *Neidium*, *Nitzschia*, *Pinnularia*, *Rhopalodia*,

Sellaphora, *Tabularia*, *Tryblionella* and *Ulnaria* under the family Bacillariophyceae. Scanning Electron Microscopic (SEM) studies have been done for three common diatom species found in Suhelwa Wildlife Sanctuary, Uttar Pradesh (Fig.1).

Jim Corbett National Park, Uttarakhand

Jim Corbett National Park was surveyed and more than 130 algal samples were collected. Identification of algal samples resulted in 74 taxa belonging to 22 genera and 13 families (Oscillatoriaceae, Nostocaceae, Calothricaceae, Aphanothecaceae, Gomontiellaceae, Sytonemaceae, Homeotrichaceae, Chroococcaceae, Microcystaceae, Microcoleaceae, Leptolyngbyaceae, Trichocoleusaceae, and Synechococcales familia incerta sedis) belonging to 4 orders (Nostocales, Chroococcales, Oscillatoriales, Synechococcales) under the class Cyanophyceae. The genus *Oscillatoria* exhibits dominance with 19 taxa, followed by *Phormidium*, *Lyngbya* and *Porphirosiphon* with 9, 7 and 5 species, respectively. Identified an indicator species *Stigeoclonium pachydermum* from the national park.

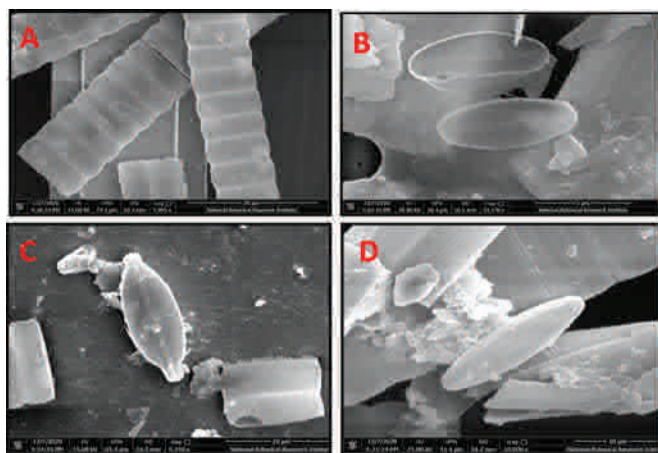


Fig. 1: SEM images of Diatoms: (A and B). *Diadesmis* sp., (C). *Navicula* sp. 1, (D). *Navicula* sp. 2

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Angiosperm systematics, floristic diversity assessment, taxonomic monographs/revision, and plant conservation

New plant species discovered

Agrostis barikii P. Agnihotri & D. Prasad, Phytotaxa 494(1): 145-150.2021 (Fig. 1).

A new grass species, *Agrostis barikii* was described from the Western Himalaya in India. It grows on open mountain slopes in grasslands and rock boulders in alpine and subalpine zones at an elevation of 2650–3600 m a.s.l. *Agrostis barikii* differs from *Agrostis griffithiana* by its ligule short-ciliate (vs. non-ciliate), lower glume 2.3–3.2 mm long (vs. 3.2–4.2 mm long), absence of mucro at lemma tip (vs. mucro present, 0.2–0.4 mm long), awn 1.8–3.6 mm long (vs. 4.8–5.6 mm long), and anthers 0.5–0.7 mm long (vs. 0.8–0.9 mm long).

Systematic Studies

Grasses of Western Himalaya

Systematic studies on grasses of western Himalaya were continued. The grass specimens were collected and studied from different regions of Himachal Pradesh, Jammu and Kashmir and Uttarakhand. The study of collected specimens revealed ca. 220 species belonging to ca. 75 genera, including 13 endemic taxa. About 60 species under 20 genera belong to tribes Paniceae and Triticeae. Similarly, ca. 65 species under 25 genera were identified in the subfamily Pooideae. The study also revealed two new records in Pooideae for India viz, *Calamagrostis himalaica* (Liou ex Chen) Paszko and *Calamagrostis nyingchiensis* (P. C. Kuo & S. L. Lu) Paszko from Himachal Pradesh.

Genus *Anemone* L.

The genus *Anemone* L., commonly known as

“windflower”, stands out as one of the largest genera in the family Ranunculaceae, representing more than 200 species worldwide. *Anemone* is mainly distributed in the temperate zones of Northern hemisphere but few taxa have also been reported from Southern hemisphere, and the maximum diversity has been observed from subtemperate to subalpine zones of Asia, Europe, Japan, and North America. In India, ca. 26 taxa of *Anemone* are found in diverse habitats of the Himalaya, Northeast India and Tamil Nadu in Western Ghats. During the reporting year, six species of *Anemone* namely, *A. obtusiloba* D. Don, *A. rauii* Goel & U.C. Bhattach., *A. rivularis* Buch.-Ham. ex DC., *A. tetrasepala* Royle, *A. trullifolia* Hook.f. & Thoms., *A. vitifolia* Buch.-Ham. ex DC. were collected from Jammu & Kashmir, Himachal Pradesh and Uttarakhand, and detailed taxonomic studies of them have been made.

Floristic study of Pangri Valley

Pangri valley is situated between the latitudes of 30°48'N to 33°13'N and longitudes of 76°15'E to 76°47' E. The entire valley is distributed over an area of 1600 square km and is divided into three forest ranges viz., Killar, Sach and Purthi. Geographically, the tract deals with the north-eastern part of the Chamba district and is bounded on the north by spur known as Trishul Dhar, which separates it from the Paddar area of Jammu and Kashmir. On the south, there is a ridge joining Ghor Dhar Jot and running up to Dhandal Dhar, where it meets the range of Pir Panjal. The eastern range touches with the Zanskar range of the main Himalayas. The valley is characterized by topographical, climatic and environmental contrast and diversity. So far, ca. 140



Fig. 1: *Agrostis barikii*. A. Ligule. B–C. Spikelets, lateral view. D–E. Spikelet with floret separated from the glumes. F. Floret in dorsal view showing the well-developed awn, G. Floret in lateral view showing the awn, the lemma glabrous at the apex, and the palea. H. Palea, ventral view. I. Anthers. J–K. Caryopsis, dorsal (left) and ventral (right) views. (Source: Prasad et al, Phytotaxa 494(1): 145-150.2021).

species have been identified from the region from among 460 collections made. Majority of study area is under forest cover, mostly occupied by mixed broad leaved forests followed by *Cedrus* and *Betula* forests. Among trees, *Corylus jacqmontii*, *Celtis australis*, *Aesculus indica*, *Pinus wallichiana*, *Acer negundo*, *Juglans regia*, *Pyrus pashia*, *Cedrus deodara*, *Betula utilis* were the dominant species. About 25 plant species belonging to 16 families are of high medicinal values, which are frequently used by Gujjar and Gaddi tribes of area. Eleven species of Orchids belonging to eight genera were also recorded. The study also recorded 38 wild edible plant species of Angiosperms from the area.

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- Mr. Sangam Sharma, Project Fellow
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Floristic inventory, plant conservation and systematic studies on angiosperms

New plant taxa discovered

Geranium aedonianum Imtiyaz Hurrah & Vijay Wagh, *Phytotaxa* 489(3): 241-251.2021. (Fig. 1A)

Geranium aedonianum (Geraniaceae) was described from Jammu & Kashmir (Panikhar village, Ladakh) in India. *Geranium aedonianum* markedly differs from its closely allied species *G. himalayensis* in having obtrullate-obtriangular leaf segments (vs rhombic), middle segment width at base 2.5–4.5 mm (vs 2.9–9.8 mm), fewer no. of lobes 3–9 (vs 8–19), longer pedicels 12–38 (vs 02–21 mm long), staminal filaments whitish, base dilated smoothly tapering towards apex, glandular hairs on margins that become stalkless at apex (vs staminal filaments purplish, base broad abruptly narrowing towards apex, margins without glandular hairs), longer fruit 38–40 mm (vs 27–30 mm long).

Geranium jainii Imtiyaz Hurrah & Vijay Wagh *Nordic J. Bot.* 38 (12).2020. <https://doi.org/10.1111/njb.02850> (Fig. 1B)

The new species *Geranium jainii* differs from its closely allied species *G. collinum* Stephan ex Willd. in having the presence of alternate cauline leaves, long trichomes along the margins and on the abaxial surface of the stamina filaments, emarginate petals, glabrous nectaries and larger size of stigmatic remains. *G. jainii* is known only from its type locality, Rothang in Lahaul and Spiti District of Himachal Pradesh, India. It occurs on partially shaded and moderately steep mountain ridges in alpine meadows at an elevation of 3900–4000 m.

Geranium lahulense Vijay Wagh & Imtiyaz Hurrah *Phytotaxa* 452 (1):75-82. 2020 (Fig. 1C).

The new species is known only from the type locality (Keylong, Lahaul & Spiti, Himachal Pradesh) and found growing on the hill slopes along road sides at 3200 m elevation. *Geranium richardsonii*, *G. pratense*, *G. clarkei*, *G. kashmirianum* and *G. himalayense* are the most closely allied species of *G. lahulense*, all belonging to the subgenus *Geranium*. The new species is characterized by monochasial inflorescence, absence of veins at mericarp apex, deltoid-subulate stipules, slightly deflexed pedicels and erect or slightly nodding fruits.

Systematics of *Geranium* and tribe *Boehmerieae* (Urticaceae)

While revising the taxonomy of Indian *Geranium* three new species, namely *G. lahulense*, *G. jainii* and *G. aedonianum* have been discovered from India. During the field survey a lesser known species *G. kishtvariense* Knuth was also rediscovered after 38 years from Jammu & Kashmir. It has often been misidentified as *G. rubifolium* in herbaria. During the revisionary study on *Boehmeria* of India, *B. penduliflora* Wedd. ex D. G. Long was recollected from Pilibhit Tiger Reserve in Uttar Pradesh, after 81 years.

Threat assessment of traded forest flora of Madhya Pradesh

Field explorations were conducted in the Chambal and Malwa eco-region of Madhya Pradesh for threat assessment of the traded forest flora of Madhya



Fig. 1: Newly discovered species of *Geranium* (A). *G. aedonianum* Imtiyaz Hurrah & Vijay Wagh, (B). *G. jainii* Imtiyaz Hurrah & Vijay Wagh and (C). *G. lahulense* Vijay Wagh & Imtiyaz Hurrah

Pradesh. Information on geographic distribution, threat and exploitation pattern of the traded forest species were gathered from various secondary data sources viz., regional floras, online herbaria and websites. A preliminary list of 25 species of traded forest flora of Madhya Pradesh has been compiled. The field observations revealed that *Commiphora wightii* and *Boswellia serrata* are highly exploited for the gum having high trade demand due to their medicinal and religious uses. The unsustainable extraction of gum from *Commiphora wightii* has depleted the population in the region and only few old plants were observed during the survey.

Establishment of Herbarium in the Botanical Garden of the Chandrapur, Maharashtra

More than 200 species, collected from Vidharbha

region of Maharashtra, have been identified, and 700 herbarium specimens have been prepared for depositing to the Herbarium being established at the Botanical Garden of the Chandrapur, Maharashtra.

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Angiosperm taxonomy, floristics, and plant conservation

New species discovered:

Elaeocarpus gadgiliai A.M. Maya, V. Suresh & K.M.P. Kumar, Phytotaxa 489 (1): 087-093.2021 (Fig. 1 A-D)

A new species in *Elaeocarpus* (Elaeocarpaceae) was described from the southern Western Ghats of Kerala and Tamil Nadu. *Elaeocarpus gadgiliai* differs from the allied *E. serratus* and *E. variabilis* by the coriaceous leaves with conspicuous venation on adaxial surface, the outer tooth of anthers with very long shining setae, and the wider fruits. *E. gadgiliai* is a moderate to large tree found in the evergreen forests at 800-1500 m a.s.l. The species is named in honor of Prof. Madhav Dhananjaya Gadgil, an Indian ecologist and head of the Western Ghats Ecology Expert Panel (WGEPP).

Systematic study on species complexes in *Impatiens* and *Strobilanthes***Recollection of *Strobilanthes lawsonii* and reinstatement of *S. pushpangadanii***

Strobilanthes lawsonii was described by Gamble based on the collection made from Sispara Ghat of Nilgiri District, Tamil Nadu. The recent expedition to Muthikulam forest of Palakkad, Kerala succeeded in the collection of *S. lawsonii*, after its type of collection in 1884. After comparing the new collections of *S. lawsonii* with *S. pushpangadanii*, it was found that both the species are distinct as evidence from the most notable morphological difference of partially fused corolla lobes and exerted stamens in *S. pushpangadanii* and therefore this species has been reinstated.



Fig. 1: *Elaeocarpus gadgiliai* A.A. Maya et al. (A). Habit; (B). Flowering twigs; (C). Fruiting twig (immature); (D). Fruiting twig

Revisiting the Impatiens inconspicua-pusilla complex

Impatiens pusilla is now found to be a distinct species and not a starved form of *I. inconspicua* as it was earlier believed and hence resurrected and validated through a description. Two varieties (viz. var. *jogensis*, var. *pushpagiriensis*) which were described under *I. inconspicua* have been now brought under *I. pusilla*. Morphologically, *I. pusilla* var. *nematostachys* Hook.f. is found to be same as *I. pusilla* var. *pusilla*, therefore the former has been synonymised under the latter.

Plant explorations in Western Ghats

Two exploration surveys were conducted to Kerala and Tamil Nadu parts of Western Ghats and collected 189 plant species, including 15 endemic species, 105 species of conservation importance, seven species of Navagraha Plants, 12 species of Zodiac plants and 27 species of Star plants for their *ex-situ* conservation in NBRI Botanical Garden.

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Diversity assessment, floristic and revisionary studies on lichens

New lichen species discovered

1. *Huriella upretiana* S.Y. Kondr., G.K. Mishra, Nayaka & A. Thell, *Acta Botanica Hungarica* 62(3–4): 309–391, 2020 (Fig. 1A.B.)

The new species is characterized by thicker apothecia, 80–96 μm higher hymenium, 80–112 (–144) μm thicker subhymenium, and widely ellipsoid (10.4–)12.8–14.4 \times (6.4–) 7.2–8(–9.6) μm ascospores. The new species is commonly found growing on siliceous rocks between elevation of 1,500–2,145 m in Jammu & Kashmir, Uttarakhand, Madhya Pradesh and Manipur.

2. *Myriospora himalayensis* G.K. Mishra, Nayaka & Upreti, *Taiwania* 66 (1): 89–92, 2021 (Fig. 1C.D.)

The new species is characterized by having pruinose apothecia with small (1.5–2.5 \times 1–1.2 μm), hyaline, ellipsoid ascospores and areolate-effigurate to squamulose-lobate thalli with grey to brownish upper surface. The species grows on rocks in the temperate zones of Western Himalaya between elevation of 2325–4500 m in Jammu & Kashmir, Himachal Pradesh, and Uttarakhand.

Lichen diversity assessment and floristic studies

Various localities of Assam including Udalguri, Sivsagar, Charaideo, Golaghat, Chaparnala and Sibsagar were surveyed. Approximately, 85 species under 18 genera were collected. The common lichens present in these localities belong to the genera *Anthracothecium*, *Diorygma*, *Dirinaria*, *Graphis*, *Parmotrema*, *Pyrenula*, *Pertusaria*, *Pyxine*, *Sarcographa*, and *Trypethelium*.

Identification of lichen specimens collected from various localities of Mandi District of Himachal Pradesh revealed 70 species belonging to 29 genera and 15 families. The study revealed 14 species of lichens as new to Himachal Pradesh. The genus *Lecanora* is dominant in the region. Among different localities surveyed, Sikandra Dhar has maximum diversity with 19 species of lichens, followed by Balh valley and Barot with 18 and 17 species, respectively. The tropical zone of the district exhibits luxuriant growth of lichen on various phorophytes like *Pinus*, *Shorea robusta*, *Prunus*, *Celtis*, *Grewia* and *Rubina*. The *Rubina* and *Populus* trees provide excellent substratum for the growth of *Candelaria concolor* together with *Physcia dilatata*. The temperate region of the district exhibits dominance of *Quercus leucotricophora* trees which support luxuriant growth of *Parmotrema nilgherrense*, *Ramalina conduplicans*, *Ramalina sinensis*, *Heterodermia diademata* and *Usnea* species.

Taxonomic revisionary studies

Family Teloschistaceae

The lichen family Teloschistaceae was revised and 115 species under 36 genera have been reported from India. *Huriella upretiana* S.Y. Kondr. *et al.* was described as new to science whereas *Lazarenkoiopsis ussuriensis* (Oxner *et al.*) S.Y. Kondr. *et al.*, *Mikhtomia gordejevii* (Tomin) S.Y. Kondr. *et al.*, *Olegblumia demissa* (Flot.) S.Y. Kondr. *et al.* and *Pachypeltis intrudens* (H. Magn.) Søchting *et al.* were reported for the first time from India.

The Western Himalayas harbour the maximum diversity of Teloschistaceae with 110 species,

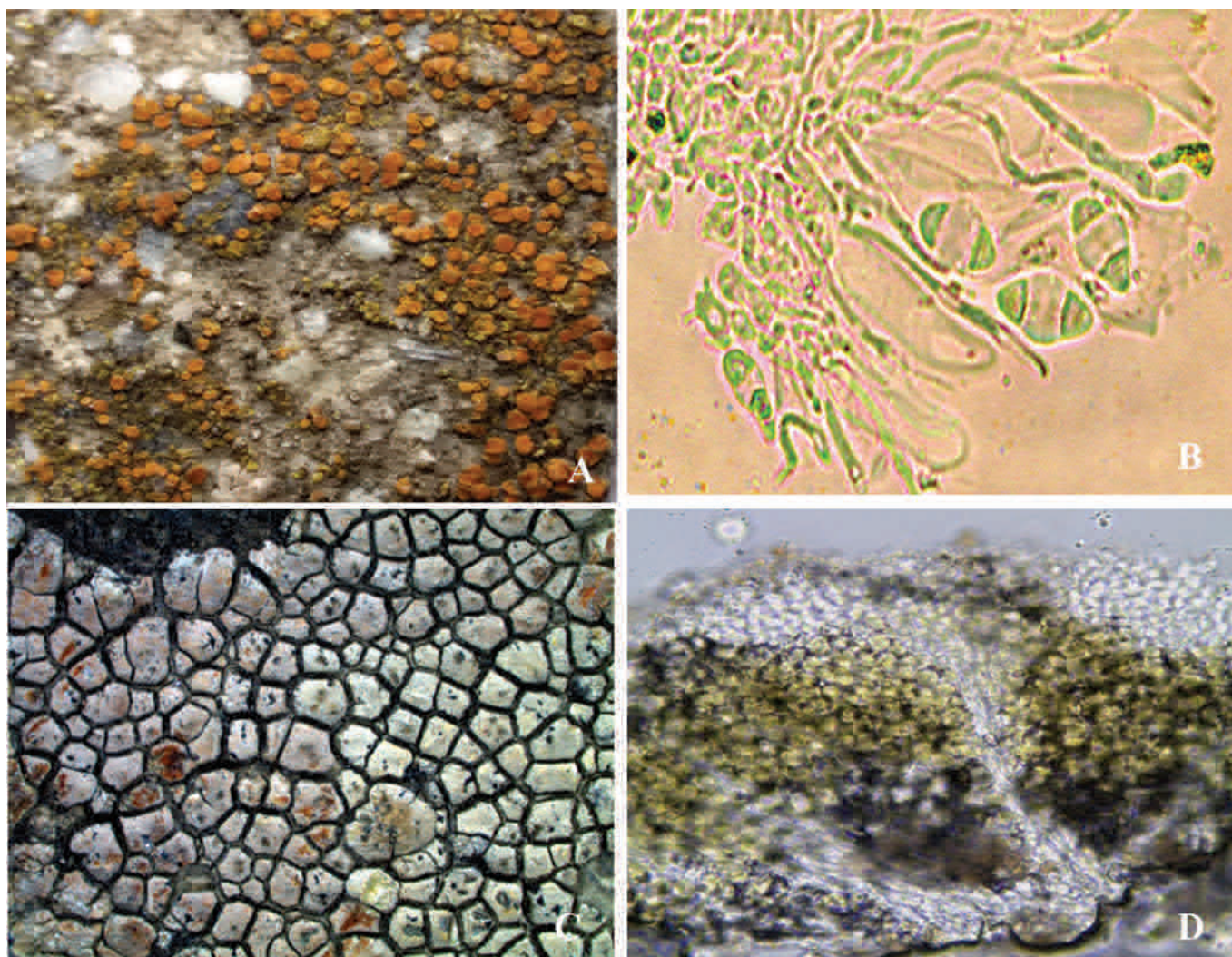


Fig. 1: New lichen species discovered. (A). *Huriella upretiana* S.Y. Kondr., G.K. Mishra, Nayaka & A. Thell, (B). Ascospores (C). *Myriospora himalayensis* G.K. Mishra, Nayaka & Upreti, (D). V.S. of thallus showing algal layer in bundle.

followed by the Central Indian region with 38 species. The genus *Caloplaca* is represented with 50 species in the country, followed by *Athallia* and *Rusavskia* with six species each. The saxicolous taxa exhibit dominance with 65 species whereas the corticolous and terricolous taxa are represented by 48 and 9 species, respectively. Among the different States of India, Uttarakhand showed the maximum diversity of Teloschistaceae with 54 species, followed by Jammu & Kashmir with 37 species, whereas Jharkhand and Meghalaya are represented only by single species each.

Genus *Myriospora*

A total of 11 species of *Myriospora* has been known so far from different parts of Asia, Antarctica, Europe, and North and South America, and a key to all the known species of *Myriospora* was prepared. The new species *Myriospora himalyensis* G.K. Mishra et al. was described, which is characterized by its rounded to irregular, white pruinose apothecial discs, small ascospores, as well as the K⁺ red and PD⁺ yellow thallus.

Pharmacognosy, Phytochemistry and Product Development



PHARMACOGNOSY, PHYTOCHEMISTRY AND PRODUCT DEVELOPMENT

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Divisions

- Pharmacognosy
- Phytochemistry
- Pharmacology and Product Development

Research Scholars Statistics

Sr. No.	Position Name	Numbers
1.	Women Scientist	01
2.	Young Scientist	02
3.	JRF/SRF Fellow	18
4.	Project Staff	20

R & D Highlights

Development of CRMs/RMs and identification of QRM for Industry

- Certified Reference Materials 3(CRMs) and Reference materials 1(RMs) have been prepared as per requirement of ISO-17034-2016. Activities related to documentation and implementation of quality system for NABL-Accreditation of the institute as reference material producer were performed. Carried out extraction and

fractionation of curcuminoids (25 mg) purified from rhizomes of *Curcuma longa*.

- Metabolic variation of berberine and palmatine in *B. lycium* (roots) was analyzed through HPTLC-UV method for the identification of sources of quality raw material (QRM) for industry.

Edible and industrial dyes from plant sources

Food colours viz. yellow, red, green and dark brown were developed from *Tagetes erecta*, *Hibiscus rosa-sinensis* flowers, *Eichhornia crassipes* leaves and *Allium cepa* red skin, respectively.

Gums and Resins

The indigenous utilization of gums and resins from *Butea monosperma*, *Anogeissus latifolia*, *Gardenia gummifera*, *Commiphora wightii* were documented and processed for advanced studies.

Development of Shodhan protocol of standardized cannabis

Classical formulations and their SOPs were prepared and evaluated through phytochemical and biological studies on *Cannabis sativa*. The main components present in the essential oil of leaves are Humulene, β -Selinene, β -Bisabolene, trans- α -Bisabolene, Caryophyllene oxide, Humulene epoxide 2, Bisabolol, Naphthalene. Method was optimized and established for the quantification of Cannabinoids using HPLC-PDA.

Pharmacognostical evaluation and Pharmacological studies

- Pharmacognostic study of *Momordica dioica* fruit was done as per the standard protocol of Ayurvedic Pharmacopoeia of India (API). Densitometric High Performance Thin Layer Chromatography (HPTLC) quantification of caffeic acid was identified at R_f value 0.44 ± 0.04 . The *in-vitro* data revealed *M. dioica* has biological potential which will be helpful in exploring the possibility of using the species in various formulations for anti-inflammatory, anti-oxidant and anti-diabetic purposes.
- Acaricidal plants, *Argemone Mexicana* (NBA22/F1) and *Datura metel* (NBA/18/D1), were collected from six agro-climatic zones of Assam



including Madhukuchi, Jorhat, Amlighat, Karbi Anglong, Gergaon, Karimganj, Gossaingaon, North Lakhimpur, Tinsukia. Berberine and Sanguinarine from *A. Mexicana*, and Atropine and Scopolamine in *D. metel* were quantified using HPTLC.

- Elite chemotype(s) of *Plumbago zeylancia* L. were collected from different phyto- geographical zones of India and Macro-microscopy and physicochemical parameters of *Rauvolfia serpentina* and *Rauvolfia tetraphylla* of four different seasons have been completed.
- Pharmacognostic studies revealed *Pterospermum lanceifolium* Roxb.(PLE) maintained the elevated levels of serum biochemical markers viz ALT, AST, GGT, ALP in N-nitroso diethyl amine

(NDEA) induced liver toxicity in rats. The external/internal wounds and antioxidant potential of selected agro wastes from *Mangifera indica*, *Litchi chinensis*, *Citrus reticulata*, *Aegle marmelos* and *Musa paradisiaca* were studied in experimental models.

Herbal Nanobiotechnology

Green nanoparticles exhibited superior anti-quorum sensing and anti-biofilm activities in *Pseudomonas aeruginosa* PAO1 via las-rhl Regulons

Products developed

- Alcohol-based sanitizer
- Herbal decongestant spray
- Traditional Kadha

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Chemical investigation of medicinal and aromatic plants and products for various application, preparation of CRMs/RMs as per the requirements of ISO-17034-2016

Preparation of certified reference materials/ reference materials:

Four Aromatic Certified Reference materials (3 CRMs and 1 RM) have been prepared as per requirements of ISO-17034-2016. Quality systems for reference material producer as per the requirements of ISO-17034-2016 have been implemented and accordingly the CRMs & RM have been prepared. CSIR-NBRI has been accredited as a reference material producer.

NABL- New Delhi after final on site assessment audit in February 2021 recommends accreditation of CSIR-NBRI as reference material producer.

Certificate Number- RC-1015

Validity- 31.03.2021-30.03.2023

Scope- Certified reference materials - (+) Limonene, Eugenol and Geraniol

Reference material-Methyl- Chavicol



Eugenol (+) Limonene Geraniol Methyl Chavicol

Prepared Aromatic Certified Reference materials (3 CRMs and 1 RM)



Conservation, Management and Promotion of Sandalwood (*Santalum album* L.) Cultivation in India.

Carbon isotope composition (¹³C/¹²C) of 55 samples of sandal wood growing in different locations was determined by Isotope Ratio Mass Spectrometer (IRMS) to develop a database for location based composition profile of sandal wood. It would act as a



National Accreditation Board for Testing and Calibration Laboratories

SCOPE OF ACCREDITATION

RMP Name :	CSIR-NATIONAL BOTANICAL RESEARCH INSTITUTE, LUCKNOW, RANA PRATAP MARG, LUCKNOW, UTTAR PRADESH, INDIA		
Accreditation Standard	ISO 17034: 2016		
Certificate Number	RC-1015	Page No	1 of 1
Validity	31/03/2021 to 30/03/2023	Last Amended on	-

S.No	Types of reference materials (Certified Reference Materials, Reference Materials or both) Category & Subcategory	Reference Material Matrix or Artefact	Property / Properties Characterized	Approach used to assign property values / Characterization Technique
Permanent Facility				
1	CERTIFIED REFERENCE MATERIAL, CHEMICAL COMPOSITION - ORGANIC REFERENCE MATERIALS	(+) LIMONENE	Purity by GLC	NMR, GCMS, AV by GLC (using a single reference measurement procedure in a single laboratory).
2	CERTIFIED REFERENCE MATERIAL, CHEMICAL COMPOSITION - ORGANIC REFERENCE MATERIALS	EUGENOL	Purity by GLC	NMR, GCMS, AV by GLC (using a single reference measurement procedure in a single laboratory).
3	CERTIFIED REFERENCE MATERIAL, CHEMICAL COMPOSITION - ORGANIC REFERENCE MATERIALS	Geraniol	Purity by GLC	NMR, GCMS, AV by GLC (using a single reference measurement procedure in a single laboratory).
4	REFERENCE MATERIAL (NON CERTIFIED), CHEMICAL COMPOSITION - ORGANIC REFERENCE MATERIALS	METHYL CHAVICOL	Purity by GLC	NMR, GCMS, AV by GLC (using a single reference measurement procedure in a single laboratory)

scientific evidence for identifying the origin of wood/ wood material. Stable carbon isotope composition ($^{13}\text{C}/^{12}\text{C}$), observed values range from -24.191 to -28.863 per mill for 15 samples collected from IWST Bangalore campus. Mean $\delta^{13}\text{C}/\delta^{12}\text{C}$ value and standard deviation were found as -27.1938 and 0.924, respectively. Similarly, for 40 samples collected from other locations $\delta^{13}\text{C}/\delta^{12}\text{C}$ values were between -24.163 to -28.163 per mill, with mean value of -26.0329 and

standard deviation of 1.104.

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Pharmacological and safety studies of herbal drugs/medicine

Antimutagenic potential of phytochemicals from agri-wastes

Oxidation and production of free radical, such as reactive oxygen species (ROS) are integral part of life and the body metabolism. Oxidative stress arising as result of an imbalance between free radical production and antioxidant deficiencies is associated with damage to biomolecules which includes lipids, proteins, nucleic acid, etc. The antioxidant potential of hydroethanolic extract of selected agro wastes (*Mangifera indica*, *Litchi chinensis*, *Citrus reticulata*, *Aegle marmelos* and *Musa paradisiaca*) were assessed. The yield of the extract varied over a wide range (8.80 to 29.9 g/100g of dry weight). Total phenolic content (TPC), total flavonols, kaempferol, quercetin, myricetin HPLC method). 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging and inhibition of linoleic acid peroxidation of the extracts

varied significantly ranging from 1.9-36.40, 0.26-4.89 g/100g of dry matter, 11.2-52.6, and the highest TPC, TFC and total flavonols exhibited superior antioxidant activity, followed by *Aegle marmelos*, *Litchi chinensis*, *Mangifera indica*, *Citrus reticulata*, and *Musa paradisiaca*. The increase in the level of antioxidant profile i.e. superoxide dismutase (SOD), catalase, glutathione reductase (GR) and glutathione peroxidase (GPx) by the natural extract may be attributed to have biological significance in eliminating reactive free radical that may affect the normal functioning of cell including the gastric ulcers in rat stomach (Fig. 1).

Effect of *Pterospermum lanceifolium* Roxb. (PLE) on NDEA induced experimental animals

The animals used in this study were categorized into five different groups. Group I- received

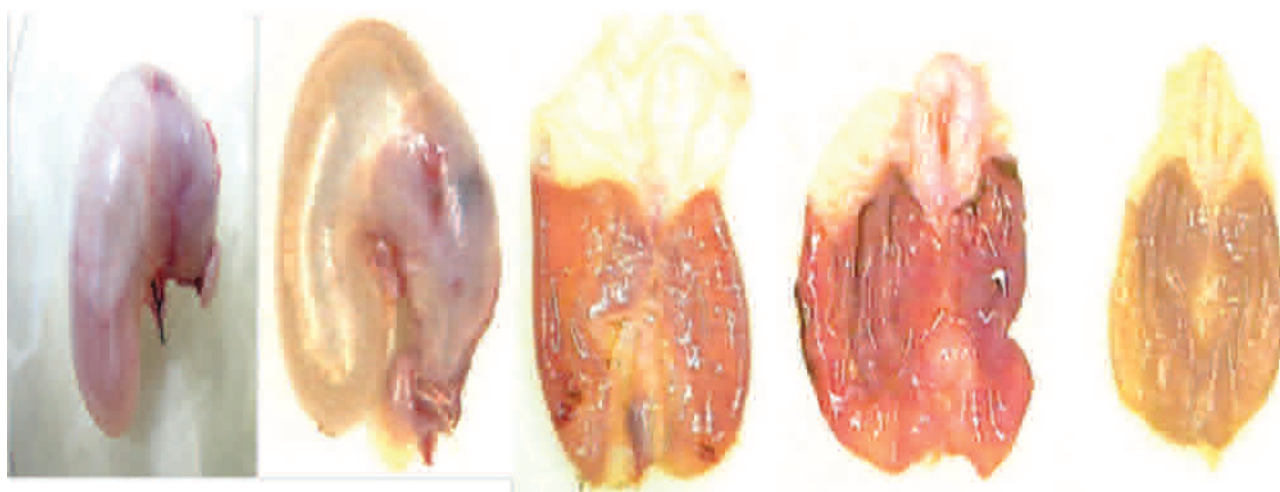


Fig. 1: Gastric ulcers in rat stomach

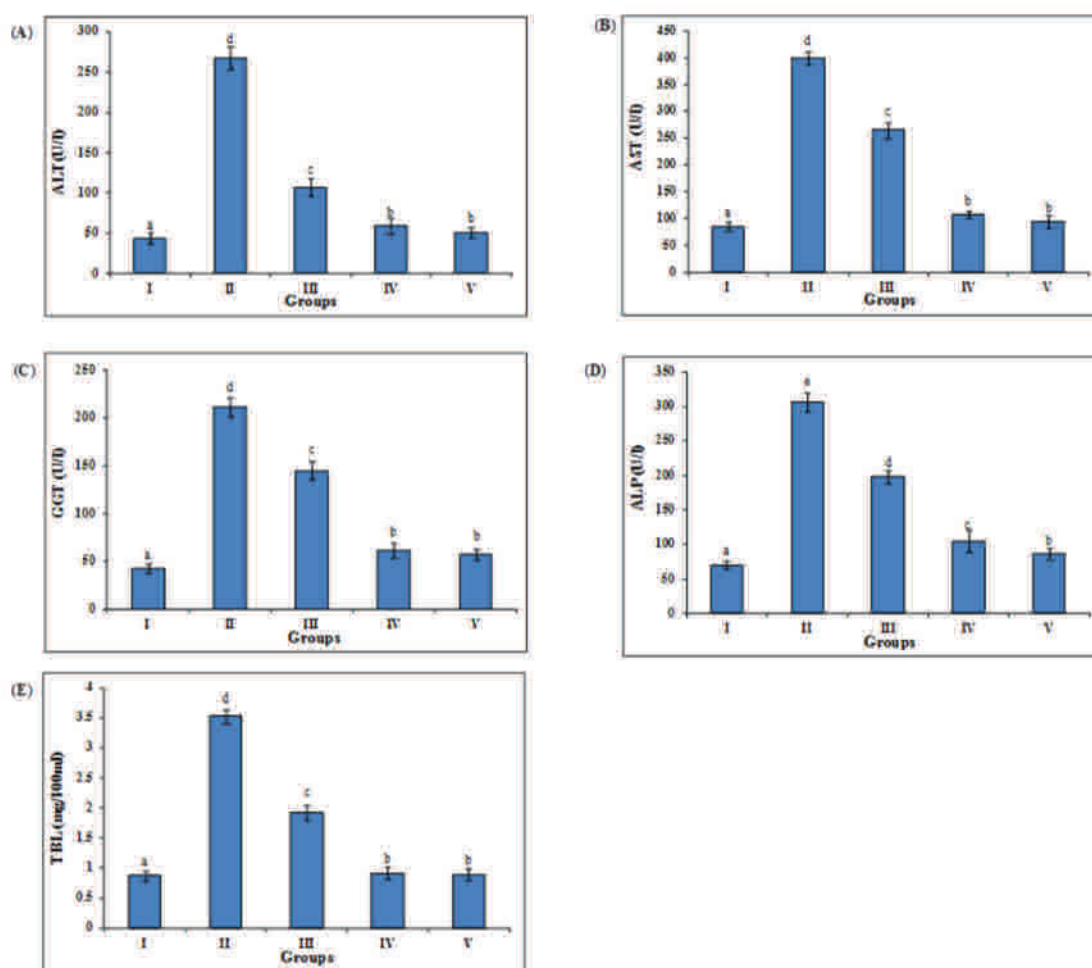


Fig. 2: *Pterospermum lanceifolium* (PLE) maintained the reduced levels of (A). ALT, (B). AST, (C). GGT, (D). ALP, and (E). TBL biochemical markers.

carboxymethylcellulose (vehicle-treated; 1% w/v CMC). Group II- carcinogen-induced rat (NDEA 200 mg/kg bw (once ip) + CCl₄ (3mL/kg/week sc. for six week). Group III- HCC induced rats (NDEA 200 mg/kg bw (od, ip) + CCl₄ (3mL/kg/week sc) were treated with test drug PLE (100 mg/kg/ body weight/day) orally for 28 days. Group IV- HCC induced rats (NDEA 200 mg/kg bw (once ip) + CCl₄ (3mL/kg/week sc) were treated with PLE (200 mg/kg/ body weight/day) orally for 28 days. Group V- HCC induced rats (NDEA 200 mg/kg bw (once ip) + CCl₄ (3mL/kg/week sc) were treated with silymarin (100 mg/kg/ body weight/day) orally for 28 days. After 24h of last dose of treatment, rats were sacrificed on overnight fast by cervical dislocation. NDEA received animals showed a significant occurrence of the liver tumor at the termination of the induction period, as

evidenced by the elevation in hepatic biochemical markers (ALT, AST, ALP, and GGT). The group II showed elevated levels of biochemical parameters as compared to group I (Fig. 2). All these elevated parameters in other groups (III, IV, V) were reverted back toward the normal range, in group III, group IV, and group V (Fig. 2). Potent inhibition of biochemical serum marker was observed in the group IV, which is almost near to the silymarin-treated group V. Thus, these serum markers were reverted by PLE administration in the group III and group IV (Fig. 2).

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Herbal product development for industrial application, stable herbal food colours

Antitermite herbal formulation

A third field trial was conducted by ICAR-IISR, Lucknow, at farmer's field of Mohanlalganj, Lucknow to test the effectiveness of the in-house developed NBRI-HF against termite in sugarcane. Sugarcane sets were treated with NBRI-HF in different concentrations of 1.5 ml/L; 2.5 ml/L and 3.0 ml/L in comparison to two-check treated with synthetic pesticide i.e. chlorpyriphos 20 EC @ 2.0 ml/L and termiguard (Herbal pesticide) @ 3.0 ml/L dipped in each treatment for 1.0 h. In treatment, 3.0 ml/L concentration, the infestation was 3.6% as compared to checks (chlorpyriphos 20 EC @ 2.0 ml/L) with an infestation upto 4.8%, whereas termiguard showed 6.1% infestation, and average infestation of 6.4% in second treatment and 22.9% of first treatment.

Development of processes for edible and industrial dyes from plant sources for enhanced income

At present, the demand for herbal/ natural colours is increasing worldwide due to the increased awareness on therapeutic and medicinal properties and their benefits among public and also because of the recognized profound toxicity of synthetic colours. Development of cost-effective, viable technology for the isolation and preparation of herbal colours and its application in food products and nutraceuticals is a challenge and the need of the day.

Food colours (yellow, red, green and dark brown) were developed from *Tagetes erecta*, *Hibiscus rosa-sinensis* flowers, *Eichhornia crassipes* leaves and *Allium cepa* red skin cover, respectively (Fig. 1). All colours were



Fig. 1: Food colours developed from flowers, leaves and *Allium cepa* red skin cover.

estimated for qualitative and quantitative analysis such as moisture, extraction yield, anthocyanin content, total phenolics, flavonoids content, heavy metals along with nutritional value.

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Chemo-profiling of medicinal plants for herbal product development

Comparative pharmacognostical and pharmacological evaluation of *Costus speciosus* (Koen) J.E. Sm. germplasm collected from Eastern Ghats of India

A comparative evaluation was made for pharmacognostical and pharmacological potential of *Costus speciosus* and validated the traditional claims and quality parameters for industry. Pharmacognostical studies were performed as per Ayurvedic Pharmacopeia of India, and quantification of diosgenin was done through HPTLC. *In vitro*

antidiabetic activity was evaluated by α -amylase inhibition assay based on starch iodine method and *in vitro* anti-inflammatory assay was done by using inhibition of protein denaturation assay. Morpho-anatomical characters showed no distinct variation in all the collected samples. The quantification of diosgenin (without hydrolysis of samples) in the samples varied significantly from 0.002 to 0.076 % on dry weight basis. The maximum content was recorded in NBCS-06 from Patiya, Bhubaneswar and was identified as distinct chemotype with high metabolite content. IC₅₀ value of *Costus speciosus*

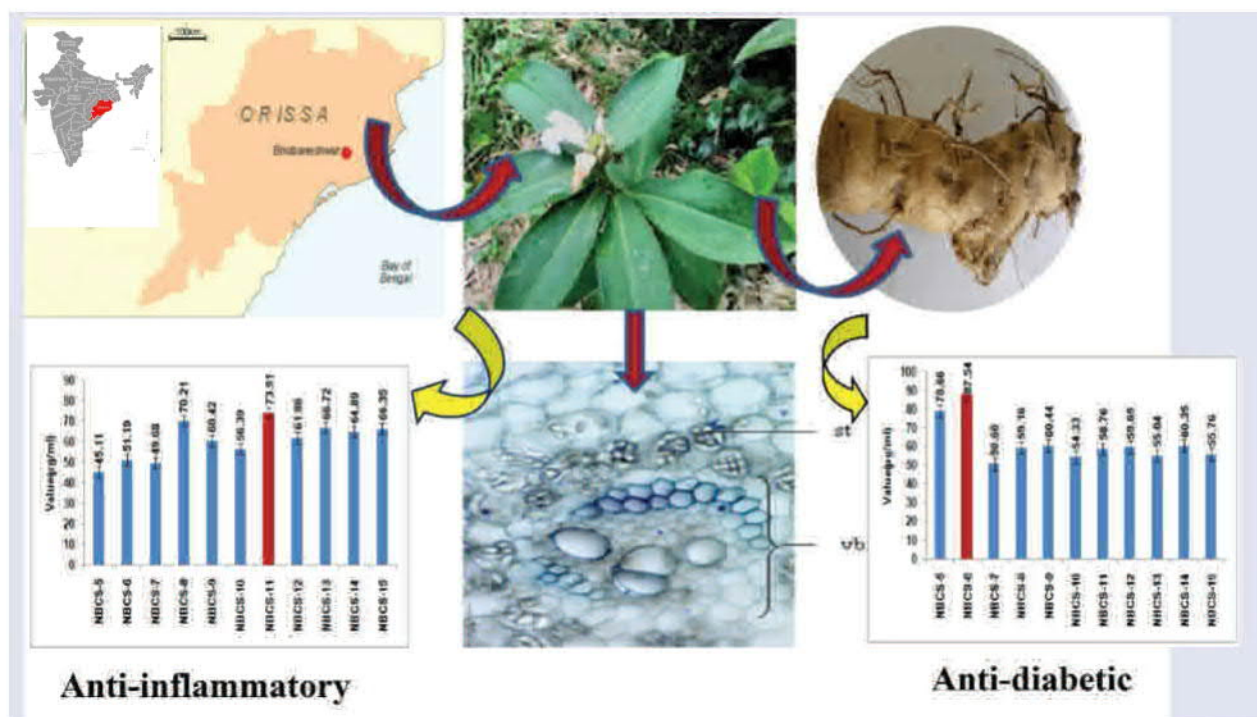


Fig. 1: Representation of pharmacognostic and pharmacological evaluation of *C. speciosus* germplasm collected from Eastern Ghats of India

extract in starch-iodine assay was found to be maximum in NBCS- 6 (87.54 µg/ml) and inhibition of protein denaturation assay was found to be maximum in NBCS- 11 (73.91 µg/ml), respectively. The study suggests that the *Costus speciosus* germplasm possess potential anti-inflammatory and anti-diabetic activity and comparative pharmacognostical parameters will be useful in collection of location specific potential samples for industrial usage along with quality control of raw materials (Fig. 1).

Chemotyping and molecular profiling of bioactive metabolites in *Hemidesmus indicus* and *Costus speciosus*, from different phytogeographical zones and identification of candidate genes related to metabolic pathways

The germplasm and rhizospheric soil of 141 samples of *Costus speciosus* (rhizome) and 96 samples of *Hemidesmus indicus* (root) were collected from different phytogeographical zones of India. After mapping and actual field assessment, passport datasheet was prepared and all the GPS coordinates were documented for each collection. The collected rhizome/root samples were subjected to evaluation of the quality parameters as per guidelines of *The Ayurvedic Pharmacopoeia of India*. Diosgenin and Vanillin are the bioactive compounds in *Costus speciosus* and *Hemidesmus indicus*, respectively which have high market potential and industrial demand. These two compounds were quantified in the collected samples for identifying the elite germplasms. Significant chemical variations were observed among the germplasms within the same phytogeographical zone as well as within different zones. Two elite chemotypes were identified viz. NBCS-88 with maximum content of Diosgenin (2.405%, on dry weight basis) from *Costus speciosus* and NBH-35 with maximum content of Vanillin (0.0127%, on dry weight) from *Hemidesmus indicus*. The elite chemotypes will be used as Quality planting material (QRM) and explored as supply material for herbal drug industries.

Intra-species metabolic variation in *Berberis lycium* Royle collected from different altitudes of Western Himalaya (India) for the identification of quality raw material

Berberis lycium Royle (Berberidaceae) is used in Indian systems of medicine for diarrhoea, jaundice,

eye infections, fever and skin diseases. In the present study, metabolic variation of berberine and palmatine in *B. lycium* (roots) was analyzed through HPTLC-UV method for the identification of sources of quality raw material (QRM) for industry. Ten natural population(s) were mapped in samples collected from the different regions of Western Himalaya. Pharmacognostical parameters of each collected raw material were evaluated as per Ayurvedic pharmacopoeia of India (API), to ensure the quality of plants as per industry requirement. The HPTLC chromatogram was developed in n-propanol: water: formic acid (9:1:0.1 v/v/v) and quantification was done at λ_{max} of 350 nm. R_f of palmatine and berberine was found at 0.2 ± 0.08 and 0.33 ± 0.03 and the method was found to be linear at a concentration range of 0.1 – 0.5 µg/spot for both markers. Limit of detection (LOD) and limit of quantification (LOQ) of palmatine and berberine was 5.25, 5.23 and 15.91, 15.86 ng/spot. The content of palmatine and berberine varied from 0.117 to 0.739% and 0.203 to 1.134% on dry weight basis. NB-03 was identified as elite source based on cluster analysis of metabolic content(s).

Studies on role of endophytes in variation of acaricidal properties of two acaricide producing plant species from North Eastern India

The main objectives of this project were to study (1) variation in acaricidal properties within the two identified plant species in different ecological conditions, (2) relationship between variation in the endophytic microbiome and (3) their acaricidal properties. The whole germplasms and rhizospheric soil samples of the two identified acaricidal plants *Argemone mexicana* (NBA22/F1) and *Datura metel* (NBA/18/D1) were collected from six agro-climatic zones of Assam including Madhukuchi, Jorhat, Amlighat, Karbi Anglong, Gergaon, Karimganj, Gossaingaon, North Lakhimpur, Tinsukia. Berberine and sanguinarine from *A. mexicana*, and Atropine and Scopolamine in *D. metel* were selected as biologically active markers for HPTLC quantification. Solvent system of n-propanol, water, formic acid (9:0.8:0.04, v/v/v) was selected as best suited for *A. mexicana* and chloroform, acetone, diethylamine (5:4:1, v/v/v) for *D. metel*. Maximum berberine (0.363%) and sanguinarine content (0.0374%) was found in NEA-02 and maximum atropine (1.017%) and scopolamine content (1.00%) was found in NED-04.

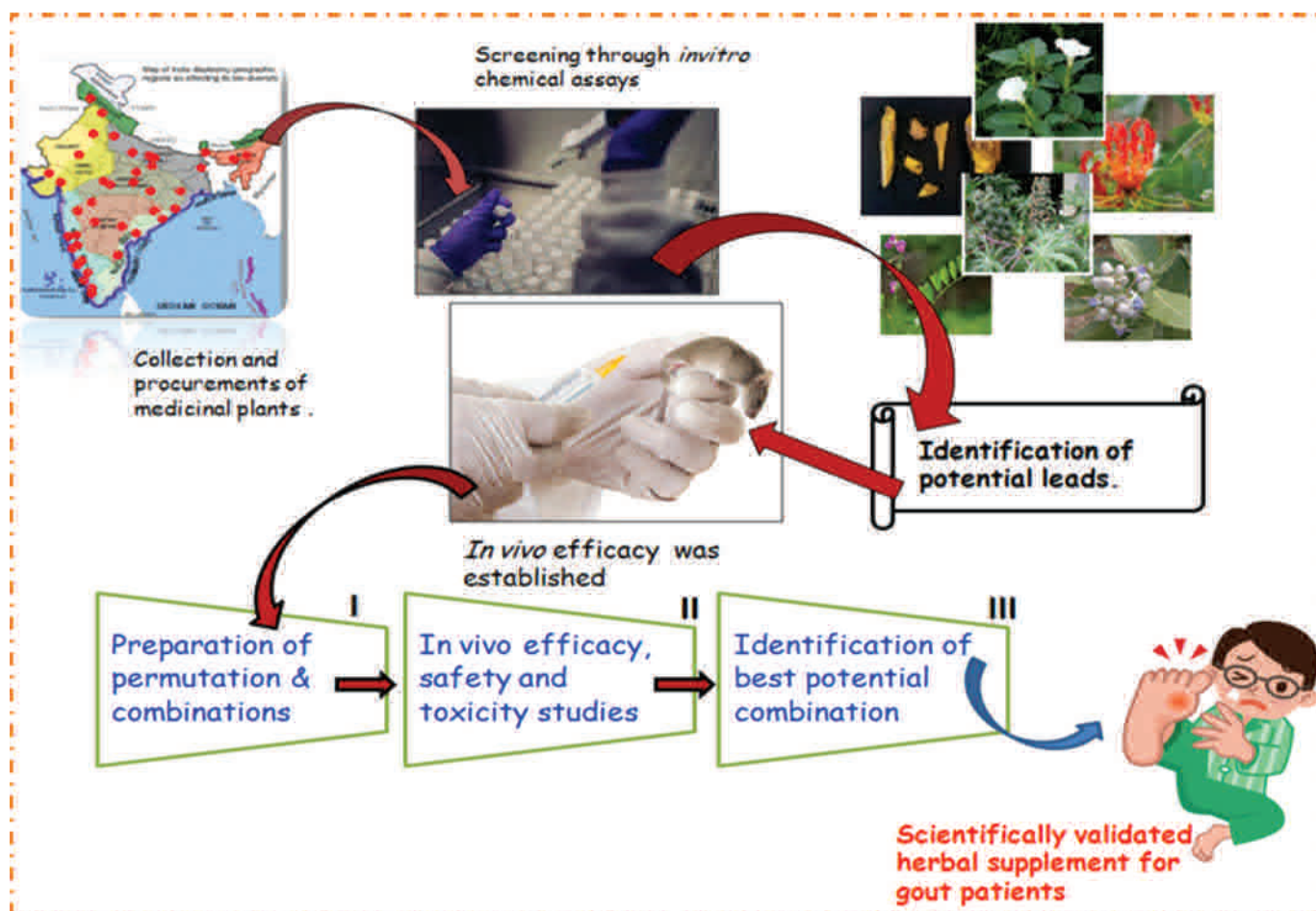


Fig. 2: Representation of steps followed in the development of the herbal supplement to alleviate gouty arthritic conditions

Herbal Product Development

Development of plant based synergistic natural supplement and its pharmacological validation to alleviate gouty arthritic conditions

Five potential herbal supplement combinations were tested for their safety and efficacy through *in-vivo* studies to alleviate arthritic conditions (Fig. 2).

Development of nutraceutical supplement for diarrhoeal condition

A nutraceutical supplement has been formulated for amelioration of diarrhoeal condition. The plant-based ingredients of this product were selected from the Indian traditional knowledge and have been scientifically tested which suppress the growth of diarrheal causing agents i.e., *Escherichia coli*, *Salmonella*

sp., *Shigella sp.*, and *Vibrio cholerae* etc. and replenish the gastrointestinal microflora. The formulated product also improves the nutrient absorption and maintains sodium level, fiber, vitamin C, vitamin B6, folate, and potassium level of body. Moreover, it complements Zinc deficiency during diarrheal conditions (Fig. 3).

Traditional Kadha

This polyherbal product is developed under the guidelines of AYUSH and has capability to reduce the initial symptoms of sore throat, coughing and sneezing. It is an effective formulation based on Indian traditional medicine to keep the body detoxified, healthy and fresh. The product is easy to use just by adding 1-2 drops in a cup of milk/tea/lukewarm water (Fig. 4).

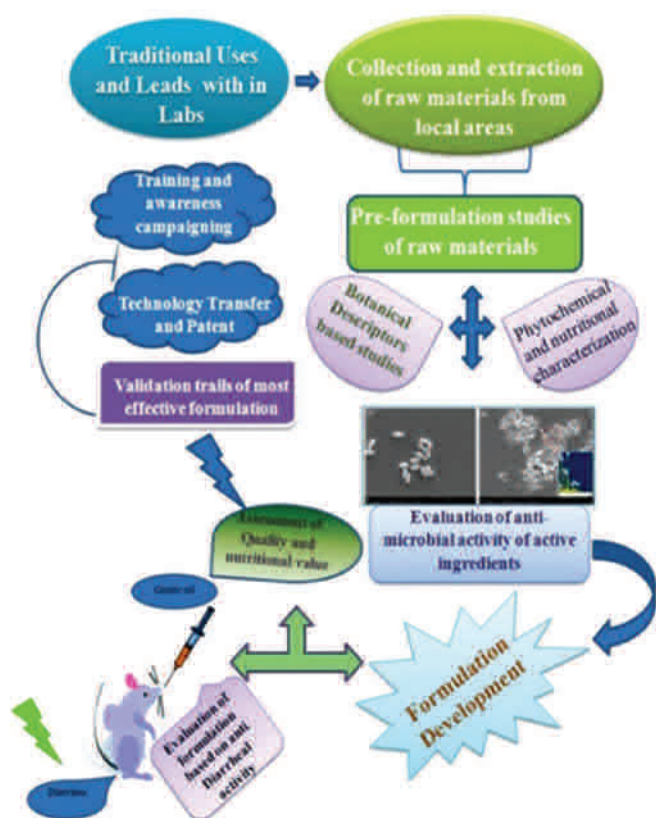


Fig. 3: Representation of development of the herbal nutraceutical supplement for diarrheal conditions

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Fig. 4: Traditional kadha in commercialized product form

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Herbal/ ayurvedic formulations, validation of traditional knowledge, developing novel compositions / formulations for better health care, and generation of income through plant wealth.

Development of *Shodhan* protocol and preparation of standardised cannabis based AYUSH formulation

A *Shodhan* protocol of cannabis was developed, and certain other classical formulations and their SOPs were prepared and their phytochemical and antimicrobial evaluation was performed detailed as below, We have carried out two types of chemical analysis:

- Extraction and Quantitative HPLC analysis of leaves of *Cannabis sativa* L.

- Gas Chromatography-Mass Spectrometry (GC-MS) analysis

Quantitative HPLC

An essential oil was extracted from the aerial parts of *Cannabis sativa* (L) and analysed on HPLC (Fig. 1).

Gas Chromatography-Mass Spectrometry (GC-MS) Analysis of essential oil of Cannabis

Chemical composition of essential oil was carried out the main components present in the essential oil

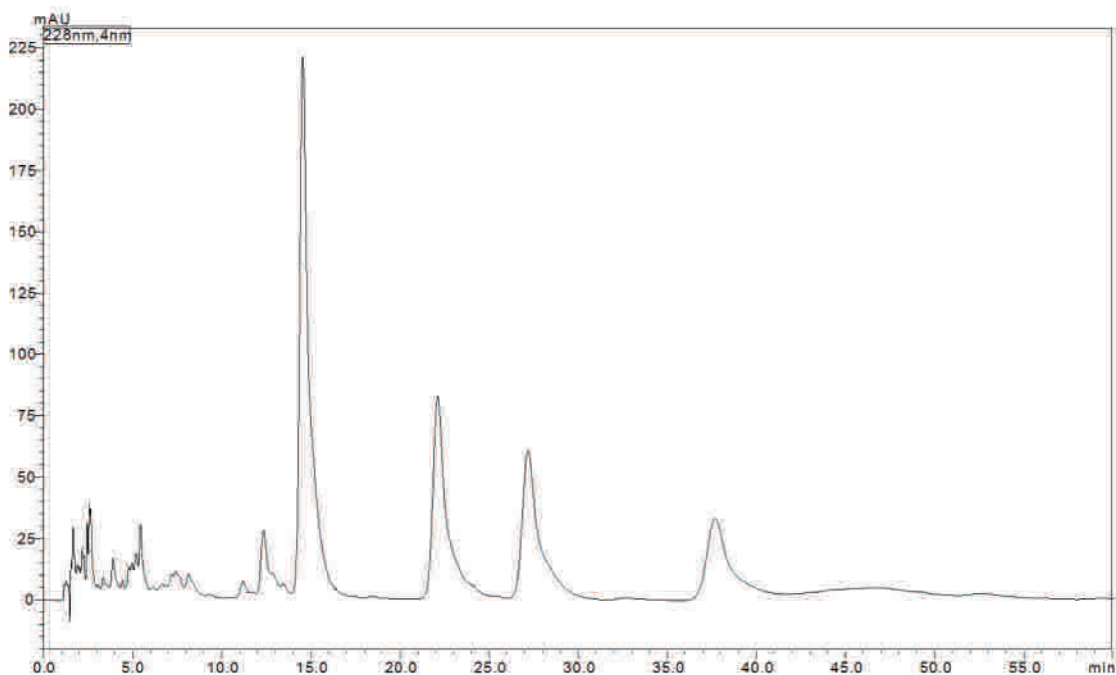


Fig. 1: HPLC analysis of extract of *Cannabis sativa* [Essential oil content (%) = 0.25 ± 0.02] (HPLC chromatogram of Cannabinoids 1 = CBDA (Cannabidiolic acid), 2 = THCV (Tetrahydrocannabivain), 3 = CBD (Cannabidiol), 4 = CBN (Cannabinol), 5 = Delta-8 Tetrahydrocannabinol, 7 = Tetrahydrocannabinolic acid)

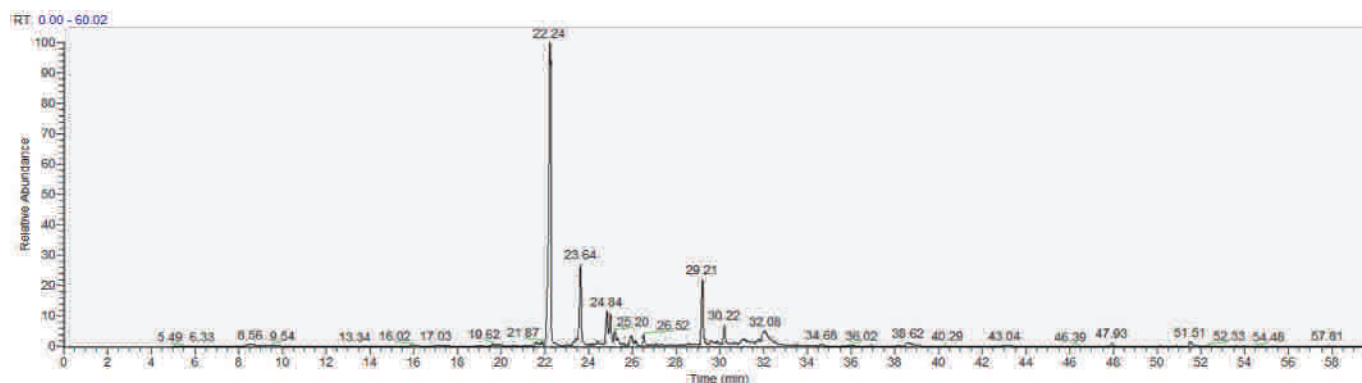


Fig. 2: GCMS chromatogram of *Cannabis sativa* inflorescence oil sample

of leaves are Humulene, β -Selinene, β -Bisabolene, trans- α -Bisabolene, Caryophyllene oxide, Humulene epoxide-2, Bisabolol, Naphthalene (Fig. 2).

Antimicrobial activity

Bacterial Growth Inhibition

The antimicrobial activity was evaluated *in-vitro* of the methanolic extracts of *cannabis* against *Escherichia coli* and *Pseudomonas aeruginosa*. The methanolic

extract of cannabis did not show any antimicrobial activity against both of the bacterial strains tested.

Out Reach and Awareness Programmes

Contributed in creating awareness regarding the benefits and uses of medicinal plants such as giloy, tulsi, kalmegh, haldi, *Aloe vera*, mint, brahmi, ashwagandha, and neem for creating better human health and lifestyle. (Fig. 3).



(Source: NavBharat Times and Dainik Jagran Newspaper; Lucknow edition)

Fig. 3: Featured articles on popularization of medicinal plant and their uses

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Phytoconstituents analysis and their content variation, phytochemical investigation, isolation of important phytomolecules

Medicinal plants are rich source of biologically important secondary metabolites. Investigation of these medicinal plants for their metabolite profiling can be used for their quality control as well as for providing a rationale for their use in traditional medicine.

Also, reference standards are essential for the quality assessment of herbal drugs especially for the quantification of secondary metabolites. Preparation of these reference materials will be helpful in providing cost effective reference compounds to the academia and industry.

Phytochemical investigation of *Alstonia scholaris*

Alstonia scholaris (Saptaparna) is an important medicinal plant used in various traditional and folk medicines. It is a constituent of AYUSH-64, a poly-herbal drug that is in use for over 40 years for various clinical conditions like fever, microfilaremia, and inflammatory conditions as well as for influenza like illness. All parts of the plant are utilized, among which the bark is most extensively used. Comparative phytochemical studies were carried out on its leaves, stem bark and fruits. Physicochemical parameters, preliminary phytochemical screening and HPTLC analysis for the presence of different triterpenoids and sterols were assessed (Fig. 1). Different extracts were found to contain ursolic acid, lupeol and β -sitosterol. Marked differences were observed when quantification as well as analysis of the different extracts for their phenolic and flavonoid constituents and their antioxidant potential was carried out. These results would be useful for the analysis of the

raw drug samples and formulations for the presence of *A. scholaris*. The HPTLC fingerprint profiles are especially useful and can be essentially used for quality control and assessment.

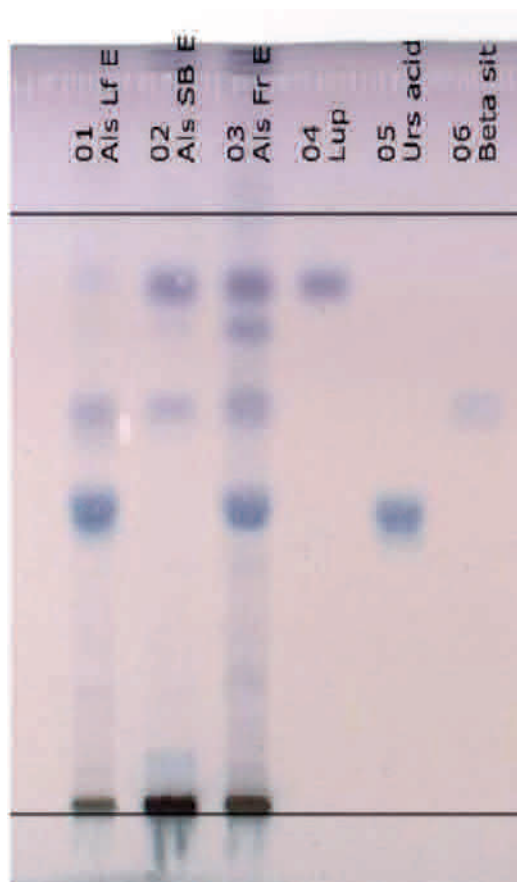


Fig. 1: HPTLC analysis of *Alstonia scholaris* (Track 1 - *Alstonia* leaf ethanolic extract; Track 2 - *Alstonia* stem bark ethanolic extract; Track 3 - *Alstonia* fruit ethanolic extract; Track 4 - Lupeol; Track 5 - Ursolic acid; Track 6 - Beta-sitosterol)

Phytochemical studies were also carried out on the stem bark of *Symplocos racemosa* and roots of *Potentilla fulgens*, two important Ayurvedic medicinal plants. Physicochemical parameters, preliminary phytochemical screening, antioxidant activities and HPTLC analysis for the presence of different chemical markers were assessed. They were found rich in

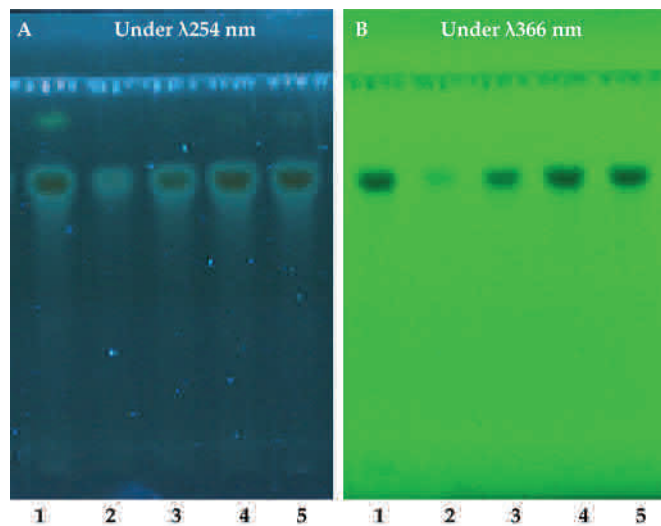


Fig. 2: HPTLC analysis of Mangiferin (Track 1- Isolated Mangiferin (impure); Track 2,3,4- Standard Mangiferin at different concentrations; Track 5- Isolated Mangiferin)

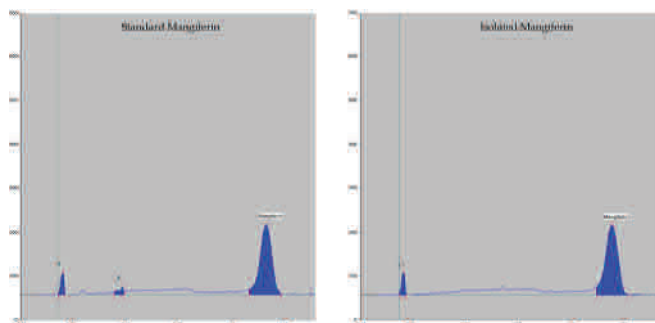


Fig. 3: Densitometric scan profiles of Mangiferin at $\lambda 254$ nm

phenolic compounds like gallic acid and ferulic acid.

Isolation of Mangiferin

Mangiferin, a xanthone C-glycoside, was isolated from the hot methanolic extract of the leaves of *Mangifera indica*. HPTLC analysis of the isolated compound was carried out with standard mangiferin (Figs. 2, 3) for comparison and purity check. mangiferin will be further processed for accreditation as a reference material.

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Phytochemical investigation, value addition and natural product development

Herbal product development for industrial application

Prepared a bioplastic film from plant seeds. Provided about 1.2 kg bioplastic film forming material to industry for its use on jute for lamination.

Prepared a plant based cleansing formulation to substitute synthetic chemicals such as sodium lauryl sulphate used in commercial cleansing/wash products. The formulation was developed in solution, flakes and film form. Integrated the cleansing solution with different medicinal and aromatic extracts viz., azadirachta, lemon and orange for value addition and identifying its synergistic

property. Physicochemical properties viz., pH, TDS, conductivity, density, specific gravity, foaming index and viscosity were determined (Fig. 1).

Plant-based biodegradable cutlery of different shapes and sizes were prepared to substitute plastic cutlery made of synthetic, toxic and non-biodegradable materials such as polystyrene in packaging. These plant-based cutlery are stable, ecofriendly and cost-effective, and can be used for food packaging and storing. Physicochemical parameters of raw material and cutlery made from them were determined. Biodegradability studies done were also in comparison to commercially used products such as sugarcane bagasse (Fig. 2).



Fig. 1: Plant-based cleansing formulations



Fig. 2: Biodegradable cutlery set

Characterization and value addition of plant-based resins, gums and waxes

Four samples of gums and resins of *Butea monosperma*, *Anogeissus latifolia*, *Gardenia gummifera*, *Commiphora wightii*) were collected from Chambal eco region, Madhya Pradesh. The indigenous knowledge and utilization of gums and resins among the tribal communities were documented. Apart from the collection from field, local markets were also surveyed for documentation of their economic values, uses and utilization.

Preparation of certified reference material of important phytomolecules

Extracted and fractionated curcuminoids from rhizome of *Curcuma longa* after standardization

of extraction and isolation protocol. Determined the purity of purified curcumin through chromatographic/ spectroscopic techniques (>95%) and prepared reference material in surplus amount (≥ 200 mg). Homogeneity and stability testing is in progress.'

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Molecular herbal nanobiotechnology, herbal product development

Green Nanoparticles exhibit superior anti-quorum sensing and anti-biofilm activities in *Pseudomonas aeruginosa* PAO1 via las-rhl regulons

Metal nanoparticles (NPs) coated with natural bioactive phytochemicals are considered potent alternative anti-virulence agents alone and in synergistic combination with ineffective antibiotics. These agents primarily inhibit quorum sensing (QS)-regulated bacterial virulence factors production without affecting essential metabolic pathways in bacteria required for their normal growth, and therefore, eliminating the chance of getting drug resistance. Silver NPs (Pg-AgNPs) and zinc oxide NPs (Pg-ZnONPs) were biosynthesized using the leaf extract of *Psidium guajava* and assessed their anti-QS and anti-biofilm activities against human pathogenic bacterium *Pseudomonas aeruginosa* PAO1. Characterized the synthesized NPs by UV-

visible spectroscopy and electron microscopy. The synthesized particles were monodispersed and spherical. We observed uniform size distribution within the range of 10-20 nm for Pg-AgNPs and 10-30 nm for Pg-ZnONPs. The presence of anti-QS phytochemicals on the surface of biosynthesized NPs was confirmed by energy dispersive X-ray analysis, X-ray diffraction, and Fourier transform infrared spectroscopy. Both Pg-AgNPs and Pg-ZnONPs showed superior inhibition of PAO1 virulence factors, including alginate, rhamnolipid, protease, pyocyanin, pyoverdine, elastase, extracellular lipopolysaccharide, esterase, and swimming and swarming motilities, compared to their chemical counterparts. The inhibition of biofilm formation which was much higher as compared to chemically synthesized NPs. The decrease in QS signaling of PAO1 caused pathogenicity inhibition, resulting in reduced virulence genes expression as evidenced by real-time PCR analysis. Thus, the study illustrates

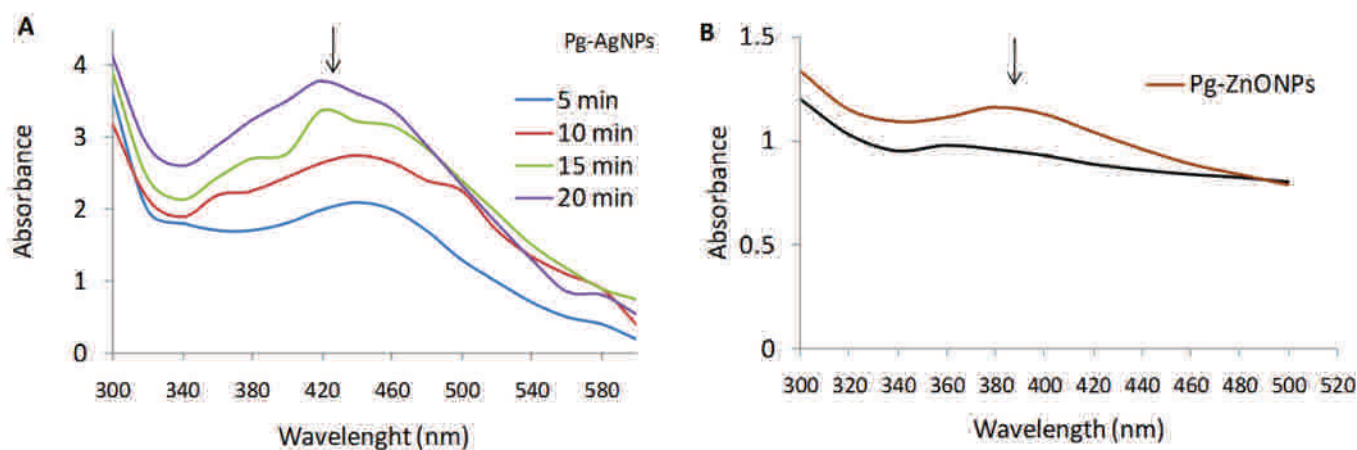


Fig. 1: UV-vis spectra of BSNPs (A). Pg-AgNPs, and (B). Pg-ZnONPs

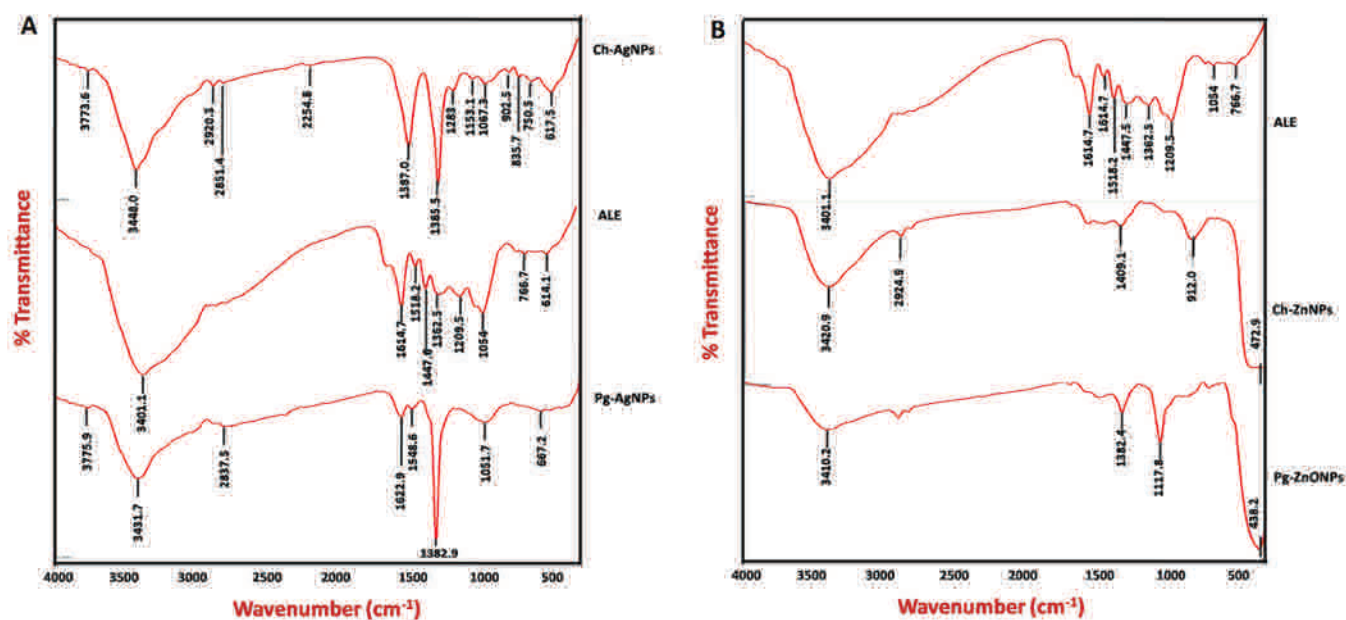


Fig. 2: (A & B). FTIR spectra of ALE, chemically synthesized AgNPs (Ch-AgNPs), Pg-AgNPs chemically synthesized ZnONPs (Ch-ZnONPs) and Pg-ZnONPs

that phyto-fabricated silver and zinc oxide NPs encapsulated with anti-QS phytochemicals of *P. guajava* were more effective than their chemical counterparts in attenuating *P. aeruginosa* QS signalling and biofilm formation.

Synthesis and characterization of green NPs

The biosynthesized nanoparticles (BSNPs) were fabricated using the aqueous leaf extract (ALE) of *Psidium guajava*. The plant has good traditional medicinal value worldwide to treat dysentery, wounds, ulcers, dental conditions, and cholera. Recent studies suggested that *P. guajava* leaves are rich in flavanoids, phenolics, carotenoids and terpenoids. In the present study, phytochemicals present in the ALE exhibited remarkable potential for reducing Ag⁺ and Zn⁺ ions, during NP synthesis and acted as capping and stabilizing agents. UV-visible spectroscopic investigation showed typical characteristic absorption peaks of silver NPs at 420-440 nm. When ALE mixed with colorless silver nitrate, solution color turned into distinctive reddish-brown due to surface plasmon resonance (SPR) excitation. A slight shift of peak from the typical wavelength range of Ag 410-420 nm (Fig. 1A) indicates an encapsulation of AgNPs by phytochemicals present in ALE (Pg-AgNPs). No significant peaks were observed in the ALE. The rapid synthesis of Pg-AgNPs was observed

within 5-10 min. Besides, we confirmed green zinc oxide NPs (Pg-ZnONPs) formation by measuring the λ max at 380 nm, while Ch-ZnONPs showed maximum wavelength at 360 nm (Figure 1B). The shift of peak in Pg-ZnONPs clearly indicates the role of phytochemicals of *P. guajava* in synthesis and encapsulation of Pg-ZnONPs.

ALE was subjected to FTIR analysis before and after bioreduction to confirm the reaction between extract and metal ions (Fig. 2A & B). Before reduction, ALE showed peaks at 3400 cm⁻¹, signifying the presence of a single bond stretch of O-H and N-H groups. A peak of free hydroxyls was observed in NPs spectra at 3400 cm⁻¹, suggesting the participation of hydroxyl group of polyphenols in metal ions' bioreduction. ALE characteristic peaks at 1614 and 1518 cm⁻¹ corresponded to stretch vibration of C=O and C=C groups, respectively. After Pg-AgNPs synthesis, the signature peaks were shifted at 1622 and 1548 cm⁻¹, indicating phytochemicals' binding to NPs. Asymmetrical hetero-oxy X-O compounds (where X=O nitrogen, sulfur, phosphorus, and silicon) bending vibration at 1548 cm⁻¹ showed strong binding of aliphatic nitro compounds on Pg-AgNPs. In Pg-AgNPs and Pg-ZnONPs, a sharp signature peak at 1382 cm⁻¹ corresponded to the bending stretch of phenols or tertiary alcohol, this peak was observed at 1362.5 cm⁻¹ in ALE. Whereas, in Pg-ZnONPs, peak

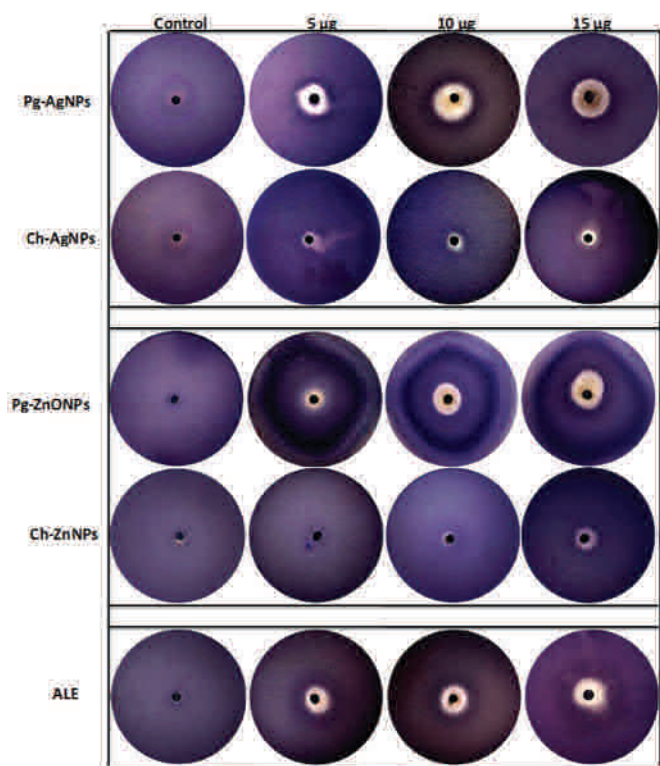


Fig. 3: Anti-quorum sensing activity of chemically synthesized and green nanoparticles in *Chromobacterium violaceum*

at 1117.8 cm^{-1} revealed cyclic ethers, large rings with C-O and C-F stretches. An absorption band at 440 cm^{-1} confirmed the formation of ZnONPs. Pg-AgNPs exhibited distinctive peaks at 1050 and 667 cm^{-1} corresponding to primary alcohol, C-O stretch and CH=CH stretch, respectively, representing alkaloids capping on NPs.

Anti-QS activity of BSNPs

Chromobacterium violaceum ATCC 12472, is a bio-monitor strain customarily used to monitor QS inhibitions in Gram-negative bacteria. The bacterium produces a QS-regulated and *N*-acyl homoserine lactone (AHL)-dependent violacein purple color pigment. Violacein inhibitory activity of biosynthesized nano particals (BSNPs), was assessed against chemically synthesized nano particles (CSNPs), and ALE in a concentration-dependent manner by measuring the zone of inhibition. Results showed substantial inhibition of violacein production when bioindicator stain was treated with BSNPs (Fig. 3). In ALE, moderate activity was observed while weak activity was noticed in CSNPs treated cultures than BSNPs-treated. Results indicated that

phytochemicals encapsulated BSNPs significantly inhibit QS-regulated violacein pigment production at a much lower concentration than ALE. Inhibition of violacein production was further quantified spectrophotometrically in broth culture tests. A significant drop in violacein production was noted in cultures treated with BSNPs in a concentration-dependent manner. As shown in Fig. 3, we observed 50% reduction in violacein at all doses of BSNPs and inhibited 90% at $15\text{ }\mu\text{g/ml}$ of Pg-AgNPs and $30\text{ }\mu\text{g/ml}$ of Pg-ZnONPs.

Antibiofilm activity of BSNPs

Biofilms formation is an essential virulence factor of *P. aeruginosa* PAO1. It acts as a protective shield against the host immune system and allows them to colonize and survive in a hostile environment. Quantitative results of biofilms inhibition in Pg-AgNPs revealed 50%, 75%, and more than 90% inhibition at 5, 10, and $15\text{ }\mu\text{g/ml}$ concentrations, respectively (Fig. 4) whereas Pg-ZnONPs inhibited 65%, 72%, and 78% at 10, 20, 30 $\mu\text{g/ml}$ concentrations, respectively. We also noticed 25% and 50% biofilm inhibition in ALE at 200 and $300\text{ }\mu\text{g/ml}$ concentrations, respectively. We observed the formation of a dense and firmly adhered biofilm at each concentration of CSNPs. Results showed 15% inhibition in Ch-AgNP-treated PAO1 while 20% inhibition was noticed in Ch-ZnONPs at their highest concentration (Fig. 4). Due to electrostatic interaction of AgNPs with bacterial cell membrane releases Ag^+ ions, it can induce reactive oxygen species (ROS) formation and damage to key enzymes involving QS-regulated biofilms production. The results obtained support the hypothesis that BSNPs encapsulated with ALE having potent anti-QS phytochemicals may enhance the anti-biofilm potential of BSNPs compared to CSNPs.

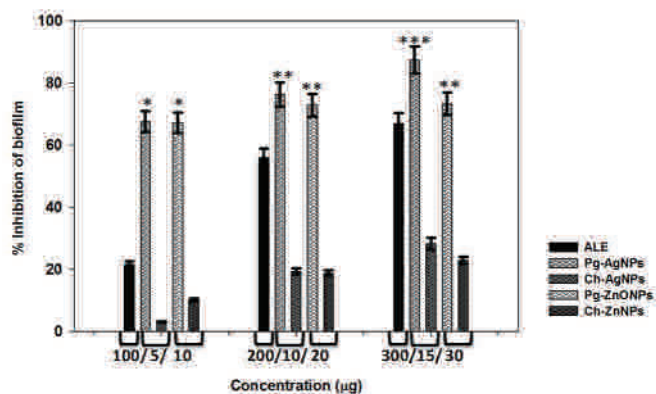


Fig. 4: Anti-biofilm activity of chemically synthesized and green nanoparticles in *P. aeruginosa* PAO1.

Inhibition of QS-regulated virulence factors by BSNPs

Pathogenicity of *P. aeruginosa* depends on producing different virulence factors, including pyocyanin, lipopolysaccharide, pyoverdine, protease, alginate, siderophores, elastase, and motility. These factors target the host defense system and intrinsically make it resistant to antibiotics. Siderophores, namely pyocyanin, pyoverdine and pyochelin act as signaling molecules for the iron transport system and enable bacteria to iron acquisition from limited environments. Pyocyanin induces the ROS in mammalian cells and subsequently increases oxidative stress. It changes host immune machinery, which causes ciliary dysfunction in the respiratory tract and induces inflammation. Treatment of PAO1 with 15 $\mu\text{g}/\text{ml}$ of Pg-AgNPs showed 70% and 60% reduction in pyocyanin and pyoverdine production. In contrast, 30 $\mu\text{g}/\text{ml}$ of Pg-ZnONPs exhibited a 57.3% reduction in pyocyanin and 43.7% in pyoverdine. Lipopolysaccharides (LPS) are important QS-controlled endotoxins of PAO1 that regulate antibiotic resistance, cell-to-cell adherence, and viscoelasticity. The study revealed that the highest concentration of Pg-AgNPs and Pg-ZnONPs effectively reduces the LPS content in bacterial culture up to 90% and 82%, respectively.

Rhamnolipid plays an essential role in *P. aeruginosa* for forming biofilm, tolerance against host immune cells, and siderophore production. CTAB plate assay results indicated that the BSNPs are superior to CSNPs in inhibiting PAO1 rhamnolipid production, measured by greenish-yellow color zone develops around the bacterial colony. Further anti-rhamnolipid effect of BSNPs and CSNPs was quantified using the carbazole method. Inhibited 48% and 89% by 15 $\mu\text{g}/\text{ml}$ of Pg-AgNPs and 30 $\mu\text{g}/\text{ml}$ of Pg-ZnONPs, respectively. BSNPs revealed a superior inhibitory effect compared to Ch-AgNPs and Ch-ZnONPs. Next, we examined the impact of BSNPs and CSNPs on the esterase activity of PAO1. Membrane-bound esterase increases the production of rhamnolipid, biofilm formation, and motility. Subsequently, Pg-AgNPs and Pg-ZnONPs inhibited 50% and 31% activity, respectively, at their higher doses. Similarly, swimming and swarming motility tests revealed a

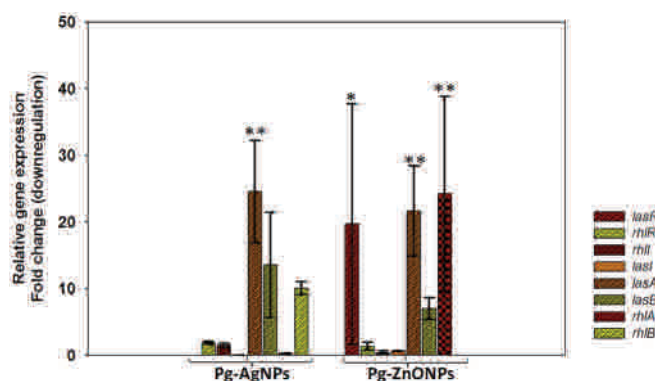


Fig. 5: Effect of BSNPs on QS-regulated gene expression of *P. aeruginosa* PAO1

significant reduction in bacterial mobility in BSNPs-treated PAO1 with non-significant inhibition in CSNPs, compared to untreated controls.

Inhibition of QS-regulated virulence gene expression by BSNPs

The effect of BSNPs on the expression of QS virulence gene was determined using RT-PCR analysis. The attenuation of virulence factors in *P. aeruginosa* was investigated by treating bacteria culture with NPs at the sub-inhibitory concentration (<MIC) to avoid phenotypic growth of PAO1. QS-related genes' expression was checked at the mid stationary phase because these genes are extensively expressed in PAO1. A significant reduction in QS-regulated virulence genes was observed in BSNPs-treated PAO1. The relative gene expression in Pg-AgNPs-treated PAO1 was found to downregulate QS-regulated genes, namely *lasR*, *rhlR*, *rhlI*, *lasI*, *lasA*, *lasB*, *rhlA* and *rhlB* by 1.9, 1.5, 0.02, 24.5, 13.5, 0.23, 10.0-fold, respectively. Similarly, a significant reduction of these genes was observed in Pg-ZnONPs-treated PAO1 (Fig. 5).

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Plant Ecology and Environmental Technology



PLANT ECOLOGY & ENVIRONMENTAL TECHNOLOGY

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Research Scholars Statistics

Sr. No.	Position Name	Numbers
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2.	Research Associate	01
3.	Project Scientist	03
4.	JRF/SRF Fellow	28
5.	Project Staff	53

Plant Ecology and Climate Change Science

Broad Areas of R&D

- Plant eco-physiological and biochemical processes in response to air pollution and climate change.
- Forest ecosystem structural and functional analysis, forest biomass, and forest Carbon sequestration.
- Restoration/rehabilitation of degraded ecosystems and threatened plants, developing new methods for EIA/CIA, ecological and

climate change modelling, bioresource mapping & GIS.

- Arsenic detoxification mechanism in rice employing biotic and abiotic agents, monitoring and assessment of toxic and pathogenic agents in environmental matrices.

Major R&D Highlights

- Impact of long-term exposure of elevated ozone (+20 ppb above ambient) was studied on photosynthetic traits and anti-oxidative defense system of *Leucaena leucocephala* in a Free Air Ozone Concentration Enrichment (O₃-FACE). The results provide evidence that *L. leucocephala* exhibited greater sensitivity to O₃ during initial exposure (up to 12 months) but showed moderate tolerance by the end of the 2nd year. Visible O₃ injuries were found in leaves grown under eO₃ conditions. Net photosynthesis, photosynthetic pigments and lipid peroxidation were significantly reduced after exposure to elevated ozone (eO₃), whereas stomatal conductance and transpiration rate were significantly decreased after 12 months of exposure to eO₃. Antioxidant enzymatic activities (catalase, ascorbate peroxidase and glutathione reductase), and ascorbate were significantly increased after exposure to eO₃.
- On subjecting tolerant and sensitive cultivars of wheat to ambient and futuristic concentrations of O₃, CO₂ and high temperature, it was identified that, wheat cultivar HD 2967 will be the most affected in future concentrations of O₃, CO₂ and higher temperature, while DBW 184 will be the least affected.
- Phytosociological study was under taken in dry, deciduous and moist deciduous forest types of Similipal Biosphere Reserve, Odisha using random quadrat sampling technique. A total of 95 tree species belonging to 78 genera and 37 families were recorded in the three forest types.
- Plant community characters viz., frequency, density, basal area importance value index (IVI) for individual tree species in each forest types were quantified. Moist deciduous forest comprises about 35-40% of the Similipal tiger reserve area and showed maximum range of



LAI values forming fairly open to very dense canopy.

- The regulation of carbon and nitrogen metabolic enzymes was studied under drought in guar, *Cyamopsis tetragonoloba* (L.) Taub. Studies suggest that during drought stress the levels of glucose increased significantly in guar varieties. Tricarboxylic acid (TCA) cycle is the main source of carbon skeletons required for NH_4^+ assimilation, and is linked to amino acid metabolism by glutamate dehydrogenase. The gene expression of acetyltransferase was upregulated in guar suggesting the translocation of carbon from glycolytic pathway through pyruvate by PeP-C to the TCA cycle. The enzyme isocitrate dehydrogenases (ICDH), is believed to be a key regulator of the TCA cycle. The study showed the downregulation in the transcript levels of this enzyme during drought. The gene expression level of glutamine synthetase (GS), glutamate synthase (GOGAT) and nitrate reductase (NR) were downregulated in guar during drought for limiting the energy flux for nitrogen metabolism.
- Work on developing Cumulative Impact Assessment (CIA) methodology has been initiated, which will help the researchers, planners and administrators for visualizing, understanding, analyzing and taking decisions for CIA of river interventions.
- Mapping areas for fragrance-bearing floral crops to provide sufficient raw materials to fragrance industries, and increase the export of fragrance products has been initiated.
- Selenium (Se), a known antagonist of As toxicity in plants, ameliorates As stress and repairs disintegration of cell wall and membranes in rice plants. Se reduces the As accumulation, in rice by over-expression of As transporter genes as well as sulfate transporters, SULTR3;1 and SULTR3;6 for countering the stress.
- During Maha-Kumbh 2013 at Prayagraj (Allahabad), the physico-chemical parameters of Ganga water deteriorated, were the microbial diversity increased from the core structure of 40 bacterial species belonging to 27 genera present during pre-Kumbh to 112 species of bacteria belonging to 43 genera.

Microbial Technology

Broad Areas of R&D

- The group focuses on disease management of commercially valuable crops and developing sustainable eco-friendly remedies.
- Biological control, plant microbe interactions and sodic soil reclamation.
- Assure food safety and protect the environment through development of economical and efficient bio-inoculant formulations both for agricultural lands and stressed soils.
- Elucidation of molecular mechanism(s) of microbe mediated abiotic and biotic stress tolerance in different crop plants.

Major R&D Highlights

- Exopolyphosphatase mutant of *Pseudomonas putida* (Δppx) having high phosphate accumulating potential was generated through knockout mutagenesis. Further inoculation of Δppx in *Arabidopsis thaliana* under phosphate starvation condition showed significantly higher silique formation and dry weight as compared to wild type strain and uninoculated plants.
- The role of silicon (Si) solubilizing bacteria in arsenic (AsIII) stress amelioration in rice was exploited. Reduced arsenic uptake in husk and grain, and improved plant growth during silicon mediated arsenic detoxification was observed in rice.
- Developed a microbial formulation for hastened decomposition of rice straw, results showed the structural damage initiated within 20-30 days post inoculation in comparison to control treatment followed by its complete disintegration after three months.
- On the basis of Zn solubilization, siderophore and organic acid production, four microbes *Bacillus pumilus*, *Pseudomonas putida*, *Pseudomonas* sp. and *Pseudomonas fluorescens* have been identified, and assessed for Fe and Zn biofortification in different rice cultivars.
- Bio-fungicide *Bacillus subtilis* NBRI-W9 (W9) inoculation showed promising effect against chemical fungicide, Propiconazole (PCZ) treated tomato plants, by improving its endophytic diversity.

- A peppermint oil based nanoemulsion (PNE) was synthesized, which is more efficacious than chemical fungicide to early blight disease management in *Solanum lycopersicum*.
- Inoculation of *Ochrobactrum* sp. (NBRISH6) in *Zea mays* L. performs multiple roles in maintaining the homeostasis under water stress conditions and mitigates the deleterious effect of drought and promotes growth.
- Work has been initiated for identification, characterization and diversity analysis of novel viruses infecting economically important crops. Development of efficient and rapid on-site diagnostic tools for early detection of plant viruses is under progress.

Environmental Technology

R&D Objectives

- Monitoring and assessment of soil pollutant(s)/contaminant(s) in respect of the water-soil-crop continuum of agriculture.

- Development of technologies for remediation of pollutant(s) contamination in crops/vegetables.
- Microplastic isolation and characterization in soil; Biochar for metal remediation and enhancing crop productivity.

Major R&D Highlights

- The monitoring and assessment of arsenic pollution in arsenic prone districts of Uttar Pradesh in the Ganga-Meghna-Brahmaputra basin, and the arsenic estimation in the irrigation groundwater samples, agricultural soil samples, and crop produce of different food crops and vegetables are on-going
- The studies on remediation and reclamation of Hexachlorocyclohexane (HCH) dumpsite by using microbial remediation technology is under progress.
- Producing pyrolysed biochar from agricultural waste and further use of this product for adsorbing contaminants like arsenic and other toxic metals from the soil is in progress.

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Eco-physiological and biochemical responses and adaptation of plants to abiotic stresses

Regulation of carbon and nitrogen metabolic enzymes under drought in *Cyamopsis tetragonoloba* (L.) Taub

Cluster bean or guar [*Cyamopsis tetragonoloba* (L.) Taub.] is a drought-tolerant, sun-loving, annual legume, and mainly cultivated during spring-summer. It is cultivated mostly in the tropical and sub-tropical regions. Apart from using its pod as a vegetable and fodder, the guar gum is extracted from

the endosperm. Drought is responsible for severe crop yield loss, which is about 50% worldwide and causes a huge economic loss. Water stress alters key functions and disrupts cellular structure in plants. The effect of drought on carbon and nitrogen interaction in leaves of four guar varieties RGC-986, HG-563, RGC-471 and Varsha was examined. For carbon assimilation, the levels of sugars play a crucial role in plant metabolism, so glucose was estimated biochemically. Glucose not only supplies carbon and energy, but

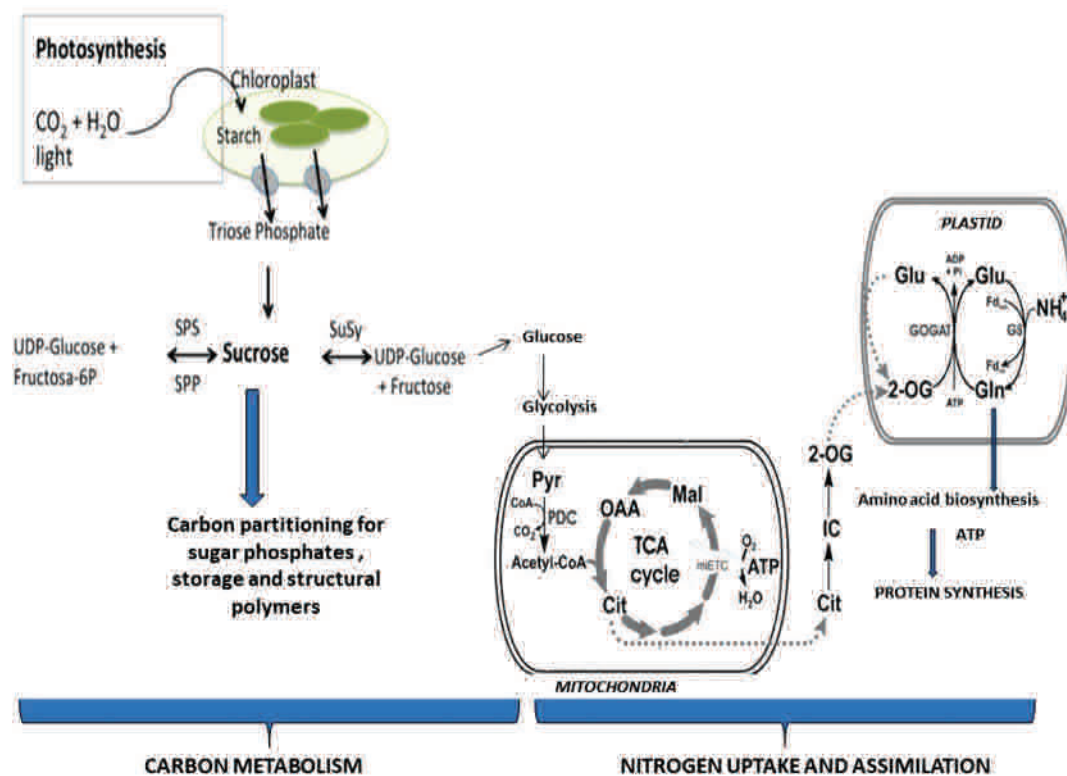


Fig. 1: Interaction between carbon and nitrogen metabolic pathways in guar. The carbon metabolic pathway provides energy (ATP) and reducing potential NAD(P)H to nitrogen assimilation process. However, the carbon skeleton part in amino acids also comes to form 2-OG of TCA cycle. NR, GS, GOGAT, 2-OG play essential role in interaction.

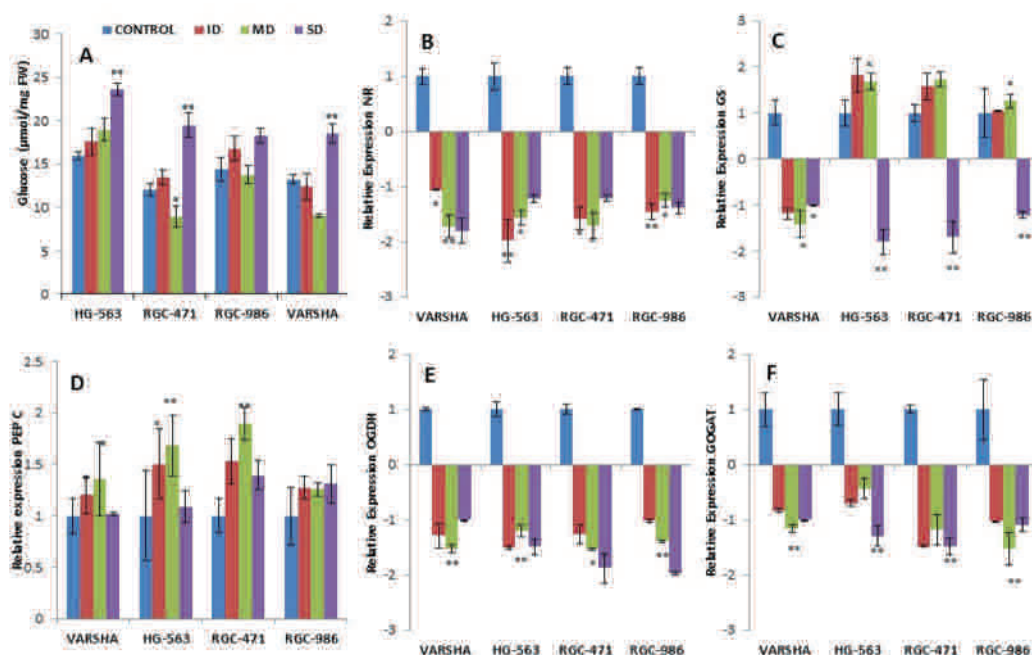


Fig. 2: Expression analysis of genes associated with TCA cycle and nitrogen metabolism in leaf tissue of guar on increasing days of drought (I, initial drought; MD, medium drought; SD, severe drought) in comparison to watered plants (control), values are means \pm SD of five biological replicates. Modulations in glucose (A), Nitrate reductase (B), glutamine synthase (C), pep carboxylase (D), oxoglutarate dehydrogenase (E), glutamine synthetase (F). Bar shows the expression value of the genes respectively in comparison with control plants.

also participates in the signalling pathway initiating the defence-mechanism in plants. The results suggest that during drought stress the levels of glucose increased significantly in all guar varieties. The increase was maximum in HG-563, while minimum in Varsha variety. We demonstrated the regulation in the transcripts levels of gene encoding enzymes of TCA cycle and nitrogen metabolism (Fig. 1). The tricarboxylic acid (TCA) cycle is the main source of carbon skeletons required for NH_4^+ assimilation, and is linked to amino acid metabolism by glutamate dehydrogenase. The TCA cycle thus links carbon and nitrogen metabolisms. As guar belongs to the legume family, the nitrogen assimilation initiates by its reduction in the inorganic form NO_3^- to NH_4^+ . Drought stress also influences the nitrogen level by interfering with steps in nitrogen metabolism. The glutamine synthetase/glutamate synthase (GS/GOGAT) cycle, yielding glutamine and glutamate (Glu) is initiated by the amination of 2-oxoglutarate (2-OG), respectively, in the TCA cycle. Further, the gene expression of acetyltransferase was upregulated in all the varieties of guar, suggesting the proper translocation of carbon from glycolysis pathway through pyruvate by PeP-C to the TCA cycle (Fig. 2A). The enzyme acetyltransferase is thought to be a key

regulatory point for carbon fluxes into the TCA cycle and to display a general importance. Upon entering into the TCA cycle, the Acetyl CoA is subsequently converted to citrate by citrate synthase, which is often regarded as the first committed step of the TCA cycle. The transcript level of this gene was upregulated up to the mid drought and then was downregulated during the severe drought conditions. Functional studies have implicated the citrate synthase to have important role as a source of carbon skeleton for nitrogen assimilation (Fig. 2B). Further as the cycle proceeds, isocitrate is oxidatively decarboxylated to 2-oxoglutarate (2-OG) by either NAD^+ or NADP^+ dependent isocitrate dehydrogenases (ICDH), generating CO_2 and NADH or NADPH, respectively. This enzyme is believed to be a key regulator of the TCA cycle as well as it plays an important role in the maintenance of the 2-oxoglutarate level and therefore in the regulation of nitrogen assimilation. During drought condition at all stages the transcript levels of this enzyme were downregulated in all the varieties. This suggests that lower expression of the ICDH gene, lead to reduced activity of the enzyme, which in turn lead to decreased production of 2-OG (Fig. 2C). As the drought stress progressed the expression of oxoglutarate dehydrogenase (OGDH) gene declined

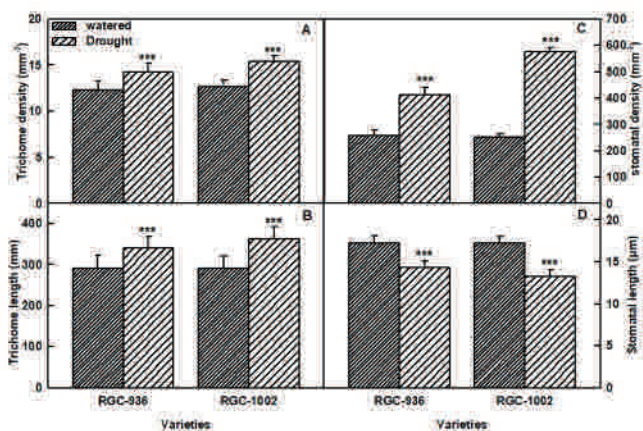


Fig. 3: Effect of water stress in leaf traits (A) trichome density, (B) trichome length, (C) stomatal density and (D) stomatal length. Data is mean of five separate plants (\pm SD).

more in Varsha variety, followed by RGC-471, RGC-986 and HG-563 varieties. Later, 2-OG is transferred from mitochondria to plastids, where it enters into GS-GOGAT pathway for N metabolism (Fig. 2D, E). The gene expression level of GS, GOGAT and nitrate reductase (NR) were downregulated during drought limiting the energy flux for nitrogen metabolism (Fig. 2F). The limitation was maximum in HG-563 and RGC-986 variety and minimum in Varsha and RGC-471 variety. This study showed that how guar employ various strategies to balance C:N ratio.

Effect of water stress on development of leaf stomata and leaf trichomes in contrasting guar [*Cyamopsis tetragonoloba*(L.)Taub.] varieties

Water stress damages the cellular structure and impairs key physiological activities. As the drought progresses, plants start to alter their leaf traits development such as stomatal, epidermal cells and trichomes resulting in alteration in complete physiology of the plant.

In the present study, along with the physiological parameters the leaf morphological traits (trichome density, trichome length, stomatal density and stomatal length) were studied in two contrasting guar varieties, RGC-936 a sensitive and another RGC-1002 a tolerant one under watered and water-stressed conditions (Figs. 3 and 4). Drought increased the leaf trichome density and trichome length in both the varieties. The leaf trichome density and trichome length were significantly increased in RGC-1002 while reduced in RGC-936 in water deficit

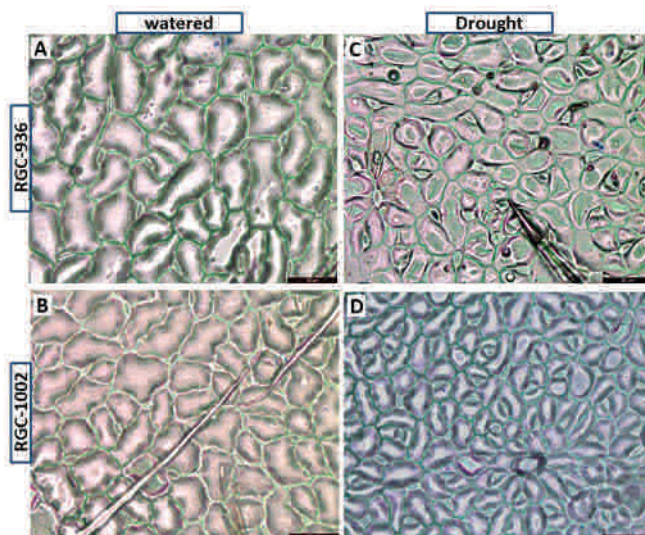


Fig. 4: Morphology of stomata in leaves of RGC-936 and RGC-1002. Light micrographs of stomata developed on abaxial surface in the leaves during, watered (A and B) and water deficit conditions (C and D), respectively.

conditions which was compensated by relatively less reduction in water level in RGC-1002 than RGC-936 (Fig. 3A, B). Due to increased trichome density and trichome length the variety RGC-1002 could cope up with the long-term water stress efficiently and is more adapted to the water stress conditions than RGC-936. Furthermore, water deficit condition significantly decreased the leaf water status, the rate of photosynthesis and stomatal conductance in both the varieties while the decrement was lesser in drought-tolerant variety RGC-1002 than in drought-sensitive RGC-936. Drought significantly increased the leaf stomatal density in RGC-1002 than RGC-936 and significantly reduced the stomatal length in the variety RGC-1002 than RGC-936. This result was correlated with relatively lesser reduction in photosynthesis and stomatal conductance in the variety, RGC-1002 than RGC-936 (Fig. 3C, D, and Fig. 4). Our findings show how water stress alters the physiological performance, leaf traits and plant adaptation mechanisms.

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Plant eco-physiological and biochemical processes in response to air pollution and climate change

Tropospheric ozone (O_3) is a phytotoxic air pollutant. Trees growing in urban areas not only sequester CO_2 but also remove O_3 through stomatal and non-stomatal mechanisms. *Leucaena leucocephala* is a fast-growing tropical and subtropical leguminous tree species. In India, it has been classified as a ‘miracle

tree species’ in agro forestry practices and is used for various economic and ecological purposes like pulp and paper manufacturing, organic manuring, preventing soil erosion as well as energy production. It is also used as fodder for animals, firewood and shade in permanent plantations. No long-term

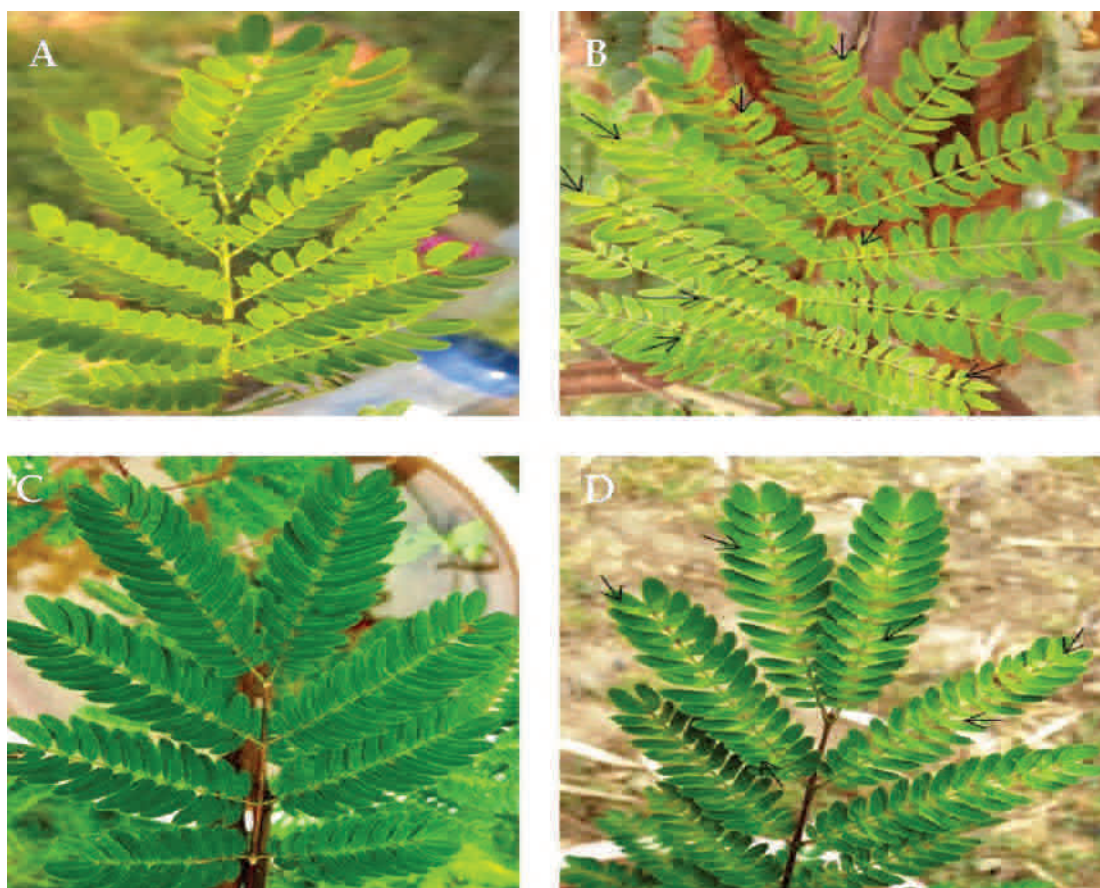


Fig. 1. Injury symptoms in young (B) and mature (D) leaves of *L. leucocephala* seedlings after 12 and 24-month continual exposure of eO_3 compared with young (A) and mature (C) leaves grown under ambient ozone. Black arrow indicates visible injury present in leaves of *L. leucocephala*.



Table 1. Effect of O₃ on leaf Antioxidant enzyme and non-enzymatic activities of *L. Leucocephala*. Statistical significances of the Two-way ANOVA show interactions between Ozone and time interval. Data shows Mean \pm standard deviation (SD) ($n=3$) values. Asterisks shows significances level of p values, * < 0.05, ** < 0.01, *** < 0.001.

Parameters	6 month		12 month		18 month		24 month		ANOVA result		
	aO ₃	eO ₃	aO ₃	eO ₃	aO ₃	eO ₃	aO ₃	eO ₃	Ozone	Time	Ozone \times Time
SOD (U g ⁻¹ FW)	312 \pm 10.8	325 \pm 12.2	376 \pm 15.8	379 \pm 17.8	339 \pm 13.9	326 \pm 12.1	300 \pm 10.7	341 \pm 13.5	ns	***	*
CAT (μ mol mg ⁻¹ protein ⁻¹ min ⁻¹)	105 \pm 3.79	124 \pm 3.30*	134 \pm 2.57	156 \pm 2.49**	102 \pm 4.23	116 \pm 2.26	139 \pm 5.25	147 \pm 1.68	***	***	*
APX (μ mol mg ⁻¹ protein ⁻¹ min ⁻¹)	4.55 \pm 0.06	4.73 \pm 0.06	4.03 \pm 0.08	4.67 \pm 0.15**	3.42 \pm 0.20	3.79 \pm 0.10	2.48 \pm 0.08	3.28 \pm 0.04**	***	***	**
GR (μ mol mg ⁻¹ protein ⁻¹ min ⁻¹)	0.07 \pm 0.002	0.08 \pm 0.002	0.16 \pm 0.004	0.19 \pm 0.003**	0.13 \pm 0.008	0.14 \pm 0.011	0.13 \pm 0.018	0.14 \pm 0.017	***	**	ns
GSH+GSSG (μ mol g ⁻¹ FW)	52.5 \pm 2.2	40.4 \pm 1.4**	75.4 \pm 3.1	67.9 \pm 3.8	55.1 \pm 1.3	50.8 \pm 1.7	42.0 \pm 1.7	32.3 \pm 1.1**	***	***	***
GSH (μ mol g ⁻¹ FW)	48.5 \pm 1.8	35.6 \pm 1.4**	65.3 \pm 2.9	54.7 \pm 4.0	48.6 \pm 1.3	43.4 \pm 1.8	39.3 \pm 1.4	28.5 \pm 1.3**	***	***	***
GSSG (μ mol g ⁻¹ FW)	3.96 \pm 0.36	4.79 \pm 0.18	10.2 \pm 0.27	13.18 \pm 0.18**	6.52 \pm 0.24	7.44 \pm 0.27	2.67 \pm 0.29	3.83 \pm 0.29	***	***	***
Total AsA (mmol g ⁻¹ FW)	20.6 \pm 0.96	23.9 \pm 0.98**	20.8 \pm 0.59	24.1 \pm 0.80*	15.6 \pm 0.53	17.2 \pm 0.44	23.2 \pm 1.32	27.0 \pm 1.38	***	***	ns
Reduced AsA (mmol g ⁻¹ FW)	12.4 \pm 0.50	16.5 \pm 0.84*	11.1 \pm 0.85	15.2 \pm 0.78**	8.8 \pm 0.73	9.9 \pm 0.43	14.8 \pm 0.47	16.8 \pm 0.53	***	***	**
DHA (mmol g ⁻¹ FW)	8.21 \pm 1.1	7.44 \pm 1.2	9.71 \pm 1.3	8.95 \pm 0.8	6.80 \pm 1.2	7.30 \pm 0.8	8.41 \pm 1.0	10.3 \pm 1.6	ns	**	ns

SOD- Superoxide dismutase; CAT-Catalase; APX- Ascorbate Peroxidase; GR- Glutathione reductase; GSSG- oxidized glutathione; GSH- reduced glutathione; GSH+GSSG- Total glutathione; DHA- Dehydroascorbate; AsA- Ascorbate

study has been conducted to understand effect of chronic O₃ exposure on *Leucaena leucocephala* (Lam.) de wit. Therefore the impact of long-term exposure of elevated ozone (+20 ppb above ambient) on photosynthetic traits and anti-oxidative defense system of *Leucaena leucocephala* was studied in a Free Air Ozone Concentration Enrichment (O₃-FACE) facility and sampling was done at different time intervals (6, 12, 18, and 24 months). Visible O₃ injuries were found in *L. leucocephala* leaves grown under eO₃ conditions (Fig 1). Results showed that net photosynthesis, and photosynthetic pigments were significantly reduced after 6, 12 and 24 months of exposure to elevated ozone (eO₃) whereas, stomatal conductance and transpiration rate were significantly decreased after 12 months of exposure to eO₃. Antioxidant enzymatic activities (catalase, ascorbate peroxidase and glutathione reductase) were

significantly increased after 12 months of exposure to eO₃. Ascorbate content increased significantly after 6 and 12 months of exposure to eO₃ while glutathione content declined significantly after 6 and 24 months of exposure to eO₃ (Table 1). The study showed that there were several negative long lasting physiological and biochemical impacts in leucaena. The results provide evidence that leucaena exhibited greater sensitivity to O₃ during initial exposure (up to 12 months) but showed moderate tolerance by the end of the 2nd year.

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Sustainable agricultural production, food safety, bioinoculant formulations, abiotic/biotic stress amelioration, soil fertility, soil ecology

The group has been involved in the development of effective bioformulations for enhancing plant growth promotion and abiotic/biotic stress amelioration. Phyto-beneficial impact of PGPR (*Ochrobactrum* sp. OC-6) was studied in maize encountering water stress, using combined approaches of morphology, physiology, biochemical, metabolics, molecular, and ecology was investigated. In addition, alkalotolerant *Bacillus* strains isolated from degraded soil were characterized for mitigating the alkaline stress in maize. *Bacillus amyloliquefaciens* (NBRI SN13) induced crosstalk among salinity and phytohormones in OsNAM-overexpressed *Arabidopsis* plants has also been elucidated.

Drought tolerant *Ochrobactrum* sp. inoculation performs multiple roles in maintaining the homeostasis in *Zea mays* L. subjected to water stress

Impact of NBRISH6 on proline, phenolics, soluble sugar content, and modulation in defense enzymes

Under water stress (WS) conditions, proline content is generally enhanced in plants but NBRISH6 inoculation protected the maize plants and the proline accumulation was significantly decreased under deficit water stress conditions by 32.1 and 29.7% in shoot and root, respectively as compared to uninoculated control (Fig. 1). Soluble sugar content was significantly lowered in plant's shoot and root tissues by 104.0 and 57.7%, respectively under drought stress condition. While inoculation with NBRISH6 not only increased the soluble sugar under normal conditions but also mitigated the deleterious effect of drought stress through helping in accumulation of soluble sugar by 93.7 and

30.45% in shoots and roots, respectively. Similar to proline content, phenolics were also significantly increased by 49.7 and 51.5% in shoot and roots of maize plants under drought stress condition as compared to normal conditions while NBRISH6 inoculation reduced the phenolics accumulation in drought stress condition by 15.4 and 30.7% in shoot and root, respectively (Fig. 1). Biochemical assay has also been performed for superoxide dismutase (SOD), catalase (CAT), ascorbate peroxidase (APX), guaiacol peroxidase (GPX) and polyphenol oxidase (PPO) activity to understand the mechanism of ROS quenching and other oxidative stress by NBRISH6. The plants subjected to drought stress had the highest activities of these enzymes (Fig. 1) and a significant reduction in the enzyme activities was recorded when inoculated with NBRISH6. The SOD, GPX, CAT, PPO and APX activities were significantly increased by 36.5 to 77.3% in shoot and 39.2 to 74.32% in roots under drought condition as compared to control (Fig. 1). Inoculation of NBRISH6 significantly decreased the activity of defense enzymes by 13.1 to 102.8% in shoot and 36 to 114.0% in root subjected to drought (Fig. 1).

Anatomical changes in the maize roots

The anatomical changes in roots are specific and are very important towards adaptation acquired by plant under drought stress conditions. Anatomical alteration in roots has been observed subjected to all treatments (Fig. 2). The proportion of aerenchyma cells decreased in NBRISH6 and NBRISH6+WS compared to that of control and WS (Fig. 2). Also, an increase in root hairs in WS was observed which was reduced in NBRISH6+WS (Fig. 2). Considering

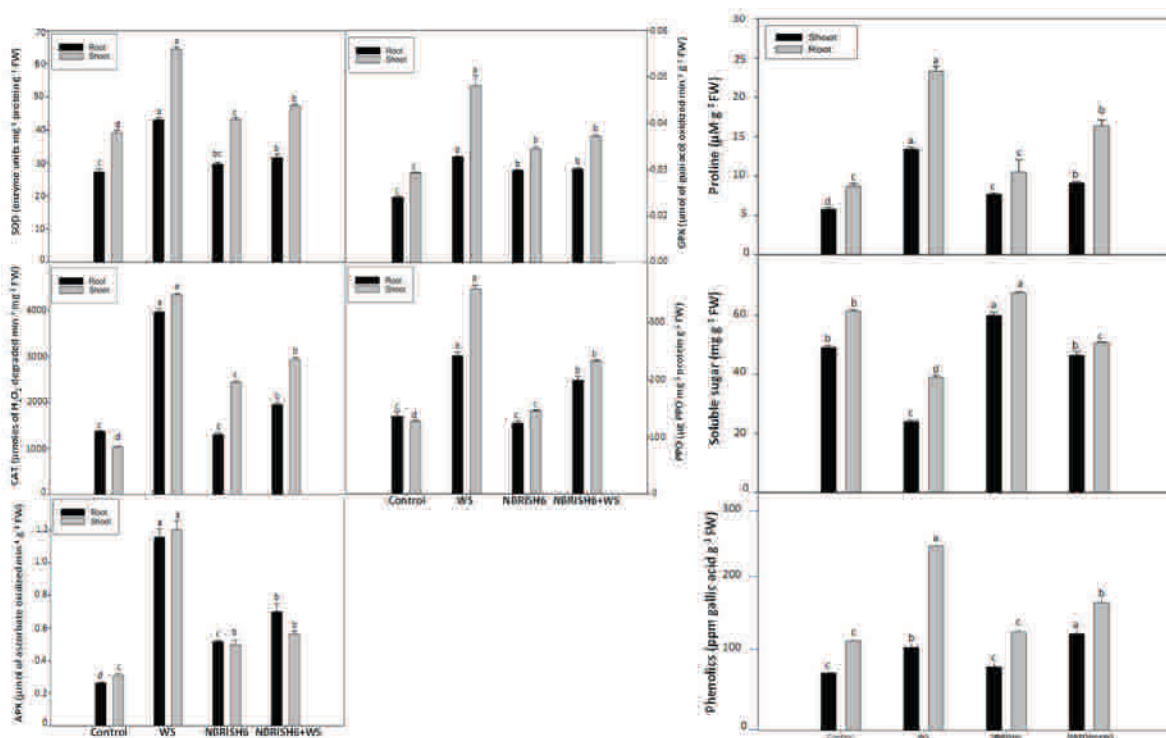


Fig. 1: Biochemical parameters and plant defense enzyme assay

changes in number of xylem cells in plant roots, NBRISH6 found to have maximum number of xylem cells followed by NBRISH6+WS, and control and WS (Fig. 2). Moreover, shrunken pith cells and presence of lignin formation was observed in intercellular spaces in the plant roots under drought stress (Fig. 2).

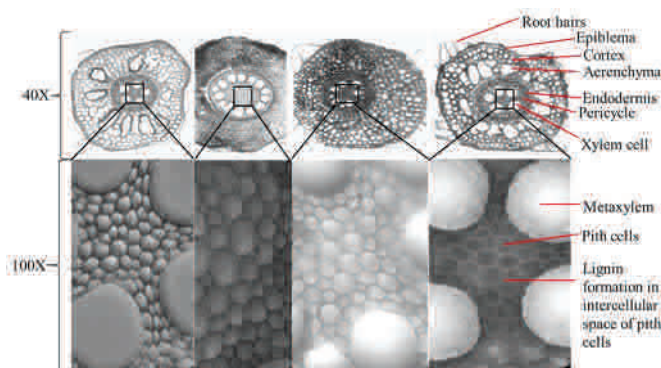


Fig. 2: Histology of cross-section of maize roots under different conditions

Phytohormone production

Phytohormones gibberellic acid (GA), abscisic acid (ABA), salicylic acid (SA) and indole acetic acid (IAA) were estimated in normal and WS condition to understand the role of NBRISH6 inoculation towards maintaining the hormonal homeostasis in maize

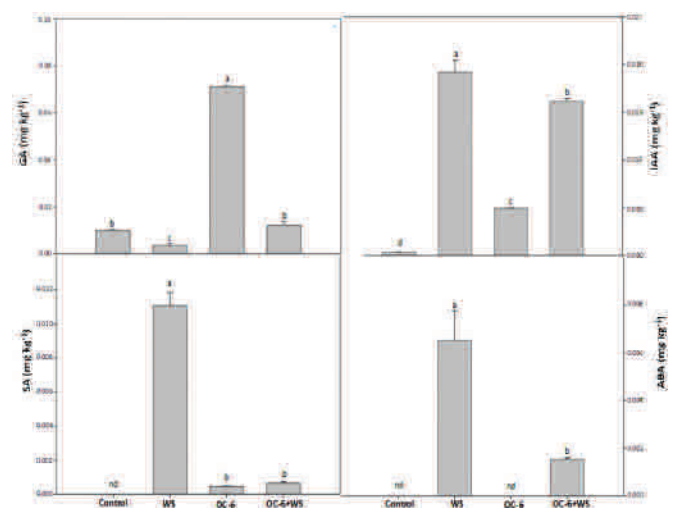


Fig. 3: Hormones content in maize shoot

plants. All the hormone levels responded to WS and level of IAA, ABA and SA was significantly increased while GA content was significantly decreased (Fig. 3). Inoculation of NBRISH6 resulted in reduction in IAA, ABA and SA, while GA level increased under WS conditions. Overall results of phytohormones analysis clearly demonstrated the role of NBRISH6 in mitigating the WS (Fig. 3).

Plant development and stress-responsive gene expression analysis

In case of expression of genes, a 2.5-3.0-fold increase in ZmbZIP in drought stress condition was observed as compared to control (Fig. 4). Expression of ZmbZIP was 2-fold higher in NBRISH6+WS, and 1.5- and 0.5-fold higher in NBRISH6 shoot and root, respectively as compared to control (Fig. 4). NBRISH6 significantly reduced ZmbZIP expression in plants under drought stress. A 2-2.5 and 1-1.5-fold induction of ZmABRE gene was observed in maize shoot and root, respectively under drought stress (Fig. 4). NBRISH6 treatment had significantly higher expression of ZmABRE in shoot but not in root compared to control (Fig. 4). Further, regarding ZmAP2-TF gene, it was found that maize roots showed 3-fold increase while, NBRISH6+WS treatment caused a decrease in gene expression under drought stress (Fig. 4). LEA genes in plants under drought stress showed the highest gene expression except for ZmMLG3 in shoot (Fig. 4). In shoot and root of WS maize, the expression of ZmLEA5A was 2.5-3.0-fold, ZmMLG3 was 3- and 6-fold, and ZmLEA14A was 3-fold when compared to control (Fig. 4). Further, genes encoding antioxidant enzymes were analyzed. Expression of ascorbate peroxidase (ZmAPX) was 2.5-3-fold higher in WS treatment and 1.2- fold higher in NBRISH6 when compared to control (Fig. 4). As expected, all water stress-responsive genes (ZmARG (arginyl-tRNA synthetase), ZmCBF (C-repeat binding factor), ZmDBF (Dehydration-responsive element binding factor), ZmDHN1 (Dehydrins), ZmERD

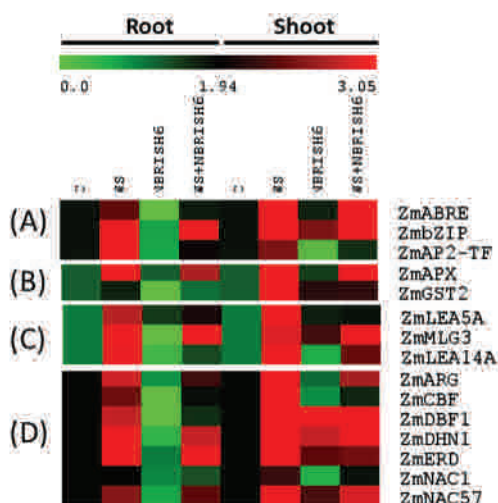


Fig. 4: Relative expression of drought stress responsive genes in maize root and shoot.

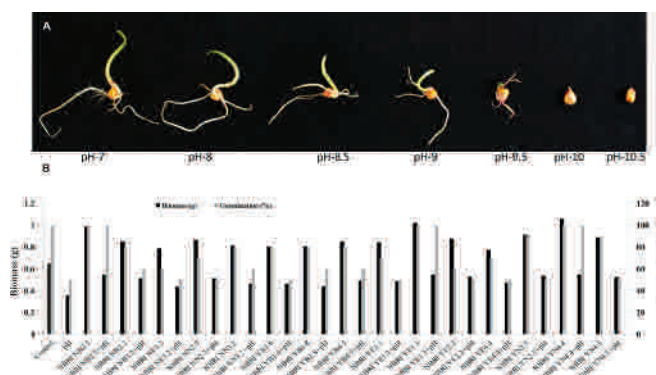


Fig. 5: *In-vitro* screening of potent PGPR: (A) Effect of different alkaline pH on maize seed germination for critical dose selection, (B) Effect of PGPR inoculation on seed germination and biomass under alkaline stress.

(Early responsive to dehydration), ZmNAC1 and ZmNAC57 [transcription factors of no apical meristem (NAM), Arabidopsis transcription activation factor (ATAF1/2) and cup-shaped cotyledon (CUC2) genes]) were significantly up-regulated by 1.2-5-fold in WS group compared to controls and the expression was down-regulated in NBRISH6+WS (Fig. 5).

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Arsenic detoxification mechanism in rice employing biotic and abiotic agents, monitoring and assessment of toxic and pathogenic agents in environmental matrices

Selenium (Se), a trace element, is a known antagonist of As toxicity in plants. The amelioration of As stress and repair of As induced disintegration of cell wall and membranes upon Se supplementation was evident in rice plants. Se supplementation reduces the As accumulation in rice by over-expression of As transporter genes as well as sulfate transporters, SULTR3;1 and SULTR3;6 for countering the stress.

Monitoring river water quality is imperative for the livelihood security of large section of the dependent population. The Physico-chemical parameters of Ganga water deteriorated during Maha-Kumbh at Prayagraj. During Maha-Kumbh the microbial diversity (112 species of bacteria belonging to 43 genera) increased from the core microbial community structure, i.e., 40 bacterial species belonging to 27 genera present during pre-Kumbh. Also, Ganga was richer in bacteriophages than Yamuna.

Mechanism of selenium mediated amelioration of arsenic toxicity in rice using omics tools

The detailed molecular mechanism of arsenic (As) stress amelioration in rice plant by application of selenium (Se) was elucidated. An integrated omics study involving the proteomic and transcriptomic in rice seedling exposed to As and As+Se was compared to explore the differential response between As, Se and As+Se treated seedlings. The As induced structural deformities involving disintegration of cell wall and membranes in the seedlings, was repaired upon Se supplementation. The expression of As transporter genes viz., NIP1;1, NIP2;1, ABCG5, NRAMP1, NRAMP5, TIP2;2 as well as sulfate transporters, SULTR3;1 and SULTR3;6, were higher

in As+Se compared to As exposure, resulting in reduced As accumulation and toxicity. The higher expression of regulatory elements like AUX/IAA, WRKY and MYB TFs during As+Se exposure also contributed towards As stress amelioration. The up-regulation of GST, PRX and GRX during As+Se exposure, which coincided with the amelioration of As induced oxidative stress, suggests the role of Se in triggering peroxidase based detoxification of ROS and vacuolar sequestration by GST. Out of 88 differentially expressed identified proteins (Fig. 1), 38 were found to be differentially regulated in all four treatments, whereas 25 proteins found expressed in three treatments (As alone, Se alone, and As+Se treatment). The abundance of proteins involved in photosynthesis (Fructose-bisphosphate aldolase, Sedoheptulose-1,7-bisphosphatase, Ribulose bisphosphate carboxylase/oxygenase activase, Oxygen-evolving enhancer protein 2, Chlorophyll a-b binding protein 1, Glyceraldehyde-3-phosphate dehydrogenase B), energy metabolism (Soluble inorganic pyrophosphatase 6, chloroplastic, AtpB, ATP synthase subunit beta, chloroplastic, Fructokinase-2, Phosphoglycerate kinase), transport (ABC transporter G family member 51, Protein STAR1, V-type proton ATPase catalytic subunit A), signaling (14-3-3-like protein GF14-C, Tubulin beta-7 chain, Puromycin-sensitive aminopeptidase, Actin-1 OS=*Oryza sativa* subsp. Indica) and ROS homeostasis (Probable L-ascorbate peroxidase 8, chloroplastic (APX8), L-ascorbate peroxidase 1, 2-Cys peroxidoredoxin BAS1, chloroplastic, cytochrome c peroxidases, Peroxidoredoxin-2E-2, chloroplastic, Heat shock 70 kDa protein 6 chloroplastic, glutathione S-transferase) were higher in As+Se than in As alone exposure.

Anatomical (epidermis, exodermis, sclerenchyma and cortex region) features of root and shoot growth were correlated with changes in enhanced expression of a number of transcription factors, and hormones like IAA31, and IAA14 and WRKY17, WRKY27 and WRKY52 involved in plant growth and As tolerance during As+Se exposure. The auxin responsive SAUR genes, which are considered as toolbox for adaptation in growth and development, also showed significant up-regulation during As+Se exposure.

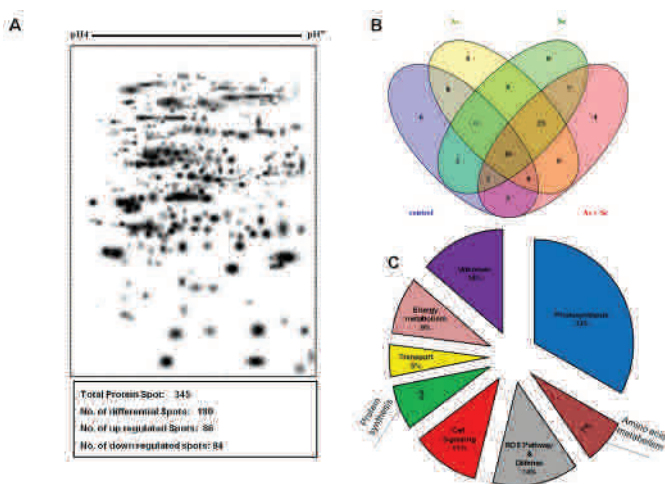


Fig. 1: Expression clustering of 88 differentially expressed proteins showing 10 clusters based on their expression profiles. Total number of proteins with same expression profile is provided in inset within the respective cluster.

Self-cleansing properties of Ganga

The plains of Ganga are among the most fertile and densely populated regions in the world. Millions of people depend on water from the holy river for their daily needs. Ganga is admired as a holy river in India. Scientific studies have revealed antimicrobial property of the water because of higher number of bacteriophages in comparison with Yamuna and Narmada rivers and dissolved oxygen indicating its intrinsic purifying capability. In order to test this hypothesis, we examined the changes in water quality due to mass gathering and bathing, the water samples 20 days before the start of bathing events during Kumbh mela 2013 (pre-Kumbh) and 20 days after the end of events (post-Kumbh) were collected along with six mass bathing events. River water samples from three major bathing sites viz. Sangam-I (S-I), Sangam-II (S-II) and after Sangam (AS), were collected for the analysis, and the water samples before the confluence of Ganga and Yamuna were

collected as control for comparison on the individual water quality of the rivers (Fig. 2). The physico-chemical properties of pre-Kumbh water samples from control sites showed that Yamuna water was nearly neutral (pH 7.24), slightly hard (within the range 17.1 to 60 mg l⁻¹) and has higher electrical conductivity in comparison with Ganga water which was alkaline (pH 8.61), relatively harder (within the range > 60- < 180 mg l⁻¹) and has lower EC. The level of total dissolved solids (TDSs) was several times higher in Ganga water than in Yamuna, the alkalinity of both rivers was almost similar at control sites. The levels of various ions such as Mg₂⁺, K⁺, SO₄⁻, Br⁻, NO₃⁻, NO₂⁻ and PO₄⁻ were generally higher in Yamuna control than in Ganga control except for the level of NH₄⁺. In contrast, the levels of chlorine dioxide and free Cl were higher in Ganga control than in Yamuna water. The biochemical oxygen demand (BOD) was below the maximum permissible limit (3 mg l⁻¹) set by WHO for bathing water in Yamuna but it was higher in Ganga (4.89 mg l⁻¹) (Fig. 3). While, the chemical oxygen demand (COD) was also higher for Ganga control than Yamuna. Dissolved oxygen (DO) was higher in Yamuna than in Ganga control though it was significantly lower than the minimum WHO limit for bathing water (5 mg l⁻¹) in both Ganga and Yamuna. During Maha-Kumbh, the level of BOD and COD further enhanced reaching to around 5-fold higher than the permissible limit for bathing, while DO reduced to lower than half the bathing water limit (Fig. 3). The EC and TDS of Yamuna water did not change significantly during the Kumbh, but pH increased to > 8, and hardness also increased though it remained lower than 60 mg l⁻¹, the limit for slightly hard water, while the water from various bathing sites after confluence as well as Ganga control exhibited high increase in EC, TDS and hardness during the Kumbh. The study found that deterioration of water quality was directly related to the bathing population at different events and bathing sites with site S-I having the biggest crowd that resulted in highest deterioration of water quality, followed by S-II. Within the different events, the change in water quality was more on Paush Purnima (27 January 2013) and MauniAmavasya (10 February 2013). The major reasons which could be attributed to the deterioration of water quality are increase in BOD, COD, total and faecal coliform, ammoniacal nitrogen (NH₄-N) and phosphate (PO₄) and decreased DO in river Ganga.



Fig. 2: Map showing five selected sampling sites at Sangam during Maha-Kumbh 2013 at Prayagraj (Allahabad): the red circles indicate the sampling points

In the pre-Kumbh samples, the control Ganga water and sediment exhibited higher levels of trace elements such as Fe, Zn, Mn, Cu, Co and Se than Yamuna water and sediment. After commencement of the month-long festival of Kumbh, the level of trace elements further increased in Ganga control and at various bathing sites, whereas their levels decreased in Yamuna control. In all water samples, the level of trace elements was in the order $Fe > Zn > Mn > Cu > Co > Se$, and their level increased at bathing events chronologically up to Mauni Amavasya with the maximum level at the main bathing site S-I. The level of toxic elements (As, Cd, Cr and Pb) was also higher in Ganga water and sediment than Yamuna control, except the level of arsenic in Ganga water and Pb in Ganga sediment. The level of As was higher than the permissible limit of drinking water ($10 \mu\text{g l}^{-1}$, WHO 1993) in many of samples collected during Kumbh. The level of Cd was also close to the permissible limit ($3 \mu\text{g l}^{-1}$), while Cr and Pb remained lower than the respective permissible limits (50 and $10 \mu\text{g l}^{-1}$, respectively).

Seventy-six species of bacteria belonging to thirty-five genera were encountered in post-Kumbh samples. *Corynebacterium*, *Pseudomonas* and *Vibrio* were the dominant genera present in pre-Kumbh Ganga water. Additionally, the species belonging to *Brevibacterium*, *Burkholderia*, *Enterobacter* and *Rhodococcus* increased during the Kumbh and post-Kumbh samples. Furthermore, a significant change in bacterial community during Maha-Kumbh was observed with an addition of 39 species belonging

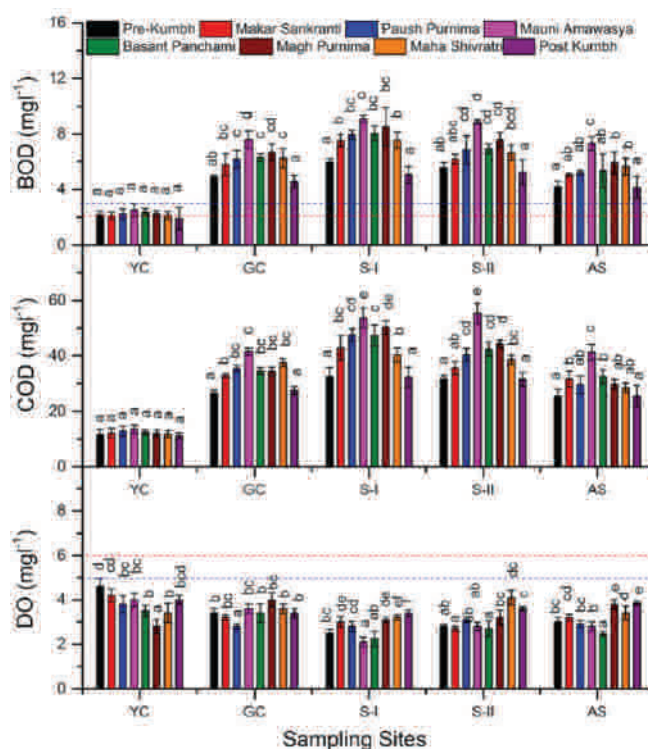


Fig. 3: Impact of mass ritualistic bathing on the level of trace elements in Ganga water during Maha-Kumbh 2013 at Prayagraj (Allahabad). Study includes five sampling sites and eight special ritualistic bathing events. YC, Yamuna control; GC, Ganga control; S-I, Sangam-I; S-II, Sangam-II; AS, after Sangam. Red dashed line, WHO limit for drinking water; blue dashed line, WHO limit for bathing water.

to 16 genera in compared the pre-Kumbh samples. Though most of these disappeared within 20 days after the last bathing event. Twenty two bacterial species, which were not present in pre-Kumbh or during Kumbh, were identified in post-Kumbh Ganga water.

Host-specific bacteriophages against *Escherichia coli* (*E. coli* B and *E. coli* K12), *Vibrio cholerae*, *Enterococcus faecalis*, *Staphylococcus aureus*, *Salmonella typhimurium* and *Pseudomonas aeruginosa* were analysed at all the selected bathing sites during each event. Results depicted that Ganga was richer in bacteriophages than Yamuna.

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Monitoring and assessment of soil pollutant(s)/contaminant(s) in respect of the water-soil-crop continuum of agriculture, development of technologies for remediation of pollutant(s) contamination in crops/vegetables

Monitoring and Assessment of Arsenic Pollution in Arsenic Prone Districts of Uttar Pradesh.

Arsenic (As) is one of the most toxic element found in the environment. The potential risks of arsenic to ecosystems and to human health, especially in South Asian region e.g., in India and Bangladesh is investigated. Arsenic (As), a non-threshold class-I carcinogen, is affecting over 150 million people worldwide through consumption of arsenic contaminated potable groundwater. There has been a global concern about the toxicity originated

from the use of arsenic-contaminated groundwater for drinking and irrigation purposes, especially in Southeast Asia. The groundwater from tubewells used for irrigating agricultural fields is adding large quantities of arsenic every year, which has resulted in elevated levels of arsenic in the agricultural soils as well as in the crops grown on these soils. For example, 1200-1600 mm water level having 100 ppb As for paddy flooding contributes approximately 40 kg per hectare per year. Arsenic gets accumulated in the edible parts of plants and subsequently finds its way into the food chain, which poses a serious health risk to humans. The transfer of As in soil-plant

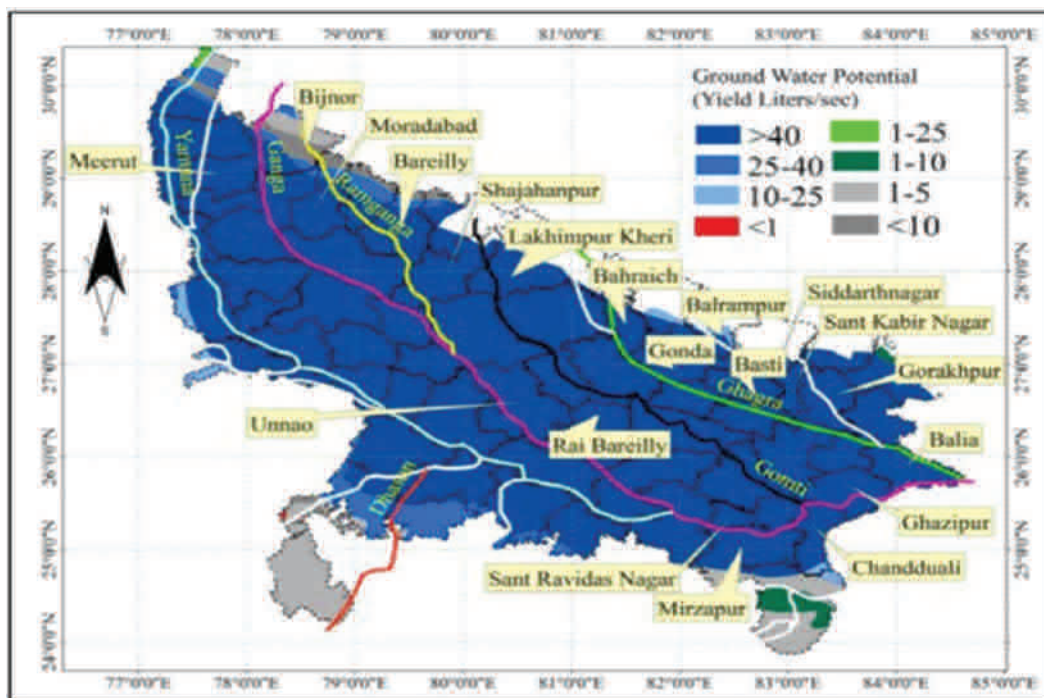


Fig. 1: Location of sampling sites in the 20 districts of Uttar Pradesh

system represents one of the principal pathways for human exposure to As. The recommendations and observations of first report committee on estimates (2014-15) of the Sixteenth Lok Sabha on "OCCURRENCE OF HIGH ARSENIC CONTENT IN GROUND WATER" has laid the foundation of arsenic mapping in the agriculture sector. The scale of the problem is grave and unprecedented, exposing 36 million people to risk of cancer and other diseases in the Ganga-Meghna-Brahmaputra (GMB) basin only. In the GMB plains, 20 districts of Uttar Pradesh have been selected: Bahraich; Ballia; Balrampur; Bareilly; Basti; Bijnor; Chandauli; Ghazipur; Gonda; Gorakhpur; Lakhimpur-Kheri; Meerut; Mirzapur; Moradabad; Rai bareli; Sant Kabir Nagar; Shahjahanpur; Siddarthnagar; Sant Ravidas Nagar; Unnao (Fig. 1).

In the first phase of the project, a gradient of arsenic content (ppb or $\mu\text{g/L}$) in irrigation groundwater sources was observed as given in the Figure 2. The gradient was categorized as (i) Low (<10ppb), (ii) Mid (10-50 ppb) and High (>50 ppb). The 550, 1804 and 286 villages were having arsenic contamination

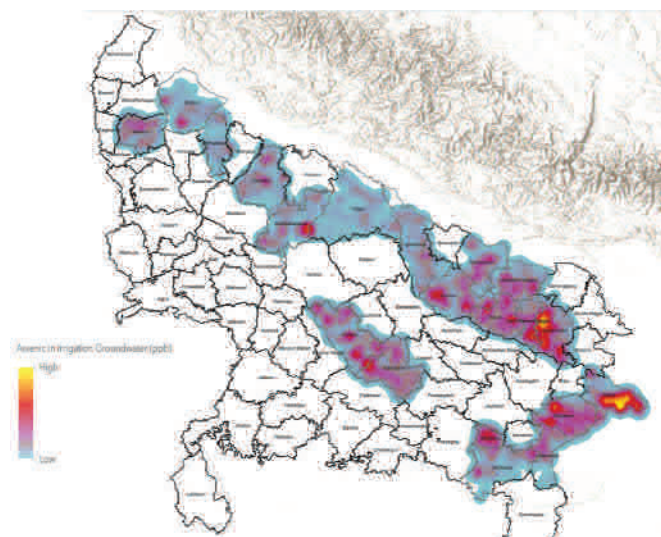


Fig. 2: Gradient Map of arsenic contamination in irrigation groundwater

in irrigation groundwater sources under the category of Low, Mid and High, respectively.

Similarly, a gradient of arsenic content (ppm or mg/kg) in agricultural soil was observed as given in the Figure 3. The gradient was categorized as (i) Low (<5ppm) 1067, (ii) Mid (5-20 ppm) 1527, and High (>20

ppm) 46. The 1067, 1527 and 46 villages were having arsenic contamination in agricultural soils under the category of Low, Mid and High, respectively.

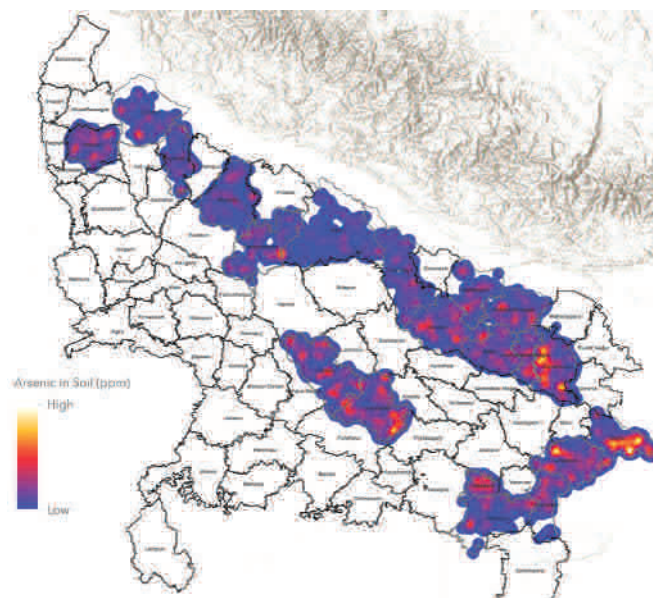


Fig. 3: Gradient Map of arsenic contamination in agricultural soil.

Following are the salient milestones achieved during the project implementation:

- Selection of hot-spots within these project districts in consultation with UP Jal Nigam (potable water), CGWB (piezometric heads) and GSI (India Mark-II hand pumps).
- Training of project staff for field sampling, standard analytical methods, use of Q-GIS for developing administrative block-wise maps of each district, and to overlay grid of 2x2 km for geo-tagging of sampling sites in field.
- A geo-portal to provide database of arsenic monitoring and assessment, which will be showcased at the website of the Dept. of Agriculture, Govt. of U.P.
- Field survey of the project districts in the rabi and kharif cropping seasons.
- Sampling of standing crop produce of different food crops, vegetables and spices grown in the agriculture fields. Sampling of irrigation groundwater and soil samples from agricultural fields being irrigated using groundwater.
- Analysis of key soil parameters (physico-chemical, microbiological and enzyme affecting arsenic loading in soils).

Remediation and reclamation of Hexachlorocyclohexane (HCH) dumpsite by using microbial remediation technology

Persistence of hexachlorocyclohexane (HCH) pesticide pose a major problem for its disposal. Soil microflora play an important role in remediating contaminated sites. Keeping concepts of microbial- and phyto-remediation together, the difference between soil microflora with and without association of HCH accumulating plant species was studied. Metagenomic analysis among the non-plant soil (BS) (Σ HCH 434.19 mg/g), rhizospheric soil of shrubs (RSS) (Σ HCH 157.31 mg/g), and rhizospheric soil of trees (RSD) (Σ HCH 105.39 mg/g) revealed significant differences in microbial communities. Shrubs and trees growing at a long-term dumpsite accumulated α - and β -HCH residues. Plant rhizospheric soils exhibited high richness and evenness with higher diversity indices compared to the non-plant soil. Order Rhizobiales was most abundant in all soils and Streptomycetales was absent in the BS soil. Proteobacteria and Ascomycota were highest in BS soil, while Actinobacteria were enriched in both the plant rhizospheric soil samples. In BS soil, *Pseudomonas*, *Sordaria*, *Caulobacter*, *Magnetospirillum*, and *Rhodospirillum* were abundant. Whereas *Streptomyces*, *Bradyrhizobium*, *Rhizobium*, *Azospirillum*, and *Agrobacterium* were abundant in RSD soil.

Selected plants accumulated HCH residues from soil and exerted positive impacts on soil microbial communities in HCH contaminated site. In the rhizospheric zones of such plants, microbes having ability to degrade α and β - residues of HCH through enzymatic actions were present confirming the plant-microbe assisted HCH degradation mechanism.

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Plant Ecology, Forest Ecosystem Structural and Functional Analyses, Forest Biomass, Forest Carbon sequestration, Ecosystem Physiology, Climate Change

Tropical forests play an important role in carbon sequestration and storage, with complex regulation mechanism by local environment (microclimate) and community structure. Our group has been working on forest productivity and carbon sequestration assessment, and modelling using field measurements. The group's primary focus is on long-term studies for understanding ecosystem functioning and carbon dynamics at tree community level, providing inputs for better model simulation in Indian tropical forests.

Phytosociological analysis in different forest types of Similipal Biosphere Reserve, Odisha

A consistent large-scale classification of floristically defined vegetation types is an important tool for ecological research, vegetation monitoring, conservation strategies and legislation and present study was conducted in Similipal Biosphere Reserve located in Mayurbhanj district, Odisha. It hosts common floristic components of both Eastern Himalayas and Western Ghats. Field work was conducted in Similipal Biosphere Reserve during 2020-2021.

Forest communities were analyzed using random sampling technique in deciduous (dry deciduous and moist deciduous) and semi-evergreen forests (Fig. 1). Phytosociological attributes were studied by laying of total 23, 46 and 25 random quadrates of 20m X 20m (400 m²) in dry deciduous, moist deciduous and semi-evergreen forests, respectively and the geo-coordinates were recorded. Frequency, density and basal area of each tree species in all the sampled quadrats were calculated. Importance value index (IVI) for individual tree species in each forest community was calculated. The tree species

of different forest communities were identified with the help of the regional and national flora. Shannon-Wiener's diversity index (H') and Simpson's dominance index (C) were calculated. A total of 95 tree species belonging to 78 genera and 37 families were recorded in the above three forest types.

Deciduous forest was categorized into dry deciduous and moist deciduous types based on moisture gradient and species composition. Dry deciduous forest community comprised of a total 33 tree species belonging to 30 genera and 20 families. *Shorea robusta* and *Cleistanthus collinus* both had 95.65% frequency, followed by *Terminalia alata* (69.57%), *Buchanania cochinchinesis* (47.83%) and *Croton persimilis* (43.48%). *Shorea robusta* had highest density with 292.39 ind./ha followed by *Terminalia alata* (135.87 ind./ha) and *Cleistanthus collinus* (113.04 ind./ha). *Shorea robusta* had highest basal cover (11.46 m²/ha) followed by *Terminalia alata* (3.04 m²/ha). *Shorea robusta* showed highest importance value (104.5) followed by *Terminalia alata* (41.90) and *Cleistanthus collinus* (36.53).

A total 70 tree species were present in moist deciduous forest community belonging to 62 genera and 35 families. *Shorea robusta* had highest frequency (71.74%) and density (65.76 ind./ha) followed by *Xylocarpus carpa* (56.52% frequency and 51.63 ind./ha density) and *Croton persimilis* (54.35% frequency and 36.41 ind./ha density). *Shorea robusta* had highest importance value (45.36). The co-dominating species were *Xylocarpus carpa* (IVI =25.49) and *Protium serratum* (IVI =22.54).

In the semi-evergreen forest, we observed a total of 61 tree species belonging to 54 genera and 30 families.

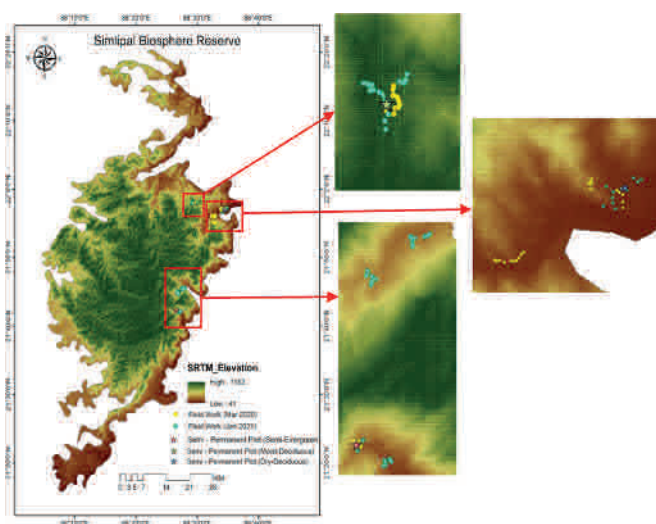


Fig. 1: Shuttle Radar Topography Mission (SRTM) derived elevation map of Similipal Biosphere Reserve (SBR) and random quadrats location in different forest types.

Distribution analysis of the tree species in the forest area showed that the dominant species was *Xylixylo carpa* with an IVI value of 47.74. The co-dominating species were *Schleichera oleosa* (IVI = 20.15) and *Croton persimilis* (IVI = 19.78). *Xylixylo carpa* showed highest frequency (88%) followed by *Croton persimilis* (64%) and *Schleichera oleosa* (60%), while the species *Xylixylo carpa* had the highest density (111 ind./ha). We also calculated the Shannon Winner's diversity index and Simpson's dominance index for the above three forest types. Simpson's index revealed the higher homogeneity in dry deciduous forest among the three forest types in Similipal Tiger Reserve, Odisha.

Leaf area index measurements in different forest types of Similipal Biosphere Reserve, Odisha

Leaf area index (LAI) were measured in different random sampling quadrats in deciduous (dry deciduous and moist deciduous) and semi-evergreen forest communities (Fig. 1). The LAI of the forest

stands within the random quadrats of 20m X 20m was measured with the LAI-2000 plant canopy analyzer (PCA) (LI-COR Inc, USA). All measurements were done during periods of overcast sky periods. All the 20 m X 20 m random quadrats were measured with one LAI measurement cycle having one above followed by ten below canopy readings. A series of 10 'below-canopy' measurements were positioned along the two perpendicular boundary lines of the random quadrat boundary during each LAI measurement cycle. The measurements in the open were conducted in larger gaps at a distance of not more than 1-2 km from the plots. All the 'below canopy' readings were taken at 270° view angle with the sensor at 2 m height from the ground level, to include all the multi-storey canopy layers and exclude the observer from the field of view. Ground LAI values ranged between 1.42 to 3.89, 1.67 to 5.77 and 1.98 to 4.99 in dry deciduous, moist deciduous and semi-evergreen forest communities during winter season in both the years 2020 and 2021, respectively. Moist deciduous forest showed maximum range of LAI values forming fairly open to very dense canopy. Moist deciduous forest, which comprises 35-40% of the Similipal tiger reserve area is well represented with three storied canopy architectures with dense ground vegetations, showed higher LAI (>3) values in majority of the stands. Further LAI was measured during post monsoon period for getting maximum canopy stage (October-November, 2021) and another set of measurement will be done during leaf senescence stage of summer season (March-April, 2022) to account for the seasonal variation of LAI in all plots.

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Plant-microbe interaction, microbial genetics, bioremediation and agri-waste management

Generation of exopolyphosphatase mutant of *Pseudomonas putida* and elucidation of its role in alleviation of phosphate starvation in *Arabidopsis thaliana*

Polyphosphates (polyP) are energy rich molecules involved in majority of functions in bacterial metabolism and growth. Increased accumulation of polyP may play an important role in persistence of microbes under different environmental conditions. We generated exopolyphosphatase mutant (Δppx) having high phosphate accumulating potential through knockout mutagenesis. Exopolyphosphatase mutant (Δppx) showed better tolerance to salinity stress as compared to wild type strain of *Pseudomonas putida* (RAR). Further inoculation of Δppx in *A.*

thaliana under phosphate (Pi) starvation condition showed significantly higher silique formation and dry weight as compared to wild type (WT) strain and uninoculated plants, which signifies the correlation of polyP accumulation with improved plant growth under P starved condition. *In-vitro* experiments showed higher root hair frequency of *A. thaliana* inoculated with Δppx mutant as compared to both control and WT treatment. Higher expression of genes involved in plant growth and repressed expression of genes associated with stress and phosphate starvation in Δppx treated plants, suggests the high phosphate accumulating mutant mediated mitigation of Pi stress in plants under phosphate starved condition (Fig. 1).

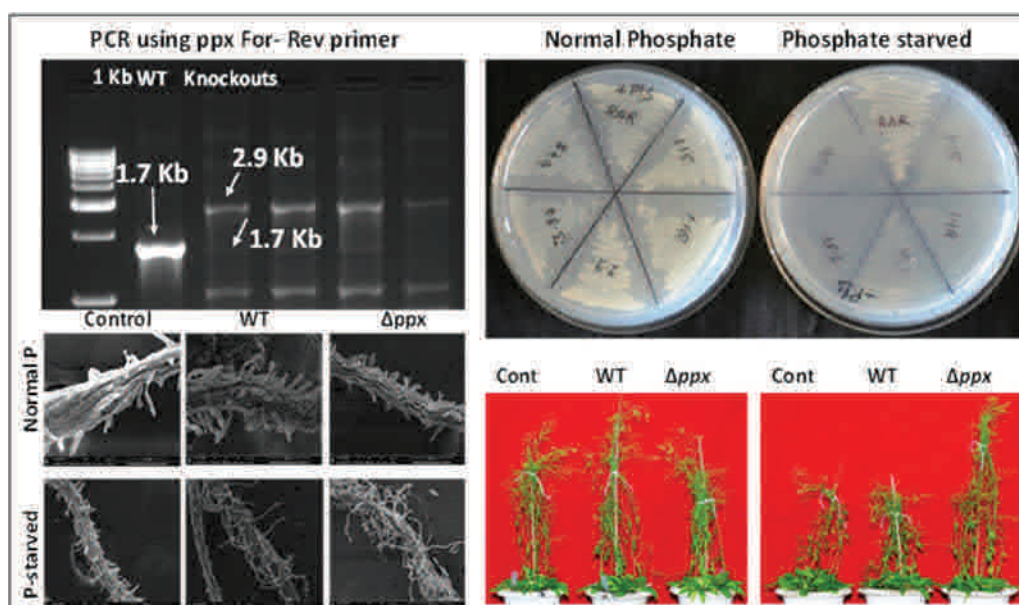


Fig. 1: Generation of exopolyphosphatase mutant (Δppx) of *Pseudomonas putida* and its effect on alleviation of P starvation in *Arabidopsis thaliana*.

Role of silicon (Si) solubilizing bacteria in arsenic (AsIII) stress amelioration in rice

Various silicate solubilizing bacteria have been identified for their Si dissolution potential from soil silicates for plants' uptake. However, studies on silicate solubilizing bacteria are limited with insights of Si mediated arsenite attenuation. Therefore, exploration of the functions at rhizosphere level would aid to devise potential strategies for amelioration of As stress in plants through the application of silicon solubilising bacteria (SSB). Present work exploits the role of a Si solubilising bacteria NBRISN13 for increased Si uptake, enhanced plant growth and reduced arsenic uptake; thus, indicating the microbe mediated Si solubilization in mitigation of As stress during SN13 inoculation-feldspar supplementation-As stressed conditions to restore plant growth and yield (Fig.2).

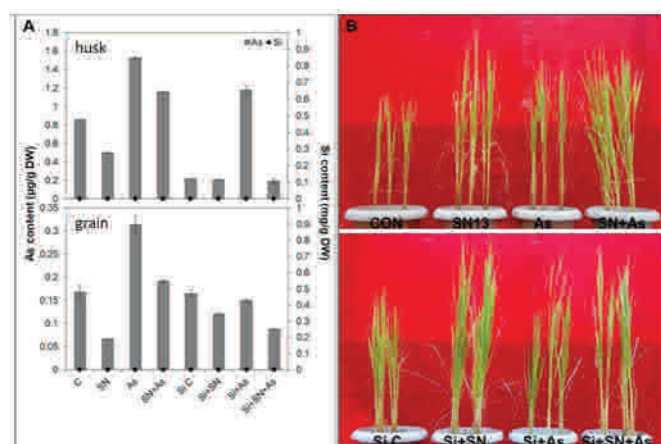


Fig. 2: Reduced arsenic uptake in husk and grain (A) and improved effect on plant growth (B) during silicon mediated arsenic detoxification in rice (greenhouse).

Assessment of microbe-mediated rice straw decomposition

Examination of structural deformity to detect morphological changes on treatment with the developed microbial formulation for hastened decomposition of rice straw was performed under microplot conditions. These changes were observed by SEM analysis which reveal the structural differences between untreated and treated rice straw at different time intervals. Results under microbial treatment showed the structural damage initiated within 20-30 days post inoculation in comparison to control treatment followed by its complete disintegration after 3 months of sowing as compared

to control. Results of structural damage thus validate the role of developed microbial formulation for rice straw decomposition (Fig.3).

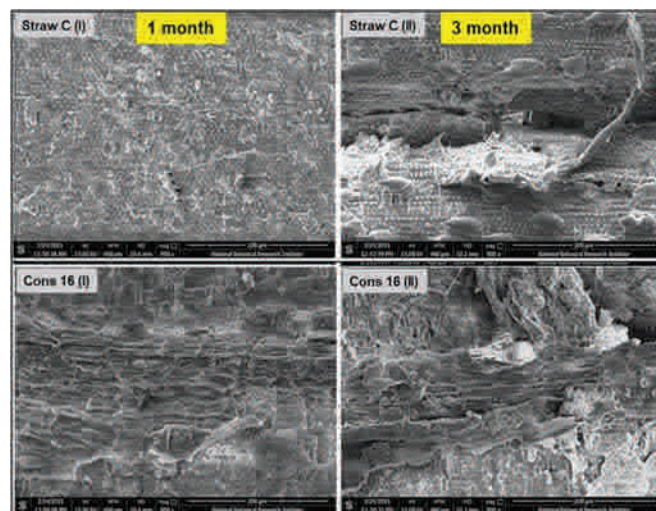


Fig. 3: SEM micrographs demonstrate morphological and structural changes on decomposition with (selected) microbial consortia.

Modulation of iron (Fe) and zinc (Zn) transporters during microbe mediated biofortification in rice

On the basis of Zn solubilization, siderophore and organic acid production, four microbes *Bacillus pumilus* (D1.2), *Pseudomonas putida* (D1.16), *Pseudomonas sp.* (D1.20) and *Pseudomonas fluorescens* (D2.16) have been identified, which were assessed for Fe and Zn biofortification in different rice cultivars (Swarnsub-1, BPT 5204, Jayanti and Sarbati). On the basis of Zn and Fe content quantified in rice grains, two strains (*Bacillus pumilus* and *Pseudomonas fluorescens*) were further selected for their effect on gene modulations related to Zn and Fe transporters in two rice cultivars (Swarnsub-1, BPT 5204). Real time PCR analysis of different Fe and Zn transporters showed that expression of different transporters varies with respect to variety as well as bacterial strains used for inoculation. Bacteria identified as *Bacillus pumilus* was found to modulate Os08G01030, homologous to a gene encoding an NAD(P) transhydrogenase, which participates in the tricarboxylic acid cycle and Os03g46470, playing role in iron accumulation, in both the tested varieties in presence of Zn. However, another selected Zn solubilizing bacteria identified as *Pseudomonas fluorescens* was able to modulate only Os-IRT2, high-affinity iron transporter that mediates iron uptake under iron-deficient condition (Fig. 4).

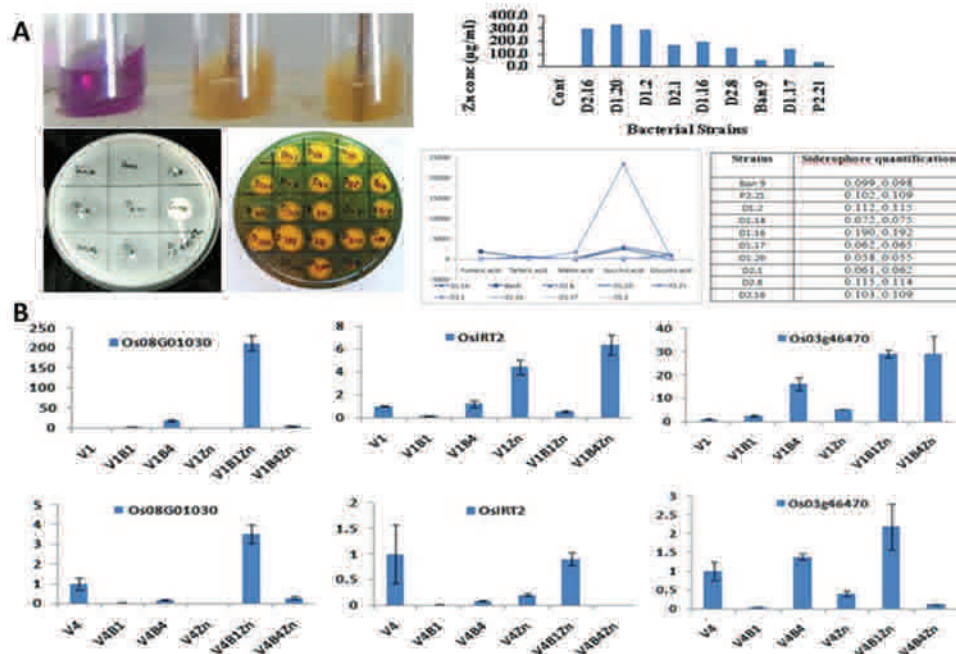


Fig. 4: (A) Qualitative and quantitative screening for Zn solubilising microbes, and (B) Effect of selected microbes on modulation of Zn and Fe transporter genes in rice cultivars.

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Synthesis and evaluation of herbal nanoemulsion against pathogens, Microbial intervention in amelioration of biotic and abiotic stresses in crop.

The aim of our research activities is to find a biological way to control, phyto pathogen and other pathogens. The group is focused on management of disease in commercially valuable crops and developing sustainable eco-friendly remedies. The envisaged goals are development of cost-effective products that have ability to replace the chemical-based fungicide or medicine and promoting green synthesis of nanopesticides by using herbal lipids.

Early blight disease management by herbal nanoemulsion in *Solanum lycopersicum*

Early blight, caused by *Alternaria solani*, is one of the most devastating diseases affecting *Solanum lycopersicum* (tomato), reducing its productivity by 80%. The present study illustrates the synthesis of nanoemulsion using peppermint oil for potent antimicrobial activity against *A. solani*. A peppermint oil based nanoemulsion (PNE) was synthesized which was further characterized by Dynamic Light Scattering and Transmission Electron Microscopy. The nano-droplets present in nanoemulsion were spherical in shape with average size <100 nm. *In-vitro* antimicrobial activity of PNE was examined against *A. solani* with the carbendazim as positive control. A green-house study was performed to evaluate the antimicrobial efficacy and plant immunity developed by nanoemulsion as well as compared with carbendazim, a chemical fungicide. PNE was much potent to reduce the disease severity up to 68.7% at 14th day and 87.5% at 21st day. Physiological modulation was seen in tomato plants against *A. solani*, which was confirmed by measuring the physical parameters, plant physiology, changes in leaf morphology and

stress responses. Significant changes were found in proline and lipid peroxidation content in infected plants whereas nanoemulsion treated infected plants were able to cope-up the stress condition. Physical parameters and Scanning Electron Microscopy (SEM) analysis (Fig. 1) also revealed similar observations. A reduced photosynthesis rate and transpiration rate were found in diseased plants as compared to other treatments, although stomatal conductance was not much affected. Defence responsive gene expression also up-regulated in PNE treated diseased plants than pathogen alone. Thus, the current study demonstrated the peppermint oil based nanoemulsion was more efficacious than chemical fungicide to early blight disease management in *Solanum lycopersicum*.

Cropping systems influence microbial diversity, soil quality and crop yields in Indo-Gangetic plains of India

Incorporation of legume crops in a cropping system apparently increased microbial biodiversity over non-legume system until 168 h. The highest AWCD was recorded in P-Gg-R which was comparable with L-R and WGg-Pm up to 168 h. The average substrate oxidation rate was 0.0760 OD h⁻¹ in P-Gg-R system, which was 22.4% and 17.6% higher than those of M-R and W-R systems, respectively (Fig. 2). The results on substrate utilization indicate that significantly higher amines/amides, amino acids, polymers, carbohydrates and carboxylic acid were utilized as sole carbon source by the microbial communities under P-Gg-R system, while the lowest utilization was in M-R system. The functional diversity indices (Shannon, Shan evenness, McIntosh, Richness and

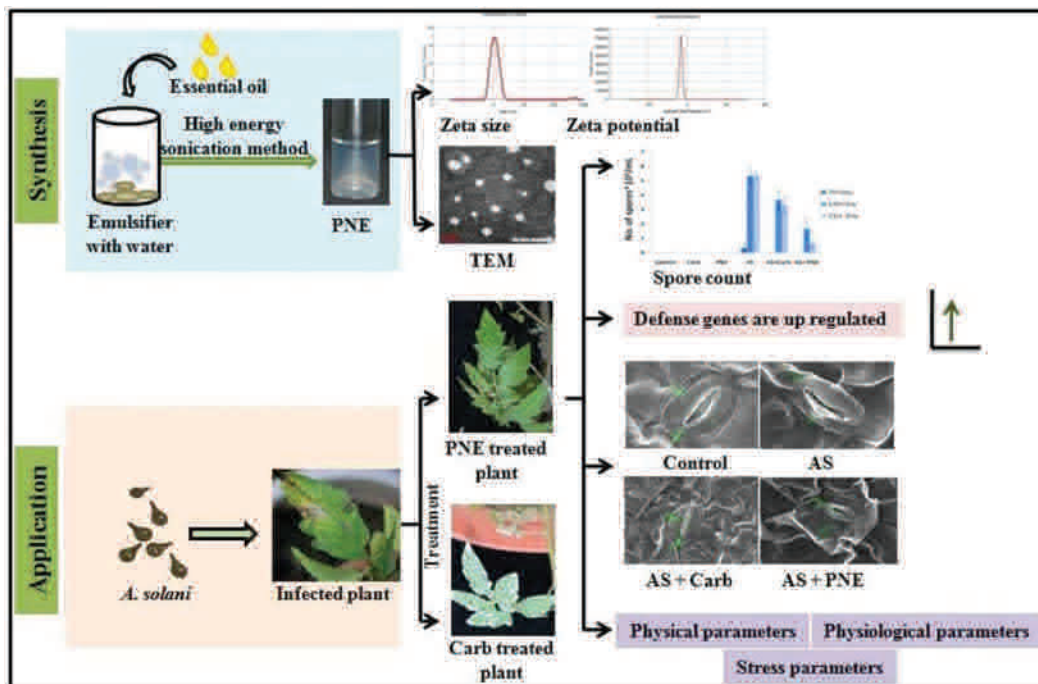


Fig. 1: Graphical presentation of Early blight disease management by herbal nanoemulsion in *Solanum lycopersicum* with bio-protective manner

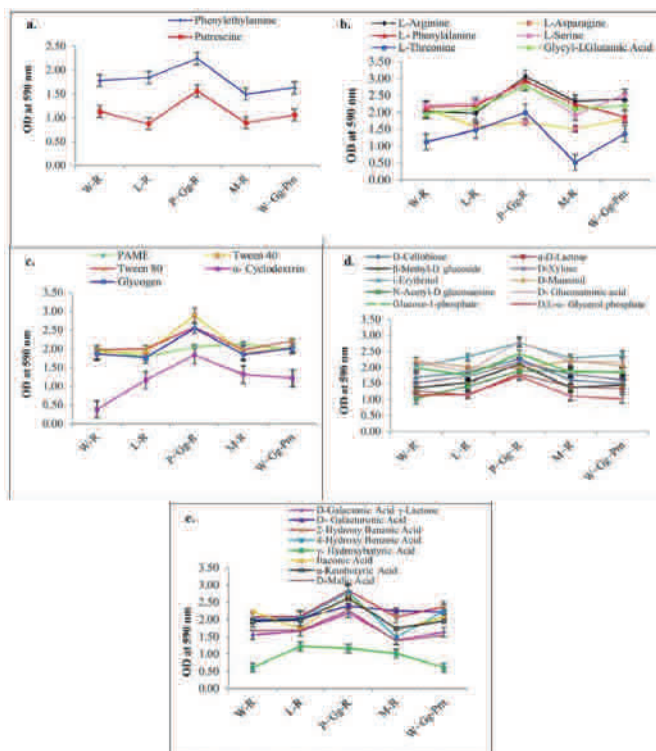


Fig. 2: Carbon source utilization pattern derived from AWCD (OD590 nm) of different components by soil microbial communities under different cropping systems in IGP region. a; amines/amides utilization pattern, b; amino acid, c; polymer utilization, d; carbohydrates, e; carboxylic acid.

Simpson-Wiener index) of soil microbial communities were found to be non-significant among the different cropping systems.

Impact of different croplands on nutrient index, microbial diversity and soil quality

This study aims to assess microbial diversity replacement of rice-wheat by vegetable (VGS), pulse (PGS), potato (PoGS) and mustard (MGS) grown system. The microbial community associated PGS system exhibited a significantly higher metabolic activity. The average substrate oxidation rate of PGS was estimated to be $0.0513 \text{ cm}^{-1} \text{ h}^{-1}$ which was 24.1% ($0.0413 \text{ cm}^{-1} \text{ h}^{-1}$), 23.6% ($0.0415 \text{ cm}^{-1} \text{ h}^{-1}$), 22.7% ($0.0418 \text{ cm}^{-1} \text{ h}^{-1}$), 17.7% ($0.0436 \text{ cm}^{-1} \text{ h}^{-1}$), and 15.0% ($0.0446 \text{ cm}^{-1} \text{ h}^{-1}$) higher than that of MGS, PoGS, VGS and WGS, respectively. The functional diversity indices of soil microbial communities (Shannon, Shan evenness, McIntosh, Richness and Simpson-Wiener indices) were higher in PGS followed by VGS, WGS and MGS (Fig. 3) The Simpson diversity index was greater among the indices and MacD diversity index was the lowest in PoGS followed by MGS.

Overall, it is concluded that PGS maintained higher nutrient index, microbial and functional diversity, but VGS improve greater soil quality.

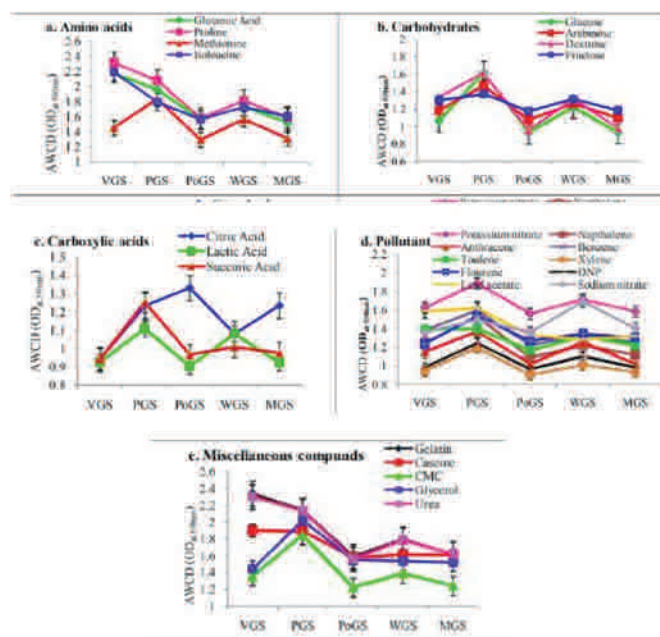


Fig. 3: Influence of various croplands grown system on carbon substrate utilization pattern by soil microbes, VGS-Vegetable grown system, PGS-pulse grown systems, PoGS- potato grown system, WGS- wheat grown system, and MGS-musturd grown system

Effect of rhizospheric inoculation of isolated arsenic (As) tolerant strains on growth, As-uptake and bacterial communities in association with *Adiantum capillus-veneris*

Soil microbial diversity plays a significant role in maintaining soil fertility, detoxification of pollutants, in plant defence against pathogen, plant growth promotion. To investigate the effect of rhizospheric inoculation on indigenous microbial richness, diversity and evenness were estimated. Shannon, McIntosh and Simpson diversity and their related evenness were calculated for microbial substrate utilization pattern on Biolog Eco plates. Our results reveal that diversity and their respective evenness were significantly affected by PGPR inoculation, both individually and in consortia. PC1 and PC2; the first two principal components, cumulatively accounted for 66.6% of the variance in the data. The PC1 demonstrated 42.4% variance, explaining significant positive correlation with (correlation index ≥ 0.6) 10 out of 31 substrates whereas negative correlations (correlation index ≤ -0.6) with 7 individual substrates. However, PC2 explaining 24.2% of the total variance in data, and was significantly positively correlated with five substrates and significantly negatively

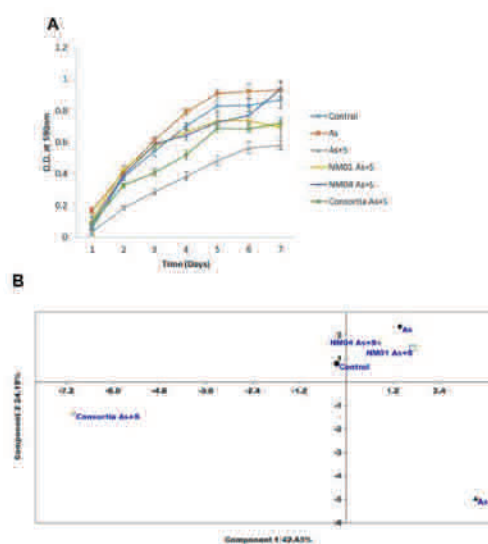


Fig. 4: (A). An Average well colour development (AWCD) of substrate utilization of Biolog Eco Plates. 7 days incubation data was recorded at 590 nm. (B). Principal Component Analysis (PCA) from substrate utilization pattern of rhizospheric soil of all treatments based on Biolog Eco Plates. The plates were incubated for 7 days and data was recorded at every 24 h at 590 nm.

correlated with only 4 out of 31 substrates (Fig. 4). The PC scoring of control treatment was less than 1 for both the components. The maximum discrimination in PCA biplot was caused by As + S and consortia As + S treatment. Interestingly, As + S treatment scored maximum positive (3.32) and negative (-4.94) on PC1 and PC2, respectively. Conversely, consortia As + S scored negatively on PC1 and PC2. The PCA biplot by carbon source utilization pattern (CSUP) shows close clustering of individually inoculated strains indicate no significant change in the microbial dynamics. Whereas, substantial changes in CSUP in As + S treatment indicate the microbial community was affected by the presence of heavy metal and nutrient. However, significant changes in the catabolic activity of microbial communities in consortia As + S treatment reveal the positive contribution of both the strains in improving microbial dynamics.

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Study the role of microbes in plant protection and growth, and soil health, and development of microbial formulations for agricultural applications and environmental problems

The focus area of the group is to study the interaction of microbes with the plants and soil systems and develop microbes based formulations for sustainable agriculture and environment. Currently the group is working on (a) Biological control of fungal disease in plants (b) Plant microbe interactions, (c) Endophytes and bio-stimulants for plant growth promotion in stressed soils and (d) microbial degradation of emergent contaminants

An insight into the endophytic bacterial community of tomato affected by the application of Propiconazole and microbial inoculants

Propiconazole (PCZ) is a widely used broad spectrum systemic fungicide. Systemic fungicides inhibit pathogenic fungi in the plants; however, their toxic nature may affect the non-target microbes in the plant. These non-target microorganisms mainly include the endophytic population. The impact of chemical fungicide PCZ on the endophytic bacterial population, diversity and function in tomato plants was studied in presence of a bio-fungicide *Bacillus subtilis* NBRI-W9 (W9). The W9 was sprayed on the plant leaves two days before spray application of PCZ. The metagenomic analysis of the endophytes was carried out in the tomato leaves collected after 72 hrs of PCZ treatment. From the metagenomic analysis a total of 250 endophytic bacteria were identified from the four treatments, which belonged to 130 bacterial genera. The rarefaction curve shows the comparative phylum richness in response to the treatments (Fig. 1A). The PCZ treated plants have least Shannon diversity index (H index) and W9 the maximum (Fig.

1B). This shows that the inoculation of W9 helped in improving the endophytic diversity. It also reflects the non-invasive nature of the strain W9 which helps to accommodate the natural population. The heat map (Fig. 2) shows that Bacilli are the most common class of bacteria present in the tomato leaves irrespective of the treatments. Similarly, gammaproteobacteria was common to all the treatments. The W9 treatment had higher diversity in the endophytic community comprising of Alphaproteobacteria, Deinococci Actinobacteria, and Betaproteobacteria. PICRUSt analysis revealed that metabolic pathways such as energy metabolism, glycan biosynthesis and metabolism, lipid metabolism, Xenobiotics biodegradation and metabolism, cell motility, membrane transport, signal transduction were more abundant in the W9 treated plants in comparison to control while these pathways were suppressed in PCZ treated plants. Replication and repair, translation, transport and catabolism, carbohydrate metabolism, enzyme families, nucleotide metabolism, showed less abundance in PCZ treated plants as compared

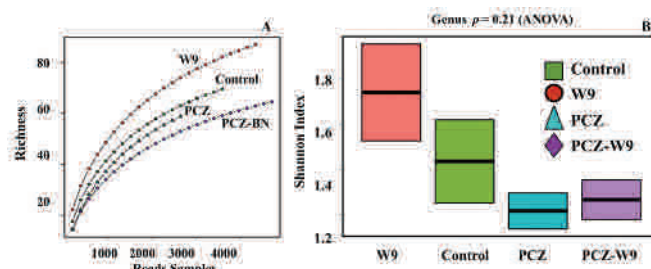


Fig. 1: Endophytic bacterial diversity and richness of tomato leaves treated with propiconazole (PCZ), biocontrol agent, *B. subtilis* (W9), PCZ+W9 and control. A: Phylum level rarefaction curve and, B: Shannon diversity index.

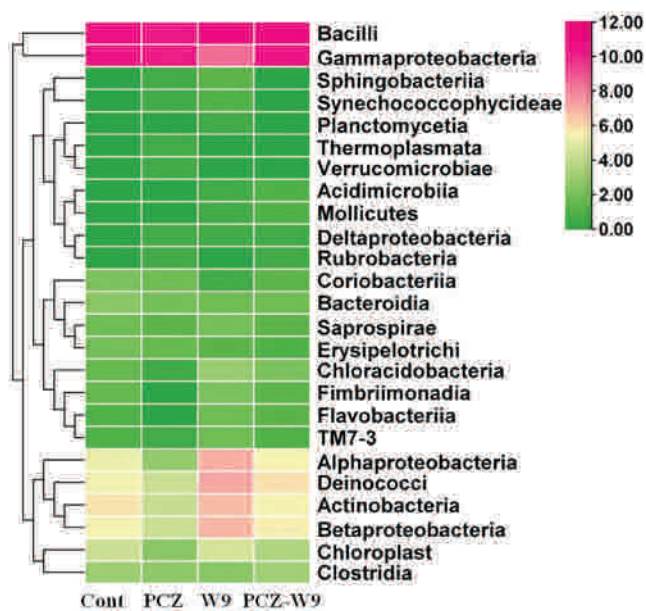


Fig. 2: Heatmap showing the bacterial endophyte diversity in tomato leaves treated with propiconazole (PCZ), biocontrol agent, *B. subtilis* (W9), PCZ+W9 and control.

to PCZ+W9 treatment. The PCZ and W9 treatments though contrasting in diversity indices showed enhanced expression of bacterial secretion system,

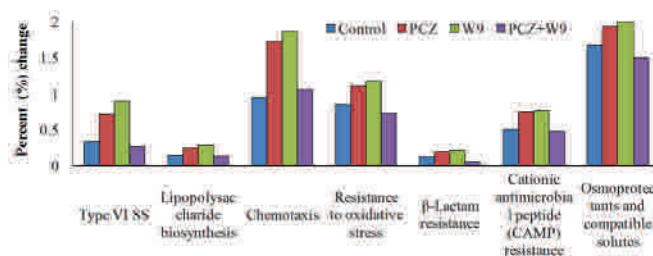


Fig. 3: Relative abundance of secretion, biotic and abiotic stress, chemotaxis related functions of microbial communities in four samples (Control, PCZ, W9 and PCZ+W9) using picrust.

biotic and abiotic stress related genes and chemotaxis related metabolic pathways as compared to the control and PCZ+W9 (Fig 3).

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Restoration/rehabilitation of degraded ecosystems and threatened plants, developing new methods for EIA/CIA, ecological and climate change modeling, bioresource mapping & GIS

New plant taxa discovered

A new species - *Aconitum sikkimensis* (H. Singh, A. Pradhan & D. Adhikari)- has been described from Sikkim in the Indian Eastern Himalaya (Fig. 1). Morphologically closest species to the new species is *A. hookeri* which resembles in colour of the flower and the shape of the lateral sepals. However, it differs in plant height i.e., *A. sikkimensis* is taller than *A. hookeri*. Other distinguishing characters include the shape of leaf and degree of dissection in the lamina, number of bracts and their shape and size, length of petiole, semi-orbicular upper sepal (vs. obliquely erect), distinctly curved, pubescent petals (vs. straight, glabrous petals) having spatulate lips (vs. obovate), and well-developed staminal pilose hairs and teeth (vs. non-developed, glabrous). Based on population data, the species was assigned the threat status of 'Critically Endangered' following IUCN criteria.

Developing new methods for EIA

The nation building strategies of India is shifting its focus in the energy production sector from carbon based non-renewable sources to renewable ventures like hydropower, wind, solar, tidal

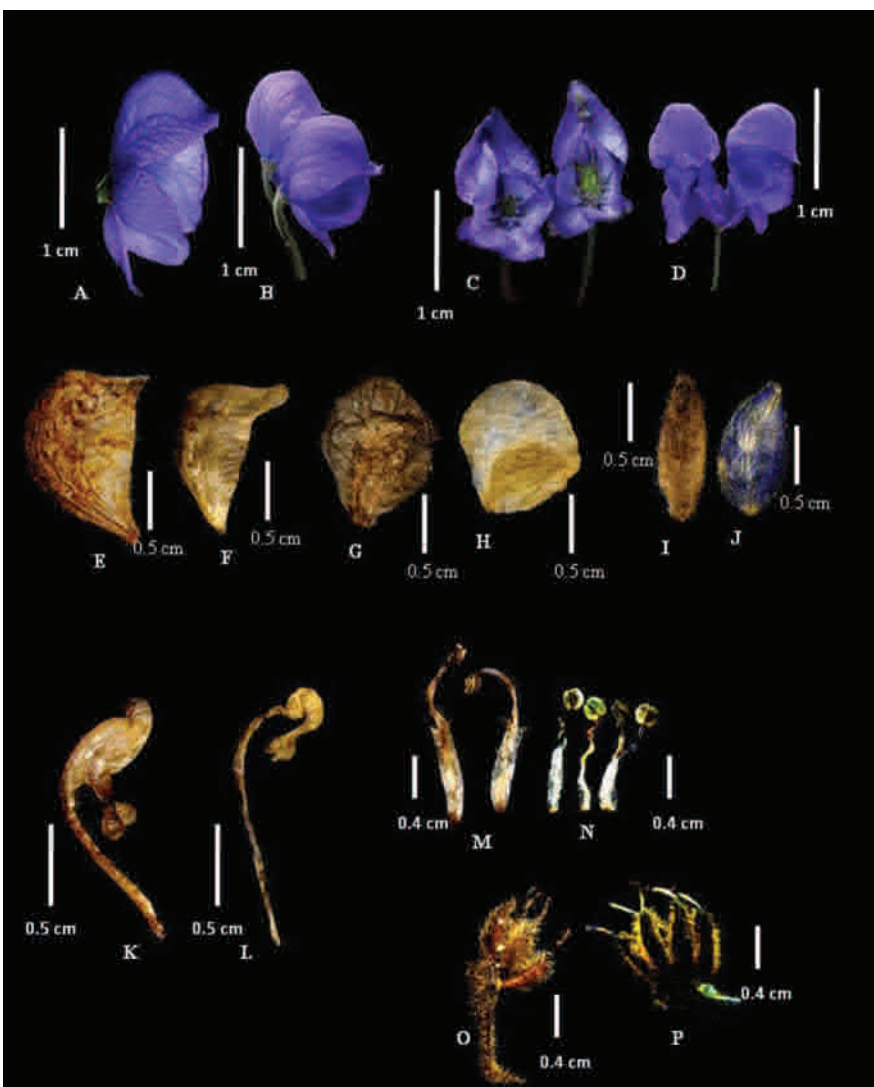


Fig. 1: *Aconitum sikkimensis* (H. Singh, A. Pradhan & D. Adhikari): A, C. Flower side and front view; E. Upper sepal; G. Lateral sepal; I. Lower sepal; K. Petal; M. Stamens; O. Carpel; *Aconitum hookeri*: B, D. Flower side and front view; F. Upper sepal; H. Lateral sepal; J. Lower sepal; L. Petal; N. Stamens; P. Carpels.

and geothermal energy projects. The Himalaya mountain belt comprising states of Jammu & Kashmir, Uttarakhand, Himachal Pradesh and Arunachal Pradesh are hubs of freshwater and the terrain in these regions have tremendous potential for hydropower generation. However, because of the rich natural resources and diverse ecosystems ranging from Tropical to Alpine, the region needs to be given special attention with respect to sustainable development in future. Therefore, construction of hydropower projects in these regions should be done using standardized Cumulative Impact Assessment (CIA) methodologies. Work has been initiated to develop standard methods in CIA which will help the researchers, planners and administrators for visualizing, understanding, analyzing and taking decisions for CIA of river interventions.

Ecological and climate change modeling, bioresource mapping & GIS: Fragrance mapping

Every year, India imports ~800 crore rupees worth of flowers and fragrance materials. Special emphasis should be given to increase the area under cultivation for fragrance-bearing floral crops to provide sufficient raw materials to fragrance industries, and increase the export of fragrance products. Therefore, special emphasis should be given to increase the area under cultivation for fragrance-bearing floral crops. Work has been initiated to map areas for such floral crops, which will help in identification of areas for cultivation.

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Impact assessment of climate change and air pollution on plants

Screening tolerant and sensitive cultivars of wheat to ambient and futuristic concentrations of O₃, CO₂ and high temperature

Food security in 21st century faces multi-faceted challenges to feed the ever increasing population with changing consumption patterns and climatic scenarios. The Special Report on Emissions Scenarios (SRES) and the Intergovernmental Panel on Climate Change (IPCC) Assessment Report Four (AR₄) predicted that O₃ may rise 20–25% between 2015 and 2050, and further increase by 40–60% by 2100. Increase in minimum temperature which is important for vernalization period of wheat affects growth and yield. Global mean surface temperatures are projected to increase by 1.4–5 °C by 2100, and the main possible cause for increase in temperatures is rise in atmospheric CO₂ and other greenhouse gases due to anthropogenic activities (IPCC 2014). The strong correlation between elevated O₃-CO₂- temperature relationships in future may influence crop responses. The objective of the present study was to assess impact of elevated CO₂, O₃ and temperature of wheat cultivars.

A factorial design experiment with two levels of ozone, ambient and elevated (+20 ppb above ambient), two levels of CO₂, ambient and elevated CO₂ (550 ppm) and two levels heat stress (ambient and elevated temperature (+2°C above ambient) was conducted in especially designed Free Air CO₂/O₃ enrichment facility to allow exposure of plants to near natural conditions.

Eight wheat cultivars were taken *viz.*, PBW 154, WB-02, HD 2967, HD-3086, DBW 184, DBW 222, DBW

187, HD 2329. Random sampling of plants was done in triplicate for each treatment as well as control for growth parameters (plant height, number of leaves, leaf area, biomass) and yield (weight of ears, number of grains plant⁻¹, wt. of grains per plant, 1000 grain wt.).

Figure 1 shows the ambient and elevated O₃ levels. Number of leaves increased in individual treatment of elevated CO₂ (ECO₂), elevated O₃ (EO₃) and ECO₂+EO₃ in all cultivars compared to ambient CO₂+ambient O₃+ ambient temperature (A). Significant reduction was recorded in elevated temperature (ET) and elevated CO₂+ elevated O₃+ elevated temperature (ECO₂+EO₃+ET) except in cultivar DBW 187 number of leaves increased in ECO₂+EO₃+ET (Fig. 2). Plant total biomass reduced in all wheat cultivars exposed to ambient and elevated levels of CO₂, O₃ and higher temperature compared to ACO₂+AO₃+AT except in DBW 222 which showed increase in total plant

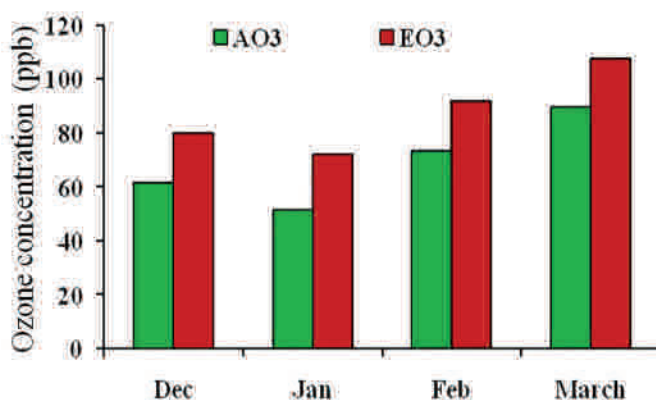


Fig. 1: Mean ambient and elevated O₃ concentration recorded during experimental period.

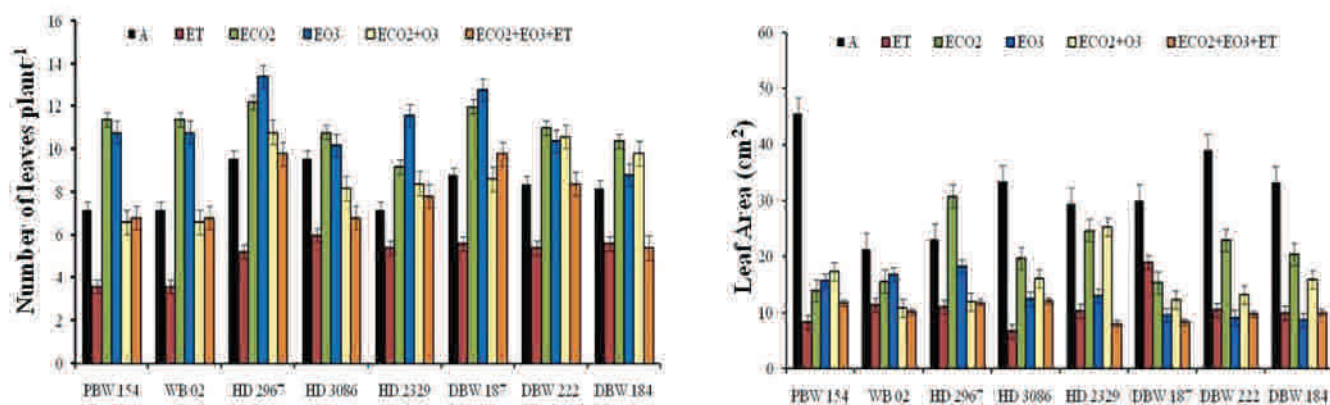


Fig. 2: Number of leaves, leaf area and total plant biomass in wheat cultivars exposed to ambient and elevated levels of CO₂, O₃ and temperature individually and in combination.

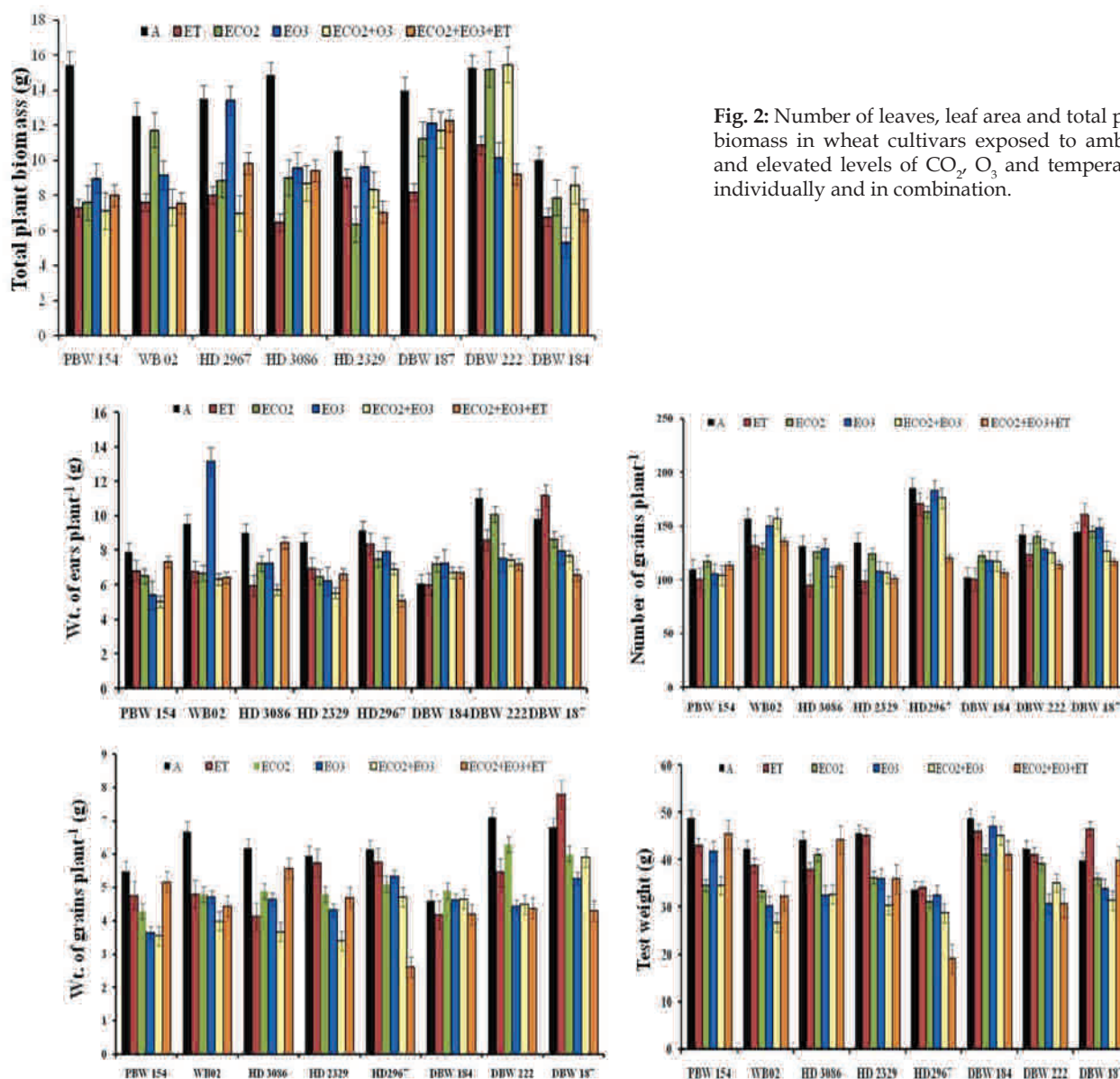


Fig. 3: Weight of ears plant⁻¹, number of grains plant⁻¹, weight of grains plant⁻¹ and test weight of wheat cultivars exposed to ambient and elevated levels of CO₂, O₃ and temperature individually and in combination.



biomass under ECO_2 and ECO_2+EO_3 treatment.

Weight of ears $plant^{-1}$, number of grains $plant^{-1}$ and test weight reduced in all the wheat cultivars exposed to all the treatments ECO_2 , EO_3 , ET, ECO_2+EO_3 and ECO_2+EO_3+ET compared to ACO_2+AO_3+AT . In cultivar HD 2967, number of grains increased in all treatments compared to ACO_2+AO_3+AT . Yield measured as weight of grains $plant^{-1}$ reduced in all the treatments. Among wheat cultivars, highest yield

reduction was recorded in HD 2967 (57.6%) and minimum in DBW 184 (9.08%) exposed ECO_2+EO_3+ET compared to ACO_2+AO_3+AT (Fig. 3).

The study concludes that differential responses were observed among wheat cultivars in terms of their growth and yield. Wheat cultivar HD 2967 will be most affected in future concentrations of O_3 , CO_2 and higher temperature and DBW 184 will be least affected.

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Microplastic isolation and characterization in soil;
 Biochar for metal remediation and enhancing crop productivity

Standardizing method of isolation of microplastics from agricultural soil

Microplastic is omnipresent in all spheres of the ecosystem. However, isolation of microplastics from the soil is a tedious task because the organic matter present in the soil makes it difficult to extract from the soil matrix. None of the published methods seem suitable for the analysis of micro plastics in soil samples. So, our primary objective is to isolate and characterize microplastics from the agricultural soil and also to see its effect on food crops.

Biochar, a pyrogenic black carbon produced by pyrolysis of biomass under oxygen-limited conditions

Our study aims at utilizing agricultural waste/

distillation waste for biochar production and further using this pyrolysed product for adsorbing contaminants like arsenic and other toxic metals from the soil. The objective is development of biochar-based product in degradation process of contaminants, their mechanisms of actions, potential feedstocks, optimizing the preparation methods, and upscaling the performance.

Different steps are involved in the standardizing of method for isolation of micro-plastics from agricultural soil (Fig. 1). Preparation of biochar from different materials viz., *Eichhornia crassipes*, *Mentha* sp. distillation waste and *Cyperus rotundus* was done and characterization work is in progress.

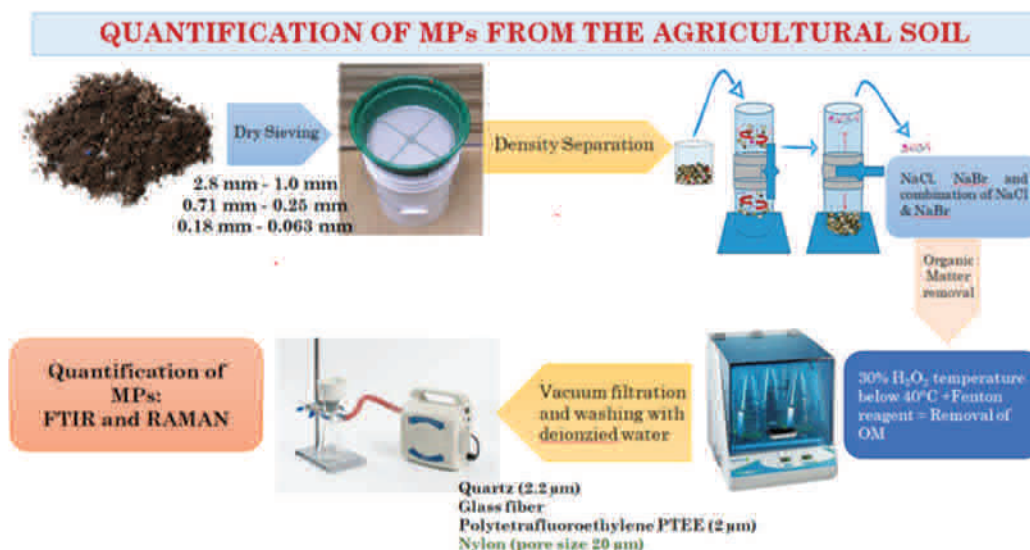


Fig. 1: Steps involved in standardization of method for isolation of micro-plastics from agricultural soil.



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Molecular diagnosis and management of plant diseases caused by viruses

Plant viruses cause significant economic yield losses in many agricultural, horticultural and flower crops worldwide. Plant viruses are ubiquitous and highly diverse obligate pathogens infecting all crops. Most of the plant viruses are transmitted by insect vectors and diseased planting material. The successful viral replication cycle results from a complex interplay between virus, host and insect encoded factors. The underlying interaction mechanism of successful virus infection and host factors involved is very less studied in case of plant virus. Viruses are difficult to control and introduction of new viruses through trade in agriculture is a major concern. The lack of efficient plant virus diagnostic methods hinders the early detection of plant viruses. Currently, there are

no direct measures to eradicate the virus, instead management of virus depends on controlling the insects and planting of virus free planting material. Our laboratory aims to conduct basic and applied research with focus on plant virus management. Current R&D activities of the lab include:

- Identification, characterization and diversity analysis of novel viruses infecting economic important crops
- Development of efficient, rapid on-site diagnostic tools for early detection of plant viruses
- Interaction of plant virus with host and insect vectors and decipher the underlying molecular mechanism through functional studies.

Molecular Biology and Biotechnology



MOLECULAR BIOLOGY AND BIOTECHNOLOGY

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Aims and Objectives

Yield, quality and nutritional value of crops and produce are dependent on various biochemical processes and networks. These processes are under tight spatial and temporal regulation of gene expression. Studies suggest that modulation in expression of genes affects various processes leading to genotype-dependent changes in specific crops. Understanding changes at genetic level in existing germplasm/ cultivars through various approaches and utilization of information generated to develop improved varieties can lead to enhancement in the yield to meet demand of increasing population. There is need to develop new strategies for engineering crops for better yield, stress tolerance and enhanced

nutritional quality preferably using genes of plant origin.

The major objective of our R&D is to understand various genetic determinants for yield and quality, and develop superior plant varieties for enhanced yield and quality using plant genes for the benefits of farmers and consumers. To fulfill these objectives, gene-mining, transgenic plant development and genome-editing technologies are being used on different crops.

Major R&D Highlights

- We have previously established the role of *HDA5* in cotton fiber initiation. Interestingly, positively co-expressed genes with *GhHDA5* exhibited a protein interaction network with *HDA6* and *SUVH1*. The molecular characterization of all the transgenic lines overexpressing, antisense and myc tag is in progress to explore the role of the *SUVH1* gene in cotton fiber development.
- Two key genes, SELF-PRUNING (*GhSP*) and SINGLE FLOWER TRUSS (*GhSFT*), induce vegetative growth (indeterminate) and transition to flowering (determinate state), respectively. To achieve determinate/semi-determinate growth habits and synchronous flowering, the gene and promoter of both genes (both A and D sub-genome) from Coker 312 (*Gossypium hirsutum*) have been cloned and sequenced and will be used for further studies.
- Cotton MYB1 transcription factor (TF) shows higher expression during the secondary cell wall biosynthesis stage at 19 days post-anthesis (DPA). To study the effect(s) of CRISPR/Cas9-based editing in fiber cells, the stable transformation of cotton plants will be carried out. The microRNA828a-encoded peptides (miPEP828a¹ and miPEP828a²) affected fibre growth in cotton ovule culture.
- Inductions of male-sterility in the female parent followed by fertility restoration in F1-hybrid are the prerequisite for the hybrid seed production on commercial scale. To achieve complete male sterility and reverse the male sterility in F1 hybrid cotton, Arabidopsis *BECLIN1* and *COPI* genes were expressed in anther tapetum of cotton plants. The aim is to establish a system



in transgenic cotton to elite parental lines of commercial hybrid through marker-assisted backcrossing (MABC) to exploit its economic benefits.

- Studies on Calmodulin binding transcription activators (CAMTAs) in cotton identified three *CAMTA1* variants (*VS*, *V₂*, and *VL*) from amplicon data. Mapping of variants on genomic DNA showed that both *CAMTA1_VS* and *VL* variants possess intron retention. Analysis of Col-0- *VS* transgenic lines showed enhanced root laterals as well as higher LR density, suggesting root laterals might be crucial during stress tolerance.
- Development of transgenic cotton through pollen transformation and establishing culture of *Pectinophora gossypiella* on artificial diet and development of six putative transgenic cotton lines expressing insecticidal protein Dhi31 under regulation of PCD promoter for aphid tolerance are in progress.
- The *GhNAC2* gene expressing cotton plants (5th generation) showed sturdier growth and more fruiting as compared to control plants, with increased boll size, weight and number. Promoter studies in hairy roots show expression in the root tips, elongation zone and lateral root primordia with regulation under control of different hormones
- Pectin methylsterases (PME) demethylsterify the pectin and in the process release methanol which is toxic to insect pests. *WsPME29*, was found to be induced early and highly bioactive during biotic stress. Transgenic plants expressing *WsPME29* under constitutive and inducible promoters have shown 75-85% mortality against both the chewing (*Spodoptera litura* & *Helicoverpa armigera*) and sap sucking (Aphid and Whitefly) insect pests on the 4th day and 6th day, respectively.
- In order to improve root growth and vigour plant stress responses, CRISPR lines of two root expressed transcription factors HSF and WRKY have been developed using single and double guide RNAs and validated through sequencing. The plants are being studied for whole plant growth with a focus on root associated phenotypes in subsequent generations.
- The *SlERF6* gene from tomato was found to alter ABA-ethylene interactions and thereby the expression of key ripening regulators. The studies on the overexpressing and antisense lines of *SlERF6* showed that *SlERF6* may govern fruit set as well as fruit growth/ripening.
- The overexpression and knocked-down lines of *GSTU5* in rice showed the involvement of this gene in As sequestration in root by utilizing *OsABCC1* vacuolar transporters. The functional characterisation of *OsHsp20* also showed its involvement is alleviating As stress.
- The chickpea over-expressing lines of *CaCYP*, *CaMTD* and *CaWAT1* showed that *CaCYP* and *CaMTD* may participate in drought stress tolerance by regulating the expression of the stress-related genes during drought. However, *CaWAT1* is apparently not involved in the response of plants to drought. The chickpea metallothionein (*MT*) and glutaredoxin (*CaGrx*) genes were validated for drought and heavy metal tolerance in *Arabidopsis*.
- miR775 is a non-conserved miRNA identified only in *Arabidopsis thaliana*. Over-expression and knockout lines of miR775 showed that it regulates rosette size by elongating petiole length and increasing leaf area and targets a probable β -(1,3)-galactosyltransferase gene at post transcriptional level. miR775 was also found to be up-regulated in response to UV-B and hypoxia. Our findings establish a role of miR775 in regulating growth and development in *A. thaliana*.
- The petal abscission in rose was found to be governed by an interaction between the jasmonic acid and ethylene pathways that alters sensitivity to ethylene. Studies showed that reduction in JA pathway genes were necessary to increase sensitivity to ethylene which promoted flower opening and petal abscission in rose. Treatment of flowers with JA delayed flower opening as well as abscission suggesting strategies for delaying abscission in fragrant rose flowers with the use of JA or JA analogues.
- Wound induction in *RbPCD1pro* was found to be regulated in a JA-independent manner by a MYB protein that is conserved between rose and *Arabidopsis*.
- Light regulatory components (*HY5* and *COP*) involved in regulation of secondary plant products has been functionally characterized by developing overexpression and edited lines using CRISPR/Cas9 approach. miPEP (microRNA encoded peptide) and a small peptide involved in

the regulation of plant growth and development have been functionally characterized in *Arabidopsis thaliana* by developing several transgenic lines in various backgrounds.

- The evolution of the HPT gene family indicated towards the parallel evolution of some dicot and monocot HPT signatures mediated through basal eudicot representatives. The functioning of the two component system module in climacteric and non-climacteric fruits showed that the TCS module functions differentially during ripening of climacteric and non-climacteric fruits.
- The cotton TLP genes were identified and their role in salt and drought stress was studied. It was

shown that GhTLP11A and GhTLP12A.1 genes might have prominent role during drought and salt stress. In a study on bHLH genes of *Nicotiana* in salt stress, five NtbHLHs showed significant higher expression during chilling stress responses. These genes might have important role during chilling stress condition.

- To understand the impact of sub-genome dominance during endoreduplication on heterosis, whole-genome sequencing in parents and their reciprocal F1 hybrids performed. The result indicates that during an endocycle, the replication of Col-0 dominates the replication of the C24 sub-genome.



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Transcription and epigenetic regulation studies

The advancement of genomes and epi-genomics has established us to make significant advances in our understanding of plant biology, allowing us to improve agricultural traits in difficult environmental conditions more efficiently and effectively. Both fields provide significant insights into the mechanisms behind growth, development, and stress response, and could be used to accomplish plant characteristic modification by genetic or physiological alterations.

Exploring the role of alternative splice variants of CAMTA1 in stress physiology of *Arabidopsis thaliana*

Several calcium-dependent transcription factors are implicated in diverse stress signaling in plants. Calmodulin binding transcription activators (CAMTAs) are widely studied calcium/ calmodulin-dependent TFs in *Arabidopsis thaliana*. During the cloning of the CAMTA1 gene, we identified several novel splice variants of CAMTA1, and implicated two of them were involved in diverse stress signaling pathways. Moreover, high depth targeted amplicon sequencing of CAMTA1 was performed under various developmental stages (leaf, root, flower, siliques) and treatments (drought, chilling, auxin, bacteria) to understand the alternative splice events with more precision. The expression analysis indicated the relative distribution across all the stages (Fig. 1).

Out of the top three CAMTA1 variants (VS, V₂, and VL) only VS and VL expression patterns could be validated by qRT-PCR across all selected stages and treatments. Furthermore, both variants were mapped on genomic DNA and found that both the CAMTA1_VS and VL variants possess 27 and 25 nucleotide intron retention (IR), respectively.

Further, transgenic lines were developed to understand their functional significance. Col-0- VS transgenic lines had enhanced root laterals as well as higher LR density, which were also depicted by microscopic observation. These higher root laterals might be crucial during stress tolerance (Fig. 2).

Exploring the molecular details of Sub-genome dominance during endoreduplication in F1 hybrids

Hybrids are imperative in enhancing crop productivity through an increase in biomass, seed yield, and adaptive fitness. Heterosis is a phenomenon wherein the superiority of F1 hybrid over its parents with respect to different heterotic traits. It has been the center of attraction to geneticists and molecular biologists to elucidate the underlying mechanism. Heterosis has been studied and implemented successfully in various crop plants, but the molecular mechanism behind heterosis is still elusive. In plants, whole-genome duplication is an essential feature of genome polyploidization and can produce functionally different sub-genomes. During evolution, sub-genome dominance has evolved as a specific phenomenon in which one of the parental sub-genome is dominated over the counterpart genome. To understand the impact of sub-genome dominance during endoreduplication on heterosis, we performed whole-genome sequencing in parents and their reciprocal F1 hybrids.

Distribution plots suggest that Col-0 and C24 parents showed almost similar distribution with minor differences across all chromosomes may be due to genotype-specific differences. Interestingly, in the case of Col-0xC24 F1, we could observe a

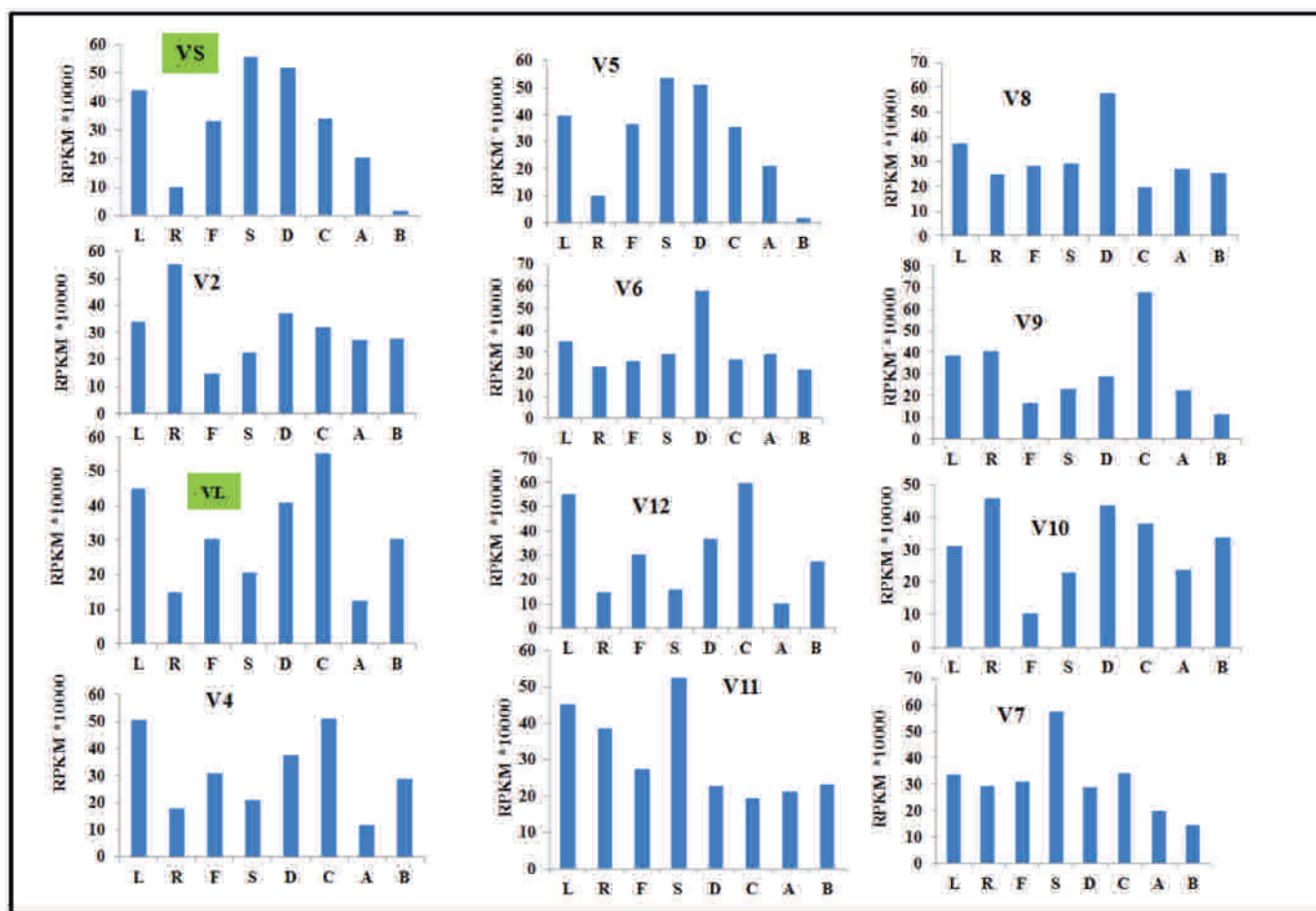


Fig. 1: Expression analyses of top 20 splice variants. Expression values (RPKM) of *CAMTA1* variants under different developmental stages and treatments. L-Leaf, R-Root, F-Flower, S-Siliques, D-Drought, C-Chilling, A-Auxin, B-Bacteria.

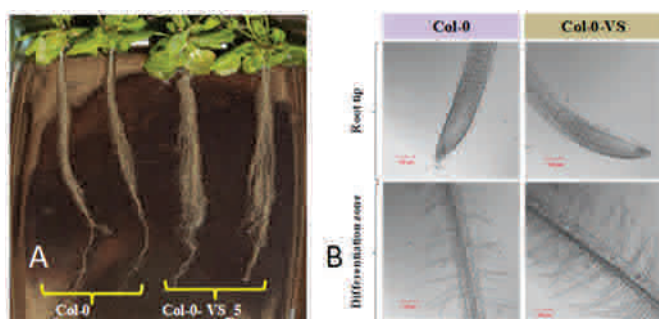


Fig. 2: Enhanced root laterals in Col-0-VS plants. Enhanced laterals are indicating higher root biomass in Col-0-VS (A). Microscopic observation of control and Col-0-VS lines at the root tip and Differentiation zone (B).

significant increase in genomic reads of the Col-0 sub-genome and a significant decline in the C24 sub-genome. These changes were consistent throughout

a chromosome and across all the chromosomes. The result indicates that during an endocycle, the replication of Col-0 dominates the replication of the C24 sub-genome. The sub-genome dominance in endocycle to augment the DNA content of one parent over the other is novel and interesting. Thus, it can be safely interpreted that the Col-0 sub-genome can perpetuate its sub-genome over its partners in an F1 cross. We are also interested to know any other genotype of Arabidopsis show such phenomena in F1 hybrids of Col-0 and C24. To fulfill this objective, we selected genotypes based on principal component analysis and developed different F1 hybrids with C24, and the result alluded that only F1 hybrids of Col-0 show sub-genome dominance. Now, we are trying to explore the mechanism responsible for it and how it is relevant to nature.

Role of *GhHDA5* during cotton fiber development in *Gossypium hirsutum*

GhHDA5 is a histone deacetylase that removes acetyl group from histone and its expression is higher

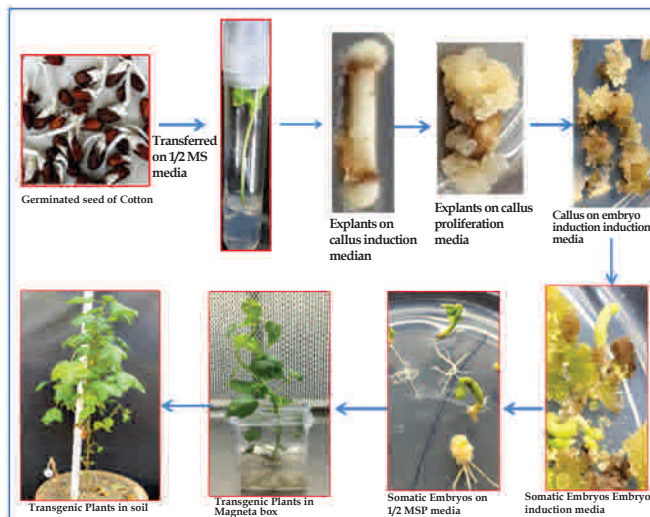


Fig. 3: Different stages of Somatic embryogenesis to develop *GhHDA5* cotton transgenic plants

during initiation of cotton fibre development (-1 and 0 DPA). Previously we showed that the inhibition of HDA5 through RNAi indicates plays an important role in cotton fibre development. To further validate *GhHDA5* role in cotton fibre development we are generating over-expression cotton (*Gossypium hirsutum* c.v. 312) lines (Fig 3) and trying to identify its molecular mechanism during cotton fibre development. To identify the genome wide binding sites of *GhHDA5* in cotton we fused the HDA5 with myc tag and develop the transgenic lines. The molecular characterization of all transgenic lines is under process.

Development of F1-Hybrid Cotton using Novel Male Sterility-Fertility Restoration System

The developments of new technologies are required to meet the demands of global food security by increasing the gross crop productivity without increasing water and fertilizer use in the definite arable land. Inductions of male-sterility in the female parent followed by fertility restoration in F1-hybrid are the

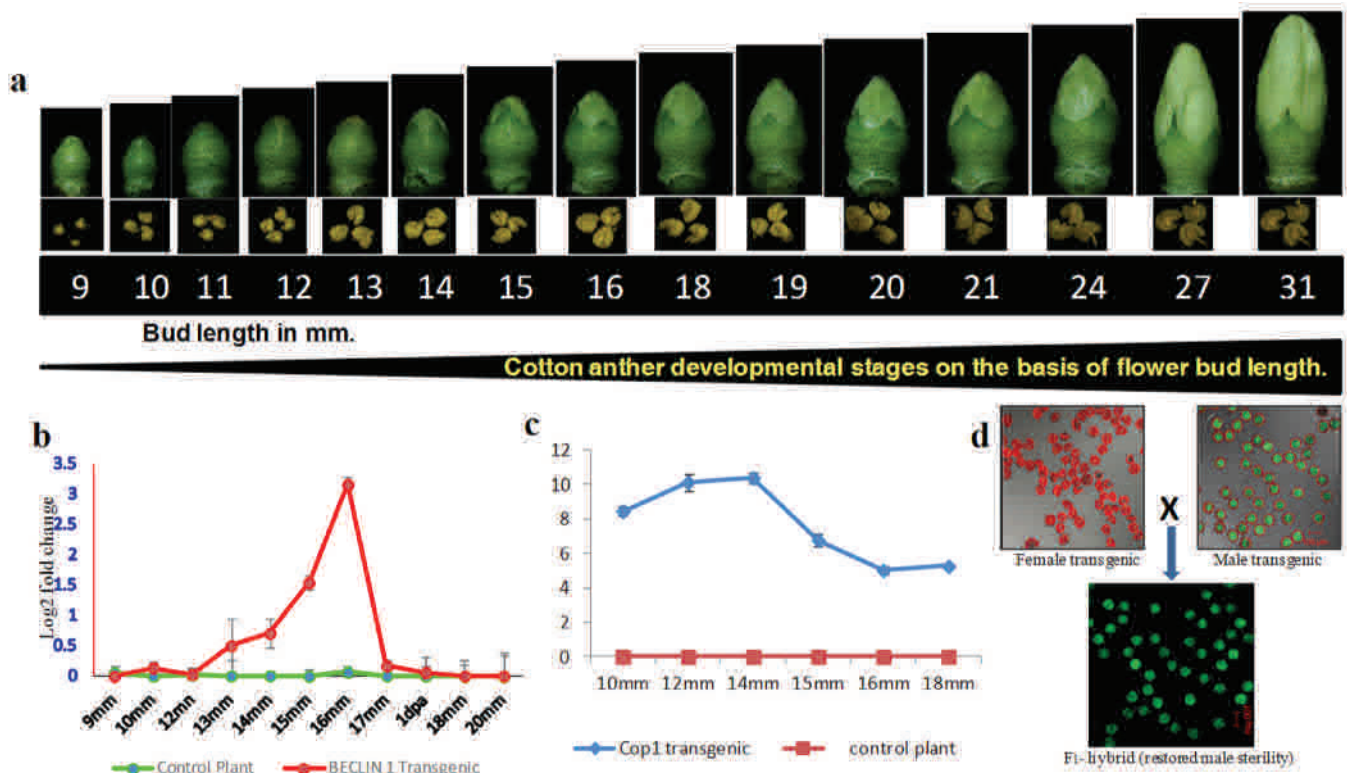


Fig. 4: Expression analysis (A). Cotton anther developmental stages on the basis of flower bud length, (B and C). Bar diagram showing the expression of *BECLIN1* and *COP1* in the different anther stages of female and male transgenics respectively. Total RNA was isolated from the different anther stages for the qRT-PCR assay ($n = 3$ independent biological repeats). *UBI14* was used as an internal control. Error bars indicate SD, (D). FDA/ PI test for pollen viability; green fluorescence of FDA shows viable pollens whereas red fluorescence of PI indicates aborted pollens.

prerequisite for the hybrid seed production at the commercial scale. Here, we developed a novel male sterility-fertility restoration system for hybrid seed production by engineering the innermost nutritive anther wall layer tapetum (Fig 4). We further aim to establish this system in transgenic cotton cocker-312 to elite parental lines of commercial hybrid through marker-assisted backcrossing (MABC) to exploit its economic benefits.

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Hormonal crosstalk in root architecture and development; petal abscission in rose; fruit growth and ripening; wound-inducible promoters

The role of *SIERF6*-mediated changes in ABA responses in vegetative growth, flowering and fruit set

We had previously identified *SIERF6* as a ripening up-regulated gene that functioned as negative regulator of ABA responses in germination, stomatal responses and senescence. Its expression delayed the onset of ripening while its suppression accelerated ripening. Nethouse studies were carried out for a more detailed study of plant growth phenotypes under field conditions. The studies showed that manipulation of *SIERF6* strongly affected both vegetative (plant height, leaf area) and reproductive growth (flowering time and fruit set).

Plants with reduced *SIERF6* expression grew much faster than controls while OEx lines had much slower growth. Suppression lines showed a 20-30% increase in height over the controls in the early stages of growth up to 45 days, while the over-expression lines showed a 20% reduction. The differences in height between over-expression and controls increased further from 45-75 days with OEx lines showing a 30-50% reduction in height and suppression lines showing a 15-20% increase over controls. These differences reduced at later stages but suppression lines remained taller than controls at harvest while over-expression lines showed a 15-18% reduction in height. Prominent differences were also observed in leaf area especially during early and mid-growth stages. Leaves of suppression lines were much larger than control and OEx lines being 30-50% larger than controls from 30-90 days. They attained their maximum size between 75-90 days unlike control leaves which continued to grow up to 105 days. Leaves of OEx lines were at least 25-40% smaller in area than

control at most stages and remained smaller by about 10% even at 120 days (Fig. 2). ABA responses as estimated by expression of the ABA responsive gene *LE25* were dramatically higher (35-70 fold) in *SIERF6* suppression lines at 30-60 days and greatly reduced (down to 10-15%) in OEx lines compared to control. The differences in growth provide evidence for the role of *SIERF6* in various aspects of plant growth and

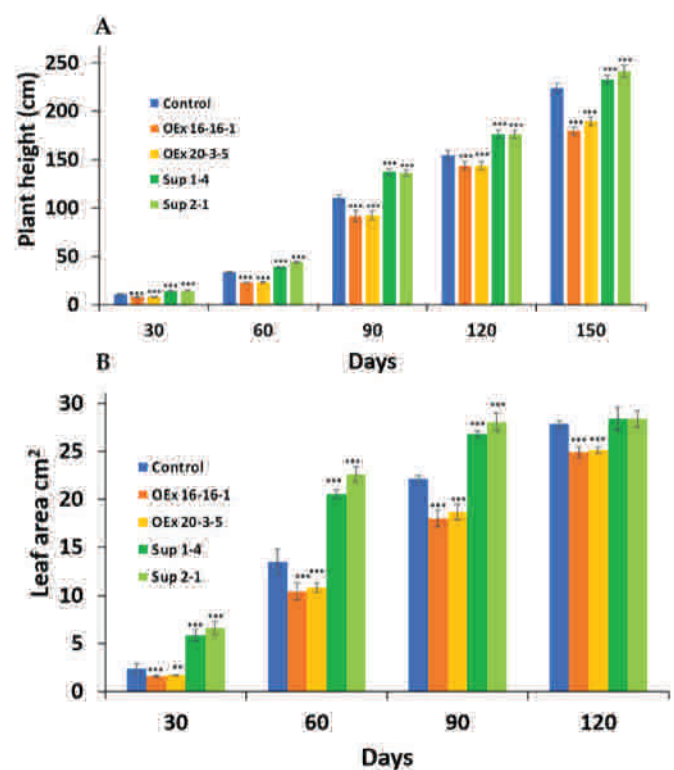


Fig. 1: Analysis of changes in plant height (top) and leaf area (bottom) in control and transgenic *SIERF6* over-expression (OEx) and suppression (sup) lines during the course of growth in the nethouse (n=10)

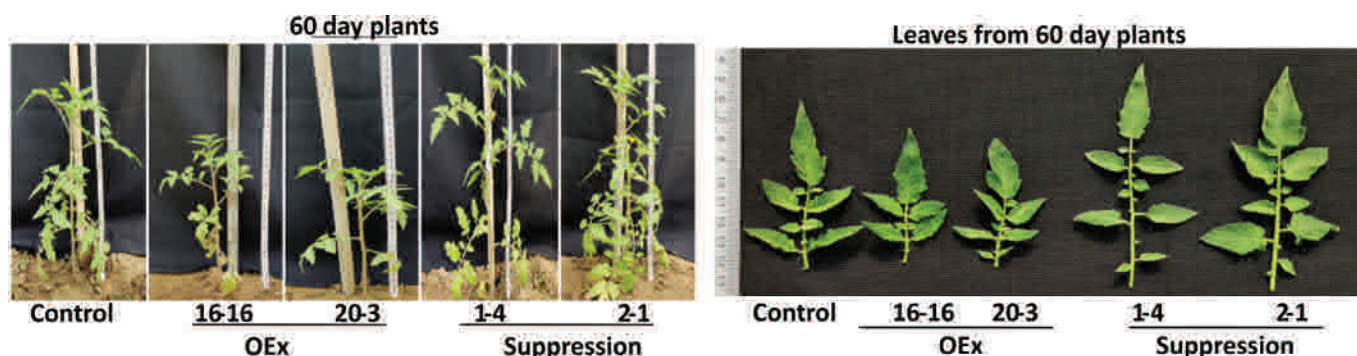


Fig. 2: Representative pictures of plant height (left) and leaf area (right) from 60-day old plants of control and transgenic *SIERF6* over-expression (OEx) and suppression (sup) lines.

development through alteration of ABA responses and possibly in combination with GA.

The accelerated growth rates also affected flowering times with suppression lines showing a marked early flowering at 56-58 days compared to ~72 days in control and 85-86 days in over-expression lines. Flower number was altered with suppression lines showing at least 12% more flowers compared to control. In contrast OEx lines showed a marked reduction of ~30% in flower number compared to control. Besides a reduction in flower number, OEx lines also showed a reduction in fruit set with ~50% flowers setting fruit compared to 60% in controls and almost 75% in suppression lines. This difference in flower number and fruit set percentage affected the final yield with the two OEx lines yielding an average of 470 and 530 g fruit/plant compared to about 1120 g fruit/plant in control. In contrast suppression lines yielded at least twice as much as the controls with 2120 and 2350 g fruit/plant (Fig. 3).

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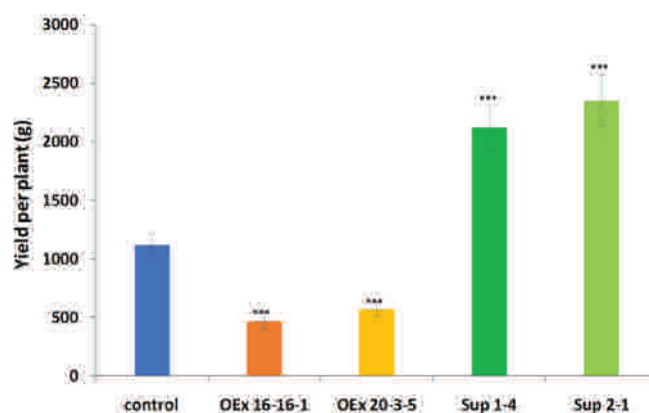


Fig. 3: Total yield/plant in control and transgenic *SIERF6* over-expression (OEx) and suppression (sup) lines of Ailsa Craig grown in the net house. Values are average of 10 plants/line

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Regulation of root growth by a tomato MYB transcription factor

During the course of its life, plant roots constantly face changes in the rhizosphere and the available water and nutrients. Adaption to these necessitates changes in the root architecture for optimum growth that is brought about through action of hormones and transcriptional regulators that function in a cell and tissue specific manner. In order to understand the molecular basis of root development tomato was chosen as a model system. A MYB family transcription factor, *SIMYBHTH*, was one amongst several root-upregulated transcription factors that were chosen for detailed studies. Expression of the gene was found to increase with developmental age of root, being 10-12 fold higher at 60 days compared to 15 and 30 day-old roots.

Expression of *SIMYBHTH* was under strong hormonal control and was greatly reduced under ABA, IAA, BAP and JA treatment to less than 50% within 30-60 min of treatment under hydroponic conditions. Not much change was seen upon GA3 and ACC treatment. Expression was also strongly reduced by mannitol (300 mM) treatment but not affected by NaCl (200 mM).

SIMYBHTH is expressed in the lateral root primordia

To obtain an insight into the expression of *SIMYBHTH*, transgenic hairy roots expressing the *SIMYBHTH* promoter (~2kbp upstream of the initiation codon) were generated. *GUS* activity was most prominently observed in lateral root primordial and lateral root tip while activity was less prominent but visible in meristematic zone of primary root indicating a role

Hormonal crosstalk in root architecture and development; molecular basis of ripening in mango

for *SIMYBHTH* in these tissues. No *GUS* activity was detected in root tip and in differentiation zone of primary root (Fig 1).

SIMYBHTH manipulation affects root growth

To further study the function of *SIMYBHTH* in root development, transgenic lines over and under-expressing these were generated and three lines each were studied in the T3 (homozygous) generation.

At least two of the suppression lines displayed a significant reduction of up to ~17 % in primary root length whereas a significant increase of up to 11-12 % in primary root length was observed in OEx lines as compared with control plant roots after 10 days.

Suppression lines also exhibited delay in lateral root

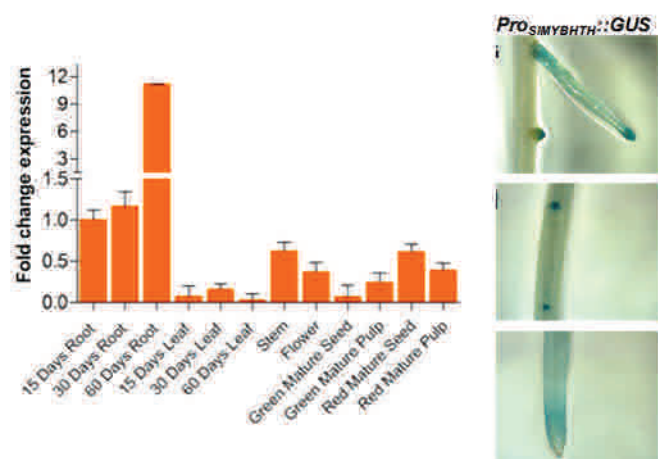


Fig. 1: Tissue specific quantification of *SIMYBHTH* expression by real time PCR (left). *SICAC* and *SISAND* were used for normalization. Histochemical *GUS* analysis showing *SIMYBHTHpro* expression in lateral root primordia and LR tips of transgenic *SIMYBHTHpro* hairy roots.

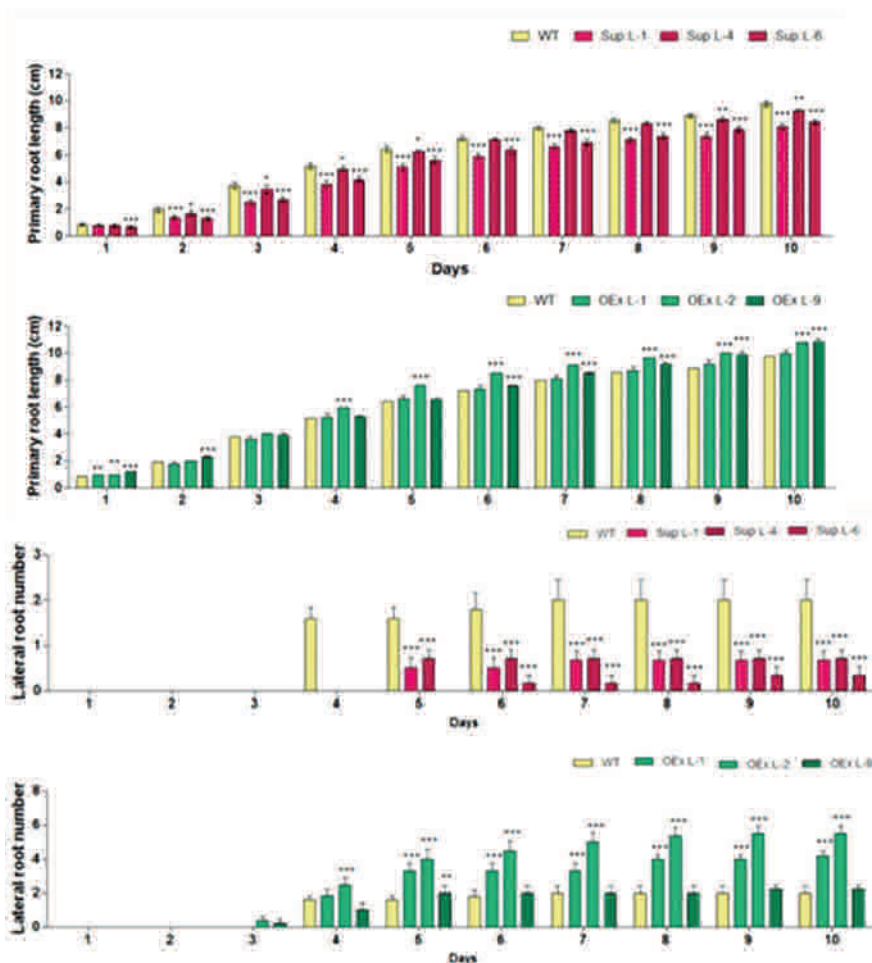


Fig. 2: Manipulation of *SIMYBHTH* in plants alters primary and lateral root growth. Graphical representation of the kinetics of primary root and growth (top and lateral root emergence (bottom) at early stages of root development up to 10 days in control, transgenic over-expression and suppression lines. Bars represent the mean value while error bars indicate \pm SE (n=10). Asterisks represent a significant difference at *P < 0.05, **P < 0.01, ***P < 0.001 (one way ANOVA).

emergence while OEx lines showed early emergence of lateral root compared to control plants. Lateral roots began emerging after 5-6 days in suppression lines compared to controls where LR emergence was seen in 4 days. In contrast, lateral roots began emerging after 3 days in OEx lines. The number of lateral roots as estimated after 10 days was higher in OEx lines as compared with control (Fig 2). The observations suggested that *SIMYBHTH* regulates the primary root elongation and lateral root emergence positively.

Interestingly, the closest MYB homologue of *SIMYHTH* in *Arabidopsis* also showed predominantly root specific expression. A T-DNA mutant of this gene showed a prominent reduction in primary root

growth although lateral root growth was not affected much.

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Genetic engineering of cotton for insect tolerance

The group is working on molecular approaches for the management of field crop insect pests. In general, there could be two basic molecular lines to handle the problem of field insect pests. (1) Expression of an insecticidal principle (protein, short interfering RNAs or secondary metabolites) inside the plant itself and (2) foliar application of insecticidal principles (chemical pesticides, biological control agents and nano-formulations). Our group is actively working on both approaches. In the first approach, we have developed the transgenic cotton expressing insecticidal proteins (Tma12-cotton, Msc14-cotton, Cry1EC-cotton) while in the second, we have demonstrated the use of carbon nanoparticles for the management of lepidopteran pests.

Waste candle soot derived carbon nanoparticles: A competent alternative for the management of *Helicoverpa armigera*

Helicoverpa armigera (Lepidoptera: Noctuidae) is considered as one of the foremost pests of global agriculture. Farmers adopt several strategies for the control of this pest but the cost associated with these strategies is always a big question. This is the first time when candle soot (CS) derived carbon nanoparticles (CNPs) are explored for the putative toxicity to *H. armigera*. In the present study, the entomotoxic effects of CNPs on *H. armigera* was investigated and compared with that of commercially available multi-walled carbon nanotubes (MWCNTs).

A significant difference was observed in the average weight of all larval instars at all the tested concentrations of both the NPs (CNPs and CNTs). However, the maximum difference in the weight

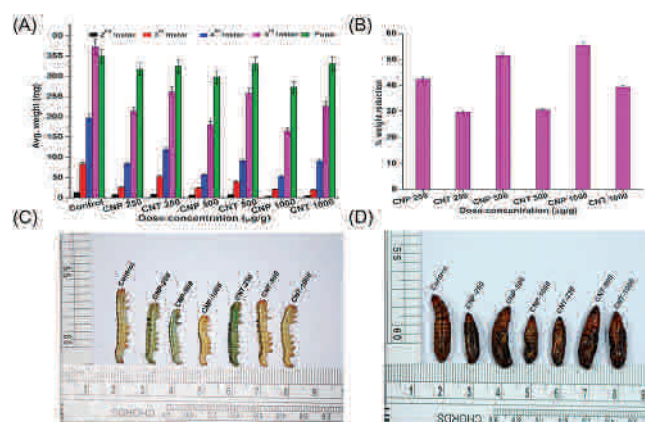


Fig. 1: Effect of carbon nanomaterials (CNTs and CNPs) on the average weight of larvae and pupae. (a) The maximum difference in the weight was observed in 5th instar larvae. Error bars represent the standard mean of error (N $\frac{1}{4}$ 30). p Value < 0.01 in all five instars and p Value > 0.05 in pupae of CNPs 250, CNTs 250 and CNTs 500, Dunnett Test. (b) Percent weight reduction in 5th instar larvae. (c) Growth reduction in larvae fed on NPs. (d) Abnormalities observed in pupae.

was observed in the fifth instar larvae. The maximum average weight reduction (55.5%) among the 5th instar larvae was observed in 1000 μ g.g⁻¹ CNPs treatment. These results demonstrated that the percent reduction in weight is directly proportional to the concentration of NPs (CNPs and CNTs) in the diet (Fig 1). However, it is notable that, CNPs showed more adverse effects on larvae and pupae than CNTs at the same concentration. About 20% of the pupae show a range of deformities like heavy pigmentation, unclear developmental rings and shrunken epidermis was observed in pupae developed from the larvae fed on all the concentrations of the CNPs. These deformities were also observed in the pupae developed from the larvae fed on CNTs but with a lesser extent.

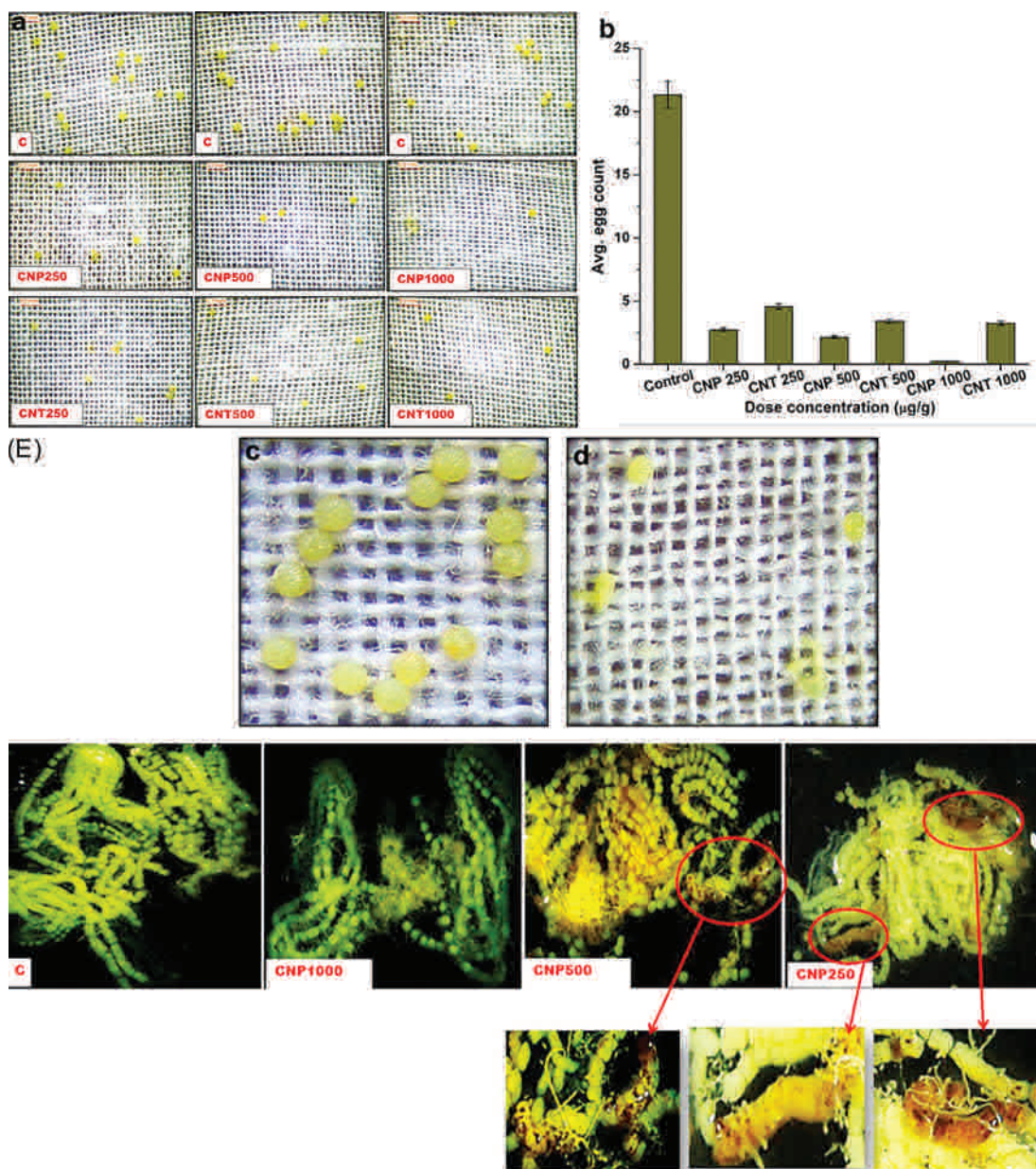


Fig. 2: Impact assessment of the carbon nanomaterials on the oviposition of the female moths. (a) Panels representing the egg-laying pattern of the moths fed on control diet (upper), and 3 different concentrations of CNPs (middle), and CNTs (lower), respectively. (b) Effect of carbon nanomaterials (CNTs and CNPs) on the average egg count of the adult. Error bar represents the standard mean of error. (p Value<0.01, Dunnett Test). Effect of CNPs on the morphology of eggs. (c) normal eggs laid by control diet fed moths. (d) Frequent bursting and abnormalities in the eggs laid by CNPs fed moths. (e) Microscopic evaluation of the ovary. Several morphological changes were observed in the ovary of CNPs fed moths.

Despite severe growth reduction and pupal morphological deformities, 70-80% of pupa converted into adults and insect mating was observed in all the tested parameters. However, egg numbers varied greatly among the treatments of CNPs and CNTs with respect to control. Oviposition was highly reduced in the case of CNP-1000 µg.g⁻¹ followed by CNP-500-

CNP-250-, CNT-1000-, CNT-500-, and CNT-250-µg.g⁻¹ (Fig 2). In all the tested concentrations of the CNPs, the laid eggs were deformed and very fragile in nature (frequent bursting was observed) with zero larval emergences. However, in case of CNTs, laid eggs were normal in size and shape with usual larval emergence though we have observed poor egg-

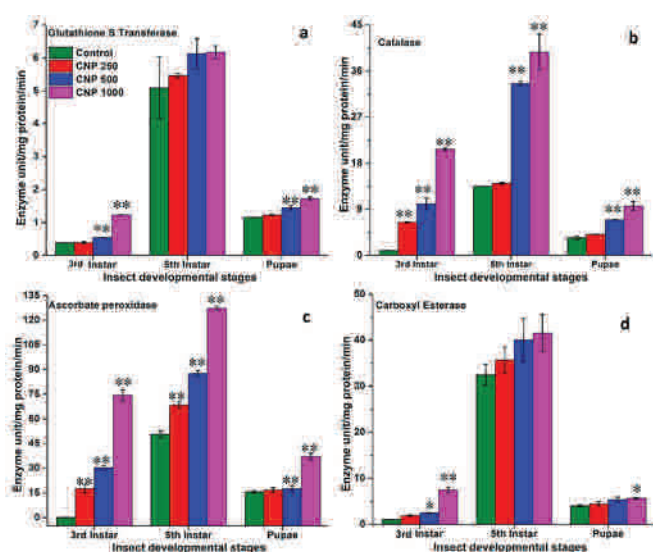


Fig. 3: Effect of various concentrations of CS derived CNPs on enzymes related to oxidative stress and defence mechanism. (a) GST, (b) CAT, (c) APX, and (d) CarE activity in 3rd and 5th instar larvae and pupae. Error bars representing the standard error (N = 3). Stars above the error bars denote significant differences between treatments in comparison to control (* = p Value < 0.05 and ** = p value < 0.01, Dunnett test)

laying. The substantial reduction in the egg-laying and zero adult emergence demonstrated that candle soot derived CNPs can significantly control the insect progeny and hence the population build-up.

To understand the reason of reduced egg laying, we performed the microscopic examinations of the ovary of female moths fed on various concentrations of CNPs (Fig. 2e). In concurrence with the previous result (poor egg-laying), we observed poor and abnormal egg filling/development in the ovary of the CNPs fed insects. The egg filling was severely decreased in the ovary of the moths reared on 1000 $\mu\text{g}\cdot\text{g}^{-1}$ of CNPs. Despite lower egg filling, patchy and dark coloured abnormal eggs were found in the case of moths fed on CNPs 500 and CNPs 250 $\mu\text{g}\cdot\text{g}^{-1}$ of diet. In insects, the incidence of oviposition is tightly regulated. It requires the complete development of ovarian structures, maturation of the eggs and feeding/ mating of the female moths. The majority of the insecticides that are being used in integrated pest management programs cause sublethal impacts on reproduction through impaired egg-laying, fecundity, longevity and egg hatchability.

Literature suggested that the generation of the ROS (reactive oxygen species) is considered as one of the most frequently reported and widely

accepted toxicities associated with nanomaterials in insects. A good correlation was found between carbon nanomaterials mediated oxidative stress and subsequently compromised reproductive performance of the insects. In order to study the impact of the CNPs on insect's detoxification and management of oxidative stress machinery the activity of four enzymes were tested and found significant higher activities of enzymes isolated from larvae fed on CNPs (Fig 3).

The study has demonstrated the potential of CS derived CNPs for the control of *H. armigera*. The CNPs, tested here, impose a significant negative impact on larval and pupal weight and reproductive ability of the moth. It exerts a range of detrimental impacts on insect physiology, defence mechanism and generation advancement even at the lowest tested concentration. These studies showcase the candidature of CNPs as low-cost competent material for the management of crop pests.

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Insect resistance in chickpea; drought and heavy metal tolerance in *Arabidopsis*

Expression of a proteinase inhibitor in chickpea was studied for insect resistance and higher plant productivity, by lowering crop losses due to biotic stresses. Genes for drought and heavy metal tolerance in *Arabidopsis* were validated.

Insect resistance in chickpea

A trypsin inhibitor from *Cocculus hirsutus* has been demonstrated to exhibit insecticidal activity. The *ChTI* (*Cocculus hirsutus* Trypsin Inhibitor) gene was

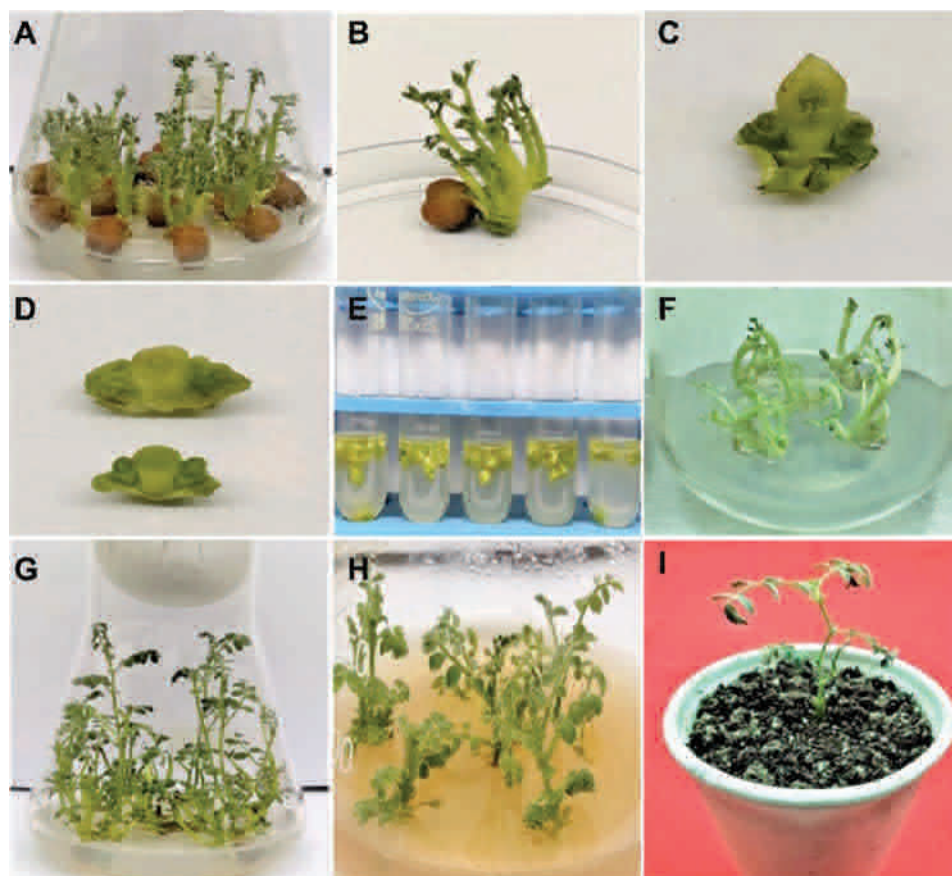


Fig. 1: Explant preparation for *in vitro* regeneration in chickpea. (A). Seedlings of chickpea cultivar P-362. (B). 20-day old seedlings. (C). Primary excised cotyledonary node. (D). Secondary excision of explants to expose the deep-seated regenerative layers. (E). Preparation of CNs for sonication at 42 kHz for 0–60 seconds. (F). Shoot buds emerging in selection medium supplemented with 250mg/L cefotaxime and 100 mg/L kanamycin. (G). Shoots subjected to the third antibiotic selection cycle. (H). Shoots incubated on regeneration medium for growth. (I). Shoots of putative transformants micro-grafted on 7-day old rootstock.

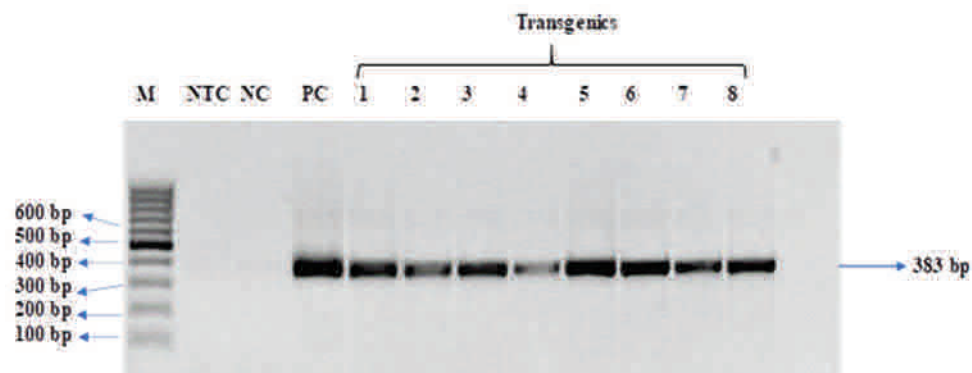


Fig. 2: PCR analysis of T_0 primary transformants of chickpea. (a) using internal primers (*ChTI*) and desired band size of 383 bp (M- 100 bp ladder, NTC-Non-template control, NC-Negative control, PC-Positive control, lane 1-8 are putative transgenic events).

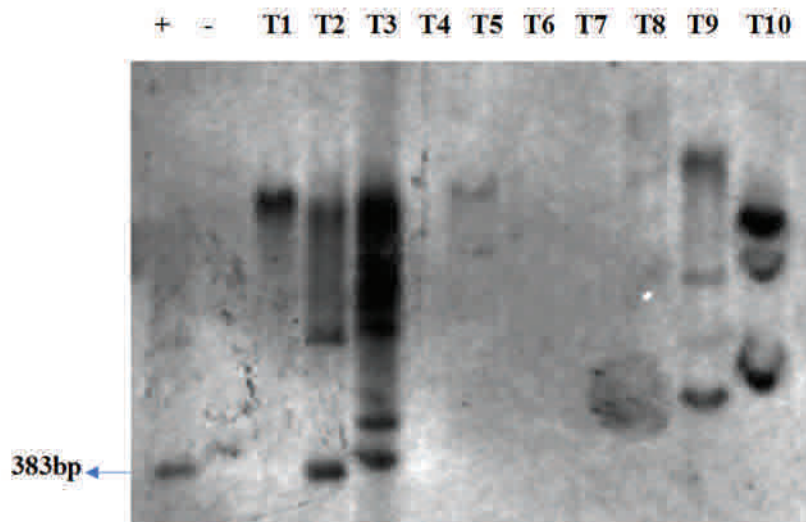


Fig. 3: Southern blot hybridization with the radiolabelled probe of *ChTI* gene (+ positive control, - negative control, lane T1, T2, T3, T5, T8, T9 & T10 are the putative transgenic events hybridizing with the probe).

designed *in silico*, synthesized and cloned in pBI121. *Agrobacterium*-mediated transformation of *ChTI* gene was performed in chickpea cultivar P-362. *In vitro* grown putatively transgenic chickpea shoots were grafted on decapitated stock of chickpea seedlings (Fig. 1). After 45–50 days of acclimatization and hardening, pod development and its maturation occurred. After screening by PCR (Fig. 2), seven transgenic events were confirmed by Southern blot hybridization analysis, showing 1–4 copies of the transgene (Fig. 3). The quantitative expression of the *ChTI* gene by qRT-PCR analysis showed up to 12–17-fold change in the T_1 progeny. Immunoblot analysis revealed the expression of 15 kDa ChTI protein in the transgenic plants. Trypsin activity assay was performed in the T_1 generation and higher anti-trypsin activity was recorded. Insect tolerance

against *Helicoverpa armigera* and *Spodoptera litura* were estimated by insect bioassay, wherein an overall mortality of 60–80% and 30–60% weight loss has been recorded in the plants of T_1 generation.

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Plant-insect interaction and strategies to control crop insects using different strategies

We have developed transgenic cotton plants with novel insecticidal proteins, lectins and SiRNA gene constructs which are showing very good toxicity against various chewing type and sap sucking pests. We had also developed the transgenic cotton plants expressing insect inducible *pectin methyl esterase* for enhanced methanol production for broad spectrum insect resistance. We have also demonstrated the Transcriptome and proteome wide analysis mealybug for the identification of potential SiRNA targets. The identified targets are now utilized for the transgenic cotton development.

Overexpression of *Pectin Methylesterase* gene in cotton for insect resistance

Pectin Methylesterases (PMEs) belong to a large multigene family and demethylesterifies the cell-wall pectin, leading to methanol release. They are regulated in a highly specific manner and are involved in vegetative and reproductive processes, in addition to plant-pathogen interactions. Methanol is naturally emitted as a volatile organic compound. Methanol is toxic to insect pests, but the quantity emitted is inadequate to protect against invading pests. There are two types of PMEs: Type-I and Type-II PMEs. Type-I PMEs comprise a PRO region, which shares similarities with the PME-inhibitor domain and keeps PME inactivated and it is cleaved by Subtilase.

In our previous study, we demonstrated that the over-expression of pectin methylesterase, derived from *Arabidopsis thaliana* and *Aspergillus niger*, in transgenic cotton plants enhanced methanol production and resistance to polyphagous insect pests. In the search for more efficient PME, we

arrived at *Withania somnifera* about which there are earlier studies, reporting that it emits more methanol as compared to other solanaceous plants. The increased methanol emission was found to be due to biotic stress. Therefore, *W. somnifera* was selected as a source to find more effective PME for inducing broad spectrum insect resistance.

In our earlier studies, we have shown that over-expression of *WsPME29* in tobacco plants exhibits pest resistance. Further, we have cloned the same gene under the control of the constitutive and inducible promoter and transformed cotton through *Agrobacterium*-mediated genetic transformation. Transgenic plants comprising constitutive and inducible *WsPME29* expression systems have shown 75-85% mortality against both the chewing (*Spodoptera litura* & *Helicoverpa armigera*) and sap-sucking (Aphid and Whitefly) insect pests on the 4th day and 6th day, respectively.

We show that over-expression of *WsPME29* provides broad-spectrum resistance against chewing and sucking insect pests through enhanced methanol emission (Fig. 1).

In vivo gene specific silencing in *Phenacoccus solenopsis* by *in-planta* expression of a double-stranded RNA

RNAi has proven to be an effective technology in agricultural pest control. In the present study, to identify three methods were utilized for the delivery of dsRNA to potential RNAi targets and assess the effectiveness of the selected target genes. The outcomes from this study proved that RNAi

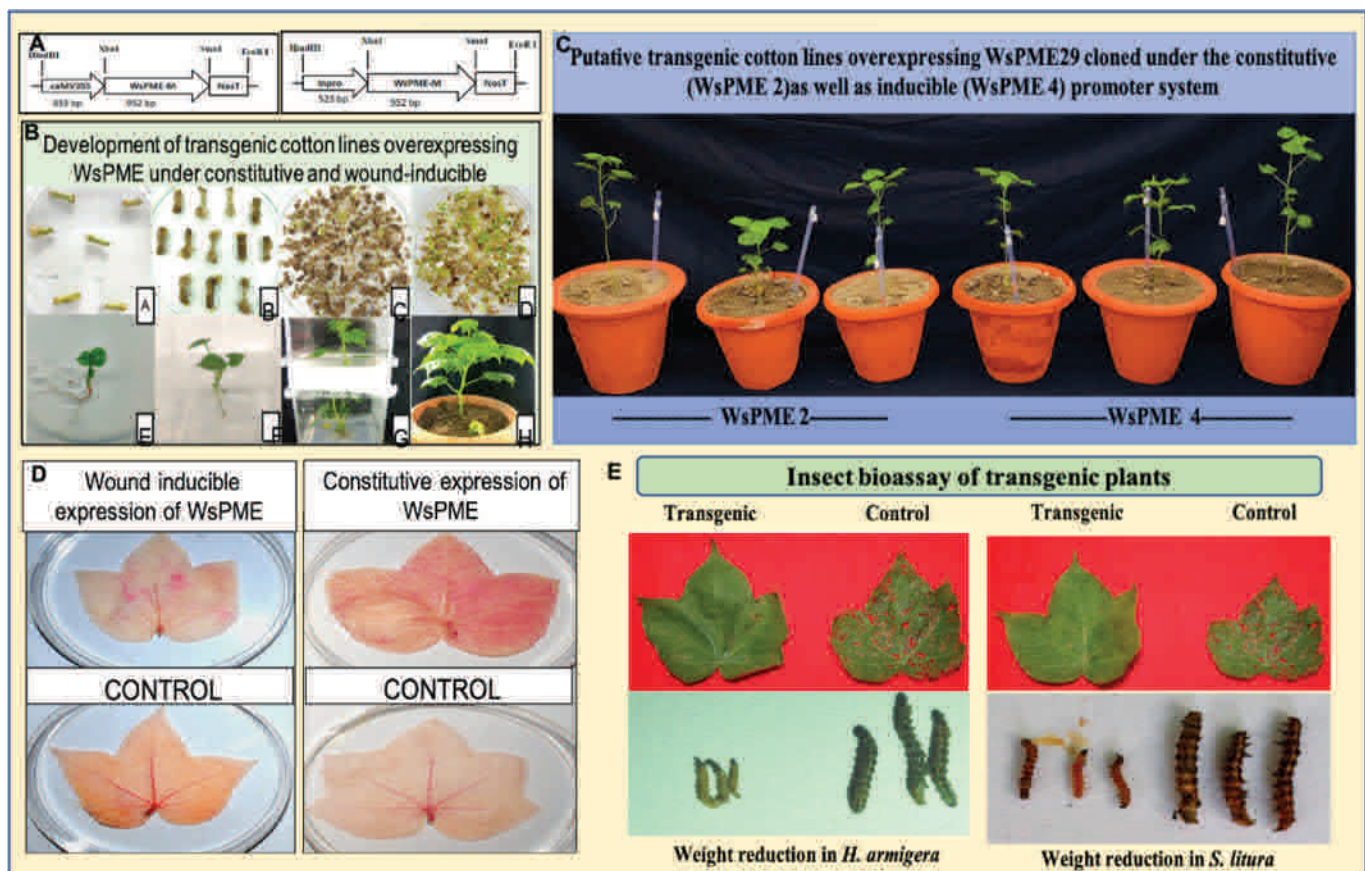


Fig. 1: (A). *WsPME29* gene construct in pBI121 vector with *CaMV35S* promoter (*WsPME2*) and wound-inducible promoter (*WsPME4*), (B). Development of transgenic cotton lines harboring *WsPME29* gene, (C). Putative transgenic cotton lines overexpressing *WsPME29* gene under constitutive and wound-inducible promoter, (D) Ruthenium red staining of cotton leaves showing degree of methyl-esterification. Higher the RR staining lower will be the degree of methylesterification, (E). Insect bioassay of transgenics with *Helicoverpa armigera* and *Spodoptera litura*

technology has a potential and promising role in controlling the cotton mealybug, *P. solenopsis*. The explanations also supported those hemipteran insects are highly sensitive to RNAi both, ingestion and oral delivery of dsRNA methods. Further, our group is working on validation of the results using proteomics and then a reverse strategy will be applied to find more effective potential RNAi targets. For proteomics the first challenge faced was standardization of protein isolation and purification protocol for cotton mealybug. Soon after overcoming this hurdle we outsourced the proteome of four different developmental stages of mealybug. Nano LC-MS/MS was performed. In the proteome data we received the 2486 peptides in the adult proteome and 1385 peptides in the third instar. We are trying to increase the peptide count by relaxing the parameters such that we do not compromise with the

peptide quality. The difference in the peptide count of the adult and third instar can be because of the metamorphic differences and also the adult stage is reproductive in nature thus expressing many extra proteins related to mating, reproduction, oviposition and etc. Till date no such study has been done on *P. solenopsis* thus the results are not only unique but pave the way for future research in pest management using RNAi for other related insects.

Enhanced post-harvest life in tomato by repressing ripening genes

Two ripening specific genes namely N-glycoprotein modifying enzymes, α -mannosidase (α -Man) and β -D-N-acetylhexosaminidase (β -Hex) and two unidentified genes Solyc04g072150.2 and Solyc12g056780.2 were selected for the gRNAs synthesis and cloned in the desired vector

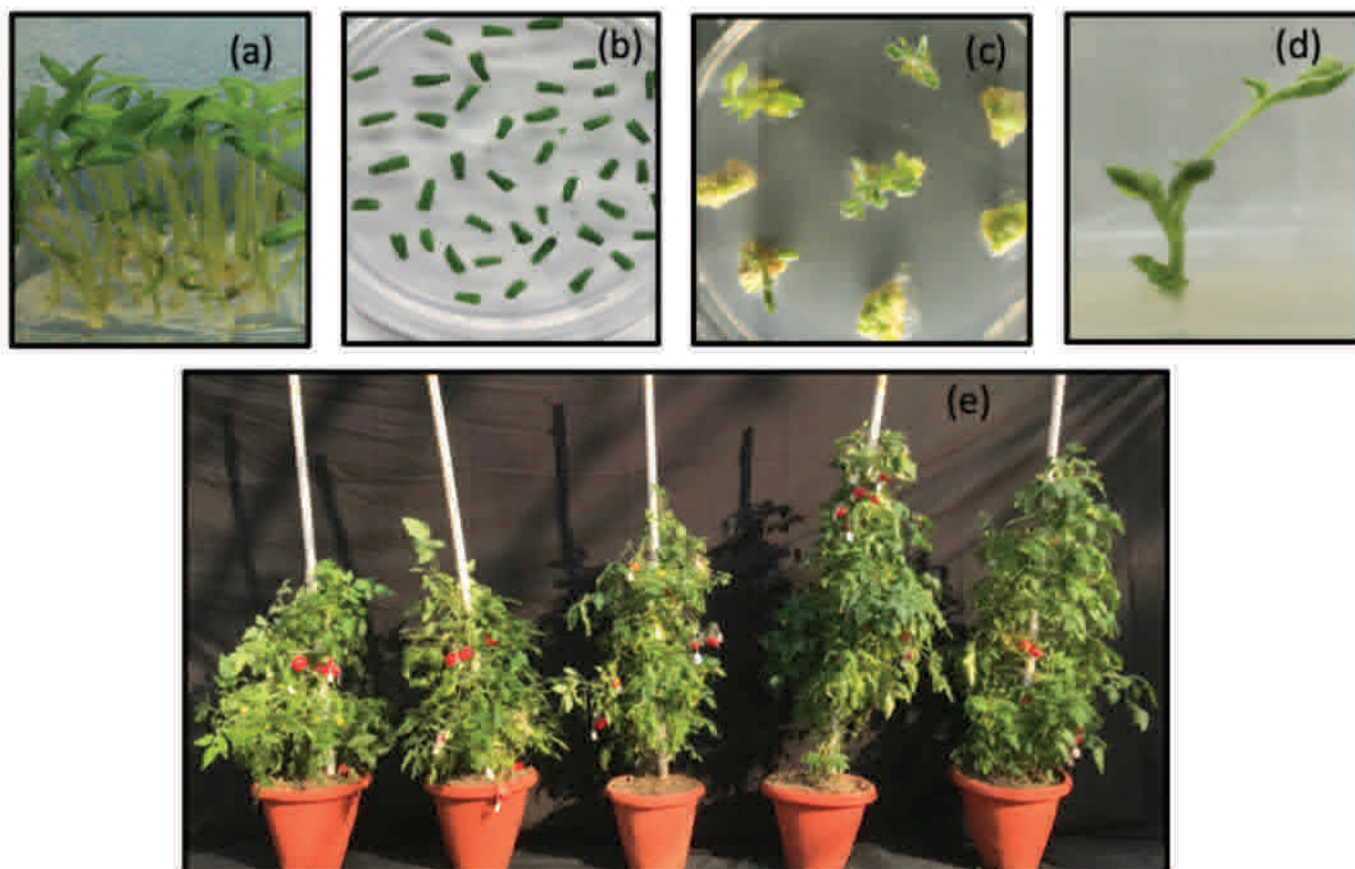


Fig. 2: Different stages of tomato transformation (A). Germinated seedlings, (B). Selection of transformed explants on hygromycin supplemented medium after *Agrobacterium*-mediated genetic transformation, (C). Callus with regenerating shoot buds growing on hygromycin supplemented medium, (D) Young plantlet, (E). Mature genome-edited tomato plants bearing fruit.

pRGEB31(Addgene) for α -Man and β -Hex and in pHSE401 for Solyc04g072150.2 and Solyc12g056780.2. The prepared constructs were transformed in *Agrobacterium tumefaciens* LBA4404 strain through electroporation. Plants are being developed with regular subculture (Fig 2) and simultaneous screening with Cas9 PCR and later PCR- based identification of insertions or deletions was analysed using Guide-it™ Mutation Detection Kit. All the amplicons are sent for Sanger sequencing for further confirmation of indels.

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Deciphering arsenic metabolism in rice: functional genomics and biotechnological intervention to reduce grain arsenic in rice; *in-vitro* culture of different ornamental and medicinal plants

A tau class Glutathione-S-transferase (OsGSTU5) confers tolerance against arsenic toxicity in rice by accumulating more arsenic in root.

Arsenic (As) toxicity has now become a global menace. Rice is a staple food in Asia but unfortunately had a higher risk of As uptake compared to the other crops. The hazardous effect of As on rice ultimately affects human health by consuming contaminated rice products. To study the differential regulation of As responsive genes we previously performed the genome-wide analysis of rice under As toxicity and identified one tau class glutathione-S-transferase (OsGSTU5) up-regulated in roots. Plant GSTs (EC 2.5.1.18; GSTs) are a group of enzymes that serve as stress signaling proteins and confer tolerance against various abiotic and biotic stresses. We analyzed the relative expression of *OsGSTU5* in rice under As toxicity and found a positive correlation between *OsGSTU5* transcript upregulation and As toxicity. Here we functionally characterized the role of OsGSTU5 using the heterologous and homologous systems. OsGSTU5 transformed bacterial cells showed enhanced resistance and better survival under As toxicity in bacterial cells compared to the empty vector (EV) transformed cells. The growth assay also confirmed that OsGSTU5 transformed bacterial cells had better growth parameters compared to the EV under As toxicity. To see the effect of OsGSTU5 in rice we have generated two contrasts in rice- one with over-expression (OE) and the other with knock-down (KD) OsGSTU5. To prepare a knockdown construct, an artificial microRNA (WMD3) tool was utilized. Both OE and KD constructs were placed under the regulation of monocot specific Ubi-Maize

promoter. Both OE and KD lines were confirmed by detecting the GSTU5 protein with anti-GST antibody in a western blot analysis, the OE lines with higher GSTU5 protein, and KD lines with negligible GSTU5 proteins were used for detailed analysis. The over-expression of *GSTU5* in rice showed better tolerance by improving the plant antioxidant system and as well as physiological activities. In contrast, the knocked-down *GSTU5* rice showed compromised physiological activities due to higher ROS production and lesser ROS scavenging system under As stress. The better tolerance capacity of OE lines was due to higher As sequestration in the root by utilizing *OsABCC1* vacuolar transporters. In contrast, the down-regulation of *OsABCC1* and up-regulation of *Lsi2* and *Lsi6* transporter in KD lines suggested a higher As transport in shoot and thus become sensitive during As stress. In addition, treatment with buthionine sulfoximine (BSO) confirms that arsenic chelation occurs in catalytic manner in rice via GSTU5. Thus, GSTU5 chelates the As in rice roots and blocks its upward translocation in the shoot, as a result, the OE lines showed better tolerance than the KD lines (Fig. 1). In conclusion, GSTU5 can be utilized as a suitable target to improve the As tolerance in rice plants.

A novel rice small heat shock protein, (OsHSP20) alleviates arsenic toxicity and its accumulation in rice grains

Plants have evolved various mechanisms to prevent disruption of protein homeostasis by maintaining protein to be functional in their native form and to prevent aggregation of non-native proteins. Hsps also termed as chaperones and stressed induced

proteins are the major components involved in protein folding, assemblage, translocation and breakdown under normal cellular processes and stress conditions. Earlier, none of the Hsps have been functionally characterized in As tolerance. In order to eradicate the problem of As stress and accumulation in rice, our study focussed on the small Hsp

(*OsHsp20*) from rice which has earlier been reported to have up-regulated in As response. In the present study the functional characterization of *OsHsp20* had been done by its over-expression and by artificial gene silencing in rice. The results manifested that under As stress, *OsHsp20* over-expressed (OE) plants showed better germination and growth parameters

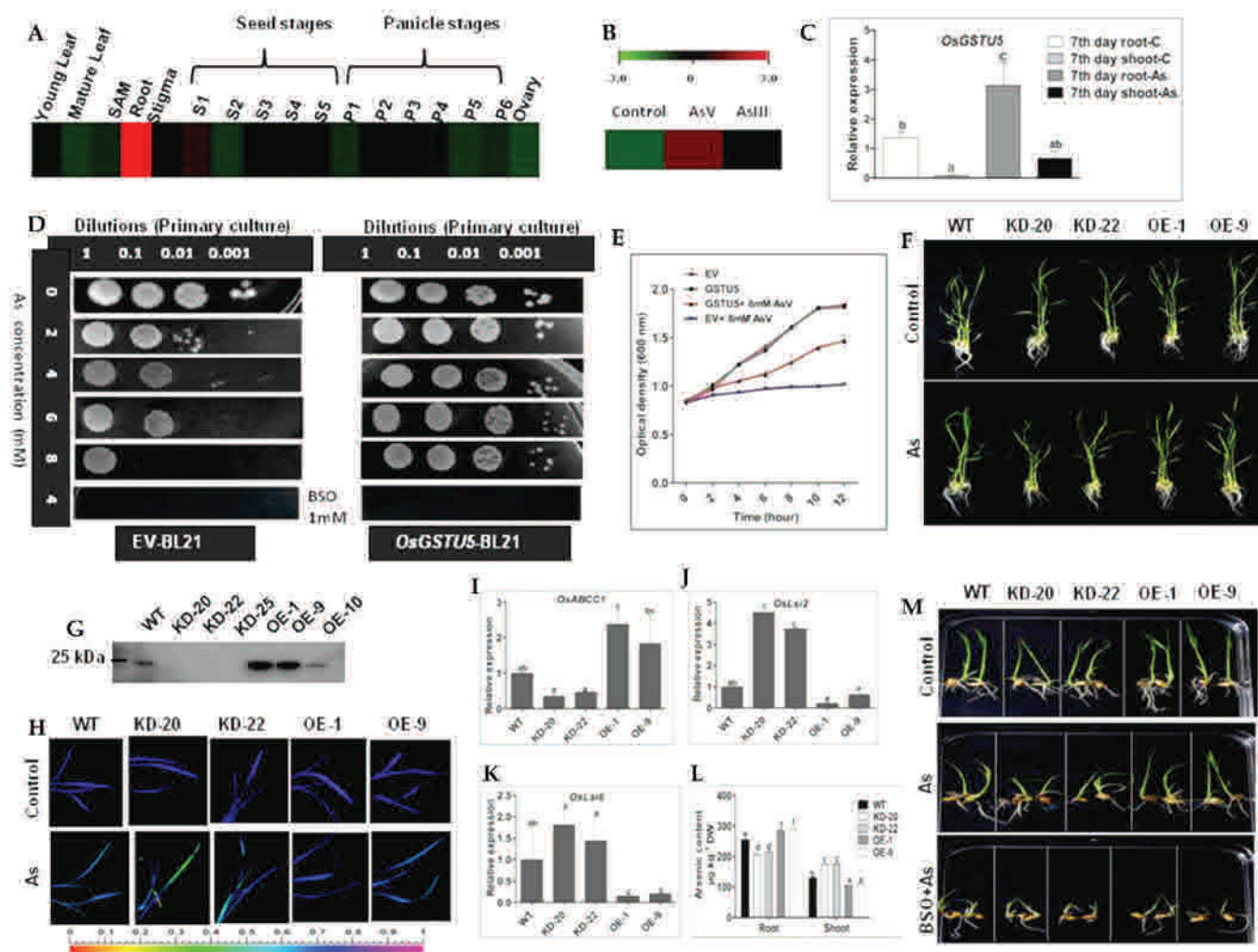


Fig. 1: (A) Cluster display of *OsGSTU5* expression profile in various developmental tissues of rice by using Affymetrix Rice Genome Array, (B) Cluster display of *OsGSTU5* expression profile in rice under sodium arsenate (AsV) and sodium arsenite (AsIII) stress. The colour scale representing the signal values is shown above, (C) Quantitative real time PCR showing relative expression of *OsGSTU5* gene in root and shoot under control and sodium arsenate (Na_3AsO_4 ; AsV) ($250 \mu\text{M}$) treatment after 7 days, (D) Growth pattern of EV and GSTU5 transformed bacterial cell under sodium arsenate (Na_3AsO_4 ; AsV) stress with and without BSO treatment, (E) Growth curve of EV and GSTU5 transformed bacterial cell with 8 mM sodium arsenate (Na_3AsO_4 ; AsV), at different time intervals (0, 2, 4, 6, 8, 10, 12 hours), (F) Morphological difference of WT, OE and KD lines were treated with $250 \mu\text{M}$ of sodium arsenate (Na_3AsO_4 ; AsV) for 7 days, (G) Western blot showing GSTU5 protein detected with anti-GST antibody in Wild type (WT), KD and OE lines under control condition. (H) Comparative fluorescence response WT, KD and OE lines under control and sodium arsenate (Na_3AsO_4 ; AsV) for 7 days. WT, OE and KD lines were treated with $250 \mu\text{M}$ of sodium arsenate (Na_3AsO_4 ; AsV) for 7 days and analyzed for relative expression of (I) *OsABCC1* in root, (J) *Lsi2* in root and (K) *Lsi6* on sheath base, (L) Arsenic accumulation in root and shoot by ICP-MS, (M) Morphological difference of WT, KD, and OE seedlings under control, 100 mM Buthionine sulfoximine (BSO), $250 \mu\text{M}$ of sodium arsenate (Na_3AsO_4 ; AsV) +100 mM BSO treatments. Values are mean \pm SE (n=3).

than WT, whereas its knockdown lines (amiRNA) had retarded growth and this shows that the over-expressed plants are tolerant to As stress. In addition, *OsHsp20* over-expressed plants showed higher PRX and SOD activities, and accumulated less H_2O_2 than WT and knockdown plants, whereas lower antioxidant activities and high H_2O_2 was observed in knockdown plants. This showed that over-expressed plants were tolerant to As stress due to the high antioxidant activity which plays role in ROS detoxification. Results of As accumulation in WT, OE, and knockdown demonstrated that OE-Hsp20 accumulated less As than WT and knockdown, whereas knockdown plants accumulated the highest As among all three types of plants (Fig. 2).

Low As accumulation in OE is probably due to the involvement of *OsHsp20* in maintaining protein homeostasis.

Growth, phytochemical and gene expression profiling for the selection of an improved prickless variety of *Solanum viarum*-Nishkantak

Solanum viarum Dunal (Synonym: *S. khasianum* C. B. Clarke var. *chatterjeeanum* sen gupta), is an important medicinal plant widely used as a source of raw material for the steroidal drug industry. The medicinal value of this plant mainly attributed due to the presence of bioactive steroids and alkaloids such

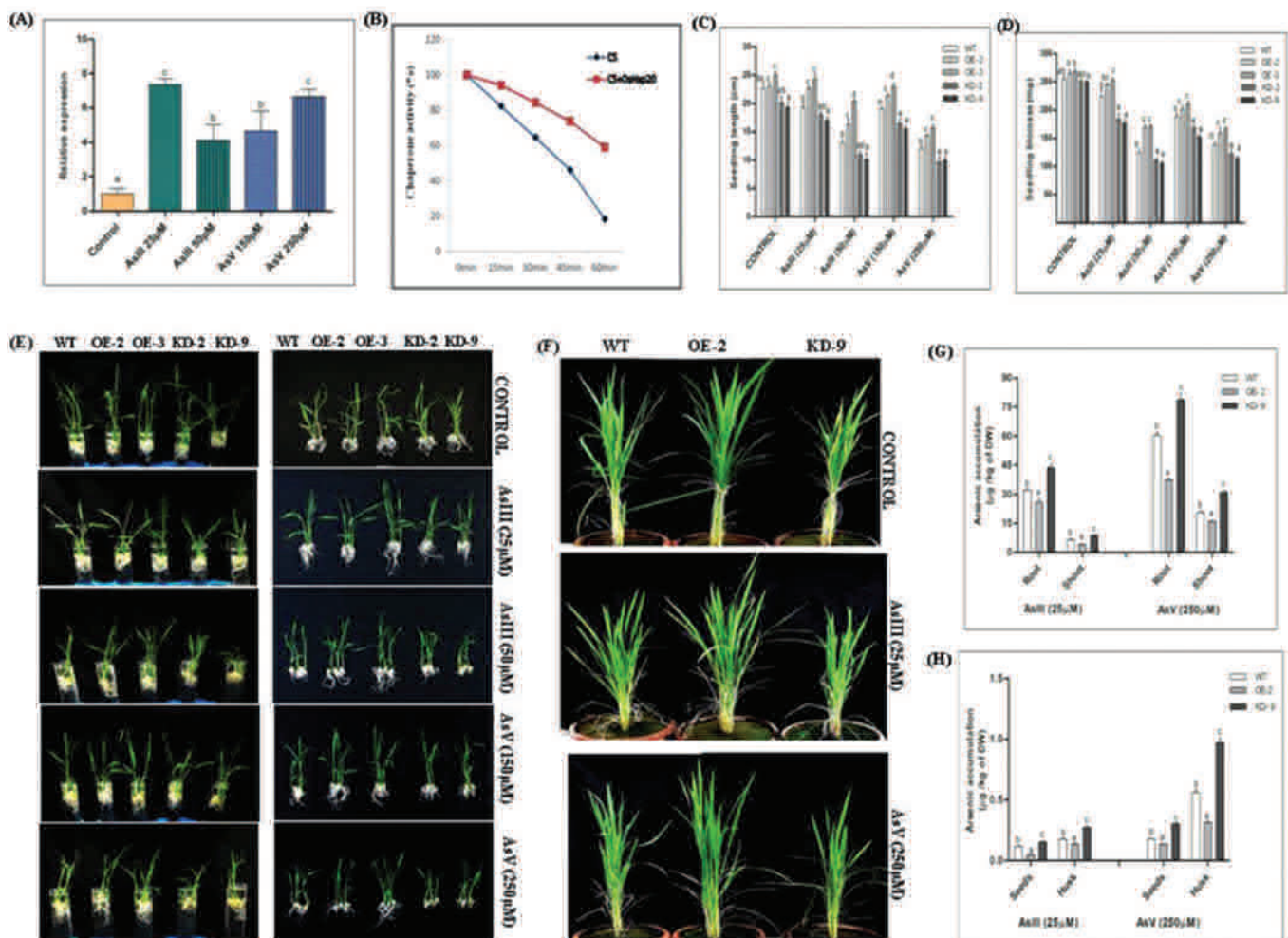


Fig. 2: (A). Gene expression analysis of *OsHsp20* in rice on different arsenic concentrations, (B). Chaperone activity of *OsHsp20* in *E. coli*, (C). Seedling length, (D). Seedling biomass, (E). Phenotype of twelve days old seedlings of WT, overexpression (OE) and knockdown (KD) *OsHSP20* transgenics under control and arsenic stress, (G). Simulated pot experiment to analyse the effect of arsenic on mature WT, overexpression (OE) and knockdown (KD) *OsHSP20* transgenics plants, (H). Arsenic accumulation in different tissues of WT, overexpression (OE) and knockdown (KD) *OsHSP20* transgenics plants.

as solasodine, α -solanine, solamargine, solanidine, etc. The aerial parts of plants are highly packed with large and sharp prickles. CSIR-NBRI has obtained a spontaneous mutant of the prickleless variety- 'Nishkantak'. This variety does not contain prickles throughout the year. In the present investigation, growth and phytochemical parameters of both prickled and prickleless germplasm were studied. Tissue-specific comparative analysis of growth and yield in two contrasting germplasms viz. prickled (wild) and prickleless (mutant) *S. viarum* was done under *in vitro* and field conditions. Quantitative analysis for the metabolites (alkaloids, glycoalkaloids, phenolics, flavonoids, and lignin) was performed for the selection of improved germplasm with better chemoprofile of in-demand metabolites. Significant variation in growth, yield and contents of glycoalkaloids, phenolics, and flavonoids were evident between two genotypes under *in vitro* and field conditions. Prickleless genotypes showed improved growth parameters in terms of nodes/plant, the number of leaves, roots biomass and etc than prickled plants both under *in vitro* and field conditions that help in contributing to higher yield over prickled plants. The tissue-specific chemical fingerprinting through high-performance liquid chromatography and gas chromatography/mass spectroscopy revealed that the leaves and roots of prickleless plants serve as a better repertoire for bioactive phytomolecules. The vegetative parts of *in vitro* grown 50-days old prickleless plants showed comparable/higher metabolite content than 7-8-month-old field-grown plants. Hence, the prickleless genotypes can be targeted for further

various multi-locational, multi-seasonal trials that enhance their utility in a wide range of commercial, selection, and breeding programs. The expression analysis of the genes involved in the regulation of important metabolite biosynthesis in both prickled and prickleless genotype of *S. viarum* were also examined. The diverse metabolite profiles are correlated with variations in gene expression profiles. This study provides information about the key metabolites and their biosynthetic pathway genes, which will be helpful for biosynthetic pathway modulation study and could be useful for the selection of an improved prickleless genotype ("Nishkantak") of *Solanum viarum*.

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Evolution of HPT in the Plant Kingdom

The two-component system (TCS), a molecular team, made up of 3 groups of genes: histidine kinase, histidine-containing phosphor-transmitter, and response regulators, is a crucial and one of the most conserved signaling cascade in plants. It plays a key role in ethylene and cytokinin signaling and affects many developmental as well as stress-responsive processes and pathways. Unlike their bacterial counterparts, this system shows a remarkable advancement in the form of an entirely new step of signal mediation through histidine-containing phosphor-transmitter proteins, which are absent in

most of the bacterial system. The question, that, why and how this small intermediate protein evolved in plants as independent group, is still not adequately answered. Although this system has been identified in a number of organisms and several other studies are available on the members of the two-component system, from bacteria to angiosperms; still, the mode of mechanism and role in regulating different biological processes is not very clear. This study explores and evaluates the histidine-containing phosphor-transmitter (HPT) and summarizes its involvement in functional and evolutionary aspects. A total of 5000 HPT representative sequences were

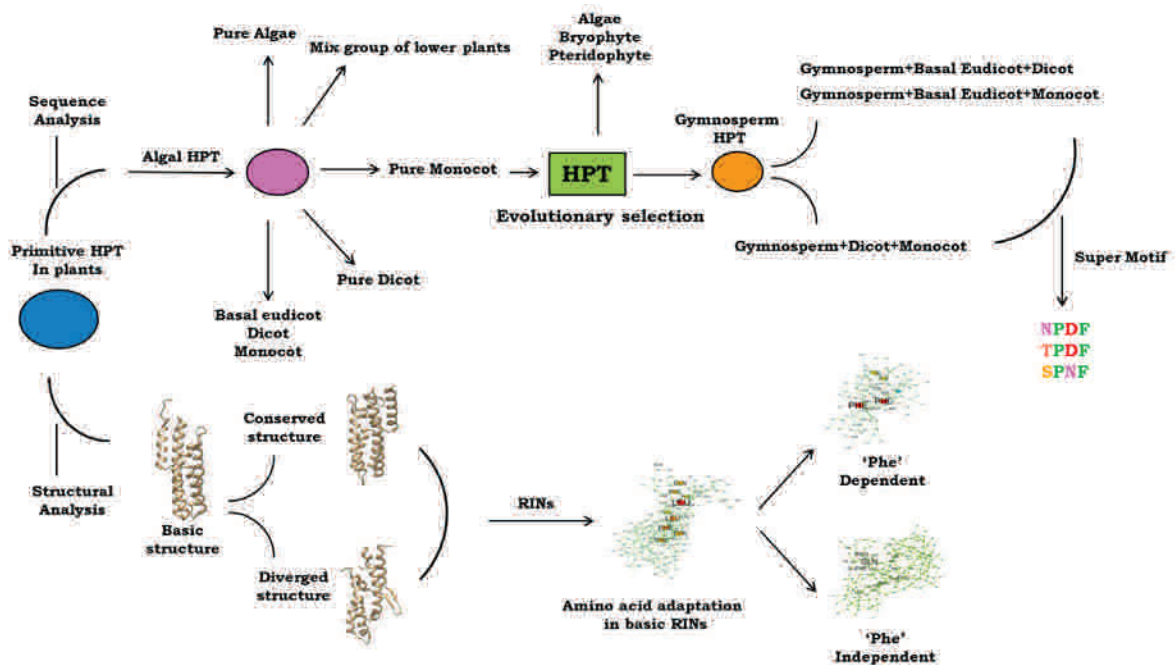


Fig. 1: Flowchart for the analysis of the HPT gene family in the plant kingdom.

identified and extracted from algae, bryophyte, pteridophyte, gymnosperm and angiosperms and subjected for detailed evolutionary analysis. Phylogenetic clustering showed the existence of 5 distinct groups in which 3 groups were pure and 2 were with mixed representative plants. This collectively indicate towards the evolutionary order, where from pure algae group, 2 mixed group arise, and they further developed the sequence signature for dicots and monocots. Phylogenetic splitting network indicated towards the further evolutionary process. It shows the signature splitting is initiated by algae, bryophyte and pteridophyte group but processed and forwarded by gymnospermic signature. It also indicated towards the parallel evolution of

some dicot and monocot HPT signatures mediated through basal eudicot representatives. There exist a number of combinations of super-motif signatures, which contain more than 30 representations in 6 classes. All of these motifs shows specificity towards specific groups but 3 motifs namely TPDF, SPNF and NPDF are more distributed. In these 3 motifs, NPDF motif is more stable and evolved signature. The structural central tendency of HPTs too shows selection of specific amino acid residue. Algal and bryophytic groups have different amino acid, but from pteridophyte the 'Phe' residue appears more frequently in other structures, thus structures can be characterized in 2 groups, 'Phe dependent' and 'Phe independent'. An overview of the results is presented in Fig. 1.

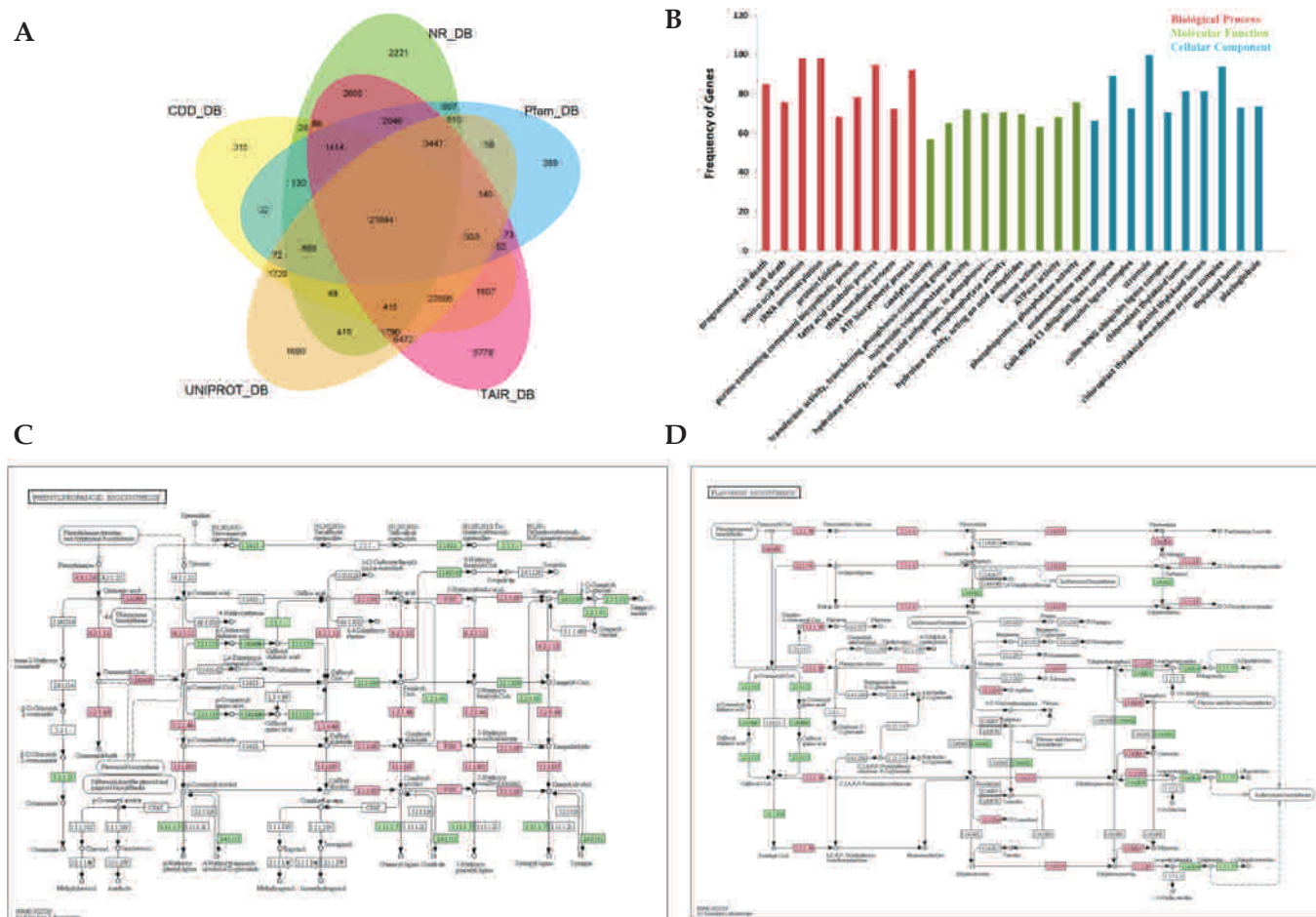


Fig. 2: Analysis of the *Psoralea corylifolia* transcriptome. (A). Venn diagram representing the annotation of transcripts from various databases. (B). GO functional characterisation of the annotated transcript, (C). Identification of genes involved in the Phenylpropanoid pathway (pink boxes represent genes identified in *Psoralea corylifolia*), (D). Identification of genes involved in the flavonoid biosynthesis pathway (pink boxes represent genes identified in *Psoralea corylifolia*).



Identification of secondary metabolite synthesis genes in *Psoralea corylifolia*

Psoralea corylifolia is an important medicinal plant of tropical and subtropical regions and produces various medicinally important phenylpropanoids in different plant parts. Illumina sequenced raw reads of psoralea leaf was pre-processed to check the quality and adapter contamination using FastQC. Total number of Raw reads were 46630634bp, after filtration the total number of high-quality reads were 43965447bp.

As there was no reference genome available *de novo* transcriptome analysis was performed using Trinity, resulting in total number of 150458 transcripts. The aligned transcripts were annotated against different database using BLAST such as TAIR10, NR, UniProt, CDD, Pfam, Glycine Max database (GMX_DB), having total of 76524, 38597, 68064, 57406, 32746 and 83598 unigenes respectively. Maximum annotation was observed using Glycine max database. Functional annotation performed to assign function to each unigenes generated from

combined assembly, gene ontology (GO) analysis was performed using AgriGO database involved in Biological Process (BP), Molecular Function (MF), Cellular Component (CC) (Fig. 2 B). The assignments of polypeptides encoded by the unigenes generated from assembly were mapped into various metabolic pathways according to the Kyoto Encyclopedia of Genes and Genomes (KEGG) involved in MEV and MEP pathways. Annotation results were used for identification of transcription factors and their gene families using Plant Transcription Factor Database (PFTDB), GenFam Database respectively. Most of the genes involved in phenylpropanoid pathway and flavonoid biosynthesis pathways were identified (Fig. 2C & D).

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Computational biology, genomics

Identification of genome-wide targets and DNA recognition sequence of the Arabidopsis HMG-box protein AtHMGB15 during cold stress response

The High Mobility Group (HMG) of proteins are the group of architectural proteins involved in modulating chromatin structure and organizing the efficient participation of other proteins in various nuclear activities such as transcription, replication and DNA repair. AtHMGB15 belongs to a group of AT rich interacting domain (ARID)-HMG proteins which are plant specific. Using ChIP-chip approach, we have identified 6128 and 4689 significantly ($p < 0.05$) enriched loci having AtHMGB15 occupancy under control and cold stressed (4 °C, 2 h) condition respectively (Fig. 1 A, B). AtHMGB15 interacts with TFs belonging to DREB, MYB, bHLH, WRKY and NAC and signalling proteins like Ca²⁺ binding proteins (Fig. 1C). The probes corresponding to these genes were classified as intergenic (promoter and downstream) or gene body probes depending upon the location of the probe from the nearest annotated TSS (Fig. 2A). To check the probe binding intensity over the genome, significant probes of control and cold datasets were visualized over the Arabidopsis genome in a 2Kb window on either side of the gene body. The results, from the mapping of AtHMGB15 enriched probes with respect to transcription start and end sites, showed a wide distribution within a 2 kb window with a marked enrichment of AtHMGB15 binding within transcribed regions. Interestingly, higher AtHMGB15 binding was observed in the gene body compared to promoter/upstream region for cold treated sample compared to control (Fig. 2B). Our TSS/TES plot results also show a wide distribution of

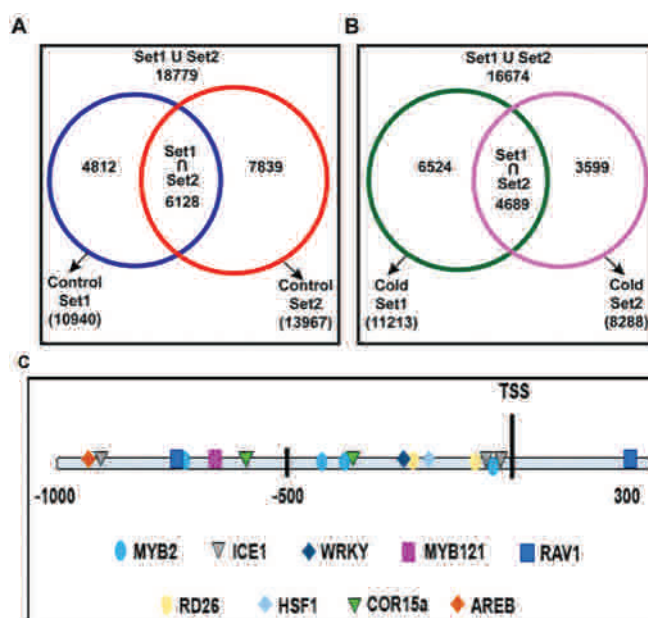


Fig. 1: Venn diagram showing the number of genes associated with the binding of AtHMGB15 in replicate sets 1 and 2 under (A). control condition, (B). cold stressed, (C). Schematic representation of transcription factors binding sites at the promoter/upstream region of AtHMGB15 gene.

AtHMGB15 binding with increment within transcribed regions which may be associated with a role played by it in transcriptional initiation (promoter clearance) and elongation. Moreover, the increase in enrichment of AtHMGB15 in the transcribed region during cold in comparison to control condition indicates at the role played by the protein in transcriptional regulation during stress response. A circos plot was used to see the correlation between the genome-wide distribution of AtHMGB15 enriched DNA sequences, euchromatic regions and DNase1 hypersensitive sites (DHS) in Arabidopsis genome (Fig. 2C). Genome

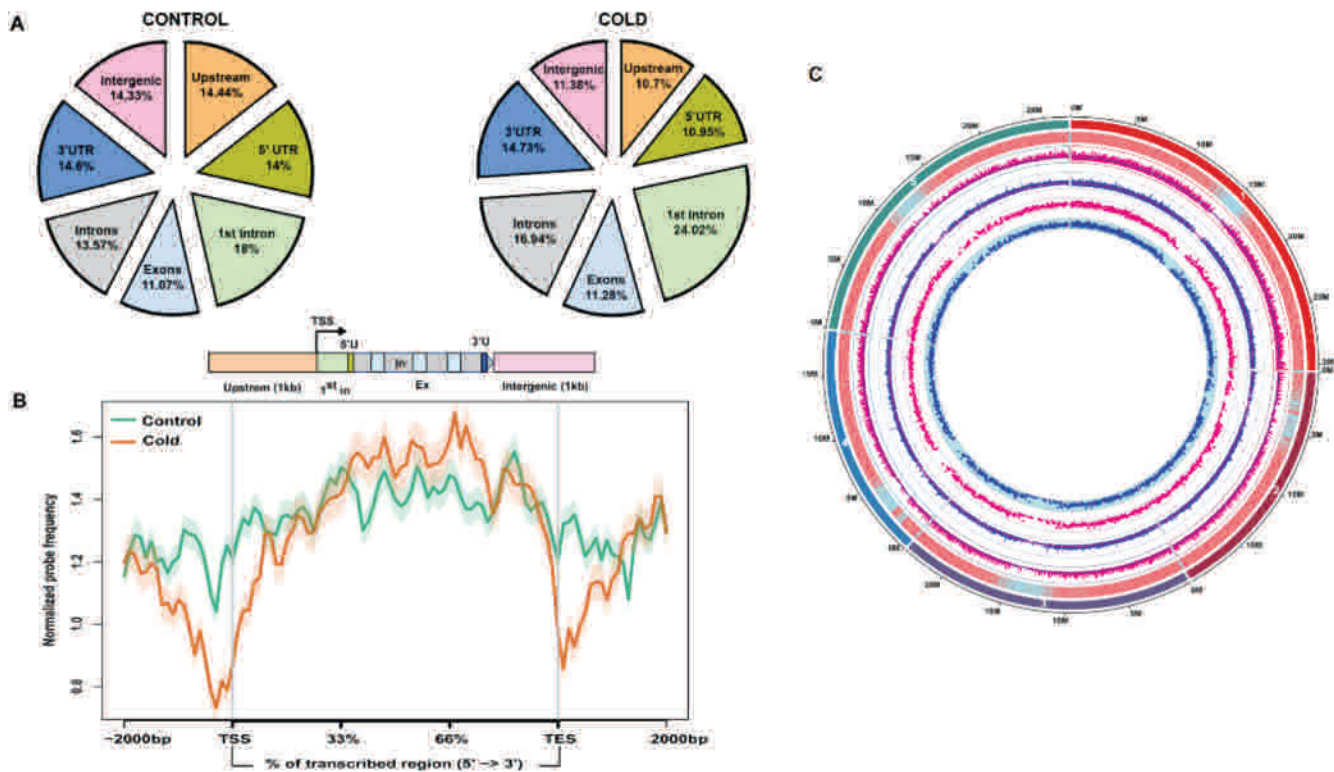


Fig. 2: Probe distribution of *AtHMGB15*. (A). Pie chart showing the probe distribution of *AtHMGB15* binding with respect to gene structure (intragenic and intergenic regions) under control and cold conditions. (B). A plot showing the normalized frequency of occurrence of binding sites of *AtHMGB15* depicted across the promoter regions. (C). Circos plot representing the genome-wide occupancy of *AtHMGB15*. The outermost ring identifies the chromosome numbers. The other rings from outer to inner represent: Gene distribution; *AtHMGB15* binding under control condition; cold condition; DHS score under control condition; DHS score under cold condition.

wide studies have shown enrichment of chromatin architectural protein HMGB1 at up-stream as well as downstream of TSS; suggesting its association with transcription initiation as well as elongation. The presence of binding sites for various stress induced transcription factors at the promoter of genome-wide binding profile of *AtHMGB15* and the cold

induced induction of *AtHMGB15* paved the way for identification of a novel role of *AtHMGB15* in plant stress response.

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Epigenetic regulation of plant response towards environmental change using natural populations of Indian *Arabidopsis thaliana*

Understanding plants' response towards changing environment still remains to be the goal of the plant biologists. This has become more important considering the present and expected future climate change scenario and demand to feed the growing world population. The accelerated climate change may force plants to adapt to the changing environment. Until now, only genetic factors were considered to reveal the underlying mechanisms involved in plant adaptation, but we focus on exploring epigenetical factors by studying the natural populations of *Arabidopsis thaliana* those are growing along the steep

altitudinal gradient ranging from 600 m amsl to 3400 m amsl of the Himalayas.

Characterization of a non-conserved microRNA miR775 in *Arabidopsis thaliana*

MicroRNAs (miRNAs) belong to a class of small RNA of 20-24 nucleotides in length. In the past two decades, biological relevance of numerous miRNA in plants has been deciphered in detail. However, majority of studies are focused on ancient miRNAs that are conserved across diverse plant species.

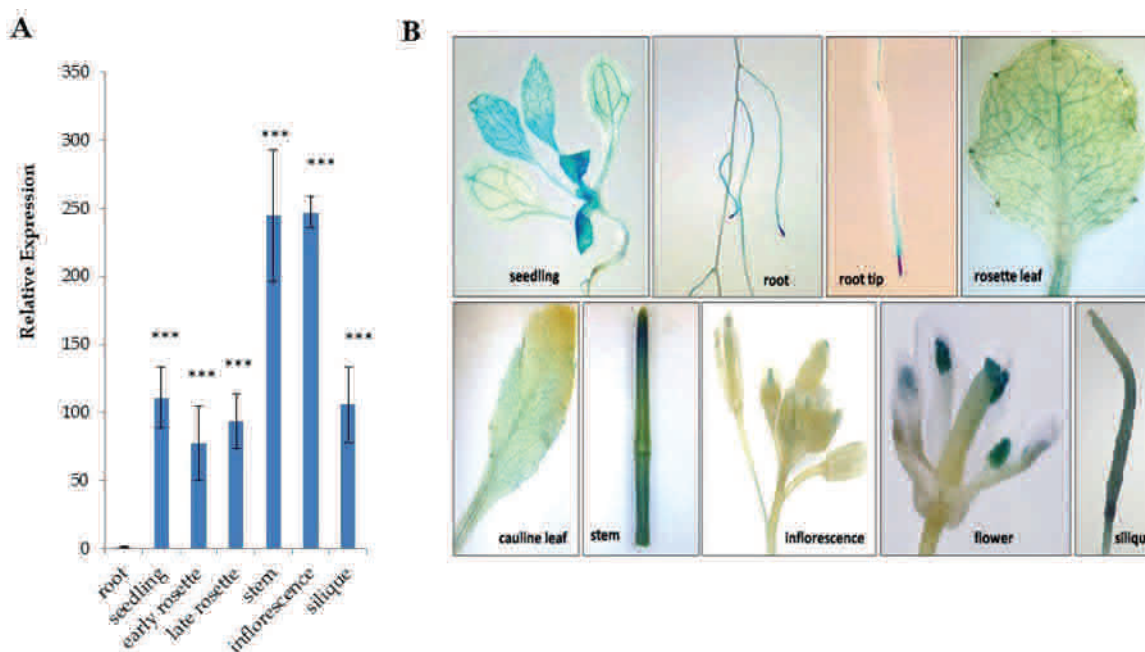


Fig. 1: Characterization of miR775 in *A. thaliana* (a) Relative expression of miR775 in different tissues of WT Col-0 as determined by qRT-PCR. Data represents mean of three replicates \pm SE, *** indicate values which were significantly different at P value <0.001 (Student's t -test). (b) Histochemical GUS staining in different tissues of *MIR775PRO-GUS* transgenic lines.

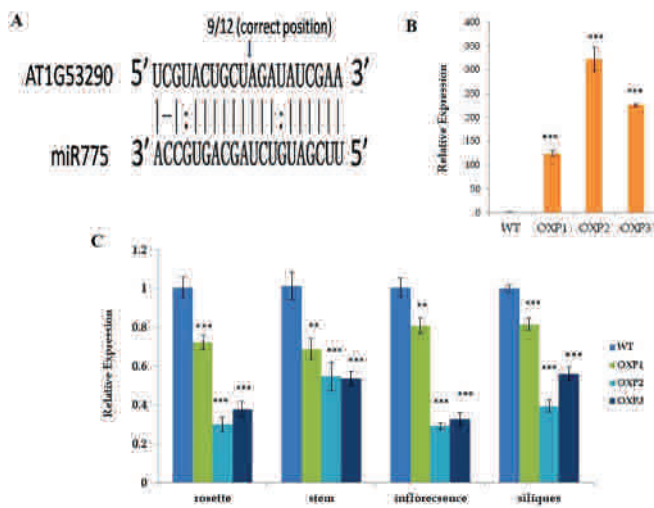


Fig. 2: Target of miR775 (a) Cleavage of AT1G53290 mRNA by miR775 as detected by modified 5'RLM-RACE is shown. The fraction of clones with cleavage at expected 5' end to the total number of clones sequenced is indicated above the target site. (b) qRT-PCR analyses of miR775 in rosette tissue of homozygous *MIR775*OXF lines and WT (c) qRT-PCR analyses of *galactosyltransferase* target gene (AT1G53290) in rosette, stem, inflorescence and siliques of homozygous *MIR775*OXF lines and WT. Data is a mean of three replicates \pm SE. **, *** indicate values which were significantly different from WT at P value <0.01 , <0.001 respectively (Student's t -test).

miR775 is one such young miRNA and we report here characterization of miR775 in *A. thaliana*.

We examined the expression pattern of miR775 in different tissues of *A. thaliana* using qRT-PCR. Expression of miR775 was detected in all the

examined tissues including seedling, root, rosette leaf, cauline leaf, stem, flower and silique. However, expression of miR775 was relatively higher in stem, siliques and inflorescence as compared to other tissues, while in roots its expression was the least (Fig. 1a). The promoter of *MIR775* was cloned in fusion with *GUS*. The *GUS* expression was observed in various tissues at different developmental stages (Fig.1b). *GUS* expression was largely confined to hypocotyls, petiole, root tips and veins of young leaves, adult rosette leaf and cauline leaf. Based on *in silico* target prediction analyses, the target of miR775 was validated using modified 5'RLM-RACE and it identified the gene encoding *GALT* protein (AT1G53290) as the only target of miR775 (Fig. 2a), confirming cleavage of *GALT* transcript by miR775. The transgenic lines over expressing *MIR775* (*MIR775*OXF) under the constitutively expressed CaMV35S promoter were developed and analyzed. qRT-PCR analysis exhibited more than 100 fold higher expression of miR775 as compared to the WT (Fig.2b). Subsequently, we determined the expression of *GALT* in different tissues of the *MIR775*OXF lines. qRT-PCR analyses suggested expression of *GALT* was down regulated in all the OXF lines as compared to the WT, in all the examined tissues (Fig. 2c). As expected, the OXF line having less expression of miR775 exhibited minimum target down regulation.

Further, *In-silico* analysis of *MIR775* promoter revealed the presence several regulatory motifs including light, hypoxia etc. However, when we

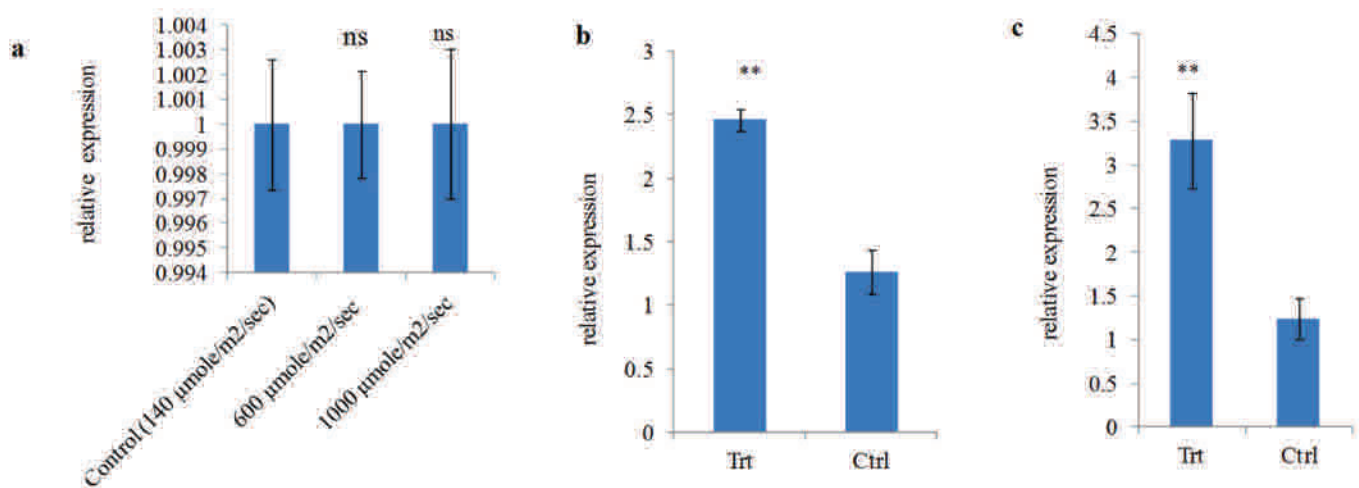


Fig. 3: Expression of miR775 in response to environmental variables (a) after 1 hour of high light treatment (b) after 1 hour of UV-B treatment (c) after 3 hours of treatment with mitochondria inhibitors, Antimycin A and Salicylhydroxamic acid. Data is a mean of three replicates \pm SE. ** indicate values which were significantly different from control with P value <0.01 (Student's t -test), ns indicates non-significant variation with respect to control.

exposed the WT plants to high light conditions ($600\mu\text{mol}/\text{m}^2/\text{s}$ and $1000\mu\text{mol}/\text{m}^2/\text{s}$) for one hour, we could not detect any significant difference in expression level of miR775 (Fig. 3a), ruling out any significant role of miR775 in high light driven regulation. Further, considering the prevalence of UV-B in high altitude area and some of the light responsive elements are UV-responsive (like the ACE present in promoter of *MIR775*), expression of miR775 was analysed from UV-B treated plants. Interestingly, a significant increase in the expression of miR775 was observed in post UV-B treated plants (Fig. 3b). Subsequently, we tested the expression of miR775 under hypoxic condition by treating the plants with mitochondrial respiratory inhibitors. The data suggested that treatment with mitochondrial inhibitors led to an increase in miR775 level (Fig.3c). We also determined the level of hydrogen peroxide under hypoxic conditions in WT, *MIR775*OXP and target mutant. After six hours of treatment with mitochondrial inhibitors, hydrogen peroxide accumulation was more in the target mutant and *MIR775*OXP as compared to the WT. This suggests that reduced level of the target gene in both target mutant and *MIR775*OXP promotes hydrogen peroxide accumulation in response to hypoxia.

To determine the role of miR775 in plant growth and development, WT, *MIR775*OXP and target mutant plants were phenotypically characterized. The rosette area was significantly higher in the *MIR775*OXP and

the target mutant as compared to WT, 20 days post-germination. This was mainly due to expanded leaves with elongated petiole in *MIR775*OXP and target mutant as compared to the WT. The rosette area of the target mutant was higher than the *MIR775*OXP. There were no significant variations in bolting time, plant height or total number of siliques in the target mutant and *MIR775*OXP as compared to WT. These results indicate prominent effect of miR775 in influencing rosette size, but relative miR775/target stoichiometry may not favour its tight regulation of reproductive traits.

We describe the functional significance of miR775, an evolutionary young miRNA that targets a probable β -(1,3)-galactosyltransferase. Both, miR775 and its target gene are ubiquitously expressed having a more pronounced role during vegetative growth leading to increased rosette area. Increased expression of miR775 under UV light and hypoxia intuitively suggest it might aid in high altitude adaptation of plants, since these are more prevalent in these area.

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Genetic transformation of crop plants, drought and *Fusarium* wilt stress in chickpea, and insect resistance in cotton

Our research is focused on two broad areas:

Drought stress tolerance in chickpea: Drought is the most important yield-limiting factor of chickpea as most important growing areas are in the arid and semi-arid zones. Because of the heavy production losses caused by drought, it remains the foremost and biggest challenge that needs to be addressed for increasing the chickpea production.

Chickpea–*Fusarium* interaction and fusarium wilt tolerance in chickpea: Chickpea production is mostly affected by vascular wilt disease due to fungus *Fusarium oxysporum f. spiciferis*. *Fusarium* can cause chickpea yield loss up to 90% worldwide. *Fusarium* is soil or seed-borne and difficult to manage by crop rotation and fungicides application.

The group has been mainly working on the identification and characterization of chickpea genes for the development of abiotic and biotic stress tolerant transgenic chickpea plants.

Development of Chickpea transgenic for drought tolerance

We have previously cloned three highly up-regulated DRGs, namely *CaCYP*, *CaMTD*, and *CaWAT1*, in the pBI121 vector and overexpressed in chickpea genotype “DCP92-3” through *Agrobacterium tumefaciens* mediated transformation. Molecular analyses of chickpea T2 lines were performed using PCR (Fig. 1), qRT-PCR, and Southern blotting. Three highly expressing transgenic lines each of *CaCYP* (*CaCYP*#1, *CaCYP*#4, and *CaCYP*#10), *CaMTD* (*CaMTD*#2, *CaMTD*#7, *CaMTD*#11), and *CaWAT1* (*CaWAT1*#1, *CaWAT1*#3, *CaWAT1*#6)

were selected for further analyses of drought related parameters. Kanamycin-resistant transgenic chickpea T2 seedlings were transferred to soil mixture and grown for 30 days. To examine whether the over-expression of *CaCYP*, *CaMTD*, and *CaWAT1* in chickpea affects the expression of genes involved in the response of plants to drought stress, we analyzed the expression levels of some genes, namely *CaSOD*, *CaCatalase*, *CaAPX*, and *CaGRX*, using qRT-PCR (Fig. 2). The expression levels of these stress responsive marker genes were found to be very low in the transgenic and WT plants under well-watered condition. However, the expression of all these genes was induced in the transgenic lines and WT plants under drought stress. Overall, the expression levels of these stress related genes were found to be higher in *CaMTD* transformed plants compared to their respective levels in *CaCYP*, *CaWAT1*, and WT plants under drought stress condition. Assessment of physiological drought tolerance of transgenic chickpea plants was carried out in pots in transgenic

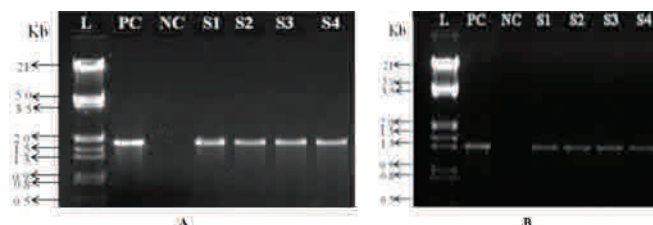


Fig. 1: PCR amplification of DEGs using genomic DNA isolated from T2 transgenic chickpea lines using forward primer against CaMV35S and gene specific reverse primer. L: DNA ladder; PC: positive control; NC: negative control; (A): S1–S4 are samples from *CaCYP*-over-expressing lines; (B): S1–S4 are samples from *CaMTD*-over-expressing lines. The amplicon size is 1776 bp and 1349 bp, respectively.

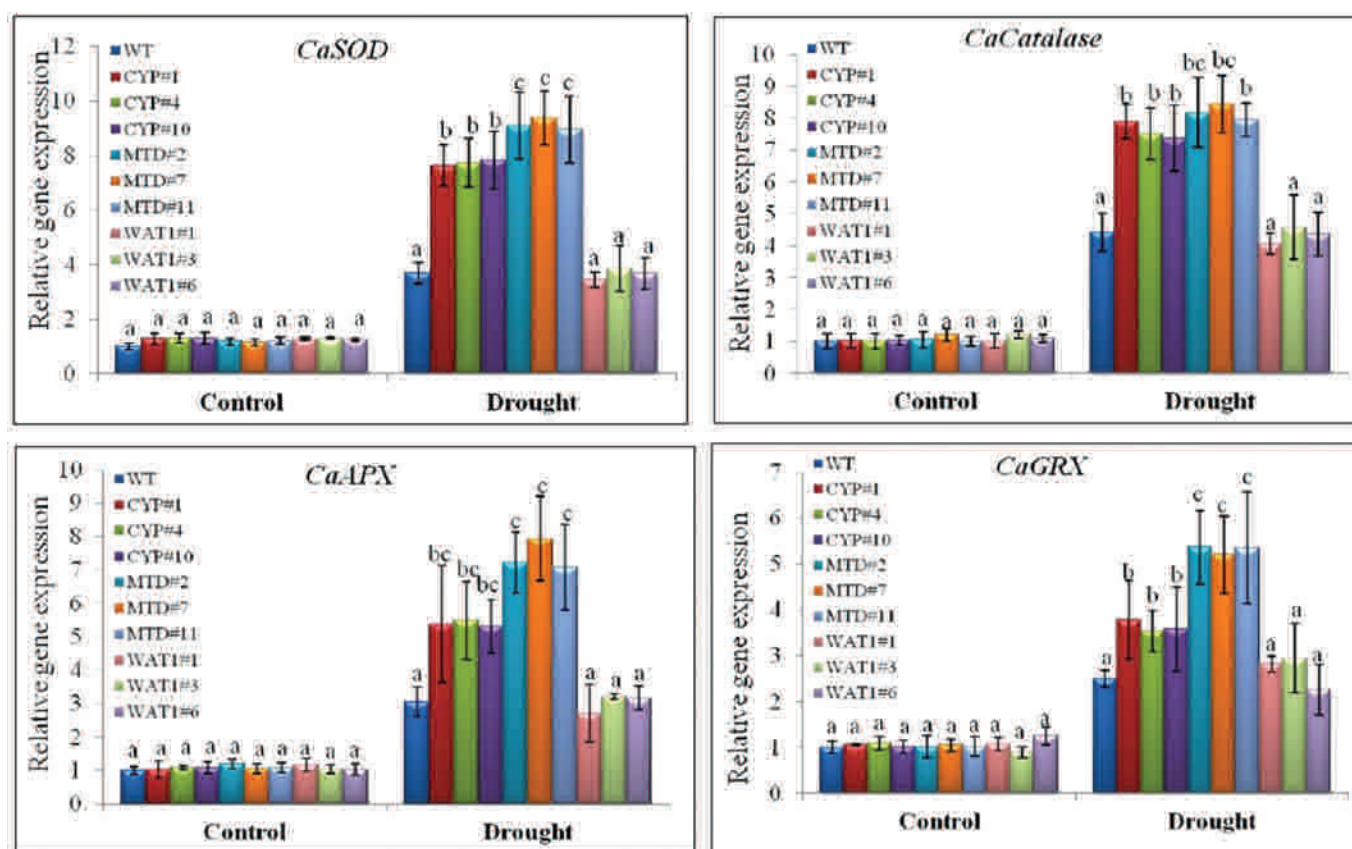


Fig. 2: Expression of *CaSOD*, *CaCatalase*, *CaAPX* and *CaGRX* in different chickpea lines under control and drought conditions.

containment facility (Fig. 3). These results suggest that *CaCYP* and *CaMTD* may participate in drought stress tolerance by regulating the expression of the stress-related genes during drought. However, *CaWAT1* is apparently not involved in the response of plants to drought.

Transcriptome profiling of chickpea under Fusarium wilt

To understand the molecular basis of wilt resistance in chickpea, we investigated xylem-specific RNA for the transcriptomes of wilt-susceptible JG-62 and wilt-resistant WR-315 cultivars under both *Fusarium oxysporum* sp. *ciceri* race2 (Foc2) challenged and unchallenged conditions. Total RNA having good RIN value was used for transcriptome sequencing. A total of 19,342 and 20,935 transcripts representing 16290 and 16442 genes loci were generated in JG62 and WR315, respectively by reference-guided assembly with chickpea genome. This analysis revealed a total of 348 and 1,368 DEGs, among them,

131 and 233 genes were upregulated and 217 and 1,135 genes were downregulated in JG62 and WR315, respectively under fusarium wilt (Fig. 4). In resistant cultivar WR315, transcription factors (TFs) belonging to 53 and in susceptible cultivar JG62 40 different families were observed to be expressed which were represented by 681 and 236 differentially expressed gene loci, respectively by comparisons between control and *Fusarium* infection conditions. The qRT-PCR analysis of selected genes was done to validate the RNA seq data. Chickpea *GAPDH* gene was used as a reference gene for normalization. qRT-PCR and RNA-seq data showed a good correlation coefficient value of 0.804. Cloning and transformation of DE genes in *Fusarium* wilt susceptible cultivar JG62 is under process. This study provides comprehensive data on differential gene expression in chickpea genotypes with contrasting *Fusarium* wilt phenotype. This study provides a rich resource for functional characterization of the genes involved in resistance mechanism and their use in breeding for sustainable wilt-resistance.



Fig. 3: Drought tolerance assessment of transgenic chickpea overexpressing *CaCYP*, *CaMTD* and *CaWAT1* genes at reproductive stage.

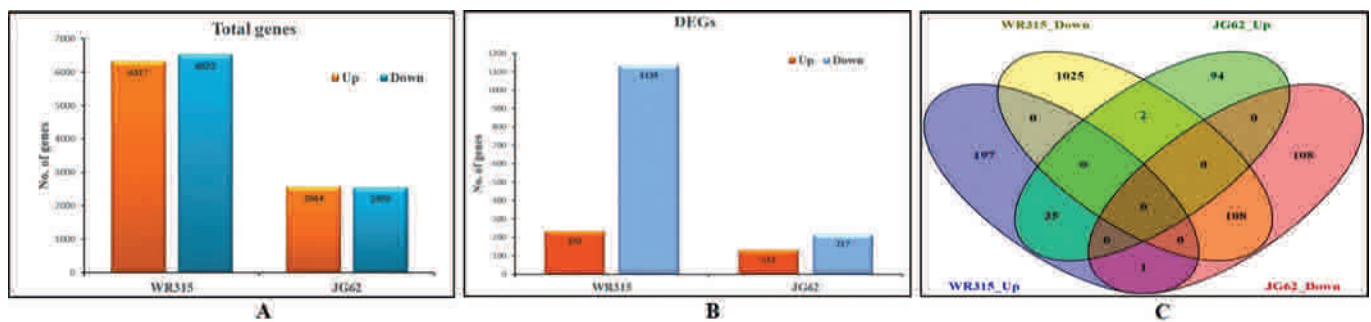


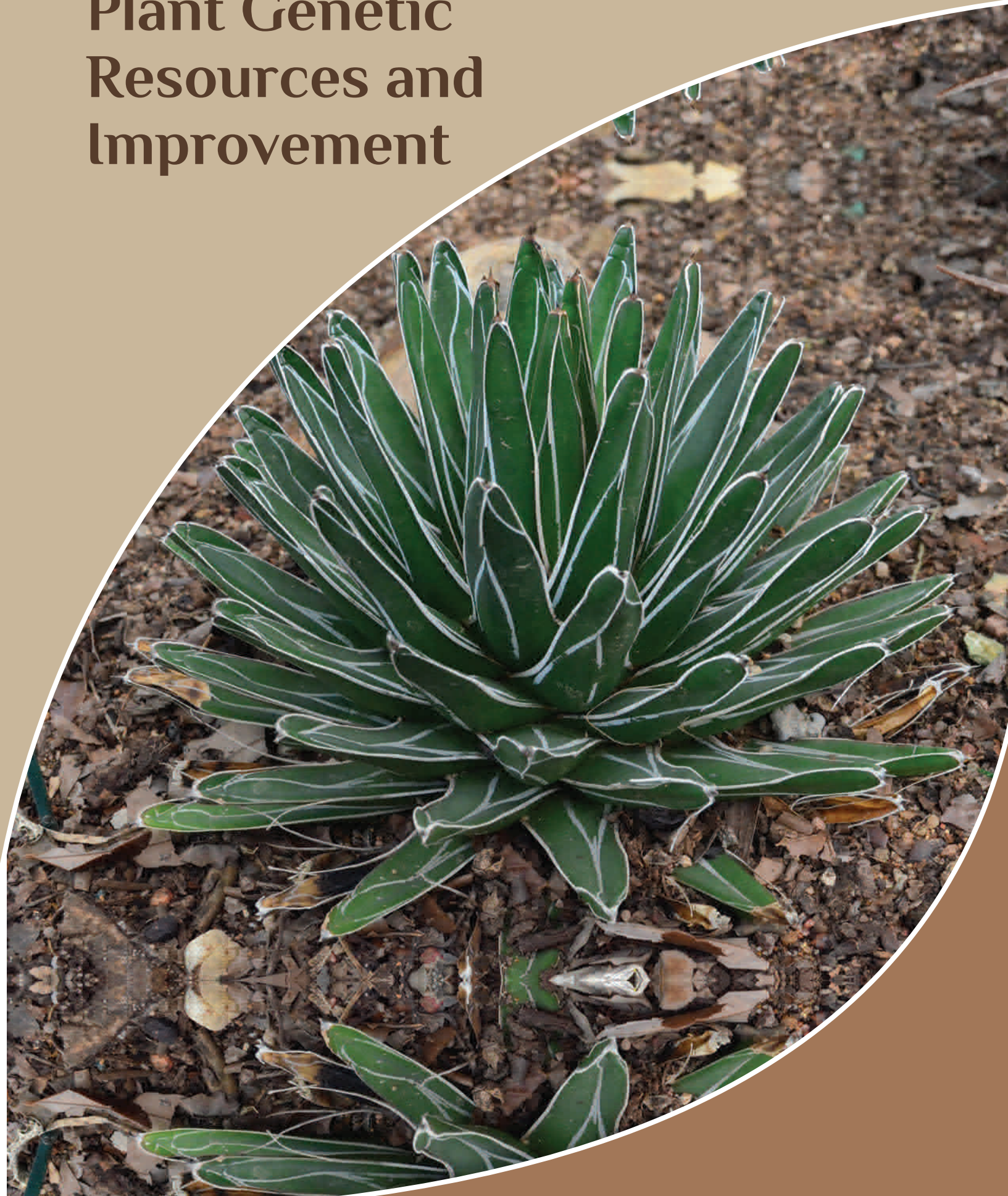
Fig. 4: Bar graph showing (A) Total no. of up and down-regulated genes (B) Differentially expressed genes and (C) Venn diagram showing number of differentially expressed genes in WR315 and JG62 under *Fusarium oxysporum* infection.

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Plant Genetic Resources and Improvement



PLANT GENETIC RESOURCES AND IMPROVEMENT

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Sr. No.	Position Name	Numbers
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2.	DST Women Scientist	01
3.	JRF/SRF Fellow	09
4.	Project Staff	18

Broad Areas of R&D

The group is working in the area of molecular markers, creation of genetic resources, linkage analysis, association mapping and genomics assisted breeding for varietal development in industrially important and orphan crops. Improvement, mainstreaming, domestication and sustainable utilization of these bioresources are the major thrust of this group.

R&D Highlights

Application of genetic and genomic tools for varietal development

- Screening and selection for different lines of the underutilized orphan legume winged bean (*Psophocarpus tetragonolobus*) on the basis of secondary metabolites is underway. Mature seeds of *P. tetragonolobus* contain 15-18% oil, similar to that of soybean. The amino acid composition of the flour from the seeds reported relatively high amounts of lysine, aspartic acid, glutamic acid and leucine and relatively low amounts of the sulphur-containing amino acids, a pattern similar to that of soybean.
- Genome-wide association studies (GWAS) of winged bean was carried out through Genotyping By Sequencing (GBS) for population structure and familial relatedness analysis. Total of 167845

tagpairs (335690 tags) were generated during the analysis process. A total of 80941 SNPs were identified. The analysis resulted in the discovery of 54 SNPs significantly associated with seed-protein traits and 88 SNPs with seed-oil traits in *P. tetragonolobus*.

- GWAS study was conducted in opium poppy with precise Opiod estimation and resulted in few key SNPs and their associated genes with thebaine pathways. A major initiative for improvement of *Cannabis* for low tetra hydrocannabinol (THC) and high Cannabidiol (CBD) has been undertaken with conventional and molecular breeding approaches.
- The chloroplast genome of *Lithocarpus dealbatus* has been assembled of size 161,476 bp. The genome consists of a large single-copy region (90,732 bp) and a small single-copy region (18,987 bp), separated by two inverted repeat regions (25,879 bp). The chloroplast genome contains 134 genes including 87 protein-coding genes, 39 tRNAs, and 8 rRNAs.
- The reference genome of *Linum usitatissimum* (L) (linseed) (IC 0526166) was prepared using Oxford Nanopore PromethION and Illumina platform. The SMART *de novo* assembly generated a total of 671 contigs with more than 10000 bp size. Three bi-parental mapping populations for elite quantitative traits have also been developed and progressed to F₃ generation leading towards formation of RILs. In addition to RILs, the generation advancement of MAGIC population had been made.
- Ethyl methane sulfonate (EMS) mediated TILLING (Targeting Induced Local Lesions IN Genomes) population of the cv. WAGAD of *Gossypium herbaceum* was developed for the functional genomics studies in diploid cotton. Genotyping-by-sequencing of 95 diverse M₃ plants selected from the TILLING population along with control was done for evaluation of nucleotide diversity.
- An attempt had been made to develop genetic and genomic resources in grain Amaranth for utilization under its crop improvement programmes. A total of 1165 accessions of grain amaranths were obtained from different centers of ICAR-NBPGR and have been grown at CSIR-NBRI garden field and Banthra Research Centre.



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Selection, improvement and mainstreaming underutilized plants for providing nutrition and economic security

Underutilized legumes with high-quality protein and calories need to be targeted for improvement. This will help to address the food and nutrition issues of the population. Selection of some ideal lines of winged bean (*Psophocarpus tetragonolobus*) on the basis of their nutritional profile is underway for registration.

Cultivar-selection of winged bean on the basis of nutritional profile

The fresh leaves, flowers, green pods, seeds and the tuberous roots of winged bean are rich in protein and are eaten either raw or cooked. When picked young, the pods lack noticeable fiber and make a succulent green vegetable. Selection for different lines of *P. tetragonolobus* on the basis of the number of secondary metabolites is underway.

Mature seeds contain 15-18% oil, similar to that of soybean. It has fairly good amounts of phosphorus and iron (Fig. 1A) and various vitamins (Fig. 1B). The amino acid composition of the flour from the seeds reported relatively high amounts of lysine, aspartic acid, glutamic acid and leucine and relatively low amounts of the sulphur-containing amino acids (Fig. 1C), a pattern similar to that of soybean. Nevertheless, there is variation amongst varieties and winged bean has greater amounts of some essential amino acids (valine, leucine, histidine, and lysine) than soybean. The fatty acid composition of winged beans is comparable to peanut (*Arachis hypogaea*, Fig. 1D) and it contains higher amounts of behenic and parinaric acid. Triglycerides showed a similar profile of fatty acids to those of whole lipid: the major fatty acids are

palmitic (10.9%), stearic (4.5%), oleic (37.1%), linoleic (19.0%), eicosenoic (3.6%), behenic (18.5%) and lignoceric (4.2%) acids. Compared to soybean and corn oil, winged bean oil contains long chain fatty acids and a fairly small amount of polyunsaturated fatty acids which is favorable for oil stability against auto-oxidation. Long chain saturated fatty acids, such as behenic and lignoceric acids, were found in relatively high amounts as compared with other edible seed oils. These findings indicate that winged bean seed is a good source of oil of favorable quality. Winged bean oil was found to contain tri-acylglycerols of larger ECN (Equivalent Carbon Number) value than soybean oil.

Proteomic profiling of winged bean root-tuber

The total proteome-analysis of the root-tuber of *P. tetragonolobus* was carried out on liquid chromatography-electrospray ionization tandem mass spectroscopy (LC-ESI-MS). These yielded proteins belonging to 154 families. Ninety six percent of these proteins were associated with biological, molecular and cellular activities. These proteins have the biological properties of conferring the root-tuber antioxidant and free-radical scavenging activity. Small heat-shock proteins (sHSPs) were the most abundant protein families constituting 13% of the identified proteins. The total protein of *Psophocarpus tetragonolobus* was separated using HPLC. Thirty two secondary metabolites with different polarities were identified through GC-MS analyses of extracts. The root-tuber in different solvent extracts exhibited antioxidant activities.

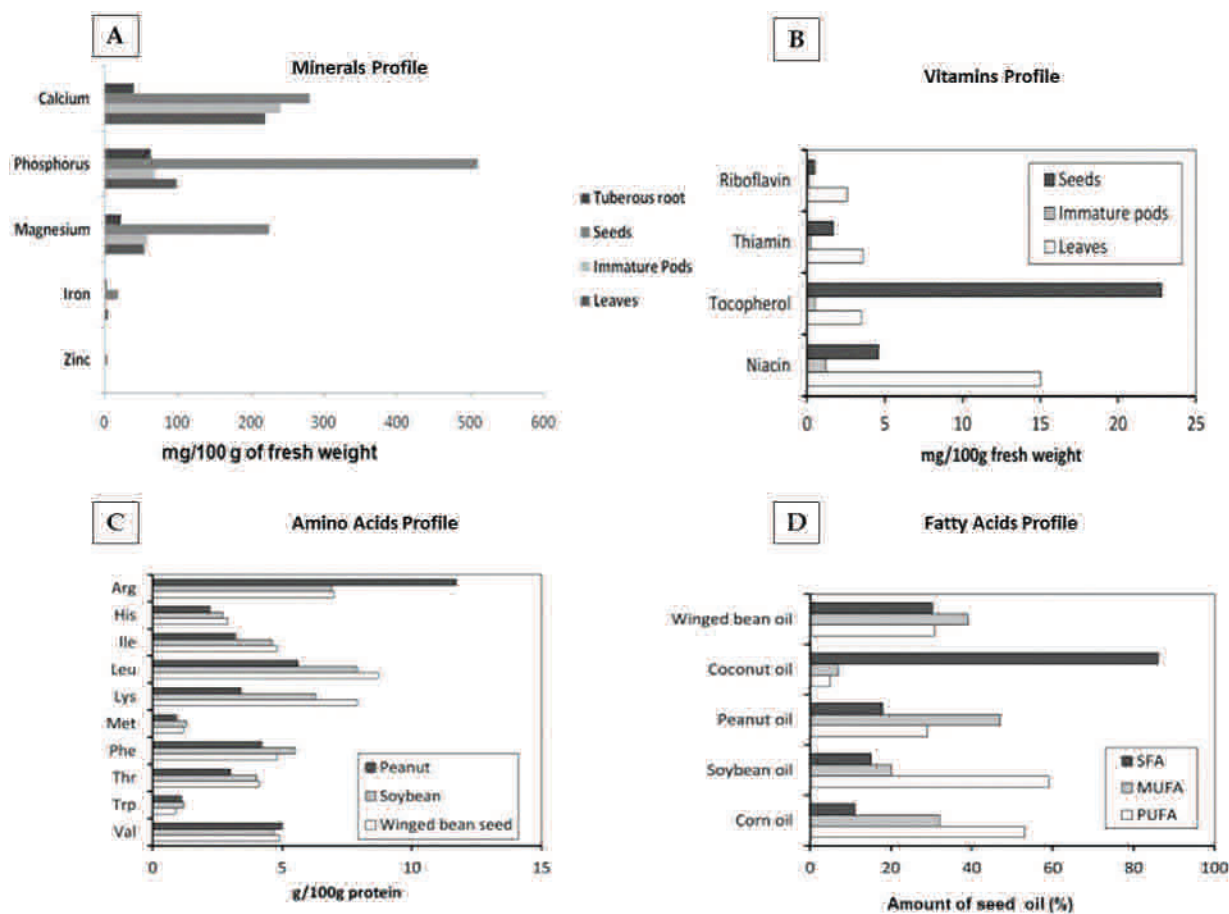


Fig. 1: Nutritional profile of winged bean (A). Mineral content, (B). Vitamins content, (C). Comparative amino acids profile, (D). Fatty acids of winged bean seed oil in comparison with other edible oils. (SFA: Saturated fatty acids, MUFA: Mono-unsaturated fatty acids, PUFA: Polyunsaturated fatty acids).

Genome-wide association studies (GWAS) of winged bean

Genotyping-by-sequencing (GBS) is attractive

because it provides thorough genome coverage and can be applied at low cost with or without a reference genome sequence. It is useful for analysis of genetic diversity and high power to detect specific

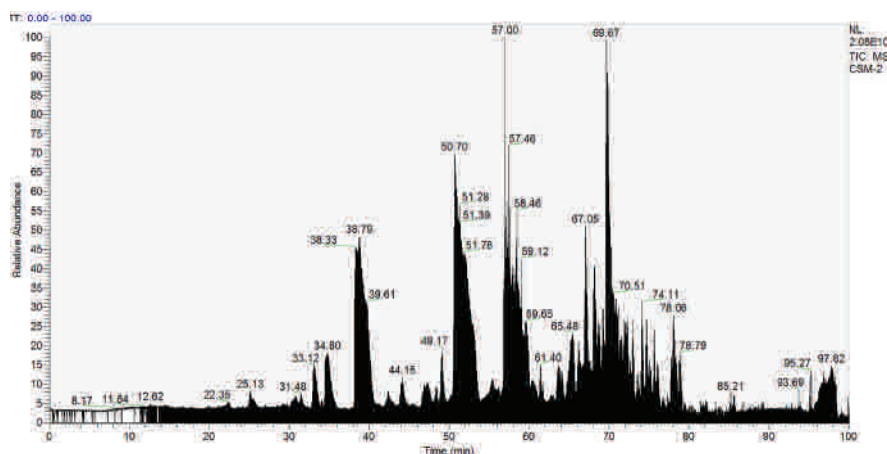


Fig. 2: Total ionic current (TIC) chromatogram profile of the root-tuber of *P. tetragonolobus* representing the intensity of masses as detected at every point of analysis.

genetic variants. GBS is employed to discover SNPs in winged bean. The genomic DNA from ninety-one winged bean accessions were digested using *ApeK1* enzyme and the GBS library was prepared from the

this plot, the negative logarithms of the P -values from the models fitted in GWAS are plotted against their expected value under the null hypothesis of no association with the trait. The analysis resulted in the discovery of 54 SNPs to be significantly associated with seed-protein traits and 88 SNPs with seed-oil traits. The associated SNPs are under validation.

Functional validation of Winged bean anthocyanidin synthase (Wb-ANS) gene through virus-induced gene silencing

Quantification and characterization of condensed tannin (CT) was carried out on the basis of structural-monomeric units catechin and epicatechin using Vanillin-HCl assay and dimethylcinnamaldehyde (DMACA) staining methods.

Anthocyanidin synthase (ANS), a 2-oxoglutarate iron-dependent oxygenase, catalyzes the penultimate step of the biosynthesis of the anthocyanin class of flavonoids. Condensation and polymerization of the anthocyanidins result in the formation of condensed tannin. The anthocyanidin synthase (ANS) was identified from winged bean and mapped phylogenetically with other members of the legume-family. Virus-induced gene silencing (VIGS) was employed for silencing of WbANS transcript. Wb-ANS-VIGS induction resulted in four-fold decrease in condensed tannin biosynthesis in *P. tetragonolobus*. As condensed tannin adversely affects digestion and considered as an anti-nutrient so, the study might be helpful in future for altering the biosynthesis of condensed tannin by manipulating the ANS-encoding molecular factors in winged bean.

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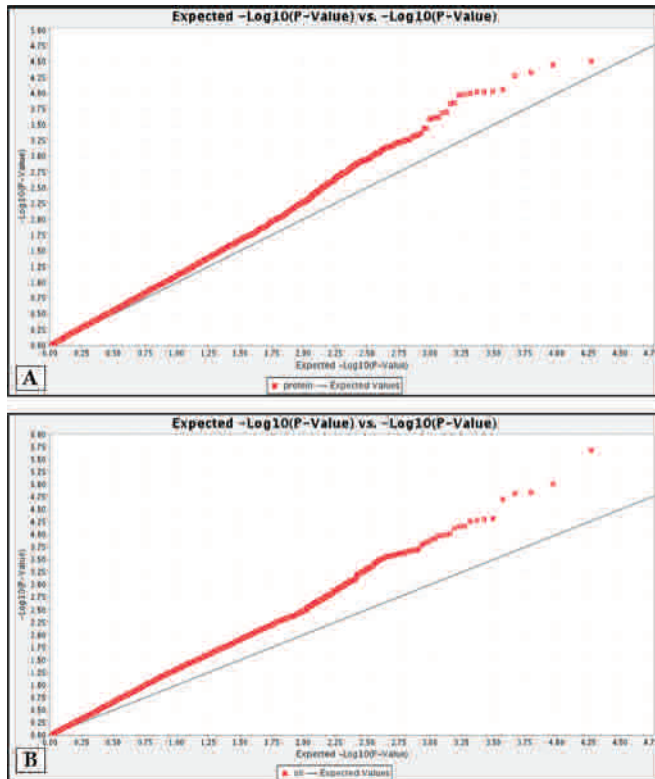


Fig. 3: QQ plot in winged bean (A). Seed protein traits (B). Seed oil traits

digested DNA fragments by ligating adaptors specific to the cut-site. The library pools were sequenced independently. Total of 167845 tagpairs (335690 tags) were generated during the analysis process. 80941 SNPs were identified at minimum MAF of 0.05 and maximum MAF of 0.5 from 80941 tagpairs (161882 tags).

The quantile-quantile (QQ) -plot is useful for assessing the model used in GWAS accounts for population structure and familial relatedness. In

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Genomics-assisted breeding for crop improvement

The group is working in the area of molecular markers, creation of genetic resources, linkage analysis and genomics assisted breeding for varietal development in industrially important crops.

Genetic and genomics resources in linseed for varietal development

Linseed (*Linum usitatissimum* (L)) is a globally cultivated oilseed and fibre crop. Its seed contains 40-45% oil which is rich in essential fatty acids such as omega-3 and omega-6. It has also been used as industrial oil in the production of paints, varnishes, inks and linoleum. So, linseed is indeed a valuable crop, but its improvement is due to under exploitation and lack of high yielding varieties. Integration of traditional breeding approaches and molecular breeding techniques is used to develop genetic and genomic resources for genetic improvement programs. The reference genome of linseed (IC 0526166) was prepared using Oxford Nanopore PromethION and Illumina platform. The SMARTdenovo assembly generated a total of 671 contigs with more than 10000 bp size. The high-quality reference genome assemblies are critical in accelerating plant breeding by selecting desirable genes with improved agronomic traits, including high yield, tolerance to various environmental stresses, and resistance to pathogens.

In addition, two bi-parental RILs were evaluated for their phenotypic characters in the cropping season of 2020-21. These include RIL Pop. 1 for oil content derived from cross of RKY-14 (high) × KL-213 (Low) and RIL Pop. 2 for flowering/maturity derived from cross of Padmini (Early) × KL-213 (Late). Phenotypic

data revealed normal distribution of traits indicating their suitability for linkage and QTL mapping (Fig. 1). Further, three bi-parental mapping populations for elite quantitative traits have also been developed and progressed to F₃ generation leading towards formation of RILs. In addition to RILs, the generation advancement of MAGIC population had been made. To advance the MAGIC population the selectively mated seven hybrids were grown in field during November 2020 to March 2021. All the hybrids were selfed to get seeds for seven different hybrids. Seeds were harvested and stored for next generation. Furthermore, to create more genetic variability, EMS mediated mutagenesis had also been attempted in linseed. The 30000 seeds of variety T-397 was treated with EMS and grown in field for evaluation during 2020-21 cropping season. The mutant plants showed visual mutation such as albinism, tall, dwarf, change in flower color and change in capsule size.

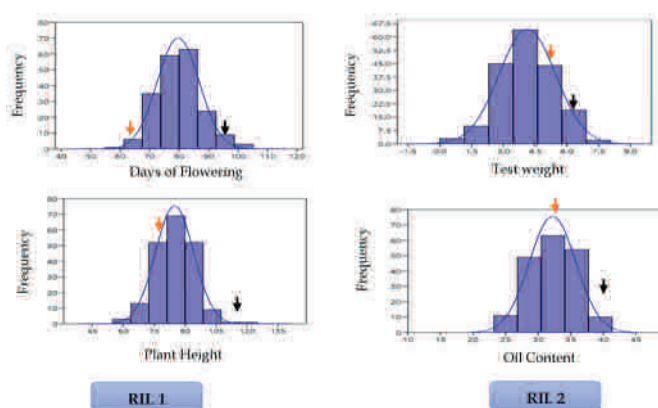


Fig. 1: Frequency distribution of quantitative traits for two Recombinant Inbred Lines (RILs)

Differential response of guar genotypes upon inoculation with *Alternaria alternata*

Cyamopsis tetragonoloba (L.) Taub. is an economically important drought tolerant legume crop. Due to presence of galactomannan or guar gum it has tremendous potential in industrial sector, ranging from pharmaceutical to textile and cosmetic to chemical industries. In recent years blight or leaf spot caused by *Alternaria* spp. has become a serious concern in guar resulting in agricultural losses. So far, there has not been any report on transcriptome study in response to biotic stress in guar to identify key components of resistance pathways. Six popular varieties of guar showing resistance and susceptibility to *Alternaria* were selected for differential response studies during early stage of infection, alteration of various physiological, histochemical and defence related enzymes. Host-pathogen interaction between guar genotypes and *Alternaria* spp. the percentage disease index after 14 days post inoculation showed that the genotypes RC-936, HG-563 are susceptible, whereas, genotypes PNB, HG-2-20, moderately susceptible and the genotypes RC-1066 and HG-365 were moderately resistant. Based on defence related enzyme assays, there was significant change in the enzyme activity for Superoxide dismutase (SOD), Catalase (CAT), peroxidase (PO), Glutathione peroxidase (GPx), Ascorbate peroxidase (APx) and Phenylalanine ammonia lyase (PAL). Maximum activity of SOD, CAT and PO was observed at 72 h post inoculation (Fig. 2). Based on Host-pathogen interaction, comparative physiological and biochemical analysis, the genotype HG-1066 showed relatively resistant and RGC-936 susceptibility.

Identification of EMS induced SNPs through GBS in TILLING population of *Gossypium herbaceum*

The diploid cotton species i.e., *G. herbaceum*, is recognized for poor fibre quality and yield, but it has the natural ability to withstand biotic and abiotic stresses such as insect/pest, drought, water logging and salinity. Very less efforts have been made to exploit the genetic potential of *G. herbaceum* for its genetic improvement. Therefore, an Ethyl methane sulfonate (EMS) mediated TILLING (Targeting Induced Local Lesions IN Genomes) population of the cv. WAGAD of *G. herbaceum* was developed for

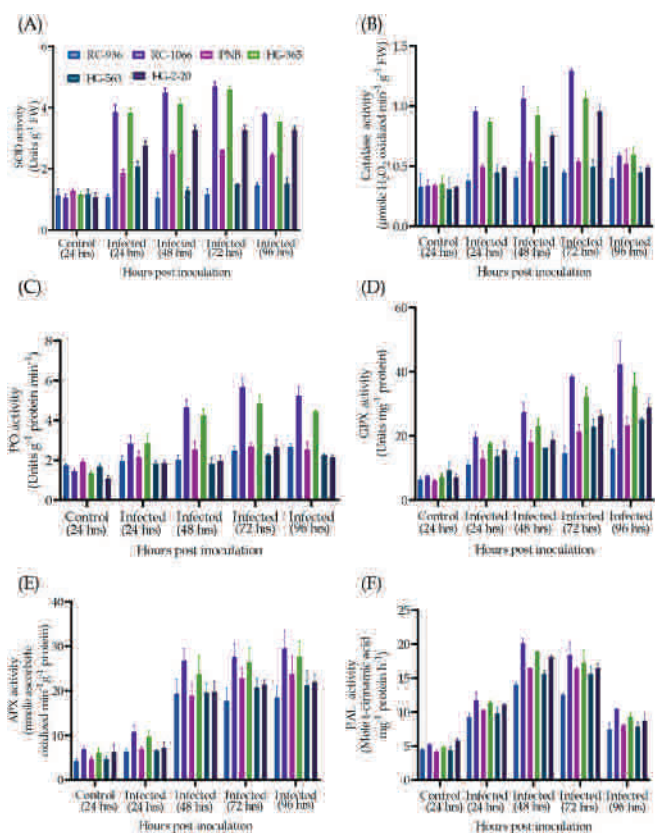


Fig. 2: Effect of *Alternaria* infection on stress related enzymes in susceptible and resistant genotypes of guar. (A). Super oxide dismutase (SOD), (B). Catalase (CAT), (C). Peroxidase, (D). Glutathione peroxidase (Gpx), (E). Ascorbate peroxidase (APx) and (F). Phenylalanine ammonia lyase (PAL).

the functional genomics studies. Genotyping-by-sequencing of 95 diverse M_3 plants selected from the TILLING population along with control was done for evaluation of nucleotide diversity. A total of 265,983,564 pair-end reads were mapped on *G. herbaceum* reference genome. On an average 3,302 SNPs were isolated per plant which ranged from 2,570 to 3,820. Similarly, indels were ranged from 0 to 435 per plant with an average of 256. EMS alkylates G nucleotide of DNA that pairs with T and leads G/C=A/T transition mutations. Here, we identified about 61% of transition mutations, and rest were transversions. Approximately 48.97% of SNPs were found in the coding region while the rest were allocated in non-coding regions. Overall impacts of all SNPs were high (33), low (4,019), modifier (5,988) and moderate (1,905) (Fig. 3). SNPs with high impact were found in 32 protein-coding genes and had a direct effect on functionality to both nonsense and frameshift mutations.

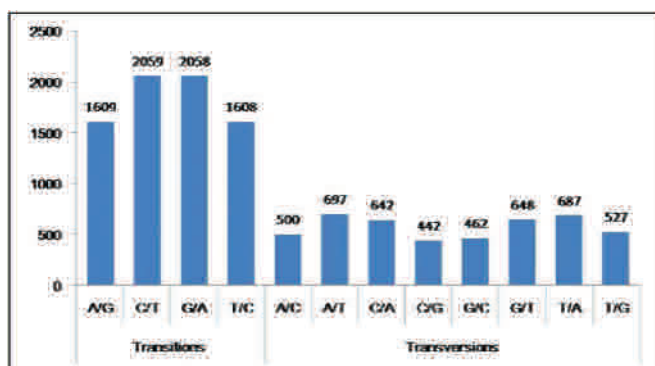


Fig. 3: Distribution of SNPs by impact on function and their allocation in the annotated genes of *G. herbaceum*.

Exploitation of grain amaranth genetic resources for accelerated genetic improvement

Grain amaranth (*Amaranthus* spp.) has been cultivated since ancient times in some countries in the world and it is one of the oldest food crops. Grain amaranth exhibits an incredible extent of morphological diversity and an extensive adaptability to diverse eco-geographical conditions. The evaluation of genetic diversity among populations of diverse phytogeographic areas is essential because for its genetic improvement and newer varietal development. Therefore, an attempt had been made to develop genetic and genomic resources in grain

amaranth at CSIR-NBRI, Lucknow for utilization under its crop improvement programmes. A total of 1165 accessions of grain amaranths were obtained from different centers of ICAR-NBPGR and have been grown at CSIR-NBRI garden field and Banthra Research Centre to multiply the seeds and record preliminary phenotypic data. The phenotypic data of 712 accessions revealed considerable degree of variability available in the accessions (Fig. 4). The core accessions will be identified once the phenotypic data of all the accessions will be available.

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Fig. 4: Variability in inflorescence traits of grain amaranth.

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Genomics, quantitative genetics and molecular plant breeding

Genetic mapping and QTL analysis for drought tolerance in upland cotton using in-house developed SSRs and SNPs

RIL population of intra-species upland cotton was generated from a cross between the drought-tolerant female parent (AS2) and the susceptible male parent (MCU13). A linkage map was constructed deploying 1,116 GBS-based SNPs and in-house developed 782 SSRs spanning a total genetic distance of 28,083.03 cM with an average chromosomal span length of 1,080.12 cM with inter-marker distance of 10.19 cM. A total of 19 QTLs were identified in nine chromosomes for field drought tolerance traits. To complement our QTL study, a meta-analysis was conducted along with the public domain database and resulted in a consensus map for chromosome 8 (Fig 1). Under field drought stress, chromosome 8 harboured a drought tolerance QTL hotspot with two in-house QTLs for chlorophyll stability index (qCSI01, qCSI02) and three public domain QTLs (qLP.FDT_1, qLP.FDT_2, qCC.ST_3). Identified QTL hotspot on chromosome 8 could play a crucial role in exploring abiotic stress-associated genes/alleles for drought trait improvement.

Cotton boll weight QTL hotspot sequencing and superior haplotype initiative

We have identified QTL hotspots on chromosome 25 (D06) with approximate 2.67Mb in our earlier study. We have selected 100 Indian core panels, out of which we have completed sequencing of two BW contrasting germplasm with CLR chemistry in Sequel II. The 62,67,743 raw sequencing reads with ~109Gb in both germplasm were obtained. Reference genome guided assembly was performed in high boll weight germplasm and resulted in nearly 2.1Gb with

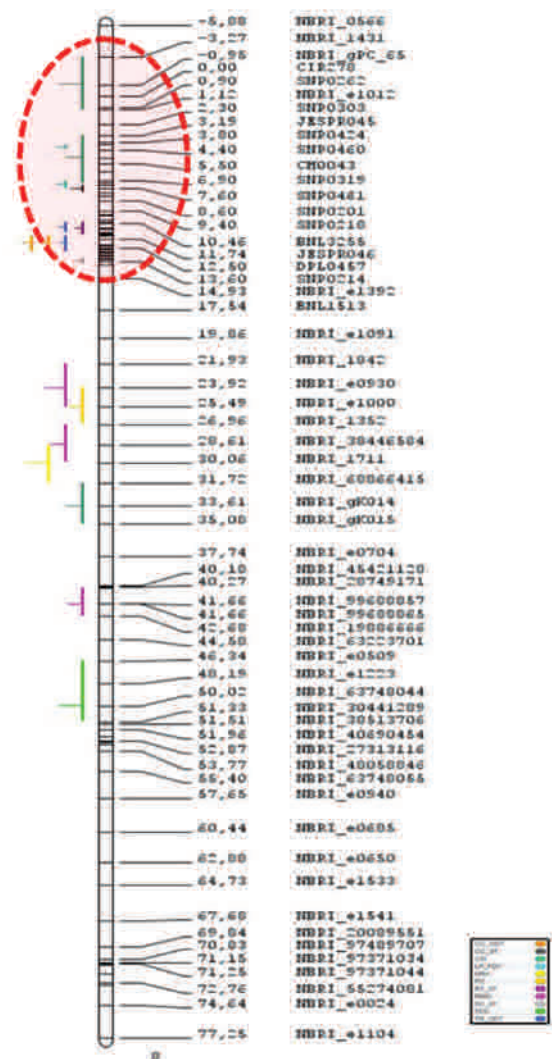


Fig. 1: Consensus map of chromosome 8 and QTL cluster analysis taking QTL and map data of in-house mapping population from the cross AS2 x MCU13 and public domain data of drought tolerance traits.

961 contigs with N50 of ~95 Mb. Both the assemblies will be compared for putative BW associated haplotype blocks and SNPs. Further, these identified haplotype blocks and SNPs shall be validated with association panel.

Opiod estimation in CSIR-NBRI's opium poppy collection and GWAS initiative

A total of 196 opium poppy germplasm collection including cultivars, varieties, land races, and breeding lines is being maintained in opium poppy experimental plot. We have also developed thebaine rich opium poppy breeding line and its MLT evaluation is on-going for its national release (Fig 2).

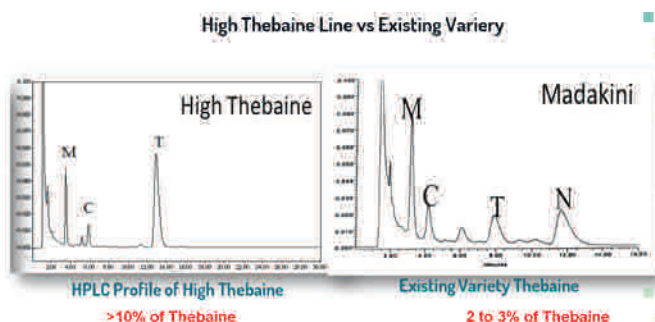


Fig. 2: Comparative chromatogram for high thebaine lines vs. existing varieties.

HPLC based cannabinoids estimation and hemp improvement

Cannabis is one of the oldest cultivated crops having high medicinal and economic importance. But due to the presence of psychoactive compound like tetrahydrocannabinol (THC), in many countries including India, Cannabis cultivation is strictly controlled by law enforcement. Due to these strict laws, scientific research on the Cannabis plant has been restricted to a great extent. Knowing the great potency of the medicinal cannabinoids, now India is emphasizing in producing *Cannabis* varieties (Hemp) having high cannabinoid contents with less THC (<0.3%). Despite large scale DNA-sequencing efforts the genomic structure of the two most important genes underlying cannabinoid (i.e. THCA synthase gene and CBDA synthase gene) remained elusive. The plant contains ~750 phytomolecules among which 104 different cannabinoids are majorly synthesized in the capitata stalked glandular trichomes of female inflorescences. Among these cannabinoids, tetrahydrocannabinol (THC) and cannabidiol (CBD)

gain the most attention due to their unique chemical properties. THC is the most psychoactive compound that induces sensation in euphoria and causes cognitive deficits. Depending on the THC content in plant dry weight, the Cannabis is categorized into two groups: fibre type (known as hemp) with <0.3% THC, and drug type (known as marijuana) with >0.3% THC.

CSIR-NBRI has been pursuing the cannabis research with greater emphasis. The group has collected a large number of germplasm covering many states of India. Besides, few exotic germplasms have also been procured and maintained in CSIR-NBRI campus for breeding. We have also standardised the HPLC protocol for cannabinoids (THC and CBD) estimation and quantification (Fig. 3). Bombay Hemp Company (BOHECO) has sponsored a project in which we have screened and selected few cannabis germplasm on the basis of their HPLC-based cannabinoid contents.

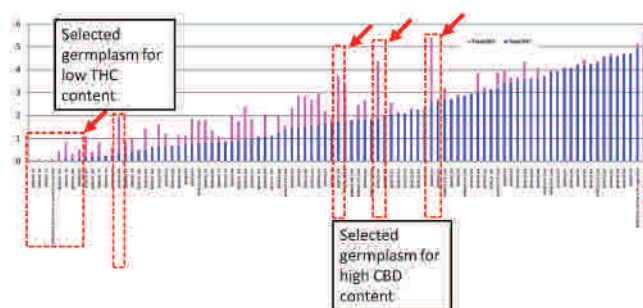


Fig. 3: Screening and selection of *Cannabis* germplasm for low THC and high CBD.

We have collected and maintained the cannabis germplasms at Cannabis research Centre, Banthra (Fig. 4). We have screened few germplasm for their cannabinoid contents and selected for hybridization with aim of hemp improvement.

FCM-based genome size estimation and determination of ploidy of North-east *Musa* germplasms

We are interested to study the genome composition of wild and cultivated bananas from the north-east India for understanding their origin and diversification that may have happened due to several evolutionary forces. Altogether, a total number of 41 germplasms have been collected from the north-eastern states and raised in CSIR-NBRI experimental field (Fig 5). We found significant variation in the morphological characters of 16 banana varieties suggesting the



Fig. 4: About 64 *Cannabis* germplasms have been collected from various states of India and maintained at Cannabis Research Centre, Banthara, Lucknow.

influence of environmental factors on their vegetative and reproductive phase. Subsequently, this finding could develop insight into their diverse origin and genome composition. In addition, flow cytometric analysis of the nuclear DNA content also indicated a variation in their genome content (1C DNA) and ploidy level (diploid or triploid) using *Glycine max* as the external reference standard. The ploidy level was estimated by comparing the samples alongside internal standards namely FHIA 03, Jurmany, G9 and *Musa laterieta* with known levels of ploidy.

Furthermore, an attempt was also made to study the genetic diversity of these wild and cultivated varieties using SSR markers. Designing of primers and successful standardization was made for 18 SSR markers for their utilization in diversity analysis. Our findings will be helpful in developing successful genetic resources of north-east banana germplasms that will facilitate the selection of elite varieties for genetic improvement program in future.

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- Dr. Priyanka Gupta, Research Associate
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Fig. 5: Morphological character in one of the banana cultivar (NBRI 0013) grown in CSIR-NBRI experimental field.

Botanic Garden, Plant Conservation and Agro-Technology



BOTANIC GARDEN, PLANT CONSERVATION AND AGRO-TECHNOLOGY

Area Coordinator

Dr. SK Tewari, Chief Scientist

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R&D Area Scholars Statistics

Sr. No.	Position Name	Numbers
1.	Research Associate	01
2.	DST Women Scientist	01
3.	Project Scientist	01
4.	JRF/SRF	01
5.	Project Staff	14

Aims and Objectives

- Development of new varieties of popular floricultural crops.
- Enrichment of plant diversity and conservation of diverse groups of plants in specialized houses and field conservatories, their propagation and

characterization, DUS testing of germplasm.

- Ecological restoration of sodic waste land through adaptable plants and trees, their conservation and interactive response.
- Evaluation of non-traditional economic plants for sodic soil.
- Collection and evaluation of medicinal, aromatic and floricultural crops for yield and quality for sodic soil.
- Standardization of agro-technology of different medicinal and aromatic plants, for sustainable utilization of sodic wastelands.
- Providing R & D support services by conservation and enrichment of various germplasm, plant propagation.
- Skill development/Outreach programmes/ Extension activities.

R&D Highlights

Botanic Garden

- Developed *Cycas* Garden as national reference centre for Indian species. This is part of the R&D activity to establish *Cycas* as a model for *ex-situ* conservation of threatened plants and for future restoration of natural populations. Collection, conservation and taxonomic studies of gymnosperms have gained momentum in the last few years and the garden is now the only such centre in the country. Morphology, pollination and seed germination studies of Indian *Cycas* are being carried out.
- Experiments have been designed for varietal development of floricultural crops such as Canna, Gladiolus, Iris, and Nymphaea. These experiments will help in developing novel varieties with elite characters.
- Seed germination studies of some threatened plants like *Pterocarpus santalinus*, *P. marsupium*, *Indopiptadenia oudhensis*, *Hardwickia binata*, *Ephedra foliata*, *Baliospermum montanum*, *Commiphora caudate*, *Commiphora wightii*, *Saraca asoca*, *Hildegardia populifolia*, *Boswellia ovalifoliolata*, *Adenanthera pavonina* etc. were done successfully.



- A database of trees and shrubs conserved in thematic gardens, plant houses, Arboretum and public places in Botanic Garden was prepared. Each tree and shrubs were geo-tagged and this information will be used for preparation of online database of flora of CSIR Botanic Garden accessible through QR embedded plant labels.
- Morphological characterization of 70 varieties of gladiolus, 20 varieties of Canna and 10 varieties of Bougainvillea was carried out based on DUS Test guidelines of PPV&FRA. Hybridization and mutation breeding of ornamental plants such as *Gladiolus*, *Canna*, *Nymphaea*, *Reinwardtia indica* are taken up for their improvement.
- Following species of ornamental/economic/conservation importance collected from different locations of Andhra Pradesh have been introduced and maintained at CSIR-NBRI Botanic Garden. *Boswellia ovalifoliolata*, *Commiphora caudata*, *Cycas sphaerica*, *Decaschistia crotonifolia*, *Embelia tsjeriam-cottom*, *Gardenia gummifera*, *Hildegardia populifolia*, *Jasminum angustifolium*, *Melastoma malabathricum*, *Pterocarpus marsupium*, *Syzigium alternifolium*, *Terminalia pallida*, *Cycas seshachalamensis*, *Hibiscus platanifolium*, *Indigofera tinctoria*, *Orthosiphon aristatus*.
- Floristic study in Western Himalaya was carried out. Field tours and botanical explorations were conducted in Sarthal Hill (J&K). A total of 166 plant samples comprising of angiosperms, gymnosperms and ferns were collected from the study area. From Bhallesa mountain, situated in Doda district of J&K, 113 plant samples were collected.
- For survey and assessment of biodiversity of Kameng river of Arunachal Pradesh, one field tour was undertaken.
- The pharmacological studies on *Picrorhiza kurroa* Royle ex Benth. revealed antioxidant, antidiabetic, immunomodulatory and anti-inflammatory properties of the species.
- A systematic ethnobotanical survey was conducted in 12 villages of district Poonch for investigation of traditional veterinary practices of Gujjar and Bakarwal tribes. Data was gathered from the local inhabitants using semi-structured questionnaires and analyzed quantitatively using use-value (UV), relative frequency of citation (RFC), informant consensus factor (ICF) and fidelity level (FL).
- Agrotechnology development for *Hemerocallis fulva* was initiated during the reporting period.
- Eighty five Rose varieties from different authentic nurseries of Kolkata have been introduced to CSIR-NBRI Rose Garden.

Plant Conservation and Agro-technology

- Fifteen accessions of *Chenopodium quinoa*, 27 of *Plantago ovata* and 13 accessions of *Cyperus scariosus* were added to the Field Gene Bank at Banthra.
- Twenty seven accessions of *Plantago ovata* were evaluated under sodic waste land conditions for their commercial cultivation and significantly higher grain yield was obtained from IM 26 germplasm.
- Fifteen accessions of quinoa were evaluated under sodic waste land conditions. There were significant differences in the length of inflorescence among the quinoa accessions. Among the germplasm, tallest plants were observed in PQ 5 (123 cm), and shortest plants were observed with PQ 14 (73 cm) germplasm. The longest inflorescence was produced on PQ 11 (34 cm), while the shortest length was obtained from PQ 10 (19 cm). The grain yield was highest in PQ 11 (41.96 g/plant), followed by accession PQ 14 (41.59 g/plant), while the shortest length was obtained from PQ 5 (12 g/plant).
- Collection, conservation and evaluation of 13 accessions of Nagarmotha (*Cyperus scariosus*) were done under sodic waste land conditions for their commercial cultivation for the extraction of root essential oil.
- Tissue culture and clonal propagation techniques were standardized for four different cultivars of neem. The inter-cropping models were developed as demonstration plots with neem as main crop.
- Enriched the amaranth germplasm repository with 1223 accessions of *Amaranth* spp. (consisting *A. hypochondriacus*, *A. cruentus*, *A. caudatus*) and evaluated them for various agronomically important quality traits and identification of traits specific lines.

- A total of 30 varieties of tuberose (*Polianthes tuberosa* L.), including single and double type flowers, have been collected and planted. Some varieties of tuberose were also exposed to gamma induced radiation for mutation breeding to obtain the new mutant variety.
- Germplasm of 25 *Aloe* species were studied to assess the cultivation potential on normal and salt affected soil with respect to quality and quantity of *Aloe* gel and other potential biochemical compounds for development of pharmaceutical, nutraceutical and cosmeceutical products, and to restore the fertility status of salt affected soils by extracting excess salts from these soils.
- Field experiments were conducted for standardization of FYM as organic source for cultivation of Kalmegh (*Andrographis paniculata*). The fresh and dry biomass significantly increased with increasing levels of FYM up to 60.0 t ha⁻¹. Nutrient profiling of *A. paniculata* under organic farming has also been done. Nitrogen and Phosphorus content in roots decreased with increasing levels of FYM. K, Ca, Mg and Na content did not show any trend in roots, stem or leaves with increasing levels of FYM. The profiling has been done for Zinc (Zn), Iron (Fe), Copper (Cu), Manganese (Mn), Molybdenum (Mo), Nickel (Ni), Chromium (Cr), Selenium (Se), Arsenic (As), Lead (Pb), Cobalt (Co) and Cadmium (Cd). The changes in soil properties (Soil pH, electrical conductivity, organic carbon, microbial population and soil enzymes activity after harvest of the crop have also been studied.
- Linseed (*Linum usitatissimum*) accessions were evaluated on partially sodic land at Banthra for

screening salt tolerance and high oil content and fiber quality.

- Field experiments are being carried out to study the response of Zeolites on growth and yield performance of dominant traditional rice-wheat cropping system of Indo-Gangetic plains. Zeolites are produced by coal combustion from electric generating plants, are also known as “intelligent fertilizers” because of the ion exchange capacity (CEC) and high porosity.

Out-reach/Training/Skill development

- Three technological interventions were made for the farmers of aspirational district Nabarangpur. 100 kg rhizomes of CSIR-NBRI turmeric variety Kesari and 30 kg tuberose bulbs were provided for distribution to farmers. The essential oil from senesced leaves has shown 34.16% α -Phellandrene, the characteristic compound for the economic value of oil. With the aim to promote the bio-fertilizer in Nabarangpur district, we organized training programme for agriculture officers on 20th August, 2020 and provided 200 packets of Biofertilizers (PSB) for the farmers. Subsequently training programme at farmers field level was conducted in six villages.
- An online entrepreneurship development Programme on “Scope for entrepreneurship in the field of turmeric cultivation and other botanical plants” was organised on 13th August 2020.
- Skill development programmes were coordinated under NWP100 project. The duration of these programmes ranged from 3 days to 29 days through which total 845 candidates have been trained under 12 training courses.



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Botanic Garden, plant conservation, floriculture, agro-technologies, skill development and outreach activities

Botanic Garden

Experiments were designed for varietal development of floricultural crops such as Canna, Gladiolus, Iris and Nymphaea. These experiments will help in developing novel varieties with elite characters. Eighty five Rose varieties from different authentic nurseries of Kolkata have been introduced to Dr. BP Pal Rose Garden of CSIR-NBRI.

- Following species of ornamental/economic/conservation importance, collected from different locations of Andhra Pradesh have been introduced and are being maintained at NBRI Botanic Garden: *Boswellia ovalifoliolata*, *Commiphora caudata*, *Decaschisti acrotonifolia*, *Embelia tsjeriam-cottom*, *Gardenia gummifera*, *Hildegardia populifolia*, *Jasminum angustifolium*, *Melastoma malabathricum*, *Pterocarpus marsupium*, *Syzigium alternifolium*, *Terminalia pallida*, *Cycas seshachalamensis*, *Hibiscus platanifolium*, *Indigofera tinctoria*, *Orthosiphon aristatus* and *Juniperus squamata*.

Enhancing production of agricultural systems, skill development and outreach programmes

The collection and conservation of elite germplasm of under-utilized but economically important plants, followed by evaluation under sodic waste land conditions for their commercial cultivation are the major activities. Thirty eight accessions of turmeric were conserved and evaluated for growth, yield and quality. The morphological descriptors were prepared for new accessions, and five promising accessions were evaluated for yield in large field experiments.

Development and promotion of Non-POPs alternatives to DDT

Standardization of *in vitro* clonal propagation and multiplication of four different cultivars of neem was done. All four types of cultivars responded to MS medium with 6-benzylaminopurine and indole 3-acetic acid. Rooting and hardening were also optimized. Unfortunately, during the lock down in the months of April and June, all the neem plants raised through tissue culture perished. However, through macro propagation, sufficient quantity of rooted cuttings were raised to develop Neem-based agroforestry models, and shade loving medicinal and aromatic plants were introduced as inter-crop. Efforts were also made towards conducting multi-location trials at 05 different agroclimatic zones of India viz., North East (Shillong); North Central (Lucknow); North (Chandigarh); South (Bengaluru); and East (Bhubaneswar).

Establishment of a DUS Test Centre at CSIR-NBRI for Bougainvillea, Gladiolus and Canna crops

Morphological characterization of 70 varieties of gladiolus, 20 varieties of Canna and 10 varieties of Bougainvillea were carried out, based on DUS Test guidelines of PPV&FRA.

Ex-situ conservation studies of *Cycas* species in India at CSIR-NBRI Botanic Garden

A *Cycas* Garden has been developed as national reference centre for Indian species. This is part of the R&D activity to establish *Cycas* as a model for *ex-situ* conservation of threatened plants and for future restoration of natural populations.

Farm based S&T interventions for socio-economic development in the aspirational district of Nabarangpur, Odisha

Rhizomes of CSIR-NBRI turmeric variety (100 kg) Kesari and tuberose bulbs (30 kg) were distributed to progressive farmers of Nabarangpur. The essential oil from senesced leaves was extracted during the harvest season in the year 2020. The sample of this oil has been analysed and 34.16% α -Phellandrene, the characteristic compound of economic value in curcuma oil, has been reported. Two hundred packets of Biofertilizers (PSB) were dispatched to Nabarangpur for distribution among the farmers. In order to promote the use of bio-fertilizers, a training programme for agriculture officers was organized at Nabarangpur on 20th August, 2020, with the support of the district administration. Besides, an Entrepreneurship Development Programme on "Scope for entrepreneurship in the field of turmeric cultivation and other botanical plants" was organized through video conference by CSIR-NBRI, Lucknow on 13th August 2020. Officials from Nabarangpur and Koraput Districts, along with scientists of CSIR-NBRI and entrepreneurs participated in the programme.

CSIR Integrated Skill Initiative

Skill development programmes were coordinated as part of the CSIR-Skill Development Initiative. The duration of these programmes ranged from 3 days to 29 days. A total of 845 candidates have been trained under 12 training courses. Because of Covid-19 pandemic, the trainings were organized majorly via virtual mode.

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Germplasm conservation and evaluation of non-traditional economic plants and development of their agro-technology, and outreach programmes/extension activities

The group is mainly working on the development of agro-technologies for non-traditional, economically important medicinal and aromatic plants (MAPs) through introduction, domestication and nutrient management, for the economic utilization of partially reclaimed sodic lands. Under the rural development initiative of CSIR, the outreach programmes towards popularizing CSIR-NBRI Green Technologies for economic upliftment of rural population were also undertaken.

Aroma Mission Project

Under CSIR Aroma Mission Phase-II, agro-technology for cultivation of turmeric for essential oil extraction from senescing leaves has been developed and disseminated among the farmers of different states (Karnataka, Jharkhand, Uttar Pradesh, Bihar, Uttarakhand, Odisha, and Maharashtra), thereby achieving a new target area of 74.6 ha. Turmeric rhizomes/seed materials (91 qt) were distributed among 56 farmers, which will serve as a seed bank. Approximately 800 farmers were imparted training on turmeric cultivation for essential oil extraction through 41 awareness/ training programmes organized at different locations of India. The agro-technology and agri-economics for improved *Curcuma* variety was also developed and optimized for cultivation under the shade of orchards, multi-location assessment and postharvest optimization in different agro-climatic regions. Capacity building, awareness and training programmes on agro-technologies, distillation and value addition were also conducted for the farmers (Fig. 1).

A comparative study of chemical constituents of leaf oil in 'Kesari' turmeric harvested from different locations was conducted. (GC-MS analysis of 21 leaf



Fig. 1: Distribution of turmeric rhizomes and awareness programme organized for farmers

samples of 'Kesari' collected from Odisha, Bihar, Jharkhand, Uttar Pradesh, Karnataka, Maharashtra, and Uttarakhand (KT1 to KT21) resulted in identification of 53 compounds from leaf oil of which α -phellandrene, terpinolene, para-cymene and turmerone were the major compounds detected. Among all the samples analyzed, maximum amount of α -phellandrene (26.92%) and Terpinol (35.78%) was detected in KT20 while para-cymene (47.73%) and turmeron levels (0.73%) were highest in KT8 and KT15, respectively.

Plant Conservation and Agro-technologies (Distant Research Centre, Banthra)

Evaluation of 27 germplasm of *Plantago ovata* (Isabgoal) was done under sodic waste land conditions. During field experiments, growth and yield parameters were evaluated and higher values of growth parameters and significantly higher grain yield were recorded for IM 26 germplasm of *P. ovata*.

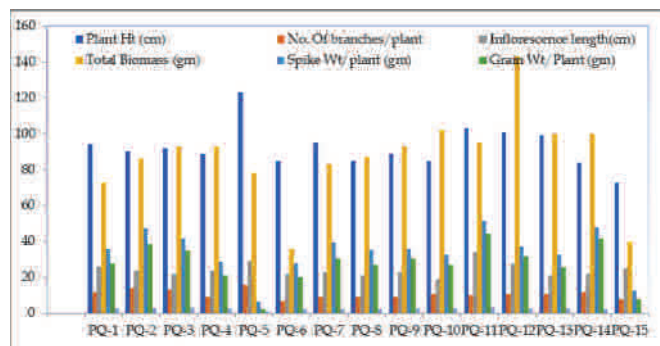


Fig. 2: Evaluation of different qualitative and quantitative traits in germplasm accessions of *C. quinoa*



Fig. 3: Germplasm of *C. quinoa* at DRC Banthra

Collection, conservation and evaluation of 15 germplasm of *Chenopodium quinoa* was done under sodic waste lands. The colour of leaf, flower, and seed was evaluated as qualitative trait. In general, green and red were the two dominant stem colours for all genotypes, with occurrence of 90% and 10%, respectively. There were significant differences in the length of inflorescence among the *Chenopodium quinoa* accessions. Among the germplasm, tallest plants were observed in PQ 5 (123 cm), and shortest plants in PQ 14 (73 cm) germplasm. The longest inflorescence was produced on PQ 11 (34 cm), followed by accession PQ 1 (26 cm), while inflorescence with the shortest length was observed in PQ 10 (19 cm). The grain yield was highest in PQ 11 (41.96 g/plant), followed by PQ 14 (41.59 g/plant), while the lowest yield was obtained from PQ 5 (12 g/plant) (Fig. 2).

Evaluation trials of 13 germplasm of *Cyperus scariosus* (Nagarmotha) are in progress for the extraction of root essential oil (Fig. 3).

Propagation of new dwarf cultivars of Neem with early maturity and higher Limonoids yield

Experiments were with four cultivars of Neem through macro propagation conducted for development of new dwarf cultivars of neem with early maturity and higher limonoids yield. Preparation of descriptors of all cultivars, development of different agroforestry models, and multi-location trials at five different agroclimatic zones viz., North East (Shillong); North Central (Lucknow); North (Chandigarh); South (Bengaluru); East (Bhubaneswar) were conducted.

Outreach Programmes/ Extension Activities

In order to popularize CSIR-NBRI green technologies, two training programmes on Betelvine cultivation, and 11 training programmes on cultivation of turmeric for extraction of essential oil from leaf waste, and two field demonstration visits to DRC Banthra were organized. Over 300 farmers were imparted training under the above events and a large number of students and teachers from various schools and colleges visited the Distant Research Centre (Banthra).

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Sustainable soil fertility, drought and salt stress management through non-traditional economic plants

Nutrients profiling of Kalmegh (*Andrographis paniculata*) under organic farming

Assessment on the effect of Farm yard manure (FYM) and nutrient profiling of Kalmegh under

different FYM levels has been continued. Our field results suggested that the FYM application beyond 34.5 t ha⁻¹ was not beneficial for organic cultivation of Kalmegh (Tables 1&2).

Table 1: Effect of Farm Yard Manure (FYM) on yield and yield attributing characters (mean of two years) of *Andrographis paniculata*

Treatments	Plant height (cm)	Leaves Plant ⁻¹	Branches Plant ⁻¹	Plant spread (cm ²)	Stem Diameter (mm)	Biomass (g plant ⁻¹)		Fresh/ Dry Biomass Ratio
						Fresh	Dry	
T ₁ - FYM - 0.00 t ha ⁻¹ , OC - 0.5%	31.17	77	8.10	308	4.36	16.80	6.81	2.47
T ₂ - FYM - 8.50 t ha ⁻¹ , OC - 1.0%	33.02	88	9.25	663	5.11	25.86	8.02	3.23
T ₃ - FYM - 17.0 t ha ⁻¹ , OC - 1.5%	33.15	98	9.50	664	5.32	27.20	8.13	3.34
T ₄ - FYM - 26.0 t ha ⁻¹ , OC - 2.0%	33.70	124	12.50	724	6.75	30.12	9.66	3.12
T ₅ - FYM - 34.5 t ha ⁻¹ , OC - 2.5%	40.37	128	14.75	763	6.90	35.62	10.37	3.43
T ₆ - FYM - 43.0 t ha ⁻¹ , OC - 3.0%	47.10	133	14.50	1133	7.33	39.37	13.62	2.89
T ₇ - FYM - 51.5 t ha ⁻¹ , OC - 3.5%	47.17	135	14.90	1153	7.36	48.50	15.75	3.08
T ₈ - FYM - 60.0 t ha ⁻¹ , OC - 4.0%	47.60	135	15.10	1185	8.07	52.12	16.43	3.17
SE m (±)	1.56	2.07	0.91	22.96	0.23	1.88	1.05	0.13
CD (P<0.05)	3.22	4.27	1.87	47.39	0.47	3.88	2.17	0.27

Table 2: Effect of Farm Yard Manure on nutrients and metal content (mean of two years) in root, stem and leaf of *Andrographis paniculata*

Treatments	N	P	K	Ca	Mg	Na	Zn	Fe	Cu	Mn	Cr	Mo	Ni	Se	As	Pb	Co	Cd
	g kg ⁻¹						mg kg ⁻¹											
Root																		
T ₁ - Control	2.02	3.20	108.3	6.32	0.71	0.39	19.18	929	21.14	21.46	39.34	1.88	9.28	1.25	0.64	1.73	0.404	0.00
T ₂ - FYM - 8.50 t ha ⁻¹	2.24	3.00	112.3	5.23	0.68	0.50	19.91	955	16.65	26.42	44.62	1.49	10.02	1.17	0.70	1.35	0.464	0.00
T ₃ - FYM - 17.0 t ha ⁻¹	1.34	2.80	91.8	3.50	0.65	0.40	11.96	297	24.82	16.92	39.14	2.01	12.95	1.19	0.09	0.71	0.264	0.00
T ₄ - FYM - 26.0 t ha ⁻¹	1.57	2.50	114.9	4.78	0.66	0.35	13.63	442	16.49	10.18	15.63	1.69	11.83	1.46	0.29	0.72	0.094	0.00

T ₅ - FYM - 34.5 t ha ⁻¹	1.56	2.83	87.5	4.34	0.66	0.32	15.69	419	7.89	9.53	41.06	1.68	10.81	1.39	0.26	0.93	0.278	0.00
T ₆ - FYM - 43.0 t ha ⁻¹	1.58	2.63	87.2	3.88	0.62	0.27	12.02	294	4.72	6.73	32.44	1.21	6.70	1.41	0.13	0.97	0.118	0.00
T ₇ - FYM - 51.5 t ha ⁻¹	1.56	1.73	86.9	3.86	0.65	0.32	17.51	324	4.26	6.66	18.22	1.00	2.36	1.34	0.12	0.85	0.026	0.00
T ₈ - FYM - 60.0 t ha ⁻¹	1.57	1.83	101.4	3.99	0.65	0.31	23.26	240	7.28	6.75	11.94	1.94	3.16	1.27	0.15	1.37	0.002	0.00
SE m (±)	0.06	0.13	3.3	0.21	0.04	0.06	0.71	54	1.88	0.89	1.57	0.52	1.38	0.04	0.10	0.14	0.056	0.00
CD (P<0.05)	0.12	0.27	6.8	0.43	0.08	0.12	1.46	111	3.88	1.84	3.24	1.07	2.85	0.08	0.21	0.29	0.117	0.00
Stem																		
T ₁ - Control	3.36	2.03	137.5	4.51	0.66	0.28	28.97	201	3.59	70.81	26.78	0.95	1.08	1.47	0.05	1.16	0.052	0.00
T ₂ - FYM - 8.50 t ha ⁻¹	3.14	1.90	114.3	4.21	0.67	0.28	27.94	261	2.66	56.81	13.67	0.84	2.17	1.42	0.08	2.37	0.000	0.00
T ₃ - FYM - 17.0 t ha ⁻¹	2.24	1.50	102.8	4.25	0.67	0.28	28.56	267	3.54	24.36	18.73	1.31	3.27	1.82	0.18	2.26	0.004	0.00
T ₄ - FYM - 26.0 t ha ⁻¹	3.81	2.50	164.0	4.79	0.66	0.37	27.33	259	3.46	33.84	13.26	0.93	2.61	1.32	0.07	0.91	0.000	0.00
T ₅ - FYM - 34.5 t ha ⁻¹	3.69	3.04	105.1	4.99	0.67	0.31	25.53	208	2.81	8.56	12.01	1.23	2.28	1.45	0.19	1.06	0.000	0.00
T ₆ - FYM - 43.0 t ha ⁻¹	3.47	3.21	132.6	4.89	0.67	0.38	23.03	260	2.99	9.85	10.08	0.97	3.02	1.51	0.19	1.19	0.000	0.00
T ₇ - FYM - 51.5 t ha ⁻¹	3.92	2.93	138.4	5.21	0.68	0.31	26.09	319	3.14	8.95	60.77	1.67	17.78	1.31	0.27	0.72	0.306	0.06
T ₈ - FYM - 60.0 t ha ⁻¹	5.15	2.43	139.8	4.68	0.86	0.51	25.46	424	4.39	9.81	56.39	1.26	30.94	1.13	0.22	0.95	0.623	0.05
SE m (±)	0.11	0.12	2.82	0.10	0.03	0.04	0.22	18.7	0.12	2.37	1.56	0.21	1.89	0.04	0.02	0.09	0.000	0.00
CD (P<0.05)	0.23	0.25	5.82	0.21	0.06	0.08	0.45	38.6	0.25	4.89	3.22	0.43	3.90	0.08	0.04	0.19	0.000	0.00
Leaves																		
T ₁ - Control	7.28	2.33	143.4	6.94	0.81	0.31	22.05	470	4.48	20.96	56.53	2.26	14.99	0.98	0.25	2.89	0.318	0.00
T ₂ - FYM - 8.50 t ha ⁻¹	7.28	2.55	121.2	6.68	0.74	0.25	21.75	368	3.21	17.81	42.15	2.37	13.16	1.09	0.33	1.31	0.181	0.08
T ₃ - FYM - 17.0 t ha ⁻¹	5.49	2.63	140.2	6.95	0.87	0.24	24.55	502	3.97	20.39	61.49	2.76	13.06	1.15	0.63	1.31	0.269	0.02
T ₄ - FYM - 26.0 t ha ⁻¹	6.94	1.73	127.5	6.98	0.73	0.25	23.81	472	4.41	20.78	73.38	2.58	22.27	1.15	0.56	1.67	0.458	0.00
T ₅ - FYM - 34.5 t ha ⁻¹	6.94	3.46	127.5	6.91	0.84	0.22	26.84	481	2.68	21.03	51.08	2.86	16.79	1.23	0.71	1.16	0.339	0.00
T ₆ - FYM - 43.0 t ha ⁻¹	5.82	3.03	116.2	6.27	0.73	0.24	27.23	563	4.37	19.97	97.93	2.37	29.45	1.34	0.91	2.12	0.641	0.00
T ₇ - FYM - 51.5 t ha ⁻¹	6.83	1.78	140.2	6.51	0.73	0.31	25.72	455	5.91	20.78	63.68	2.38	16.76	1.24	1.02	2.14	0.313	0.00
T ₈ - FYM - 60.0 t ha ⁻¹	8.18	1.81	138.4	6.95	0.88	0.31	26.22	483	3.37	25.25	71.91	2.35	25.42	1.38	1.05	1.11	0.512	0.00
SE m (±)	0.33	0.17	1.87	0.08	0.04	0.03	0.18	10.9	0.11	0.47	1.37	0.15	1.10	0.03	0.11	0.11	0.046	0.00
CD (P<0.05)	0.68	0.35	3.86	0.17	0.08	0.06	0.37	22.5	0.23	0.97	2.83	0.31	2.27	0.06	0.23	0.23	0.096	0.00

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The work is focused on socio-economic development of weaker section of society (marginal and poor farmers) through dissemination of appropriate agro-technology, especially for economic utilization of partially reclaimed sodic lands using non-traditional economic plants, including medicinal and aromatic plants. Training/outreach programmes for promoting different agricultural and diverse cropping systems, *ex-situ* conservation, selection of elite material with good growth and yield, propagation protocol for large scale multiplication are also organized for the farmers.

Plant Conservation and Agro-technology

Bambusetum

The germplasm collection in Bambusetum, at DRC Banthra, was assessed to identify suitable species that can be grown in partially sodic wastelands. Besides, it was also used for display, education, conservation and related studies. The bambusetum was created with an aim to develop appropriate agro-technology integrated with value chains for bamboo products, appropriate trainings, business development services for better income generation opportunities.

Amaranthus

The repository was enriched with the addition of 1223 accessions of *Amaranthus* spp., including *A. hypochondriacus*, *A. cruentus* and *A. caudatus* (Fig. 1). These were also evaluated for identification of various agronomically important quality traits, specific lines, as well as preparation of core set of germplasm for molecular marker studies and marker assisted

Ecological development and sustainable utilization of sodic wastelands, conservation and enrichment of various germplasm, outreach programmes/extension activities for famers and entrepreneurs

breeding. The improved lines of grain amaranth will help the farmers fetch good prices in local market and also to improve their health.



Fig. 1: *Amaranthus* germplasm collection at Distant Research Centre, Banthra

Screening tuberos varieties for cultivation in partially sodic land

Collection, conservation and evaluation of 30 varieties of tuberos (*Polanthes tuberosa* L.), including single type and double type flower, were done. Some varieties of tuberos were also exposed to gamma induced radiation to obtain the new mutant varieties.

Evaluation of quinoa (*Chenopodium quinoa*) for screening of salinity tolerance

Fourteen accessions of quinoa (*Chenopodium quinoa*) were evaluated for their growth and yield performance at different sodicity level. Quinoa plant is much adaptable to contrasting environments such as saline soils, nutrient-poor soils and drought stressed marginal agro-ecosystems. Therefore, it has been selected as an experimental crop to sustainably utilize the sodic wastelands (Fig. 2).



Fig. 2: *Chenopodium quinoa* germplasm collection at Distant Research Centre, Banthra

Evaluation of Linseed (*Linum usitatissimum*) on partially sodic land Linseed is an important crop produced for natural textile fibre (linen) or oil. A study was undertaken on 300 accessions of linseed for screening the promising germplasms that can be successfully grown in partially sodic waste land and those having high oil content and fibre quality. These lines are also being studied for their tolerance level for salt stress soil, by conducting the experiments at DRC Banthra.

Application of carbon dots as growth enhancers in agriculture system

The study aims to evaluate the efficacy of the mode of carbon dots application (induction) into the plant system vis-a-vis their effectiveness. These carbon dots were synthesized from rice-wheat straw and represent kind of nanotechnology-based plant

growth regulators or enhancers, which are not much explored for increasing agricultural production in a sustainable manner. The effect of carbon dots on crop physiology, photosynthesis and yield attributes along with the crop yield and biomass yield are being measured. Initial laboratory studies indicated that there is a huge potential for these nano-particles like carbon dots as plant growth regulators or enhancers through activation of photosynthesis.

Synthesis of zeolites from fly ash for application in agriculture

Zeolites, known as 'intelligent fertilizers' are produced by coal combustion from electricity generating plants. Because of their ion exchange capacity (CEC) and high porosity, these have ability to improve fertilizer efficiency resulting in increased productivity and reduced leaching of nutrients from the soil. Field experiments were carried out to study the response of zeolites on growth and yield performance of dominant traditional rice-wheat cropping system of Indo-Gangetic plains. The technology will not only enable to consume coal ash in bulk quantity but also offer competitive prices for fertilizer industry. Farmers will be benefited using this technology as application of zeolites will improve the fertilizer efficiency and reduce their cost of cultivation.

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Plant conservation, domestication of wild ornamentals, improvement of ornamental plants, reproductive biology, plant taxonomy, evolution and diversification of gymnosperms

New *Cycas* species discovered

A new species *Cycas divyadarshanii* Khuraijam & Rita Singh was discovered and described from Sadar Hills of Manipur in North East India. (Fig. 1). The species is unique in having large cylindrical ovoid male cone bearing long narrow microsporophylls with long apical spines, and deeply pectinate wooly megasporophylls with appendiculate apical spine. The new species has an extended distribution in Myanmar, China, Thailand, Vietnam.

Domestication of wild ornamentals

Wild ornamental plants have great potential in floriculture and dry flower markets. The absence of information on wild native ornamentals plants of India has curtailed the chances of exploring ornamental values of the native plants. Due to this drawback the ornamental potentials of native plants cannot be harnessed efficiently in main stream floriculture market and such plant treasures are exploited in the hands of selective plant collectors. A list of wild ornamentals found across the country are prepared and efforts are being made to domesticate them. Seeds or cuttings of species in large populations were collected rather than the whole live plants. Developing new ornamental cultivars with improved floral attributes is a major goal in floriculture. Horticultural intervention and mutation breeding methods were employed for improvement of wild ornamentals such as *Iris*, *Hoya*, *Cycas*, etc.

Floricultural Research

Morphological characterization of 70 varieties of *Gladiolus*, 20 varieties of *Canna* and 10 varieties of *Bougainvillea* were carried out based on DUS Test

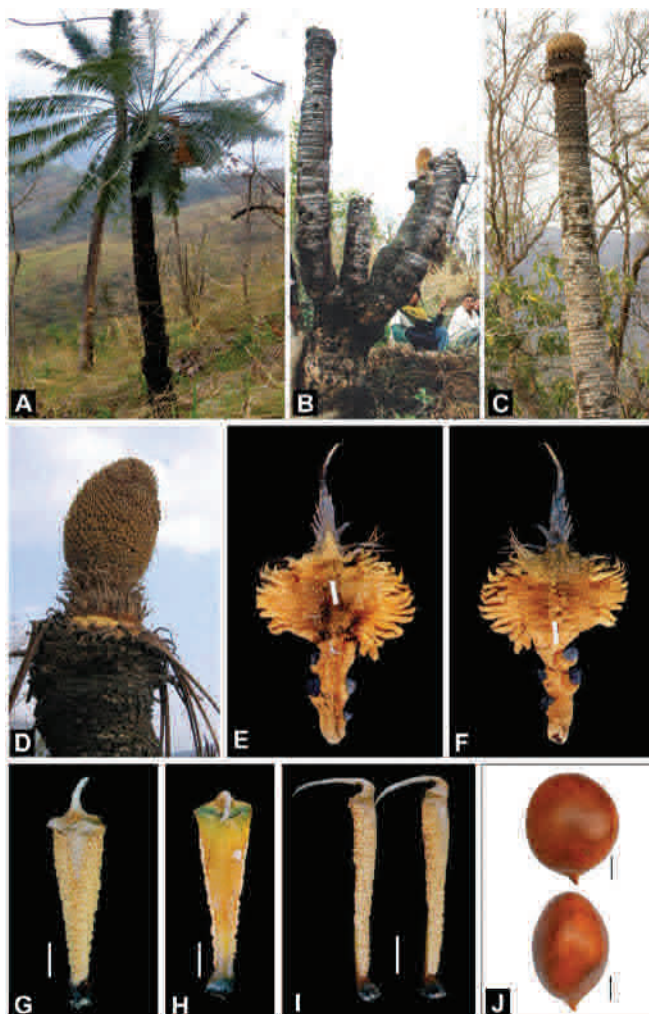


Fig. 1: *Cycas divyadarshanii* Khuraijam & Rita Singh (A). A slender tree, (B). A branched male plant with male cone, (C). An unbranched female plant, (D). A mature male cone, (E-F). Megasporophyll with long apical spine and deeply pectinate wooly lamina and stalk with aborted ovules, (G-I). Microsporophylls with inflexed apical spine, J. Mature seeds. Scale bar: 1 cm (Source: *Cycads* 5 (1): 59-76. 2020).

guidelines of PPV&FRA. Hybridization and mutation breeding of ornamental plants such as *Gladiolus*, *Canna*, *Nymphaea*, *Reinwardtia indica* are taken up for their improvement (Fig. 2).



Fig. 2: *Reinwardtia indica*- An ornamental plant

Plant introduction and conservation

Field trips were carried out and several species were introduced successfully. Seed germination studies of some threatened plants were carried out. Hundreds of plants were raised through seed germination and vegetative propagation. Some of the species are: *Pterocarpus santalinus*, *P. marsupium*, *Indopiptadenia oudhensis*, *Hardwickia binata*, *Ephedra foliata*, *Baliospermum montanum*, *Commiphora caudata*, *Commiphora wightii*, *Saraca asoca*, *Hildegardia populifolia*, *Boswellia ovalifoliolata*, *Adenanthera pavonina*, *Taxus wallichiana*, etc. (Fig. 3).

Seeds and plants of cycads were introduced in Cycad House at Botanic Garden. Some of the



Fig. 3: Seedlings of *Indopiptadenia oudhensis*- A threatened plant at Botanic Garden

newly introduced species are: *Cycas divyadarshanii*, *C. seshachalamensis*, *C. couttsiana*, *C. cairnsiana*, *C. multipinnata*, *C. taitugensis*, *C. pranburiensis*, *C. siamensis* and *Certozamia mexicana* (Fig. 4 & 5).



Fig. 4: Seed germination of *Certozamia mexicana* - a newly introduced cycad plant at botanic garden



Fig. 5: Inner view of Cycad House at Botanic Garden

Database of flora of NBRI Botanic Garden

A database of trees and shrubs conserved in thematic gardens, plant houses, Arboretum and public places in CSIR- NBRI Botanic Garden was prepared. Each tree and shrubs are geo-tagged and this information will be used for preparation of online database of flora of CSIR Botanic Garden accessible through QR embedded plant labels.

Gymnosperm Research

Morphology, pollination and seed germination studies of Indian *Cycas* have been initiated. This ongoing research will help in understanding the morphological variations, reproductive biology mechanism and conservation.

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Bio-resource inventory, bioprospection, ecology, reproductive biology, varietal development and germplasm conservation of medicinal, aromatic and horticultural crops, and out-reach/training/skill development

Floristic study in Western Himalaya

Sarthal Hill (Jammu & Kashmir) located in Western Himalaya is a rich repository of floristic diversity due to its varied topography and climatic conditions. The regions remain covered with snow for at least three months in a year and remain cut-off from public. One botanical exploration field tour was conducted for the collection and documentation of plant species occurring in Sarthal region. A total of 166 plant samples were collected comprising angiosperms, gymnosperms and ferns from the study area. The tree canopy mostly comprised of conifers such as *Abies pindrow*, *Cedrus deodara*, and *Picea smithiana*, and flowering plants such as *Alnus nitida*, *Betula utilis*, *Quercus semecarpifolia*, and *Ulmus wallichiana*. The shrub layer is dominated by *Berberis jaechkeana*, *Phlomooides bracteosa*, *Salix denticulata*, and *Viburnum grandiflorum*, whereas the herb layer was represented by *Arnebia benthamii*, *Geranium wallichianum*, *Potentilla atosanguinea*, *P. nepalensis*, *Ranunculus laetus*, *Rhodiola wallichiana*, and *Saxifraga sibirica*. The work is in progress.

Ecological study in Northeast India

Survey and assessment of biodiversity of Kameng river of Arunachal Pradesh (Northeast India) was initiated under a project - 'Cumulative impact assessment for cascading interventions in Himalaya Rivers (Ci2HR)'. One field trip during the late winter season (2-9 February 2021) was conducted for plant survey, collection, and assessment of biodiversity along Kameng river. Site selection for phytosociological study pertaining to frequency, density, basal area, IVI and volume was undertaken

for tree, shrub and herb species growing in the study area. Common tree species recorded from the study area included *Acacia pycnantha*, *Acer campbellii*, *Albizia lebbek*, *Dendrocalamus strictus*, *Gymnocladus assamicus*, *Dysoxylum hamiltonii*, *Macaranga denticulata*, *Phoebe cooperiana*, *Oroxylum indicum*, *Pinus roxburghii* and *Tetrameles nudiflora*. The common shrub and herb species included *Ageratum conyzoides*, *Abroma augusta*, *Amorphophalus bulbifer*, *Argyrea nervosa*, *Brugmantia suaveolens*, *Chromolena odorata*, *Cissampelos pareira*, *Costus speciosus*, *Crasocephalum crepioides*, *Eichhornia crassipes*, *Lantana camara*, *Datura stramonium*, *Mahonia nepalensis*, *Melastoma malabathricum*, *Meremia tridentata*, *Oxyspora paniculata*, *Paederia scandens*, *Sida acuta*, *Stachytaphata imbricata*, *Tinospora cordifolia* and *Trichosanthes bracteata*.

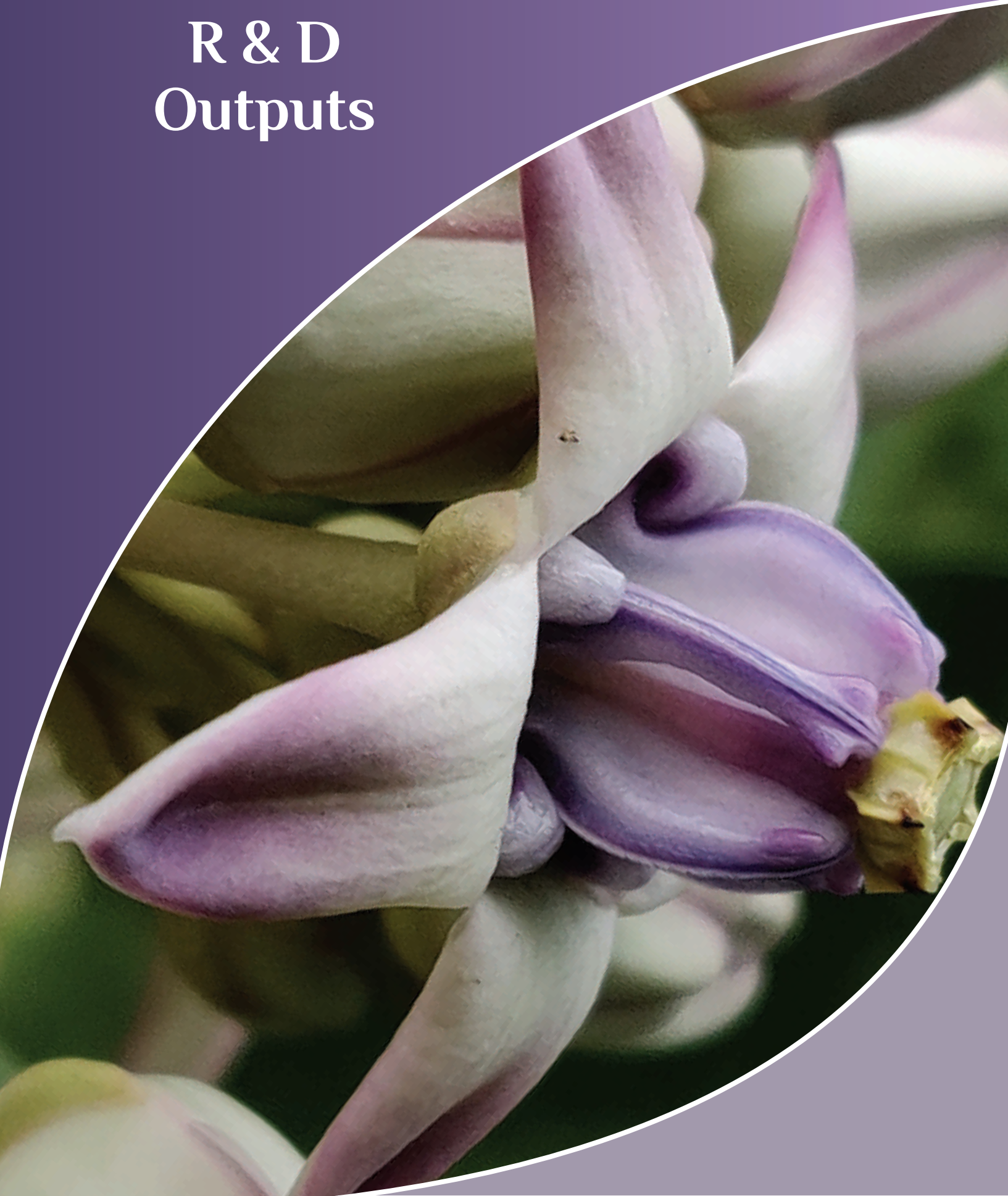
Skill Development and Outreach Activities

Under CSIR programmes Aroma mission, Floriculture mission and Skill development, 11 one day awareness-cum-skill development training programmes were conducted in various regions of Uttar Pradesh for extension and popularization of CSIR technology with the aim to increase farmer's income, and employment opportunities.

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R & D Outputs



PUBLICATIONS

Publications in SCI Journals

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PATENTS FILED/GRANTED

Patents Granted (International)

Title	Inventors	Application No.	Country	Grant Date	Patent No.
Novel reversible expression system for transgene expression in plants	Sawant SV, Singh SP	15/567040	USA	March 02, 2021	10934556

Patents Filed (India)

Sr. No.	Title	Inventors	Application No.	Filed Date
1.	An herbal nano-emulsion for skin care and a process for the preparation thereof	Mishra A, Pandey S, Giri VP	202011049588	November 11, 2020
2.	Herbal formulation of essential oil for dental treatment and a process for preparation thereof	Barik SK, Singh BN, Rao ChV, Prateeksha	202111006546	February 16, 2021

Patents Granted (India)

Sr. No.	Title	Inventors	Application No.	Grant Date	Patent No.
1.	A novel formulation for polyherbal masticatory product useful for tobacco de-addiction and health rejuvenation	Nautiyal CS, Kumar D, Rawat AKS, Agarwal S, Mani D, Ojha SK, Pal A, Rao ChV, Darokar MP, Kalra A	2008DEL2013	September 30, 2020	348376
2.	Herbal composition for the management of diabetes	Nautiyal CS, Rao ChV, Ojha SK, Rawat AKS, Mani D, Pal A, Kumar D	1591DEL2014	December 28, 2020	354536
3.	A synergistic pharmaceutical composition for gastrointestinal disorders	Pandey G, Rao ChV, Sidhu OP, Rawat AKS, Nautiyal CS	1698DEL2014	March 01, 2021	359877

**HUMAN RESOURCES DEVELOPMENT****CSIR-NBRI Participation in Trainings/Exhibition/Flower Shows/Seminars**

Sr. No.	Event Details	Venue	Date	Participating Division
1.	Biosphere Reserve in India: Identification, Conservation and Management	Govt. Madhav Sadashiv Rao Golbalkar Collage, Rewa, Madhya Pradesh	March 15-19, 2021	Botanic Garden
2.	Fruit, Vegetable and Flowers Exhibition	Raj Bhawan, Governor's House, Lucknow	February 06-08, 2021	TTBD and Botanic Garden

Trainings Received by Individual

Sr. No.	Name of Person (s)	Subject of Training Course	Organizer/ Place	Date/ Period
1.	Dr. Sanjeeva Nayaka	Biological Data Science Training (Introductory Bioinformatics, Next Generation Sequencing (RNA Seq., DNA Seq., Metagenomics), Data Analysis, Protein Structure Modeling, Visualization and Molecular Dynamics Simulations)	Bioinforres (OPC) Pvt. Ltd., Mussa Chak R.S. Pura, Jammu	01 June – 31 July, 2020
2.	Dr. KJ Singh	Online training course on "Biodiversity Conservation"	Wildlife Institute of India, Dehradun	February 22-26, 2021
3.	Dr. KJ Singh, Dr. Anju Patel	Orientation/ Induction Programme (Induction programme for newly recruited scientists)	CSIR-HRDC, Ghaziabad	March 01-10, 2021
4.	Dr. ChV Rao	Micro Enterprises Development for Project Officers and Field officers of Govt. Department	National Institute for Micro, Small and Medium Enterprises, Hyderabad	March 15-19, 2021
5.	Ms. Vedika Gupta	Online training on Application of Geoinformatics in Ecological Studies	Indian Institute of Remote Sensing, Indian Space Research Organization, Dehradun	June 13-24, 2020
		E-workshop on 'Mushroom, Medicinal and Aromatic Plant Cultivation'	Department of Botany, Mahatma Jyotiba Fule Commerce, science and Vitthalrao Raut Arts college, Bhatkuli, Dist. Amravati, (Maharashtra)	June 29-30, 2020
6.	Mr. Ajay Mishra	National workshop on 'Intellectual Property Rights'	Government P. G. College Nagnath-Pokhari, Chamoli, Uttarakhand & National Research Development Corporation, New Delhi, India.	July 21, 2020
7.	Dr. SK Tewari	DUS testing data management/ Automation/Image Analysis	Protection of Plant Varieties and Farmers' Rights Authority, New Delhi	October 07-08, 2020

Trainings Imparted to Groups

E-trainings organized by Botanic Garden, CSIR-NBRI, Lucknow

Sr. No.	Subject of Training	No. of Participants	Date/Period
1.	Bonsai Technique	164	November 10, 2020
2.	Home Gardening	153	August 26-28, 2020
		116	October 07-09, 2020
3.	Dehydrated Floral Crafts	23	June 18, 2020
		100	January 20, 2021
		227	March 05, 2021
4.	Training on biofertilizer production and application technique	117	September 02-04, 2020

Other Group Trainings Imparted

Sr. No.	Co-ordinating Division	Subject	No. of participants	Place	Date
1.	CSIR-NBRI	Utilization of temple flower waste by extraction of colour for making herbal gulal	100	Mahila Modern Jail, Ayodhya	November 29, 2020
2.	Vigyan Foundation, Lucknow & Botanic Garden, CSIR-NBRI, Lucknow	Training programme for school children and teachers	45	CSIR-NBRI, Lucknow	February 17, 2021
3.	Babasaheb Bhim Rao Ambedkar University, Lucknow & Botanic Garden, CSIR-NBRI	One day training programme for farmers, NGOs and entrepreneurs for the state of UP, Himachal Pradesh, Uttarakhand	36	Not Given	February 25, 2021
4.	CSIR-NBRI and Department of Horticulture, Lucknow, Uttar Pradesh	'Betelvine Production in Model Bareja', especially for scientific updates to the farmers	32	Distant Research Centres, Banthra	February 18, 2021
			55		February 24, 2021
			26		March 01, 2021

Trainings Imparted

CSIR-Aroma Mission: Cultivation of turmeric for essential oil from leaf

Sr. No.	No. of Participants	Place	Date
1.	20	Seepa, Arunachal Pradesh	February 06, 2021
2.	15	Hupra, Dhanbad, Jharkhand	February 14, 2021



3.	38	CSIR-NBRI, Distant Research Centre, Banthra, Lucknow (UP)	February 18, 2021
4.	52		February 24, 2021
5.	35		March 01, 2021
6.	16	Village- Deeha, Malihabad, Lucknow (UP)	March 04, 2021
7.	23	Village- Nabipanah, Malihabad, Lucknow (UP)	
8.	15	Village-Vairgal Dubauliya, Basti (UP)	March 05, 2021
9.	35	Village-Shivgarh, Raebareli (UP)	March 08, 2021
10.	23	Village- Rajmau, Raebareli (UP)	
11.	26	Village-Ptiyasha, Jajal, Muzaffarpur, Bihar	March 12, 2021

Skill Development Programmes Organized

Sr. No.	Name of the Programme	Date/period	Number of the candidates	Title
1.	CSIR Integrated Skill Initiative	September 02-04, 2020	117	Biofertilizer Production and Application Techniques
2.	CSIR Integrated Skill Initiative	July 08-August 09, 2020	15	Phytochemicals Analysis Technician
3.	Green Skill Development Program (GSDP) of Ministry of Environment, Forest & Climate Change (MoEF&CC), Govt. of India.	February 09- March 19, 2021	11	Plant Tissue Culture Techniques & Its applications
		December 22, 2020 January 25, 2021	07	Pollution Monitoring: Soil Pollution
			17	Greenbelt Development for Industries

HONORS/AWARDS/DISTINCTIONS

Honours/Awards/Recognitions Received by Individual

Dr. PK Singh awarded INSA Fellowship 2020

Dr. P. K. Singh, Senior Principal Scientist, CSIR- National Botanical Research Institute, Lucknow, has been elected for the prestigious Indian National Science Academy Fellowship on 20th October 2020. Dr. P K Singh has made outstanding contributions towards identification of novel molecules and approaches to control insect pests in field crops. His work provides a complete model, from discovering new proteins to genes, making synthetic genes to develop transgenic crop lines and their performance evaluation. Transgenic cotton lines expressing three different novel genes (cry1EC, Tma12 and Msc 14) developed by his group provide next-generation insecticidal approaches for control of insect pests. Tma12 GM cotton has been provided to Punjab Agricultural University, Ludhiana for development of whitefly tolerant cotton varieties. He has also developed a GM cotton that functions as a Trap-cum-Death sink for whitefly and associated viruses. Trap cotton has a potential to provide defence to a variety of vegetable and horticultural crops prone to viral diseases at a negligible cost. A similar technology is not yet available in the world. His work provides rare research procedures developed completely in India.

Sr. No.	Name of the Person	Award (s)
1.	Dr. BN Singh	<ul style="list-style-type: none"> Industrial Medal Award of Biotech Research Society, India (BRSI) for the year 2019
2.	Dr. KJ Singh	<ul style="list-style-type: none"> Prof. AP Das Biodiversity Medal 2020 (East Himalayan Society for Spermatophyte Taxonomy, Siliguri) Fellow, Association of Plant Taxonomy, Dehradun
3.	Dr. Sanjeeva Nayaka	<ul style="list-style-type: none"> Fellow of Linnean Society (FLS), London Fellow of Mycological Society of India (FMSI), Chennai Fellow of Indian Botanical Society (FBS), Lucknow Fellow of Society for Science of Climate Change and Sustainable Environment (FSSCE), New Delhi Fellow of Association for Plant Taxonomy (FAPT), BSI, Howrah

Member, Editor, Referee, Expert, Reviewer, Judge etc. (selected, recognized, enrolled, empaneled, nominated)

Sr. No.	Name of the person	Details
1.	Dr. Aradhana Mishra	<ul style="list-style-type: none"> Editor of <i>Plos One</i>
2.	Dr. BN Singh	<ul style="list-style-type: none"> Editors of journal '<i>Surgery Insights</i>', '<i>Cancer Biology</i>'
3.	Dr. ChV Rao	<ul style="list-style-type: none"> Editorial Board member of journal '<i>Pre-Clinical Research</i>' CPCSEA Nominee by Ministry of Environment and Forest, New Delhi Management committee member, Indian Association for the Study of Traditional Asian Medicine, India Research council member of Dr. APJ Abdul Kalam Technical University, Amity University and Integral University, Lucknow Member of expert panel, Bureau of Indian Standards, AYUSH Sectional Committee - FAD 26
4.	Dr. KJ Singh	<ul style="list-style-type: none"> Member, IUCN/Species Survival Commission, Cycad Specialist Group, Conifer Specialist Group and Western Ghats Plant Specialist Group Member, International Association of Plant Taxonomy



		<ul style="list-style-type: none">• Member, The Cycad Society• Member, International Society for Horticultural Science• Member, Society of Herbarium Curators• Life Member, Indian Botanical Society• Life Member, Society of Ethnobotanists• Life Member, East Himalayan Society for Spermatophyte Taxonomy• Editor-in-Chief, 'NeBIO'• Editor, 'Cycads' (IUCN/SSC Cycad Specialist Group)• Associate Editor, 'Asian Journal of Conservation Biology'
5.	Dr. KM Prabhukumar	<ul style="list-style-type: none">• Section Editor of 'Phytotaxa'• Associate Editor of 'Webbia'
6.	Dr. KN Nair	<ul style="list-style-type: none">• Member, Quinquennial Review Team (2013-2018), ICAR-National Bureau of Plant Genetic Resources, New Delhi• Member, Quinquennial Review Team (2013-2018), AICRN- Potential Crops, ICAR-National Bureau of Plant Genetic Resources, New Delhi• Member, Task Force for CSIR-TKDL Project " Digitization of Indian Systems of Medicines-Sidha and Sowa Rigpa (MLP0005)", CSIR, New Delhi• Member, Task Force (06/2020) for "Development of DUS test Guidelines for Gerbera", PPVFRA, New Delhi
7.	Dr. LB Chaudhary	<ul style="list-style-type: none">• Managing Editor of the journal 'Ethnobotany'• Reviewer of Journal of Threatened Taxa, Phytokeys and Phytotaxa
8.	Dr. PC Verma	<ul style="list-style-type: none">• Section Editor of Journal 'BMC Genomics', 'Current Pharmaceutical Biotechnology'• Guest Editor of journal 'Life'
9.	Dr Poonam C Singh	<ul style="list-style-type: none">• Associate editor of journal 'BMC Microbiology' and editorial board member of journal 'Global Journal of Microbiology and Biotechnology'
10.	Dr. Priyanka Agnihotri	<ul style="list-style-type: none">• Editor of 'Phytotaxa'
11.	Dr. PS Chauhan	<ul style="list-style-type: none">• Associate Editor of journal 'Frontiers in Microbiology'• Academic Editor of journal 'Plos One'
12.	Dr. PK Srivastava	<ul style="list-style-type: none">• Reviewer of journals 'Chemosphere, Science of the Total Environment, Ecological Engineering, Journal of Arid Land Research Management'• Associate editor of journal 'Bioremediation and Biodegradation'
13.	Dr. Sharad Srivastava	<p>Member/Experts of the following committees:</p> <ul style="list-style-type: none">• Selection committee for Women Scientist (WOS-B) -Societal Scheme from DST• Expert committee for AWSR award scheme of Vigyan Prasar• Expert committee for SYST scheme of DST• Expert committee to TIASN, DST• Expert committee to TARA/Core group, DST• Expert committee for PPA scheme of DST• Expert panel for spices & culinary herbs of FSSAI• Expert panel for IPC• PSC of NMPB• Expert panel for Food Safety Network of FSSAI• Expert committee APEDA
14.	Dr. Vijay Anand Raj S	<ul style="list-style-type: none">• Life Member of Indian Virological Society: New Delhi, INDIA and World Society for Virology: Massachusetts, USA, Life Member

PHDs SUBMITTED AND AWARDED

Ph.D Theses Awarded

Sr. No	Name of the Student	Title of Thesis	Guides	University
1.	Ms. Arpita Bhattacharya	Defence modulating strength of endophytes in inducing resistance in <i>Solanum lycopersicum</i> in wilt disease infested environment	Dr. Aradhana Mishra, Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
2.	Mr. Ashish Sharma	CRISPR/Cas9-mediated genome editing of <i>Arabidopsis thaliana</i> miR858 and functional characterization of its regulatory miPEP	Dr. PK Trivedi, Former Senior Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
3.	Mr. Bhoopendra K Pandey	Exploring the role of alternative splice variants of CAMTA1 in stress physiology of <i>Arabidopsis thaliana</i>	Dr. Samir V Sawant, Senior Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
4.	Ms. Deepali Srivastava	Identification and characterization of abiotic stress-responsive genes in rice for enhanced stress tolerance	Dr. Debasis Chakrabarty, Principal Scientist	Kumaun University, Nainital
5.	Ms. Madhu Tiwari	Interaction of <i>Agrobacterium VirE2</i> protein with host protein of Rice (<i>Oryza sativa</i> L.): Implications for the T-DNA transfer process	Dr. Debasis Chakrabarty, Principal Scientist/ Prof. AK Mishra	BHU, Varanasi
6.	Ms. Meenakshi Kushwaha	Contribution of microbial diversity in soil organic matter (SOM) pool in a tropical dry deciduous forest	Dr. Vivek Pandey Senior Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
7.	Ms. Nitanshi Jauhari	Bacteria-mediated degradation of petroleum hydrocarbons in <i>in-vitro</i> conditions	Dr. DK Upreti, Former Chief Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
8.	Ms. Pallavi Agarwal	Characterization and functional analysis of PGPR induced genes in rice	Dr. Vidhu A Sane, Senior Principal Scientist/Dr. Alvina Farooqui	Integral University, Lucknow
9.	Ms. Prateeksha	Lichenized fungi metabolites derived nanomaterials and their biomedical application	Dr. BN Singh, Senior Scientist/ Mohd. Aslam Yusuf	AKTU, Lucknow



10.	Mr. Ram Naresh	Role of <i>GhNAC2</i> in root development	Dr. Vidhu A Sane, Senior Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
11.	Ms. Shipra Pandey	Synthesis and characterization of bio-nanomaterials for management of early blight disease in tomato	Dr. Aradhana Mishra, Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
12.	Mr. Shravan Paswan	Studies on the mechanisms of selected traditional plants on wound healing activity	Dr. ChV Rao, Senior Principal Scientist/ Dr. Sajal Srivastava	Amity University, Lucknow
13.	Ms. Sonal Srivastava	Role of phosphate accumulating bacteria in abiotic stress amelioration and elucidation of its mechanism	Dr. Suchi Srivastava, Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
14.	Ms. Suman B Singh	Environmental studies on arsenic bioavailability and its regulation for risk assessment and remediation of contaminated soils	Dr. PK srivastava, Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
15.	Mr. Swapnil Pandey	Extraction and characterization of phytomolecules from <i>Betula utilis</i> L. from their antiaging and neuroprotective activities in <i>Caenorhabditis elegans</i>	Dr. PS Chauhan, Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
16.	Mr. Vinod Kumar	Characterization of root specific transcription factor SIMYBHTH from tomato	Dr. Vidhu A Sane, Senior Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
17.	Mr. VK Maurya	Impact of ambient Ozone on some crops under elevated CO ₂ condition	Dr. Vivek Pandey, Senior Principal Scientist/ Dr. Nalini Pandey	Lucknow University, Lucknow

Ph.D. Theses Submitted

Sr. No.	Name of the student	Title	Guides	University
1.	Mr. Anil Kumar	Over-expression of glutaredoxin (<i>Grx</i>) gene and its role in drought stress.	Dr. Indraneel Sanyal, Senior Principal Scientist/ Prof. Veena Pande	Kumaun University, Nainital

2.	Mr. Ankesh Pandey	Expression of <i>Cocculus hirsutus</i> trypsin inhibitor (<i>ChTI</i>) for resistance to <i>Helicoverpa armigera</i> and <i>Spodoptera litura</i> .	Dr. Indraneel Sanyal, Senior Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
3.	Ms. Deepika Singh	Characterization of root specific WRKY genes from tomato	Dr. Vidhu A Sane, Senior Principal Scientist	Integral University, Lucknow
4.	Mr. Lal Chand Pal	Anticancer potential of selected medicinal plants against hepatocellular carcinoma using cancer cell lines	Dr. ChV Rao, Senior Principal Scientist/ Prof. Veena Pande	Kumaun University, Nainital
5.	Mr. Mohd. Akram Ansari	Morphological, biochemical and molecular responses of Guar (<i>Cyamopsis tetragonoloba</i> (L.) Taub.) to drought stress	Dr. Vivek Pandey, Senior Principal Scientist/ Prof. Veena Pande	Kumaun University, Nainital
6.	Ms. Neha Agrawal	Role of NPR1 in global nucleosomal remodeling in <i>Arabidopsis thaliana</i>	Dr. Samir V Sawant, Senior Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
7.	Ms. Poorwa Badola	Molecular components involved in miR858-dependent plant growth and development	Dr. PK Trivedi, Former Senior Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
8.	Ms. Radha Shivhare	Transcript profiling of pearl millet (<i>Pennisetum galucum</i> L.) under drought stress and functional characterization of a stress-responsive gene	Dr. Charu Lata, Former Scientist,	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
9.	Mr. Rahul Michael	Light-mediated transcriptional regulation of terpenoid biosynthetic pathway in <i>Arabidopsis thaliana</i>	Dr. PK Trivedi, Former Senior Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
10.	Ms. Ria Khare	Molecular mechanisms involved in arsenic stress response under limiting sulphur condition in <i>Arabidopsis thaliana</i> natural variation	Dr. PK Trivedi, Former Senior Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
11.	Ms. Rekha Kannaujia	Assessing the effects of biologically synthesized silver Nanoparticles (AgNPs) and Ethylenediurea (EDU) on some Indian plants under ambient ozone stress.	Dr. Vivek Pandey, Senior Principal Scientist/ Prof. Vivek Prasad	Lucknow University, Lucknow



12.	Mr. Vinay Kumar	Molecular marker and phenotypic trait based genetic diversity analysis in <i>Lepidium sativum</i> Linn.	Dr. HK Yadav, Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
13.	Mr. YV Dhar	Bioinformatics based structural analysis of bi-functional TCS protein modules involved in ripening mechanism of fruits	Dr. Mehar H Asif, Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.

MD Theses Submitted

Sr. No.	Name of the student	Title	Guide	University
1.	Ajay Kumar Tiwari MD (Dravyguna) (2018-2021)	Ethnobotanical survey of herbal drugs used in traditional ayurveda at Katarniaghat wildlife sanctuary of Bahraich district U.P.	Dr. SK Ojha, Senior Principal Scientist	PG Dept. of Dravyguna, State Ayurvedic College & Hospital, Lucknow
2.	Dhanesh Awasthi MD (Dravyguna) (2018-2021)	Controlled clinical study to evaluate the efficacy of karanjadi lepa in case of dadru w.s.r. To <i>Tinea</i> infection	Dr. SK Ojha, Senior Principal Scientist	Post Graduate Department of Dravyguna, L.H.S.P.G. Ayurveda College and Hospital, Pilibhit
3.	Sushil Kumar MD (Dravyguna) (2018-2021)	Comparative analytical studies on wild and cultivated varieties of <i>Asparagus adscendens</i> roxb.	Dr. SK Ojha, Senior Principal Scientist	Post Graduate Department of Dravyguna, L.H.S.P.G. Ayurveda College and Hospital, Pilibhit

S & T
Support



PLANNING, MONITORING AND EVALUATION DIVISION

Anil Kumar Gauniyal

a.k.gauniyal@nbri.res.in

Area Co-ordinator, S&T Support Services and Head,
Planning, Monitoring and Evaluation Division

Highlights and Major Activities

The Planning, Monitoring and Evaluation (PME) Division of the Institute acts as a liaison between Director and various R&D groups; CSIR HQ and other organizations. PME 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 PME 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 2020-21, 14 Grant-in-Aid/ Sponsored projects were populated in the R&D module as a part of ERP solutions for quick online accessibility and usability of complete accurate information. In order to commence online operations of project activities, project details of new Contract R&D were entered in the Research and Development Portal to facilitating online operation. The associated staff in the respective projects were mapped.

Projects Initiated during April 01, 2020 to March 31, 2021

S. No.	Project Number	Project title	Funding Agency	Principal Investigator	Duration Details
Projects funded by outside agencies					
1.	GAP 3480	Construction of SNP based high-density consensus linkage map and QTL identification in <i>Linseed</i>	SERB, New Delhi	Dr. HK Yadav	36 months w.e.f. June 11, 2020
2.	GAP 3481	Development of nutraceutical supplement for diarrheal conditions	DST, New Delhi	PC: Dr. Sharad Srivastava PI: Dr. SP Singh	24 months w.e.f. June 08, 2020
3.	GAP 3484	U.P. State COVID-19 project at CSIR-NBRI, Lucknow	Government of Uttar Pradesh, Lucknow	Dr. SV Sawant/Dr. PK Singh	8 months w.e.f. July 23, 2020



4.	GAP 3485	Assessment of diversity and species composition of bryophytes in Chail Wildlife Sanctuary (Himachal Pradesh) in relation to anthropogenic intervention and conservation strategies for potential and rare taxa	SERB, New Delhi	PC: Dr. AK Asthana PI: Dr. Reesa Gupta	24 months w.e.f. July 20, 2020
5.	GAP 3486	National coordination of scheme of young scientists and technologists (SYST)	DST, New Delhi	Prof. SK Barik & Dr. SK Srivastava	36 months w.e.f. November 12, 2020
6.	GAP 3487	Agri waste management by developing hygroscopic rice straw pellets for alleviating drought stress and improving soil fertility through microbial intervention	DST, New Delhi	PC: Dr. Poonam C Singh PI: Dr. Pallavi Agarwal	36 months w.e.f. May 01, 2020
7.	GAP 3488	Threat assessment of traded forest flora of Madhya Pradesh	Madhya Pradesh State Biodiversity Board	Dr. VV Wagh & Prof. SK Barik	36 months w.e.f. December 09, 2020
8.	GAP 3489	Cumulative impact assessment for cascading interventions in Himalayan rivers (Ci2HR)	GB Pant National Institute of Himalayan Environment (NIHE), Almora, Uttarakhand	Prof. SK Barik	30 months w.e.f. December 22, 2020
9.	GAP 3490	Certificate course on plant tissue culture technique and its application	MoEF&CC, New Delhi	Dr. Pankaj Srivastava	3 months w.e.f. January 01, 2021
10.	GAP 3491	Deciphering limb regeneration potential in ladybird beetles	SERB, New Delhi	Dr. PC Verma	36 months w.e.f. December 30, 2020
11.	GAP 3492	Enabling tribal farmers of Dudhwa regions of Uttar Pradesh for on-farm utilization of rice straw for better soil health and productivity through awareness cum demonstration program	The National Academy of Sciences (NASI), Prayagraj	Dr. Suchi Srivastava	24 months w.e.f. January 12, 2021
12.	GAP 3493	Rapid composting of rice straw in field for crop residue management in rice wheat cropping system through microbial intervention	DBT, New Delhi	Dr. Suchi Srivastava	36 months w.e.f. January 18, 2021

13.	GAP 3494	Deciphering the role of <i>Paenibacillus lentimorbis</i> NRRL B-30488 in controlling the early blight in Tomato caused by <i>Alternaria solani</i> by using metabolomics approach	SERB, New Delhi	PC: Dr. PS Chauhan PI: Dr. Garima Gupta	36 months w.e.f. January 01, 2021
14.	GAP 3495	Application of selenium for reducing arsenic level in rice (<i>Oryza sativa</i> L.) during arsenic stress	The National Academy of Sciences (NASI), Prayagraj	PC: Prof. SK Barik PI: Dr. RD Tripathi	36 months w.e.f. January 04, 2021
CSIR funded & In-house projects					
15.	HCP 0007	CSIR Aroma Mission-II nd Phase: Catalyzing rural empowerment through cultivation processing, value addition and marketing of aromatic plants	CSIR, New Delhi	Dr. Devendra Singh	15 months w.e.f. December 30, 2020
16.	HCP 0023	Next Generation Insect Resistance in Cotton: Development of next-generation transgenic cotton for broad spectrum resistance to field pests for yield protection (2 nd Phase)	CSIR, New Delhi	Dr. PK Singh	51 months w.e.f. December 10, 2020
17.	HCP 0037	CSIR Floriculture Mission	CSIR, New Delhi	NS: Prof. S.K. Barik Co-NS: Dr. SK Tewari	26 months w.e.f. January 18, 2021
18.	HCP 0101	Pilot Implementation of CSIR-Virtual Laboratory (for school student)	CSIR, New Delhi	NS: Dr. Vivek Srivastava Co-NS: Dr. AK Gauniyal	3 months w.e.f. December 02, 2020
19.	MLP 0006	Small RNAs and associated factors for enhanced post-harvest life (sRNA-Life) - Phase II	CSIR, New Delhi	Dr. MH Asif	26 months w.e.f. January 28, 2021
20.	MLP 0007	Genome editing for crop improvement (GE Crop)	CSIR, New Delhi	Dr. PC Verma	26 months w.e.f. January 28, 2021
21.	MLP 0027	Characterization and value addition of plant-based resins, gums and waxes (Phase II)	CSIR, New Delhi	Dr. Manjoosha Srivastava	26 months w.e.f. January 28, 2021
22.	MLP 0029	Pathway elucidation and identification of genes involved in guggulsterones biosynthesis in <i>Commiphora</i> sps (Phase II)	CSIR, New Delhi	Dr. MH Asif	26 months w.e.f. January 28, 2021



23.	MLP 0030	Sub-genome dominance in endoreduplication and its implication in heterotic benefits to F1-hybrids for biomass and their adaptation (Phase II)	CSIR, New Delhi	Dr. SV Sawant	26 months w.e.f. January 28, 2021
24.	MLP 0033	A novel herbal product for <i>Vulvovaginal candidiasis</i>	CSIR, New Delhi	Dr. BN Singh	20 months w.e.f. July 15, 2020
25.	MLP 0034	Testing of COVID-19	CSIR, New Delhi	Dr. SV Sawant	22 months w.e.f. May 29, 2020
26.	MLP 0035	Unravelling molecular details of drought tolerance in cotton	CSIR, New Delhi	Dr. SV Sawant	26 months w.e.f. January 28, 2021
27.	MLP 0036	Epigenetic modifications in <i>Rhizoctonia solani</i> during interaction with <i>Bacillus amyloliquefaciens</i> and its implication for biotic stress management in rice	CSIR, New Delhi	Dr. Suchi Srivastava	26 months w.e.f. January 28, 2021
28.	MLP 0037	Regulation of pectin methyltransferase inhibitor for enhancing plant-generated methanol for broad spectrum insect resistance	CSIR, New Delhi	Dr. PC Verma	26 months w.e.f. January 28, 2021
29.	MLP 0038	Deciphering the role of sRNA during synergistic interaction between two <i>Trichoderma</i> spp.	CSIR, New Delhi	Dr. Poonam C Singh	26 months w.e.f. January 28, 2021
30.	MLP 0039	Fe and Zn bio-fortification in rice through integrated microbial and soil nitrogen management in crop field	CSIR, New Delhi	Dr. Shekhar Mallick	26 months w.e.f. January 28, 2021
31.	MLP 0040	Arsenic (As) risk assessment in vegetable crops in arsenic affected areas and mitigation through microbial consortia containing AsMT activity	CSIR, New Delhi	Dr. Debasis Chakrabarty	26 months w.e.f. January 28, 2021
32.	MLP 0041	Conservation of threatened plant species of India	CSIR, New Delhi	Dr. TS Rana	26 months w.e.f. January 28, 2021
33.	MLP 0042	Plant resource mapping of Chambal Ravines	CSIR, New Delhi	Dr. AP Singh	26 months w.e.f. January 28, 2021
34.	MLP 0043	Leveraging genetic resources for accelerated genetic improvement of grain amaranth using genomics and phenotyping approaches	CSIR, New Delhi	Dr. HK Yadav	26 months w.e.f. January 28, 2021
35.	MLP 0044	To identify the potential <i>Aloe</i> species for cultivation in salt affected soils	CSIR, New Delhi	Dr. Lal Bahadur	26 months w.e.f. January 28, 2021

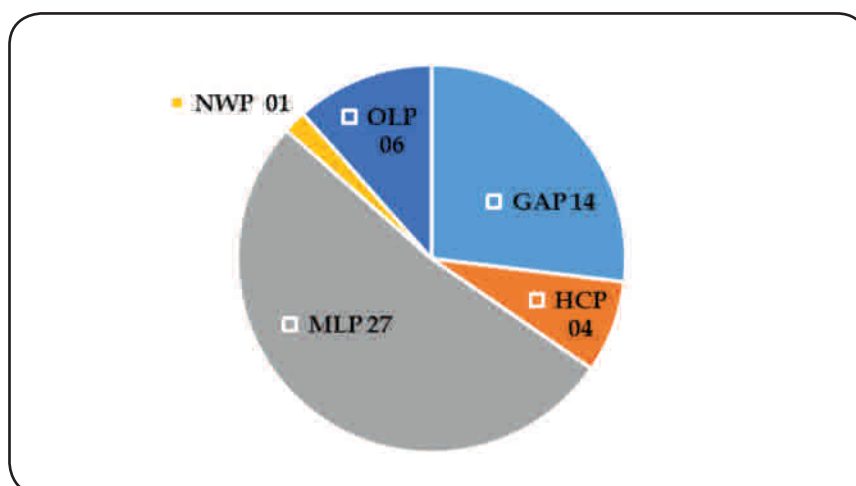
36.	MLP 0045	Conservation, Agronomics, Metabolomics and Genomics of Indian Lotus (KAMAL)	CSIR, New Delhi	PC: Prof. SK Barik PI: Dr. MH Asif	26 months w.e.f. January 28, 2021
37.	MLP 0046	Targeted metabolite genetics in two underutilized narcotic crops (Cannabis and Opium poppy) for <i>Cannabinoids</i> and <i>Oripavine</i> improvement	CSIR, New Delhi	Dr. SN Jena	26 months w.e.f. January 28, 2021
38.	MLP 0047	Characterization of boll-weight (BW) QTL hotspots for cotton yield improvement	CSIR, New Delhi	Dr. SN Jena	26 months w.e.f. January 28, 2021
39.	MLP 0048	Deciphering the mechanism(s) of host endophytes coevolution enhanced secondary metabolite production and crop productivity	CSIR, New Delhi	PC: Prof. SK Barik PI: Dr. PS Chauhan	50 months w.e.f. January 28, 2021
40.	MLP 0049	Bio-stimulants for stress amelioration, enhanced plant productivity and soil health	CSIR, New Delhi	PC: Prof. SK Barik PI: Dr. PS Chauhan & Dr. RC Nainwal	26 months w.e.f. January 28, 2021
41.	MLP 0050	Bio-efficacy and toxicity data generation for CIB registration of microbial formulations applicable for the biological control of Fusarium diseases in different crops	CSIR, New Delhi	Dr. Suchi Srivastava	20 months w.e.f. July 24, 2020
42.	MLP 0051	Field trial for early maturity of cotton using Anacardic Acid formulation and CIB registration of the product	CSIR, New Delhi	Dr. SV Sawant	20 months w.e.f. July 24, 2020
43.	MLP 0052	Preparation of certified reference materials of important phytomolecules	CSIR, New Delhi	Dr. Alok Lehri	20 months w.e.f. July 24, 2020
44.	MLP 0053	Development of processes for edible and industrial dyes from plant sources for enhanced income	CSIR, New Delhi	Dr. Mahesh Pal	20 months w.e.f. July 24, 2020
45.	MLP 0208	Synthesis of zeolites from flyash for agriculture applications	CSIR, New Delhi	PC: Prof. SK Barik PI: Dr. RC Nainwal	26 months w.e.f. January 28, 2021
46.	NWP 0100	CSIR Integrated Skill Initiative Phase II	CSIR, New Delhi	PC: Prof. SK Barik NS: Dr. SK Tewari	53 months w.e.f. October 16, 2020



47.	OLP 0108	Response of plant species to climate change and screening pollution ameliorating plants	CSIR-NBRI, Lucknow	Dr. PA Shirke	31 months w.e.f. August 07, 2020
48.	OLP 0109	Endophytes and bio-stimulants for enhancing crop production	CSIR-NBRI, Lucknow	Dr. PS Chauhan	31 months w.e.f. August 07, 2020
49.	OLP 0110	Mapping of arsenic pollution & mitigation of arsenic contamination to crops using bioremediation.	CSIR-NBRI, Lucknow	Dr. PK Srivastava	31 months w.e.f. August 07, 2020
50.	OLP 0111	Microbial enzymes for environment and agriculture	CSIR-NBRI, Lucknow	Dr. PC Singh	31 months w.e.f. August 07, 2020
51.	OLP 0112	Enhancing cotton yield through GM and non-GM approaches	CSIR-NBRI, Lucknow	Dr. SV Sawant	31 months w.e.f. August 07, 2020
52.	OLP 0113	Genetic improvement of Hemp (<i>Cannabis sativa</i> L.) for industrial and medicinal purposes through the intervention of conventional and molecular breeding	CSIR-NBRI, Lucknow	Dr. SN Jena	31 months w.e.f. August 07, 2020

Team

- Dr. RN Gupta, Senior Technical Officer
- Mr. VK Gupta, Technical Assistant
- Ms. Sandhya Srivastava, Senior Stenographer
- Mr. Atul Srivastava, Senior Stenographer
- Mr. Shubham Tandon, Technician
- Mr. Sagar Kumar, MTS

Projects Initiated during 2020-21

TECHNOLOGY TRANSFER & BUSINESS DEVELOPMENT DIVISION

Vivek Srivastava

vivek@nbri.res.in

Technology Transfer & Business Development,
Outreach Programme, Scientist-Student Interaction
activities

Highlights and Major Activities

The TTBD Division is an interface of the institute for bridging the gap between R&D at lab and stakeholders. It identifies key inventions for intellectual property right protection. Scientists are helped for preparing patent draft, prior art search and response to office action. Division interacts with industry for information dissemination by participating in various exhibitions, putting up information on web site and interacting and exchanging information by various mode of communication. Various agreements viz., Consultancy, Secrecy, Sponsored, Technical Services, with project funding agencies, with academia for

joint R&D work are also facilitated.

The division has been facilitating training programme each year for post graduate students of various universities and colleges which entail updating the skills and knowledge of the outside students and faculty in the core competences of the institute.

Many activities under the pilot implementation of CSIR-Virtual Laboratory (HCP 0101) were also undertaken. Diverse areas of institute were selected for developing novel and interesting content for Virtual Lab and convert this content into impactful audio-visual or reading material. It was based on relevance and interest of students.

Technologies Transferred

S. No.	Name	Client	Date
1.	Alcohol based liquid hand sanitizer	Fervid Healthcare Pvt. Ltd., Lucknow, U.P.	April 15, 2020
		Amar Pharmaceuticals and labs (I) private limited, Kanpur, U.P.	April 20, 2020
		Hotghee Technologies Pvt. Ltd., Bengaluru	June 06, 2020
2.	Alcohol based herbal hand sanitizer gel	Parashar Agrotech Bio. Pvt. Ltd., Varanasi	April 17, 2020
		Maa Durga Marketing, Chandauli, U.P.	July 21, 2020
3.	Floor mop (Turmeric leaf essential oil based)	Vishvakseenah Enterprise, Muzaffarpur, U.P.	June 15, 2020
		Maa Durga Marketing, Chandauli, U.P.	July 21, 2020
5.	Herbal formulation useful in Urolithiasis	Marc Laboratories Limited, New Delhi	October 27, 2020
6.	Traditional Kadha		December 09, 2020
7.	Mask Stress Reducer		

**MoUs/MoAs/MTAs/MoCs/Secrecy Agreements Signed**

S. No.	Details	Client	Date
National			
1.	For academic purpose	King George's Medical University, Lucknow	April 13, 2020
2.	For evaluation of alcohol-based hand sanitizer gel, 'Zenthodent and Dentogel'	M/s. Bhartiya Agro Pharma Pvt. Ltd., Kanpur	May 29, 2020
3.	For evaluation of hand sanitizer gel and floor mop and herbal beer	M/S Vajarakavach Strategic Solutions Pvt. Ltd., Mumbai	July 27, 2020
4.	MTA and Commercial Use Agreement for Material "Tma 12-cotton event and its derivative varieties and hybrids".	ICAR-Central Institute for Cotton Research (ICAR-CICR), Nagpur Maharashtra	July 28, 2020
5.	For project 'CRISPR-mediated genome editing of plant for functional validation and biogenesis'	Department of Biotechnology, New Delhi	July 30, 2020
6.	For the evaluation of bio-film	Birla Corporation Ltd., Kolkata	August 04, 2020
7.	For procurement of GPF vector	National Institute of Plant Genomic Research, New Delhi	August 11, 2020
8.	For evaluation of Herbal beer	M/s. Herry & Jerry, Bhilwara, Rajasthan	August 22, 2020 (w.e.f. September 08, 2020)
9.	For research and academic activities	University of Calicut, Kerala	September 23, 2020
10.	For procurement of germplasm <i>Chenopodium quinoa</i>	ICAR-National Bureau of Plant Genetic Resources, New Delhi	October 07, 2020
11.	For collaboration in developing and promoting phyto-pharmaceutical products for therapeutic uses	Indian pharmacopeia Commission (IPC), Ghaziabad	October 13, 2020
12.	For disclosing the material 'Microbial formulation (<i>Bacillus subtilis</i> NBRI-W9)'	ICAR-Directorate of Rapeseed-Mustard Research, Sear, Bharatpur, Rajasthan	October 22, 2020
13.	For sponsored research for working in the area of medicinal and aromatic plants including <i>Cannabis</i> (hemp)	Indica Nutraceuticals LLP, New Delhi	November 10, 2020
14.	For research and academic activities	Saraswati Dental College, Lucknow	December 04, 2020
15.	For research and academic activities	University of Lucknow, Lucknow	December 08, 2020
16.	For collaborative work in terms of taking up cost effective activities on medicinal and aromatic plants in Manipur	Manipur State Medicinal Plants Board, Govt. of Manipur, Imphal	December 14, 2020
17.	For research and academic activities	Babasaheb Bhimrao Ambedkar University, Lucknow, U.P.	December 22, 2020

18.	For research and academic activities	Amrita Vishwa Vidyapeetham, Coimbatore, Tamil Nadu	December 30, 2020
19.	For research and academic activities	Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu	January 11, 2021
20.	For the project sanctioned by DBT entitled 'Minor oilseeds of Indian origin: Leveraging genetic resources for accelerated genetic improvement of linseed using comprehensive genomics and phenotyping approaches'	ICAR-National Bureau of Plant Genetic Resources, New Delhi	January 13, 2021
21.	For support in administering the 'Pushpangadan Biodiversity Access & Benefit Sharing Award'	Dr. Palpu Pushpangadan Charitable Society, Thiruvananthapuram	February 10, 2021
22.	For the project 'Evaluation of topical applicable herbal nano-emulsion and ultrafine solutions'	CSIR-IITR, Lucknow	February 11, 2021
23.	For joint collaboration for CSIR-Floriculture Mission	Agricultural & Processed Food Products Export Development Authority, New Delhi	March 04, 2021
24.	Tripartite MoU signed with the objectives of 'Strengthening of infrastructural facilities in Botanic gardens, Botanical selections in popular gardens and centers of <i>ex-situ</i> conservation.'	Ministry of Environment, Forest and Climate Change, New Delhi and Botanical Survey of India, Kolkata	March 15, 2021
International			
1.	For the procurement of plasmid vector 'pAD-sfGFP'	ADDGENE, USA	March 01, 2021

Training for Post Graduate Students

A total number of 42 students were imparted research trainings in different disciplines of the plant science and applied subjects. The short term training/project work/dissertation for the students from various universities and colleges are coordinated by the division.

A revenue of Rupees seven lakh forty-three thousand was generated as training fee during the year 2020-21.

School Visits

Due to current pandemic conditions of Covid-19, physical visits of individuals including research

scholars, students from various universities, schools and colleges, farmers, general public to Institute's facilities such as botanic garden, exposition and various laboratories were restricted. However, division coordinated physical visits of only 137 students of three school under the Covid-19 protocols and guidelines. The online tour/visit was also organized for the students of Madhya Pradesh under Vigyan Manthan Yatra - 2020.

Team

- Mrs. Swati Sharma, Senior Technical Officer
- Mr. BL Meena, Technical Assistant
- Mr. Yatish Tiwari, Senior Stenographer

NBRI JIGYASA CORNER

Mission Objective

CSIR-NBRI is known for its national role in promoting both classical and cutting-edge research in Systematic Botany, Conservation Biology, Plant Diversity Prospecting, Microbial diversity, Plant Improvement, Genomics and Plant Biotechnology, Primary and Secondary Metabolism, Botanical Informatics, and Floriculture. These diverse areas of institute were selected for developing interesting content for Virtual Lab. It was based on relevance and interest of students.

Mode of Engagements

Due to current pandemic conditions of Covid19, development of virtual educative and informative content including virtual lab tours, short science films, online quiz, etc., for the students was done.

Major Activities

Under Jigyasa initiative, CSIR-NBRI created some short science films, animated informative films and science quiz games for the students during the year 2020-21.

Short Science Films (Fig.1)

- A short film on 'Botanic Garden' of the institute

has been produced which includes the basic introduction about botanic garden and different facilities. It has been made as introductory film to generate interest among students.

- A short film on the objective of '*Aatm Nirbhar Hum*' has been created which showcased the hand sanitizer production by the local population from the commonly available mahua plant by a very easy method. The main objective of the film was to motivate students towards looking for novel solutions for problems from local resources.
- A short film on 'Plant Diversity Exploration' has been made to showcase the exploration studies of the plants diversity. The film highlighted the discovery of plants from different climates and their analysis for making useful products / services.
- An interesting short film on 'Lichens' has been made to explain their type, habit, habitat and uses.
- A short science film on 'Plant Tissue Culture' has been made with a view to take students to the aspects of science where excitement of developing whole plant from one tissue. This film tells basics of plant tissue culture especially in banana.

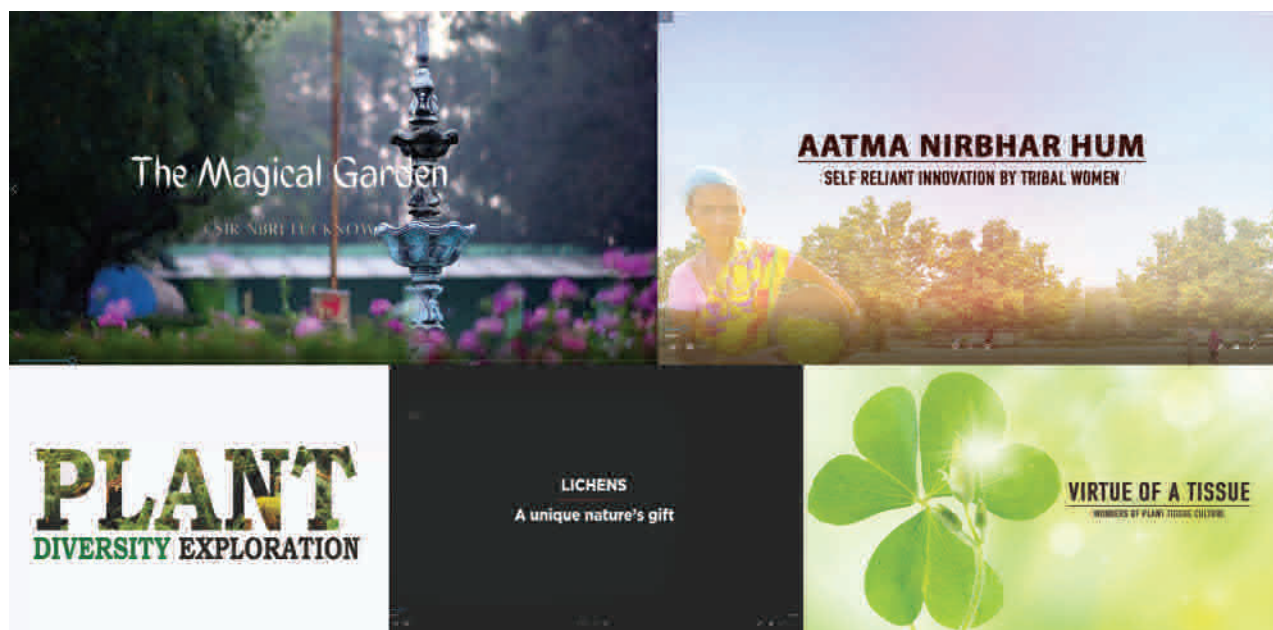


Fig. 1: Some screen shots of the short science films

Animated Films

Three science animation films have also been prepared for students to generate curiosity. (Fig. 2)

- Arsenic Menace and its Remedial Measures : Film explains about problems associated with arsenic and it's remedy.
- Plant Resources for Healthy Life: Bioprospection process has been explained in this film. Students will find it interesting to know, how plant wealth is studied and its' uses in different aspects of our daily life.
- Transgenic cotton against White Flies : Film explains about how scientists at CSIR-NBRI have explored a novel gene and protein coded by it from fern which has been expressed in cotton by biotechnological tools, to give protection against white flies which causes damage to plants and crop loss.

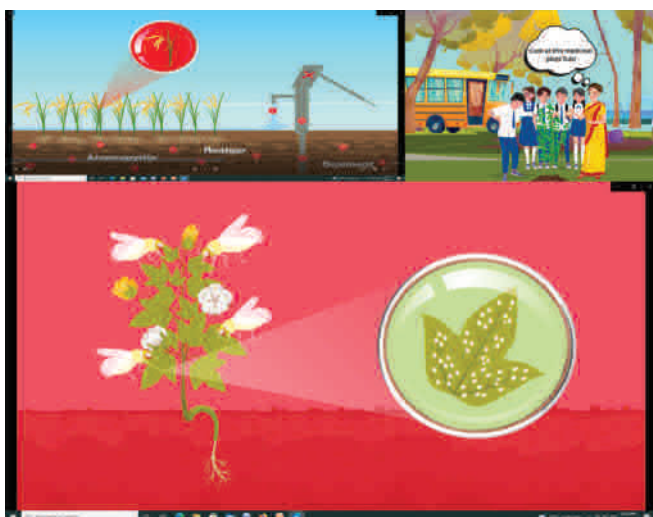


Fig. 2: Screen shots of the animated science films created

Science Quiz Games

A board game based on concept of Snake and Ladder has been developed with a science quiz about beneficial and harmful plants. In this game two students can play the game at a time with on screen dice, where with movement of dice, players token moves on board, where information about plants is placed. Students can learn while playing. (Fig.3)

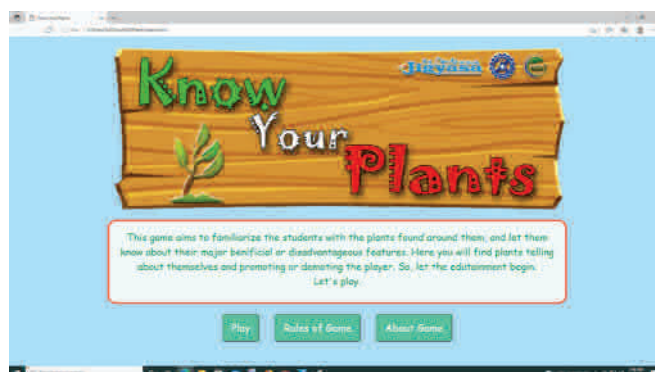


Fig. 3: Science Quiz Game-Know Your Plants

Jigyasa NBRI Team

Nodal Scientist:

Dr. Vivek Srivastava

Co-nodal Scientist:

Dr. AK Gauniyal

Team Members:

Dr. SK Tewari, Dr. KN Nair, Dr. Alok Lehri, Dr. SV Sawant, Dr. PK Singh, Dr. PC Verma, Dr. S Nayaka, Dr. SK Ojha, Dr. Lal Bahadur, Dr. Pankaj Srivastava, Dr. Shekhar Mallick, Dr. SK Bag, Dr. KJ Singh, Dr. Vinay Sahu, Dr. KK Rawat, Dr. DK Purshottam, Mr. Harendra Pal, Mr. RR Rastogi, Mr. BL Meena, Mrs. Swati Sharma



INFORMATION, PUBLICATION AND EXPOSITION DIVISION

Highlights and Activities

Information and Publication works as one of the important S&T support systems of the Institute. The division primarily manages the scientific publication work of the institute.

Besides, effective dissemination of the S&T information and R&D achievement also caters through print and electronic media. The division also manages the organization of different scientific events, press meets, celebration of various national and international days designated for scientific, technological and strategic importance to nation. It also bears the public relation to the press and media for promoting and showcasing institute's achievements to the science community and the public.

Its primary function is publication of the research and development outcomes and outputs of the Institute in the form of *Annual Report*, and other science and popular books, bulletins on different themes of topical interests on plants, environment, biotechnology, agro-technology, ornamental horticulture, etc.

Publication Works

CSIR-NBRI Annual Report for the year 2019-20 was

compiled and released on the occasion of Annual Day of the Institute on October 25, 2020.

Progress report of 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 2019-20.

Sale of Publications : ₹ 5,245/-

Parliament Questions: Twenty-Two parliament questions received from CSIR HQ were answered.

Section-In-charge

Dr. PA Shirke

Chief Scientist

Email ID: info-nbri@nbri.res.in

Team:

- Dr. KN Nair, Senior Principal Scientist
- Mr. Yogendra Nath, Principal Technical Officer
- Mr. AC Little, Principal Technical Officer
- Mr. Rajat Raj Rastogi, Technical Assistant

LIBRARY-KNOWLEDGE RESOURCE CENTRE (KRC)

The KRC provides services and facilities to meet the S & T knowledge requirements of the Institute's R& D activities. It operates with the following objectives to:

- Support the learning process of the researchers through provision of knowledge / information.
- Meet knowledge/information needs of the scientists, researchers and students to support their research activities.
- Respond effectively, where possible, to the knowledge/information needs of the Institute's clientele.

CSIR-NBRI KRC is an automated open access library. KRC is fully automated with LibSys automation software. It provides automated circulation services to the users throughout working hours of the institute. Bibliographic information of the KRC resources is made available to the users through an Online Public Access Catalogue (OPAC). 'Inter Library Loan (ILL)' and 'Document Delivery Service (DDS)' facilities are provided to the users of the institute, CSIR and DST laboratories/organizations. KRC enables to provide online access of Electronic Resources like e-journals, e-databases to the end users. It also conducts training programs and workshops from time to time on using e-resources for the benefit of the scientists, technical staff, researchers and students of the institute. Every year, especially on the occasion of the Hindi Pakhwada, KRC organizes an exhibition of Hindi books.

Library Holdings and Reprography Services

KRC currently holds a total of 31065 books and 30069 bound journals. It currently subscribes a total of 554 journals, including 57 print and 472 online journals covering diverse fields of Plant Sciences, besides four databases viz., iThenticate (Plagiarism Checker), Web of Science and TAIR (The Arabidopsis Information Resource) and JSTOR Collection on Global Plants.

KRC plays a major role in information dissemination by providing reprography services to the scientific community of the CSIR and DST labs free of cost, and to the other organizations of India and abroad on payment basis.

A Botanical Archive has been maintained in the KRC which houses rare and hand-written manuscripts in Persian and Arabic languages, illustrations of plants dating back to 18th century and other original botanical literature and files containing biographic

details, signatures, and important documents of eminent botanists/scientists and institutions/societies

CSIR-NBRI KRC Collections	
Books	31065
Journals Bound Volumes	30069
Total No. of Books and Bound Journals	61134
Theses	
• AcSIR	67
• Other Universities	83
Annual Reports	
• CSIR Institutes	44
• Other Organizations	137

Additions in KRC holding during the year 2020-21	
Books:	
• Purchased	00
• Received as Complimentary copies/Gifts	29
Bound journals	00
Total number of books and bound journals added during 2020-21	29
Current Periodicals Subscribed:	
• Print only	57
• Print + Online	01
• Online subscribed directly by CSIR-NBRI	09
• Online subscribed through CSIR Consortium (NKRC) on share basis	472
• Complimentary /Gifts	30
Total number of Periodicals (titles)	569
Databases subscribed:	
• Subscribed direct by KRC, CSIR-NBRI.	01
• Subscribed through CSIR Consortium (NKRC) on share basis	02

Training Imparted and Special Demonstration Programmes Held

KRC provides one year apprentice training to 6 students (4 Degree & 2 Diploma holders) in Library Science every year under the Apprentice Scheme of Government of India.

Sectional In-charge

Dr. KN Nair

Senior Principal Scientist

Email ID: knnair@nbri.res.in

Team

- Mr. Yogendra Nath, Principal Technical Officer
- Mrs. Leena Wahi Gupta, Senior Technical Officer



CENTRAL INSTRUMENTATION FACILITY (CIF)

Objectives

The facility is established with following objectives:

- Plant based analytical testing services to the industries / organization / universities / individuals.
- Development of different projects in public private partnership mode
- Creating Joint IPR with industries.
- Instrumental and infrastructural support to R&D activities of institutes.

Highlights and Major Activities

CIF (Central Instrumentation Facility) of the institute is having high tech and sophisticated instruments to provide the services to the industries institutes/ organizations/individuals. CIF is NABL accredited based on the requirements of ISO-IEC-17025-2017. CIF is providing services for the analysis of essential oils, vegetable oils, herbal drugs, and heavy metals using sophisticated analytical instruments like GCMS, IRMS, TD-NMR, TEM, SEM, GLC, HPLC, HPTLC and AAS. The institute has expertise in quantitative and qualitative analysis of several groups of secondary metabolites viz. polyphenols, alkaloids, withanolides, andrographolides, furocoumarins, fatty acid, aromatic chemicals etc. Complete infrastructural facilities for analysis of medicinal and aromatic plants and contract research (in public-private mode of partnership) are available with the institute.

Analytical Testing and other Technical Services

Technical Services provided and Achievements:

Central Instrumentation Facility has provided analytical services to industries/ organization/ entrepreneurs/individuals (External samples) and various scientist/staff of the institute (Internal samples). The details of external and internal samples analyzed are given below.

Analytical testing services provided (1 st April 2020 to 31 st March 2021)	
External Samples	
No. of External samples analyzed	69

Revenue Generated	Rs. 1,63,076.00
No. of new industries/ organizations/ Entrepreneurs/individuals benefitted	16
Internal Samples	
Internal samples analyzed	4329
Total number of job (internal equipments repairing) completed	230
NABL/ other similar Accreditation status	
NBRI has been accredited since 2008 as per the requirements of ISO-17025/2005 from NABL (National Accreditation Board for Testing and Calibration Laboratories) Quality Council of India (QCI), Govt. of India, New Delhi. NABL-New Delhi after on-site transition audit recommends for continuation of NABL-Accreditation of the institute up to 17.10.2021	
Certificate No. : TC-7972	
Area of Scope- Herbal drugs, Essential oils, Vegetable oils, Soil and water	
Participated in International and National PT/ILC programme: 03	
NABL Accreditation as per the requirements of ISO-17034-2016.	
NABL- New Delhi after on-site final assessment audit on 24-25 February 2021 recommends accreditation of CSIR-NBRI as reference material producer.	
Certificate Number- RC-1015	
Validity- 31.03.2021-30.03.2023	
Scope- Certified reference materials -Limonene, Eugenol and Geraniol Reference material-Methyl chavicol	

Scientist In-charge

TN Khoshoo Block

Dr. Alok Lehri

Senior Principal Scientist

KN Kaul Block

Dr. Vivek Pandey

Senior Principal Scientist

Team:

- Dr. Anil Kumar, Senior Technical Officer
- Dr. Sanjay Dwivedi, Senior Technical Officer
- Dr. Abhishek Niranjana, Senior Technical Officer
- Dr. SK Behera, Senior Technical Officer
- Dr. GG Sinam, Senior Technical Officer
- Mr. Jai Chand, Technical Officer
- Mr. Dileep Singh, Technician
- Mr. Pawan Kumar, Technician

INFORMATION AND COMMUNICATION TECHNOLOGY DIVISION (ICT)

Information and Communication Technologies (ICT) looks after IT requirements of R&D projects and organization's functioning. It provides networking, mailing and computer services at the institute. Under ICT efforts the following activities are being performed:

- Maintenance of CSIR - NBRI website www.nbri.res.in
- Maintenance of CSIR - NBRI Intranet site
- Maintenance of CSIR - NBRI Local Area Network
- Maintenance of several servers including Web Server, E-mail server, Exchange Server, Library Server etc.
- Management of Network Security - UTM (Cyber Roam CR500ia-10F)
- Upgrading Antivirus on all nodes of CSIR-NBRI LAN.
- Facilitating day to day troubleshooting, antivirus updates, projection facilities & other ICT related work

New Facilities Installed

- The LAN network of the institute has been shifted to new core switch for uninterrupted internet services.
- LAN network facility was extended in Garden Block, Covid Lab and newly constructed lab of Environmental Sciences.
- Online streaming services provided for webinars/conferences
- Provided assistance for online organization of the IISF-Biodiversity Conclave-2020, held during December 23-24, 2020.
- ICT provided facilities for organizing meetings on MS Teams in symposium on Biodiversity from March 20-22, 2021.

Scientist In-charge

Dr. SK Bag, Principal Scientist

Email ID: sumit.bag@nbri.res.in

Team

- Mr. Prashant Srivastava, Technical Officer
- Mr. Dev Ranjan, Technical Assistant



ENGINEERING AND ESSENTIAL DIVISION

The Division mainly works with following two sub groups:

- Civil Engineering Services
- Electrical and Essential Services
- Civil engineering section looks after the construction and maintenance works of entire infrastructure of the Institute's premises situated at different locations.
- The Electrical and Essential services division primarily manages the electrical operation and supply works, maintenance of electrical equipments, functioning of Gen-set, substation, UPS, CCTV etc.

Besides, the Vehicle section is also attached with this division.

Division In-charge

Er. Lalit Kumar Srivastava, Superintending Engineer

Civil Engineering Section

Section In-charge

Er. Lalit Kumar Srivastava,
Superintending Engineer
Email ID: l.srivastav@nbri.res.in

Team Members

- Mr. Moinuddin Khan, Senior Technician
- Mr. Harish Chand, MTS
- Mr. Om Prakash, MTS

Electrical and Essential Services

Section In-charge

Er. Somanath Swain,
Assistant Executive Engineer
Email ID: somanathswain@nbri.res.in

Team Members

- Mr. Ajay Kumar, Technician
- Mr. Rakesh Kumar, Technician

Vehicle Section

Section In-charge

Mr. Jyoti Tandon, Senior Technician

Team Member

- Mr. Anoop Kumar, Technician

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- राजभाषा विभाग, गृह मंत्रालय, भारत सरकार द्वारा जारी दिशा निर्देशों का पालन।
- कार्यालयी कामकाज को राजभाषा हिंदी में करने हेतु प्रयास।
- संस्थान की विभिन्न वैज्ञानिक एवं तकनीकी गतिविधियों/उपलब्धियों को जनसामान्य तक राजभाषा हिंदी में पहुंचाने हेतु प्रयास।
- संस्थान में राजभाषा विभाग, गृह मंत्रालय, भारत सरकार द्वारा जारी दिशा निर्देशों के अनुसार निर्धारित समय में राजभाषा कार्यान्वयन समिति की चार तिमाही बैठकों का आयोजन कराना।
- हिंदी कार्यशालाओं, हिंदी दिवस आदि का आयोजन कराना।

o"lZ2020&21 dh çefk xfrfof/k k

वर्ष 2020-21 में आयोजित विभिन्न कार्यक्रमों, व्याख्यानों कार्यशालाओं, प्रशिक्षण कार्यक्रमों एवं अन्य विशिष्ट गतिविधियाँ –

fgah fnol dk vk; kt u

संस्थान द्वारा हिंदी दिवस समारोह का दिनांक 14 सितम्बर, 2020 को एम.एस. टी.एम के माध्यम से ऑनलाइन आयोजन किया गया। इस अवसर पर प्रो. राज कुमार, कुलपति, उत्तर प्रदेश आयुर्विज्ञान विश्वविद्यालय, सैफई, इटावा मुख्य अतिथि के रूप में उपस्थित थे। प्रो. राज कुमार ने 'कोरोना, इसके लक्षण, रोकथाम व चिकित्सा' विषय पर विशिष्ट व्याख्यान प्रस्तुत किया।

fgah dk; Zkkyk dk vk; kt u

संस्थान की राजभाषा कार्यान्वयन समिति के तत्वाधान में दिनांक 17.03.2021 को कार्यालयी कामकाज में राजभाषा हिंदी के प्रगामी प्रयोग में और भी वृद्धि लाने के लिए हिंदी कार्यशाला (टेबल वर्कशॉप) का

आयोजन किया गया। कार्यशाला में संस्थान के हिंदी अधिकारी श्री बिजेन्द्र सिंह द्वारा संबंधित अनुभागों/प्रभागों के अधिकारियों/कर्मचारियों को राजभाषा विभाग, गृह मंत्रालय, भारत सरकार द्वारा जारी दिशानिर्देशों से अवगत कराया गया।

'foKlu ok k* jkt Hk'lk i f=dk dk çdk ku

संस्थान द्वारा प्रकाशित होने वाली राजभाषा गृह पत्रिका विज्ञानवाणी अंक 26 वर्ष 2020 का विमोचन दिनांक 19 मार्च, 2021 को संस्थान में आयोजित 'भारतीय वानस्पतिक सोसायटी के 43वें अखिल भारतीय वानस्पतिक सम्मेलन' के अवसर पर मुख्य अतिथि श्री दुर्गाशंकर मिश्रा, सचिव, मिनिस्ट्री ऑफ हाउसिंग एण्ड अर्बन अफेयर्स, भारत सरकार, नई दिल्ली द्वारा किया गया।

jkt Hk'lk dk; kb; u l fefr

1.	प्रो. सरोज कान्त बारिक, निदेशक	अध्यक्ष
2.	डॉ. श्रीकृष्ण तिवारी, वरिष्ठ प्रधान वैज्ञानिक	उपाध्यक्ष
3.	श्री आनन्द प्रकाश, वरिष्ठ प्रधान वैज्ञानिक	सदस्य सचिव
4.	नियंत्रक (प्रशासन)	सदस्य
5.	डॉ. संजीव कुमार ओझा, प्रधान वैज्ञानिक	सदस्य
6.	डॉ. के.के. रावत, वरिष्ठ तकनीकी अधिकारी	सदस्य
7.	श्रीमती किरन टोप्पो, वरिष्ठ तकनीकी अधिकारी	सदस्य
8.	श्रीमती स्वाति शर्मा, वरिष्ठ तकनीकी अधिकारी	सदस्य
9.	श्री संजीव शेखर, वित्त एवं लेखा अधिकारी	सदस्य
10.	श्री दिनेश कुमार भण्डार एवं क्रय अधिकारी	सदस्य
11.	श्री बिजेन्द्र सिंह, हिंदी अधिकारी	सदस्य
12.	श्रीमती सोना लमसल, सहा. अनुभाग अधिकारी	सदस्य
13.	श्री रजत राज रस्तोगी, तकनीकी सहायक	सदस्य

fgah vf/kdkj h- श्री बिजेन्द्र सिंह

b&esy vkbMh- brijesh-singh@nbri-res-in

सहयोगी- श्री शैलेन्द्र कुमार

EVENTS

World Environment Day

CSIR-NBRI, Lucknow organized a webinar on the occasion of World Environment Day on June 05, 2020. Prof. S.P. Singh, Former Vice-Chancellor, HNB Garhwal University, Uttarakhand was Chief Guest and speaker of the live webinar. Prof. Singh delivered the lecture on Global Climate Change and Himalayan Systems.

Prof. Singh informed that rise in earth's temperature due to global climate change has varying consequences to humans, plants, animals, environment, leading to increased extremes and uncertainty scenarios. We need to learn to live with climate change and subsequently explore the solutions.

74th Independence Day

The 74th Independence Day was celebrated with great enthusiasm and joy at CSIR-NBRI on August

15, 2020. On the occasion, Prof. SK Barik, Director hoisted the flag at Main Building as well as distant research center, Banthra.

67th Annual Day of CSIR-NBRI

CSIR-National Botanical Research Institute, Lucknow celebrated its 67th Annual Day on October 27, 2020 through online mode. Prof. J.P. Khurana, INSA Vice-President (International Affairs) & Former Head, Department of Plant Molecular Biology, University of Delhi, South Campus, New Delhi was the Chief Guest of the function and delivered Annual Day Lecture. Dr. Shekhar C. Mande, DG, CSIR and Secretary, DSIR, Government of India presided the function. On this occasion, the institute's Annual Report 2019-20 was released by the dignitaries.

A know-how technology of the newly developed herbal product 'NBRI-Uro-05' was transferred to M/s Marc Laboratories, Lucknow for commercial production. NBRI-Uro-05 is a synergistic herbal combination for mitigating the conditions of urolithiasis, nephrolithiasis and post lithotripsy conditions. The ingredients of this herbal product are limited to five herbs which are easily available across the country. The product is cost effective and showed 80% decrease in levels of stone crystals in renal cortex in rat model with 70% reduction in number of stones.



Know how technology transfer of herbal product 'NBRI-Uro-05'

Curtain Raiser event of IISF-Biodiversity Conclave

Under the 6th India International Science Festival, a curtain raiser ceremony of the 'Biodiversity' event was organized today at CSIR-NBRI, Lucknow. Hon'ble minister of Uttar Pradesh Govt. Sri Brajesh Pathak was the chief guest of the function, while Dr Shekhar C. Mande, Secretary, Department of Science and Industrial Research, Govt. of India and DG, CSIR delivered the keynote address.

Mr. Shreyansh Mandloi, Organizing Secretary, Vigyan

Bharati, Avadh Prant, informed about the programs organized in the past, and highlighted the features of the current festival. Mr Mandloi appreciated this program for awakening scientific consciousness among the people of India, especially the youth. Prof. S.K. Barik, Director, CSIR-NBRI informed about the Science festival as well as Biodiversity event. Dr. KN Nair, Principal Co-ordinator of the conclave proposed vote of thanks.



Glimpses of curtain raiser event of IISF-Biodiversity Conclave

Biodiversity Conclave under India International Science Festival-2020

Under 6th India International Science Festival (IISF-2020), the Biodiversity Conclave was organized during 23-24 December, 2020. The IISF-2020 was supported and organized by the Department of Science and Technology (DST), Department of Biotechnology (DBT), Ministry of Earth Sciences (MoES), Department of Health and Family Welfare (DHF) and Council of Scientific and Industrial Research (CSIR) from Government of India and Vijnana Bharati (VIBHA). The two-day event included the invited talks from globally recognized experts, E-poster gallery, Biodiversity Innovation Expo, Indigenous Communities- S & T Experts Meet, Entrepreneurs- Industry Meet and Short films and nature wildlife photo exhibition.

The conclave was inaugurated on December 23, 2020 by the Chief Guest Shri Justice Adarsh Kumar Goel, Chairperson, National Green Tribunal, New Delhi.

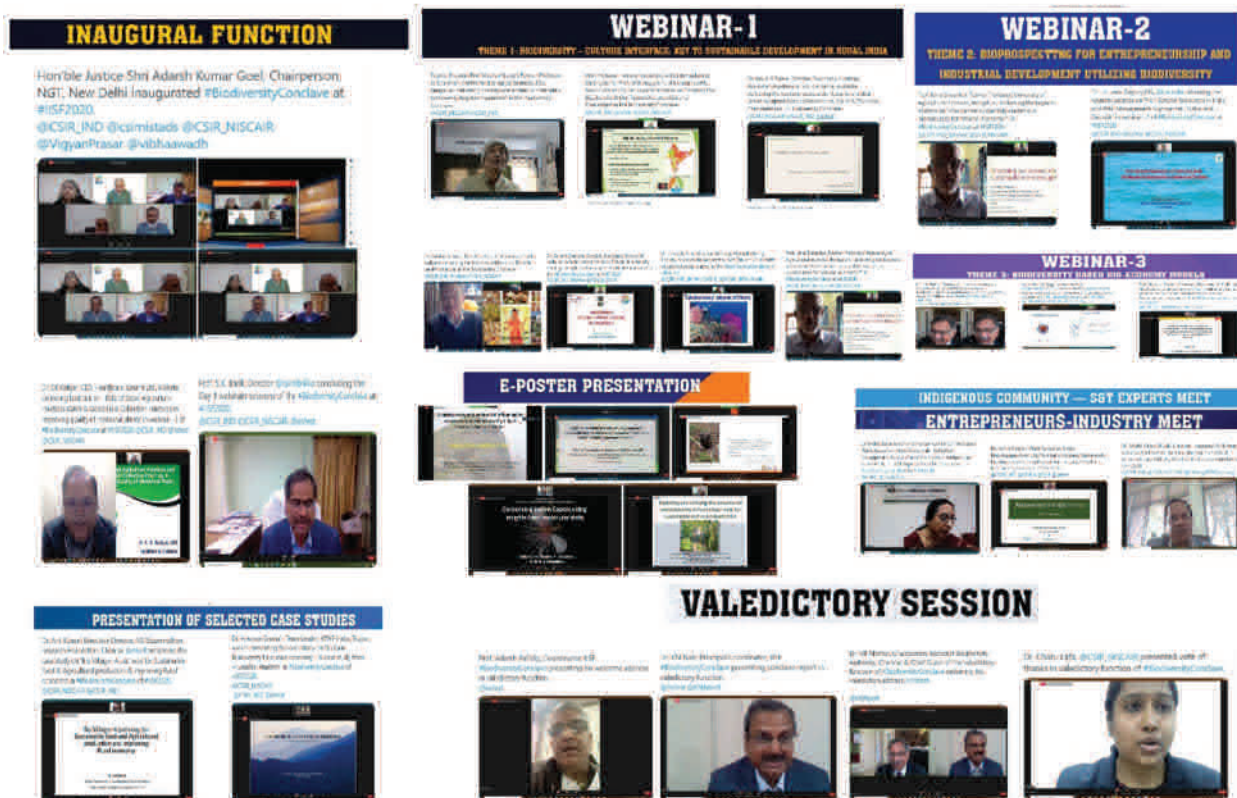
Biodiversity Conclave at IISF 2020 showcased the rich biodiversity of India at ecosystem, species and genetic

levels, long tradition of bio-diversity conservation by traditional communities, and country's efforts towards mapping the distribution of biodiversity and conservation of critical ecosystems and threatened species.

The webinars addressed by eminent experts of the field included Padma Bhushan Prof. Madhav Gadgil, Former Professor & Chairman, Centre for Ecological Sciences, Indian Institute of Science, Bengaluru; Prof. Kamaljit S Bawa, Founder President, ATREE, Bengaluru and Distinguished Professor of Biology, University of Massachusetts Boston; Dr. Kevin R. Thiele, Director, Taxonomy Australia, Australian Academy of Science, Canberra, Australia; Prof. Uma Shaanker, Former Professor, University of Agricultural Sciences, Bengaluru; Dr. J.K. Jena, Deputy Director General, Indian Council of Agricultural Research, New Delhi; Dr. V.B. Mathur, Chairperson, National Biodiversity Authority, Chennai; Prof. Akhilesh Tyagi, Former Professor,

6th India International Science Festival (IISF-2020)

Biodiversity Conclave
Theme: Biodiversity for Bioeconomy-based Self Reliant India
December 23-24, 2020



Glimpses of Biodiversity Conclave under 6th India International Science Festival

University of Delhi and Former Director, NIPGR, New Delhi; Prof. K.N. Ganeshiah, Former Professor, University of Agricultural Sciences, Bengaluru; Dr. C.K. Katiyar, CEO, Health Care, Emami Group; Dr. Kailash Chandra, Director, Zoological Survey of India, Kolkata; Dr. Deepak Apte, Director, Bombay Natural History Society, Mumbai; Dr. Ashiho A. Mao, Director, Botanical Survey of India; Prof. Rup Lal, NASI Senior Scientist Platinum Jubilee Fellow, The Energy and Resources Institute (TERI), New Delhi; Prof. R. Uma Shaanker, University of Agricultural Sciences, Bengaluru among others.

The Conclave concluded on December 24, 2020 with valedictory function. Dr. VB Mathur, Chairperson, National Biodiversity Authority, Chennai was the chief guest of the concluding ceremony. Dr. KN Nair, Principal Coordinator, Biodiversity Conclave, IISF-2020 presented the conclave report of various events and activities held during the two-day event. Dr. Nair also declared the winners of different competitions/ events held during the conclave. Earlier Prof. Adrash Pal Vig, Co-coordinator, GNDU welcomed the Chief Guest of the concluding session and Dr. Charu Lata Co-coordinator, CSIR-NISCAIR proposed vote of thanks.

72nd Republic Day

CSIR-National Botanical Research Institute, Lucknow celebrated 72nd Republic Day on January

26, 2021. Prof. SK Barik, Director, CSIR-NBRI hoisted the National Flag at the main campus and Banthra Research Centre on the occasion.

4th Prof. KN Kaul Memorial Lecture and National Science Day

CSIR-National Botanical Research Institute, Lucknow remembered its Founder Padma Bhushan Professor Kailash Nath Kaul by holding its 4th Prof KN Kaul Memorial Lecture on February 26, 2021. The Institute also celebrated National Science Day on the occasion. The theme for 2021 science day was 'Future of Science, Technology and Innovation (STI): Impacts on Education, Skills and Work'.

On this occasion Prof. KN Ganeshiah, F.N.A., Former Professor, University of Agricultural Sciences, GKVK, Bengaluru was the Chief Guest and Mrs. Deepa Kaul, daughter of Prof. KN Kaul and former Cabinet Minister, UP Government was present as the Guest of Honour.

Prof. Ganeshiah presented the Memorial Lecture on "Do Plants Behave like Animals" and explained through various examples that plants do not have sensory organs like eyes, nose or ears to understand the environment around them, however, they have sensory signals, on the basis of which they adapt themselves and behave according to the environment.

Prof. Ganeshiah also felicitated the retirees who had retired during September 2019-August 2020 and employees completing their 25 years of service. Prof. Ganeshiah also declared the winner of 'Pushpangadan Biodiversity Access and Benefit Sharing Award-2020'. The award is given for contribution in tribal welfare in India and carries a cash prize of one lakh rupees and citation.



4th Prof. KN Kaul memorial Lecture and National Science Day: (A). Floral tribute to Prof. KN Kaul by the dignitaries, (B). Prof. KN Ganeshiah delivering the memorial lecture, (C). Felicitation of the winner of 'Pushpangadan Biodiversity Access and benefit Sharing Award-2020', (D). Felicitation of retirees by the chief guest.

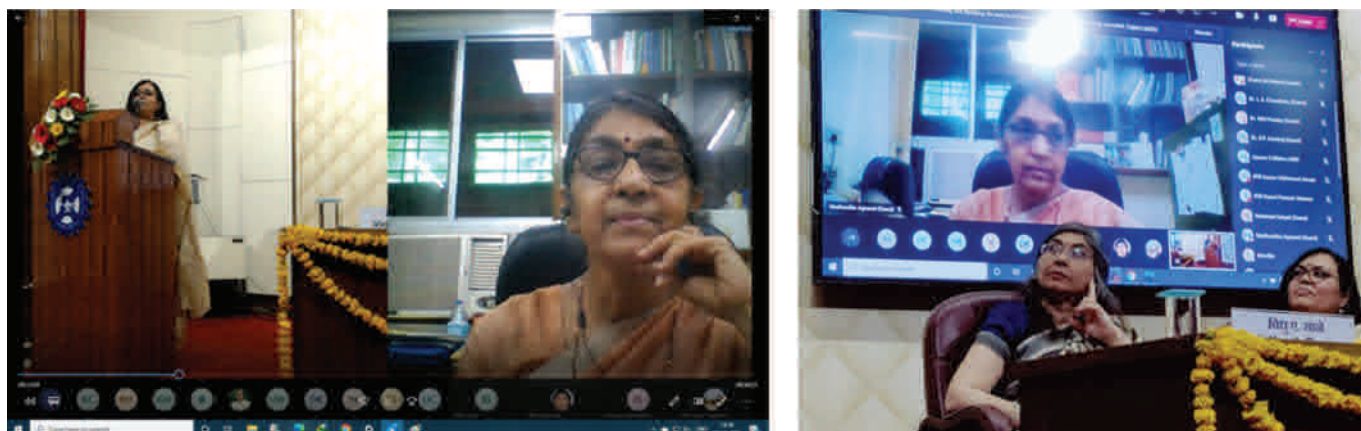
International Women's Day

CSIR-NBRI celebrated International Women's Day on March 08, 2021. On the occasion, Dr. Vandana Prasad, Director, BSIP, Lucknow was the chief guest, while Prof. Madhoolika Agrawal, Faculty of Science, Department of Botany, BHU joined the function virtually as Guest of Honor.

Dr. Vandana Prasad, in her address said that it should be a matter of concern why we have to organize Women's Day in the twenty-first century. Women face many challenges in the society and have to prove themselves in different spheres of life. In

such a situation, it is necessary that we understand that women empowerment is not just the name of empowering women, but it is also necessary to provide them proper place, equal status and equal opportunities in society.

Prof. Madhoolika Agrawal, in her presidential address reminded us the theme of Women's Day and said that women can accept every challenge that prevents them from playing the main role in family, work place and society, and change comes only from challenges.



Glimpses of International Women's Day Celebration

43rd All India Botanical Conference and Indian Botanic Garden Conference

CSIR-NBRI organized the joint '43rd All India Botanical Conference of Indian Botanical Society (IBS)' and 'Indian Botanic Garden Conference' during March 19-21, 2021. The theme of the conference was "Sustainable Development of Plant Resources and Conservation of Threatened Plants in Botanic Gardens".

About 300 delegates from different states of India participated in the conference. There were six lead lectures, 74 oral presentations and 111 posters presented in the conference. Besides this, four medal lectures and three memorial lectures were also delivered by the different eminent experts.

Shri Durga Shanker Mishra IAS, Secretary, Ministry of Housing & Urban Affairs, Government of India,

New Delhi was the Chief Guest of the Inaugural Function whereas Dr. Shekhar C. Mande, DG, CSIR, New Delhi & Secretary, DSIR, Govt. of India, presided over the function virtually.

Prof. Seshu Lavania, Secretary, IBS presented the report of the society and informed about the Centenary Celebration of Indian Botanical Society. She also informed about the felicitations and awards which were awarded for the year by IBS. The Life Time Achievement Award, HY Mohan Ram award for Excellence in teaching and advancement of plant sciences and PC Trivedi Medal Award for Editorial Excellence were conferred to Prof. SVS Chauhan, Agra; Prof. Debashis Banerji, Devas and Prof. T. Pullaiah, Anantpur, respectively.



43rd All India Botanical Conference and Indian Botanic Garden Conference: (A). Dignitaries releasing of abstract book of the conference, (B). Shri Durga Shanker Mishra, Chief Guest, addressing the participants in inaugural function, (C) and (D) Felicitation of awardees on the occasion of Centenary Celebration of Indian Botanical Society, (E) & (F). Poster presentation during the conference, (G) & (H). Memorial lecture by eminent experts, (I) Round table talk during the Indian Botanic Garden Conference, (J). Felicitation of the invited speakers in the conference, (K) & (L). Felicitation of winners of medals/awards.



ACADEMY OF SCIENTIFIC & INNOVATIVE RESEARCH (AcSIR)

Established in 2011 as an 'Institution of National Importance' (interim operations started in June, 2010), the Academy of Scientific and Innovative Research (AcSIR) has adopted the mandate to create and train some of the best of tomorrow's Science & Technology leaders through a combination of innovative and novel curricula, pedagogy and evaluation. AcSIR's focus will be on imparting instruction and providing research opportunities in such areas that are not routinely taught in regular academic universities in India.

Department of Scientific and Industrial Research (DSIR), Ministry of Science & Technology, Government of India has recognized AcSIR as a

Scientific and Industrial Research Organization (SIRO).

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. 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.

Courses offered at AcSIR-NBRI during 2020 - 2021			
S. No.	Subject	Code	Status
1.	Research Methodology-4 Credits	AcSIR-25-RM	Compulsory
2.	Research Publication & Ethics-2 Credits	AcSIR-25-RPE	Compulsory
3.	Basic Chemistry for Biologist	AcSIR-25-ID-OO1	Optional
4.	Cell and tissue engineering	AcSIR-25-ID-OO2	Optional
5.	Climate change and plants	AcSIR-25-ID-OO3	Optional
6.	Genomics assisted breeding of plants	AcSIR-25-ID-OO4	Optional
7.	Introduction to bioinformatics	AcSIR-25-ID-OO5	Optional
8.	Phylogenomics	AcSIR-25-ID-OO6	Optional
9.	Soil fertility and nutrient management	AcSIR-25-ID-OO7	Optional
10.	Agro-horticulture Technology	AcSIR-25-BS-AD-OO1	Optional
11.	Cell signaling	AcSIR-25-BS-AD-OO2	Optional
12.	Developmental biology-Plants	AcSIR-25-BS-AD-OO3	Optional
13.	Environmental Biochemistry & Biotechnology	AcSIR-25-BS-AD-OO4	Optional
14.	Genomics and Epigenomics	AcSIR-25-BS-AD-OO5	Optional
15.	Phytochemistry and their utilization	AcSIR-25-BS-AD-OO5	Optional
16.	Plant Biodiversity and Systematics	AcSIR-25-BS-AD-OO7	Optional
17.	Plant Microbe interaction	AcSIR-25-BS-AD-OO8	Optional
18.	Societal Program (4 Credits)		Compulsory
19.	Seminar course (Seminar Bio & Presentation)		Compulsory

Number of students enrolled for Ph.D. until March 31, 2021	23
Ph.Ds. awarded during 2020-21	11
Ph.Ds. theses submitted during 2020-21	12

Coordinator

Dr. Vidhu A Sane, Senior Principal Scientist

Executive Consultant

Ms. Harshita Nag

RESEARCH COUNCIL (As on 31.03.2021)

Prof. Paramjit Khurana Head, Department of Plant Molecular Biology, University of Delhi South Campus, Benito Juarez Marg, New Delhi-110021	Chairman	Dr. KV Prasad Floriculture (Member), Director, ICAR-Directorate of Floriculture, College of Agriculture, Campus Shivajinagar Pune-411005	Member (Agency Representative)
Prof. SR Yadav Department of Botany, Shivaji University, Kolhapur-416004	Member	Dr. DS Reddy Director, CSIR-Indian Institute of Integrative Medicine, Canal Road, Jammu-180001	Member (Sister Laboratory)
Dr. Anil Prakash Joshi Founder, Himalayan Environmental Studies and Conservation Organization (HESCO), Dehradun-248001	Member	Dr. Vibha Malhotra Sawhney Head, Technology Management Directorate (Socio-economic Ministry Interface), CSIR-HQ, Rafi Marg, New Delhi-110001	Member (CSIR HQ Invitee)
Dr. Shree Kumar Apte DST JC Bose National Fellow & Distinguished Professor, University of Mumbai-Department of Atomic Energy, Centre of Excellence in Basic Science, Vidyanagari, Mumbai-400098	Member	Dr. Utpal Nath, Associate Professor, Department of Microbiology and Cell Biology, Indian Institute of Science Bangalore-560012	DG's nominee
Prof. Madhoolika Agarwal Ecology and Environmental Science Head, Department of Botany, Banaras Hindu University Varanasi-221005	Member	Prof. SK Barik Director, CSIR-National Botanical Research Institute, Rana Pratap Marg, Lucknow-226001	Member
Dr. Usha Barwale Zehr Director and Chief Technology, Mahyco Private Limited Jalna-Aurangabad Road Post Box No.76, Dawalwadi Jalna-431203	Member	Dr. PK Srivastava Principal Scientist, CSIR-National Botanical Research Institute Rana Pratap Marg, Lucknow-226001	Member-Secretary

**MANAGEMENT COUNCIL (As on 31.03.2021)**

Prof. SK Barik Director CSIR-National Botanical Research Institute Lucknow - 226 001	Chairman
Prof. Alok Dhawan Director CSIR-Indian Institute of Toxicological Research, Lucknow	Member <i>(Upto November, 2020)</i>
Prof. Tapas Kumar Kundu Director CSIR-Central Drug Research Institute Lucknow-226001	Member <i>(w.e.f. January, 2021)</i>
Dr. AK Gauniyal Chief Scientist CSIR-National Botanical Research Institute Lucknow - 226 001	Member
Dr. KN Nair Senior Principal Scientist CSIR-National Botanical Research Institute Lucknow - 226 001	Member
Dr. Samir V Sawant Senior Principal Scientist CSIR-National Botanical Research Institute Lucknow - 226 001	Member
Dr. Suchi Srivastava Principal Scientist CSIR-National Botanical Research Institute Lucknow - 226 001	Member
Dr. BN Singh Senior Scientist CSIR-National Botanical Research Institute Lucknow - 226 001	Member
Dr. Abhishek Niranjana Senior Technical Officer CSIR-National Botanical Research Institute Lucknow - 226 001	Member
CoFA/Finance & Accounts Officer CSIR-National Botanical Research Institute Lucknow - 226 001	Member
CoA/AO CSIR-National Botanical Research Institute Lucknow - 226 001	Member-Secretary

EXPENDITURES AND EARNINGS 2020-21

I. EXPENDITURE	Figure in Lakhs of Rupees
A. Revenue	
1. Salary & Salary Linked Allowances	2721.538
2. Other Allowances	
a. Reimbursement of Medical Expenses/CGHS/Medical Charges	72.616
b. Overtime Allowance	
c. Honorarium	5.152
d. Leave Travel Concession	23.000
e. Travel Allowances (India)	4.997
f. Travel Allowances (Foreign)	
g. Professional Update Allowance	
h. Total Other Allowances (a to g)	105.765
3. Total Salaries (1+2h)	2827.303
4. P-04 Contingencies	463.289
5. P-05 H.R.D.	
6. P-06 Lab. Maintenance	366.799
7. P-701 Staff Qrs. Maintenance	56.098
8. P07 Chemical/Consumables & Other Research Expenses	219.575
9. Total Revenue (3 to 8)	3933.064
B. Capital	
a) P-50 Land Cost	
b) (i) P-50 Works & Services/Electrical Installations (Lumpsum)	220.022
b) (ii) P-50 Works & Services/Electrical Installations (Other)	47.970
c) P-50 App. & Equip./Computer Equipments	149.644
d) P-50 Workshop Machinery	
e) P-50 Office Equipments	
f) P-50 Furniture & Fittings	
g) P-50 Library (Books/ Journals/ e-Journal)	52.154
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 Quarters (Construction) (Lumpsum)	8.610
m) (ii) P-702 Staff Quarters (Construction) (Other)	
Total Capital (a to m)	478.400
Total A+B	4411.464
C. Special Project FBR/NCP/FTC/FTT/RSP/HCP/HARIT/Lab Projects etc.	
1. Revenue	
(i) Travel Allowances (India)	2.395
(ii) Travel Allowances (Foreign)	
(iii) Contingencies	2.660
(iv) Maintenance	2.812
(v) Chemical, Consumables & Other Research Expenses	121.654
Total Rev.(C1)	129.521



2. Capital	
(i) Work's & Services	
(ii) Apparatus & Equipment	5.877
(iii) Other Capitals	
Total Capital(C2)	5.877
C. Total allocation FBR/NCP/FTC/FTT/RSP/HCP/HARIT/ Lab Projects etc. (C1+C2)	135.398
Total National Labs. (A+B+C)	4546.862
D. OTHERS	
P-804 Pension & Other retirement benefits	2773.000
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	
(ii) House Building Advance	
(iii) Others	
Total Central Admin.	2773.000

II. Earnings	
RECEIPTS	
R04 Donation	
R05 Contribution	
R06 Miscellaneous Receipts	115.875
R906 Recovery of Advances	0.614
TOTAL R06+R906	116.489
R071 LAB RESERVE	
a) Royalty Premia	61.580
b) Testing & Analytical Charges	3.432
c) Other Technical Service	
d) Job Work	10.834
e) Rest of R 071 heads	1039.340
Total Lab Reserve(R-071)	1115.186
R909 EXTERNAL CASH FLOW	
a) Government departments/PSU's	1175.806
b) Private agencies	
c) Foreign government/agencies	17.534
TOTAL ECF (a+b+c)	2425.015
Royalty & Premia for distribution (R907)	

PERSONNEL (As on 31.03.2021)

Director

SK Barik

Chief Scientists

PA Shirke

SK Tewari

TS Rana

AK Gauniyal

Sr. Principal Scientists

KN Nair

Anand Prakash

LB Chaudhary

Vivek Pandey

Samir V Sawant

AP Sane

Vidhu A Sane

Alok Lehri

PK Singh

ChV Rao

Sharad K Srivastava

Sanjeeva Nayaka

Ashish K Asthana

Mahesh Pal

SK Ojha

Vivek Srivastava

Indraneel Sanyal

Principal Scientists

Subha Rastogi

Debasis Chakrabarty

CS Mohanty

HK Yadav

MH Asif

Arvind Jain

PS Chauhan

Shekhar Mallick

PK Srivastava

SK Behera

SN Jena

PC Verma

SK Bag

Manjoosha Srivastava

Suchi Srivastava

AP Singh

Aradhana Mishra

Poonam C Singh

Baleshwar

Dibyendu Adhikari

SK Rath

Senior Scientists

Sribash Roy

Devendra Singh

Priyanka Agnihotri

Lal Bahadur

BN Singh

VV Wagh

RC Nainwal

Manoj Kumar

KM Prabhukumar

KJ Singh

Bikarma Singh

Richa Rai

Scientists

GK Mishra

Anju Patel

Vijay A Selva

Pr. Technical Officers

Yogendra Nath

AC Little

D K Purshottam

Sr. Tech. Officers (3)

R K Tripathi

Shankar Verma

Lalit K Srivastava

Anil Kumar

Daya Shanker

Sanjay Dwivedi

Abhishek Niranjan

Sr. Tech. Officers (2)

Bhagwan Das

Atul Batra

Sushma Verma

RN Gupta

Rajeev Kumar

Girdhari Sharma

Harendra Pal

SK Behera

Vinay Sahu

Sr. Tech. Officers (1)

MK Shukla

Kiran Toppo

MM Pandey

Surjit Kumar

Swati Sharma

Leena Wahi Gupta

SK Sharma

KN Maurya

Babita Kumari

GG Sinam

Sumit Yadav

KK Rawat

Somanath Swain

Technical Officers

Satish Kumar

Prashant Srivastava

Jai Chand

Shweta Singh

Rameshwar Prasad

Rekha Kannaujia

Shashank K Mishra

Komal K Ingle

Bharat Lal Meena

Vivek K Gupta



Technical Assistants

RR Rastogi
Devranjan
Vandana Tiwari
MG Prasad

Administration

BJ Deuri, CoA
Sanjeev Shekhar, F&AO
Dinesh Kumar, SPO
RS Chaudhary, SPO
Prasoon Misra, SO
SK Singh, SO

Sachin Mehrotra, SO
RK Verma, SO
Prabha Tirkey, SO
KK Saxena, SO
BP Pande, PS
SK Pandey, Security Officer
Bijendra Singh, Hindi Officer



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