वार्षिक प्रतिवेदन
ANNUAL REPORT
2021-2022




वै.औ.अ.प.-राष्ट्रीय वनस्पति अनुसंधान संस्थान, लखनऊ

CSIR-NATIONAL BOTANICAL RESEARCH INSTITUTE, LUCKNOW

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Front Cover **:**

1. A newly developed *Chrysanthemum* variety 'NBRI Swadheen75'
2. Transverse section of root of Guar 'Sarda'
3. Newly introduced Lotus variety 'Grannies Love'
4. Differential Interference Contrast (DIC) microscopy image of developing seed of *Arabidopsis*

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With best compliments from

Director

CSIR-NBRI, Lucknow

वै.औ.अ.प.-राष्ट्रीय वनस्पति अनुसंधान संस्थान

(वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद, नई दिल्ली)

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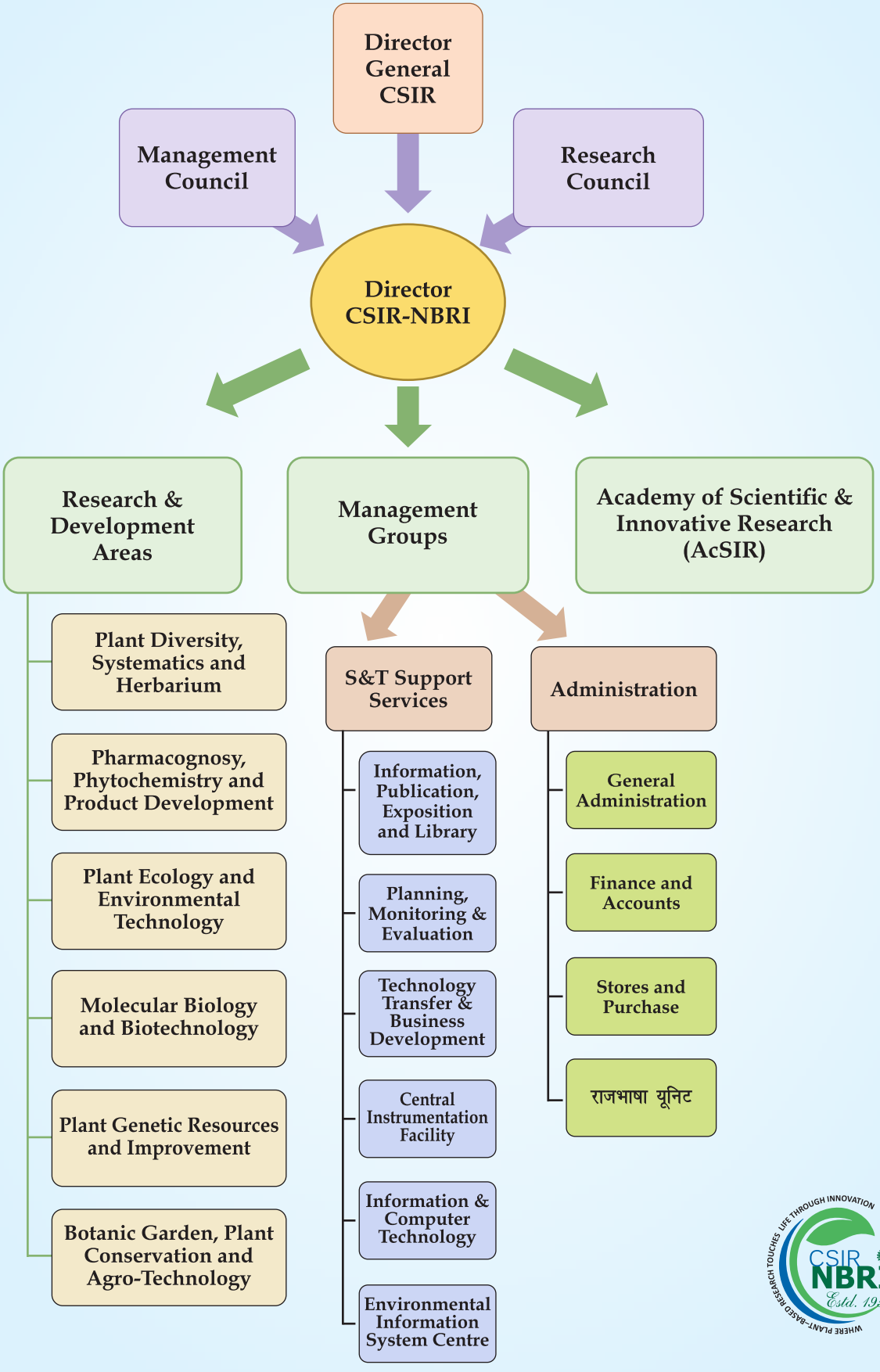
Organizational Set-Up



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Annual Progress At A Glance

Publications

SCI Journals	178
Average IF Per Paper	3.475
Total IF Per Scientist	10.48

Patents Granted

National	01
International	03

Patents Filed

National	03

Technologies Transferred

- Alcohol based Herbal Hand Sanitizer
- Anti Dandruff Herbal Hair Oil

HRD

Ph.D Awarded/Submitted	23/10
Training Programmes Organized	40
Skill Development Programmes	11
No. of Individuals Trained	2168
PG Students Trained	55

Extra Budgetary Resources

(Rupees in lakh)

Total ECF	63.208
EBR	724.496

Plant Inventory

New Species Discovered	10
New Geographical Records to India	31

Projects Undertaken

New Projects Initiated	20
Projects Under Implementation	122

Staff Strength

Group IV	59
Group III	45
Group II	25
Group I	14
Administration	149
Research Scholars	326

CSIR FLORICULTURE MISSION

This mission is being implemented in 24 states/Union Territories across India to enhance farmer's income and entrepreneurship development through high value floriculture utilizing CSIR technologies with eight verticals

1. Development of new floral varieties
2. Expansion of areas under floricultural crops
3. Urban Floriculture
4. Development of post-harvest and value addition technologies
5. Integration of apiculture and floriculture
6. National level registration and release of existing and new varieties
7. Establishing effective domestic and international market linkage
8. Development of Institutional Floriculture Garden

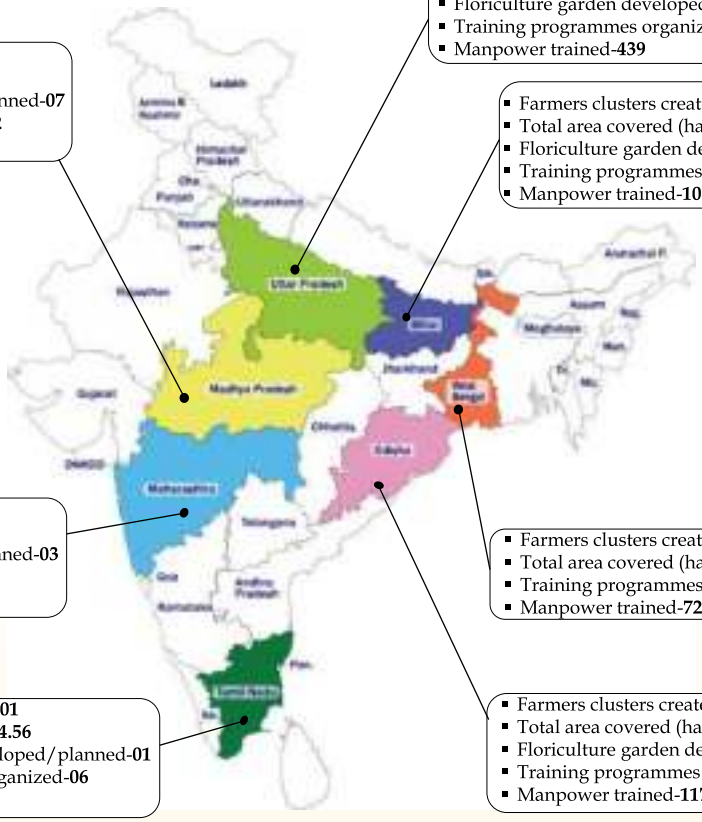
Crops Covered: Marigold, Tuberose, Gladiolus, Chrysanthemum, Rose and Jasmine

Major highlights during 2021-22

- Farmers clusters created-**18**
- Total area covered (ha)-**62**
- Floriculture garden developed/planned-**08**
- Training programmes organized-**14**
- Manpower trained-**439**

- Farmers clusters created-**03**
- Total area covered (ha)-**5.07**
- Floriculture garden developed/planned-**07**
- Training programmes organized-**02**
- Manpower trained-**33**

- Farmers clusters created-**05**
- Total area covered (ha)-**8.5**
- Floriculture garden developed/planned-**03**
- Training programmes organized-**09**
- Manpower trained-**106**



- Farmers clusters created-**09**
- Total area covered (ha)-**118**
- Floriculture garden developed/planned-**03**
- Training programmes organized-**07**
- Manpower trained-**192**

- Farmers clusters created-**04**
- Total area covered (ha)-**4.67**
- Training programmes organized-**5**
- Manpower trained-**72**

- Farmers clusters created-**01**
- Total area covered (ha)-**14.56**
- Floriculture garden developed/planned-**01**
- Training programmes organized-**06**
- Manpower trained-**375**

- Farmers clusters created-**07**
- Total area covered (ha)-**13**
- Floriculture garden developed/planned-**06**
- Training programmes organized-**10**
- Manpower trained-**117**

Under the project, the institute also distributed more than one lakh number of planting materials (seeds, plantlets, corns etc.) to the farmer clusters. Under the objective, integration of floriculture and apiculture, CSIR-NBRI covered more than 500 ha of area, distributed more than 450 apiculture boxes and trained 615 individuals.

PARTICIPATING CSIR LABORATORIES: CSIR-NBRI, Lucknow **(Nodal Laboratory);** CSIR-IHBT, Palampur; CSIR-NEIST, Jorhat; CSIR-CFTRI, Mysuru; CSIR-IIIM, Jammu

निदेशक की कलम से

वर्ष 2021–22 के लिए सीएसआईआर–एनबीआरआई की वार्षिक रिपोर्ट प्रस्तुत करते हुए मुझे खुशी हो रही है। इस अवधि के दौरान जैसे ही COVID–19 महामारी का प्रकोप कम हुआ, हमारे वैज्ञानिकों, तकनीकी कर्मचारियों, शोध छात्रों और प्रशासन ने पूरे उत्साह के साथ हमारे निर्धारित अनुसंधान लक्ष्यों की दिशा में योगदान दिया।

हम एनएमआर 600 मेगाहर्ट्ज की सुविधा को स्थापित करने और चालू करने में सक्षम रहे। यह हमें मेटाबोलामिक्स पर अपने काम को आगे बढ़ाने में सक्षम बनाएगा। मानव सिर की त्वचा पर डैंड्रफ को नियंत्रित करने के लिए एंटी–डैंड्रफ हर्बल हेयर ऑयल की एक तकनीक उद्योग को हस्तांतरित की गई।

समय और संस्थान की टैगलाइन *"जहां पादप–आधारित अनुसंधान नवाचार के माध्यम से जीवन को स्पर्श करता है"* को ध्यान में रखते हुए हमने इस रिपोर्टिंग अवधि में 20 नई परियोजनाएं शुरू कीं जिनमें 17 सरकारी सहायता प्राप्त परियोजनाएं (जीएपी) और 03 मेगा लैब परियोजनाएं (एमएलपी) शामिल हैं। ये परियोजनाएं ज्ञान पैदा करने के अलावा कृषि और मानव स्वास्थ्य से संबंधित कई मुद्दों को भी संबोधित करेंगी। संस्थान ने जनसम्पर्क, प्रशिक्षण और कौशल विकास कार्यक्रमों के माध्यम से विभिन्न अंतिम उपयोगकर्ताओं को सेवाएं प्रदान करना जारी रखा और 24 समझौता ज्ञापनों तथा एमटीए पर हस्ताक्षर किए।

फार्माकोग्नॉसी, फाइटोकेमिस्ट्री और उत्पाद विकास में महत्वपूर्ण मील के पत्थर हासिल किए गए हैं। आईएसओ–17034–2016 की आवश्यकताओं के अनुसार कुल नौ प्रमाणित संदर्भ सामग्री [(+) लिमोनेन, यूजेनॉल, गेरानियोल, (–) मेन्थॉल, एल–कारवोन, मैंगिफेरिन, मिथाइल चाविकोल, करक्यूमिन, एंड्रोग्राफोलाइड्स] तैयार किए गए हैं। एक एंटीडैंड्रफ हेयर ऑयल फॉर्मूलेशन विकसित किया गया है। भांग के फोर्मूलेशन (मदानंद मोदक, कामेश्वर मोदक, त्रैलोक्य विजयवती और शुद्ध भांग) तैयार किए गए और भेषज मानकीकरण और जैव रासायनिक अनुमानों के लिए आगे अध्ययन किए गए। आयुर्वेदिक औषधि ''दारुहरिद्रा'' के विकल्प के रूप में संभावनाओं की खोज हेतु तीन *महोनिया* प्रजातियों का तुलनात्मक भेषज विज्ञान अध्ययन किया गया। *अर्जिनिया इंडिका* बल्ब में एचपीटीएलसी के माध्यम से ओलीनोलिक एसिड, बीटा–सिटोस्टेरॉल और ल्यूपोल की समवर्ती मात्रा का आंकलन किया गया। *इन–विट्रो* कोशिका लाइनों में हेपजी2 कोशा और *इन–विवो* पशु प्रणाली का उपयोग करके *सेलेजिनेला ब्रायोप्टेरिस* के एंटीकैंसर प्रभाव का मूल्यांकन किया गया और *इन–विट्रो* कोशिका लाइनों में आशाजनक परिणाम दिखे। छोटे पशु मॉडल सिस्टम में *सिनामोमम वेरम* व्युत्पन्न जैवसक्रिय–क्रियाशील स्वर्ण नैनोपार्टिकल्स को उच्च वसा वाले आहार स्थितियों में उपयोग करके आंत की माइक्रोबायोटा रीशेपिंग के माध्यम से मोटापा–विरोधी प्रभाव को बढ़ाने के लिए दिखाया गया।

चार पादप आधारित मोम उत्पादों (एनबीआर–डब्ल्यूपी1, एनबीआर–डब्ल्यूपी2, एनबीआर–डब्ल्यूपी3 और एनबीआर–डब्ल्यूपी4) को सहक्रियात्मक हाइड्रोफोबिक बायोडिग्रेडेबल उत्पादों को तैयार करने के लिए खाद्य/न्यूट्रास्यूटिकल्स और प्राकृतिक योजक के रूप में/के लिए उपयोग करने के लिए विकसित किया गया।

गुलदाउदी *क्राइसेन्थेमम मोरीफोलियम* की 'एनबीआरआई–स्वाधीन 75' नामक एक नई उत्परिवर्ती 'सजावटी' प्रकार की, देर से खिलने वाली किस्म विकसित की गई है। भारत की स्वतंत्रता के प्लेटिनम जयंती समारोह वर्ष के दौरान *आजादी का अमृत महोत्सव* को चिह्नित करने के लिए इस किस्म को 'एनबीआरआई–स्वाधीन 75' नाम दिया गया है, जिसे 30 जनवरी 2022 को माननीय सीएसआईआर महानिदेशक डॉ शेखर सी मांडे द्वारा जारी किया गया। 'केल्विन विक्ट्री' और 'हेमंत सिंगार' किस्मों के

उत्परिवर्तन के माध्यम से क्रमशः पोम्पोन–प्रकार के फूल युक्त वांछित नवीन कट–स्प्रे किस्म और 'नो–पिंच–नो–स्टेक' विशेषता के साथ एक बौनी किस्म के लिए नई उत्परिवर्ती रेखाओं को प्रेरित किया गया।

ग्लेडियोलस में संकरण किया जा रहा है। ये क्रॉस बेहतर सजावटी विशेषताओं के साथ कई नई संकर किस्में पैदा कर सकते हैं जिनकी तत्काल बाजार क्षमता उपलब्ध होगी। गामा विकिरण और रासायनिक उत्परिवर्तनों के माध्यम से संकरण और उत्परिवर्तन प्रजनन की तकनीकों का उपयोग करते हुए केना, कुमुदनी और कमाल जैसे फूलों की खेती और सजावटी पौधों की किस्मों का विकास किया गया है। उद्यान में हमारे वन्य संग्रह में आईरिस प्रजाति, *होया प्रजाति, बारलेरिया* प्रजाति, *बेगोनिया* प्रजाति, *इम्पेशेंश* प्रजाति, ऑर्किड, *निम्फिया* और कमल शामिल हैं जिन्हें सफलतापूर्वक उगाया गया है।

हमारे पादप विविधता समूह के वैज्ञानिकों और शोधकर्ताओं ने विविधता विश्लेषण, वर्गिकी, संरक्षण और जैव–पूर्वेक्षण के लिए भारत के विभिन्न पादप–भौगोलिक क्षेत्रों में सर्वेक्षण किए, जिससे उभयोद्भिद, घास, मैंग्रोव प्रजातियों और लाईकेन की नई प्रजातियों की खोज हुई। भारत में प्रजातियों की मौजूदा सूची में लाईकेन के 25 से अधिक नए रिकॉर्ड भी जोड़े गए। देश के विभिन्न हिस्सों से लगभग 32 संकटग्रस्त पादप प्रजातियों को एकत्र किया गया है, जिनमें से 15 को सीएसआईआर–एनबीआरआई वनस्पति उद्यान में सफलतापूर्वक संरक्षित किया गया है। उनमें से कई को सीएसआईआर–एनबीआरआई के वनस्पति उद्यान में माइक्रोप्रोपेगेशन तकनीकों का उपयोग करके गुणन किया जा रहा है। पौधों को अंततः समर्पित संरक्षणशाला में स्थानांतरित कर दिया जाएगा। भारत में कई प्रजातियों की विविधता और वितरण पैटर्न की व्याख्या करने के लिए आणविक मार्करों का उपयोग करते हुए उनका वंशानुक्रम–भौगोलिक अध्ययन शुरू किया गया है।

आणविक तंत्र को समझने और फसल सुधार के लिए स्थिर आनुवंशिक लाइनें स्थापित करने के लिए कपास, टमाटर, गुलाब, काबुली चना, चावल और सब्जियों पर पर्याप्त अध्ययन किया गया। T2 पीढ़ी में Pnu08 GM कॉटन (n=2) की स्थिर लाइनों को स्थापित करने के लिए महत्वपूर्ण संकेत प्राप्त किया गया है जो सफेद मक्खी और कॉटन बॉलवर्म से बचाव के लिए प्रमोटर At4 के नियमन के तहत कीटनाशक प्रोटीन को व्यक्त करता है। T1 पीढ़ी में PCD प्रमोटर के नियमन के तहत कीटनाशक प्रोटीन को व्यक्त करने वाली Dhi31 GM कपास लाइनों पर उन्नत शोध के आशाजनक परिणाम मिले हैं। लगभग 380 कपास RNAseq डेटा बिंदुओं को जीनोम के 400–गुना कवरेज के साथ सुसंगत मानचित्रण तकनीकों का उपयोग करके रीमैप किया गया था। आंकड़ों ने रेशों की कोशिका प्रतिबद्धता, आरंभ, बढ़त, और माध्यमिक कोशिका भित्ति उत्पादन के चरण–विशिष्ट पहलुओं के साथ–साथ रेशों के विकास के अद्वितीय नियंत्रण के लिए संभावित सीआईएस–नियामक तत्वों का खुलासा किया। यह अध्ययन कपास के रेशों के विकास और वृद्धि से जुड़े कई आवश्यक कारकों को उजागर करता है, जिन्हें ''कॉटन एक्सप्रेस–ओमिक्स'' डेटाबेस में संकलित किया गया है। टमाटर अनुसंधान में भी महत्वपूर्ण बढ़त प्राप्त की गई है जिसमें दिखाया गया है कि टमाटर से *एसएलईआरएफ* 6 जीन जो एबीए प्रतिक्रियाओं को बदल देता है, फल–विशिष्ट 2, 11 प्रमोटर के तहत व्यक्त किया गया, जिससे नियंत्रण की तुलना में फल पकने में लगभग 6 दिनों की देरी हुई, इससे यह संकेत मिले कि टमाटर में फलों के पकने में विलंबन हेतु एसएलईआरएफ 6 का उपयोग किया जा सकता है। आम में सुगंध के आणविक तंत्र को समझने के लिए, इलुमिना अनुक्रमण द्वारा *डे नोवो* ट्रांस्क्रिप्टोम असेंबली और *मैंगीफेरा इंडिका* (दशहरी) का विश्लेषण किया गया। सुगंध जैवसंश्लेषण में शामिल संभावित जीनों की पहचान की गई। यह अध्ययन आम के फल में सुगंध के पाथवे को समझने के लिए एक महत्वपूर्ण कदम साबित हो सकता है। चावल पर किए गए अध्ययनों से पता चला है कि टाऊ वर्ग ग्लूटाथियोन–एस–ट्रांसफरेज (ओएसजीएसटीयू5) वीरई2 प्रोटीन के साथ परस्पर क्रिया करता है और चावल में एग्रोबैक्टीरियम–मध्यस्थत जीन स्थानांतरण की दक्षता को नियंत्रित करता है।

संगणनात्मक जीव विज्ञान में, सूखे, लवण, भारी धातुओं और रोगजनक हमले के जवाब में पौधों की तनाव सहनशीलता का अध्ययन किया गया। लवण और सूखा–तनावग्रस्त कपास का प्रतिलेखीय मेटा–विश्लेषण किया गया। विश्लेषण से सूखे और लवण तनाव की स्थिति के प्रमुख नियामक हब जीन का पता चला, जिनका कार्यात्मक सूखा और लवण तनाव–प्रतिक्रियाशील (डीएसएसआर) जीन के साथ उल्लेखनीय संबंध है। फल पकने के लिए उत्तरदायी जीन के विकास की पहचान करने के लिए मूसा प्रजाति का पैन–जीनोम विश्लेषण किया गया। फल पकने से संबंधित ईआरएस जीन का विस्तार से विश्लेषण किया गया था, और विभिन्न *मूसा* प्रजातियों में पकने से संबंधित महत्वपूर्ण अंतरों की पहचान की गई।

पादप आनुवंशिक संसाधनों और सुधार के तहत, अलसी की किस्मों के विकास, अनाज *ऐमारैंथ* के आनुवंशिक सुधार, केले की उत्पत्ति और शारीरिक अनुकूलन की समझ, *क्वेरकोइडी* में वंशानुक्रम को हल करने, कीमोटाइप–आधारित पारंपरिक और आणविक प्रजनन के माध्यम से भारतीय भांग के सुधार में महत्वपूर्ण बढ़त हासिल की गई और अफीम में ओरिपेविन के लिए जीनोम वाइड एसोसिएशन स्टडी (जीडब्ल्यूएएस) किए गए।

पादप पारिस्थितिकी एवं जलवायु परिवर्तन समूह ने खुलासा किया कि ग्वार (*सायमोप्सिस टेट्रागोनोलोबा*) के सूखा संवेदनशील किस्में की तुलना में जल तनाव वाले पौधों में, पत्ती के प्रोटोक्साइलम, मेटैक्साइलम और कॉर्टिकल कोशिकाओं की परत में काफी कम कमी दिखी। एक अन्य अध्ययन में, फलीदार वृक्ष प्रजाति ल्यूसेना ल्यूकोसेफला को उच्च O_3 (EO_3) में रखने से पादप वृद्धि एवं राइजोस्फेरिक मृदा कार्बन और फास्फोरस में कमी आई है। सिमिलिपाल बायोस्फीयर रिजर्व, ओडिशा के तीन अलग–अलग वन प्रकारों में पादप समुदाय संरचना और भूमि से ऊपर के जैव–भार का अध्ययन किया गया। प्रमुख वृक्ष घटक में कार्बन का भंडारण कार्बन चक्र की गणना के लिए निर्धारित किया गया था। इन वन प्रकारों में अधिकतम जैवभार योगदान करने वाले पेड़ों की पहचान की गई।

पर्यावरण और सूक्ष्मजैविक प्रौद्योगिकी के विकास में महत्वपूर्ण प्रगति हासिल की गई है। बैक्टीरिया एंडोफाइट, *बैसिलस सबटिलिस* से एक कुशल जैव नियंत्रक एजेंट विकसित किया गया है जो *मैक्रोफोमिना फेजोलिना* संक्रमण के कारण होने वाले चारकोल रॉट रोग का दमन कर सकता है और सोयाबीन की कार्यिकी विशेषताओं को बढ़ाता है। एक आशाजनक *बेसिलस सबटिलिस* प्रभेद NBRI-W9 (MTCC–25374) की पहचान की गई है और विभिन्न फसलों जैसे कि ग्लेडियोलस, टमाटर और पान में फुसैरियम संक्रमण के एक शक्तिशाली जैव नियंत्रण एजेंट के रूप में मूल्यांकन किया गया। *अरेबिडोप्सिस थैलियाना* के साथ एक अध्ययन से पता चला है कि *पैनीबैसिलस लेंटिमोरबस*, बी–30488 जड़ संरचना को बदल देता है और पादप होर्मोन और जीन अभिव्यक्ति के मॉड्यूलेशन के माध्यम से विकास को नियंत्रित करता है, सूखा सहनशीलता को बढ़ाता है और समग्र रूप से पौधों की वृद्धि में काफी सुधार करता है। पपीता रिंगस्पॉट वायरस का शीघ्र पता लगाने के लिए पॉलीक्लोनल एंटीबॉडी (पीएबी) का उपयोग करके लेटरल फ्लो इम्युनोसे (एलएफआईए) के सिद्धान्त पर एक त्वरित और क्षेत्र में प्रयोग किए जाने लायक डायग्नोस्टिक किट विकसित किया जा रहा है। *रिविना ह्यूमिलिस* की पत्तियों से तैयार जैविक रूप से संश्लेषित चांदी के नैनोकणों की वायरस प्रबंधन के लिए जांच की जा रही है। साइनाइड के जैव उपचार के लिए नवीन सूक्ष्मजैविक प्रभेद के अनुप्रयोग की क्षमता का मूल्यांकन किया जा रहा है, जिसमें साइनाइड–दूषित ब्लास्ट फर्नेस एफ्लुएंट और स्टील प्लांट के सक्रिय कीचड़ से अलग किए गए जीवाणु और कवक प्रभेद का उपयोग किया जाता है।

राष्ट्रीय संदर्भ केंद्रों के रूप में काम करने के लिए साइकैड्स, वॉटर लिली और कमल के लिए एक संरक्षण केंद्र बनाया गया है। जम्मू और कश्मीर क्षेत्र से *पाइरोसिया सार्थलेंसिस* (पॉलीपोडियासी) और *स्वर्शिया पटनीटॉपिएनसिस* (जेंटियानेसी) की नई प्रजातियों का वर्णन किया गया। भारत में संकटग्रस्त पादप प्रजातियों को सूचीबद्ध करने के लिए एक सीएसआईआर–एनबीआरआई ऑनलाइन डेटाबेस बनाया गया है। वर्तमान डेटाबेस में पौधों के सभी समूहों की प्रजातियां शामिल हैं और यह उनकी आईयूसीएन संरक्षण की स्थिति उपलब्ध कराता है। एनबीआरआई द्वारा विकसित फूलों की फसलों और किस्मों को बढ़ावा देने के लिए देश के कई राज्यों में स्कूलों और कॉलेजों में पुष्पकृषि उद्यानों की स्थापना के रूप में एक नई सुविधा का निर्माण किया गया।

वर्तमान वर्ष में, भारत में चंदन (*सैंटलम एल्बम*) की खेती के संरक्षण, प्रबंधन और प्रचार पर काम शुरू किया गया और रेड सैंडर्स (*टेरोकार्पस सैंटलिनस*) के संरक्षण और उत्पादकता में सुधार किया गया है।

पादप संरक्षण और कृषि–प्रौद्योगिकी के तहत, बंथरा में बांस उद्यान में भारत के विभिन्न क्षेत्रों से एकत्र की गई बांस की 12 और प्रजातियों को जोड़ा गया, जिससे यह 67 प्रजातियों का संरक्षण भूखंड बन गया है। *ऐमारैंथ* जर्मप्लाज्म भंडार को 1223 परिग्रहणों से समृद्ध किया गया, जिनका विभिन्न कृषि और गुणवत्ता लक्षणों के लिए मूल्यांकन किया जा रहा है। सोडिक बंजर भूमि की स्थिति के तहत नागरमोथा (*साइपेरस स्केरियोसस*) के 52 परिग्रहणों का संग्रह, संरक्षण और मूल्यांकन उनकी व्यावसायिक खेती और जड़ के आवश्यक तेल के निष्कर्षण के लिए किया गया था। चार हिमालयी राज्यों से *जुनिपरस* के कुल

139 नमूने एकत्र किए गए, और पश्चिमी हिमालय से एकत्रित चार आबादियों से प्राप्त आवश्यक तेल का लक्षण वर्णन किया गया है।

जनसम्पर्क और कौशल विकास कार्यक्रमों के तहत, जीर्ण पत्तों से आवश्यक तेल निकालने के लिए हल्दी की खेती को लोकप्रिय बनाने के लिए विभिन्न स्थानों पर 22 जागरूकता सह प्रशिक्षण कार्यक्रम आयोजित किए गए एवं 863 किसानों को प्रशिक्षण दिया गया। सीएसआईआर–अरोमा मिशन के तहत, नौ राज्यों में 59 किसानों, जो 387 हेक्टेयर क्षेत्र को कवर करते हुए बीज किसानों के रूप में कार्य करते हैं, के बीच हल्दी की किस्म 'केसरी' के 253 क्विंटल प्रकंद वितरित किए गए हैं। UNIDO नीम परियोजना के तहत औषधीय और सुगंधित पौधों के साथ विभिन्न कृषि वानिकी मॉडल विकसित किए गए। चार अलग–अलग नीम की किस्मों के तुलनात्मक अनुकूलन का मूल्यांकन करने के लिए पांच अलग–अलग कृषि जलवायु क्षेत्रों में बहु–स्थानिक परीक्षण किए गए।

रिपोर्टिंग वर्ष के दौरान, संस्थान ने एससीआई पत्रिकाओं में 618.55 के संचयी प्रभाव कारक के साथ 178 शोध पत्र प्रकाशित किए (IF 3.47 प्रति पेपर)। तीन पेटेंट भारत में दायर किए गए थे, जबकि एक पेटेंट भारत में और तीन विदेश में प्रदान किए गए। 23 छात्रों को भारत में वैज्ञानिक और अभिनव अनुसंधान अकादमी (एसीएसआईआर) और अन्य विश्वविद्यालयों द्वारा पीएचडी से सम्मानित किया गया।

मैं अपने सभी वैज्ञानिक, तकनीकी और प्रशासनिक कर्मचारियों एवं छात्रों को हमारी संस्थागत गतिविधियों को बनाए रखने में उनकी प्रतिबद्धता, उत्साह और समर्पण के लिए धन्यवाद देना चाहता हूं। 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 का भी आभार व्यक्त करता हूं। मैं इस अवसर पर सीएसआईआर के महानिदेशक के रूप में कार्यभार ग्रहण करने पर डॉ. एन. कलाइसेल्वी को बधाई देता हूं, और मुझे विश्वास है कि उनके सक्षम नेतृत्व और समर्थन के तहत, सीएसआईआर–एनबीआरआई नई ऊंचाइयों को छुएगा। मैं हमारे अनुसंधान एवं विकास और प्रबंधन एजेंडा को तैयार करने और संस्थागत प्रदर्शन और प्रगति की निगरानी में हमारा मार्गदर्शन करने के लिए सीएसआईआर–एनबीआरआई के अनुसंधान और प्रबंधन परिषदों के अध्यक्ष प्रोफेसर (डॉ) परमजीत खुराना और माननीय सदस्यों को धन्यवाद देना चाहता हूं। मैं सभी प्रायोजकों, फंडर्स, उद्योग भागीदारों, सहयोगियों, साथियों, शिक्षाविदों, अन्य समर्थकों और जनता का बहुत आभारी हूं कि उन्होंने हमें कई तरह से उदार समर्थन और सहयोग दिया। मैं इस तरह के सहयोग की सराहना करता हूं और हमारे भविष्य के सभी प्रयासों में आपके अपार समर्थन की आशा करता हूं।

सरोज बारिक

(सरोज के बारिक)
निदेशक

From the Director's Desk

It is my pleasure to present before you the Annual Report of CSIR-National Botanical Research Institute (CSIR-NBRI) for the year 2021–22. Despite COVID–19 pandemic (that peaked during this period), our Scientists, Technical Staff, Research Scholars, and Administrative staff contributed immensely to achieve the goal of CSIR-NBRI.

We installed the facility of NMR 600 MHz in the beginning of the year giving a boost to bioprospection research and works on metabolomics. Conforming to the institute's tagline, Where Plant-Based Research Touches Life through Innovation, the know-how to control dandruff on the human scalp anti-dandruff herbal hair oil technology was transferred to the industry.

We initiated 20 new projects during the period under report that include 17 external funded Projects (GAP), and 03 Major Lab Projects (MLP) from CSIR. These projects, apart from generating knowledge, would also pave the way to address important issues related to agriculture and human health. The institute continued to provide services to various end users through outreach, training, and skill development programmes, and signed 24 MoUs/ MTAs with various institutions and industries.

In the field of pharmacognosy, phytochemistry and product development, several products and technologies were developed during the year. Nine Certified Reference Materials viz., (+) Limonene, Eugenol, Geraniol, (-) Menthol, L- Carvone, Mangiferin, Methyl Chavicol, Curcumin, Andrographolides have been prepared as per requirements of ISO-17034-2016. Four *Cannabis* medicinal formulations were prepared, and were subjected for pharmacognostical standardization and biochemical estimations. Comparative pharmacognostical studies of three Mahonia species were undertaken to explore the possibilities as a substitute to ayurvedic drug "Daruharidra". Concurrent quantification of oleanolic acid, β-sitosterol and lupeol in the bulbs of *Urginea indica* Kunth were done through HPTLC. The anticancer effect of *Selaginella bryopteris* was evaluated in vitro using HepG2 cell and in vivo animal system that showed promising results in in vitro cell lines. *Cinnamomum verum* derived bioactive-functionalized gold nanoparticles (Au@P-NPs) have been shown to enhanced anti-obesity effects through gut microbiota reshaping using in high-fat diet (HFD) conditions in small animal model system. Four plant based wax products (NBR-WP1, NBR-WP2, NBR-WP3 and NBR-WP4) have been developed to be used as/for edibles/ nutraceuticals and natural additive to formulate synergistic hydrophobic biodegradable products.

A new mutant 'Decorative' type, late-blooming floral variety of *Chrysanthemum morifolium* named 'NBRI-Swadheen75' was developed. This variety has been named 'NBRI-Swadheen75' to mark the Azadi Ka Amrut Mahotsava during Platinum Jubilee celebration year of independence of India, and was released by the Hon'ble, DG CSIR Dr. Shekhar C. Mande on January 30th 2022. New mutant lines of *Chrysanthemum morifolium* have been induced through mutagenesis of vars. 'Kelvin Victory' & 'Hemant Singar' for desired novel cut-spray variety having pompon-type flowers & a dwarf variety with 'no-pinch-no-stake' characteristic, respectively.

Hybridization in Gladiolus was undertaken. These crosses have resulted in new hybrid varieties with improved ornamental characteristics. Varietal development of floricultural and ornamental plants such as *Canna*, *Nymphaea*, and *Nelumbo* using the techniques of hybridization and mutation breeding such as gamma radiation and chemical mutagens have been undertaken. Ornamentals from wild viz., *Iris* sp., *Hoya* sp., *Barleria* sp., *Begonia* sp., *Impatiens* sp., Orchids, Nymphaea, and lotus have been successfully domesticated.

The scientists and researchers of our plant diversity group botanically explored different undersurveyed phytogeographical regions of India. Such explorations have resulted in critical analysis diversity, systematic, conservation and bioprospecting studies leading to discovery of new species of bryophytes, grass, mangrove species and lichens. More than 25 new records of lichens were added to the existing list of species in India. Thirty two threatened plant species were taken up for successful conservation. All these species are being multiplied

using macro- and micro-propagation techniques at CSIR-NBRI Botanic Garden. Phylogeographic studies of several species using molecular markers were undertaken to explain their diversity, distribution and evolutionary trend.

Several studies were undertaken on cotton, tomato, rose, chickpea, rice and vegetables for crop improvement. Significant leads were obtained to establish stable lines of Pnu08 GM cotton (n=2) in T2 generation that expressed insecticidal proteins under the regulation of promoter *At4* for defense against whitefly and cotton bollworm. Advance research on Dhi31 GM cotton lines that expressed insecticidal protein under the regulation of PCD promoter in T1 generation yielded promising results. Approximately 380 cotton RNAseq data points were remapped using consistent mapping techniques with 400-fold coverage of the genome. Data revealed stage-specific aspects of fiber cell commitment, initiation, elongation, and Secondary Cell Wall (SCW) production, as well as probable cis-regulatory elements for the unique control of fiber development. This study uncovers numerous essential factors connected to cotton fibre development and enhancement, which are compiled in the "Cotton Express-omics" database. Leads were also obtained in tomato research showing that the *SlERF6* gene from tomato alters ABA responses, which was expressed under the fruit-specific 2A11 promoter, leading to delay in fruit ripening by about 6 days compared to the control, suggesting that *SlERF6* could be used for delayed ripening in tomatoes. In order to understand the molecular mechanism of aroma in mango, *de-novo* transcriptome assembly and analysis of *M. indica* (Dashehari) was performed by Illumina sequencing. Potential genes involved in aroma biosynthesis were identified. This study would prove to be a stepping stone to understand aroma pathway in mango fruit. Studies on rice showed that the tau class glutathione-S-transferase (*OsGSTU5*) interacts with VirE2 protein and modulates the efficiency of *Agrobacterium*-mediated gene transfer in rice.

In computational biology, the stress tolerance of plants in response to drought, salt, heavy metals, and pathogen attack was studied. The transcriptome meta-analysis of the salt and drought-stressed cotton was carried out. The analysis revealed key regulatory hub genes of drought and salt stress conditions have notable associations with functional drought and salt stress-responsive (DSSR) genes. There were 5,962 and 3,510 differentially expressed genes (DEGs) identified in drought and salt stress data. There were 3,132 and 2,830 up and down regulated genes in drought and 2,265 and 1,245 up and down regulated genes in salt stress data. The pan-genome analysis of *Musa* sp. was carried out to identify the evolution of the ripening-responsive genes. The ripening-related ERS gene was analyzed in detail, and significant differences concerning ripening were identified in different Musa species.

Under plant genetic resources and improvement, significant leads were achieved in linseed varietal development, and genetic improvement of grain amaranth. Works on understanding the origin and physiological adaptation of Banana, resolving the phylogeny in Quercoideae, improvement of Indian Cannabis through chemotype-based conventional and molecular breeding, and Genome Wide Association Study (GWAS) for oripavine in opium poppy were other significant activities.

Plant Ecology and Climate Change group revealed that in, water stressed plants of guar *Cyamopsis tetragonoloba* (L.) Taub., the anatomical sections of leaf showed a significantly less reduction in the width of protoxylem, metaxylem, and the layer of cortical cell as compared to drought sensitive varieties. In another study on the long-term exposure of leguminous tree species, *Leucaena leucocephala*. L. to elevated O_3 (EO_3) resulted in reduction in growth, and carbon and phosphorus in the rhizospheric soil. Plant community composition and the aboveground biomass were studied in three different forest types of Similipal Biosphere Reserve, Odisha. Storage of the carbon in the dominant tree component was determined to compute the carbon cycle. Trees contributing maximum biomass in these forest types were identified.

Under environmental and microbial technology programme, an efficient biocontrol agent *Bacillus subtilis* was isolated that could suppress the charcoal rot disease caused by *Macrophomina phaseolina* infection and enhanced the physiological attributes of soybean. A promising *Bacillus subtilis* strain NBRI-W9 (MTCC-25374) was identified and evaluated as a potent biocontrol agent of *Fusarium* infection in different crops such as gladiolus, tomato and betelvine. A study with *Arabidopsis thaliana* showed that *Paenibacillus lentimorbus*, B-30488 alters root architecture and regulates growth via modulation of phytohormones and genes expression and enhances drought tolerance and overall significantly improves plant growth. A rapid and field deployable diagnostic kit, for early detection of *Papaya ringspot virus* (PRSV) is being developed on the principle of lateral flow immunoassay (LFIA) using polyclonal antibody (PAb). Biologically synthesized silver nanoparticles prepared with the leaves of *Rivina humilis* is being investigated for virus management. The potential of

application of novel microbial strains for the bioremediation of cyanide is being assessed, using bacterial and fungal strains isolated from cyanide-contaminated blast furnace effluent and activated sludge of a steel plant.

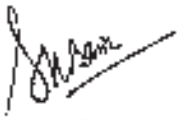
A conservation centre has been created for Cycads, Water lily and Lotus to serve as National Reference Centres. New species of *Pyrrosia sarthalensis* (Polypodiaceae) and *Swertia patnitopiansis* (Gentianaceae) were described from Jammu & Kashmir region. A CSIR-NBRI online database has been created for enlisting the plant species which are threatened in India. The current database includes species from all groups of plant taxa and provides their IUCN conservation status. For the promotion of NBRI-developed floricultural crops and varieties, the creation of a new facility in the form of establishing a floriculture garden in schools and colleges was undertaken in many states of the country.

Under plant conservation and agro-technology division, 12 more species were added to the Bambusetum at Banthra, making it a Bambusetum of 67 spp. of bamboos. The grain amaranth germplasm repository was further enriched to 1223 accessions which are being evaluated for various agronomical and quality traits. Collection, conservation and evaluation of 52 accessions of Nagarmotha (*Cyperus scariosus*) was done under sodic waste land conditions for their commercial cultivation and extraction of root essential oil. A total 139 accessions of Juniperus were collected from four Himalayan states, and characterization of essential oil has been done from four populations from Western Himalaya.

Under out-reach and skill development programmes, 22 awareness cum training programmes involving 863 farmers were organized at different location for popularization of turmeric cultivation for essential oil extraction from senescing leaves. Under CSIR-Aroma Mission, 253 quintals rhizomes of turmeric variety 'Kesari' were distributed among 59 farmers in nine states, who would act as seed farmers, covering 387 ha area. Different agroforestry models were developed with medicinal and aromatic plants under the UNIDO Neem project. The multi-location trials were planted at five different agroclimatic zones to evaluate comparative adaptation of four different Neem cultivars.

During the reporting year, the institute published 178 research papers in SCI journals, with a cumulative impact factor of 618.55 (IF 3.47 per paper). Three patents were filed in India, while the number of patents granted included one in India and three abroad. 23 students were awarded PhD by the Academy of Scientific and Innovative Research (AcSIR) and other universities in India.

I would like to thank all my scientific, technical, and administrative staff and students for their commitment, enthusiasm, and dedication to sustain our institutional activities. 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. I also take this opportunity to congratulate Dr. N. Kalaiselvi, on taking charge as DG, CSIR, and I am sure that under her leadership and support, CSIR-NBRI shall scale newer heights. We would like to thank Prof. (Dr) Paramjit Khurana, Chairperson and all the 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 their kind gestures and look forward to the unstinted support in all our future endeavours.



Saroj K Barik
Director

कार्यकारी सारांश

सीएसआईआर–एनबीआरआई संस्थान भारत की पादप विविधता पर बुनियादी विज्ञान अनुसंधान और पारंपरिक तथा उन्नत जैवप्रौद्योगिकी दृष्टिकोण के माध्यम से उसके व्यवस्थित प्रलेखन, संरक्षण और सतत उपयोग में उत्कृष्टता के लिए जाना जाता है।

संस्थान के पास पादप विविधता मूल्यांकन, वर्गिकी, संरक्षण, जीनोमिक्स, पारंपरिक एवं आणविक प्रजनन के माध्यम से पौधों में सुधार, आनुवंशिक अभियांत्रिकी, अजैविक व जैविक तनाव हेतु पारजीनी पादप विकास, जलवायु परिवर्तन अध्ययन, पौधों और सूक्ष्मजीवों के माध्यम से प्रदूषण निवारण, पादप–सूक्ष्मजीव अंतःक्रिया, पादप उपचार, पुष्पकृषि, बागवानी, कृषि प्रौद्योगिकी, पादप संरक्षण एवं आर्थिक महत्व की नई किस्मों का विकास, औषध विज्ञान, पादप रसायन, जैव पूर्वेक्षण और न्यूट्रास्युटिकल, कॉस्मेटिक और स्वास्थ्य देखभाल उत्पादों का विकास तथा जनसंपर्क कार्यक्रमों के माध्यम से सामाजिक विकास गतिविधियों के क्षेत्रों में मुख्य दक्षताएं उपलब्ध हैं।

वर्ष 2021–22 में सीएसआईआर–एनबीआरआई की वैज्ञानिक, तकनीकी और जनसंपर्क गतिविधियों में कई महत्वपूर्ण उपलब्धियां देखी गईं, जिनका सारांश निम्नवत है:

पादप विविधता, वर्गिकी एवं पादपालय

पादप विविधता विभाग के विभिन्न समूहों ने भारत के विभिन्न राज्यों जम्मू और कश्मीर, हिमाचल प्रदेश, उत्तराखंड, महाराष्ट्र, मध्य प्रदेश, राजस्थान, गुजरात तमिलनाडु, पूर्वोत्तर राज्यों के कम खोजे गए क्षेत्रों, जिनमें चम्बल घाटी एवं पश्चिमी घाट आदि भी सम्मिलित हैं, में कई वानस्पतिक सर्वेक्षण किए।

नवीन प्रजातियों की खोज एवं भारत के लिए नए वितरण रिकोर्ड

यूजेनिया (मिर्टेसी) की नई प्रजाति *यूजेनिया पोक्कुदानियाई* का वर्णन दक्षिणी पश्चिमी घाट के पलक्काड जिले में नेल्लियामपैथी पहाड़ियों से किया गया।

जेरेनियम इण्डिकम को कसौली एवं दगशाई (हिमाचल प्रदेश), बागेश्वर, पुरोला एवं मसूरी (उत्तराखंड) से वर्णित किया गया जबकि *जिरेनियम ओसेलेटम* किस्म अल्बिफ्लोरम को उत्तराखंड के टिहरी जिले में वानस्पतिक सर्वेक्षण के दौरान दर्ज किया गया। दो नयी प्रजातियाँ *केलेमोग्रोस्टिस नंदादेविएंसिस* और *ब्रोमस हुसैनिआइ* को नंदा देवी बायोस्फीयर रिजर्व, वैली ऑफ फ्लावर्स राष्ट्रीय पार्क, चमोली, उत्तराखंड से खोजी गईं।

पश्चिमी हिमालय (हिमाचल प्रदेश, कुल्लू, मनाली) से एक नई घास प्रजाति *ट्राइसेटोप्सिस पीरपंजालेंसिस* तथा एक अन्य नई पुष्पीय प्रजाति *वेलिवोक्लोआ यादवाई* की खोज की गई।

भारत के जम्मू और कश्मीर के रामबन जिले के राख जरगोह गाँव से एक नई प्रजाति *रोट्बेलिया हुसैनाई* (पोएसी) का वर्णन किया गया। लाइकेन की एक नई प्रजाति *रिनोडिना इंडिका* दर्ज की गई।

पादप विविधता अन्वेषण और प्रलेखन

पादप विविधता विभाग के विभिन्न समूहों ने भारत के विभिन्न राज्यों के कम खोजे गए क्षेत्रों में कई वानस्पतिक सर्वेक्षण किए। इनके परिणामस्वरूप रिंकोसिया जाति (लेगुमिनोसी) के 200 से अधिक नमूने, मध्य प्रदेश (श्योपुर, मुरैना और भिंड जिले) और उत्तर प्रदेश (इटावा और आगरा) की चंबल घाटी से 176 जातियों, 72 परिवारों और 258 प्रजातियों से संबंधित लगभग 1650 पुष्पीय नमूने एकत्र किये गए।

महाराष्ट्र के यवतमाल जिले से तीन नए पवित्र वन शिला शिवाय, करई माता और लहन भीसा हनुमान की खोज की गई।

हिमाचल प्रदेश, उत्तराखंड और सिक्किम राज्यों का दौरा किया गया एवं *एनीमोन* की 11 प्रजातियों का संग्रह किया गया।

पादप–भौगोलिक अध्ययन के भाग के रूप में पूर्वोत्तर और प्रायद्वीपीय भारत से 114 *एनसेट ग्लौकम* और 167

एनसेट सुपर्बम के नमूने एकत्र किए गए और उनका दस्तावेजीकरण किया गया।

भारत में बाल्सामिनेसी परिवार पर अद्यतन जानकारी के लिए एक चेकलिस्ट तैयार की गई है।

समीक्षाधीन अवधि के दौरान चंबल के बीहड़ों के पौधों के विविध समूहों अर्थात शैवाल (160 प्रजातियां), लाइकेन (11 प्रजातियां), ब्रायोफाइट्स (44 प्रजातियां), टेरिडोफाइट्स (17 प्रजातियां), जिम्नोस्पर्म (01 प्रजातियां) और एंजियोस्पर्म (341 प्रजातियां) पर एक आधारभूत डेटा तैयार किया गया।

उत्तर प्रदेश और मध्य प्रदेश की चंबल घाटी के विभिन्न क्षेत्रों में तीन पादप सर्वेक्षण–सह–संग्रह दौरों में पुष्पीय पौधों के कुल 1825 नमूने और अपुष्पी पौधों के 337 नमूने एकत्र किए गए।

लाइकेन जाति *बुएलिया* पर पुनरीक्षण अध्ययन जारी रखा गया। कुल 94 नमूनों का विस्तार से अध्ययन किया गया, जिसके परिणामस्वरूप भारत के लिए चार नए वितरण रिकॉर्ड सहित 17 प्रजातियों की पहचान की गई।

भारत के आर्थोनएल्स के पुनरीक्षण और वंशानुक्रम अध्ययनों की निरंतरता में एक ई–मोनोग्राफ विकसित किया गया है जिसे www.arthoniales.in के माध्यम से एक्सेस किया जा सकता है। आर्थोनिएलियन लाइकेन के संग्रह के लिए जम्मू एवं कश्मीर और हिमाचल प्रदेश के दो दौरे किए गए।

लाइकेन जाति *परमोट्रेमा* के भीतर पाए जाने वाले एंडोलाइकेनिक कवक पर अध्ययन जारी रखा गया। मूल रूप से प्राप्त 450 आइसोलेट्स में से एंडोलाइकेनिक कवक के कुल 100 आइसोलेट्स की पहचान की गई।

लाइकेन जाति *रिनोडिना* के पुनरीक्षण की निरंतरता में कुल 180 नमूनों का विस्तार से अध्ययन किया गया जिसमें भारत के लिए एक वितरण रिकॉर्ड रिनोडिना लेपिडा सहित 11 प्रजातियां प्राप्त हुईं।

पाइरेनोकार्पस लाइकेन के पुनरीक्षण अध्ययन के दौरान लाइकेनिकोलस मायकोटा *आर्थोनिया तवारेसाई*, जो पहले ऑस्ट्रिया से ज्ञात थी, को देश में एक नए रिकॉर्ड के रूप में वर्णित किया गया।

भारतीय क्षेत्र से ब्रायोफाइट जातियों *फाइमेटोसेरोस* (उत्तराखंडः बिनसर, मसूरी) एवं *प्लेजिओनियम जैपोनिकम* (उत्तराखंडः उत्तरकाशी) को पहली बार दर्ज किया गया।

पूर्वोत्तर क्षेत्र में स्थित असम के ब्रायोफाइट समृद्ध इलाकों में चयनित 32 ग्रिडों में विविधता के मात्रात्मक आकलन पर एक अध्ययन किया गया है।

मणिपुर (पूर्वोत्तर भारत) के विभिन्न इलाकों में मॉस की विविधता के आकलन के दौरान 34 परिवारों में 84 जातियों से संबंधित मॉस की कुल 126 प्रजातियों की जांच और वर्णन किया गई है।

नियमगिरी पहाड़ियों, ओडिशा के विभिन्न इलाकों से 18 परिवारों के तहत 34 जातियों से संबंधित दो किस्मों सहित 58 टैक्सा के कुल 519 टेरिडोफाइट नमूने एकत्र किए गए हैं। नियमगिरी पहाड़ियों से एकत्रित *पिट्रोग्रामा कैलोमेनलोस* का सजीव पौधा संस्थान के उद्यान में लगाया गया।

इन–विट्रो संवर्धनों और सजावटी टेक्सा *नेफ्रोलेपिस ऑरिकुलाटा* के बड़े पैमाने पर प्रसार का अध्ययन किया गया।

एक डेटाबेस (यूजर इंटरफेस) विकसित किया गया है जिसका नाम ''चंबल घाटियों के पादप संसाधन (पीआर सीआर) – चंबल घाटियों का एक डिजिटल फ्लोरा'' है।

साईथिया स्पाइनुलोसा और *साईथिया जाईगेन्शिया* के वितरण पैटर्न पर एक अध्ययन किया गया। *इन–विट्रो* अध्ययन के लिए *साईथिया स्पाइनुलोसा* और *साईथिया जाईगेन्शिया* के बीजाणु एकत्र किए गए। इन दो प्रजातियों की जनसंख्या संरचना का रूपात्मक लक्षणों के मापन के साथ परिमाणीकरण किया गया।

साईथिया स्पाइनुलोसा, साईथिया जाईगेन्शिया और *साईथिया खासियाना* के बीजाणु जीविता, अंकुरण प्रतिशत और युग्मकोद्भिद के विकासात्मक पैटर्न पर *इन–विट्रो* अध्ययन किए गए।

आणुविक वर्गिकी अध्ययन

बर्जीनिया सिलियाटा की आनुवंशिक और जीनोमिक पृष्ठभूमि को और समझने के लिए डे *नोवो* आरएनए

अनुक्रमण किया गया। *जिम्नेमा सिल्वेस्ट्रिस* की कुल 11 प्राकृतिक आबादियों की जांच 25 मार्करों (डीएएमडी और आईएसएसआर) के साथ की गई, जिससे प्रजातियों के स्तर पर बहुरूपता के उच्च स्तर का जबकि जनसंख्या स्तर पर बहुरूपता का निम्न स्तर का पता चलता है। इसके अतिरिक्त संकटग्रस्त पौधों की 100 लक्षित प्रजातियों में से 32 प्रजातियों को एकत्र किया गया है। आणविक और व्यवस्थित अध्ययन के लिए जुनिपरस की सभी छह प्रजातियों के कुल 169 नमूने तैयार किए गए।

भारत में *एनसेटे ग्लौकम* और *एनसेटे सुपर्बम* पर वंशानुक्रम–भौगोलिकी अध्ययनों को आनुवंशिक विविधता और वंशानुक्रम–भौगोलिकी संरचना का अनुमान लगाने, भारत में एनसेटे आबादी के विचलन समय को निर्धारित करने के उद्देश्यों के साथ जारी रखा गया।

सिट्रस मेडिका में वंशानुक्रम–भौगोलिकी अध्ययन को पूर्वोत्तर भारत में 16 आबादियों से लिए गए 129 नमूनों में दो क्लोरोप्लास्ट मार्करों, टीआरएन एल–एफ (टीआरएनएल इंट्रॉन और टीआरएनएल–एफ स्पेसर) और आरपीएस16 इंट्रॉन के विस्तारित विश्लेषण के साथ जारी रखा गया था।

संकटग्रस्त पौधों का संरक्षण

तीन सीएसआईआर संस्थानों क्रमशः सीएसआईआर–एनबीआरआई (नोडल लैब), सीएसआईआर–आईएच–बीटी और सीएसआईआर–एनईआईएसटी द्वारा 'भारत के संकटग्रस्त पौधों के संरक्षण' पर बहु–संस्थागत परियोजना द्वारा शुरू की गई।

देश और विदेश में विभिन्न पादपालयों में स्थित संकटग्रस्त पौधों की प्रजातियों के नमूनों के डेटा का दस्तावेजीकरण किया जा रहा है। बीएसडी, एलडब्ल्यूजी, सीडीआरआई, डीडी, एमएच, आईएफजीटीबी, सीएएलआई, सीएमपीआर, टीबीजीटी, आरएचटी, सीएएल, और केएफआरआई जैसे विभिन्न भारतीय पादपालयों से परामर्श किया गया और इन पादपालयों में लक्षित संकटग्रस्त पौधों की प्रजातियों के 2280 वाउचर नमूनों का अध्ययन किया गया।

भारत में संकटग्रस्त पौधों की प्रजातियों को सूचीबद्ध करने के लिए एक सीएसआईआर–एनबीआरआई ऑनलाइन डेटाबेस बनाया गया है। वर्तमान डेटाबेस में पादपों के सभी समूहों की प्रजातियां शामिल हैं और उनके आईयूसीएन संरक्षण की स्थिति प्रदान करता है।

उत्तर प्रदेश, मध्य प्रदेश, केरल और तमिलनाडु के पश्चिमी घाट के हिस्सों से एकत्रित 24 संकटग्रस्त और 32 स्थानिक प्रजातियों को संस्थान के वानस्पतिक उद्यान में *एक्स–सीटू* संरक्षण के लिए प्रदान किया गया।

संरक्षण की स्थिति की विभिन्न श्रेणियों से संबंधित फर्न की लगभग 67 प्रजातियों को फर्न हाउस में बनाए रखा और संरक्षित किया गया। फर्न हाउस को समृद्ध करने के लिए *सायथिया जाईगेंशिया, स्फेनोमेरिस चाईनेंसिस, एस्प्लेनियम कीलियोसोरम* और *पैरालेप्टोसिलस डिकरेन्स* के जीवित पौधे भी लाए गए थे। संरक्षण पर अध्ययन के एक भाग के रूप में, दुर्लभ पौधे *अथलामिया पिंगुइस* के *इन–विट्रो* प्रसार को स्थापित किया गया।

इन–विट्रो बीजाणु संवर्धन के माध्यम से *एस्प्लेनियम निडस, डिप्लाजियम एस्कुलेंटम, क्रिस्टेला डेंटाटा, ड्रायोप्टेरिस कोक्लीटा*, और *टेरिस बियाउरिटा* के पौधों का उत्पादन किया गया। सीएसआईआर–एनबीआरआई के फर्न हाउस में *क्रिस्टेला डेंटाटा* को नया पेश किया गया है।

जैव–पूर्वेक्षण अध्ययन

हिमालयी लाइकेन पर जैवपूर्वेक्षण अध्ययन जारी रखा गया। लाइकेन *रैम्लाइना कॉन्डुप्लिकन्स* और *अस्निया लोंगिसीमा* के मेथनॉल, क्लोरोफॉर्म और एसीटोन निष्कर्षणों ने *एसिनेटोबैक्टर बॉमनी, स्यूडोमोनास एरुजिनोसा* और *क्लेबसिएला न्यूमोनी* के खिलाफ उच्च रोगाणुरोधी गतिविधियों का प्रदर्शन किया। लाइकेन के अर्क ने स्तन कैंसर कोशिका लाइनों (एमसीएफ–7 और एमडीए–एमडी– 231) के खिलाफ कैंसर विरोधी गतिविधि हेतु दिलचस्प परिणाम दिए।

औषध विज्ञान, पादप रसायन एवं और उत्पाद विकास

प्रमाणित संदर्भ सामग्री का विकास

आईएसओ–17034–2016 की आवश्यकताओं के अनुसार कुल नौ प्रमाणित संदर्भ सामग्री (+) लिमोनेन,

यूजेनॉल, गेरानियोल, (–) मेन्थॉल, एल–कारवोन, मैंगिफेरिन, मिथाइल चाविकोल, करक्यूमिन, एंड्रोग्राफोलाइड्स, तैयार किए गए हैं।

पादप रसायन अध्ययन

विभिन्न स्थानों में उगने वाले चंदन की लकड़ी के 175 नमूनों और कर्नाटक के विभिन्न स्थानों में उगने वाले लाल चंदन के 300 हार्टवुड कोर नमूनों के लिए स्थिर कार्बन समस्थानिक संघटन ($^{13}C/^{12}C$) निर्धारित किया गया।

औषध एवं भेषज विज्ञान अध्ययन

आयुर्वेदिक औषधि ''दारुहरिद्र'' के विकल्प के रूप में संभावनाओं की खोज हेतु तीन *महोनिया* प्रजातियों का तुलनात्मक भेषज विज्ञान अध्ययन किया जा रहा है.

सेलाजिनेला ब्रायोप्टेरिस के कैंसररोधी प्रभाव का *इन विट्रो* मूल्यांकन हेपजी 2 कोशिका और *इन विवो* पशु प्रणाली का उपयोग करके किया गया और *इन विट्रो* कोशिका लाइनों में आशाजनक परिणाम दिखे।

चार पादप–आधारित मोम उत्पाद (एनबीआर–डब्ल्यूपी1, एनबीआर–डब्ल्यूपी2, एनबीआर–डब्ल्यूपी3 और एनबीआर –डब्ल्यूपी4) विकसित किए गए हैं जिनका उपयोग सहक्रियात्मक हाइड्रोफोबिक बायोडिग्रेडेबल उत्पादों को तैयार करने के लिए खाने योग्य/न्यूट्रास्यूटिकल्स और प्राकृतिक योज्य के रूप में/ के लिए किया जाएगा।

सिनामोमम वेरम व्युत्पन्न जैवसक्रिय–क्रियात्मक गोल्ड नैनोपार्टिकल्स (एनपीएस) ने छोटे पशु मॉडल तंत्र में उच्च वसा वाले आहार (एचएफडी) स्थितियों का उपयोग करके आंत माइक्रोबायोटा को पुनः आकार देने के माध्यम से मोटापा–विरोधी प्रभाव को बढ़ाया।

एक एंटीडैंड्रफ हेयर ऑयल फॉर्मूलेशन विकसित किया गया।

पादप पारिस्थितिकी और पर्यावरण प्रौद्योगिकी

पादप पारिस्थितिकी और जलवायु परिवर्तन विज्ञान

भारत में *साइट्रस* (रुटैसी) की छह प्रजातियों के जलवायु क्षेत्र और संभावित वितरण क्षेत्रों को 130 उपस्थिति रिकॉर्ड और 19 जैव–जलवायु चर का उपयोग करके तैयार किया गया।

ग्वार (*सायमोप्सिस टेट्रागोनोलोबा*) की सहिष्णु और संवेदनशील किस्मों में पत्ती और जड़ के ऊतकों की शारीरिक रचना पर पानी के दबाव के प्रभाव का मूल्यांकन किया गया। ग्वार के पत्तों की सहनशील किस्मों ने सूखा संवेदनशील किस्मों की तुलना में प्रोटोजाइलम, मेटाजाइलम और कॉर्टिकल कोशिकाओं की परत की चौड़ाई में काफी कम कमी का खुलासा किया।

सिमिलिपाल बायोस्फीयर रिजर्व, ओडिशा के तीन अलग–अलग वन प्रकारों में पादप समुदाय संरचना और भूमि के ऊपर के जैव भार का अध्ययन किया गया। कार्बन चक्र की गणना के लिए प्रमुख वृक्ष घटक में कार्बन का भंडारण निर्धारित किया गया। इन वन प्रकारों में अधिकतम जैवभार योगदान करने वाले पेड़ों की पहचान की गई।

फलीदार वृक्ष प्रजाति *ल्यूसेना ल्यूकोसेफला* के पौधों की वृद्धि और राइजोस्फेरिक मृदा के जैव रासायनिक मापदंडों पर उन्नत O_3 (EO_3) के दीर्घकालिक जोखिम के प्रभावों को समझने के लिए अध्ययन किए गए। EO_3 के संपर्क में आने के 12 से 24 महीनों के दौरान तनों की लंबाई, जड़ों, तनों एवं पत्तियों के जैव भार में कमी देखी गयी।

राइजोस्फेरिक मृदा में कुल पोषक तत्व जैसे कार्बन और फास्फोरस 24 महीनों के बाद काफी कम हो गए, और उन्नत O_3 उपचार के लिए सूक्ष्मजैविक जैवभार कार्बन, नाइट्रोजन और फास्फोरस में उल्लेखनीय कमी स्पष्ट थी।

भविष्य के जलवायु परिवर्तन परिदृश्यों, O_3, CO_2 और तापमान के उच्च स्तर के संपर्क में आने वाली संवेदनशील और सहनशील गेहूं की किस्मों में आरओएस सफाई तंत्र की विभेदक प्रतिक्रिया को समझने के लिए अध्ययन किए गए। आरओएस सफाई की क्षमता के आधार पर, गेहूं की किस्म एचडी 2967 को भविष्य के जलवायु परिवर्तन परिदृश्यों के प्रति सहिष्णु पाया गया।

सूक्ष्मजैविक प्रौद्योगिकी

बैक्टीरिया एंडोफाइट *बैसिलस सबटिलिस* से एक कुशल जैव नियंत्रक एजेंट विकसित किया गया है जो

मैक्रोफोमिना फेजोलिना संक्रमण के कारण होने वाले चारकोल रॉट रोग को दबा सकता है और सोयाबीन की शारीरिक विशेषताओं को बढ़ाता है।

एक आशाजनक *बेसिलस सबटिलिस* प्रभेद एनबीआरआई –डब्लू9 (एमटीसीसी–25374) की पहचान की गई है और विभिन्न फसलों जैसे कि ग्लेडियोलस, टमाटर और पान में *फुसैरियम* संक्रमण के एक शक्तिशाली जैव नियंत्रण एजेंट के रूप में मूल्यांकन किया गया है।

अरेबिडोप्सिस थेलियाना के साथ एक अध्ययन से पता चला है कि *पैनीबैसिलस लेंटिमोरबस*, बी–30488 जड़ संरचना को बदल देता है और पादपहोर्मोन और जीन अभिव्यक्ति के मॉड्यूलेशन के माध्यम से विकास को नियंत्रित करता है और सूखा सहनशीलता को बढ़ाता है तथा समग्र रूप से पौधों की वृद्धि में काफी सुधार करता है।

पपाया रिंगस्पॉट वायरस (पीआरएसवी) का शीघ्र पता लगाने के लिए पॉलीक्लोनल एंटीबॉडी (पीएबी) का उपयोग करते हुए लेटरल फ्लो इम्यूनोएसे (एलएफआईए) के सिद्धांत पर एक तेजी से और क्षेत्र में प्रयोग की जाने लायक निरीक्षण किट विकसित की जा रही है।

रिविना ह्यूमिलिस की पत्तियों से तैयार जैविक रूप से संश्लेषित चांदी के नैनोकणों की वायरस प्रबंधन के लिए जांच की जा रही है।

पर्यावरण प्रौद्योगिकी

दो सहिष्णु घास प्रजातियों जैसे वेटिवर (*क्राइसोपोगोन जिजानियोइड्स*) और लेमनग्रास (*सिंबोपोगोन सिट्रेटस*) में सिमुलेटेड बैटरी इलेक्ट्रोलाइट अपशिष्ट (ईडब्ल्यू) दूषित मिट्टी पर उगाए गए पौधों में निकिल और कैडमियम के संचय पर एक तुलनात्मक अध्ययन किया गया। उन्होंने खुराक पर निर्भर तरीके से जड़ों में काफी उच्च स्तर के साथ निकिल और कैडमियम दोनों के संचय का प्रदर्शन किया।

एक स्टील प्लांट के साइनाइड–दूषित ब्लास्ट फर्नेस एफ्लुएंट और सक्रिय कीचड़ से पृथक जीवाणु और कवक प्रभेद का उपयोग करके साइनाइड के जैवउपचार के लिए सूक्ष्मजैविक प्रभेद के अनुप्रयोग की क्षमता का मूल्यांकन किया जा रहा है।

आर्सेनिक दूषित भूजल में उगाई जाने वाली सब्जियां मानव भोजन के माध्यम से दैनिक आर्सेनिक ग्रहण की मात्रा को कई गुना बढ़ा सकती हैं। मानव खाद्य श्रृंखला में आर्सेनिक के प्रवेश के विभिन्न पहलुओं पर अध्ययन किए गए। अत्यधिक आर्सेनिक प्रभावित जिलों से सब्जियों के संग्रह के लिए पश्चिम बंगाल, बिहार और उत्तर प्रदेश राज्यों का चयन किया गया। इन सब्जियों के आर्सेनिक डेटा विश्लेषण से पता चला है कि पत्तेदार सब्जियों में आर्सेनिक का संचय अधिक रहा है, इसके बाद कंद/जड़ और फल सब्जियों का स्थान है। उत्तर प्रदेश के बलिया जिले के बेलहारी प्रखंड के चौन छपरा में पालक में आर्सेनिक का स्तर सबसे अधिक था, जो विश्व स्वास्थ्य संगठन और एफएओ द्वारा निर्धारित अनुमेय सीमा से लगभग दो गुना अधिक है।

आणुविक जैविकी एवं जैव प्रौद्योगिकी

कीट प्रतिरोधी कपास एवं रेशों का विकास

सफेद मक्खी के खिलाफ पीएयू लुधियाना, सिरसा, हरियाणा के विभिन्न फील्ड स्टेशनों पर *टीएमए12* जीएम कपास का और सीआईएसएच, लखनऊ और आईआईवीआर, वाराणसी में सफेद मक्खी संचालित विषाणु रोगों से टमाटर और पपीते की सुरक्षा के लिए गार्ड कपास के रूप में एमएससी14 जीएम का प्रदर्शन मूल्यांकन परीक्षण किया जा रहा है।

T_2 पीढ़ी में Pnu08 GM कपास (n=2) की स्थिर लाइनें स्थापित की गईं, जो सफेद मक्खी और हेलिकोवर्पा आर्मिजेरा से बचाव के लिए At_4 प्रमोटर के नियमन के तहत कीटनाशक प्रोटीन को व्यक्त करती हैं। आरटी–पीसीआर के माध्यम से ट्रांसजीन अभिव्यक्ति का विश्लेषण किया गया। दो लक्षित पीड़कों के साथ जैव परीक्षण का कार्य प्रगति पर है।

T_1 पीढ़ी में PCD प्रमोटर के नियमन के तहत कीटनाशक प्रोटीन को व्यक्त करने वाली Dhi31 GM कपास लाइनों पर अनुसंधान को उन्नत किया गया। कपास के एफिड्स

और सफेद मक्खी के खिलाफ कीट जैव परीक्षण का कार्य प्रगति पर है। एक सामान्य फेनोटाइप (फूल और बीज सेटिंग) के साथ जीएम कपास लाइन का परीक्षण मॉस कीटनाशक जीन Dhi31 के साथ किया गया है, जिसमें आशाजनक परिणाम मिले हैं।

हमने जीनोम के 400–गुना कवरेज के साथ सुसंगत मैपिंग तकनीकों का उपयोग करके लगभग 380 कपास RNA-seq डेटा बिंदुओं को रीमैप किया है। हमने रेशा कोशिका प्रतिबद्धता, शुरुआत, बढ़ाव, और द्वितीयक कोशिका भित्ति उत्पादन के चरण–विशिष्ट पहलुओं के साथ–साथ रेशों के विकास के अद्वितीय नियंत्रण के लिए संभावित सीआईएस–नियामक तत्वों का खुलासा किया। नतीजतन, हमारी डेटा–खनन जांच कपास के रेशों के विकास और वृद्धि से जुड़े कई आवश्यक कारकों को उजागर करती है, जिन्हें ''कॉटन एक्सप्रेस–ओमिक्स'' डेटाबेस में संकलित किया गया है।

फलों का पकने में विलंबन एवं विगलन

टमाटर से ABA प्रतिक्रिया को बदल देने वाले SlERF6 जीन को फल विशिष्ट 2A11 प्रमोटर के तहत व्यक्त किया गया। विकसित ट्रांसजेनिक लाइनों ने बिना किसी हानिकारक प्रभाव के सामान्य कायिक विकास दिखाया। नियंत्रण की तुलना में फलों के पकने में लगभग 6 दिनों की देरी से यह संकेत दिया गया कि टमाटर में फलों के पकने में विलंबन के लिए SlERF6 का उपयोग किया जा सकता है।

आम में सुगंध के आणविक तंत्र को समझने के लिए, इलुमिना अनुक्रमण द्वारा *डे नोवो ट्रांस्क्रिप्टोम असेंबली* और *मैन्गीफेरा इंडिका* (दशहरी) का विश्लेषण किया गया। सुगंध जैव–संश्लेषण में शामिल संभावित जीन टेरपेनॉइड, कैरोटेनॉइड, फ्लेवोनोइड, लैक्टोन, लिपोक्सीजेनेस, एरोमैटिक अमीनो अम्ल, अल्कलॉइड, फेनिलप्रोपेनाइड पाथवे के थे। टेरपेनॉइड पाथवे में और अधिक जानकारी प्राप्त करने के लिए, दशहरी आम में इन जीनों का अध्ययन विभिन्न ऊतकों और विकासात्मक चरणों में किया गया। प्राप्त परिणाम मेवलोनेट (एमवीए) और मिथाइलएरिथ्रिटोल फॉस्फेट (एमईपी) पाथवे जीन की एक अंतर अभिव्यक्ति का सुझाव देते हैं। यह अध्ययन आम के फल में सुगंध के पाथवे को समझने के लिए एक कदम है।

फल पकने के प्रति क्रियाशील जीन के विकास की पहचान करने के लिए मूसा प्रजाति का पैन जीनोम विश्लेषण किया गया। पकने से संबंधित ईआरएस जीन का विस्तार से विश्लेषण किया गया और विभिन्न मूसा प्रजातियों में पकने के संबंध में महत्वपूर्ण अंतरों की पहचान की गई।

सुगंधित गुलाब में विलगन के आण्विक आधार को समझने के लिए *इनफ्लोरेसेंस डिफिसिएंट इन एब्सिसन* (इडा) परिवार के चार सदस्यों की पहचान की गई। गुलाब में इडा के तीन सदस्यों अर्थात् RbIDL1, RbIDL2 और RbIDL4 को क्रम और अभिव्यक्ति में संरक्षित किया गया, और एथिलीन–प्रेरित दल विलगन के साथ–साथ प्राकृतिक विलगन के दौरान दल विलगन क्षेत्र (AZ) में 3–4 गुना बढ़ गया।

अजैविक और जैविक तनाव में शामिल जीनों का अभिलक्षणन

काबुली चने में शीघ्र घाव–प्रतिक्रियाओं के संकेतों को समझने के लिए, कम से कम 14 WRKY जीनों की पहचान की गई, जिन्होंने घाव के 5–20 मिनट के भीतर अभिव्यक्ति में 5–50 गुना वृद्धि दिखाई।

हमारे अध्ययन के आधार पर हमने प्रस्तावित किया कि टाऊ वर्ग ग्लूटाथियोन–एस–ट्रांसफरेज (OsGSTU5) VirE2 प्रोटीन के साथ परस्पर क्रिया करता है और चावल में *एग्रोबैक्टीरियम*–मध्यस्थ जीन स्थानांतरण की दक्षता को नियंत्रित करता है।

छोटे आरएनए जैसे माइक्रोआरएनए (एमआईआरएनए) और छोटे इन्टरफेरिंग (सी) आरएनए छोटे, 20–24 न्यूक्लियोटाइड के गैर–कोडिंग आरएनए हैं। वे पौधों और अन्य जीवों में जीन अभिव्यक्ति के प्रमुख नियामक हैं। कई 22–न्यूक्लियोटाइड लंबे miRNAs विभिन्न विकासात्मक और तनाव प्रतिक्रियाओं में शामिल ट्रांस–एक्टिंग सेकेंडरी स्मॉल इंटरफेरिंग आरएनए के कैस्केड के जैवसंश्लेषण को उद्दीपित करते हैं।

यह समझ में आया कि हिमालयन *अरेबिडोप्सिस थेलियाना* में miR158 लोकस में प्राकृतिक उत्परिवर्तन होने से पेंटाट्रिकोपेप्टाइड (पीपीआर) जैसे लोकस में मजबूत कैस्केड साइलेंसिंग प्रदर्शित होती है। ये कैस्केड sR-NAs वाष्पोत्सर्जन और रंध्र के खुलने में शामिल जीन के टर्शियरी साइलेंसिंग को उद्दीपित करते हैं। यह जोज अनुकूलन में sRNA नेटवर्क का एक नया मॉड्यूल है।

संगणकीय जैविकी के क्षेत्र में सूखे, नमक, भारी धातुओं और रोगजनक हमले के जवाब में पौधों की तनाव सहनशीलता का अध्ययन किया गया। लवण और सूखे से प्रभावित कपास का ट्रांसक्रिप्टोम मेटा–विश्लेषण किया गया। विश्लेषण से पता चला कि सूखे और लवण तनाव की स्थिति के प्रमुख नियामक हब जीन का लवण और नमक तनाव–प्रतिक्रियाशील (डीएसएसआर) कार्यात्मक जीन के साथ उल्लेखनीय संबंध हैं। सूखे और लवण तनाव डेटा में 5,962 और 3,510 विभेदित रूप से व्यक्त जीन (डीईजी) की पहचान की गई। सूखे में कुल 3,132 और 2,830 अप और डाउन रेगुलेटेड जीन और लवण तनाव डेटा में 2,265 और 1,245 अप और डाउन रेगुलेटेड जीन देखे गए।

पादप आनुवंशिक संसाधन एवं विकास

नयी पादप किस्मों का विकास

गुलदाउदी *क्राईसेंथेमम मोरीफोलियम* की एक नई उत्परिवर्ती पुष्प किस्म विकसित की गयी, जिसका नाम 'एनबीआरआई–स्वाधीन 75' है, जो एक 'सजावटी' प्रकार की, देर से खिलने वाली किस्म है। भारत की स्वतंत्रता के प्लैटिनम जुबली उत्सव वर्ष के दौरान 'आजादी का अमृत महोत्सव' को चिह्नित करने के लिए इस किस्म का नाम रखा गया था और इसे 30 जनवरी, 2022 को माननीय सीएसआईआर महानिदेशक डॉ शेखर सी मांडे द्वारा जारी किया गया।

पोम्पोन–प्रकार के फूलों वाली वांछित नवीन कट–स्प्रे किस्म और 'नो–पिंच–नो–स्टेक' विशेषता के साथ एक बौनी किस्म के लिए क्रमशः 'केल्विन विक्ट्री' और 'हेमंत सिंगार' किस्मों के उत्परिवर्तन के माध्यम से नई उत्परिवर्ती रेखाओं को प्रेरित किया गया है।

ग्लेडियोलस में संकरण किया जा रहा है। ये संकरण बेहतर सजावटी विशेषताओं के साथ कई नई संकर किस्में पैदा कर सकते हैं जिनमें तत्काल बाजार क्षमता उपलब्ध होगी।

इस अवधि के दौरान गामा विकिरण और रासायनिक उत्परिवर्तनों के माध्यम से संकरण और उत्परिवर्तन प्रजनन की तकनीकों का उपयोग करते हुए केना, कुमुदनी और कमल जैसे फूलों की खेती और सजावटी पौधों के विभिन्न विकास किए गए।

किस्मों के विकास के लिए फसली पौधों की आनुवंशिकी और जीनोमिक्स संसाधन

अलसी की जीनोम असेंबली को हाई–सी (नेक्स्ट जेन सीक्वेंसिंग विद क्रोमोसोम कन्फर्मेशन कैप्चर) डेटा के साथ सुधार किया गया। अलसी की दो आरआईएल (रीकोम्बिनेंट इनब्रेड लाइन) मैपिंग लाइनों के फेनोटिपिक लक्षणों का वर्णन 10 महत्वपूर्ण कृषि संबंधी लक्षणों के लिए किया गया है। इनमें तेल मात्रा और पुष्पन/परिपक्वता के लिए आरआईएल आबादियां शामिल हैं।

त्वरित आनुवंशिक सुधार के लिए *ऐमारैंथ* आनुवंशिक संसाधनों का दोहन किया गया है। एसएनपी आधारित एसोसिएशन मैपिंग के लिए ऐमारैंथ के 300 परिग्रहणों के एक उपसमुच्चय को ''कोर एक्सेस'' के रूप में पहचाना गया।

लिंकेज/क्यूटीएल मैपिंग के लिए *एम्ब्रेंथ* में दो आरआईएल की ~300 लाइनों में अनुक्रमण (जीबीएस) द्वारा जीनोटाइपिंग की गयी।

केले की उत्पत्ति और शारीरिक अनुकूलन को समझने के लिए, जंगली और खेती योग्य मूसा जीनोम की संरचना को फ्लो–साइटोमेट्री का उपयोग करके चित्रित किया जा रहा है।

क्वेरकोइडी में वंशानुक्रम को हल करने के लिए क्लोरोप्लास्ट जीनोम का अनुक्रमण और संयोजन किया जा रहा है।

कीमोटाइप आधारित पारंपरिक और आणविक प्रजनन के माध्यम से भारतीय भांग में सुधार की दिशा में पहल की गई है।

पोस्त में ओरिपेविन के लिए जीनोम वाइड एसोसिएशन स्टडी (जीडब्ल्यूएएस) की गई। सभी एसएनपी मार्करों का उपयोग करते हुए ओपियोड के औसत मूल्यों के आधार पर मार्कर ट्रेट एसोशिएशन (एमटीए) का मूल्यांकन किया गया।

वनस्पति उद्यान एवं कृषि प्रौद्योगिकी

वानस्पतिक उद्यान

भारतीय साइकस और कुमुदनी–कमल के लिए एक संरक्षण केंद्र बनाया गया है। यह सुविधा राष्ट्रीय संदर्भ केंद्र के रूप में भी काम करेगी।

आगे के *एक्स–सीटू* अध्ययनों के लिए सीएसआईआर – एनबीआरआई वानस्पतिक उद्यान में साइकैड गृह और भारतीय साइकस उद्यान में कई पौधे एकत्र किए गए और लगाए गए।

जम्मू और कश्मीर से दो नई प्रजातियों, *पायरोसिया सरथेलेंसिस* (पॉलीपोडिएसी) और *स्वर्टिया पटनीटॉप–पिएनसिस* (जेंशियानेसी) का वर्णन किया गया।

आइरिस प्रजाति, होया प्रजाति, *बारलेरिया* प्रजाति, *बेगोनिया* प्रजाति, *इम्पेशेंस* प्रजाति सहित जंगली सजावटी पौधों को सफलतापूर्वक घरेलु स्थितियों में उगाया गया। इन्हें वानस्पतिक उद्यान में स्थापित किया जा रहा है।

वनस्पति उद्यान को *एक्स–सीटू* संरक्षण के लिए भारत के विभिन्न हिस्सों से कटिंग, पौधे, जीवित पौधे और बीज के रूप में एकत्र की गई कई पौधों की प्रजातियों के साथ समृद्ध किया गया।

संग्रह में *विक्टोरिया अमेजोनिका*, मणिपुर के दुर्लभ 108 पंखुड़ी वाले कमल सहित कमल की 38 किस्म., निम्फिया की 15 प्रजातियां/किस्में, केना की 17 किस्में, होया की 8 किस्में, रिंकोस्टाइलिस की 5 किस्में, टोलुमनिया की 5 किस्में, *डेंड्रोबियम, डिस्किडिया पेक्टिनोइड्स, ऑक्सीस्टेल्मा सेकुलेंटम, लुडविगिया एडसेनडेंस, अल्ट्रिकुलेरिया ऑरिया, मार्सिलिया माइन्यूटा, नुफर लुटिया, हाइड्रोक्लेज निम्फोइड्स* की 50 किस्में, गुलाब की 2 किस्में, हेलिकोनिया की 5 किस्में, कॉस्टस इंसिग्निस और कई अन्य सजावटी और संकट ग्रस्त पौधे शामिल हैं।

NBRI द्वारा विकसित फूलों की फसलों और किस्मों को बढ़ावा देने के लिए देश के कई राज्यों में स्कूलों और कॉलेजों में पुष्पकृषि उद्यानों की स्थापना की गयी।

पादप संरक्षण एवं कृषि प्रौद्योगिकी

कालमेघ (*एंड्रोग्राफिस पैनिकुलेटा*) की कृषि प्रथाओं के मानकीकरण के लिए प्रेसमड की विभिन्न खुराक के साथ क्षेत्र प्रयोग किया गया।

नमक प्रभावित मिट्टी में खेती के लिए संभावित *एलो* प्रजातियों की पहचान करने के लिए *एलो* की पच्चीस प्रजातियों और परिग्रहणों का मूल्यांकन किया गया।

बंथरा में बांस उद्यान में भारत के विभिन्न क्षेत्रों/भागों से बांस की बारह और प्रजातियों को जोड़ा गया, जिससे यह 67 प्रजातियों का संरक्षण भूखंड बन गया है।

ऐमारैंथ जनन द्रव्य भंडार को 1223 परिग्रहणों से समृद्ध किया गया था, जिनका विभिन्न कृषि और गुणवत्ता लक्षणों के लिए मूल्यांकन किया जा रहा है।

व्यावसायिक खेती और जड़ों के आवश्यक तेल के निष्कर्षण के लिए नागरमोथा (*साइपरस स्केरियोसस*) के 52 परिग्रहणों का संग्रह, संरक्षण और मूल्यांकन सोडिक बंजर भूमि की स्थिति के तहत किया गया।

चार हिमालयी राज्यों से *जुनिपेरस* के कुल 139 नमूने एकत्र किए गए। पश्चिमी हिमालय से चार आबादियों से आवश्यक तेल का निष्कर्षण और लक्षण वर्णन किया गया है।

जनसंपर्क / कौशल विकास

UNIDO नीम परियोजना के तहत औषधीय और सुगंधित पौधों के साथ विभिन्न कृषि वानिकी मॉडल विकसित किए गए। चार अलग–अलग नीम की किस्मों के तुलनात्मक अनुकूलन का मूल्यांकन करने के लिए पांच अलग–अलग कृषि जलवायु क्षेत्रों में बहु–स्थानिक परीक्षण लगाए गए।

सीएसआईआर–अरोमा मिशन के तहत हल्दी किस्म 'केसरी' के 253 क्विंटल प्रकंद नौ राज्यों में 59 किसानों के बीच वितरित किए गए हैं, जो 387 हेक्टेयर क्षेत्र को कवर करते हुए बीज किसानों के रूप में कार्य करते हैं।

हल्दी की खेती को लोकप्रिय बनाने के लिए अलग–अलग स्थानों पर कुल 22 जागरूकता सह प्रशिक्षण कार्यक्रम आयोजित किए गए, जिसमें जीर्णायु पत्तों से आवश्यक तेल निकालने के लिए 863 किसानों को प्रशिक्षण दिया गया।

परियोजनाएं, प्रकाशन और पेटेंट

संस्थान ने कई जनसंपर्क, प्रशिक्षण और कौशल विकास कार्यक्रमों के माध्यम से विभिन्न अंतिम उपयोगकर्ताओं को सेवाएं प्रदान करना जारी रखाय 24 समझौता ज्ञापनों, एमटीए आदि पर हस्ताक्षर किए। इस अवधि के दौरान संस्थान ने 17 सरकारी सहायता प्राप्त परियोजनाओं (जीएपी) और 03 मेगा लैब परियोजनाओं (एमएलपी) सहित 20 नई परियोजनाओं की शुरुआत की। 618.55 के संचयी प्रभाव कारक के साथ SCI पत्रिकाओं में 178 शोध पत्र प्रकाशित किए (IF 3.47 प्रति पेपर)। तीन पेटेंट भारत में दायर किए गए, जबकि 04 पेटेंट (एक भारत में और तीन विदेश में) प्रदान किये गए, और 23 छात्रों को वैज्ञानिक और अभिनव अनुसंधान अकादमी (एसीएसआईआर) और भारत के अन्य विश्वविद्यालयों द्वारा पीएचडी से सम्मानित किया गया।

EXECUTIVE SUMMARY

CSIR-NBRI is known for its excellence in basic science research on plant diversity of India and their systematic documentation, conservation and sustainable utilization through traditional and advanced biotechnological approaches.

The institute has core competencies in the areas of plant diversity assessment, systematics, conservation, genomics, plant improvement through conventional and molecular breeding, and genetic engineering, transgenic plant development for abiotic and biotic stresses, climate change studies, pollution remediation through plants and microbes, plant-microbe interactions, floriculture, horticulture, agrotechnology, development of new varieties of economic importance, pharmacognosy, phytochemistry, pharmacology, bioprospection and development of nutraceuticals, cosmeceuticals and health care products, and societal development activities through outreach programmes.

The year 2021-22 witnessed several significant achievements in the scientific, technological and outreach activities of CSIR-NBRI, a summary of which is given below:

PLANT DIVERSITY, SYSTEMATICS AND HERBARIUM

Various groups of the Plant Diversity Division conducted several floristic surveys in unexplored areas of different states of India like, Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Maharashtra, Madhya Pradesh, Rajasthan, Gujarat, Tamil Nadu, the North-Eastern states, and also Chambal ravines and the Western Ghats.

New species discovery and new distribution records to India

Eugenia pokkudanii A.M. Maya & al., and *Tripogon sugathakumariae* Jabeena & al., were described from the Nelliyampathy hill ranges in Palakkad Districts of southern Western Ghats. *Geranium indicum* was reported from Kasauli and Daghshai (Himachal Pradesh), Bageshwar, Purola and Mussoorie (Uttarakhand). While, *Geranium ocellaum* var. *albiflorum* Imtiyaz Hurrah & Vijay Wagh, was recorded during floristic field surveys in Tehri district of Uttarakhand. *Calamagrostis nandadeviensis* P. Agnihotri & D. Prasad and *Bromus husainii* P. Agnihotri & R. Yadav were the new species discovered from Nanda Devi Biosphere Reserve, Valley of Flowers National Park, Chamoli, Uttarakhand. *Trisetopsis pirpanjalensis* D. Prasad & P. Agnihotri- a new grass species was described from the Western Himalaya (Himachal Pradesh, Kullu, Manali), while *Tzveleviochloa yadavii* D. Prasad & P. Agnihotri- a new species was discovered from Kullu, Manali in Himachal Pradesh. *Rottboellia husainii*- A new species of (Poaceae), was described from Rakh Jargoh village in Ramban district of Jammu and Kashmir, India. A new species of lichen- *Rinodina indica* was also recorded.

Plant diversity exploration and documentation

More than 200 specimens' of genus *Rhynchosia* (Leguminosae), about 1650 angiosperm specimens belonging to 176 genera, 72 families and 258 species were collected from Chambal ravines of Madhya Pradesh (Sheopur, Morena and Bhind districts) and Uttar Pradesh (Etawah and Agra districts). Three new sacred groves Shila Shivay, Karai mata and Lahan bhisa Hanuman were discovered from Yavatmal district of Maharashtra. Field visits to the states of Himachal Pradesh, Uttarakhand, & Sikkim resulted in the collection of 11 species of *Anemone.*

As part of phylogeographic studies, 114 *Ensete glaucum* and 167 *E. superbum* samples were collected and documented from the northeast and peninsular India.

A checklist for an updated account on the family Balsaminaceae in India has been prepared. A total of 326 taxa, comprising 302 species plus 24 subspecies/ varieties, belonging to 2 genera were recorded from the country.

A baseline data on diverse group of plants *viz*. algae (160 species); lichens (11 species), bryophytes (44 species), pteridophytes (17 species), gymnosperm (01 species) and angiosperms (341 species) of the Chambal ravines was prepared during the reporting period. A total of 1825 specimens of flowering and 337 specimens of non-flowering plants were collected in three subsequent plant survey-cum-collection tours in different areas of the Chambal ravines of Uttar Pradesh and Madhya Pradesh.

The revisionary study on lichen genus *Buellia* was continued. A total of 94 specimens were studied in detail, resulting in the identification of 17 species including four new distributional records for India.

In continuation of revision and phylogenetic studies of Arthoniales of India an e-monograph was developed which can be accessed through www.arthoniales.in. For the collection of Arthonialean lichens, two tours were conducted to Jammu & Kashmir and Himachal Pradesh.

The studies on endolichen fungi occurring within lichen genus *Parmotrema* were continued. A total of 100 isolates of endolichenic fungi were identified from the 450 originally obtained isolates.

In continuation of the revision of lichen genus *Rinodina* a total of 180 specimens were studied in detail that yielded 11 species including *R. lepida* (Nyl.) Müll. Arg. - a new distributional record for India.

A bryophyte genus, *Phymatoceros* Stotler & al. has been recorded for the first time from Indian region (Uttarakhand: Binsar, Mussoorie). *Plagiomnium japonicum* (Lindb.) T.J. Kop. has been recorded for the first time from Indian region (Uttarakhand: from Osla to Taluka, Uttarkashi).

A study on the quantitative estimation of diversity in the selected 32 grids at bryophyte rich localities of Assam lying-in North-East region was carried out.

During the assessment of moss diversity in various localities of Manipur (North-east India), 126 species of mosses belonging to 84 genera in 34 families have been investigated and enumerated.

A total of 519 Pteridophyte specimens of 58 taxa including two varieties belonging to 34 genera under 18 families have been collected from different localities of Niyamgiri Hills, Odisha. Live plant of *Pityrogramma calomenalos* (L.) link collected from Niyamgiri Hill, was introduced in the garden of the Institute.

In-vitro cultures and mass propagation of ornamental taxa *Nephrolepis auriculata* (L.) Trimen was established.

A database named "Plant Resources of Chambal Ravines (PRCR) – A Digital Flora of Chambal Ravines" has been developed.

A study on distribution pattern of *Cyathea spinulosa* and *C. gigantea* was made. Spores of *Cyathea spinulosa* and *C. gigantea* were collected for *in-vitro* studies. Quantification of the population structure of these two species was done along with measurement of the morphological characters. *In-vitro* studies on spore viability, germination percentage and gametophyte developmental pattern of *C. gigantea, C. spinulosa* and *C. khasyana* were made.

Molecular Systematics Studies

To further understand the genetic and genomic background of *B. ciliata*, de novo RNA sequencing was carried out.

A total of 11 natural populations of *Gymnema sylvestre* was investigated with 25 markers (DAMD & ISSR) revealing significantly high level of polymorphism at species level while, low level of polymorphism at population level. Out of 100 threatened plant species, 32 species have been collected.

A total of 169 voucher specimens of all six species of genus *Juniperus* L. were prepared for molecular and systematics studies.

Phylogeographic studies on *Ensete glaucum* and *E. superbum* were continued with the objectives to estimate genetic diversity and phylogeographic structure, determine the divergence time of *Ensete* populations in India.

Phylogeographic study in *Citrus medica* was continued with an expanded analysis of two chloroplast markers, trn L-F (trnL intron and trnL-F spacer) and rps16 intron in 129 individuals sampled from 16 populations in northeast India.

Conservation of Threatened Plants

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 herbarium specimen data of threatened plant species housed at different herbaria in the country and overseas are being documented. Different Indian herbaria such as BSD, LWG, CDRI, DD, MH, IFGTB, CALI, CMPR, TBGT, RHT, CAL, and KFRI were consulted, and 2280 voucher specimens for the proposed threatened plant species housed in these herbaria were studied.

A CSIR-NBRI online database has been created for enlisting the plant species that are threatened in India. The current database includes species from all groups of plant taxa and provides their IUCN conservation status.

Twenty four threatened and 32 endemic species collected from Uttar Pradesh, Madhya Pradesh, Kerala and Tamil Nadu parts of Western Ghats were brought for ex-situ conservation in NBRI Botanical Garden.

About 67 species of ferns belonging to different categories of conservation status have been maintained and conserved in the fern house. Live plants of *Cyathea gigantea, Sphenomeris chinensis, Asplenium cheilosorum* and *Paraleptochillus decurrens* were also brought to enrich the fern house.

As a part of study on conservation, *in vitro* propagation of rare plant *Athalamia pinguis* Falc. was established.

The plantlets of *Asplenium nidus, Diplazium esculentum, Christella dentata*, *Dryopteris cochleata,* and *Pteris biaurita* were produced through *in-vitro* spore culture. *Christella dentata* has been introduced which is new to the fern house of CSIR-NBRI.

Bioprospecting Studies

The bioprospecting studies on Himalayan lichens were continued. The methanol, chloroform and acetone extract of lichens *Ramalina conduplicans* Vain. and *Usnea longissima* Ach. exhibited high antimicrobial activities against *Acinetobacter baumannii, Pseudomonas aeruginosa* and *Klebsiella pneumoniae*. The lichen extracts also gave interesting results for anticancer activity against the breast cancer cell lines (MCF-7 and MDA-MD- 231).

PHARMACOGNOSY, PHYTOCHEMISTRY AND PRODUCT DEVELOPMENT

Development of Certified Reference Materials

A total of nine Certified Reference Materials ((+) Limonene, Eugenol, Geraniol, (-) Menthol, L-Carvone, Mangiferin) (Methyl Chavicol, Curcumin, Andrographolides) have been prepared as per requirements of ISO-17034-2016.

Phytochemical Studies

The stable carbon isotope composition ($^{13}C/^{12}C$) was determined for 175 samples of Sandal wood growing in different locations, and of 300 heartwood core samples of Red sanders growing in different locations of Karnataka.

Pharmacognostical and pharmacological studies

The anticancer effect of *Selaginella bryopteris* was evaluated *in vitro* using HepG2 cell and *in vivo* animal system and showed promising results in *in vitro* cell lines.

Developed four plant-based wax products (NBR-WP1, NBR-WP2, NBR-WP3 and NBR-WP4) to be used as/for edibles/ nutraceuticals and natural additive to formulate synergistic hydrophobic biodegradable products.

Cinnamomum verum derived bioactive-functionalized gold nanoparticles (Au@P-NPs) enhanced anti-obesity effects through gut microbiota reshaping using in high-fat diet (HFD) conditions in small animal model system.

A antidandruff hair oil formulation was developed.

PLANT ECOLOGY AND ENVIRONMENTAL TECHNOLOGY

Plant Ecology & Climate Change Science

The group working on Plant Ecology and Climate Change Science, evaluated the anatomy of leaf and root tissue in drought tolerant and sensitive varieties of guar, *Cyamopsis tetragonoloba* (L.) Taub. The tolerant varieties of guar leaves revealed a significantly less reduction in the width of protoxylem, metaxylem, and the layer of cortical cell as compared to drought sensitive varieties.

Plant community composition and the aboveground biomass were studied in three different forest types of Similipal Biosphere Reserve, Odisha. Storage of the carbon in the dominant tree component was determined to compute the carbon cycle. Trees contributing maximum biomass in these forest types were identified.

Studies were undertaken to understand the effects of long-term exposure of elevated O_3 (EO_3) on plant growth and biochemical parameters of rhizospheric soil of leguminous tree species *Leucaena leucocephala. L.* A reduction in shoot length; root, shoot and leaf biomass during 12 to 24 months of exposure to EO_3. Total nutrients viz., carbon and phosphorus in the rhizospheric soil significantly reduced after 24 months, and a significant decrease was apparent in

microbial biomass carbon, nitrogen and phosphorus to elevated O_3 treatment.

Studies were undertaken to understand the differential response of ROS scavenging mechanism in sensitive and tolerant wheat cultivars exposed to future climate change scenarios, of high levels of O_3, CO_2, and temperature. Based on ROS scavenging potential, the wheat cultivar HD 2967 was found to be tolerant to future climate change scenarios.

Microbial Technology

An efficient biocontrol agent has been developed from bacterial endophyte, *Bacillus subtilis* that can suppress the charcoal rot disease caused by *Macrophomina phaseolina* infection and enhances the various antioxidant responsive enzymes.

A promising *Bacillus subtilis* strain NBRI-W9 (MTCC-25374) has been identified and evaluated as a potent biocontrol agent of Fusarium infection in different plants such as gladiolus, tomato and betelvine.

A study on *Arabidopsis thaliana* showed that *Paenibacillus lentimorbus*, B-30488 alters root architecture and regulates growth via modulation of phytohormones and gene expression and enhances drought tolerance and significantly improves overall plant growth.

A rapid and field deployable diagnostic kit, for early detection of *Papaya ringspot virus* (PRSV) is being developed on the principle of lateral flow immunoassay (LFIA) using polyclonal antibody (PAb).

Biologically synthesized silver nanoparticles prepared with the leaves of *Rivina humilis* is being investigated for virus management.

Environmental Technology

A comparative study was made on the accumulation of Ni and Cd grown on simulated battery electrolyte waste (EW) contaminated soil, in two tolerant grass species namely Vetiver (*Chrysopogon zizanioides*) and lemongrass (*Cymbopogon citratus)*. They exhibited accumulation of both Ni and Cd in a dose-dependent manner with significantly higher level in the roots.

The potential of application of novel microbial strains for bioremediation of cyanide is being evaluated using bacterial and fungal strains isolated from cyanide-contaminated blast furnace effluent and activated sludge of a steel plant.

Vegetables grown in arsenic contaminated groundwater can add many fold daily arsenic intake through human food. Studies were made on various aspects of arsenic entry into human food chain. The states of WB, Bihar and UP were selected for the collection of vegetables from highly arsenic affected districts. Arsenic data analysis of these vegetables showed that the accumulation of arsenic has been high in leafy vegetables followed by tubers/roots and fruity vegetables. The level of arsenic was highest in spinach in Chain Chhapra, block Belhari of Ballia district, U.P., which is about two fold higher than the permissible limit set by WHO and FAO.

MOLECULAR BIOLOGY AND BIOTECHNOLOGY

Insect Resistant Cotton and Fibre Development

Performance evaluation trials are being conducted for Tma12 GM cotton at different field stations of PAU Ludhiana, at Sirsa, Haryana against whitefly and of Msc14 GM as guard cotton for protection of tomato and papaya against whitefly vectored viral diseases at CISH, Lucknow, and IIVR, Varanasi. Established stable lines of Pnu08 GM cotton (n=2) in T2 generation that express insecticidal proteins under the regulation of promoter *At4* for defense against whitefly and *Helicoverpa armigera*; analysis of the transgene expression through RT-PCR; bioassay with the two target pests is under progress.

Advanced the research on Dhi31 GM cotton lines that express insecticidal protein under the regulation of PCD promoter in T1 generation; insect bioassay against the cotton aphids and whitefly is under progress. GM cotton line with a normal phenotype (flowering and seed setting) has been tested with the moss insecticidal gene *Dhi31* with promising results.

Approximately 380 cotton RNAseq data has been remapped using consistent mapping techniques with 400-fold coverage of the genome. Stage-specific aspects of fiber cell commitment, initiation, elongation, and Secondary Cell Wall (SCW) production were revealed, as well as probable cis-regulatory elements for the unique control of fiber development. As a result, the data-mining investigation uncovers numerous essential factors connected to cotton fibre development and enhancement, which are compiled in the "Cotton Express-omics" database.

Delayed Fruit Ripening & Flower Abscission

The *SlERF6* gene from tomato that alters ABA responses gene was expressed under the fruit specific 2A11 promoter. The transgenic lines developed, showed normal vegetative growth without any deleterious effects. Fruit ripening was delayed by about 6 days compared to control suggesting that *SlERF6* could be used for delayed ripening in tomato.

In order to understand the molecular mechanism of aroma in mango, *de novo* transcriptome assembly and analysis of *M. indica (Dashehari)* was performed by Illumina sequencing. Potential genes involved in aroma biosynthesis were of terpenoid, carotenoid, flavonoid, lactone, lipoxygenase, aromatic amino acid, alkaloid and phenylpropanoid pathways. To gain further insight into the terpenoid pathway, these genes were studied in different tissues and developmental stages in *Dashehari* mango. Results suggest a differential expression of Mevalonate (MVA) and Methylerythritol phosphate (MEP) pathway genes. This study is stepping stone to understand aroma pathways in mango fruit.

The pan genome analysis of *Musa* sp. was carried out to identify the evolution of the ripening responsive genes. The ripening related ERS gene was analyzed in detail and significant differences in relation to ripening were identified in different Musa species.

To understand the molecular basis of abscission in the fragrant rose, four members of the *INFLORESCENCE DEFICIENT IN ABSCISSION* (*ida*) family were identified. Three members of *ida* in rose were conserved in sequence and expression, namely *RbIDL1*, *RbIDL2* and *RbIDL4* and increased 3-4 fold in petal abscission zones (AZ) during ethylene-induced petal abscission as well as natural abscission.

Characterisation of Genes involved in Abiotic and Biotic Stress

To understand the signals of early wound-responses in chickpea, at least 14 WRKY genes that showed 5-50 fold increase in expression within 5-20 minutes of wounding were identified.

A tau class GST, OsGSTU5, interacts with VirE2 and modulates the *Agrobacterium*-mediated transformation in rice. It is proposed that the tau class glutathione-S-transferase (OsGSTU5) interacts with VirE2 protein and modulates the efficiency of *Agrobacterium*-mediated gene transfer in rice.

Small RNAs such as microRNAs (miRNAs) and small interfering (si) RNAs are short 20-24-nucleotide non-coding RNAs. They are key regulators of gene expression in plants and other organisms. Several 22-nucleotide long miRNAs trigger biogenesis of cascades of trans-acting secondary small interfering RNAs, involved in various developmental and stress responses. It was deciphered that in Himalayan *Arabidopsis thaliana* accessions having natural mutations in miR158 locus exhibit robust cascade silencing in pentatricopeptide (*PPR*)-like locus. These cascade sRNAs trigger tertiary silencing of a gene involved in transpiration and stomatal opening. This is a new module of sRNA network in plant adaptation.

In the area of computational biology, the stress tolerance of plants in response to drought, salt, heavy metals and pathogen attack was studied. The transcriptome meta-analysis of the salt and drought stressed cotton was carried out. The analysis revealed key regulatory hub genes of drought and salt stress conditions that have notable associations with functional drought and salt stress-responsive (DSSR) genes. There were 5,962 and 3,510 differentially expressed genes (DEGs) which were identified in drought and salt stress data. The genome & transcriptome sequencing of Indian Lotus has carried out.

PLANT GENETIC RESOURCES AND IMPROVEMENT

Development of New Plant Varieties

A new mutant floral variety of *Chrysanthemum morifolium* named as, 'NBRI-Swadheen75' was developed, which is a 'Decorative' type, late-blooming variety. The variety was named to mark the 'Azadi Ka Amrut Mahotsava' during Platinum Jubilee celebration year of independence of India and was released by the Hon'ble, DG CSIR Dr. Shekhar C. Mande on Jan. 30, 2022.

A new mutant of *Chrysanthemum morifolium* lines have been induced through mutagenesis of vars. 'Kelvin Victory' & 'Hemant Singar' for desired novel cut-spray variety having pompon-type flowers & a dwarf variety with 'no-pinch-no-stake' characteristic, respectively.

Hybridization in *Gladiolus* is being done. These crosses may yield many new hybrid varieties with

improved ornamental characteristics having market potential.

Varietal developments of floricultural and ornamental plants like *Canna*, *Nymphaea* and *Nelumbo* using the techniques of hybridization and mutation breeding through gamma radiation and chemical mutagens was undertaken during this period.

Genetic and genomics resources of crop plants for varietal development

Genome assembly of linseed was improvised with addition of Hi-C (chromosome conformation capture with next-generation sequencing) data. Phenotypic characterization of two RILs (recombinant inbred line) mapping population of linseed has been done for 10 important agronomic traits. These include RIL populations for oil content and flowering/maturity.

Exploitation of grain amaranth genetic resources has been undertaken for accelerated genetic improvement. A subset of 300 accessions of grain amaranths have been identified as "core accessions" for SNP based association mapping. The genotyping by sequencing (GBS) was carried out in gain amaranth for ~300 lines of two RILs for linkage/QTL mapping.

To understand the origin and physiological adaptation of Banana, the composition of wild and cultivated Musa genome is being characterised using Flow-cytometry.

To resolve the phylogeny in Quercoideae, sequencing and assembling chloroplast genome of *L. dealbatus* is being carried out.

Initiative has been taken towards Indian *Cannabis* improvement through chemotype based conventional and molecular breeding.

Genome Wide Association Study (GWAS) for oripavine in opium poppy was carried out. Marker trait association (MTA) using all SNP markers was evaluated based on the average values for Opiod.

BOTANIC GARDEN AND AGROTECHNOLOGY

Botanic Garden

A Conservation Centre has been created for Indian *Cycas* and Waterlily-Lotus. This facility shall also serve as National Reference Centre.

Several seedlings were collected and planted in Cycad House and Indian *Cycas* Garden for further studies in *ex-situ* at CSIR-NBRI Botanic Garden.

Two new species, *Pyrrosia sarthalensis* (Polypodiaceae) and *Swertia patnitopiansis* (Gentianaceae) were described from Jammu & Kashmir.

Some wild ornamentals including, *Iris* sp., *Hoya* sp., *Barleria* sp., *Begonia* sp., and *Impatiens* sp. were successfully domesticated and are being established in the Botanic Garden.

The Botanic Garden was enriched with numerous plant species collected from various parts of India, in the form of cuttings, saplings, live plants and seeds for *ex-situ* conservation in the garden. The collections include *Victoria amazonica*, 38 varieties of lotus including rare 108 petal lotus of Manipur, 15 varieties of *Nymphaea*, 17 varieties of *Canna*, 8 varieties of *Hoya*, 5 varieties of *Rhynchostylis*, 5 varieties of *Tolumnia*, 50 varieties of *Dendrobium, Dischidia pectinoides*, *Oxystelma seculentum, Ludwigia adscendens, Ultricularia aurea, Marsilea minuta, Nuphar lutea, Hydrocleys nymphoides*, 2 varieties of Rose, 5 varieties of *Heliconia, Costus insignis* and several other ornamental and threatened plants.

For promotion of NBRI developed floricultural crops and varieties, establishment of floriculture garden in schools and colleges was undertaken in many states of the country.

Plant Conservation and Agro-technology

For standardizing the agro-practices of Kalmegh (*Andrographis paniculata*), field experiment was conducted with various doses of press mud.

To identify the potential *Aloe* species for cultivation in salt affected soils, twenty-five *Aloe* species and accessions were evaluated.

Twelve more species were added to the Bambusetum at Banthra, making it a conservation plot of 67 spp. of Bamboo from different regions/parts of India.

The grain amaranth germplasm repository was further enriched to 1223 accessions, which are being evaluated for various agronomical and quality traits.

Collection, conservation and evaluation of 52 accessions of Nagarmotha (*Cyperus scariosus*) were done under sodic waste land conditions for their commercial cultivation and extraction of root essential oil.

A total 139 samples of *Juniperus* were collected from four Himalayan states. Extraction and characterization of essential oil have been done from four populations from western Himalaya.

Out-reach/Skill Development

Under the UNIDO Neem project, different agroforestry models were developed with medicinal and aromatic plants. The multi-location trials were carried out at five different agroclimatic zones to evaluate comparative adaptation of four different Neem cultivars.

Under CSIR-Aroma Mission, 253 quintals rhizomes of turmeric variety 'Keasri' has been distributed among 59 farmers in nine states.

A total of 22 awareness cum training programmes were organized at different locations for popularization of turmeric cultivation for essential oil extraction from senescing leaves, training 863 farmers.

Projects, Publications and Patents

The institute continued to provide services to various end users through several outreach, training and skill development programmes, for fullfling these activities, the institute signed 24 MoUs, MTAs etc. The institute during this period initiated 20 new projects, including 17 Government Aided Projects (GAP) and 03 Mega Lab Projects (MLP). Published 178 research papers in SCI journals, with a cumulative impact factor of 618.55 (IF 3.47 per paper). Three patents were filed in India, while 04 patents were granted, one in India and three abroad, and 23 students were awarded PhD by the Academy of Scientific and Innovative Research (AcSIR) and other universities of India.

Research & Development

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

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वै.औ.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, वर्गिकी, प्रलेखन, पूर्वेक्षण एवं आनुवांशिक सुधार आदि पर बुनियादी एवं प्रायोगिक अनुसंधान करना है। संस्थान निम्न क्षेत्रों के प्रमुख सामर्थ्य रखता है।

- पादप विविधता, वर्गिकी एवं निम्न तथा उच्च पादप समूहों के लिए डेटाबेस
- जैव पूर्वेक्षण 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 सतत् 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

CSIR NBRI Estd. 1953

WHERE PLANT-BASED RESEARCH TOUCHES LIFE THROUGH INNOVATION

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. Sanjeeva Nayaka, Senior Principal Scientist
- Dr. AK Asthana, Senior Principal Scientist
- Dr. AP Singh, Principal Scientist
- Dr. Sachitra Kumar Rath, Principal Scientist
- Dr. Priyanka Agnihotri, Principal Scientist
- Dr. VV Wagh, Senior Scientist
- Dr. KM Prabhukumar, Senior Scientist
- Dr. Sandeep Kumar Behera, Senior Scientist
- Dr. Gaurav Kumar Mishra, Scientist

Technical and Support Staff

- Dr. Sushma Verma, Senior Technical Officer
- Dr. Kiran Toppo, Senior Technical Officer
- Dr. Vinay Sahu, Senior Technical Officer
- Dr. KK Rawat, Senior Technical Officer
- Mr. Rameshwar Prasad, Technical Officer
- Dr. KK Ingle, Technical Officer
- Dr. Vandana Tiwari, Technical Assistant
- Mr. MK Srivastava, Senior Technician
- Yogeshwar Sahu, 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.	TARE Fellow	01
2.	NPDF	01
3.	INSPIRE Faculty	01
4.	Research Associate	01
5.	JRF/SRF/INSPIRE	29
6.	Project Staff	29

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 21 grant-in-aid projects sponsored by different funding agencies like SERB-DST, New Delhi; DBT, New Delhi; MOEF & CC, Government of Maharashtra and CSIR, New Delhi.
- The group has significantly contributed towards bio-prospecting plant resources with other disciplines like Molecular Biology, Phytochemistry, Pharmacognosy & Pharmacology and Botanical Garden of the institute, which has led to development of new varieties, processes and technologies. The scientists of the division have published 48 research papers, 5 book chapters, 10 new species to science and 28 new records from India. Besides scientists of the division are also teaching various courses to AcSIR students.

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, Balsaminaceae, Lamiaceae, Euphorbiaceae and Asteraceae of Uttar Pradesh, Herbaceous flora of Lucknow and its adjoining districts, cultivated legumes of Uttar Pradesh, grasses of the Himalaya are in progress.

HERBARIUM: A NATIONAL FACILITY

Curator

Dr. KM Prabhukumar, Senior 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.

Accessioning of specimens

Plants are collected from different parts of the country under various research projects handled by scientists of the Plant Diversity, Systematics and herbarium Division. These plant specimens are properly processed and herbarium specimens are prepared and ultimately deposited to the institute's herbarium. During the period, 2190 specimens of angiosperms, 198 specimens of pteridophytes, 1357 specimens of bryophytes, 305 specimens of algae and 8500 specimens of lichens were accessioned in LWG herbarium.

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 reporting period, students from nine organisations visited the herbarium for various purposes at different occasions.

Plant Specimen Identification/Authentication and Certification

The herbarium provides services to general people 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; Kailash Institute of Pharmacy & Management, Gorakhpur; CSIR-Central Building Research Institute, Roorkee; Integral University, Lucknow and BBD University, Lucknow were identified and certificates were issued to them.

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

De novo transcriptome and EST-SSR development in *Bergenia ciliata* (Haw.) Sternb. (Saxifragaceae)

Bergenia ciliata (Haw.) Sternb. is commonly known as '*pashanbheda*' due to its habitat and lithotryptic activities. Due to limited genetic and genomic information, transcriptome or RNA sequencing (RNA-seq), technology was used to develop the microsatellites markers for *B. ciliata*. To further understand the genetic and genomic background of *B. ciliata*, *de novo* RNA sequencing was carried out with the following objectives : (i) characterization of transcriptome of *B. ciliata*, (ii) development of polymorphic EST-SSRs in *B. ciliata* and (iii) validating their transferability in the allied species of the family Saxifragaceae. The SSR frequency of unigenes obtained from the transcriptome data in *B. ciliata* was 28.03%. Dinucleotide repeats were found to be the most prominent, followed by mono and trinucleotide repeats. The assembled transcriptomic data showed significant similarities when compared with seven functional databases available in public domain. The novel SSR markers developed from transcriptomic data would be useful for future in investigating the genetic diversity in Indian Himalayan Region (IHR). Finding out those potential genotypes could be useful for futuristic conservation studies and plant breeding programmes.

Although the species is widely distributed in the temperate and subtropical regions in South, Central and East Asia, the current harvesting practices and climate change has impacted the natural populations of *B. ciliata*. It is therefore critical to assess the impact of climate change on the distribution pattern, current and future habitat suitability of the species and the major environmental variables governing the growth and distribution of *B. ciliata*. This can be predicted using species distribution models (SDMs) such as Maximum entropy (MaxEnt). MaxEnt modelling was used to predict the potential impact of climate change on the current and future distribution in different scenarios of the *B. ciliata* in Indian Himalayan Region IHR)

Genetic diversity and population structure of *Gymnema sylvestre* in India

Gymnema sylvestre (Retz.) R. Br. ex Schult. (Apocynaceae: Asclepiadoideae) is a perennial, slow growing, woody climber, distributed in tropical parts of Africa, Asia and Australia. It is commonly known as *Gurmar* or *Meshashringi* or *Madhunashini* because of its reported anti-diabetic properties. It has hypolipidaemic, anti-inflammatory, hepato-protective, neuro-protective, immuno-modulatory, cardio-protective, anti-cancerous, antibacterial, antioxidant and antiviral properties because of the presence of various triterpenoidic saponins. In India, the species is widely distributed in the peninsular region, Andaman and Nicobar islands and in areas of Uttar Pradesh and Bihar covering tropical moist to dry deciduous forests, tropical thorn forests, tropical semi-evergreen forests, and tropical wet and dry evergreen forests. Plant samples were collected from seven Indian states and investigated for its genetic diversity and population structure using dominant markers such as DAMD (Directed Amplification of Minisatellite region DNA) and ISSR (Inter Simple Sequence Repeats). A total of 11 natural populations of *G. sylvestre* was investigated with 25 markers

(DAMD & ISSR) revealing significantly high level of polymorphism at species level while, low level of polymorphism at population level. Among the natural populations studied, high diversity and low diversity areas were questioned for conservation and management programmes. Statistical and cluster analysis was done using various softwares as, GenAlEx, FREETREE, TREEVIEW, POPGENE, STRUCTURE, NTSYS, etc. it was concluded that there is significant amount of genetic diversity at species level but probably due to partitioning of genetic diversity by the populations in wild, low diversity is detected at population level.

Phylogeny of the genus *Uraria* (Leguminosae)

Taxonomy of the genus *Uraria* Desv. was studied using micro and macro-morphological characters. Floral parts were dissected under stereo zoom microscope, measured, and documented with LEICA S8 APO (Wetzler, Germany). Detailed taxonomic descriptions were made along with illustrations. The nomenclature was updated after scrutinizing various literature and herbarium type specimens. About 240 voucher specimens were accessioned and deposited at LWG herbarium.

Among the members of the genus, *U. prunellifolia* and *U. paniculata* are medicinally important, and rare in occurrence. The former is believed to be extinct in some parts of India, and the latter was recently rediscovered. The nomenclatural issues of *U. prunellifolia* and *U. paniculata* were resolved and both the names were typified during the study.

Phylogenetic studies were carried out in the Indian species of the genus *Uraria* with nuclear and chloroplast genes. DNA sequences were generated for ITS, *trnL*, *psbA-trnH* and *matK* regions. The sequenced data were edited manually using the software BioEdit. The edited sequences were aligned using MEGAX. All available sequences of the different genera in the tribe Desmodieae for these markers were also downloaded from NCBI. The downloaded sequences were scrutinized for its quality and identity. Both sequenced and downloaded datasets were compiled and the final data matrix was prepared. A total of 92 sequences consisting 32 genera of the tribe Desmodieae were considered for constructing the phylogenetic tree with four primer pairs. The Bayesian Inference (BI), Maximum Parsimony (MP) and Maximum Likelihood (ML) analyses were carried out in the softwares, Mr. Bayes, PAUP and RAxML GUI, respectively. The tree topology remained same in all the three methods, with high to very high bootstrap and posterior probability values. The Bayesian Inference resulted an average standard deviation of split frequencies with 0.004332. Furthermore, the work related to the genetic diversity analyses of *U. picta* using microsatellites is under progress.

Bioprospection and systematics of the genus *Juniperus* (Cupressaceae) in India

Juniperus L. (Cupressaceae) are aromatic shrubs or tree species mostly dioecious, and comprises of approximately 75 species globally with different varieties. In India, there are about 8 species under the genus *Juniperus*, distributed throughout the temperate Himalayan region from Kashmir to Arunachal Pradesh at an altitude range of 2500 – 4700 m. Junipers are widely used for food, flavour, fragrance, timber, ornamentals and possess aesthetic value in highlands of Himalayas since ancient times. Junipers are economically important plants whose parts like berries, aerial parts, fruits and bark are widely used traditionally and commercially for treatment of common ailments. It is used as a carminative, antiseptic, curing acute and chronic cystitis, leucorrhoea, abdominal disorders, diabetes, etc.

The plant material was collected from four states and two union territories of India, viz. Jammu & Kashmir, Ladakh, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh for carrying molecular and systematics studies of the genus *Juniperus* L. (Fig. 1). A total of 169 voucher specimens for all six species of *Juniperus* L. were prepared. All the species of the genus were subjected for comprehensive taxonomic studies under stereo zoom microscope with LEICA S8 APO (Wetzler, Germany) software.

Phylogenetic relationship amongst Indian species of *Juniperus* using nuclear (ITS A_B) and chloroplast (petN_psbM, trnD_trnT, trnS_trnG, rbcL) genes were also examined. A total of 72 DNA sequences were generated and edited manually using BioEdit and aligned in MEGAX. Other Juniper sequences were downloaded from Gene Bank for comparison with the sequences generated manually. The phylogenetic analysis of the aligned sequence data will be analyzed individually for phylogenetic inference using maximum likelihood (ML), maximum parsimony

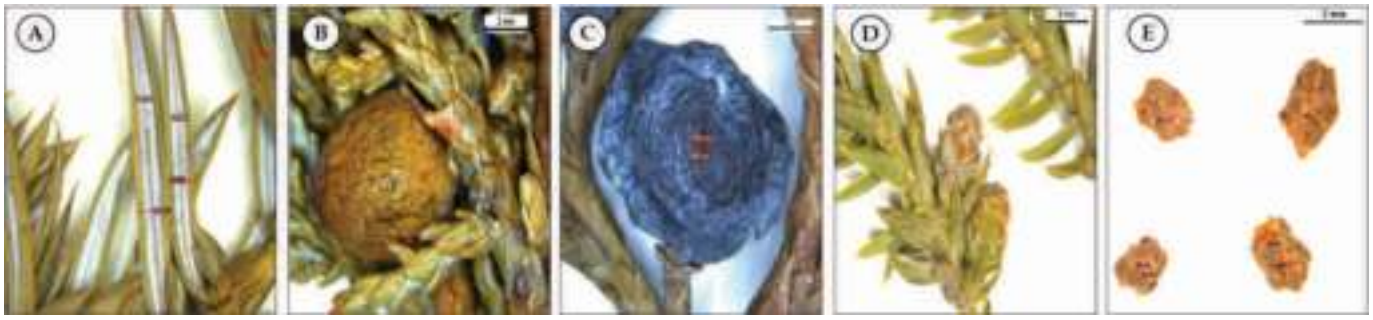

Fig. 1: *Juniperus* species selected for the study: (A). *J. Communis,* (B). *J. Indica,* (C). *J. Semiglobosa*, (D). *J. Squamata*, (E). Male cone of *J. squamata*

(MP) and neighbour joining (NJ), methods with different softwares such as MEGAX, and Mr. BAYES, with high bootstrap and posterior probability values.

Studies on genetic diversity and population structure of medicinally important plant *J. communis* was carried using DAMD and ISSR markers in IHR. Plant material was collected from the states of Western Himalayan region (Uttarakhand, Himachal Pradesh and Jammu and Kashmir) and a total of 65 accessions were targeted for genetic diversity studies. DNA was isolated from all the accessions using conventional CTAB method with minor modification, and further work is underway.

Juniperus L. is an aromatic genus having high medicinal properties. The essential oil from species viz., *J. communis*, *J. squamata*, *J. indica*, *J. excelsa*, *J. recurva* and *J. semiglobosa* was extracted using Clevenger apparatus and characterized using Gas chromatography-Mass Spectrometry (GC-MS) technique. The analysis showed that it is rich in monoterpene hydrocarbons like α-pinene, sabinene, β-myrcene and L-limonene followed by sesquiterpenes and non-terpenes hydrocarbons. It also showed strong antibacterial and antifungal properties of both cones and leaves of species. GC-MS analysis with Juniper species is completed in triplicates to validate the data and the work with other species is under progress.

Conservation of Threatened Plants of India

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 the IUCN criterion, (2) estimate the genetic variability in Critically Endangered (CR) species, (3) develop DNA barcodes for the threatened plant species, (4) develop technologies for mass-multiplication of threatened plant species using macro as well as micro-propagation, and (5) develop threatened plant species conservatory and gene bank at CSIR-NBRI, Lucknow, CSIR-IHBT, Palampur and CSIR-NEIST, Jorhat.

During the period under report, CSIR-NBRI conducted several field exploration trips in the states of India *viz*., Nagaland, Meghalaya, Uttarakhand, Rajasthan, Madhya Pradesh, Uttar Pradesh, Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu, and Kerala. Out of 100 threatened plant species, 32 species have been collected. Secondary data of all the proposed threatened plant species have been documented, and the data related to the locality of occurrence, distribution pattern in India, habit and habitat, geo-coordinates, altitude, distinguishable characteristics, and uses were documented. The data required for IUCN conservation assessments such as the declining of the population/individual, area of occupancy (AOO), extents of occurrence (EOO), number of mature individuals, number of fragmented populations, number of sub-populations are being recorded. The herbarium specimen data of threatened plant species housed at different herbaria in the country and overseas are being documented. Different Indian herbaria such as BSD, LWG, CDRI, DD, MH, IFGTB, CALI, CMPR, TBGT, RHT, CAL, and KFRI were consulted, and 2280 voucher specimens for proposed threatened plant species housed in these herbaria were studied. The reassessment in conservation status of *Dipterocarpus indicus, Ixora jhonsonii* and Ecological Niche Modelling of *Dipterocarpus indicus*, *Vateria indica* and *Ixora jhonsonii* has been completed.

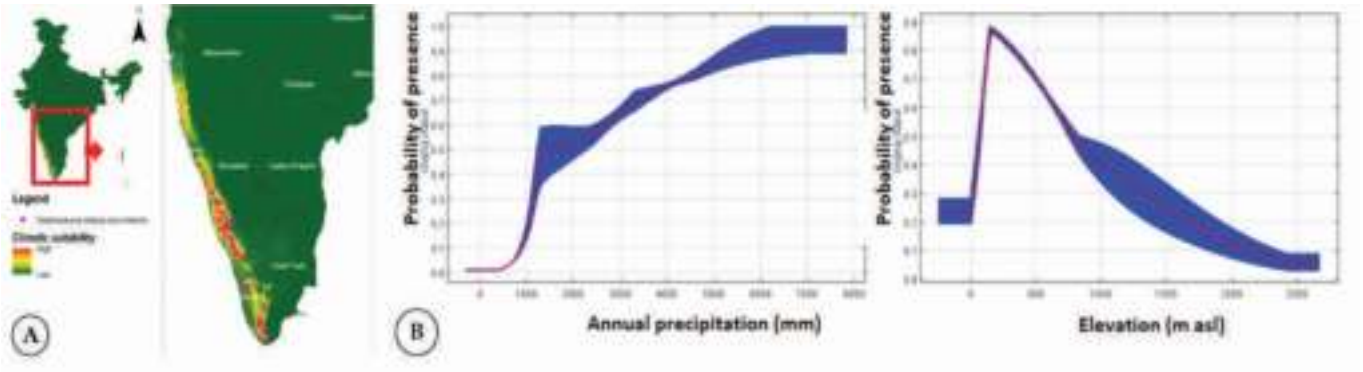

Fig. 2: (A). Map showing the occurrence of *Dipterocarpus indicus* according to climate suitability, (B). Response curves showing how each environmental variable affects the Maxent prediction i.e., the probability of the presence of *D. indicus*

Genomic DNA from 36 samples of 14 species of threatened plants were isolated. Quantitative and qualitative analysis of the genomic DNA was carried out by Nanodrop spectrophotometer and Agarose gel electrophoresis. Besides, *de novo* transcriptome sequencing of two Critically Endangered species namely *Hildegardia populifolia* and *Nothopegia castaneifolia* is also been carried out to identify the microsatellite markers (SSRs) to study the genetic diversity and population structure of these CR species. Plant DNA barcode sequencing of four species *viz., Madhuca bourdillonii, Syzygium palghatense, Ilex khasiana,* and *Nepenthes khasiana* have also been done with ITS, rbcL, and matK markers during the period.

The threatened plants such as *Ephedra foliata* (stem cuttings: 400), *Cleistanthus collinus* (stem cuttings: 100), *Indopiptadenia oudhensis* (stem cuttings: 100), *Cycas seshachalamensis* (seeds: 30), *Cycas sphaerica* (seeds: 30), *Cycas beddomei* (seeds: 30), are being multiplied using micropropagation techniques at CSIR-NBRI Botanic Garden. The plants will be eventually transferred to the dedicated field conservatory. The protocol for the *in-vitro* establishment of *Indopiptadenia oudhensis, Dalbergia latifolia,* and *Cyathea gigantea* was standardized. Out of 32 species collected from the wild, 15 have been successfully conserved in the CSIR-NBRI Botanic Garden.

Research Group Members

- Dr. Vandana Tiwari, Technical Assistant
- Mr. Narender Kumar, Research Scholar
- Ms. Jahnabi Gogoi, Research Scholar
- Ms. Kanchana Vaishnav, Research Scholar
- Mr. Naresh Kumar, Project Associate-I
- Mr. Harish C Singh, Research Scholar
- Mr. AT Bhat, Research Scholar
- Mr. Jaideep Sharma, Research Scholar
- Ms. Arshi Fatima, Research Scholar
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Plant molecular systematics, phylogeography and genetic diversity assessment

Phylogeographic study in *Citrus medica* was continued with an expanded analysis of two chloroplast markers, *trn* L-F (*trn*L intron and *trn*L-F spacer) and *rps*16 intron in 129 individuals sampled from 16 populations in northeast India. A higher level of haplotypic and nucleotide diversity was detected along with moderate genetic diversity, low genetic differentiation, and high gene flow among the studied populations.

As part of phylogeographic studies, 114 *E. glaucum* and 167 *E. superbum* samples were collected and documented from the northeast and peninsular India. MaxEnt-based niche modelling identified high suitable habitats for *E. glaucum* in the Indo-Burma biodiversity hotspot. A germplasm collection comprising 15 *E. glaucum* and 16 *E. superbum* accessions was established at CSIR-NBRI botanic garden. A seed collection of *Ensete glaucum* (9 accessions -1500 seeds) of *E. superbum* and *E. glaucum* (13 accessions- 3500 seeds) was stored for seed germination studies, and distribution to other botanic gardens.

Genetic diversity and phylogeography of two wild species of Indian *Citrus*

Phylogeographic study in *Citrus medica* was continued with an expanded analysis of two chloroplast markers, *trn* L-F (*trn*L intron and *trn*L-F spacer) and *rps*16 intron in 129 individuals sampled from 16 populations in northeast India. A higher level of haplotypic and nucleotide diversity was detected among the studied populations. Hierarchical AMOVA results showed that a large proportion (75.09%) of variation was partitioned within the population and 24.91% variation between the populations. AMOVA revealed a moderate level of genetic differentiation (Fst = 0.249; P<0.01) among the populations of *C. medica*. Total gene diversity (Ht= 0.660) among all the populations was comparatively higher than genetic diversity within the populations (Hs= 0.496). Nst (0.239; P>0.01) was lower than Gst (0.248; P> 0.01) and not significant, reflecting the absence of any phylogeographic structure in *C. medica.* Both, moderate genetic differentiation, and absence of phylogeographic structuring support that high gene flow occurred in the *C. medica* populations in the northeast region of India. Population demographic analysis (Tajima *D* and Fu'*Fs*) and unimodal graph of pairwise mismatch distribution revealed historical demographic expansion in *C. medica*. Divergence time estimation of infraspecific (haplotype) lineages in *C. medica* revealed that all the haplotypes diverged in the Pleistocene period. The cpDNA sequence analysis revealed significant genetic diversity, low genetic differentiation, and high gene flow in *C. medica* populations. Analysis of genetic diversity and population genetic structure in *C. medica* using 10 polymorphic SSR primers with 127 individuals from 16 populations is in progress.

SSR-based genetic diversity assessment in the Indian wild orange (*Citrus indica*) has been initiated. The preliminary analysis involved application of six polymorphic SSR primers in 43 individuals sampled from five populations of *C. indica* in northeast India. The study indicated a low to moderate level of heterozygosity (Ho = 0.11 to 0.32) across the accessions. Polymorphic information content (PIC) of SSR loci ranged between 0.37 and 0.76,

with a mean of 0.65, indicating a high level of polymorphism. AMOVA revealed a high level of genetic differentiation supported with a low level of gene flow (Nm = 0.17) between the populations. The SSR analysis with a greater number of SSR primers is in progress.

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

Phylogeographic studies on *Ensete glaucum* and *E. superbum* were continued with the objectives to estimate genetic diversity and phylogeographic structure determine the divergence time of *Ensete* populations in India, and conserve *Ensete* germplasm at CSIR-NBRI.

Thirteen field trips were conducted to all the known localities of *Ensete* in India, and 114 samples of *E. glaucum* and 167 samples of *E. superbum* were collected. The samples included leaf materials for DNA isolation, voucher specimens for herbarium preparation, and fresh seeds and seedlings for *ex-situ* conservation. Distribution maps were prepared using georeferenced occurrence records and Q-GIS software. In addition, the MaxEnt-based niche modelling has been done to predict current suitable habitats for both species. High suitable habitats for *E. glaucum* were found in the Indo-Burma biodiversity hotspot while less suitable regions were observed in most of the countries of Southeast Asia. The major bioclimatic variable contributing to the niche prediction of *E. glaucum* was the precipitation of warmest quarter. The predicted suitable habitat regions can be used to conserve the genetically diverse and vulnerable populations of *Ensete glaucum*. Prediction of potentially suitable habitat for *E. superbum* in current and future climate scenarios is in progress.

As part of genetic diversity and phylogeographic study, genomic DNA was isolated from silica-dried leaf materials using a modified CTAB protocol. PCR amplification of chloroplast markers (*psbA-trnH* and *RPS-16*) were optimized and 110 and 75 accessions of *E. superbum* and *E. glaucum*, respectively, and were sequenced for the two loci. The sequences were aligned and checked for quality using BioEdit v7.2. The quality sequences were then used for the data analysis. EST SSRs were identified from the transcriptome data of *E. glaucum*, using MISA version 1.0. Fifty-two EST SSR primer pairs from the transcriptome data and 44 SSR primer pairs from the published literature were synthesized. The screening was completed, and 16 polymorphic primers were identified for each species. Genotyping of all accessions using polymorphic primers and fragment analysis are in progress.

Fig. 1: *Ensete* germplasm collection at CSIR-NBRI. (A) & (C). *Ensete glaucum*, (B) & (D). *Ensete superbum*

Fig. 2: *Ensete* seed accessioning and storage (A). Seeds stored in polycarbonate bottles, (B). Seeds of *Ensetesuperbum*, (C). Seeds of*Ensete glaucum*

To conserve the germplasm, seedlings of *E. glaucum* and *E. superbum* were introduced to the CSIR-NBRI garden. The plants were kept in the introductory section for one year in pots and transferred to the field at the onset of the monsoon. The present collection includes 15 accessions of *E. glaucum* and 16 accessions of *E. superbum* (Fig 1. A&B). Both the species are sensitive to winter as well as summer seasons. Plants undergo a dormant stage during these dry seasons without any leaves. All the plants were established in the NBRI garden through proper winter and summer care. *Ensete glaucum* and *E. superbum* bloomed at the NBRI conservatory (Fig 1. C&D). The bright attractive inflorescence makes *Ensete* species as potential wild ornamental plants.

Seeds of *Ensete glaucum* and *E. superbum* were also collected, accessioned and stored at NBRI. The present seed collection includes 13 accessions (3500 seeds) of *E. superbum* and 9 accessions of *E. glaucum* (1500 seeds). The seed morphological characters were documented for both species. The initial moisture content of seeds of both the species (<20%) showed the orthodox nature of seeds. Seeds were stored in polycarbonate bottles at room temperature for short-term storage, seed germination studies, and distribution to other gardens and universities as part of popularization (Fig. 2).

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Plant diversity, Ethnobotany

Plant resource mapping of Chambal Ravines

Field tour was undertaken for collection, survey, mapping of the plant resources and documentation of the ethnobotanical knowledge in the different forests blocks of Chambal Forests Range in Agra and Etawah Districts. During the study different villages were visited and interviews conducted with the knowledgeable and experienced people and village headman for the documentation of useful medicinal and economic plants used by the local people in the area. Some of the potential plant species like *Acacia leucophloea, A. nilotica, Achyranthes aspera, Aegle marmelos, Adhatoda zeylanica, Boerhavia diffusa, Calotropis procera, Capparis decidua, C. sepiaria, Cissampelos pareira, Citrullus colocynthis, Crinum asiaticum, Datura metel, Elytraria acaulis, Enecostema axillare, Euphorbia hirta, E. thymifolia, Evolvulus alsinoides, Grewia hainesiana, G. flavescens, Nyctanthes arbor-tristis, Phyla nodiflora, Solanum surattense, Tephrosia purpurea* and *Tinospora cordifolia* were found useful in the study area for the economic upliftment and healthcare. The plant species *Enecostema axillare* was used for lowering glucose level in blood, treating fever and spermatorhoea issues by the local people, while *Capparis decidua* is commercially utilized in making pickle and sauces.

Ethnobotanical surveys and documentation of indigenous knowledge

Ethnobotanical field surveys and plant collection tour was undertaken in Tulasipur and Rampur Forest Ranges of Suhelwa Wildlife Sanctuary Uttar Pradesh. During the study 28 medicinal and economic plant species viz., *Aloe vera, Antidesma acidum, Artocarpus lacucha, Asparagus racemosus, Amorphophallus paeonifolius, Basella alba, Bauhinia purpurea, Boerhavia diffusa, Bombax ceiba, Bridelia squamosa, Buchanania lanzan, Capparis zeylanica, Centella asiatica, Chlorophytum tuberosum, Cordia dichotoma, Costus speciosus, Crotolaria juncea, Curculigo orchioides, Diplazium esculentum, Dioscorea appositifolia, D. belophylla, D. bulbifera, D. glabra, Euphorbia neriifolia, Kalanchoe pinnata, Mallotus philippensis, Ficus virens* and *Xeromphis uliginosa* used by the local people and tribal populations have been identified and documented.

Fig. 1: Field survey at Suhelwa Wildlife Sanctuary. (A). *Asparagus racemosus*: used in skin diseases, (B). Tribal man collecting wild *Chlorophytum tuberosum* from wild habitat, (C). *Cordia dichotoma*: fruits are used in pickles

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Taxonomy and bioprospecting of lichens, lichenicolous and endolichenic fungi

New Species Discovered

Rinodina indica **Vishal Kumar, R. Ngangom & Nayaka, Taiwania 66(2): 193, 2021. Fig. 1.**

The new species is characterized by its corticolous habitat, ochraceous to brown, areolate thallus,

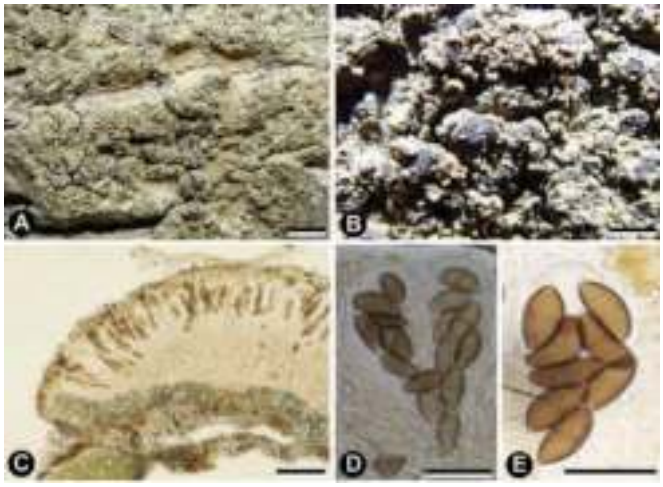

Fig. 1: *Rinodina indica*- A New Species Described: (A). Thallus with habitat, (B). Thallus and apothecia showing blastidia, (C). Vertical section of apothecium, (D). Immature ascospores in ascus, (E). Mature ascospores. Scale bars: A = 5 mm; B = 1 mm; C = 5 µm; D & E = 20 µm.

presence of blastidia on thallus and apothecial margins, *Teichophila*-type of ascospores with smooth outer walls and lack of lichen compounds. It does not resemble with any *Rinodina* species known so far from India. It is similar to *R. herrei* H. Magn. but differs in having persistent thalline margin and smaller ascospores of size 11.5–19 × 5.5–8.5 µm.

Species reported as new record for India

1. *Acarospora contigua* H. Magn. - Earlier reported from North America and Mexico).
2. *Arthonia atra* (Pers.) A. Schneid - Earlier reported from Asia, Africa, Australia, Europe, Macaronesia, North and South America).
3. *Astrothelium alboverrucoides* Aptroot - Earlier reported from Indonesia.
4. *Graphis brevicarpa* M. Nakan., Kashiw. & K.H. Moon - Earlier reported from Oceania.
5. *Japewiella tavaresiana* (H. Magn.) Printzen - Earlier reported from Europe, Macaronesia and Eastern North America.
6. *Micarea erratica* (Körb.) Hertel, Rambold & Pietschm- Earlier reported from England, Scotland, Ireland, Central Europe, North America, Australia and New Zealand.
7. *Ocellularia albomaculata* Hale - Earlier reported from Sri Lanka and Thailand.
8. *O. ascidioidea* Hale - Earlier reported from Seychelles, Sri Lanka, New Caledonia and Thailand.
9. *O. kanneliyensis* Hale - Earlier reported from Sri Lanka
10. *O. monosporoides* (Nyl.) Hale - Earlier reported from New Zealand, Sri Lanka and Thailand.
11. *O. pertusariiformis* (Leight.) Zahlbr. - Earlier reported from Phillippines, Sri Lanka and Thailand.

12. *O. rhicnopora* Hale - Earlier reported from Sri Lanka.
13. *Pertusaria cicatricosa* var. *deficiens* A.W. Archer, Elix & Streimam - Earlier reported from Papua New Guinea.
14. *Porina exserta* Müll. Arg. - Earlier reported from Thailand, Christmas Island, the Northern Territory, eastern Queensland, Taiwan and Tahiti.
15. *P. siamensis* P. M. McCarthy - Earlier reported from Thailand.
16. *P. subargillacea* Müll Arg. - Earlier reported from Australia and New Zealand.
17. *Pyrenula dissimulans* (Müll. Arg.) R.C. Harris - Earlier reported from North and South America.
18. *P. pyrenastrospora* Aptroot - Earlier reported from Papua New Guinea.
19. *P. rinodinospora* Aptroot - Earlier reported from Papua New Guinea.
20. *Pyxine schmidtii* Vain. - Earlier reported from Asia, Australia and Papua New Guinea.
21. *Rinodina archaea* (Ach.) Arnold - Earlier reported from British Columbia, Southern California, Arizona, Europe, Siberia and Scandinavia.
22. *R. dolichospora* Malme, Bih. K. Svenska Vetensk. - Earlier reported from Australia, Brazil, south-western Europe, Russia and USA.
23. *R. mniaroeiza* (Nyl.) Arnold - Earlier reported from Norway, Sweden, Greenland, Finland, North America and Nepal.
24. *R. obnascens* (Nyl.) H. Olivier - Earlier reported from North America, California, France, Spain, Switzerland, Bulgaria and Sweden.
25. *R. oleae* Bagl. - Earlier reported from Alaska, California, Sierra Nevada, Europe, China, Japan, Russia and South Korea.
26. *R. plana* H. Magn. - Earlier reported from Spain, Mediterranean region and Central Europe.
27. *R. pyrina* (Ach.) Arnold - Earlier reported from Australasia, British Isles, Norway, Sweden, Finland, North America, northern Africa, central and southern Europe, Taiwan, Japan, South Korea and China.
28. *R. trevisanii* (Hepp) Körb. - Earlier reported from Scandinavia, Siberia, Southern Alps, Caucasus, Turkey, Siberia, Minor and western North America, Russia, Western Mongolia, Kazakhstan and China.

Lichen flora of Sunderdhunga Valley, Uttarakhand

An assessment of lichen diversity in Sunderdhunga valley of Uttarakhand is initiated. A maiden field tour was conducted from Kharkiya to Jatoli enroute to Sunderdhunga and a total of 450 lichen samples were collected. The identification so far resulted in 134 species belonging to 47 genera and 19 families. Among them the lichen family Parmeliaceae was dominant with 35 species belonging to 11 genera (*Bulbothrix, Cetrelia, Flavoparmelia, Hypotrachyna, Myelochroa, Parmelia, Parmelinella, Parmotrema, Punctelia, Remototrachyna,* and *Usnea*) followed by Physciaceae with 24 species belonging to 7 genera (*Heterodermia, Phaeophyscia, Physcia, Physciella, Physconia, Polyblastidium,* and *Rinodina*).

Lichen flora of Kishtwar High Altitude National Park, Jammu & Kashmir

A field tour was undertaken to Yeerdu, Qaderna, Janakpur, Deharna and Loharna areas of the Kishtwar High Altitude National Park and more than 300 lichen specimens were collected. Out of them, 212 specimens were identified so far which resulted in 67 lichen species belonging to 34 genera and 14 families. The study also resulted two new distributional records for India (*Bacidia schweinitzii* (Fr. ex E. Michener) A. Schneid.; *Phaeophyscia trichophora* (Hue) Essl.

Lichen flora of Suhelwa Wildlife Sanctuary (SWLS), Uttar Pradesh

In continuation of lichen studies in Suhelwa Wildlife Sanctuary the lichens specimens collected during the previous year were identified which resulted in 19 lichen species belonging to 12 genera and 11 families. The crust forming lichen exhibited their dominance in the study area represented by 16 species while the sanctuary had poor representation of foliose lichens with three species. Out of 11 families, members of Graphidaceae exhibit their dominance with five species followed by Pertusariaceae and Pyrenulaceae with three species each. The most common genera of the area are *Bacidia, Caloplaca, Fissurina, Graphis* and *Pyrenula*.

Lichen flora of Chambal Ravines

A total of 13 localities in Chambal ravines spread over two districts (Agra and Etawah) of Uttar Pradesh were surveyed and 34 lichen samples were collected. The identification of the samples resulted in 10 species belonging to six genera and three families. Among them *Heppia adglutinata* A. Massal. and *H. solorinoides* (Nyl.) Nyl. are new record to India. *Endocarpon nanum* A. Singh & Upreti and *E. pallidum* Ach. are the most common and abundant lichens in the study area. The soil and rock are the major substrate for the growth of lichens, while *Peltula corticola* Büdel & R. Sant. was the only corticolous species.

Phylogenetic study of Arthoniales

In continuation of revision and phylogenetic studies of Arthoniales of India, an e-monograph was developed which can be accessed through www.arthoniales.in. For the collection of Arthonialean lichens two tours were conducted to Jammu & Kashmir and Himachal Pradesh. The genus *Crypthonia* was revised with two accepted species (*C. paleotropical* Frisch & G. Thor; *C. albida* (Fée) Frisch & G. Thor) along with detailed world distribution and key for the identification. Further, DNA sequencing of 17 Arthonialean members were completed, and phylogenetic analysis is in progress.

Revision of lichen genus *Buellia s. l.*

The revisionary study on lichen genus *Buellia s. l.* was continued. A total of 94 specimens were studied in detail, resulting in the identification of 17 species including four new distributional records for India (*Amandinea extenuate* (Müll. Arg.) Marbach, *Buellia pusillula* (Nyl.) Zahlbr, *B. rhizocarpica* Etayo, Giralt & Elix and *B. spuria* (Schaer.) Anzi). Further, a new species of *Endohyalina* was described and communicated for publication in the journal Taiwania along with world key for all nine known species. The diversity of secondary metabolites among species of *Buellia s. l.* was studied using thin layer chromatography which resulted in occurrence of norstictic acid and atranorin as the major lichen compounds.

Revision of lichen genus *Rinodina*

In continuation of revision of lichen genus *Rinodina* a total of 180 specimens were studied in detail that yielded 11 species including *R. lepida* (Nyl.)Müll. Arg. a new distributional record for India. Meanwhile from the previous study a new species (*Rinodina indica* Vishal Kumar, R. Ngangom & Nayaka) was published along with eight distributional records for India (see new species and new record list). It is now clear from the revisionary study that the genus *Rinodina* has 21 species in India. Among them 17 species are crustose while four have crustose to sub-squamulose thallus. *Rinodina sophodes* (Ach.) A. Massal. is the most common species within the genus and it is abundant in Gangetic plains. This species is also considered as air pollution tolerant and utilized for pollution monitoring studies elsewhere.

Diversity of lichenicolous fungi

The studies on lichenicolous fungi inhabiting parmelioid lichens was continued. About 1600 specimens of parmelioid lichens deposited at herbarium LWG of CSIR-NBRI were examined, out of this 120 were found hosting lichenicolous fungi. The study resulted in 31 species under 24 genera of lichenicolous fungi, out of them 10 are new distributional records for India while four are likely to be new to science (*Arthophacopsis* sp., *Endohyalina* sp., *Xenonectriella* sp. and *Zwackhiomyces* sp.). Further, new host were recorded for five species of lichenicolous fungi.

During the lichen study at Kishtwar High Altitude National Park three species of lichenicolous fungi were also identified (*Plectocarpon* cf. *opegraphoideum* Christnach, Ertz, Diederich & Wedin, *Lichenostigma cosmopolites* Hafellner & Calat., and *Muellerella hospitans* Stizenb.). Out of them *Plectocarpon* cf. *opegraphoideum* Christnach, Ertz, Diederich & Wedinand *Muellerella hospitans* Stizenb. are new distributional records for India.

A new study on taxonomy and ecology of lichenicolous fungi of Arunachal Pradesh is initiated. As baseline information in the form of a list of all lichens occurring in Arunachal Pradesh is prepared based on published literature, which resulted in 774 species under 184 genera and 56 families. A total of 60 specimens of lichens from the state of Arunachal Pradesh deposited in LWG herbarium were observed for the presence of lichenicolous fungi. Out of these four specimens were found to be serving as host to lichenicolous fungi (*Arthonia coronata* Etayo, *Sphaerellothecium reticulatum* (Zopf) Etayo, *Vouauxiomyces truncatus* (B. de Lesd.) Dyko & D. Hawksw. and *Zwackhiomyces* sp.).

Diversity and bioprospecting endolichenic fungi

The studies on endolichen fungi occurring within lichen genus *Parmotrema* were continued. A total of 100 isolates of endolichenic fungi were identified from the 450 originally obtained isolates. A preliminary antimicrobial screening of these 100 isolates were carried out against seven bacteria by soft agar method. A total of 30 isolates were found to have antibacterial activity and out of these ten potential isolates (showing activity against 3 or more bacteria) were selected for bulk culture in Potato Dextrose Broth. The culture broth was then filtered, separated in ethyl acetate and rotavapoured to obtain the crude extract. The crude extract of all the ten isolates were again screened for antimicrobial activity through disc diffusion method. The minimum inhibitory concentration was performed. Further, antioxidant activity (DPPH assay, FRAP, NO scavenging activity, hydroxyl radical scavenging activity) was carried out for all the 10 isolates. Finally, five most potential isolates (*Daldinia eschscholtzii* (Ehrenb.) Rehm, *Xylaria feejeensis* (Berk.) Fr., *Nemania diffusa* (Sowerby) Gray, *Preussia* sp., *Trichoderma* sp.) were selected for chemical analysis using GC-MS.

Bioprospecting Himalayan lichens

The bioprospecting studies on Himalayan lichens were continued. The methanol, chloroform and acetone extract of the lichens *Ramalina conduplicans* Vain. and *Usnea longissima* Ach. exhibited high antimicrobial activities against *Acinetobacter baumannii, Pseudomonas aeruginosa* and *Klebsiella pneumoniae*. The lichen extracts also gave interesting results for anticancer activity against the breast cancer cell lines (MCF-7 and MDA-MD- 231). The free radical scavenging potential of the lichen extracts was increased by increasing the concentration. The gas chromatography of methanol extract of *Parmotrema nilgherrense* (Nyl.) Hale yielded about 24 compounds. Among them, benzoic acid and 2,4-dihydroxy-3,6-di methyl, methyl ester may be responsible for good anticancer activities based on the earlier report. In case of *R. conduplicans* about 100 compounds were identified. Among them, Cyclopentadecane- Bis (2-ethylhexyl) phthalate, 2-Ethylacridine, Eicosane, 2-Bromododecane, 5-Sec-butylpyrogallol, Cyclododecane, 4,6-Diamino-O-cresol, Cetrimonium bromide, 1, 3-Benzenediol, 5-pentyl (Olivetol), Ethyl tridecanoate, Pyridine-3-carboxamide, oxime and N- 2-trifluoromethylphenyl may be responsible for the strong antimicrobial and antioxidant activities. In *U. longissima* about 35 compounds were identified. Among them, Benzoic acid, 2,4-dihydroxy-3, 6-dimethyl (atraric acid) depsides, Eicosane, Octadecane, Orcinol (3,5-di-hydroxytoluene), 3-chloro-N, N-dimethylpropan-1-amine and Usnic acid may be responsible for antimicrobial, anti-cancer and antioxidants activities. From the methanolic extracts of *U. longissima*, usnic acid was isolated using column chromatography, purified up to 99% and confirmed by HPLC for further bioprospecting.

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

New addition to the flora of India

1. **Genus *Phymatoceros* Stotler & al.** has been recorded for the first time from Indian region (Uttarakhand: Binsar, Mussoorie). The critical and comparative study has suggested that, Indian plants belong to *Phymatoceros phymatodes* (M. Howe) R.J. Duff & al. A detailed morphotaxonomic study along with SEM of spores have been carried out in Fig.1 (1-19).
2. ***Plagiomnium japonicum*** (Lindb.) T.J. Kop. has been recorded for the first time from Indian region (Uttarakhand: from Osla to Taluka, Uttarkashi) Fig.2 (A-F).

Conservation status of endemic Indian hornworts

With an objective to assess the conservation status of endemic hornwort taxa, a study on the following species have been carried out:

***Anthoceros pandei* Udar & A.K. Asthana** was earlier discovered from Mao, Nagaland in 1985 and since then there is no further report of its occurrence in India and elsewhere after so many explorations. During the present study, it has been revealed that the species is known to occur in much fragmented state confined to single a location in India within highly restricted area of occupancy less than 100 km^2. Therefore, as per the IUCN Red List categories and criteria version 3.1 (ref. 6), *Anthoceros pandei* belongs to Critically Endangered category [CR B1 + 2a-c; D] at global level in the present state of our knowledge.

***Phaeoceros udarii* A.K. Asthana & Nath** was initially discovered from Mussoorie as its type

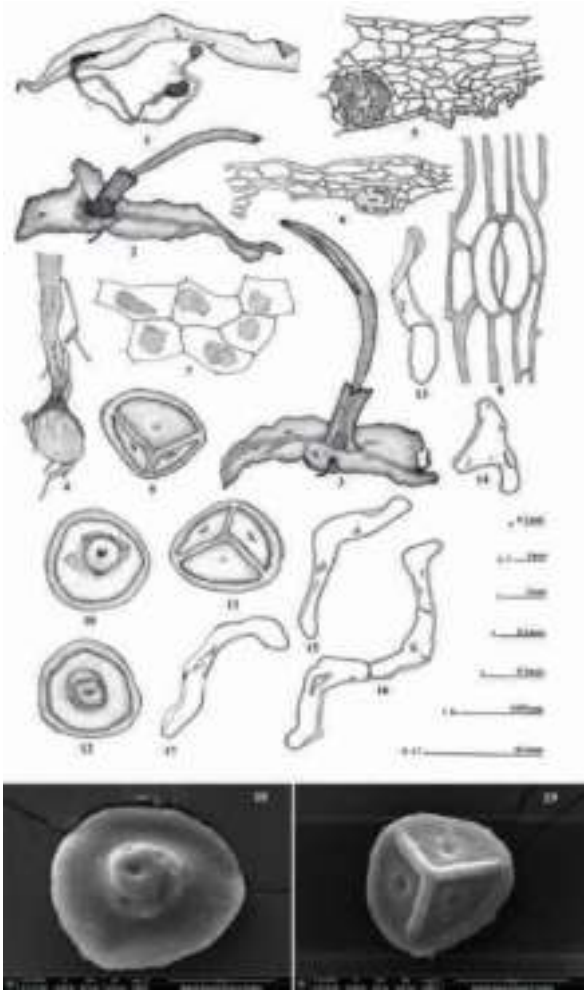

Fig. 1: *Phymatoceros phymatodes* (Howe) Duff & al-(1). A vegetative thallus with stalked tubers, (2-3). Female thallus, (4). A tuber with stalk, (5-6). Cross section of thallus, (7). Epidermal cells with chloroplast, (8). Epidermal layer of capsule wall with stomata, (9-11). Proximal face of spores, (10-12). Distal face of spores, (13-17). Pseudoelaters, (18). Distal face of spore with central hump, (19). Proximal of spore with notch on each triradial region.

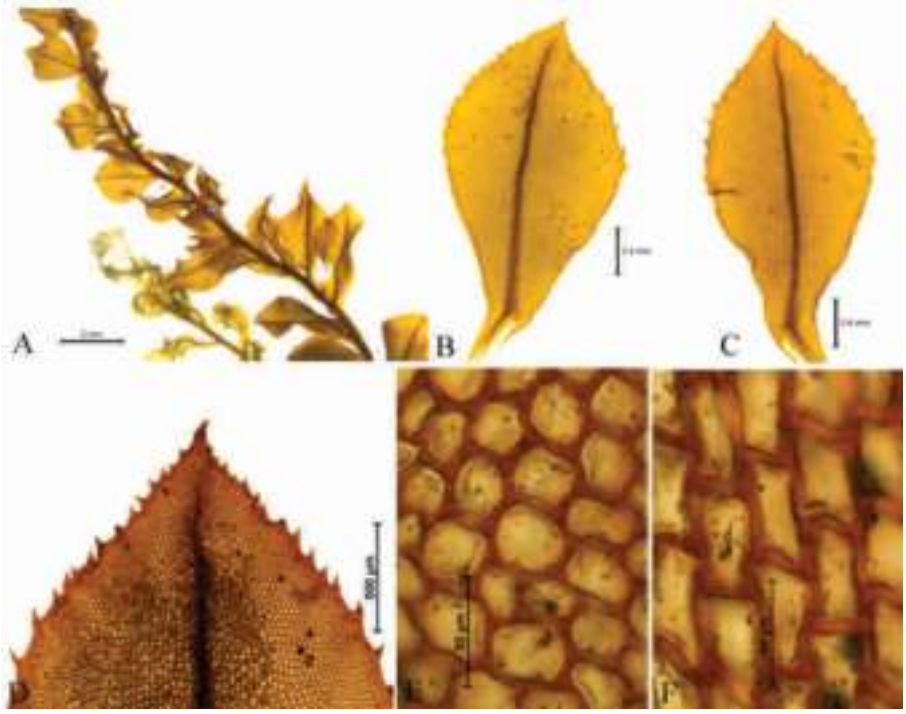

Fig. 2: *Plagiomnium japonicum* (Lindb.) T.J. Kop. (A). plant habit, (B-C). leaves, (D). leaf apex, (E). leaf median cells, (F). leaf basal cells.

locality. Later on, it was discovered in central India at Pachmarhi Biosphere Reserve (PBR). During recent field exploration, it was identified in Maharashtra at Matheran (Raigadh) and Brahmagiri hills (Trimbakeshwar). In the present state of our knowledge, this species is known only from above three localities in India after the various field surveys and investigations made in different bryogeographical regions of country till now. The plants were found in very few numbers and restricted in small pockets spreading across Mussoorie (Uttarakhand), PBR (Madhya Pradesh), Matheran and Trimbakeshwar (Maharashtra) with an 'extent of occurrence' of much less than 5000 km^2 and a highly restricted 'area of occupancy'. Therefore, as per the IUCN Red List categories and criteria version 3.1 (ref. 6), *Phaeoceros udarii* belongs to Endangered category [ENB1a + 2a; C2a(i)] at global level in the present state of our knowledge.

Another endemic species, ***Folioceros dixitianus* (Mahab.) D.C. Bharadwaj** was discovered in 1941 from Khandala (Western Ghats) and reported from only seven sites in the states of Maharashtra, Karnataka, Assam and Andaman of India with fragmentary populations in very restricted pockets at these sites. In a recent foray to Maharashtra to assess the conservation status of endemic hornworts of India, very few plants of this species have been identified in a very small isolated pocket of Brahmagiri hills at Trimbakeshwar (least disturbed site). Considering the population structure and current distribution status of this species according to IUCN guidelines, this species comes under Vulnerable (Vu) category.

***Folioceros satpurensis* K.P. Srivast. ex D.C. Bharadwaj & K.P. Srivast**. was discovered in 1978 from Pachmarhi (Madhya Pradesh). Since then, after several field collections from all over the India and recent exploration to the various sites of Pachmarhi *viz*., Pansy pool, Chhota Mahadev and Jambudweep, from where it was earlier reported, this species couldn't be found. Hence in the light of above facts it may be designated under critically endangered category . A critical investigation of the species has also been done with detailed study of morpho-taxonomic features.

Bryophyte diversity at Chambal Ravines

A field survey and exploration of bryophyte plant resources at Chambal ravines of Uttar Pradesh region and Madhya Pradesh region have been done for the first time. About Hundred samples of bryophytes were collected, studied, processed for preservation and deposited in the Herbarium of CSIR-NBRI, Lucknow (LWG). A critical and comparative morpho-taxonomic study of bryophytes has revealed that 11 taxa of mosses viz., *Barbula indica* (Hook.) Spreng., *B. dharwarensis* Dixon, *Desmatodon latifolius* (Hedw.) Brid., *Hydrogonium arcuatum* (Griff.) Wijk. & Marg., *H. pseudoehrenbergii* (M. Fleisch.) P.C. Chen, *H. javanicum* , *H. consanguineum* (Thwaites & Mitt.) Hilp., *Tortula hoppeana* (Schultz) Ochyra, belonging to family Pottiaceae, *Physcomitrium eurystomum* Sendtn., *Physcomitrium immersum* Sull. and *Funaria hygrometrica* Hedw. belonging to family Funariaceae and 5 taxa of thalloid liverworts viz., *Riccia billardieri* Mont. & Nees, *R. Discolour* Lehm. & Lindenb., *R. gangetica* S. Ahmad ex L. Soderstr and *R. Frostii* Austin belonging to family Ricciaceae, *Asterella*

wallichiana (Lehm. &Lindenb.) Grolle belonging to family Aytoniaceae occur in the above-mentioned localities. So far as distribution pattern of these taxa in the region is concerned *Barbula indica* and *Riccia discolor* form the dominant vegetation of bryophytes. All the taxa were found growing in the terrestrial habitat, on the soil of elevated ravines.

Assessment of bryophyte diversity in selected localities of Assam (North-East India)

A study on the quantitative estimation of diversity in the selected 32 grids at bryophyte rich localities of Assam lying-in North-East region has been carried out. Assessment has been made in 160 macroplots of 10×10 m, randomly established in the forest and within each macro-plot, multiple microquadrats (10×10 cm) were placed at different habitats *viz.* saxicolous, terricolous and epiphytic. A total of 80 taxa belonging to 29 species of liverworts under 18 genera and 10 families and about 51 species of mosses belonging to 27 genera and 13 families were assessed. In the study area, families Lejeuneaceae and Fissidentaceae and taxa *Cololejeunea latilobula* (Herzog.) Tixier and *Entodontopsis tavoyensis* (Hook ex Harv.) W. R. Buck & R. R. Ireland were the dominant. Four species are new additions to North-East India and seven taxa are new reports for Assam region. The present study elucidated the species diversity as well as the species richness and evenness of the region which can further define their importance in the community.

Floristic analysis of bryophytes of Manipur

During the assessment of moss diversity in various localities of Manipur, 126 species of mosses belonging to 84 genera in 34 families have been investigated and enumerated. Ten species, namely *Amblystegium serpens, Entodontopsis leucostega, Entodontopsis tavoyensis, Homalia trichomanoides, Lindbergia duthiei, Philonotis mollis, Philonotis thwaitesii, Taxiphyllum giraldii, Tortella humilis* and *Thuidium sparsifolium* are new additions to Eastern Himalaya, while 92 species of mosses have been reported for the first time from Manipur. Ten Indian endemic taxa have also been identified from the explored sites. The majority of the taxa were recorded from epiphytic habitats.

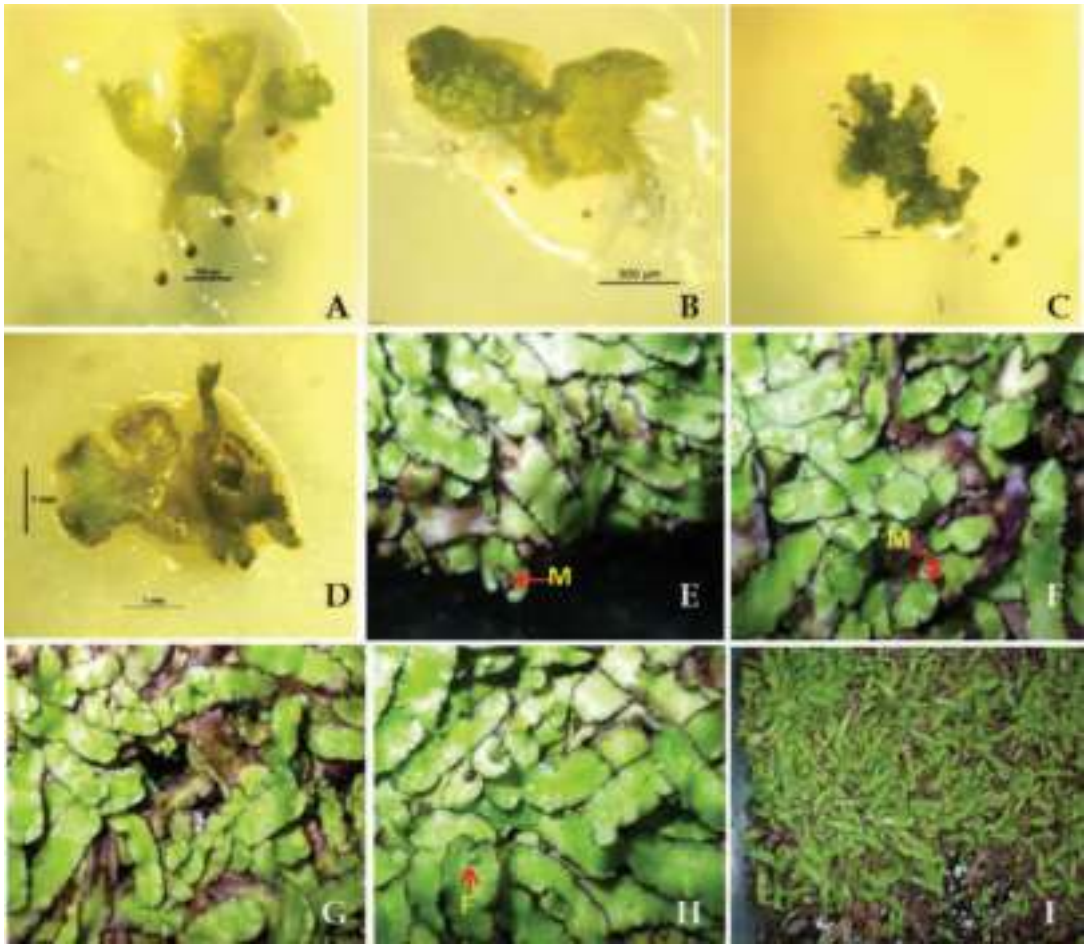

Fig. 3: (A-I): *In-vitro* propagation of *Plagiochasma intermedium* Lindenb. & Gottsche in Hoagland medium +1% sucrose. (A-B). Thallus growth during 8-9 weeks, (C-D). Development of dichotomously branched thalli during 9-12 weeks, (E-F). Mature (12 weeks old) thalli with male receptacle, (G-H). Well grown population of plants (with female receptacles) in tray during 7-11 weeks, (I). Bulk population of well-developed thalli in 16 weeks. (M - male receptacle, F - female receptacle).

Study on Indian Mniaceae

During the course of investigation of family Mniaceae, three genera and seven species (*Mnium heterophyllum* (Hook.) Schwaegr, *M. Lycopodioides* Schwaegr., *Orthomnion bryoides* (Griffith) Nork., *Plagiomnium acutum* (Lindb.) T.J. Kop., *P. japonicum* (Lindb.) T.J. Kop., *P. medium* (Bruch and Schimp.) T.J. Kop. and *P. rhynchophorum* (Hook.) T.J. Kop., of the moss family Mniaceae have been identified at Govind Wildlife Sanctuary (Uttarakhand). *Plagiomnium japonicum* is newly reported from India. *Orthomnion bryoides*, *Plagiomnium medium* and *P. Rhynchophorum* are new additions to the bryoflora of western Himalaya which were earlier known from eastern Himalaya only while *Plagiomnium acutum* is for the first time reported from Uttarakhand. A detailed morpho-taxonomic study of these species, with their current status has been carried out and completed.

In-vitro propagation and conservation

As a part of study on conservation, *in vitro* propagation of rare plant *Athalamia pinguis* Falc. has been done using Nitsch medium with and without IBA & BA; Nitsch medium with and without 1% sucrose. This experiment has revealed that Nitsch medium with IBA and BA is more suitable for in-vitro propagation of this species. Endemic hornwort, *Anthoceros bharadwajii* Udar & Asthana has been cultured in three different forms viz., semi-solid, solid and liquid of Hoagland medium. In vitro study of this plant has revealed that exine of spores ruptured only in semi-solid and solid medium, but germination rate was high only in semi-solid medium. However, further germination and growth occurred only in solid medium but not in liquid or semi-solid medium. Well-differentiated fan-shaped dichotomously branched young thalli were developed only in solid form of Hoagland medium after 26 weeks of inoculation. Potentially important liverwort *Plagiochasma intermedium* Lindenb. & Gottsche has been grown *in-vitro* for germplasm multiplication. Hoagland medium supplemented with 1% sucrose and ½ Knop's medium were used. This experiment has revealed that Hoagland medium with 1% sucrose is more effective. Broad thallus gradually developed with thick base and dark green dorsal surface, similar to plants in nature. Living germplasm has been multiplied using this growth medium Fig. 3 (A-I).

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

Floristic survey & biodiversity assessment

A baseline data on a diverse group of plants *viz.* algae (160 species), lichens (11 species), bryophytes (44 species), pteridophytes (17 species), gymnosperm (01 species) and angiosperms (341 species) of the Chambal ravines was prepared during the reporting period. A total of 1825 specimens of flowering and 337 specimens of non-flowering plants were collected in three subsequent plant survey-cum-collection tours in different areas of the Chambal ravines of Uttar Pradesh and Madhya Pradesh. Study on these collections revealed the occurrence of 214 species of angiosperms, 94 algae, 10 lichens, 7 bryophytes and 4 pteridophytes, with a new record of 2 species of algae, 2 lichens, 3 bryophytes, 1 pteridophytes and more than 12 species of angiosperms (Fig. 1A-K).

Grid-based (in 29 grids comprised of 6.25 x 6.25 km^2) survey for quantification and mapping of the plant diversity and population of threatened plants in Chambal Ravines Ecosystem (CRE) of Uttar Pradesh and Madhya Pradesh were performed to determine the current conservation status.

Baseline data on ethnobotanical usefulness of 136 species belonging to 112 genera under 47 families from the Chambal ravines was prepared. Information on the highest usefulness of 23 different species of plants was collected during the reporting period. Identified 13 potential plant species including *Enecostema axillare* (lowering blood glucose); *Capparis decidua* (useful in making pickles and sauces) being used by the local communities of CRE and playing key-role in their livelihood.

Fig. 1: Plant survey-cum-collection at Chambal ravines of Uttar Pradesh. A species of algae recorded(A). *Enteromorpha sp.,* (B). Magnified view of a branch of *Enteromorpha*, some of the lichen species collected, (C). *Endocarpon pusillum*, (D). *Heppia solorinoides,* some of the pteridophytes collected (E). *Marsilea minuta*, (F). *Azolla pinnata,* some of the angiosperms collected, (G). *Elytraria sp.,* (H). *Grewia sp.,* (I). *Tamarix sp.* and some of bryophytes collected, (J). *Barbula dharwarensis,* (K). *Riccia billardierii*

A database (user interface) named "Plant Resources of Chambal Ravines (PRCR) – A Digital Flora of Chambal Ravines" have been developed, which is accessible only on our local IP address (192.168.1.214/prcr). For now, this database consists of only secondary

data. The secondary data uploaded in the database has 101 species of algae, 11 lichens, 43 bryophytes, 18 pteridophytes and 106 angiosperm.

Survey-cum-collection and preliminary taxonomic study of 138 specimens of pteridophytes from Pachmarhi Biosphere Reserve in Madhya Pradesh has revealed the occurrence of 56 species under 36 genera.

Survey-cum-collection and preliminary taxonomic study of 59 specimens of pteridophytes from Suhelwa Wildlife Sanctuary (SWLS), Uttar Pradesh has revealed the occurrence of 12 species *viz. Helminthostachys zeylanica, Lygodium flexuosum, Christella dentata, Diplazium esculentum, Microlepias pleuncae, Adiantum philippense, Selaginella ciliaris, Selaginella* sp., *Adiantum incisum, Ampelopteris prolifera, Equisetum ramosissimum, Cheilanthes bicolor, Christella* sp., *Pteris biaurita* belonging to 11 genera under 9 families (Fig. 2A-H).

Survey-cum-collection and preliminary taxonomic study of 220 specimens of pteridophytes from west Kameng district of Arunachal Pradesh has revealed the occurrence of about 51 species under 30 genera belonging to 22 families.

Taxonomic study on 52 specimens of pteridophytes collected from different areas of Meghalaya and Nagaland with a record of their ecological data was made. A preliminary taxonomic study has identified the occurrence of 36 taxa under 23 genera.

Prepared updated baseline data on conservation status of five pteridophyte species *viz. Adiantum flabellulatum* L., *Cyathea contaminans* (Wall. ex Hook.) Copel., *C. crinita* (Hook.) Copel., *C. gigantea* (Moore ex Kuhn) Domin and *C. khasyana* (Moore ex Kuhn) Domin in India. A taxonomic study on 71 specimens of pteridophytes collected from different areas of Kerala and Tamil Nadu with a record of their ecological data has revealed the occurrence of about 32 species belonging to 19 genera, including the *Cyathea crinita.* A database on 102 consulted herbarium sheets on *Cyathea gigantea* (96 herbarium specimens), *C. crinita* (3 herbarium specimens), *C. contaminans* (1 herbarium specimen), *C. khasyana* (2 herbarium specimens) in five different herbaria *viz.* MH (Madras Herbarium, Coimbatore), RHT (Rapinat Herbarium, Tiruchirapalli), CALI (Calicut University Herbarium, Thenhipalam), CMPR (Centre for Medicinal Plants Research Herbarium, Kottakkal), KFRI (Kerala Forest Research Institute Herbarium, Peechi) were prepared.

Developmental biology & reproductive behavior

A study on distribution pattern of *Cyathea spinulosa* and *C. gigantea* was made. Spores of *Cyathea spinulosa* and *C. gigantea* were collected for *in-vitro* studies. Quantification of the population structure of these two species was done along with measurement of the morphological characters. *In-vitro* studies on spore viability, germination percentage and gametophyte developmental pattern of *C. gigantea, C. spinulosa* and *C. khasyana* were made. *In-vitro* studies in *C. gigantea* shown that, the spore germinated on 67th day with 17.42% germination. Gametophytes reached 3-6 celled stage with 28.22% germination on 72nd day and 9-11 celled filamentous stage with 31.88% germination on 79th day. Occasionally, uniseriate gametophytes showed branching and each branch elongates in uniseriate filament. The 2-d gametophyte develops on 86th days with 36.70%

Fig. 2: Some pteridophytes growing in the Sohelwa Wildlife Sanctuary Uttar Pradesh. (A). *Adiantum philippense,* (B). *Adiantum incisum,* (C). *Ampelopteris prolifera,* (D). *Cheilanthes bicolor,* (E). *Equisetum ramosissimum,* (F). *Lygodium flexuosum,* (G). *Helminthostachys zeylanica,* (H.) *Christella* sp.

germination, later becoming spatulate gametophytes on 93rd day with 40.24% germination; semi-cordate gametophyte on 107th and cordate gametophytes on 126th days with 56.97% germination. Numbers of small, sessile, globose antheridia developed at ventral side on 142nd days with 57.96% germination. An average of 10.6 antheridia per gametophyte were observed. Multiflagellar antherozoids released from the antheridia on 149th day with 58.65% spore germination. At this stage gametophytes did not shown appearance of any archegonia on 156th day with 59.72% spore germination. The germination pattern of spore is *Cyathea*-type and further prothalial development is *Adiantum*–type. The cultures (replicates of the petridishes) containing these gametophytes has shown 60.53% spore germination on 163rd day in composite culture. The germination percentage reached up to 61.60% on 177th day. The study is in progress. *In-vitro* study on pre-sexual, isolated gametophytes (in 20 replicates) of *C. gigantea* have been performed to observe the sexual expression and mating behaviour of the gametes on individual gametophytes to ascertain the preferential mating in homozygous or heterozygous gametophytes. The study is in progress. During *In-vitro* study on the reproductive biology of *C. khasyana*, spore viability was observed for a period of 1 year 4 months and 21 days after the date of collection. Spore germination begins on the 28th day with a spore germination percentage of 2.87%, reaching up to 2-3 celled stage with 5.23 % spore germination on 35th days. The apical 1-2 cells elongate and turn into a 6-7 celled filamentous stage. These 6-celled uniseriate gametophytes becomes 5-6 wide with 5.46% spore germination on 42nd day and develop into spatulate gametophytes on 49th day with 6.69% germination and bi-lobed gametophyte on 72nd day with 8.17% spore germination. Plurimeristematic activity resulted in multilobes gametophytes on 86th days with 31.97% spore germination. The gametophyte matures into the chordate stage with a deep apical notch on 93rd day onwards. Archegonia comprising (4-5 cells long) 4-tier of cells develop on the ventral side of the gametophytes on 107th day with 49.08% spore germination. An average number of archegonia (per gametophyte) were observed to be 7.6 on 107th day, and gametophyte remained archegoniate. Germination pattern of spore was *Cyathea*-type and prothalial development was *Adiantum*–type.

Mass Propagation

Propagation of 14 ornamental ferns viz. *Adiantum capillus-veneris, Colysis elliptica, Christella dentata, Diplazium esculantum, Microlepia strigosa, Microsorum punctatum, M. alternifolium, Nephrolepes biserrata, N. cordifolia, N. exaltata, N. tuberosa, Pteris vittata, Tectaria macrodonta, Selaginella bryopteris* (Sanjeevani Booti) was made to provide on sale. Large-scale propagation of *Pronephrium nudatum, Tectaria coadunate* and *Microsorum scolopendrium* has been made for prospection of potential molecules (Fig. 3A).

In-vitro multiplication and new introduction

The plantlets of *Asplenium nidus, Diplazium esculentum, Christella dentata, Dryopteris cochleata,* and *Pteris biaurita* were produced through *in-vitro* spore culture. *Christella dentata* have been introduced new to the fern house of CSIR-NBRI (Fig.3 B-D).

Fig. 3: (A). Large-scale propagation of *Pronephrium nudatum, Tectaria coadunata* and *Microsorum scolopendrium* for the prospection of potential molecules (B-D). *In-vitro* multiplication of *Christella dentata.*

Ex-situ conservation of plants in fern house

About 67 species of ferns belonging to different categories of conservation status have been maintained and conserved in the fern house. Live plants of *Cyathea gigantea, Sphenomeris chinensis, Asplenium cheilosorum* and *Paraleptochillus decurrens* were also brought to enrich the fern house.

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Diversity and floristic studies of algae

Diversity of algae in Chambal Ravines of Uttar Pradesh and Madhya Pradesh

Field explorations were conducted in the Chambal ravines of Madhya Pradesh and Uttar Pradesh for assessment of algal flora. A total of 120 algal samples were collected and identification resulted in 97 taxa belonging to 8 Classes (Cyanophyceae, Chlorophyceae, Trebouxiophyceae, Euglenophyceae Bacillariophyceae, Zygnematophyceae, Charophyceae and Ulvophyceae) belonging to 46 genera and 28 families (Chlorellaceae, Selenastraceae, Microcoleaceae, Gomontiellaceae, Coelosphaeriaceae, Bracteacoccaceae, Scenedesmaceae Desmidiaceae, Merismopediaceae, Pseudanabaenaceae, Bacillariaceae, Characeae, Zygnemataceae, Leptolyngbyaceae, Oscillatoriaceae, Euglenidae, Phacaceae, Coleofasciculaceae, Rivulariaceae, Chlamydomonadaceae, Nostocaceae, Sellaphoraceae, Cocconeidaceae, Catenulaceae, Gomphonemataceae, Synechococcaceae, Ulvaceae and Chroococcaceae) under 17 order (Chlorellales, Sphaeropleales, Oscillatoriales, Synechococcales, Desmidiales, Bacillariales, Charales, Zygnematales, Euglenida, Nostocales, Chlamydomonadales, Naviculales, Achnanthales, Thalassiophysales, Cymbellales, Ulvales and Chroococcales). The genus *Scenedesmus* occurred abduantly and frequently with 9 taxa followed by *Phormidium, Desmodesmus Spirogyra* and *Ankistrodesmus*.

Most diverse family is Cyanophyceae (43%) with 20 genera followed by Chlorophyceae (20%), Bacillariophyceae (11%), Trebouxiophyceae (9%), Zygnematophyceae (7%), Charophyceae (4%), Euglenophyceae (4%), and the member of Ulvophyceae (2%) limited in number with only **1** genera.

A total of 34 pure algal strains have been isolated under 3 classes - Cyanophyceae (6): *Limnothrix* sp., *Calothrix* sp., *Chroococcus* sp., *Westiellopsis* sp., *Blennothrix* sp., *Phormidium* sp.; Trebouxiophyceae (3): *Chlorella* sp1. *Chlorella* sp 2, *Chlorella* sp 3; Chlorophyceae (3): *Scenedesmus* sp 1, *Chlorococcum* sp. and *Scenedesmus* sp 2 and are maintained in the repository of Algology Laboratory, CSIR-NBRI. It's interesting to note that the freshwater Chambal River included *Enteromorpha intermedia* Bliding (Fig. 1), a macroalga generally seen in marine environments. Further work on isolation, identification, and maintenance of microalgae isolates are in process.

Fig. 1: (A&B) Micrograph of *Enteromorpha intermedia* Bliding documented from Chambal River.

Suhelwa Wildlife Sanctuary, Uttar Pradesh

A total of 25 algal samples were collected from Suhelwa Wildlife Sanctuary during the reporting period. The identification resulted in 32 taxa under 25 genera belonging to four classes, 11 orders and 15 families. Class Cyanopyceae which was found to be predominant resulted in a total of 24 taxa under 17 genera belonging to 10 families under six orders. This was followed by class Chlorophyceae with a total of six taxa under six genera belonging

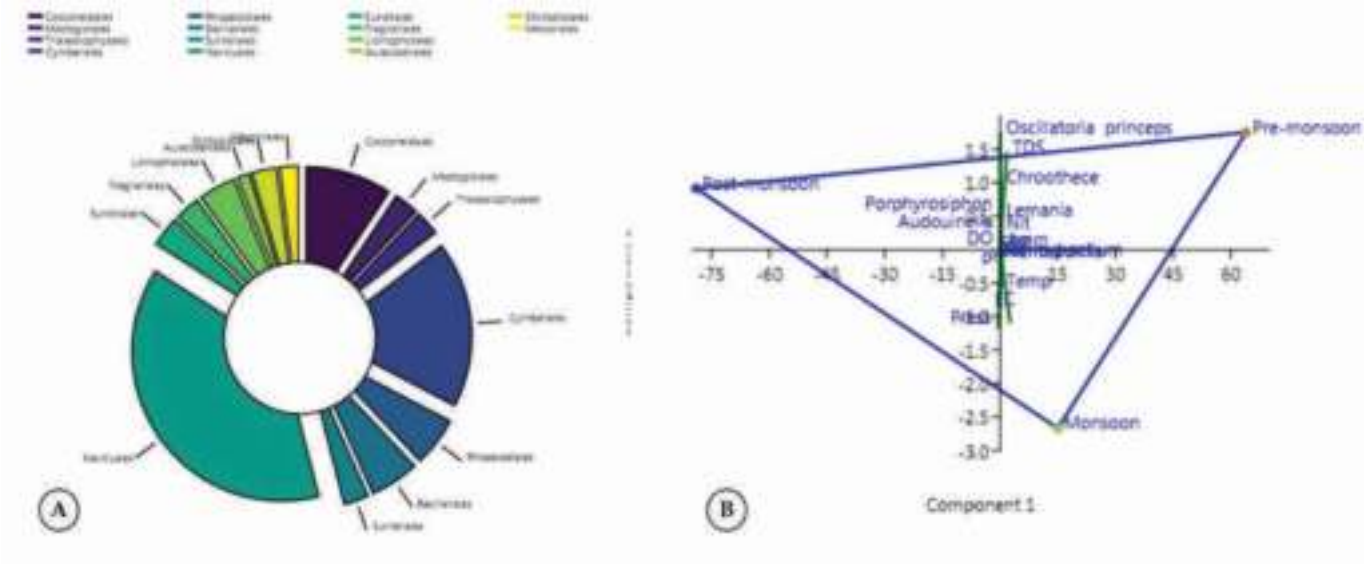

Fig. 2: (A). Diversity of diatoms from Jim Corbett National Park, Uttarakhand, (B)**.** Principal Component Analysis (PCA Plots) showing relationship between niche specific algal species and different seasons and environmental variables

to three families under three orders. On the other hand, Trebauxiophyceae and Euglenophyceae each documented as a single taxon each.

Jim Corbett National Park, Uttarakhand

Jim Corbett National Park was surveyed and more than 165 algal samples were collected. Identification of samples resulted in 116 taxa under Class Bacillariophyceae belonging to 38 genera, under 24 families (Melosiraceae, Benetoraceae, Aulacoseiraceae, Ulnariaceae, Fragilariaceae, Eunotiaceae, Diadesmidaceae, Pleurosigmataceae, Stauroneidaceae, Sellaphoraceae, Pinnulariaceae, Naviculaceae, Neidiaceae, Diploneidaceae, Surirellaceae, Bacillariophyceae, Rhopalodiaceae, Gomphonemataceae, Cymbellaceae, Anomoeneidaceae, Catenulaceae, Achnanthaceae, Achnanthidiaceae and Cocconeidaceae) belonging to 14 orders (Cocconeidales, Matogloiales, Thalassiophysales, Rhopalodiales, Cymbellales, Bacillariales, Surirellales, Navicuales, Eunotiales, Fragilariales, Licmophorales, Aulacoseirales, Stictodiscales and Melosirales). The most dominant order of diatoms that is reported from the park is Navicuales followed by Cymbellales and Cocconeidales.

The niche-specific algal species that were reported from the park includes a single taxon of *Porphyrosiphon* (Cyanophyceae), four taxa of red algae (Rhodophyceae): *Achrochaetium*, *Audouinella*, *Chroothece*, and *Lemania* and one taxon of *Trentepohlia* (Ulvophyceae). These niche specific algae play important role as they are indicator of the undisturbed ecosystem. The result of analysis of

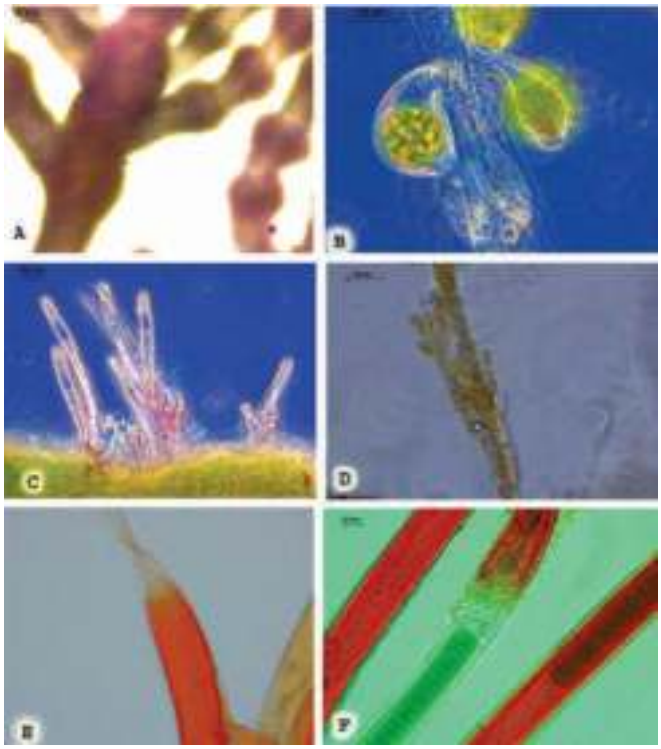

Fig. 3: Microphotographs of some freshwater microalgae documented from Jim Corbett National Park, Uttarakhand (A). *Lemania* sp., (B). *Chroothece* sp., (C). *Achrochaetium* sp., (D). *Audouinella* sp., (E-F). *Porphyrosiphon* sp.

the 10 physico-chemical parameters across 3 seasons (Post-monsoon, monsoon and pre-monsoon) were subjected to multivariate exploratory principal component analysis (PCA). PCA is explained by two components: Component 1 accounts for 99.89% variation and Component 2 accounts for 0.10% variation. Principal Component Analysis (PCA) showed that the interactions between niche specific algal species and abiotic indicators are strongly associated with three seasons (Fig. 2). This finding confirms the utility of PCA in the context of environmental parameters, specifically related to water quality of the park (JCNP). Niche algal species *Porphyrosiphon* and *Audouinella* showed positive interactions with post-monsoon season. *Chroothece*, *Lemania*, and *Oscillatoria princeps* showed positive interactions with pre-monsoon season. Total 26 pure algal strains have been isolated under 3 classes - Chlorophyceae (11), Trebouxiophyceae (4) and Cyanophyceae (11). These strains are maintained in the repository of Algology Laboratory, CSIR-NBRI. Water quality of the park has been classified under oligotrophic and oligo-mesotrophic status indicating clean water conditions. This is the first-time trophic status has been reported from the park.

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Angiosperm systematics, floristic diversity assessment, taxonomic monographs/revisions, biodiversity conservation

New plant species discovered

1. ***Calamagrostis nandadeviensis*** P. Agnihotri & D. Prasad, Phytotaxa 505 (2): 221–228. 2021 [Fig.1(I)]

A new grass species, *Calamagrostis nandadeviensis* was discovered from Nanda Devi Biosphere Reserve, Valley of Flowers National Park, Chamoli, Uttarakhand at an elevation of 3438m. The species differs from *C. lahulensis* by its 6.1–7.8 mm long ligule size (vs. 1.0–5.1 mm long), panicle effuse (vs. congested), callus hairs 1.0–2.6 mm long (vs. 0.8–1.2 mm long) and from *C. scabrescens* by its short, weakly geniculate awn, hardly exerted from spikelets and 2.6–4.5 mm long (vs. long, geniculate, exerted from spikelet and 4.5–7.7 mm long), however, differs from them by having palea apically deeply cleft (vs. almost entire) and lodicules fused in lower half (vs. not fused).

2. ***Bromus husainii*** **P. Agnihotri & R. Yadav,** Phytotaxa 516 (1): 073–082. 2021 [Fig.1(II)]

Bromus husainii, a new species of Poaceae was described from Valley of Flowers National Park, Uttarakhand at an elevation of 3567 m. The new species differs from *B. confinis* Nees ex Steud. (1854: 320) in having heteromorphic (normal and robust) spikelets (vs. single type spikelets); a band of hairs present on its collar (vs. absent); spikelets 3.3–4.3 cm long (vs. 1.5–2.5 cm long); upper glume 13–16 mm long (vs. ca. 9 mm long); lemma 17.3–20.5 mm long (vs. 10–15 mm long); awn 6–10 mm long (vs. 2.5–6 mm long); palea shorter than lemma (vs. as long as lemma); anthers 3.4–3.6 mm long (vs. 3.5– 4 mm long) and robust spikelets (vs. absent).

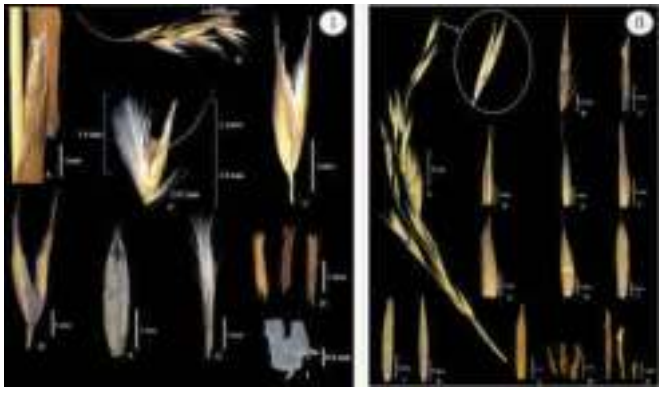

Fig. 1: New plant species discovered: (I). *Calamagrostis nandadeviensis sp. nov.*- (A). Ligule, abaxial view, (B). Lower branch of panicle, (C). Spikelet, (D). Upper and lower glume, lateral view, (E). Floret, (F). Palea, (G). Rachilla extension, (H). Anthers, (I). Lodicule; (II). *Bromus husainiisp. nov.*- (A). Inflorescence, (B). Robust spikelet, (C). Lower glume, (D). Upper glume, (E–K). Lemma, (L). Palea, (M). Anthers, (N). Gynoecium

3. ***Trisetopsis pirpanjalensis*** D. Prasad & P. Agnihotri, Nordic Journal of Botany. *39 (11): 1-10. 2021 [Fig. 2 (I)]*

A new grass species *Trisetopsis pirpanjalensis* was described from the Western Himalaya (Himachal Pradesh, Kullu, Manali) in India at an elevation 3000 m a.s.l. The reported species differs from *Trisetopsis virescens* by having ligules 0.4–0.5 mm long (vs. 1–5 mm long), collar densely bearded (vs. glabrous), lower panicle branches in 2 whorls (vs. 3–4 whorls), spikelets 8.2–10.2 mm long (vs. 12.5–14.6 mm long) and bearing 2 fertile florets and 1 diminished floret (vs. 3–4-fertile florets and 1 diminished floret), lower glumes 4.3–6.4 mm long (vs. 6.8–7.2 mm long), lemmas 7–9 mm long (vs. 9.4–9.8 mm long), paleas 6.1–6.5 mm long (vs. 7–7.4 mm long) with entire apex (vs. bifid).

4. ***Tzveleviochloa yadavii*** D. Prasad & P. Agnihotri, Nordic Journal of Botany. *39 (11): 1-10 [Fig. 2 (II)]*

The new species *Tzveleviochloa yadavii* was discovered from Himachal Pradesh, Kullu, Manali at an elevation of 3450 m a.s.l. The species differs from *Tzveleviochloa parviflora* by having panicle interrupted in lower part (vs. consistent, not interrupted) and lower branch ascending, 2.5–3.0 cm long (vs. spreading, 5–9 cm long), spikelet 8.2–9.5 mm long (vs. 7.0–8.2 mm long) and bearing 2 fertile florets and 1 diminished floret (vs. 3–4-fertile florets and diminished floret), lower glume 1-nerved (vs. 3-nerved), palea keel ciliolate (vs. long ciliate) and anthers 3.0–3.5 mm long (vs. 1.3–2.0 mm long).

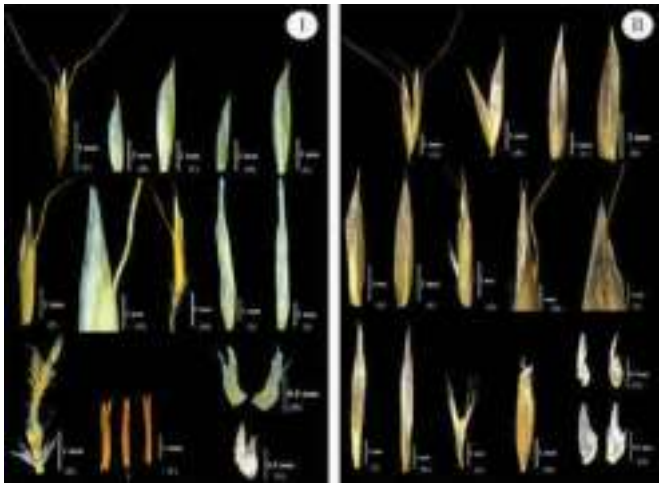

Fig. 2: New plant species discovered: (I). *Trisetopsis pirpanjalensis* sp. nov.- (A). Spikelet, (B). Lower glume, ventral view, (C). Upper glume, lateral view, (D). Lower glume, lateral view, (E). Upper glume, lateral view, (F). Lemma, (G). Lemma, apical view, (H). Upper floret, (I). Palea, dorsal view, (J). Palea, ventral view, (K). Ovary and lodicules, (L). Anthers, (M–N). Lodicules; (II). *Tzveleviochloa yadavii* sp. nov.- (A). Spikelet, (B). Glumes, (C). Lower glume, dorsal view, (D). Upper glume, ventral view, (E). Upper glume, dorsal view, (F). Upper glume, ventral view, (G). Lower floret, (H). Lemma apex, later view, (I). Lemma apex, dorsal view, (J). Palea, dorsal view, (K). Palea, ventral view, (L). Rachilla, (M). Caryopsis, (O). Lodicules.

5. ***Rottboellia husainii*** P. Agnihotri & S. Tripathi, *Phytotaxa* 507 (1): 098–104. 2021 (Fig. 3)

A new species of *Rottboellia* (Poaceae), *R. husainii* is described from Rakh Jargoh village in Ramban district of Jammu and Kashmir, India. The reported species differs from *R. cochinchinensis* by hairy leaf sheath margin (vs. glabrous), spikelets 5.5–6.5 mm long (vs. 3.5–5.0 mm long), pedicels 3.5–4.0 mm long (vs. 3.0–3.5 mm long); glumes 5.5–6.0 mm long (vs. 4.5–5.0 mm long) and glumes bearing tuberculate spiny hairs on upper margin (vs. glabrous) and anthers 3.0–3.5 mm long (vs. 2.0–2.5 mm long).

Fig. 3: New plant species discovered: *Rottboellia husainii* P. Agnihotri & S. Tripathi – (A). Culm and leaf sheath, (B). Ligule, (C). Nodes of the culm, (D). Inflorescence, (E–F). Pair of spikelets, (G). Sessile spikelet, adaxial view, (H). Sessile spikelet, abaxial view, (I). Pedicel, (J). Lower glume of sessile spikelet, (K). Upper glume of sessile spikelet, (L). Joint (internode), (M). Upper lemma, (N). Palea, (O). Anthers

Systematic studies

As part of ongoing study in the family Poaceae from western Himalaya, frequent field visits were made to assess the diversity and collection of grass specimens in different localities of the western Himalayas. Based on the botanical survey as well as scrutiny of literature, we found that most taxa of subfamily panicoideae and chloridoideae exhibit dominance in tropical to subtropical regions while subfamily pooideae in temperate to the alpine region of western Himalaya. A total of ca 600 specimens

were collected, of which 90 species belonging to 26 genera in subfamily pooideae, 22 species under 11 genera in subfamily panicoideae, and 18 species under 8 genera in subfamily chloridoideae have been identified. In addition to plant collections, grass specimens housed at BSD, DD, CAL, and BSHC were also examined. A detailed systematic study in genus *Muhlenbergia* Schreb. has been carried out. In addition, two species in genus *Eragrostis* Wolf *i.e., E. aspera* (Jacq.) Nees and *E. macilenta* (A.Rich.) Steud. and one species of *Papalum canarae* (Steud.) Veldkamp were reported for the first time from western Himalaya, while *Elymus nepalensis* (Melderis) Melderis and *Agrostis clavata* Trin. were found as new record for India. Moreover, *Setaria homonyma* (Steud.) Chiov. was reported for the first time from Jammu & Kashmir. The study also revealed a rediscovery of *Agrostis schmidii* (Hook.f.) C.E.C. Fisch after two centuries as well as the first geographic record from Himalaya. Typification has been done in the genus *Arundinella* Raddi, *Duthiea* Hack. ex Procop., *Eragrostis,* and *Urochloa* P.Beauv. An update on taxonomy along with morphometrics and micromorphological studies in *Calamagrostis nagarum* (Bor) G. Singh and its allies has also been carried out. Further, the taxonomy of *Helictotrichon schmidii* (Hook.f.) Henrard was revisited with updated regional distribution and conservation status.

The genus *Anemone* comprising more than ca. 150 species (Tamura 1995; Ehrendorfer et al. 2001; Schuettpelz et al., 2002) is one of the largest genera in the family Ranunculaceae, distributed throughout the world but most commonly and majority of species occurs in temperate zones of the Northern hemisphere as compared to Southern hemisphere. Based on molecular phylogenetic studies, *Anemone s.l.* from India which comprises 26 taxa (Rajput et al. 2020), has been split into six genera viz., *Anemonastrum*, *Anemone s.s.*, *Anemonoides*, *Eriocaptiella*, *Hepatica* and *Pulsatilla*. Out of these 26 taxa, 14 taxa have been shifted to *Anemonastrum*, two species to *Pulsatilla* whereas three species into *Eriocapitella*. *Anemonoides* contains a single species, *Anemonoide griffithii* (Hook.f. & Thomson) Holub, found in Eastern Himalaya of India whereas *Anemone s.s.* were documented with only four species named, *Anemone coronaria, A. howellii, A. raui* and *A. tscherwanaii*.

Total six field visits were conducted in the states of Himachal Pradesh, Uttarakhand, & Sikkim and collected 11 species of *Anemone* i.e., *Anemone elongata* D. Don, *A. falconeri* Thomson, *A. obtusiloba* D. Don, *A. polyanthese* D. Don, *A. raui* Goel & U.C. Bhattach., *A. rivularis* Buch.-Ham. ex DC., *A. rupicola* Cambess., *A. smithiana* Lauener & Panigrahi, *A. tetrasepala* Royle., *A. trullifolia* Hook.f. & Thomson and *A. vitifolia* Buch.-Ham. ex DC. One typification also has been done in *Anemonoides griffithii* (Hook.f. & Thomson) Holub.

Anemone raui Goel & U.C. Bhattach., an endemic species has restricted distribution in Uttarakhand of Western Himalaya at elevation ranging from 2500 to 3500 m asl. Considering the importance of phytochemicals and ethnobotanical uses of genus *Anemone*, identification of potentially bioactive compounds by GC-MS analysis in *Anemone raui* has been made. A total of nine phytochemical components of various classes were characterized such as pentasiloxane, dodecamethyl (15.6%), 15-hydroxy-7-oxodehydroabieticacid,methylester,15-trimethylsilyl (14.1%), cyclohexasiloxane, dodecamethyl (12.5%), tetradecamethylcycloheptasiloxane (11.6%), tetrasiloxane, 3,5-diethoxy-1,1,1,7,7, 7-hexamethyl-3,5 (11%), and 2-hydrazino-4,6-dimethylpyrimidine tritms (10.3%) were found as the major compound whereas three minor compounds viz. anthraquinone, 1,2,4-trimethyl (6.4%), fluoren-9-ol, 3,6-dimethoxy-9-(2-phenylethynyl) (8.8%), and cyclopentasiloxane, decamethyl (9.3%) were also found.

Floristic studies

Pangi Valley is one of the most remote tribal territories in Himachal Pradesh concealed between the Pir Panjal and Zanskar mountains of the Western Himalaya. The valley is a cold semi-desert area in the Trans Himalayas with rugged terrain, harsh weather, little rainfall, and considerable snowfall. It is drained by the Chandrabhaga (Chenab) river and is separated into three forest ranges viz., Sach, Killar and Purthi. The only protected area in this region is Saichu Tuan Nala Wild Life Sanctuary, to protect and preserve the flora and fauna there, thus, it serves as one of the valley's wildlife refuges. The valley shows enormous floral diversity including rare, endemic, and endangered plant species. To fulfil the objective of floristic study, three field trips have been executed to the Pangi valley and a total of 350 specimens have been collected. Approximately 80 species belonging to 36 families have been identified.

The vegetation of Pangi includes three types of forests viz. the Himalayan Temperate Forests (at low altitudes between 1,900-2,800 m) commonly inhabited by

Abies spectabilis, Cedrus deodara, Picea smithiana, Pinus gerardiana and *P. wallichiana*; the Subalpine Forests (at altitudes between 2,800-3,800 m) commonly represented by *Allium humile, Angelica glauca, Bunium persicum, Bupleurum falcatum, Carum carvi, Elsholtzia ciliata, Geranium wallichianum* and *Heracleum lanatum* while the Alpine Forests (at altitudes above 3,800 m) occupied by *Arnebia euchroma, Betula utilis, Capparis himalayensis, Cassiope fastigiata, Cortia depressa, Corydalis meifolia, Myricaria squamosa, Primula macrophylla, Rhododendron campanulatum, Saussurea graminifolia,* etc. People in tribal communities have long relied on natural resources to meet their daily requirements, and plants are their only source of health care. In the process, they discovered a variety of ethnobotanical uses of the plant wealth. The majority of plants are used to treat stomach issues, fever, cough, and skin diseases.

Pindari valley lies between the Nanda Devi and Nandakot peaks in Bageshwar district of Uttarakhand. Pindari Glacier gives rise to Pindar river which drains the valley. The trail to reach the glacier crosses the villages of Saung, Loharkhet, over the Dhakuri, pass onto Khati village (the last inhabited village on the trail), Dwali, Phurkia and finally zero point Pindari. The vegetation is affected by the climatic conditions and range of altitude prevailing in the valley. To fulfil the objective of floristic study, three field trips have been executed to the Pindari valley and a total of 450 specimens have been collected. Approximately, 200 species belonging to 110 genera have been identified. The high mountainous region is covered with green forest of grasses, known as bugyals. *Quercus leucotrichophora, Q. semecarpifolia, Alnus nepalensis, Acer caesium, Aesculus indica, cedrus deodara, Pyrus pashia, Juglans regia* and *Ulmus wallichiana, Rhododendron arboretum, R. campanulatum* etc. are the main components of trees diversity. At higher altitudes, pure patches of *Betula utilis* are found with luxuriant growth. The valley is also home to some high value medicinal plants viz., *Aconitum heterophyllum, Aconitum violaceum, Anemone obtusiloba, Arnebia euchroma, Bistorta affinis, Corydalis cashmeriana, Dactylorhiza hatagirea, Fritillaria roylei, Jurinea dolomiaea, Malaxis muscifera, Nardostachys jatamansi, Paris polyphylla, Picrorhiza kurrooa, Sinopodophyllum hexandrum* and *Trillium govanianum*.

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Floristic inventory, documentation of bioresources, plant conservation and systematic studies of the plant groups

New plants species discovered

***Geranium indicum* Imtiyaz Hurrah & Vijay Wagh, Nordic Journal of Botany 40(1): 1-11. 2021. (Fig. 1A)**

The new species *Geranium indicum* is similar to *G. ocellatum* Cambess. in having persistent basal rosette leaves, with cordate lamina base, non-accrescent sepals and glabrous mericarps transversely wrinkled with less prominent ribs, but most obviously different in their habit; the former being acaulescent while the latter is caulescent with erect or ascending stem. In addition, the new species differs from *G. ocellatum* in having orbicular and palmatipartite leaves with an obtriangular middle segment, scapigerous cymose inflorescense, solely eglandular hairs on vegetative parts, and shorter staminal filaments and fruits. *Geranium indicum* is reported from Kasauli and Daghshai (Himachal Pradesh), Bageshwar, Purola and Mussoorie (Uttarakhand) India. It grows in open grassland, along roadsides in gravel, underneath pine forest at an altitude of 900–2000 m a.s.l.

***Geranium ocellaum* var. *albiflorum* Imtiyaz Hurrah & Vijay Wagh, Phytotaxa 530(3): 271-279. 2022 (Fig. 1B.)**

During recent floristic surveys in Tehri district of Uttarakhand, we detected a population of *Geranium*, growing in grassy patches of temperate forests. After critical examination, it was found to represent an undescribed variant of *Geranium ocellatum* Jacquem ex Cambessèdes. which belongs to *Geranium* subg. *Robertium* sect. *Trilopha* Yeo. The present taxon exhibits differences in flower color and inflorescence type. Therefore, it is recognized as a new variety of *Geranium ocellatum*. *G. ocellatum* var. *albiflorum* is similar to the type variety *G. ocellatum* var. *ocellatum* but differs in having petals with white-coloured base (*vs* dark purple base), inflorescence dichasial (*vs* monochasial inflorescence) and peduncle (0–)1–4.5 cm long (*vs* (0–)1–8 cm long). The species grows on hill slopes in pine forest, on road margins and in low grassland vegetation at an elevation of 1500–1700 m a.s.l.

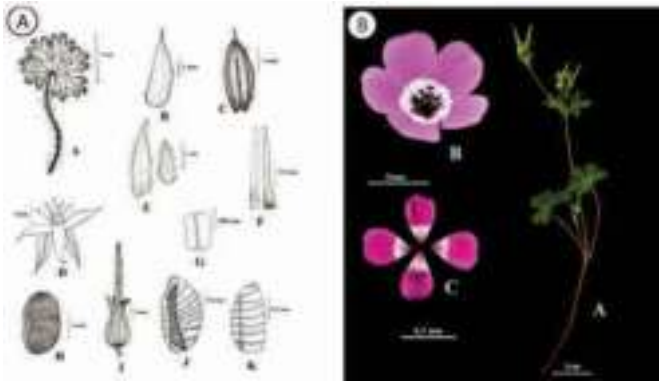

Fig. 1: Newly discovered taxa of *Geranium* (A). *Geranium indicum* Imtiyaz Hurrah & Vijay Wagh, (B). *Geranium ocellaum* var. *albiflorum* Imtiyaz Hurrah & Vijay Wagh

Floristic inventory, plant systematic studies and conservation of plant species

Plant systematic studies

***Geranium* L. (Geraniaceae)**

Geranium L. is a large genus, with ca. 325 species, distributed in almost every continent and ecosystem, being absent only at the poles, arid deserts and low-altitude tropical areas. In recent floristic survey conducted in different localities of Indian Himalayan Region one new species and one variety i.e. *Geranium indicum* and *Geranium ocellatum* var. *albiflorum* have been discovered.

During the course of ongoing revisionary studies on *Geranium* from India, we found that the typification of *Geranium arnottianum* Steud. is incomplete and needs to be updated. The specimen with barcode E00174280 provides marked exhibition of the diagnostic characters of *G. arnottianum*: peduncles much longer than leaves, stipules lanceolate with acuminate apex, leaf segments cuneate, ovate and villous on the nerves beneath, petals twice as long as the sepals. Therefore, among all the original materials, E00174280 is selected as the lectotype of *G. arnottianum*.

Tribe *Boehmeriae* (Urticaceae)

The apomictic genus is the largest genus in tribe *Boehmerieae*. A total of 47 species are currently known from both new world and old world, out of which 15–20 species are known from Indian territory, distributed mostly in tropical regions and infrequently in temperate regions. field tours were conducted in different states of India viz. Jammu and Kashmir, Maharashtra, Uttarakhand and West Bengal for the collection of the specimens of tribe Boehmerieae . Some herbaria including BLAT, SUK, BSI, MH, DD, BSD and LWG were also consulted for taxonomic and nomenclature studies.

Boehmeria clidemioides Miq. was recorded for the first time in Uttarakhand state of India. Until now it has only been known from eastern Himalayan region of India.

Systematic studies on genus *Rhynchosia* (Leguminosae)

The genus *Rhynchosia* Lour. belongs to the subtribe Cajaninae, tribe Phaseoleae, in the family Fabaceae. The genus is the largest in the subtribe, comprising about 232 species, distributed throughout the tropics and subtropics and extending to North America from Mexico to some parts of the United states as well as in Africa and Madagascar where it is most diverse. Presently, in India the genus is represented by 28 species, one variety and one subspecies of which 7 species are endemic to India and around 60% are found in Eastern Ghats. Five field tours were conducted in different state of India (Uttarakhand, Maharashtra, Madhya Pradesh, Rajasthan, Gujarat Tamil Nadu etc.) and more than 200 specimens were collected during the reporting period. In addition to field survey, different national and international herbaria were also consulted.

Rhynchosia suaveolens is reported for the first time from the Vidarbha region of Maharashtra. It is also rediscovered after 144 years from Maharashtra. Previously this species was recorded only from the southern part of India.

During the revisionary study of the genus *Rhynchosia* in India, we realized the need for typification of *Glycine aurea*, the basionym of *Rhynchosia aurea* (Wildenow) Candolle, therefore, the original material is established and lectotype is designated following (Art. 9.3) of the International Code of Nomenclature.

While studying the nomenclature status of *Rhynchosia suaveolens*, we discovered the typification of this species is needed. In order to select the lectotype for the homotypic names viz. *Rhynchosia suaveolens* and *Glycine suaveolens*. The specimen housed at LINN (LINN 901.18) is the best preserved specimen, henceforth selected as a lectotype whose original label bears the description of *G. suaveolense*, the handwriting on the label is also matched that of Filius Linnaeus and the specimen is housed at C (C10012343) as an isolectotype.

Plant resource mapping of Chambal ravines

Three field tours were conducted in Chambal ravines of Madhya Pradesh (Sheopur, Morena and Bhind district) and Uttar Pradesh (Etawah and Agra district). Total 1650 angiosperm specimens belonging to 176 genera, 72 families and 258 species were collected. *Prosopis juliflora*, *Capparis decidua*, *Capparis sepiaria* and *Salvadora persica* were found to be the dominant species of the region.

Threat assessment of traded forest flora of Madhya Pradesh

Madhya Pradesh harbours a rich flora and fauna and has always been a center of attraction for botanists. Right from the beginning, the vegetation of this state has been studied from various points of view. Many medicinally important plants occur in this state, of which several species are threatened, endangered, and endemic and have also been being reported from the protected areas of Madhya Pradesh.

Five field tours were undertaken in Madhya Pradesh state to locate the targeted traded rare and threatened plants. Local wholesale markets were also visited to collect the information related to traded medicinal plants. Through the field survey and consultation of secondary data, we have documented 168 traded

plant species. They belong to 69 families, out of which 65 were angiosperms and 4 were pteridophytes. Out of the 168 traded plants species, 66 were herbs, 18 were shrubs, 57 were trees, and 22 were climbers. The family Fabaceae contributed the highest number of plants (25 species), followed by the Apocynaceae (8 species), Asteraceae (6 species), and Orchidaceae (6 species). Three families (Malvaceae, Combretaceae, and Asparagaceae) had five plant species each. Roots and fruits were the most frequently traded plant parts accounting for 48 species and 31 species, followed by seeds (27 species), whole plant (21 species), bark (15 species), leaf and wood (12 species each) and gum (11 species) (Fig. 2). Most traded plant parts were harvested from the aerial parts of the plant (53%) and the rest comprised of underground and the whole plants (47%). Using primary and secondary data, the preliminary threat status has been assessed. The critically endangered category represents 21 species, endangered 24 species, vulnerable 35 species, near

Fig. 2: Most traded plant parts of the traded plant species

threatened six species, and data deficient 79 species (Fig. 3). A total of 85 plant species comes under the threat category, and faces severe threat due to exploitation. The market demand for these species is very high and the extraction of these species is from the wild only.

Floristic diversity assessment in the sacred groves of Yavatmal district Maharashtra

During reporting period, five floristic surveys were conducted in Yavatmal district of Maharashtra for the

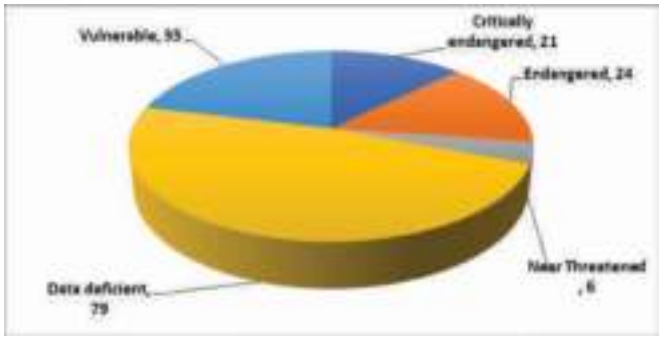

Fig. 3: Number of Taxa in each threat category

documentation of ethnomedicinal uses and floristic diversity. Three new sacred groves Shila Shivay, Karai mata and Lahan bhisa Hanuman were discovered from the study area namely. Total 350 accessions were collected revealing 198 species. Out of total species 125 species are ethnomedicinally important and playing important role not only in primary health care but also in livelihood enhancement.

Conservation of threatened plants

Introduced 38 plant species of threatened as well as wild ornamental category in Botanic Garden of CSIR-NBRI collected from the Shivaji University, Kolhapur as well as parts of western ghat.

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Angiosperm taxonomy, floristics, and plant conservation assessments

New plant species discovered

***Eugenia pokkudanii* A.M. Maya & al., Phytotaxa 502 (3): 283–288 (Fig. 1 A-C)**

This new species in *Eugenia* (Myrtaceae) was described from the Nelliyampathy hill ranges in Palakkad District of southern Western Ghats. *Eugenia pokkudanii* differs from the allied *E. discifera* by the shape, size and indumentum of leaves, number of lateral nerves, 0.7–1 cm across small flowers, oblong bracteoles and broadly elliptic petals. *Eugenia pokkudanii* is a shrub to small tree between 900 to 1000 m elevation. The species is named in honor of the late Mr. Kallen Pokkudan (1937–2015), an environmental activist from the state of Kerala, India, in recognition of his efforts for the protection and proliferation of the mangrove forests in Kerala.

Fig. 1: ***Eugenia pokkudanii***. A. Habit, B. & C. Flowering and fruiting twigs;

***Tripogon sugathakumariae* Jabeena & al., Phytotaxa 536 (1): 101–105 (Fig. 2 A-F).**

Tripogon sugathakumariae (Poaceae), a new species has been described from the Nelliyampathy hill ranges in Palakkad Districts of southern Western Ghats. The new species *T. sugathakumariae* differs from the allied *T.bromoides* by the distinct eciliate membraneous

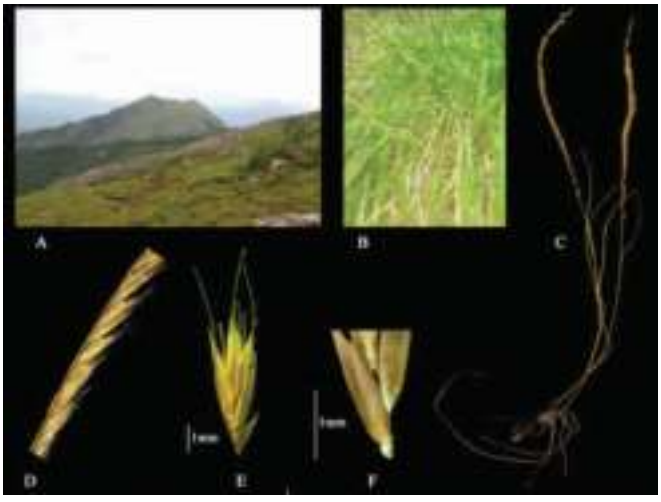

Fig. 2: ***Tripogon sugathakumariae*** A. Habitat. B. & C. Habit. D. Portion of raceme. E. Single spikelet. F. A portion of spikelet showing callus hairs

ligule fringed with long hairs at the ends of leaf sheath, straw-coloured spikelets, unidentate awned upper glume, 3-lobed and 3-awned lemma without a definite lobe between the median and lateral awns and the median awn equal or slightly longer than lemma. The new species grow at an elevation of 1100–1200 m in open montane grasslands along with *T. bromoides*. The specific epithet is named after the renowned writer in Malayalam poetry, who stood with her strong words for mother Nature

and conservation of natural resources, Padmasree Smt. Sugathakumari. She was at the forefront of environmental and feminist movements in Kerala and played a prominent role in the save Silent Valley movement.

Revisionary/other taxonomic studies undertaken

Systematic analysis of the genus *Eriocaulon* L. in India based on molecular and morphological evidence. Systematics and Biodiversity, 19:7, 693-723 (Fig. 3 A-L, Fig. 4 A-K).

The genus *Eriocaulon* L. (Eriocaulaceae) is one of the most diverse genera of Eriocaulaceae and around one-quarter of the world's representation is in India. The taxonomy of the genus has been challenging due to high intraspecific and low interspecific variation. With about 70% of Indian species endemic to the country, sparse representation in earlier phylogenetic studies did not provide phylogenetic resolution of Indian species. This is the first-ever comprehensive molecular systematic study of Indian *Eriocaulon* species based on the critical appraisal of the freshly collected 552 accessions of 66 *Eriocaulon* spp., a critical analysis of morphology including microscopic seed surface characters of 55 species was made for the first time. Phylogenetic analyses based on ITS and *trn*L–F data yielded three major clades of Indian *Eriocaulon* species. Based on the morphological and molecular data, *Eriocaulon baramaticum, E. govindiana, E. gulnarparianum, E. idukkianum, E. maharashtrense and E. pradeepii* were synonymized. Also, *Eriocaulon rhodae* was reinstated. Our molecular data exhibited little congruence with the earlier available taxonomic treatments for Indian species. Several morphological characters were also mapped onto a phylogeny and none were found to characterize monophyletic groups.

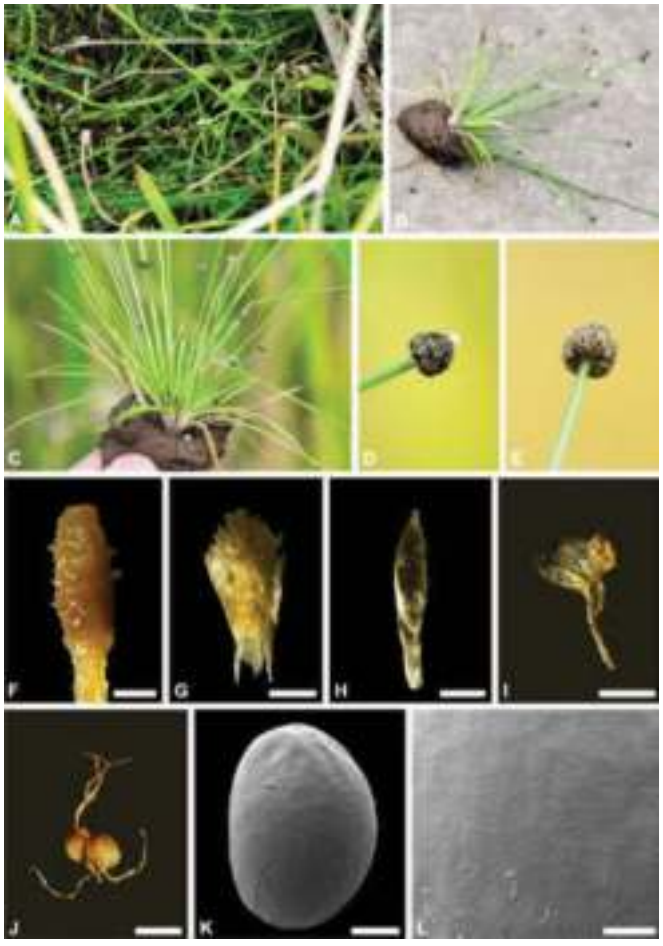

Fig. 3: ***Eriocaulon cinereum.*** A. Habitat, B. Habit, C. Leaves, D. & E. Heads, F. Receptacle, G. Involucral bract, H. Floral bract, I. Male flower, J. Female flower, K. Photomicrograph of seed, L. Seed appendages

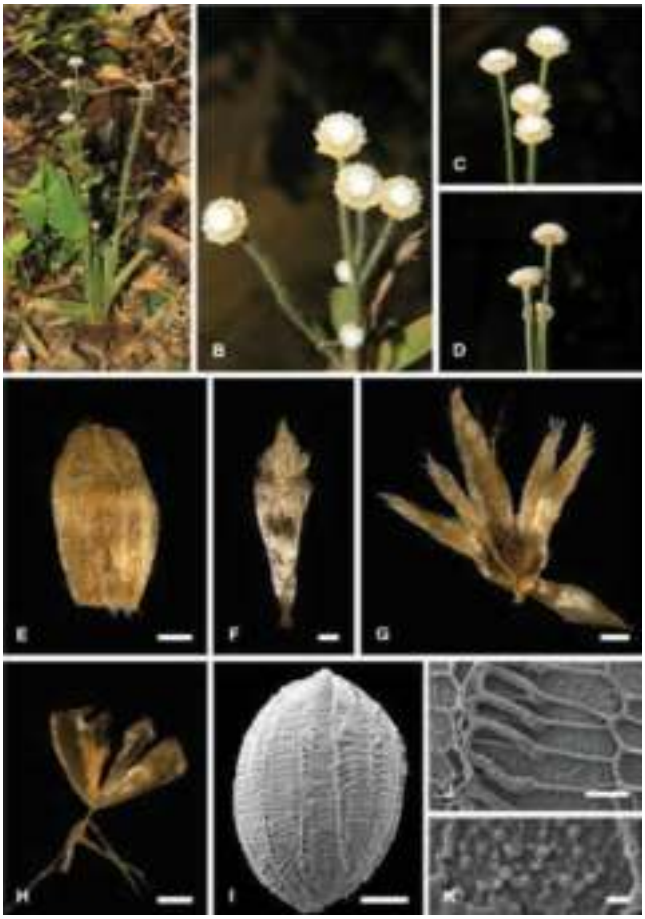

Fig.4: ***Eriocaulon rhodae.*** A. Habit and Habitat, B. to D. Heads, E. Involucral bract, F. Floral bract, G. Female flower, H. Male flower, I. Photomicrograph of seed, J. Seed appendages, K. Seed surface

Taxonomic and phylogenetic studies on *Impatiens* Sect. *Annuae* (Balsaminaceae)

The study focused to address the systematics and molecular phylogeny of the *Impatiens* species under the section *Annuae* found in Western Ghats using morphological as well as molecular markers. It will also help us to understand the intraspecific distribution of *Impatiens* and various bioclimatic factors associated with it. This is the first-ever attempt to integrate morphological, phylogenetic and ecological studies to understand a genus which has a great proportion of endemic species in India.

Taxonomically, the genus *Impatiens* is difficult to classify. Due to the semi-succulent stems and fleshy leaves, providing well-dried herbarium specimens are challenging. Flowers are extremely fragile and in dried specimens most are folded and coalesced, making separation and reconstruction of the different parts laborious. Conversely, due to the hypervariable flower morphology within the genus, determining shapes and sizes of sepals and petals is crucial for identification. In addition, capsules and seeds are quite diverse and often considered to be important morphological characters for solving classification issues. Because of the explosive nature of mature seed pods, seeds or fruits are often missing on herbarium specimens. Descriptions of floral and fruit characters based on herbarium specimens may therefore be incomplete or ambiguous. The study therefore, aimed to (1) study the morphological variations between *Impatiens* spp. of the sect. *Annuae* in Western Ghats, (2) to study the distribution patterns and to understand the effect of bioclimatic variables on the distribution for *Impatiens* species, (3) to study the phylogenetic relationships between Indian *Impatiens* species using molecular markers and (4) since most of the plants of 'Balsams' have ornamental value, the present endeavour would be to conserve these plants in botanic garden, and domesticate them for their ornamental potential

A checklist of Indian Balsaminaceae

Taxonomy of the genus *Impatiens* has been in a state of flux even after publication of many research papers. For *Impatiens,* five diversity hotspots have been recognized so far, i.e. tropical Africa, Madagascar, southern India and Sri Lanka the eastern Himalayas, and south-east Asia. In this context, a checklist for an updated account on the family Balsaminaceae in India has been prepared. A total of 326 taxa, comprising 302 species plus 24 subspecies/varieties, belonging to 2 genera were recorded from the country. Presently, India is one of the centres of diversity with 326 taxa followed by Madagascar with more than 260 species. The concentration of species of *Impatiens* in India is curiously local and occurs in two perfectly defined regions, *viz*. the Himalaya in north and the Western Ghats in the south.

Plant explorations in Western Ghats

Four exploration surveys have been done in Uttar Pradesh, Madhya Pradesh, Kerala and Tamil Nadu parts of Western Ghats (38 days) related to Conservation of Threatened Plants of India and Chambal Ravine projects, collected / documented 612 plants including 24 threatened plants, 32 endemic species and of which 84 plants were provided to ex-situ conservation in NBRI Botanical Garden.

Apart from this, 1181 plants were collected for Floriculture Mission Project and out of which 980 are conserved in CSIR-NBRI garden.

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Systematics, reproductive biology and conservation of pteridophytes

Systematic studies

A total of 519 specimens of 58 taxa including two varieties belonging to 34 genera under 18 families have been collected from different localities of Niyamgiri Hills.

Voucher samples of 95 specimens of 37 taxa including two varieties belonging to 19 genera under 14 families have been prepared mentioning their areas of occurrence, altitude, GPS data and the families to which they belong.

Reproductive biology studies

In-vitro cultures and mass propagation of ornamental taxa *Nephrolepis auriculata* (L.) Trimen was studied. The spores were reniform or planoconvex, 15µm x 20 µm in size, yellow-brown, monolete, opaque, bean to kindey shaped in equatorial view and elliptical in polar view with a smooth surface with single fissure. The spore remained viable for 6 months only. Germination of spore started on 12th day after sowing with the emergence of green protonemal initial. The spore germination was *Vittaria* type where the cell grows and emerges from the leisure. The first rhizoid usually emerges from the basal cell. The protonema became two celled stage on 13th day. The gametophyte development was *Aspidium* type. The young prothallus of *N. auriculata* was mostly asymmetrical. A cordate gametophyte with rhizoids on its posterior end developed on 30th day. The cordate gametophyte developed archegonia below the notch on 46th day. The antheridia borne on 54th day throughout the gametophyte, i.e. close proximity to archegonia below the notch, in the rhizoidal end and in the wings. It defines that the

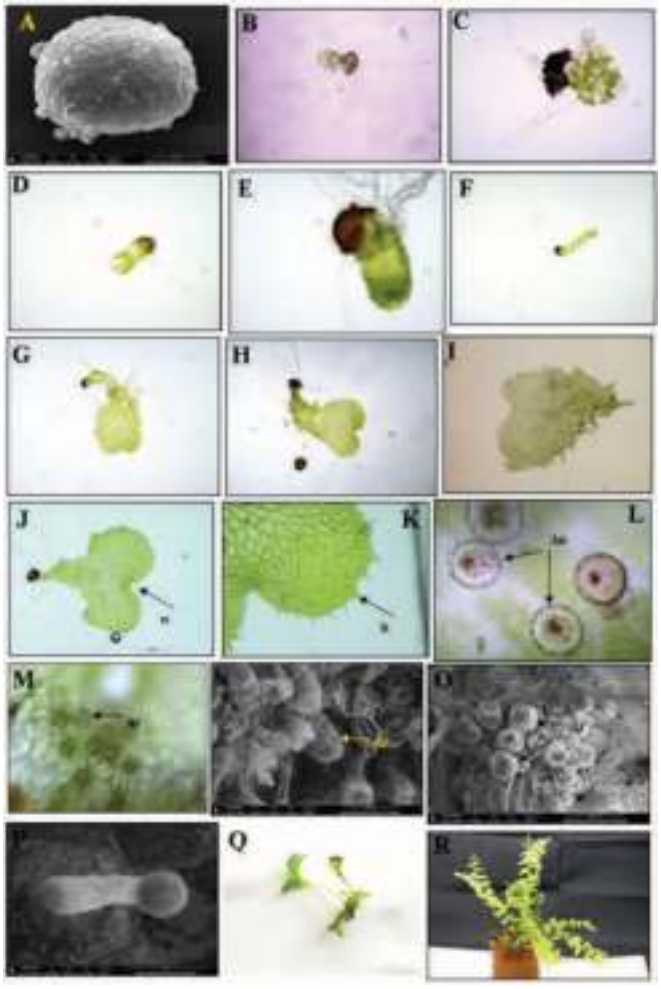

Fig. 1: *In-vitro* spore culture of *Nephrolepis auriculata.* (A). Spore structure, (B-C). First cell stage with proliferating rhizoidal initial, (D-E). Second celled stage, (F). Filamentous stage, (G-H). Spathulate tage, (I). Lopsided stage, (J-K). Cordate stage, (L-M). Archegonia, (N-O). Anthridia, (P). Unicellular capitates hair, (Q). Sporophyte from gametophyte, (R). Plants after acclimatisation. [an-antheridia and ar-archegonia]

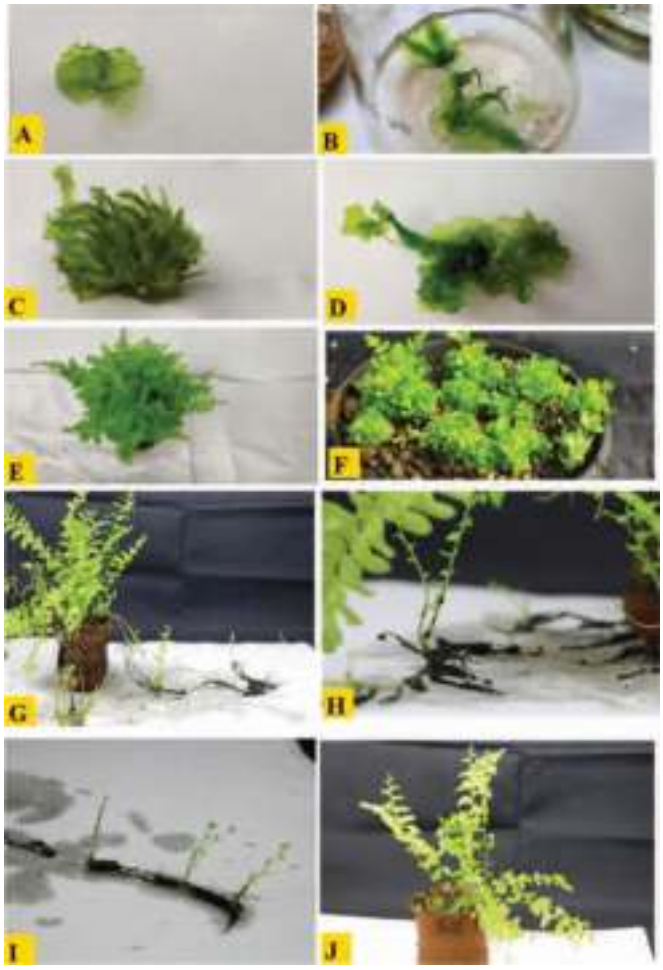

Fig. 2: *In-vitro* culture of *Nephrolepis auriculata.* (A). Gametophyte explant devoid of any sex organ, (B). Inoculated explants in the medium containing vitamins and PGRs, (C-D). Regenerated gametophytes from the explant, (E-F). Initiation of sporophyte formation from the regenerated secondary gametophyte, (G-I). Stolon regeneration and sporophyte production, (J). Regenerated sporophytes transferred to earthen pots

gametophyte was protogynous. After fertilization the gametophyte underwent a developmental phase to form sporophyte on 78th day. The margins of the sporophytes were always covered with unicellular, incurved glandular hairs, more abundant towards the apex.

The isolate culture produced archegonia and antheridia on 52nd and 60th day respectively ultimately forming sporophytes on 85th day which defines that the plants can perform both intergametophytic and intragametophytic selfing. Around 20 days after germination, superficial hairs appeared on the ventral surface of the prothallial lamina. These hairs were morphologically similar to the marginal ones, and presented the maximum density around the central area of the lamina (Fig. 1).

The mature gametophytes just before the emergence of sex gametangia were inoculated into the media as explants containing various concentrations of BAP and Kinetin. The primary media used for the propagation was Parkers and Thompsons media containing growth regulators and vitamins in half strength. The greatest numbers of regenerated gametophytes with sporophytes were found on the medium with the growth regulators containing 1mg/l Kinetin and 0.5mg/l NAA. In the second experiment, full strength of Parkers and Thompsons media supplied with 0.01mg/l NAA produced maximum number of stolons (Fig. 2).

Ex-situ Conservation

Live plant of *Pityrogramma calomenalos* (L.) Link collected from Niyamgiri Hill, Odisha was introduced in the garden of the Institute.

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Biodiversity assessment, floristic, revisionary and bio-deterioration studies on lichens

Species reported as new record for India

***Arthonia tavaresii* Grube & Hafellner**

This lichenicolous fungus *Arthonia tavaresii* Grube & Hafellner inhabitin the lichen *Pyrenula* sp. was recorded first time from Uttarakhand, India at an alt. of 2200 m.

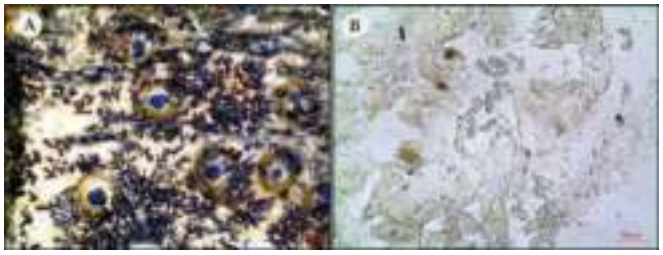

Fig.1: *Arthonia tavaresii* Grube & Hafellner- new record to India (A). Habitat, (B). Ascospore

Biodiversity assessment and floristic studies

Epiphytic lichens survey

During the reporting period, survey of various tropical localities in Madhya Pradesh, Uttar Pradesh, Punjab and Uttarakhand were conducted for epiphytic lichens on mango tree. Approximately 200 lichen specimens were collected, comprising 139 species under 54 genera belonging to 31 families. The crustose lichens exhibited their dominance, represented by 105 species followed by 30 foliose and 4 species of squamulose lichens. Uttar Pradesh state represented maximum diversity of lichens with 59 species followed by Madhya Pradesh with 40 species. Among the lichen families, Lecanoraceae with 17 species exhibited dominance followed by Ramalinaceae with 14 species. *Lecanora* genus with 16 species is most diverse followed by *Bacidia* and *Pertusaria* having 11 species each. The young, smooth barked mango trees in moist, shady places provide substratum for growth of some exclusive taxa of lichens which bear perithecia. Eight species of perithecia bearing lichens *viz.*, *Anthracothecium* and *Pyrenula* were mostly growing on smooth, fleshy bark of mango trees. The hard fissured bark of mature mango tree is preferred by crustose species of lichens. The tree trunk from ground up to 4 feet exhibit dominance of crustose lichen genera *viz. Lecanora, Caloplaca, Bacidia, Pertusaria* and *Graphis*, whereas above 4 feet, luxuriant growth of foliose lichen genera *viz. Dirinaria, Hyperphyscia, Parmotrema, Phaeophyscia* and *Pyxine* was observed. Among the tropical trees, mango exhibits rich diversity of lichens, mostly belonging to lichen family Physciaceae. *Pyxine cocoes* is the most common foliose lichen species found growing luxuriantly on mango orchard in Indian tropical regions and frequently used for environmental pollution monitoring studies in the area.

Bio-deterioration study

During the reporting period, lichen diversity on monuments of Bhimbetka Rock shelters at Raisen district in Madhya Pradesh was studied. The micro-climatic conditions of the monuments provide excellent habitat for lichens to colonize. Out of 40 species recorded from these areas, 32 species exhibited biodeterioration chelating properties. The lichen communities like Lecideoid, Teloschistacean, Crustose, Squamulose, Leprioid, Parmelioid and Physcioid exhibited a vast array of secondary lichens substances. The common lichen substances such as

atranorin, parietin, lecanoric, sekaikaic, divaricatic, zeorin and usnic acid play important role in biodeterioration. The species belonging to *Caloplaca*, *Buellia*, *Diploschistes*, *Dirinaria*, *Phaeophyscia* and *Pyxine* are most effective biodeterioant of the region. *Caloplaca*, *Buellia* and *Diploschistes* have crustose or squamulose thallus, tightly attached to the substratum throughout the lower surface and also produce a number of chelating substances. *Dirinaria*, *Pyxine* and *Phaeophyscia* are foliose lichen loosely attached to the substrate at few places with the help of their hair like rhizines on the lower side of the thallus. They also produce chelating substances and are moderate biodeteriorant. Lichen communities growing on rocks undergo regular patterns of successional change, assemblage of species may occupy a given rock surface for several years, steadily altering the substratum in ways that eventually better accommodate a new combination of species. Most of the communities prefer to grow on sandstones both in exposed and shaded rocks while siliceous, acidic, granite and bauxite dry exposed rocks bear only Teloshcistacean and Physcioid communities. The pores in the sandstone are large enough to accommodate lichens and may partially account for abundance of lichens on the sandstone rocks. The lichens exhibiting a close relationship with microclimatic factors thus can be used for microclimatic monitoring of monuments. Most of the lichens particularly, cyanolichens (Cyanobacteria contacting photobiont) act as cloth to protect the exposed rock from high temperature and rains providing bioprotetion to the substrate.

Taxonomic revisionary studies

During the revisionary study of pyrenocarpous lichens, the lichenicolous mycota *Arthonia tavaresii* Grube & Hafellner, previously reported from Austria, is reported as a new record to the country. *Arthonia tavaresii* is characterized by scattered *Ascomata*, as brownish patches, clavate *Asci*, 50–60 × 16–20 µm, 8-spored, obovate *Ascospores*, a gelatinous sheath around young spore. The species is found growing on bark at elevation of 2200 m in Western Himalayan state Uttarakhand.

Fig.2: Aggressive lichen species: (A). *Megaspora subpoliotera* (Y. Joshi & Upreti) S. Y. Kondr., Upreti & A. Thell (B). *Neobrownliella cinnabarina* (Ach.) S. Y. Kondr., Upreti & A. Thell.; Moderant lichen species: (C). *Dirinaria confluens* (Fr.) D. D. Awasthi, (D). Physcia sp.; Bioprotective lichen species: (E). *Endocarpon rosettum* Ajay Singh & Upreti, (F). *Parmotrema praesorediosum* (Nyl) Hale.

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Pharmacognosy, Phytochemistry and Product Development

CSIR NBRI Estd. 1953

WHERE PLANT-BASED RESEARCH TOUCHES LIFE THROUGH INNOVATION

PHARMACOGNOSY, PHYTOCHEMISTRY AND PRODUCT DEVELOPMENT

Area Co-ordinator

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Scientific Staff

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- Mr Dileep Singh, Technican
- Mr. Pawan Kumar, Technician
- Mr. Santram , Lab Assistant

Divisions

- Pharmacognosy
- Phytochemistry
- Pharmacology and Product development

Research Scholars Statistics

Sr. No	Position Name	Numbers
1	Women scientist	01
2	Young Scientist	01
3	JRF/SRF	20
4	Project Staff	21

R & D Highlights

Preparation of Certified Reference Materials (CRMs)/Reference Materials (RMs)

- Under ATMA NIRBHAR BHARAT, CSIR-NBRI has prepared a total nine Certified Reference Materials (6 CRMs and 3 RMs) as per requirements of ISO-17034-2016. CSIR-NBRI has been accredited as Reference Material.

Certificate Number	RC-1015
Validity	March 31,2021-March 30, 2023
Scope	
Certified Reference Materials (CRMs)	**Reference Materials (RMs)**
(+) Limonene Eugenol Geraniol, (-) Menthol L- Carvone Mangiferin	Methyl Chavicol Curcumin Andrographolide

CSIR-NBRI has also got NABL Accreditation as per requirement of 17034: 2016 and recognition of CSIR-NBRI as Reference Material Producer.

Conservation, Management and Promotion of Sandalwood (*Santalum album* Linn.) cultivation in India.

The carbon isotope composition was determined by flash combustion elemental analyzer-isotope ratio mass spectrometer (IRMS). Stable carbon isotope composition ($^{13}C/^{12}C$) was determined for 175 samples of Sandal wood growing in different locations.

Conservation and Productivity Improvement of Red sanders (*Pterocarpus santalinus*)

Stable carbon isotope composition ($^{13}C/^{12}C$) was determined for the 300 heartwood core samples of Red sanders growing in different locations of Karnataka.

Conservation, Agronomics, Metabolomics and Genomics of India Lotus (KAMAL)

Petals, flower pods, petiole, rhizomes, leaves of different varieties of *Nelumbo nucifera*, collected from various parts of India were processed for total phenolic content, total flavonoid content and antioxidant activity. Whole flower was also used for cold solvent extraction to prepare absolute and concrete fractions.

New Facility Created

Distillation Units

Two distillation units viz. SS Field Distillation Unit having capacity of 2000 Litres and SS Cohobition Distillation Unit having capacity of 500 Litres capacity for distillation of essential oils have been installed at Banthra Research Station and Botanic Garden of CSIR-NBRI respectively.

Nuclear Magnetic Resonance (NMR) 600 MHz

A facility of NMR 600 MHz has been installed in CIF of institute. NMR spectroscopy is used in the field of metabolomics and also to determine the effect of geographical and climatic condition in plant metabolites.

Preparation of colours for textile (Cotton, Silk and Wool)

Chemical profiling of colour molecules from extracted from floral and leaf wastes were evaluated and showed Lutein from marigold flowers, Chlorophyll-b from tulsi leaves, Chlorophyll-a from bel patra leaves, Pelargonidin and Cyanidin from rose flowers respectively

Pharmacognostical and pharmacological studies

- *Cannabis* formulations were prepared (Madananand Modak, Kameshwar Modak, TrailokyaVijayaVati and Purified Bhang) and were subjected for pharmacognostical Standardization and Biochemical estimations.
- Comparative Pharmacognostical Studies of Three *Mahonia* Species: Exploring the Possibilities as a substitute of Ayurvedic Drug "Daruharidra"
- Concurrent quantification of oleanolic acid, β-sitosterol and lupeol through validated HPTLC in *Urginea indica* Kunth bulb
- Influence of seasonal variation on diosgenin content in *Costus speciosus* (J. Koenig) Sm. rhizome quantified through validated RP-HPLC-PDA method
- Mangiferin, a xanthone C-glycoside, of >95% purity was isolated from the hot methanolic extract of the leaves of *Mangifera indica*.
- The anticancer effect of *Selaginella bryopteris* was evaluated *in vitro* using HepG2 cell and *in vivo* animal system and showed promising results in *in vitro* cell lines.
- Superior anti-quorum sensing activity of phyto-synthesized nanoparticles were prepared using the aqueous leaf extract of *Koelreuteria paniculata* as a reducing and capping agent.
- *Cinnamomum verum* derived bioactive-functionalized gold nanoparticles (Au@P-NPs) enhanced anti-obesity effects through gut microbiota reshaping using in high-fat diet (HFD) conditions in small animal model system.
- Developed four plant based wax products (NBR-WP1, NBR-WP2, NBR-WP3 and NBR-WP4) to be used as/for edibles/ nutraceuticals and natural additive to formulate synergistic hydrophobic biodegradable products.
- We have prepared and characterized a wax product rich in cholesterol lowering nutraceutical marker (Policosanols).

Product development

- Antidandruff hair oil formulation

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Chemical investigation of medicinal and aromatic plants and products for various applications. Preparation of CRMs/RMs as per the requirements of ISO-17034-2016

Preparation of Certified Reference Materials (CRMs)/Reference Materials (RMs)

Certified Reference Material (CRM)/ Reference Material (RM) of high purity active molecules are widely needed to underpin the adulterations, impurities in commercial products and related services. The CRMs are required for the calibration of equipment's, validation of methods for quantitative measurements services based on the medicinal and aromatic plants (MAPs) to enable their trade, quality and commercialization. The Outcome driven (RM/CRM) translational activities on MAPs will lead to phyto-pharmaceuticals, nutraceuticals, cosmeceuticals, aroma, flavours and fragrances to promote agri-entrepreneurship in MAPs for make in India and exports. Therefore under ATMA NIRBHAR BHARAT, CSIR-NBRI has prepared a total of nine Certified Reference Materials (6 CRMs and 3 RMs) as per requirements of ISO-17034-2016. CSIR-NBRI has been accredited as Reference Material.

NABL-Gurugram after the surveillance audit in March 2022 recommended NABL Accreditation of CSIR-NBRI as reference material producer.

Certificate Number	RC-1015
Validity	March 31,2021-March 30, 2023
Scope	
Certified Reference Materials (CRMs)	**Reference Materials (RMs)**
• (+) Limonene • Eugenol • Geraniol, • (-) Menthol • L- Carvone • Mangiferin	• Methyl Chavicol • Curcumin • Andrographolide

Conservation, Management and Promotion of Sandalwood (*Santalum album* Linn.) cultivation in India

The carbon isotope composition was determined by flash combustion elemental analyzer-isotope ratio mass spectrometer (IRMS). Stable carbon isotope composition ($^{13}C/^{12}C$) was determined for 175 samples of Sandal wood growing in different locations. The range of carbon isotope ratio across the country was from 25.761 to -29.277 per mil.

Conservation and Productivity Improvement of Red sanders (*Pterocarpus santalinus*)

Stable carbon isotope composition ($^{13}C/^{12}C$) was determined for the 300 heartwood core samples of Red sanders growing in different locations of Karnataka. Range of carbon isotope ratio was observed to be from -24.197 to -28.047 per mil.

Conservation, Agronomics, Metabolomics and Genomics of India Lotus (KAMAL)

Petals of three varieties of *Nelumbo nucifera*, i.e., pink single floret, pink multiple florets and white flowers were processed for hydrodistillation and cold solvent extraction to collect essential oil and the absolute and concrete fractions. Oil recovery (%) was 0.01-0.06 (hydrodistilation of petal) and absolute recovery (%) was 0.26-0.31 (cold solvent extraction of petals). Chemical composition of extracted oils were analysed by using GCMS. Total Phenolic and flavonoid content were estimated for seed pod, petiole and rhizome of these varieties of *Nelumbo nucifera* using Gallic acid and Rutin, respectively as standard. Further, specific phenolic components were analyzed by using HPLC.

TPC of seedpod, petiole and rhizome was observed in the range of 40.77 – 58.252, 10.776 to 13.66 and 3.756-13.989 mg/g, respectively. TFC of seedpod was observed (mg/g) in the range of 7.67- 14.25, 4.15-4.33 in petiole while in rhizome, it was in the range of 1.767 to 17.1 mg/g.

New Facility Created

Distillation Units

Two distillation units viz. SS Field Distillation Unit having capacity of 2000 Litres and SS Cohobition Distillation Unit having capacity of 500 Litres capacity for distillation of essential oils have been installed at Banthra Research Station and Botanic Garden of CSIR-NBRI respectively (Fig. 1, 2).

Fig. 1: SS Field Distillation Unit Banthara Research Centre.

Fig. 2: SS Cohabitation Distillation Unit at Botanic Garden, CSIR NBRI.

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Safety and efficacy of herbal drugs in *in vitro* and *in vivo* animal model system and product development

Resveratrol chewable tablet against Non-Alcoholic Fatty Liver Disease (NAFLD)

Resveratrol is an orally administered hepatoprotective drug used to treat Non-Alcoholic Fatty Liver Disease (NAFLD). Eight formulations of chewable tablets were made of 100mg and 150mg and subjected for detailed studies. The hepatoprotective activity of Resveratrol was investigated in *in vivo* animal model system. Rats of different groups were treated with high-fat diet (HFD), RSV100, RSV150 and standard. Liver biochemical parameters of resveratrol at 50 and 100 mg/kg were significantly reduced the elevated levels of SGOT, SGPT, ALP and TBL (Fig: 1).

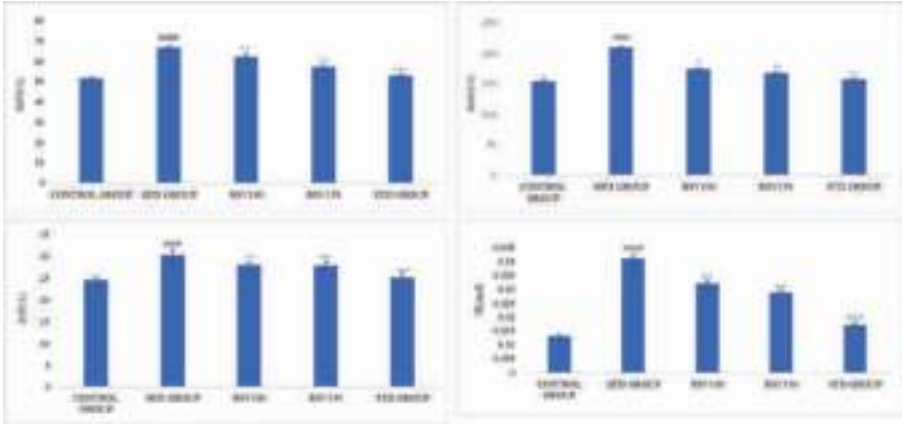

Fig: 1: Hepatoprotective activity of Resveratrol (100 and 150 mg/kg, o.d) on fatty liver in rat ($^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$ compared to HFD; $^{\#\#\#}p<0.01$ compared to control group).

Effect of *Selaginella bryopteris* on Nitrosodiethylamine –induced hepatocellular carcinoma

Selaginella bryopteris is used traditionally in the treatment of several health-related problems but mostly remains to be scientifically validated. The anticancer effect of *S. bryopteris* was evaluated *in vitro* using a human hepatocellular carcinoma HepG2 cell line. Gas chromatography-mass spectrometry (GC–MS) was carried out to analyze the phytoconstituents of *S. bryopteris* extract. Different techniques were used in this *in vitro* anticancer study to evaluate cell viability, alteration in nuclear morphology, mitochondrial membrane potential, and generation of reactive oxygen species (ROS). For an *in vivo* study, Sprague Dawley (SD) rats were induced with N- nitrosodiethylamine (200 mg/kg b.w. once, i.p.) and carbon tetrachloride (3 mL/kg/week b.w., s.c.) up to six weeks. The induced animals were treated with *S. bryopteris* extract (100 and 200 mg/kg) and silymarin (100 mg/kg) for 28 days. The level of liver function parameters and antioxidant enzymes were assessed and showed significant promising activity at 200 mg/kg. A reverse transcriptase-polymerase chain reaction was also used to evaluate the gene expression patterns of p53, Bax, caspase-3, caspase-9, and Bcl-2 mRNAs.

Research Group Members

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- Ms. Arti Gautham, Project Fellow

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Chemoprofiling of medicinal plants for herbal product development

Concurrent quantification of oleanolic acid, β-sitosterol and lupeol through validated HPTLC in *Urginea indica* Kunth bulb

Urginea indica Kunth bulb was used for the quantification of oleanolic acid, β-sitosterol and lupeol using HPTLC. Separation of metabolites was done in mobile phase using toluene: ethyl acetate: methanol: acetone (7:2:0.2:0.2 *v/v*) and quantification was done after derivatization by dipping in anisaldehyde sulphuric acid; densitometric scan was performed at 530 nm. The proposed method for quantification was linearly calibrated in the range of 200 - 1000 ng/spot for oleanolic acid and β-sitosterol; 100 - 500 ng/spot for lupeol and was found to be specific and repeatable. The R_f was found at 0.44 ± 0.03, 0.55 ± 0.05 and 0.68 ± 0.08, LOD and LOQ were 1.045, 0.524, 0.525 µg/spot and 3.167, 1.588, 1.592 µg/spot for oleanolic acid, β-sitosterol and lupeol respectively. Precision and recovery study for sample and standards are within the limit of ICH guidelines. Oleanolic acid, β-sitosterol and lupeol were found to be 0.113, 0.105 and 0.036% respectively in methanolic extract of plant on dry weight basis. This study will help in checking routine quality control of herbal drugs as well as herbal formulations containing *U. indica*.

Comparative Pharmacognostical Studies of Three *Mahonia* Species: Exploring the Possibilities as A Substitute of Ayurvedic Drug "Daruharidra"

Mahonia species (Family: Berberidaceae) is well known plant used in traditional systems of medicine for the treatment of fever, cold, jaundice, diarrhoea, dysentery, dermatitis, eczema and postnatal treatment. The present study deals with comparative pharmacognostical studies and HPTLC quantification of benzylisoquinoline alkaloid berberine of three *Mahonia* species *viz*. *Mahonia leschenaultia* (Wallich *ex* Wight & Arn.) Takeda (ML), *Mahonia nepaulensis* DC. (MN) and *Mahonia borealis* Takeda (MB). The macroscopic examination showed characteristic differences in leaf, inflorescence and fruit of the three species. The pharmacognostical parameters *viz.* moisture content, ash and extractive values of samples was found to be within the standard limit. The phytochemical evaluation of metabolites through spectroscopy reveals the presence of flavonoid, phenolics, starch, sugar and tannin, former was found to be the highest (0.45%) among all. HPTLC quantification showed that the maximum content of berberine was found in *Mahonia leschenaultia*

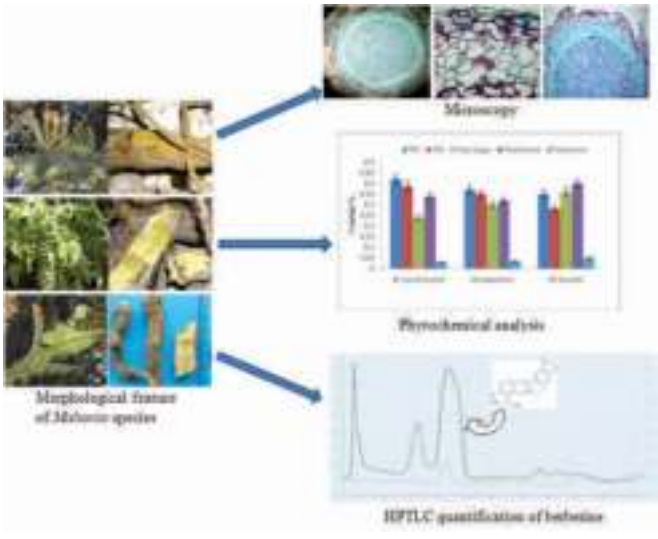

Fig. 1: Pharmacognostic analysis of three *Mahonia* sp.

i.e. 0.197% ± 0.01 dry wt. basis. The study explores the possibilities of *Mahonia* species as a substitute of Ayurvedic drug "Daruharidra" *i.e. Berberis aristata* and will also aid in quality control of products containing "Daruharidra" in herbal drug industry (Fig. 1).

Influence of seasonal variation on diosgenin content in *Costus speciosus* (J.Koenig) Sm. rhizome

This study was aimed to evaluate the seasonal variation on diosgenin content in *Costus speciosus* rhizome. The rhizomes were collected in four different seasons i.e., rainy (August), autumn (October), winter (February) and summer (May) from Lucknow, India. The HPLC method was validated in terms of linearity, precision, repeatability, accuracy, sensitivity and robustness. Diosgenin was separated under isocratic elution on an RP-HPLC column (4.6 X 250 mm, 5 µm) with a mobile phase consisting of methanol and water, eluted at retention time (R_t) of 18.396 minute and content was calculated using standard curve. The limit of detection (LOD) and limit of quantification (LOQ) was found to be 522.68 and 1583.90 ng (nano gram), respectively. The diosgenin content varied significantly in different seasons. The results suggested that the summer and rainy seasons were the optimum conditions to collect rhizome for high yield, as diosgenin content was high in both the seasons. Harvesting at optimal season may fulfil the commercial demand and reduce the overexploitation of the species from the wild (Fig. 2).

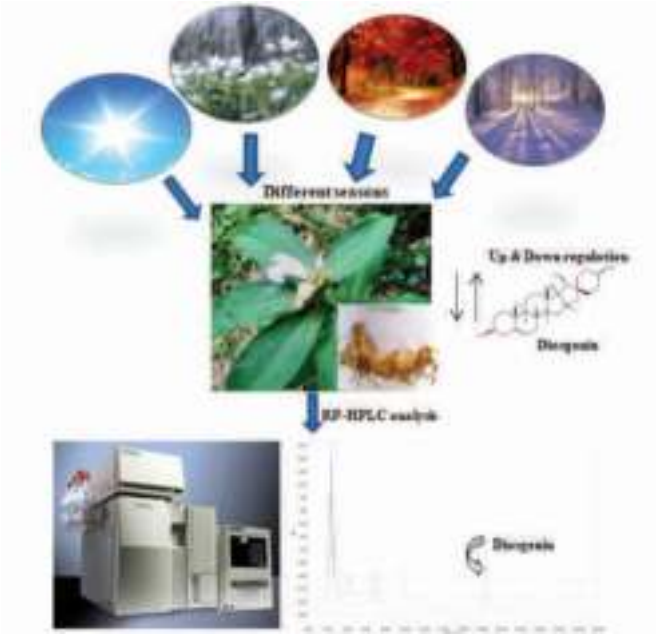

Fig. 2: Quantification of diosgenin through RP-HPLC-PDA system.

Herbal Product Development

Antidandruff hair oil formulation

An oil base formulation with 3 active ingredients was developed to mitigate the dandruff from human scalp. The selected ingredients exhibit potential efficacy and safety against *Malassezia furfur* and *Staphylococcus epidermidis*, the two main causative agents of dandruff. The formulation also possesses wound healing property and maintains the texture and, lustre of hair strands. Transferred for commercialization to M/S. MARC laboratories (India) Ltd. This technology has earned 4 lakhs as license fee and a recurring royalty of 3% (Fig. 3).

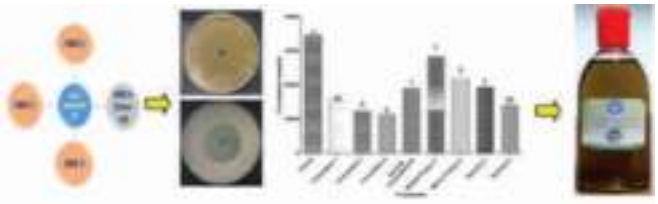

Fig. 3: Development of herbal antidandruff hair oil.

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Herbal product development, stable herbal food colours

Preparation of colours for textile (Cotton, Silk and Wool)

The herbal colours for textiles were developed by using the easily available sources such as vegetable peels, water hyacinth and temple floral waste, etc (Fig. 1). A total number of 30 colour shades for textile (cotton, silk and wool) developed using different natural and herbal mordants. The stability checks of colours have been carried with colorimeter for durability capacity.

Herbal Gulal from flowers and leaves

Floral and leaves wastage from temples have been utilized for making of herbal gulal. Chemical profiling of colouring molecules has also performed for the different flower sources (Fig. 2).

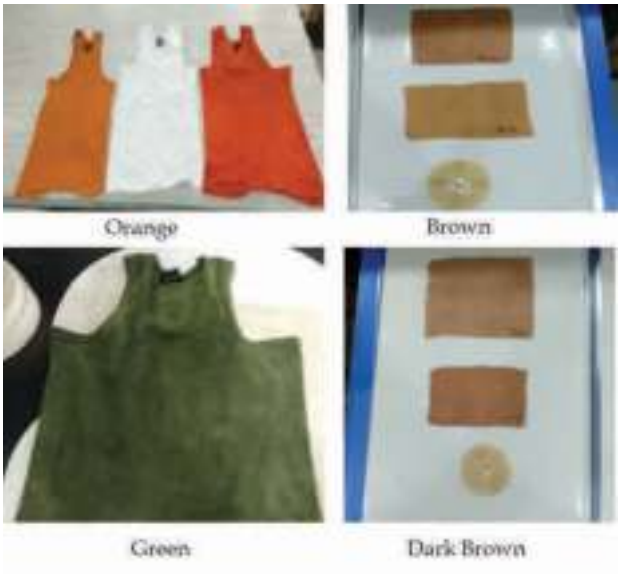


Fig. 1: Development of herbal colours for textiles.

Preparation of Certified Reference Material (CRM)- Andrographolide

Andrographolide belongs to the family of chemicals called terpenoids. It is a labdanediterpenoid gamma lactone. It is one of the principal bioactive chemical

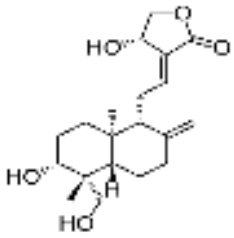
Fig. 2: Chemical profiling of colour molecules from extracted from floral and leaf wastes, (A). Lutein from marigold flowers, (B). Chlorophyll-b from tulsi leaves, (C). Chlorophyll-a from bel patra leaves, (D-E). Pelargonidin and Cyanidin from rose flowers respectively.

constituents of *Andrographis paniculata*. It has broad range of therapeutic applications including anti-inflammatory, anti-cancer, immunostimulant and hepatoprotective effects. It also shows potent anti-viral effects against dengue virus.

Andrographolide was isolated and purified from *Andrographis paniculata*, the characteristic of the CRM was as follows:

Purity: >95%

IUPAC Name– 3-[2-[Decahydro-6-hydroxy-5-(hydroxymethyl)-5,8a-dimethyl-2-methylene-1-napthalenyl]ethylidene]dihydro-4-hydroxy-2(3H)-furanone



Chemical Formula – $C_{20}H_{30}O_5$

Molar Mass – 350.45 g/mol

Melting point- 230-231°C

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To develop technology/product for sustainable and economical use of herbs for safe and affordable health care

Development of Shodhan protocol and preparation of standardised *Cannabis* extracts based AYUSH formulation

Cannabis formulations were prepared (Madananand Modak, Kameshwar Modak, Trailokya Vijaya Vati and Purified Bhang) and were subjected for pharmacognostical standardization and biochemical estimations.

Pharmacognostical standardization of NBR (*Cannabis* formulations) samples

Pharmacognostical standardization of ten samples were established, which includes the estimation of moisture content, extractive values (alcohol soluble and water soluble extractive value) and Ash value (total ash and acid insoluble ash) as per Ayurvedic Pharmacopeia of India (2016). Moisture content of formulation varies from 2.6 to 7.6% (Fig. 1). Alcohol soluble extractive value was found higher than water soluble and content varies from 1.77 to 23.02% and 1.62 to 15.73% (Fig. 2 and Fig. 3). The total ash and acid insoluble ash content varies from 0.007 to 0.454% and 0.0049 to 0.162% (Fig. 4).

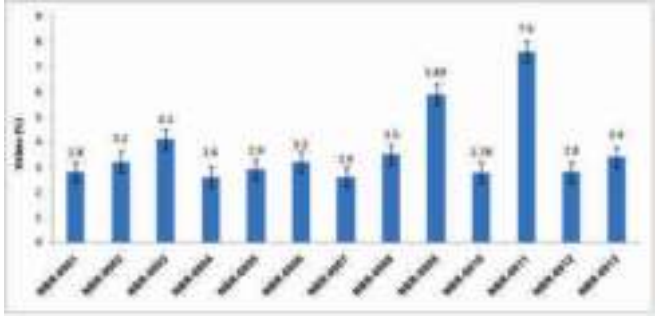

Fig. 1: Moisture content of the samples as per API (Values are mean ± SE).

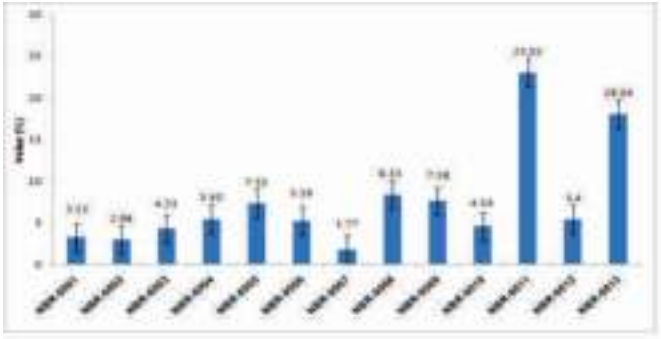

Fig. 2: Alcohol soluble extractive values of the samples as per API (values are mean ± S.E).

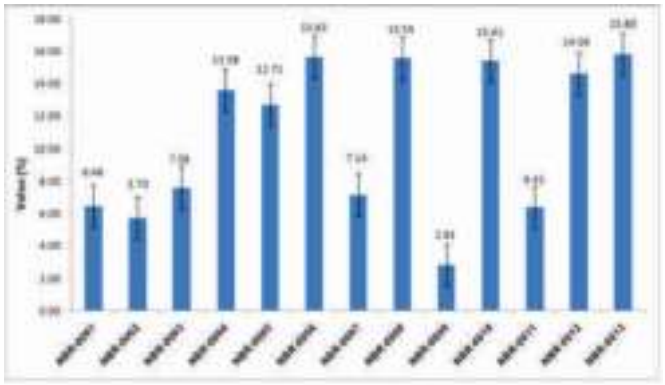

Fig. 3: Water soluble extractive values of the samples as per API (values are mean ± S.E).

The determination of water content is essential as the presence of excess amount of water (moisture) in medicinal plants will promote microbial growth, fungi or insects infestation, and lead to deterioration of sample.

The residue remaining after incineration of plant material is the ash content of the drug, which simply represents its inorganic content i.e. inorganic salts, naturally occurring in drug or adhering to it or

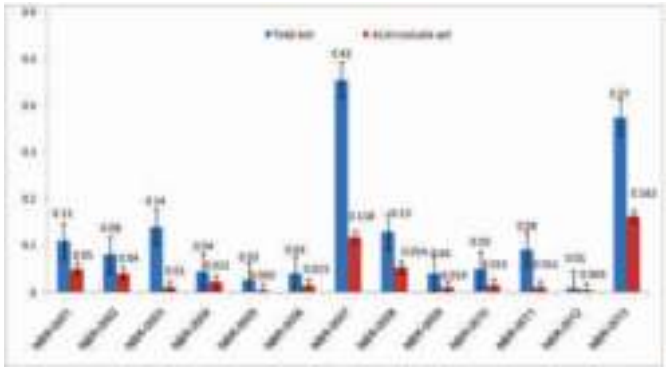

Fig. 4: Total ash and water soluble ash values (%) of samples as per API (Values are mean ± S.E).

deliberately added to it as a form of adulteration. The crude drugs are frequently admixed with various mineral substances like sand, soil, calcium oxalate, chalk powder or other drugs with different inorganic contents. For the determination of total ash, the powdered drug is incinerated, so as to burn out all the organic matter present in it and is one of the criterions to judge the identity or purity of crude drugs. Total ash usually consists of carbonates, phosphates, silicates and silica.

Acid-insoluble ash is a part of total ash which is insoluble in diluted hydrochloric acid and is recommended for natural drugs. Adhering dirt and sand may be determined by acid-insoluble ash content.

Extractive value is a measure of the content of the drug extracted by solvents. Extractive value can be water soluble, alcohol soluble and other non aqueous solvent soluble. This method determines the amount of active constituents in a given amount of medicinal plant material when extracted with solvents. The extraction of any drug with a particular solvent yields a solution containing different phyto-constituents.

HPTLC Quantification of delta-8 –tetrahydrocannabinol and Cannabidiol in marketed formulations

The chromatogram was developed by derivatizing in anisaldehde sulphuric acid reagent; delta-8 –tetrahydrocannabinol and cannabidiol was identified at R_f 0.335 and 0.369 (Fig. 5).

The content of delta-8 –tetrahydrocannabinol in samples varies from 0.025 to 0.462 µg/ul and

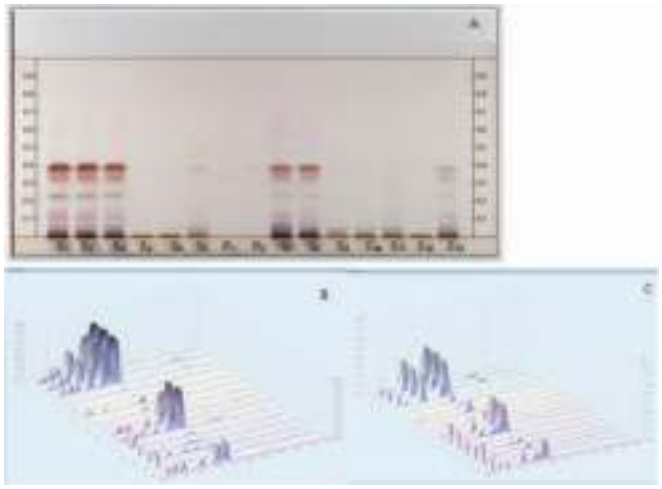

Fig. 5: HPTLC chromatogram of samples (S1 to S13) and reference marker (R1:delta-8 –tetrahydrocannabinol, R2: cannabidiol (A), (B) Overlay spectra of samples and delta-8 –tetrahydrocannabinol at UV 510 nm, (C) Overlay spectra of samples and cannabidiol at UV 690 nm.

cannabidiol varies from 0.006 to 0.0128 µg/ul. In five samples i.e. NBR-004, NBR-005, NBR-006, NBR-009 and NBR-012, delta-8 –tetrahydrocannabinol was not quantifiable under the developed protocol. This may be either due to absence of quantified markers or the content is found in traces. Similarly, in NBR-004 and NBR-0012, cannabidiol was not quantifiable under the developed protocol (Fig. 6).

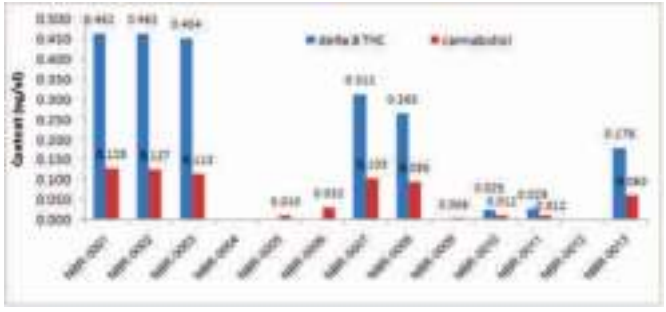

Fig. 6: Quantification (µg/ul) of delta-8 –tetrahydrocannabinol and cannabidiol in *Cannabis* formulations (NBR samples).

Facility Created

NBRI Dispensary

A separate Dispensary of CSIR-NBRI was established at the Botanic Garden to facilitate medical consultations for the NBRI staff and their family members.

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Phytoconstituents analysis and their content variation; Phytochemical investigation; Isolation of important phytomolecules and preparation of Certified Reference Materials (CRMs)

Phytochemical investigation of *Potentilla fulgens* Wall. ex Hook.

Potentilla fulgens Wall. ex Hook. is an important Himalayan medicinal herb of Rosaceae family. It is commonly known as Bajradanti. It is one of the highly valued medicinal drugs used in indigenous system of medicines having antitumor, hypoglycaemic, antibacterial, anti-inflammatory and antiulcerogenic properties. Studies aimed at quantification of phenolic acids, triterpenoids and sterols, total polyphenolic content, total flavonoids and antioxidant potential in the roots of *P. fulgens* were carried out. Major chemical markers (phenolics, triterpenoids and sterols) in the roots (Fig. 1) were quantified using HPTLC. Results showed that all phenolic compounds were higher in aqueous methanolic extract as compared to methanolic extract. The aqueous methanolic extract of *P. fulgens* roots also had higher total phenolic content as compared to methanolic extract. Aqueous methanolic extract showed higher antioxidant capacity**.** The results indicated that the *P. fulgens* root extracts are a good source of phytochemicals that exhibit tremendous defensive action against diseases caused by oxidative stress. These components are of great medicinal value in the maintenance of human physiological system and, therefore, can be used in functional food formulations.

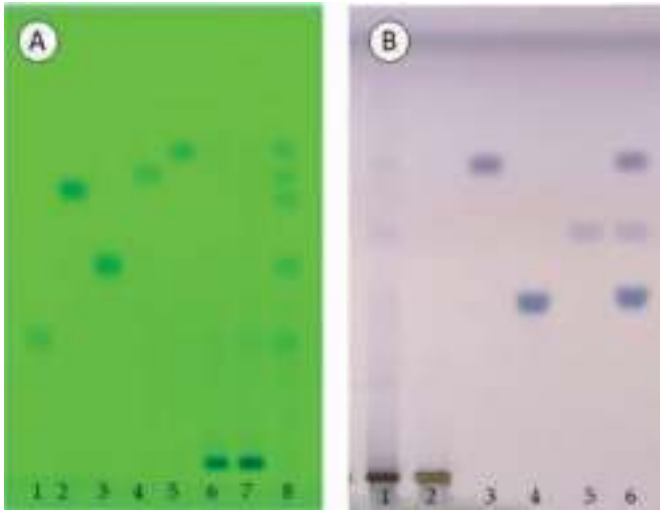

Fig. 1: HPTLC fingerprint profiles of *P. fulgens* roots (A). For phenolics (Track-1: Catechin, 2: Protocatechuic acid, 3: Gallic acid, 4: Syringic acid, 5: Ferulic acid, 6: Methanolic extract, 7: Aqueous methanolic (50%) extract, 8: Standards mixed; captured under (A) λ 254); (B). for triterpenoids and sterols (Track-1: Methanolic extract, 2: 50% Aqueous methanolic extract, 3: Lupeol, 4: Ursolic acid, 5: Beta-sitosterol, 6: Standards mixed; captured under visible light after derivatization),

Seasonal impact on the phytoconstituents of *Moringa oleifera* Lam. and their shelf-life study

Samples were collected in four different seasons (monsoon, autumn, winter and spring seasons). Different extracts of the samples were prepared and analysed for their physicochemical parameters as well as the presence of various phytoconstituents viz. phenolics, flavonoids, triterpenoids and sterols. Six to seven compounds belonging to different phytochemical groups have been identified and their quantitative estimation in various samples, using HPTLC and HPLC, is underway to study the seasonal impact on these phytoconstituents.

Production of Mangiferin as Certified Reference Material (CRM)

Mangiferin, a xanthone C-glycoside, of >95% purity

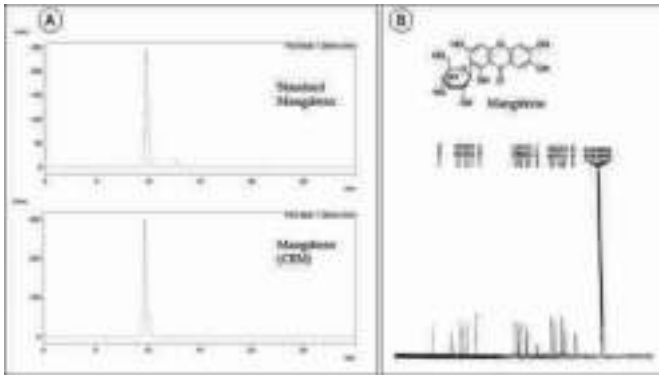

Fig. 2: (A). HPLC Chromatograms of Standard Mangiferin and prepared Mangiferin CRM; (B). ^{13}C-NMR Spectrum of Mangiferin in DMSO-d6.

was isolated from the hot methanolic extract of the leaves of *Mangifera indica*. Its identification using HPLC and ^{13}C-NMR (Fig. 2), HPLC analysis for homogeneity and stability studies and assignment of property values, etc were completed as per the requirements of ISO/17034:2016.

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Phytochemical investigation, value addition and natural product development

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

The indigenous knowledge and ethnomedicinal uses was documented for *Butea monosperma, Anogeissus latifolia, Gardenia gummifera, Commiphora wightii, Buchanania lanzan, Boswellia serrata, Sterculia urens, Senegalia catechu gums* from Chambal eco region, Madhya Pradesh, Maharashtra, Gujrat, Rajasthan, Uttar Pradesh and Uttarakhand; Resins of *Pinus species* from Dehradun, Chakrata, Rishikesh and adjacent area of Uttarakhand. Information about these species was gathered for the economic values, uses and utilization by different tribes i.e. Meena, Rawat, Prajapati and Bhil by interacting with locals, students and teachers in different villages of Rajasthan.

Formulations were prepared on the basis of location specific best resins, gums, wax materials, identified their physicochemical characteristics and markers for enhancing hydrophobicity in hydrophilic materials. A resin (NBR-Rr1) was selected on the basis of availability and characterized markers for developing synergistic combinant with wax materials. Process standardization and stabilization was done for batch consistency and up-scaling of biodegradable hydro-stable combinants to substitute Synthetic plastics.

Four wax products developed in two batches (NBR-WP1, NBR-WP2, NBR-WP3and NBR-WP4) with characterized chemical markers using GC-MS from plant waxes to be used as/for edibles/ nutraceuticals and natural additive to formulate synergistic hydrophobic biodegradable products.

We have prepared and characterized a wax product rich in cholesterol lowering nutraceutical marker (Policosanols). The product has been evaluated for requisite physicochemical and functional standard parameters as per BIS standard.

Preparation of Certified Reference Material of important phytomolecules

We have isolated and purified curcumin from rhizomes of *Curcuma longa*. Determined purity of curcumin through chromatographic/ spectroscopic techniques and prepared it as reference standards material in requisite amount (≥200 mg, purity ≥ 95%). Homogenity and short-term along with long term stability has been recorded. This phytomolecule is useful for food and health care applications.

Conservation, agronomics, metabolomics and genomics of Indian lotus (Kamal)

Extraction of metabolites from lotus flowers (pink, white and mixed) was carried out in polarity gradient solvents to know the maximum extractives in respective solvents and identify the best extraction method. Identified major and minor functional groups for value addition. Flower and leaf extracts were characterisation for marker compound identification by GC-MS and extraction of lotus seeds for nutraceutical characterization is in progress.

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- Mr. Shivam Pal, Project Assistant-I
- Mr. Mohan Tiwari, Project Assistant-II

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Herbal nanobiotechnology, molecular pharmacology, herbal product development

Superior anti-quorum sensing activity of phyto-synthesized nanoparticles

Quorum sensing (QS)-regulated biofilm formation by bacteria is a crucial issue in causing resistance against existing antibiotics. An approach has been found to inhibit the bacterial QS interconnection by the use of metallic nanoparticles. We biosynthesized silver nanoparticles (Ka-AgNPs) using the aqueous leaf extract of *Koelreuteria paniculata* as a reducing and capping agent (Fig. 1). The synthesis of Ka-AgNPs was confirmed by UV-Vis spectroscopy at 420 nm. *Transmission electron microscopy* (*TEM*) image revealed the spherical shape distribution of synthesized nanoparticles. The average size of Ka-AgNPs was 30.0 ± 5 nm. The anti-QS activity of Ka-AgNPs was assessed using a bio-indicator bacterium *Chromobacterium violaceum* ATCC 12472 and a multi-drug resistant *Pseudomonas aeruginosa* (PA01) as model strain. The results demonstrated that the Ka-AgNPs superiorly inhibited bacterial QS-regulated virulence factors and biofilm formation in PA01 without affecting cell viability, compared to chemically synthesized AgNPs (Cs-AgNPs). Treatment of Ka-AgNPs effectively inhibited the production of virulence factors of PA01. RT-PCR results revealed the enhanced inhibition of QS-regulated virulence genes expression by Ka-AgNPs in PA01 as compared to Cs-AgNPs. These results suggest that the phytosynthesized AgNPs could be used as a promising anti-infective agent for treating drug-resistant PA01.

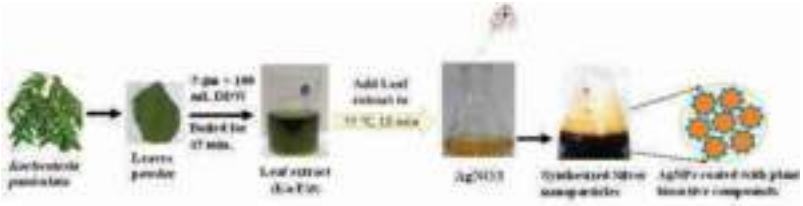

Fig. 1: Graphical illustration of silver nanoparticles synthesized by *Koelreuteria paniculata* leaf extract.

Phytochemicals-functionalized gold nanoparticles for enhanced anti-obesity effects through gut microbiota reshaping

Existing drugs have limited success in managing obesity in human due to their low efficacy and severe side-effects. Surface-modified gold nanoparticles have now received considerable attention of researchers for efficient biomedical applications owing to their superior uptake by cells, biocompatibility, hydrophilicity and non-immunogenicity. We prepared *Cinnamomum verum* derived bioactive-functionalized gold nanoparticles (Au@P-NPs) and assessed their impact on obesity and related immune-metabolic complications in high-fat diet (HFD) conditions. Au@P-NPs treatment prevented weight gain, decreased fat deposition, reduced metabolic inflammation and endotoxaemia. Au@P-NPs exhibited better glucose tolerance and insulin sensitivity than HFD-induced group. These impacts were related to increased energy expenditure and enhanced *Ucp1* expression in the brown adipose tissues of Au@P-NPs treatment, which was strongly linked with the mRNA expression of the membrane bile acid receptor TGR5. Treatment with Au@P-NPs altered plasma bile acid profile, and increased *Akkermansia muciniphila* and decreased *Lactobacillus* populations in the faeces. (Fig. 2). These results established that gold nanoparticles

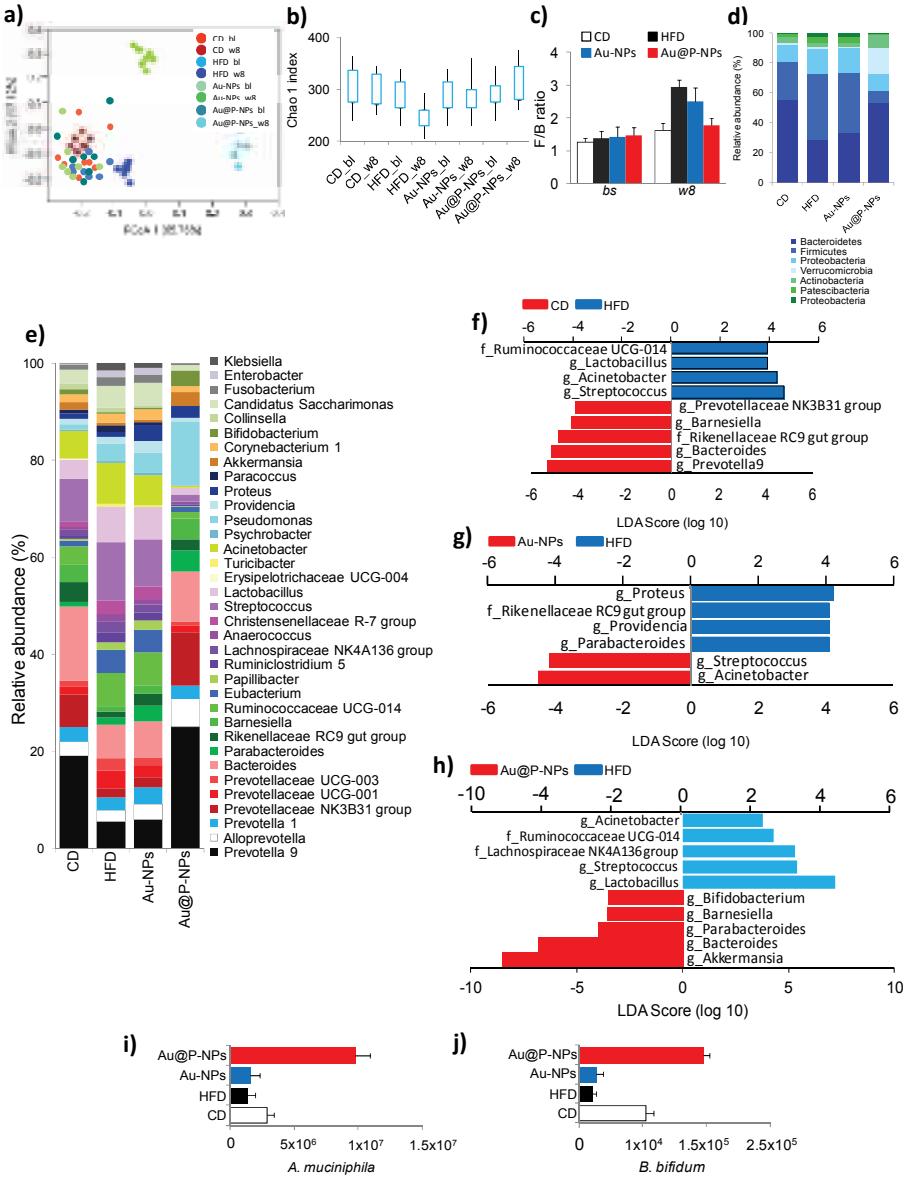

Fig. 2: Effect of Au@P-NPs on obesity-associated gut microbiota imbalance. Faecal pellets of indicated treatments were collected. Faecal samples were also harvested during the last week of adaptation on a CD (indicated to bl), before the administration of the HFD or Au@P-NPs. After getting good quality of genomic DNA, 16S rRNA gene-based gut microbiota profiling was carried out. (a). PCoA, (b). Chao1 index at OTU level, (c). F/B ratio. The relative richness of phylotypes at (d). phylum and, (e). lowest taxonomic level (LTL) attained. LEfSe was figured out to investigate the taxa within the LTL likely that more sturdily distinguish between the gut microbiota of (f). CD *vs* HFD, (g). Au-NPs *vs* HFD, and (h). Au@P-NPs *vs* HFD, (i & j). qPCR amplification of *A. muciniphila* normalized by $3x10^9$ copies of 16S (total bacteria) in faecal sample.

functionalized with bioactive compounds of *C. verum* have high potential to be an anti-obesity drug.

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- Mr. SC Gupta, Research fellow
- Mr. NK Nagpoore, Project fellow
- Ms. Shruti Sharma, Project fellow
- Ms. Akanksha Rai, Project fellow
- Mr. Anand Anunay, Project fellow
- Ms. JS Chauhan, Project fellow

Plant Ecology and Environmental Technology

CSIR NBRI Estd. 1953

LIFE THROUGH INNOVATION

WHERE PLANT-BASED RESEARCH TOUCHES

PLANT ECOLOGY & ENVIRONMENTAL TECHNOLOGY

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- Dr. Shekhar Mallick,Principal Scientist
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- Dr. Shashank K Mishra, Technical Officer

Research Scholars Statistics

Sr. No.	Position Name	Numbers
1.	INSPIRE Faculty	01
2.	Women Scientist	01
3.	Research Associate	02
4.	JRF/SRF Fellow	34
5.	Project Staff	31

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 modeling, 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

(i) The climatic niche and potential distribution areas for six species of citrus in India was modeled.

(ii) Evaluations were made on the effect of water stress on the anatomy of leaf and root tissue in tolerant and sensitive varieties of guar [*Cyamopsis tetragonoloba* (L.) Taub.]. Under water stress, the tolerant varieties of guar leaves revealed a significantly less reduction in the width of protoxylem, metaxylem, and the layer of cortical cell in the varieties as compared to drought sensitive varieties.

(iii) Studies were carried out on three different forest types of Similipal Biosphere Reserve, Odisha, to fill the knowledge gap on composition of plant communities, their aboveground biomass, storage of the carbon in the dominant tree component, and the carbon cycle. Common dominant tree species were selected in semi-evergreen, moist deciduous and dry deciduous forest community. Trees contributing maximum biomass in these forest types were identified.

(iv) Due to the compression of thermal zones and isolation caused by low temperature, the alpine landscape has the highest level of sensitivity to climatic changes. A long-term monitoring network known as HIMADRI (Himalayan Alpine Dynamics Research Initiative) was established by Space Application Centre (SAC), Indian Space Research Organization (ISRO) in collaboration with CSIR-NBRI as one of its other participating organization. Under HIMADRI initiatives, six long-term monitoring sites were established having 20 summits in India. Studies are being carried out on microclimate characterization of Alpine ecosystem ecotone vis-a-vis cryptogam diversity assessment in Indian Himalayas.

(v) Increasing concentrations of ground-level ozone (O_3) exerts significant impact on the plants, but there is limited data for belowground processes. Studies were made to understand the effects of long-term exposure of elevated O_3 (EO_3) on plant growth and biochemical parameters of rhizospheric soil of leguminous tree species *Leucaena leucocephala*. *L.* A significant reduction in shoot length, root, shoot and leaf biomass during 12, 18 and 24 months of exposure to EO_3. Total nutrients in rhizospheric soil like carbon and phosphorus were significantly reduced after 24 months. Most of the available nutrients showed significant reduction after 6, 12 and 24 months of EO_3 exposure. A significant decrease was apparent in microbial biomass carbon, nitrogen and phosphorus after 6, 12, 18 and 24 months of EO_3 treatment.

(vi) Studies were made to investigate the differential response of ROS scavenging mechanism in sensitive and tolerant wheat cultivars exposed to future climate change scenarios, of high levels of O_3 and CO_2, and temperature. Based on ROS scavenging potential, it was concluded that, cultivar HD 2967 was tolerant and DBW 184 was a sensitive cultivar under future climate change scenarios.

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-inoculants 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

(i) An efficient biocontrol agent has been developed from bacterial endophyte, *Bacillus subtilis* that can suppress the charcoal rot disease caused by *Macrophomina phaseolina* infection and enhances the physiological attributes of soybean.

(ii) A peppermint oil-based nanoemulsion (PNE) has been synthesised, which has proved to be a promising antimicrobial agent against fungal pathogens; it can be used for sustainable disease management in crop plants.

(iii) A promising *Bacillus subtilis* strain NBRI-W9 (MTCC-25374) has been identified and evaluated as a potent biocontrol agent of Fusarium infection in different crops such as gladiolus, tomato and betelvine.

(iv) Molecular mechanism was elucidated of interaction of necrotrophic fungi, *Rhizoctonia solani,* responsible for sheath blight disease in rice with the biocontrol agent *Bacillus amyloliquefaciens*. *B. amyloliquefaciens* was found to have various defence responsive genes and secondary metabolites for the control of *Rhizoctonia solani*.

(v) A bacterial strain, *Pseudomonas sp.*was identified to contain arsenite methyl transferase activity, which reduces the arsenic uptake in leafy vegetable Spinach by volatizing arsenic.

(vi) A study showed that *Paenibacillus lentimorbus,* B-30488 alters root architecture and regulates growth via modulation of phytohormones and genes expression and enhances drought tolerance and overall significantly improves plant growth.

(vii) A rapid and field deployed -diagnostic kit, for early detection of *Papaya ringspot virus* (PRSV) is being developed on the principle of lateral flow immunoassay (LFIA) using polyclonal antibody (PAb).

(viii) Biologically synthesized silver nanoparticles prepared with the leaves of *Rivina humilis* is being investigated for virus management.

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

(i) Phytoremediation of heavy metals, stress tolerance mechanism, Arsenic detoxification mechanism in rice employing biotic and abiotic agents, monitoring and assessment of toxic agents in environmental matrices

(ii) A comparative study was made on the accumulation of Ni and Cd grown on simulated battery electrolyte waste (EW) contaminated soil, in two tolerant grass species namely Vetiver (*Chrysopogon zizanioides*) and lemongrass (*Cymbopogon citratus)*. They exhibited accumulation of both Ni and Cd in a dose-dependent manner, with significantly higher level in the roots.

(iii) A geo-referenced database of arsenic mapping in agriculture has been developed with the help of "Remote Sensing Applications Centre", Lucknow, Uttar Pradesh (*RSAC*-UP) using ArcGIS for 20 districts of Uttar Pradesh.

(iv) A study on microbe-assisted plant-based bioremediation strategy for remediating Hexachlorocyclohexane (HCH) contamination in soil showed promising results.

(v) The potential of application of novel microbial strains for the bioremediation of cyanide is being evaluated, using bacterial and fungal strains isolated from cyanide-contaminated blast furnace effluent and activated sludge of a steel plant.

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

Effect of water stress on the anatomy of leaf and root tissue in four varieties of guar [*Cyamopsis tetragonoloba* (L.) Taub.]

Guar or cluster bean (*Cyamopsis tetragonoloba* (L). Taub.) is a drought-tolerant, annual arid legume crop, cultivated mainly during the summer season, with seed sowing during June–July and is harvested up to October. Water stress changes key physiological functions and disrupts cellular attributes in plants. In the present study, anatomical traits of leaves and root tissue of four guar varieties *viz*. RGC-1002 and

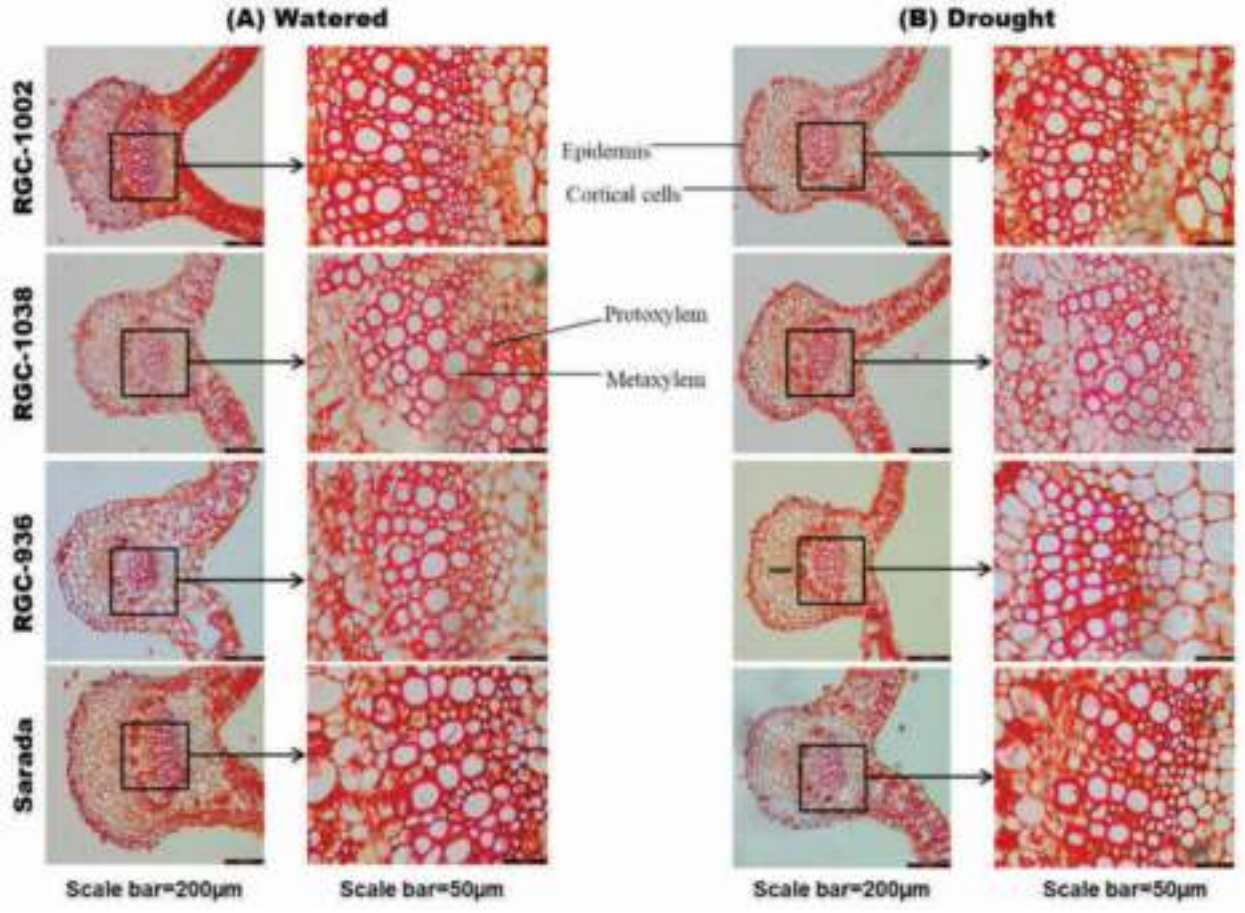

Fig.1: Effect of water stress in transverse section of leaf in four varieties of guar, (A). Watered and (B). drought.

RGC-1038 (drought tolerant) and, RGC-936 and Sarada (drought sensitive) were monitored under-watered and water deficit conditions. In general, tissues exposed to conditions with little access to water have generally shown a reduction in cell size, more number of vascular tissues, and thicker cell walls. Under water stress, the transverse section of leaves revealed a significantly less reduction in the width of protoxylem, metaxylem, cortical cells and the layer of cortical cell in the varieties RGC-1002 and RGC-1038 as compared to RGC-936 and Sarada (Fig. 1 and Table 1). Along with the leaf anatomical traits, the cross-section of root tissue followed a similar pattern of reduction in anatomical traits under water stress conditions (Fig. 2 and Table 2). Our findings demonstrate that guar plants exhibited lower growth potential, which was linked with plant water status under drought. Several structural features may have made it easier for this species to withstand drought conditions. Therefore, under conditions of prolonged drought, plants generate leaves and roots with narrow cortical cells, xylem tissue and thick-walled vessels. All these attributes provide the anatomical basis of drought adaptation in guar plants through

Table 1: Alterations in leaf anatomical traits under water stress

Guar varieties	Treatments	Width of protoxylem (µm)	Width of metaxylem (µm)	Length of cortical layer (µm)	Width of cortical cells (µm)
RGC-1002	Watered Drought	23.8±7.5 19.1±5.6**	33.69±11.5 29.77±9.42***	217.0±36.8 191.6±27.8***	49.52±15.12 41.0±13.25***
RGC-1038	Watered Drought	24.0±6.2 18.9±5.4**	51.70±7.40 41.62±2.84***	279.7±16.6 233.8±15.6***	53.0±15.16 42.30±14.35***
RGC-936	Watered Drought	20.0±7.4 13.3±5.3***	36.38±13.6 28.69±11.9***	323.6±31.5 215.4±28.2***	40.20±17.65 31.57±12.46***
Sarada	Watered Drought	17.9±4.7 13.8±4.2***	33.77±8.61 26.31±7.84 ***	253.8±38.2 204.6±31.9***	37.35±13.19 29.46±9.79**

Data is mean ±SD of 5 leaves of 3rd/4th position from the apex of 5 independent plants, 10 sections per leaf passing through midrib. Asterisks represents significant variation at $^{*}P$ <0.05, $^{**}P$ < 0.01 and $^{***}P$<0.001 level according to *t*-test.

Table 2: Alterations in root anatomical traits under water stress

Guar varieties	Treatments	Width of protoxylem (µm)	Width of metaxylem (µm)	Length of cortical layer (µm)
RGC-1002	Watered Drought	68.46±16.13 59.08±14.34**	118.21±28.76 106.36±25.15**	356.64±40.87 320.82±45.18***
RGC-1038	Watered Drought	69.31±20.24 60.38±17.50**	114.0±37.64 96.36±28.63***	363.0±54.28 330.0±44.54***
RGC-936	Watered Drought	53.85±17.69 41.38±13.1***	101.0±26.92 82.64±17.76***	367.73±41.37 306.27±37.60***
Sarada	Watered Drought	49.0±15.35 34.77±13.43***	100.43±19.9 80.57±17.7***	366.91±39.2 284.27±36.4***

Data is mean ±SD of 5 root tissue dissected from 5 independent plants, 10 sections per root tissue. Asterisks represents significant variation at $^{*}P$ <0.05, $^{**}P$ < 0.01 and $^{***}P$<0.001 level according to *t*-test.

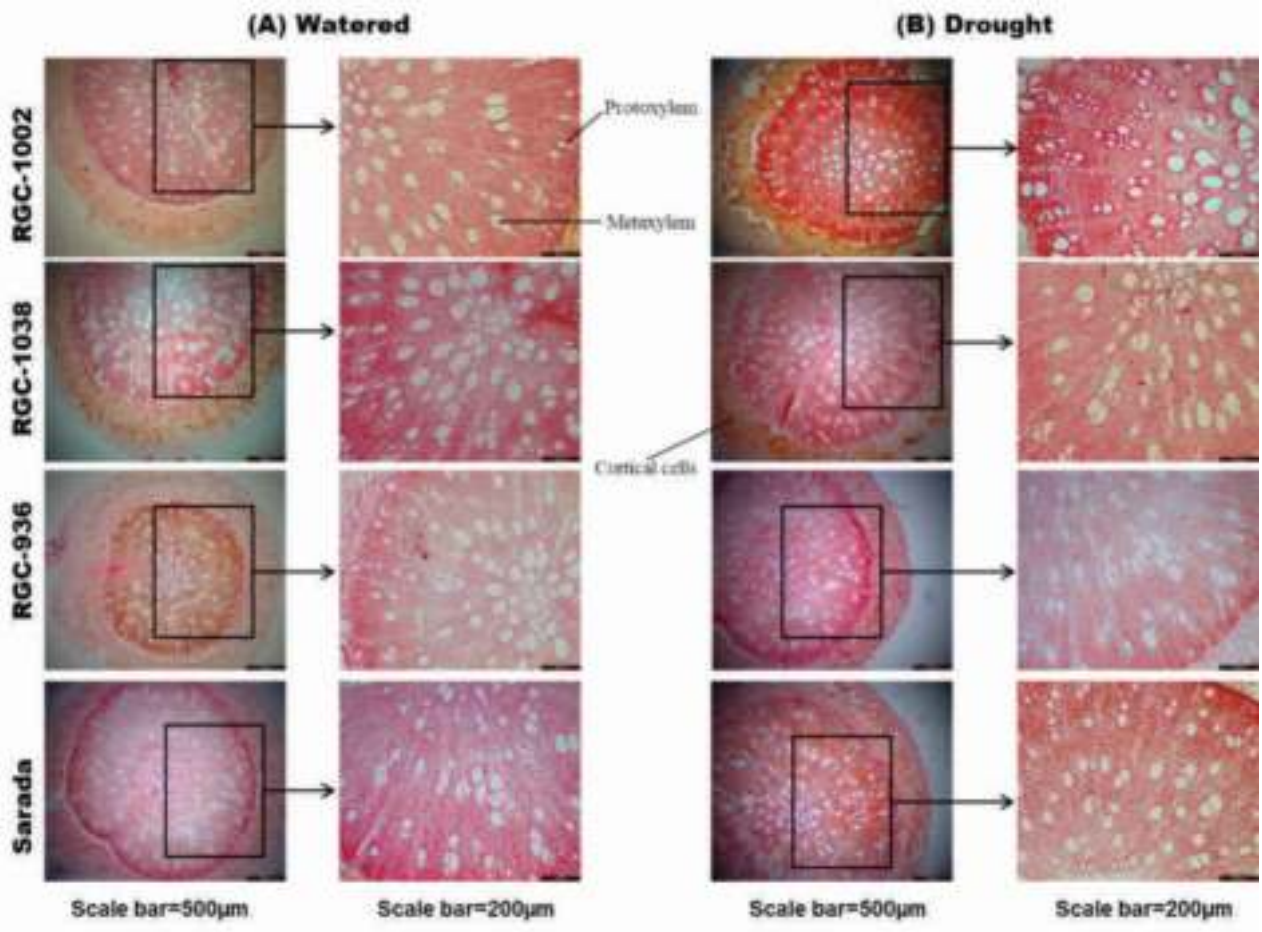

Fig. 2: Effect of water stress in transverse section of root in four varieties of guar, (A). Watered and (B). drought.

the ability to modify their leaf and root structures so they could survive and develop in dry and arid conditions.

Synchronised regulation of carbon and nitrogen provides drought tolerance in *Cyamopsis tetragonoloba*

Drought is a major adverse environmental factor that limits plant productivity. Concomitant assimilation of carbon (C) and nitrogen (N) in illuminated leaves requires the regulated partitioning of reductant and photosynthate to sustain the demands of amino acid and carbohydrate biosynthesis (Fig. 3). The short-term exposure to drought and its responses of photosynthesis and photosynthate partitioning to N enrichment was studied in *Cyamopsis tetragonoloba* (L.) Taub (guar). Four contrasting varieties of guar, HG-563, RGC-986 (drought-tolerant) and RGC-471, Varsha (drought-sensitive) were subjected to 15 days water stress and leaf tissues were studied in order to contemplate the counter strategy engaged under drought conditions. In guar plants, sensors trigger a signalling cascade that activates numerous proteins to induce the expression of certain genes involved in carbon and nitrogen metabolism. The levels of glucose, starch, and Glutamate dehydrogenase (GDH), Aspartate aminotransferase (AspAT), isocitrate dehydrogenase (ICDH), Nitrate Reductase (NR), and Nitrite reductase (NiR) activities were determined biochemically during 15 days drought treatment, at three stages. Further, the carbon (oxidative phosphorylation and TCA cycle) - nitrogen metabolic pathway interaction was studied at the molecular level. The respiratory pathway genes were upregulated, while the nitrogen metabolic pathway genes were downregulated under all stages of drought in guar plants. The physiological, biochemical and molecular data suggests that the high rates of dark respiration was insufficient to provide extra carbon required to assist amino acid synthesis but rather sufficed by a rapid metamorphosis in the

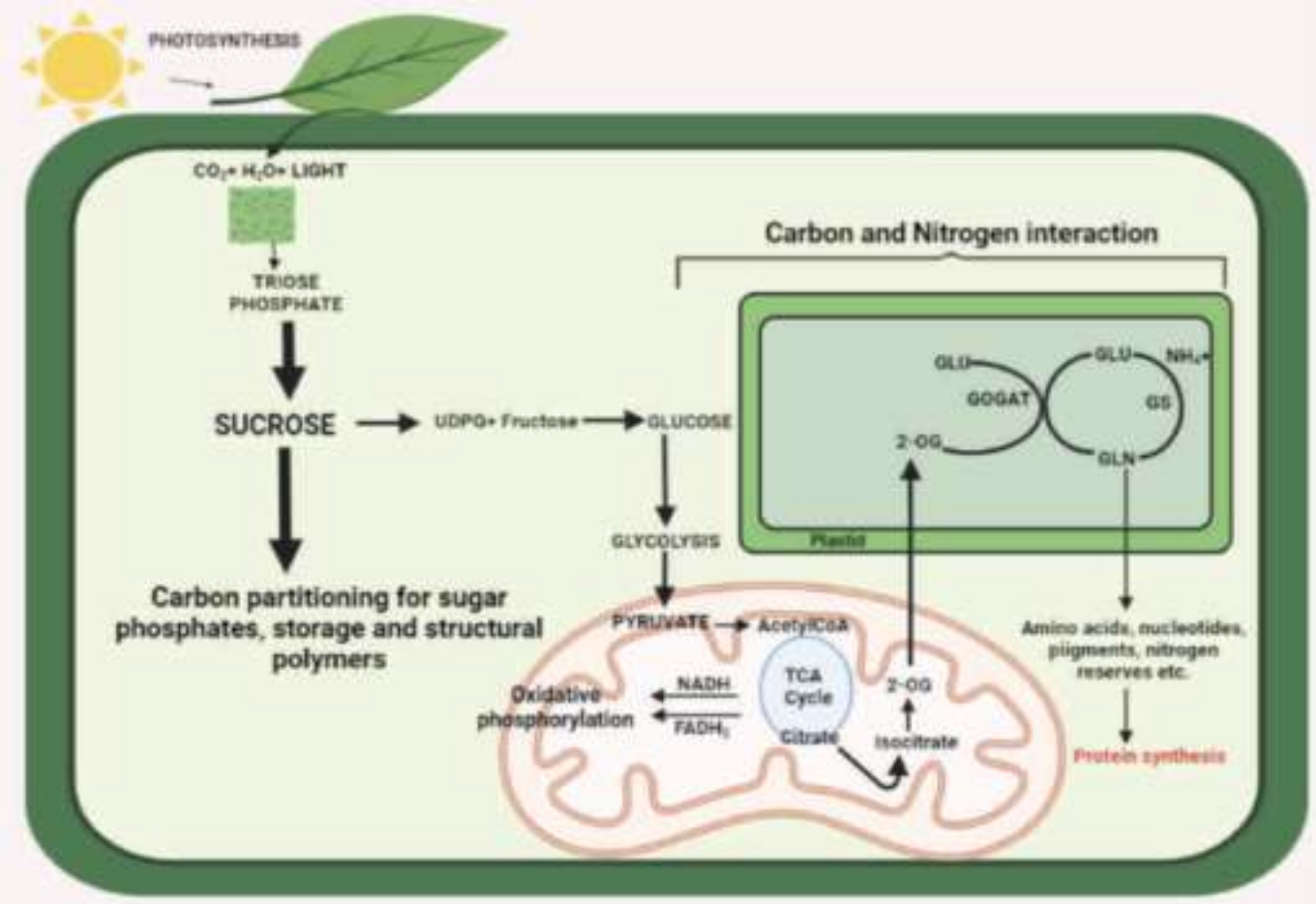

Fig. 3: Interaction of carbon and nitrogen pathways. The carbon metabolic pathway provides energy (ATP) and reducing potential NAD(P)H to nitrogen assimilation process. Moreover, the carbon skeleton part in amino acids also comes from 2-OG (2-oxoglutarate) of TCA (tricarboxylic acid cycle) cycle. The carbon and nitrogen both can act as potent signalling molecules to regulate expression of several genes involved in metabolism.

photosynthetic carbon partitioning to amino acid metabolism via the nitrogen metabolism.

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

Changes in growth pattern and rhizospheric soil biochemical properties of *Leucaena leucocephala* under long-term exposure to elevated ozone

Increasing concentrations of ground-level ozone (O_3) exert significant impacts on the plants, but there is limited data for belowground processes. We studied the effects of long-term exposure of elevated O_3 (EO_3) on plant growth parameters (plant height and biomass) and biochemical parameters (nutrients, microbial biomass and enzymatic activities) of rhizospheric soil of leguminous tree species *Leucaena leucocephala*. *L. leucocephala* seedlings were grown under ambient O_3 (AO_3) and EO_3 (+20 ppb above ambient) under Free Air Ozone Concentration Enrichment (O_3-FACE) facility and changes in plant growth and their rhizospheric soil properties

Table 1: Soil nutrient parameters of *L. leucocephala* rhizospheric soil at different exposure periods. The student's t-test shows individual differences between AO_3 and EO_3 and the repeated measurement one-way ANOVA shows interactions between ozone and time interval. Data are mean ± standard error (SE) (n = 6). Asterisks indicate the level of significance, *P<0.05, **P<0.01, and ***P<0.001.

Soil Nutrient factors	6 month		12 month		18 month		24 month		RM-ANOVA		
	AO_3	EO_3	AO_3	EO_3	AO_3	EO_3	AO_3	EO_3	Time	Ozone	Time x Ozone
pH	8.5±0.06	8.3±0.04	8.6±0.04	8.6±0.02	8.6±0.04	8.4±0.04	8.8±0.04	8.5±0.07	*	ns	ns
Available phosphorus (mg kg^{-1})	138±2.0	114±3.7***	174±2.5	147±4.3***	126±1.1	123±1.3	225±8.0	192±4.4**	***	***	ns
Available nitrogen (mg kg^{-1})	374±24	299±12	286±26	243±12	340±23	250±12*	355±12	280±20***	***	***	**
Available sulfur (mg kg^{-1})	15.3±0.01	12.9±0.05***	20.0±0.38	17.1±0.56*	14.0±0.39	12.1±0.52	17.8±0.18	15.3±0.18***	**	***	ns
Total organic carbon (mg kg^{-1})	8623±84	8491±84	8867±235	8667±208	8623±84	8491±85	8975±220	7426±288*	***	**	*
Total nitrogen (mg kg^{-1})	747±8	743±10	780±6	769±5	747±8	755±5	822±3	803±11	***	***	***
Total phos-pho-rus (mg kg^{-1})	1418±26	1353±23	1454±78	1224±59	1498±62	1463±56	1732±29	1479±44*	***	**	ns
C:N ratio	11.6±0.23	11.4±0.19	11.4±0.31	11.3±0.29	11.6±0.16	11.2±0.15	10.9±0.30	9.3±0.39*	***	*	*

Table. 2: Microbial biomass carbon, phosphorus, nitrogen, and their ratio with soil nutrients of *L. leucocephala* rhizospheric soil. The student's t-test shows individual differences between AO_3 and EO_3 and the repeated measurement one-way ANOVA shows interactions between ozone and time interval. Data are mean ± standard error (SE) (n = 6). Asterisks indicate the level of significance, *P<0.05, **P<0.01, and ***P<0.001.

Response variables	6 month		12 month		18 month		24 month		RM-ANOVA		
	AO_3	EO_3	AO_3	EO_3	AO_3	EO_3	AO_3	EO_3	Time	Ozone	Time x Ozone
Microbial biomass carbon (mg kg^{-1})	295±4.22	280±3.61	417±4.17	322±5.90***	339±2.31	287±2.12***	391±1.18	306±0.077***	***	***	***
Microbial biomass phosphorus (mg kg^{-1})	69±1.31	54±1.18**	77±3.19	60±2.64**	72±1.88	60±2.51*	85±2.21	54±0.83***	***	***	***
Microbial biomass nitrogen (mg kg^{-1})	55±0.99	45±1.57**	53±0.69	46±1.28*	61±1.95	49±2.56*	63±0.48	55±2.61*	***	***	ns
MBC:MBP ratio	4.3±0.11	5.2±0.14*	5.5±0.24	5.4±0.33	4.7±0.09	4.8±0.21	4.6±0.10	5.7±0.07***	***	**	**
MBC:MBN ratio	5.4±0.14	6.3±0.29	7.9±0.12	7.1±0.25*	5.6±0.22	6.0±0.35	6.2±0.06	5.7±0.26	***	ns	**
MBC:TOC ratio	0.03±0.00	0.03±0.00	0.05±0.00	0.04±0.00**	0.04±0.00	0.03±0.00**	0.04±0.00	0.04±0.00	**	**	***
MBP:TP ratio	0.05±0.00	0.04±0.00*	0.05±0.00	0.05±0.00	0.05±0.00	0.04±0.00*	0.05±0.00	0.04±0.00***	**	**	ns
MBN:TN ratio	0.40±0.01	0.38±0.01	0.54±0.00	0.42±0.01***	0.45±0.01	0.38±0.00***	0.48±0.00	0.38±0.00***	***	***	ns

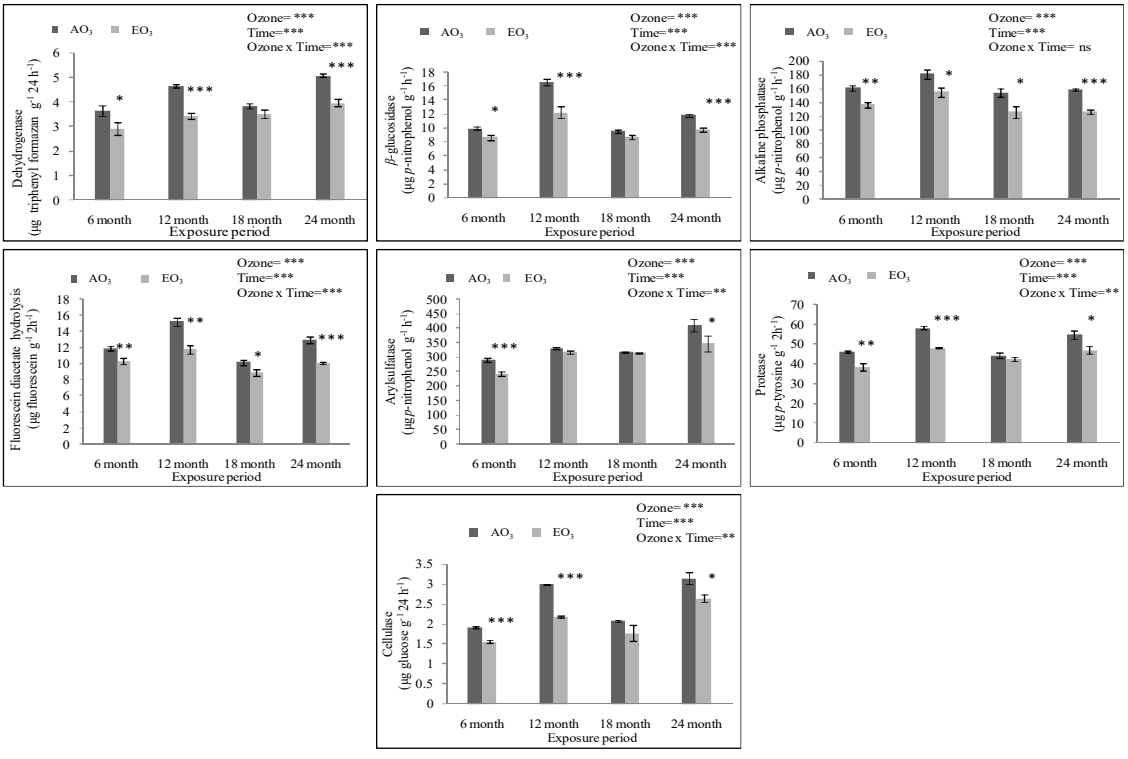

Fig. 1: Soil enzymatic activities of *L. leucocephala* rhizospheric soil under elevated O_3 (EO_3) and ambient O_3 (AO_3) exposure. The student's t-test shows individual differences between AO_3 and EO_3 and the repeated measurement one-way ANOVA shows interactions between ozone and time interval. Data are mean ± standard error (SE) (n = 6). Asterisks indicate the level of significance, *P<0.05, **P<0.01, and ***P<0.001.

were studied during 6, 12, 18 and 24 months of EO_3 exposure. *L. leucocephala* showed significant reductions in shoot length, root biomass, shoot biomass, leaf biomass and total biomass during 12, 18 and 24 months of exposure to EO_3. Total nutrients in rhizospheric soil like carbon and phosphorus were significantly reduced after 24 months of EO_3 exposure. Most of the available nutrients showed significant reduction after 6, 12 and 24 months of EO_3 exposure (Table 1). A significant decrease was apparent in microbial biomass carbon, nitrogen and phosphorus after 6, 12, 18 and 24 months of EO_3 treatment (Table 2). RM-ANOVA results showed significant interactions between O_3 and time on MBC, MBP, MBC/MBP and MBC/TOC ratio. Significant reductions were observed in extracellular enzymatic activities (dehydrogenase, alkaline phosphatase, β-glycosidase, fluorescein diacetate, arylsulfatase, cellulase and protease) of soil after 6, 12 and 24 months of EO_3 exposure (Fig 1). These results suggest that increasing O_3 concentrations will directly impact *L. leucocephala* growth as well as have indirect impact on the nutrient contents (C, N, and P), microbial biomass and extracellular enzymatic activities of rhizospheric soil of *L. leucocephala*. Our results suggest that continuous increase in O_3 concentrations will have serious implications for aboveground plant growth and belowground soil fertility in this region considered as O_3 hotspot.

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Sustainable agricultural production, food safety, bio-inoculant formulations, abiotic/biotic stress amelioration, soil fertility, soil ecology

Paenibacillus lentimorbus enhanced abiotic stress tolerance through lateral root formation and phytohormone regulation

Under the stressed conditions plant growth-promoting rhizobacteria (PGPR) are able to stimulate plant growth through several mechanisms, including enhanced antioxidants alleviation, regulation of stress responsive genes and phytohormones etc. The present study was conducted to investigate the impact of *Paenibacillus lentimorbus* B-30488 inoculation on salinity and drought stress mitigation in *Arabidopsis thaliana* through modulation in defense enzymes, phyto-hormones and root system architecture associated gene expression profiling. *In vitro* experiments demonstrated the role of B-30488 in stimulating the root length, branches, lateral root formation and biomass under salinity and drought stress (Fig. 1). Microscopy results showed decrease in lateral roots hair formation under both stresses and B-30488 inoculation not only mitigated but also enhanced the lateral root formation (Fig. 2). The inoculation of B-30488 modulated the phytohormones levels to protect the plants from salinity and drought stress (Fig. 3). Similarly, defence enzymes were also activated under the stressed conditions, but B-30488 inoculation reduced the antioxidants content during salinity and drought stress as compared to their respective controls. Gene expression analysis through real time polymerase chain reaction (RT-PCR) showed modulated expression of several genes related to root development, stress and lateral root formation in B-30488 inoculated seedlings (Fig. 4). Results based on the present study showed that B-30488 is also involved in alteration root architecture, its growth regulation via modulation in phytohormones and genes expression and overall significant improvement in plant growth under stress conditions.

Drought stress has been reported for its adverse effect on several physiological and metabolic processes of the plant, which collectively impart a negative impact on the overall yield of crops, including chickpea.

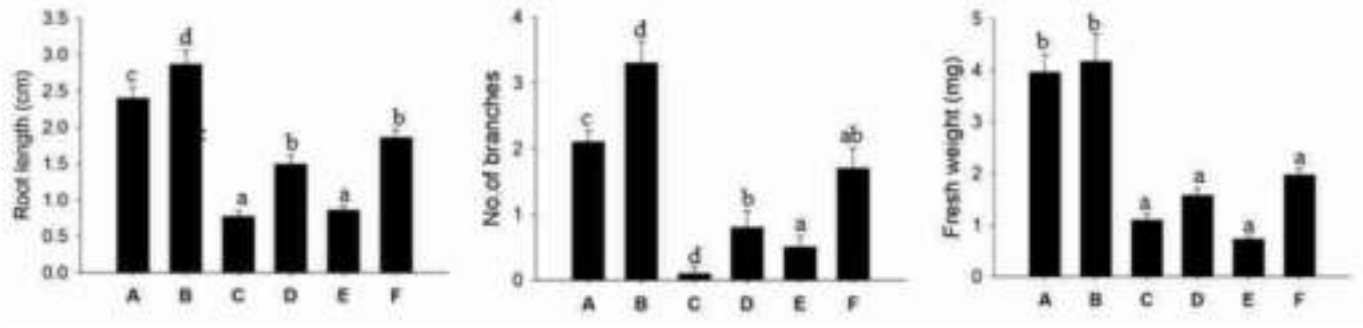

Fig. 1: Effects of B-30488 inoculation on growth parameters of *Arabidopsis thaliana* seedlings under control and stressed conditions; Control (A), B-30488 (B), NaCl (C), B-30488 + NaCl (D), Mannitol (E) and B-30488 + Mannitol (F). Surface-sterilized seeds were sown on Murashige and Skoog agar-solidified medium (half strength) supplemented with 75 mM NaCl and 150 mM Mannitol in Petri dish.

Fig. 2: Effects of B-30488 on root hair development in *Arabidopsis thaliana* seedlings; Control (A), B-30488 (B), NaCl (C), B-30488 + NaCl (D), Mannitol (E) and B-30488 + Mannitol (F). Seedlings grown with different treatments, growth of root hairs was observed in response to B-30488 after 7 days. Images were taken by using stereo microscope.

Comparative transcriptomic and proteomic studies helped to identify numerous stress-responsive genes. Additionally, functional analysis of several plant proteins induced under stress conditions has been also done in model plants, including *Arabidopsis thaliana*. Plant *14-3-3* proteins are highly conserved, phospho-binding proteins, ubiquitous in nature that control major cellular functions. The genes encoding *14-3-3* family proteins are reported for involvement in plant stress tolerance. Therefore, based on the results of our comparative proteomics analysis the function of chickpea (*Cicer arietinum* L.) *14-3-3-like protein B* with increased expression induces

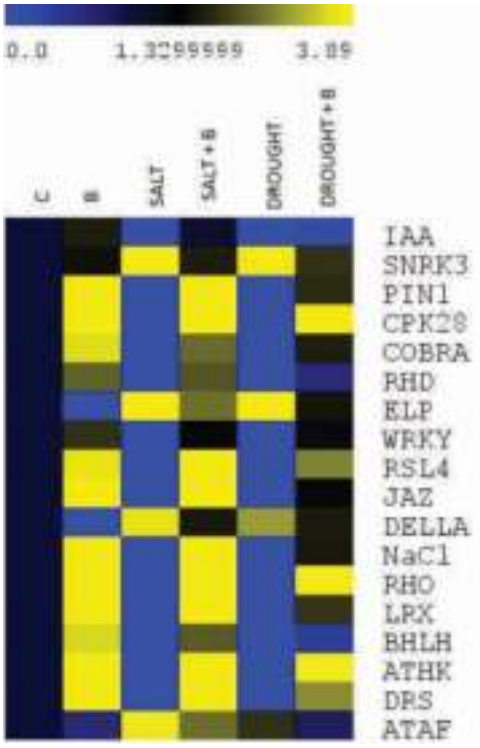

Fig. 4: Expression pattern of root development related genes after inoculation with B-30488 under stress condition; Gene expression of root hair development and stress related genes were analysed by qRT-PCR. The data represented means of six biological replicates ($p \leq 0.05$level).

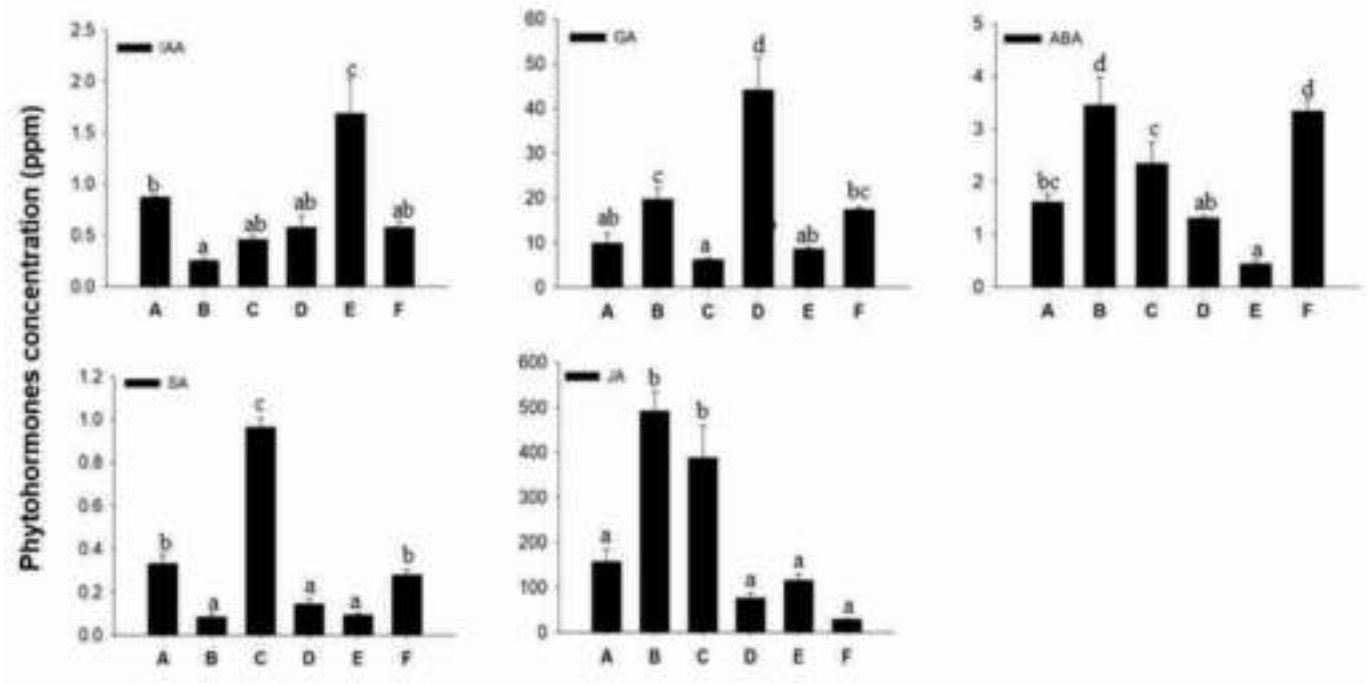

Fig. 3: Effect of B-30488 inoculations on phytohormone levels in *Arabidopsis thaliana* under different abiotic stresses.

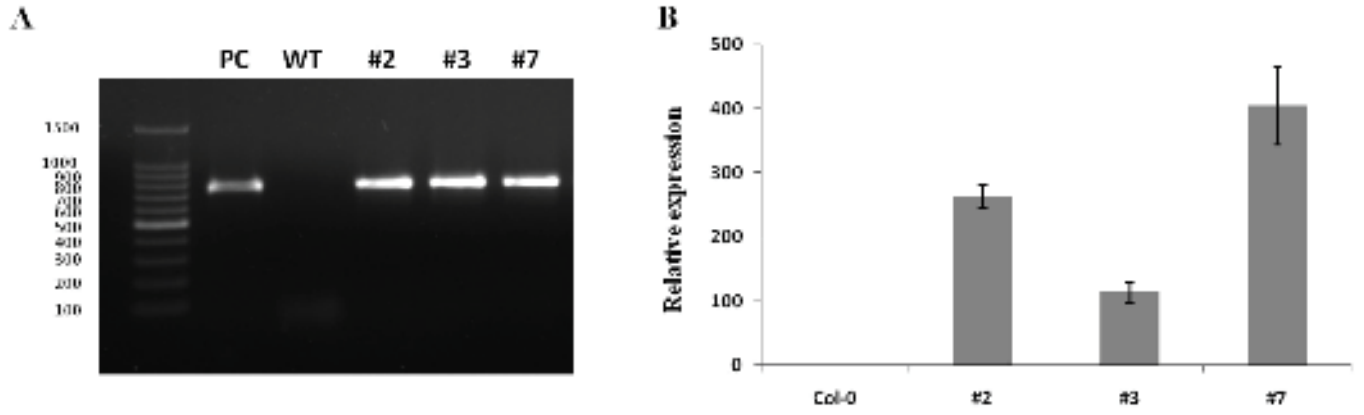

Fig. 5: Selection of Ca-14-3-3 expressing transgenic lines. APCR amplification of *Ca-14-3-3-B* gene from the leaves of T3 transgenic lines #2, #3, #7, WT, and PC (positive control). **(B)** Expression of *Ca-14-3-3-B* in the leaves of the T3 transgenic lines and Col-0, #2, #3, and #7 using q-RT-PCR.

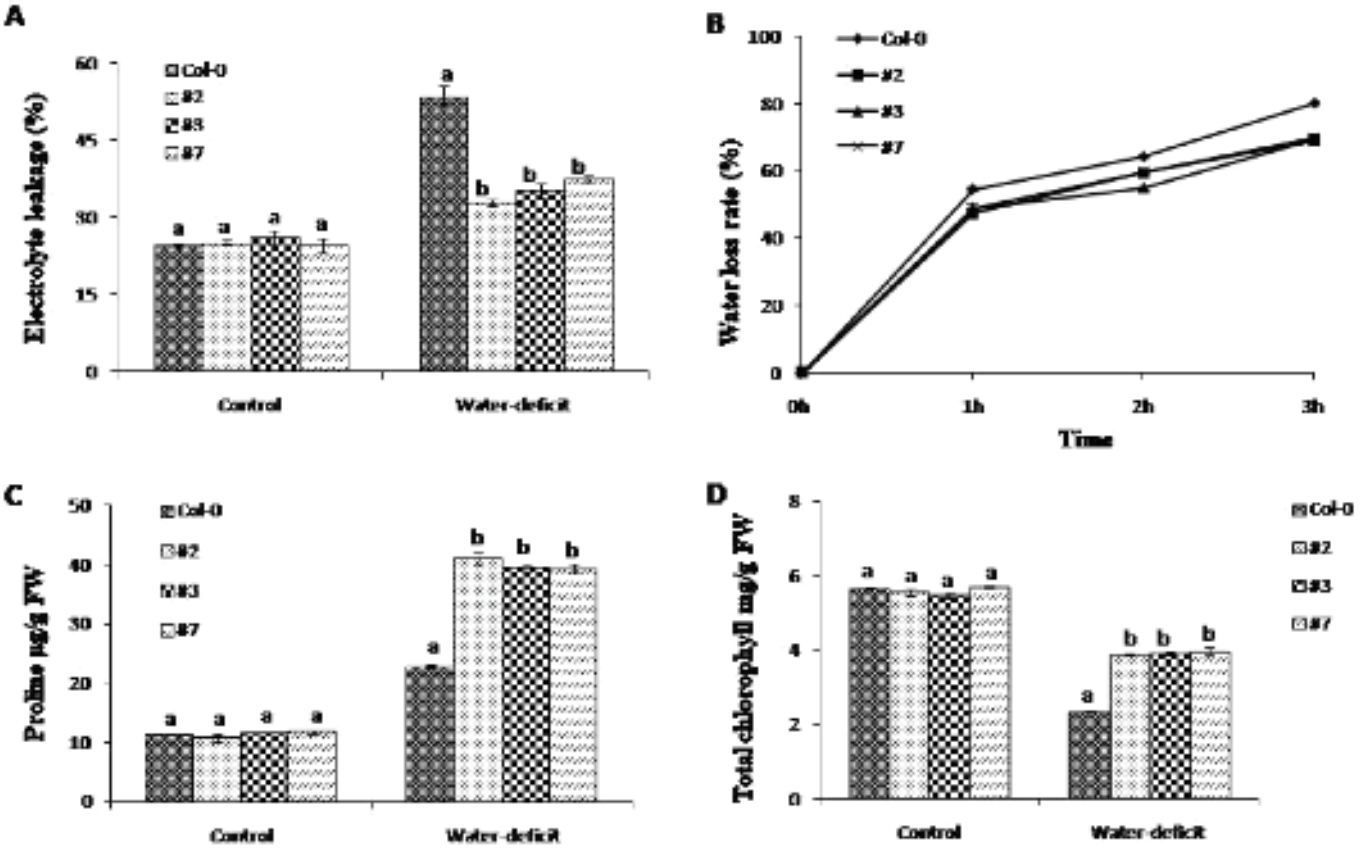

Fig. 6: Physiological changes under water-deficit condition in transgenic plants. **(A)** Electrolytic leakage (EL), **(B)** Rate of water loss, **(C)** Proline content, and **(D)** Chlorophyll content in wild-type (WT) plants and transgenic (#1, #6, #9) lines. Values are represented as mean values of three replicates ± SE. Different letters above the bars specify significant differences ($p < 0.05$) as examined by Tukey's test.

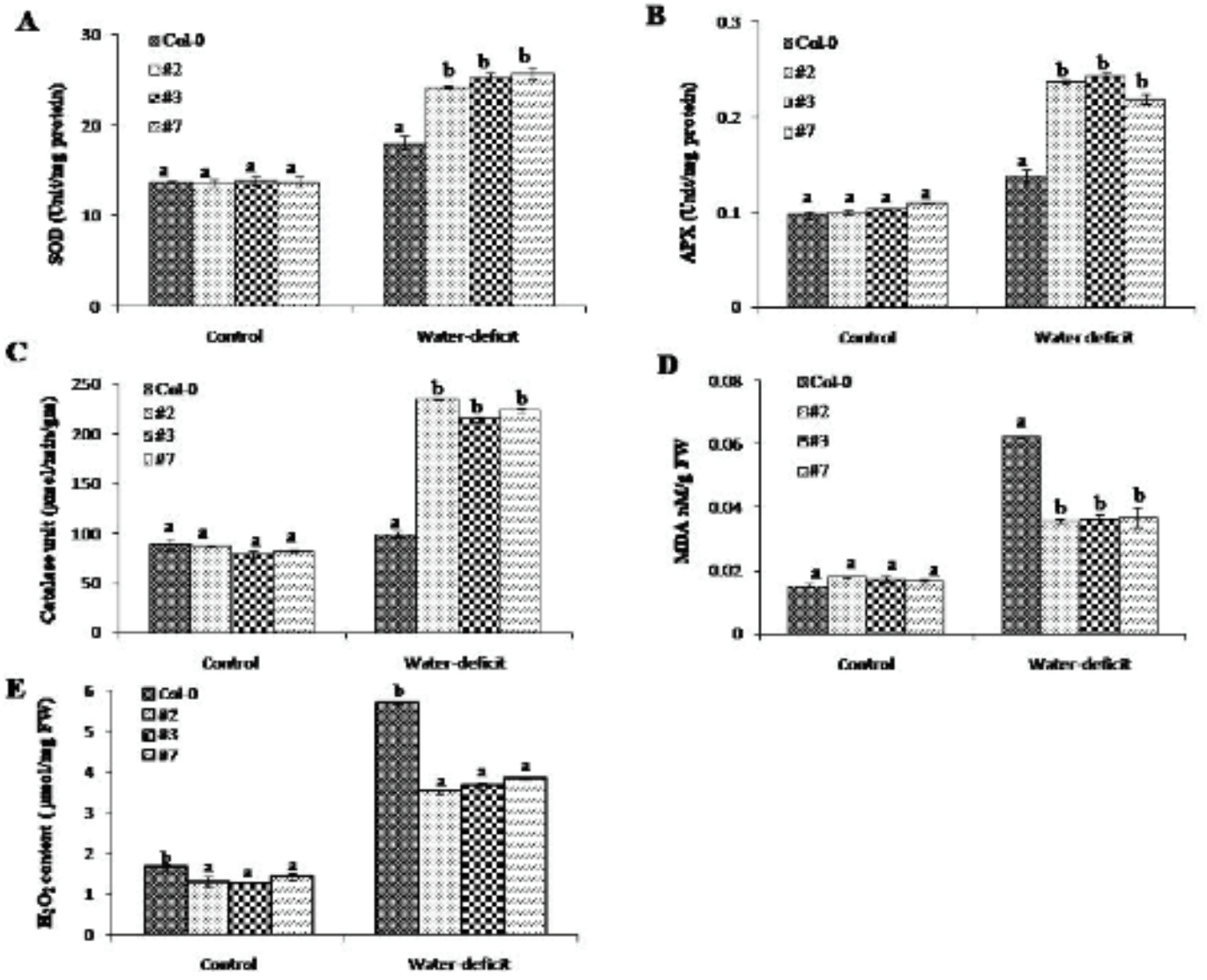

Fig. 7: Effect of Ca-14-3-3 like protein B overexpression on antioxidant enzymes activity, MDA and H_2O_2 in WT and transgenic plants after drought stress. **(A)** SOD, **(B)** APX, **(C)** Catalase, (**D)** MDA, and **(E)** H_2O_2 content under control and drought stress condition. Values are represented as mean values of three replicates ± SE. Different letters above the bars specify significant differences ($p < 0.05$) as examined by Tukey's test.

drought stress in transgenic *Arabidopsis thaliana* lines (Fig. 5). Compared to wild type, *Ca-14-3-3-like protein B* overexpressing lines showed a high rate of germination, more biomass, and increased root length at the seedling stage under osmotic stress caused by both polyethylene glycol (PEG-6000) and mannitol. In addition, chlorophyll content, proline content, relative water content (RWC), antioxidant enzyme activities, net photosynthesis, and water use efficiency were also higher in transgenic lines as compared to WT after drought stress (Figs. 6-7). Staining with DAB and NBT indicated that transgenic lines accumulated less H_2O_2 than WT plants. Furthermore, *Ca-14-3-3-like protein B* overexpression also upregulated the transcript level of the certain stress-responsive genes (*RD20, PDF1*, and *P5CS1*) and of genes involved in lignin biosynthesis (*PAL* and *CAD*) (Fig. 8). Overall it can be concluded that *Ca-14-3-3-like protein B* improves the drought tolerance when overexpressed in *Arabidopsis* plants and the gene thus appears to be a promising candidate for crop improvement efforts.

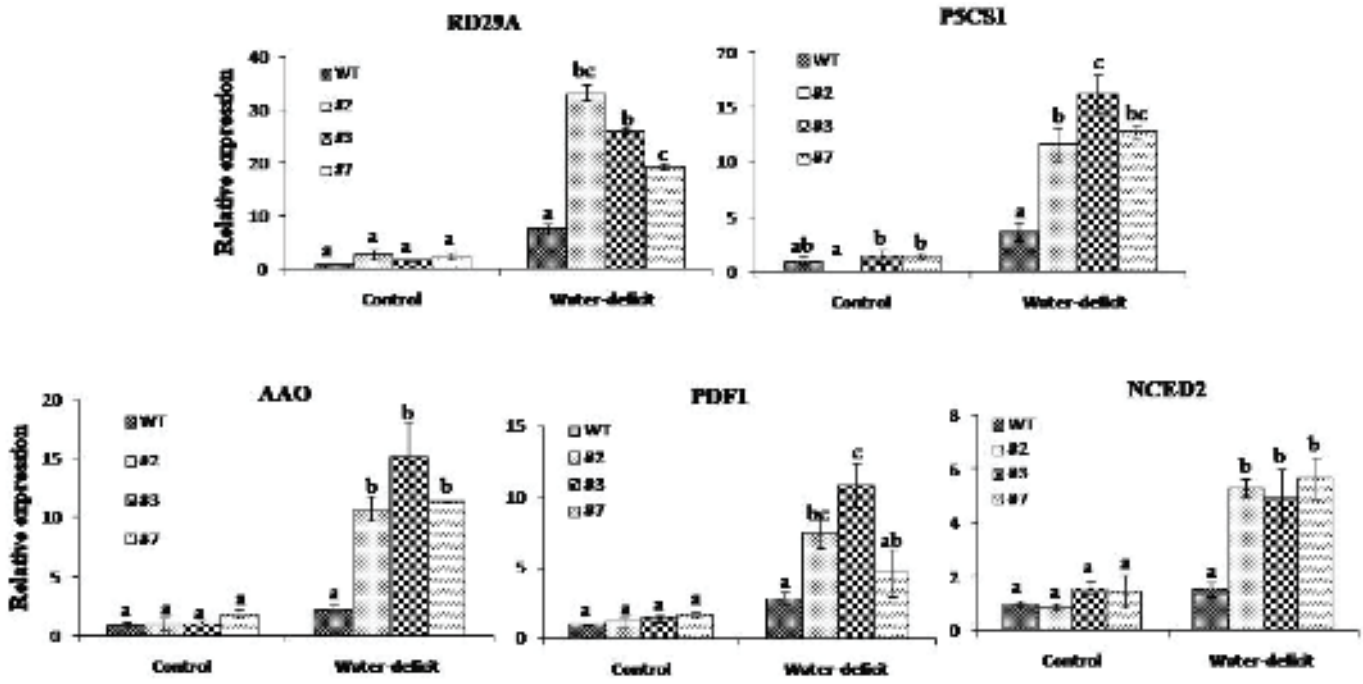

Fig. 8: Expression profile of some stress responsive and ABA biosynthetic genes in root of WT and transgenic lines under control and drought stress condition. Values are represented as mean values of three replicates ± SE. Different letters above the bars specify significant differences ($p < 0.05$) as examined by Tukey's test.

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Phytoremediation of heavy metals, stress tolerance mechanism, Arsenic detoxification mechanism rice employing biotic and abiotic agents, monitoring and assessment of toxic agents in environmental matrices

Comparative account of metal phytoextraction efficiencies by vetiver and lemongrass grown on Ni–Cd battery waste contaminated soil

The comparative study of the accumulation of Ni and Cd grown on simulated 1%, 2% and 4% battery electrolyte waste (EW) contaminated soil, in two tolerant grass species namely Vetiver (*Chrysopogon zizanioides*) and lemongrass (*Cymbopogon citratus*), exhibited accumulation of both Ni and Cd in a dose-dependent manner, with significantly higher level in the roots. Also, accumulation for both the metals was higher in vetiver than in lemongrass. Accumulation of Ni (µg g^{-1}) in the roots of vetiver increased significantly by 94 ± 1, 197 ± 2 and 253 ± 9, in EW treatments, respectively compared to 5 ± 0.3 in the control. Ni (µg g^{-1}) accumulation was higher in shoots (36.8) and roots (252.9) of vetiver than in lemongrass (12.5 and 79.7, respectively). Similarly, level of Ni in lemongrass was 62 ± 1, 68 ± 3, and 80 ± 1, respectively in EW treatments as compared to 5.9 ± 0.7 in control. The increase of Ni in the vetiver roots from EW1% to EW2% was higher (109%) than from EW2% to EW4% (28%), on the contrary in lemongrass roots, the increase was lower (10%) from EW1% to EW2% and also from EW2% to EW4% (17%).

Percentage increase in Ni accumulation across the lower leaf, middle leaf and apical leaf, in both the grass species, increased at the lower contamination i.e. from EW1% to EW2%, which was higher in vetiver i.e. 122%, 79% and 258%, respectively than in lemongrass viz. 95%, 71% and 72%, respectively. However, the increase was lesser at higher contamination i.e. from EW2% to EW4% i.e. 59%, 57% and 30%, respectively in vetiver and 7%, 35% and 28%, respectively in lemongrass. Accumulation of Cd (µg g^{-1}) in the roots of vetiver was 107.6 ± 9.1, 142.9 ± 15.7 and 232.2 ± 13.2 while in lemongrass root was 86.1 ± 6.7, 114.9 ± 14.9 and 156.5 ± 7.1, respectively. Similarly, Cd (µg g^{-1}) accumulation in vetiver and lemon grass roots was 232.2 and 147.2, respectively, however, accumulation in the vetiver shoot (43.4) was less than in lemongrass (99.9). The translocation factor (TF) increased for both metal in each plant species, with increase in contamination. In vetiver, translocation of Ni was higher than Cd for EW1% and EW2%, but at EW4%, translocation of Cd increased. In contrast,

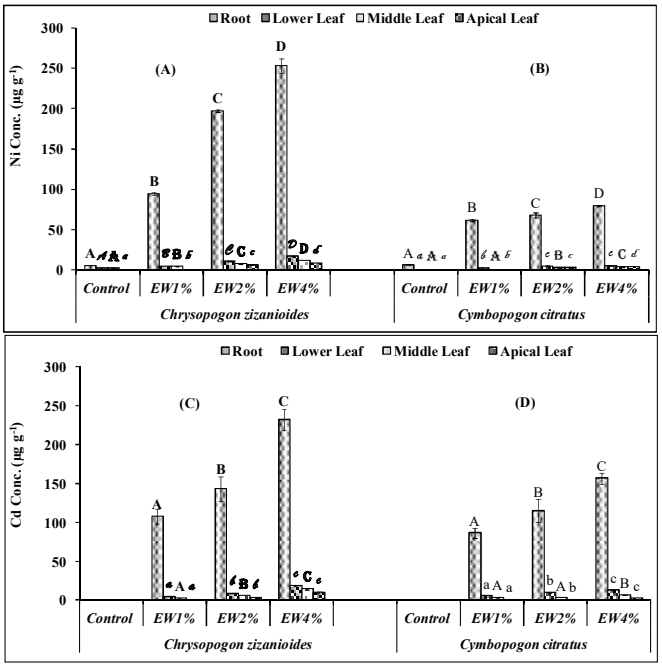

Fig. 1: Ni and Cd (µg g^{-1} DW) accumulation in *Chrysopogon zizanioides* and *Cymbopogon citratus* grown on incremental contamination level of Ni-Cd battery electrolyte (EW).

translocation of Cd in lemongrass was higher than Ni at EW1% but reverse at the higher contamination levels, i.e. EW2% and EW4%. The bioaccumulation factor (BF) of Ni increased by 0.7–1.2 and 0.08–0.2 in vetiver root and shoot, respectively from EW1% to EW4%. Similarly, the BF of Cd was greater (0.2–0.3) in roots than (0.01–0.05) in the shoots. In comparison, the highest BF for both Ni and Cd was observed against EW4%, in both the grasses. Also, BF of root and shoot of both the grass species was higher for Ni than for Cd.

The uptake of Ni and Cd by the root as well the shoot for both the grass species were modelled through a multiple linear regression (MLR) model as a function of five independent parameters namely, pH, salinity, total phosphorus (TP), organic matter (OM) and soil bioavailable metals. The developed MLR models implied a strong correlation between the soil physico-chemical parameters and the metal accumulation in the root and shoots of both the grasses.

Comparative assessment of fluoride uptake and its toxic manifestation on the biochemistry and oil content of *Brassica juncea*

Rapeseed (mustard) ranks third most important oilseed worldwide, while second in India, which contributes to 27.8% of India's oilseed economy and 19.8% of world production. Fluoride (F^-) contamination of groundwater and subsequently to surface soil owing to irrigation, affects the seed yield and oil quality, unfolding into several adverse effects both qualitatively and commercially. The physiological, morphological and biochemical changes during the growth stage and reproductive stage show a significant change in F^- translocation. During reproductive stage, F^- affects the oil yield and its fatty acids (FAs) composition in *Brassica juncea* L. compared between its growth under two regimes of F^- contamination: (i) F^- pre-contaminated soil (Tr) and (ii) irrigation with F^- contaminated water (Ir) at two doses (5 and 10 µg g^{-1}) (Fig. 3). Seed of *Brassica juncea* L. cv. Basanti was sowed into prefilled experimental earthen terracotta pots. In one set of pots, soils were pre-spiked with F^- salt (NaF) to attain contamination levels of 5 and 10 mg F^- g^{-1}, whereas another similar set was irrigated with 5 and 10 mg F^- L^{-1} of water, representing F^- contaminated soil and irrigation with contaminated water, respectively. The plants were harvested at two intervals i.e., 60 days (I^{st} harvesting, reproductive stage) and 95 days (II^{nd} harvest, mature stage) for estimating F^- level in different plant tissues viz. root, shoot, leaf and seed (only for II^{nd} harvest).

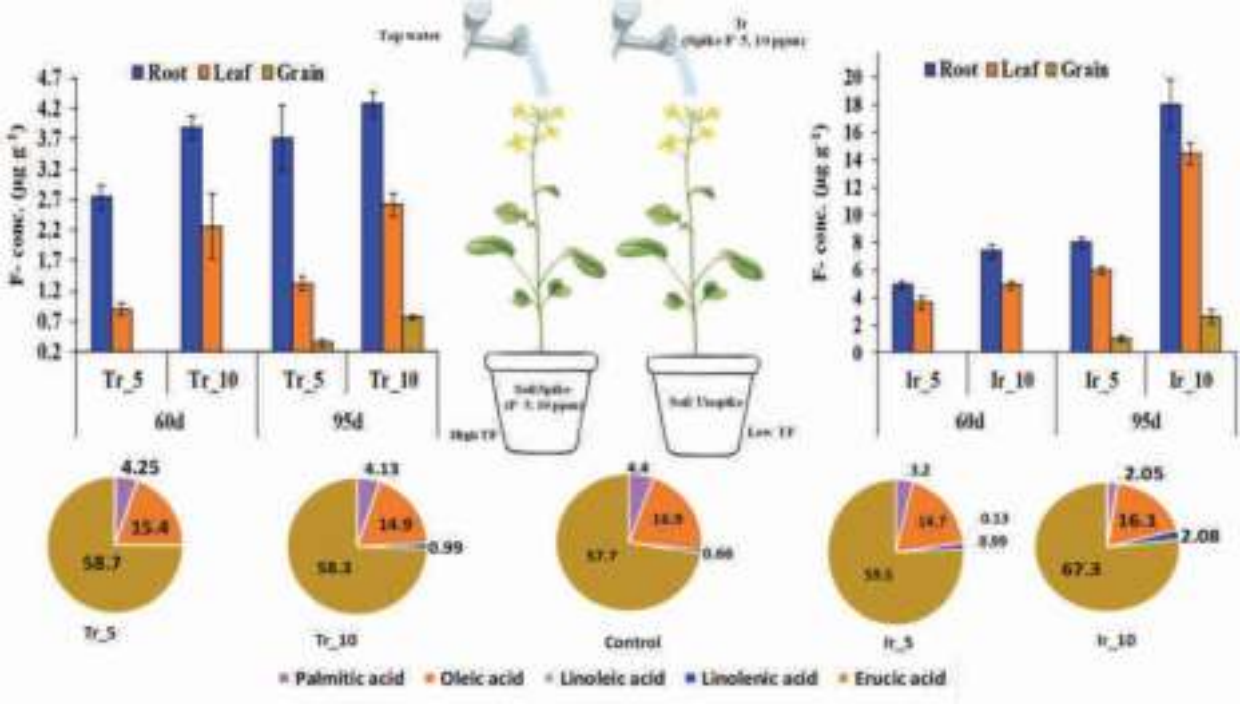

Fig. 3: Experimental design and results obtained by growing *Brassiac juncea* on two regimes of F^- contamination under simulated condition.

Accumulation of F^- in roots, leaves and seeds in plants among all the treatments, followed the order Ir_10> Ir_5> Tr_10> Tr_5> Control, both during flowering stage (I^{st} harvest) and mature stage (II^{nd} harvest). The accumulation of F^- was lowest in the seeds followed by leaves and roots, among all the plant tissues in all the treatments (Fig 4).

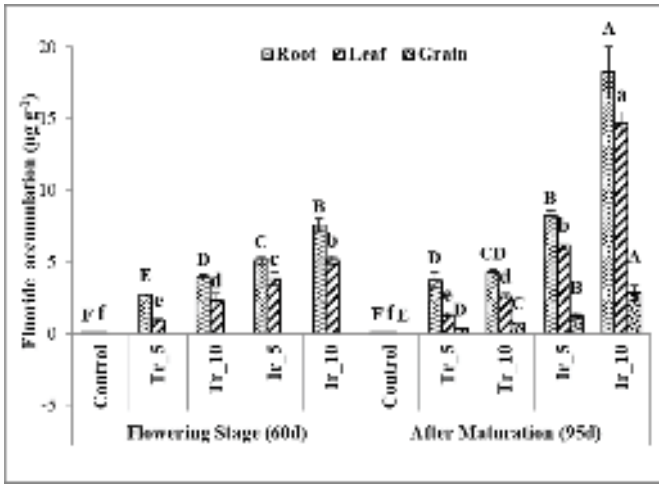

Fig 4: Fluoride accumulation in *B. juncea* tissues (root, leaf and grain) grown in uncontaminated soil (Control), F^- pre-contaminated soil, (Tr_5 and Tr_10) and contaminated water (Ir_5 and Ir_10).

The level of F^- (µg g^{-1}) in the plant tissues (root, leaf and grains) was significantly higher (18.3, 14.7 and 2.8, respectively) Ir than under Tr (4.3, 2.6 and 0.77, respectively). Similarly, the decrease in oil yield (%) was greater (19.5) with Ir than Tr (44.9). Erucic acid content (%) in oil increased from 57.73 in control to 58.3 and 67.37 in plants grown on Tr and Ir, respectively. The study highlights the toxicity due to F^- is greater under Ir than Tr, and the erucic acid content of oil increases with its toxicity.

The maximum accumulation of F^- (µg g^{-1}) in roots, leaves and seeds grown under Ir_10 regime was 18.25, 14.67 and 2.83, respectively at maturity, while at the flowering stage, F^- level in roots and leaves was 7.56 and 5.11, respectively.

Similarly, F^- accumulation (µg g^{-1}) in seeds harvested from mature plants, as recorded in Tr_5, Tr_10, Ir_5 and Ir_10 was 0.35, 0.77, 1.23 and 2.83, respectively.

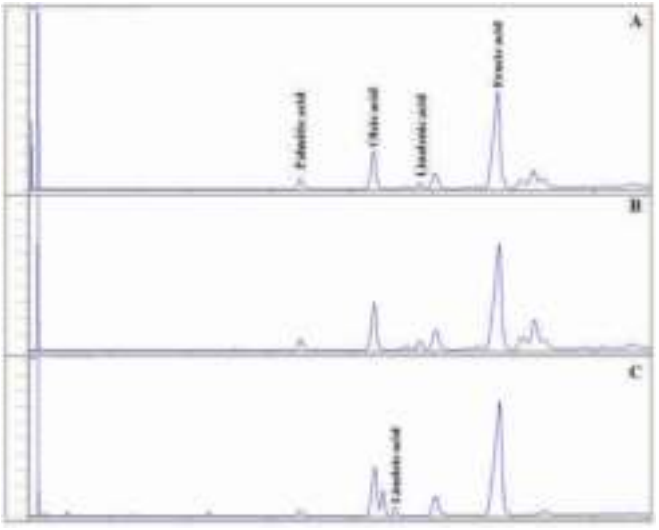

Fig 5: Chromatograph of Fatty acids composition of mustard oil in control (A), Tr_10 (B) and Ir_10 (C) regime.

Comparing the translocation factor (TF) between the two regimes of treatment, exhibited higher for Ir_5 and Ir_10 (0.75 and 0.80, respectively), than their respective Tr treatments (0.36 and 0.61, respectively) at the mature stage while during vegetative growth, TF for Tr_5, Tr_10, Ir_5 and Ir_10, was 0.33, 0.58, 0.75 and 0.68, respectively. Translocation of F^- from root to leaf was comparatively higher at the mature stage than during the flowering stage.

Mustard oil is especially known for its erucic acid content. Composition (%) of palmitic acid, oleic acid and erucic acid out of the total FAs, in the control plant was 4.4, 16.9 and 57.7, respectively whereas the level in Tr_10, was 4.13, 14.95 and 58.3, respectively and that in Ir_10 was 2.05, 16.18 and 67.4, respectively (Fig. 5).

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Pollution Monitoring and Remediation Technologies

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

A geo-referenced database of arsenic mapping in agriculture has been developed with the help of the Remote Sensing Application Centre using ArcGIS for 20 districts of Uttar Pradesh. The prediction of arsenic contamination has also been interpolated using spatial kriging for four major arsenic-affected districts of Uttar Pradesh, namely Ballia, Ghazipur, Bahraich, and Lakhimpur-Kheri among twenty districts mapped under the project. The prediction was based on the arsenic contents of irrigation groundwater falling in ranges (i) <50 ppb, (ii) 50-100 ppb, (iii) 100-200 ppb, (iv) 200-300 ppb, and (v) >300 ppb; and that of agricultural soil falling in ranges (i) <5 ppm, (ii) 5-10 ppm, (iii) 10-20 ppm, (iv) > 20 ppm. Farmer's Meets were organized in Ballia and Ghazipur districts with progressive farmers of 30 blocks for discussing sources of arsenic contamination in agriculture; risks of arsenic contamination in agriculture: Do's and Don'ts; cultivation calendars to restrict arsenic accumulation in food production; and distribution of seeds of arsenic safe rice variety "Muktoshree (IET-21845)" for its popularization trials. The recommendations to mitigate arsenic toxicity in the arsenic-affected areas with reference to safeguarding agriculture were provided to the Department of Agriculture, Govt. of Uttar Pradesh.

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

Soil samples were collected from a long-term HCH dumpsite situated at a village of district Barabanki, Uttar Pradesh, India. Results of earlier metagenomic study revealed the potential to develop a microbe-assisted plant-based bioremediation strategy for remediating HCH contamination in soil. Plants of *Abutilon indicum, Ricinus communis, Holoptelia integrifolia* and *Pongamia pinnata* have shown accumulation of HCH residues from soil and exerted positive impacts on rhizospheric soil microbial communities in the HCH contaminated site. Eight fungal strains were enumerated from the HCH dumpsite soil using the enrichment culture technique. These strains belong to *Pseudallescheria, Epicoccum, Scedosporium, Aspergillus, Penicillium, Pleurostoma, Alternaria*, and *Cladosporium*. The maximum 10-fold increase in lindane dechlorination (µg free Cl/ml broth) was shown in the cell-free extract of *Pseudallescheria* strain compared to the control. This was followed by the strains of *Pleurostoma*, *Scedosporium* and *Alternaria*. The GC-MS data of broth showed the presence of pentachlorocyclohexene, 2,5-dichlorophenol, phenol, hydroquinone, and benzene during the experiment confirming the lindane degradation pathway.

Cyanide remediation using novel microbes

Cyanide, a potent rapid-action poison, is discharged by various industrial activities. Even in small quantities, cyanide is highly fatal to humans and other species. The present study was focused on assessing cyanide biodegradation by novel microbial strains through enzymatic activity utilizing cyanide as a source of nitrogen. Two bacterial strains and three fungal strains isolated from cyanide-contaminated blast furnace effluent and activated sludge of a steel

plant were selected for the study. The efficiency of these microbial strains to degrade cyanide was assessed at different concentrations ranging from 10 to 50 mg L^{-1} in batch cultures. About 99% cyanide degradation occurred at 20 mg L^{-1} of cyanide at 3rd day. The rhodanese enzyme activity and siderophore production were observed in all these microbial strains. These microbial strains exhibited an increase in the levels of rhodanese enzyme activity by 30%, oxidized glutathione content by 50%, and increased growth upon exposure to cyanide at 20 mg L^{-1}. Changes in the contents of fatty acids (lipids), amides, carboxylic and hydroxyl groups present in the cell wall of the strains were also revealed under cyanide treatment through FTIR analysis. The degradation kinetics was evaluated and the first-order kinetics of cyanide degradation was best fitted to the results obtained in the study. The study suggests the application of these novel microbial strains for the bioremediation of cyanide

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Plant ecology, forest ecosystem structural and functional analysis, forest biomass, forest carbon sequestration, ecosystem physiology, climate change

The role of forests in carbon sequestration has become an important means of mitigating the impact of increase in atmospheric carbon dioxide concentrations from anthropogenic activities. Tropical forests play disproportionately important role in carbon sequestration and storage, with complex regulation mechanism by local environment (microclimate) and community structure. Our group has been working in the field of forest productivity and carbon sequestration assessment, and modelling using field measurements. The group is primary focusing on long-term studies for understanding the ecosystem functioning and carbon dynamics at tree community level and thereby provide inputs for better model simulation in Indian tropical forests.

Above-ground biomass measurements in different forest types of Similipal Biosphere Reserve, Odisha

Studies on biomass of forest vegetation are essential for determining storage of carbon in the dominant tree component and computing the carbon cycling at regional as well as global level. The present attempt was undertaken to fill these knowledge gap between composition of plant communities along with their aboveground biomass in three different forest types of Similipal Biosphere Reserve, Orissa, India.

During the study, we laid three semipermanent plots of 50m x 20m (0.1 ha) in three forest types for aboveground biomass estimation. In selected forest communities the dominant tree species were *Syzygium cumini, Dillenia pentagyna, Protium serratum, Terminalia tomentosa, Xantolis tomentosa, Protium serratum, Anogeissus latifolia, Schleichera oleosa, Croton persimilis, Shorea robusta, Xylia xylocarpa, Lannea coromandelica* and *Cleistanthus collinus*. *Terminalia tomentosa* is a common dominant species with respect to biomass in semi-evergreen and moist-deciduous forests while in dry-deciduous forest community maximum biomass was estimated in *Shorea robusta.* The highest aboveground biomass (AGB) during 2020-2022 (Fig.1) were observed in moist deciduous forest (457.36 Mg ha^{-1}, 479.97 Mg ha^{-1} and 499.3 Mg ha^{-1} in 2020, 2021 and 2022, respectively) followed by semi-evergreen forest (414.41 Mg ha^{-1}, 429.29 Mg ha^{-1} and 443.45 Mg ha^{-1} respectively). However, Dry-deciduous forest recorded lowest biomass in constitutive years with 174.4 Mg ha^{-1}, 179.96 Mg ha^{-1} and 187.74 Mg ha^{-1} in 2020, 2021 and 2022, respectively.

In semi evergreen forest *Syzygium cumini, Dillenia pentagyna, Protium serratum, Terminalia tomentosa* and *Xantolis tomentosa* contributed major portion of the aboveground biomass. In moist-deciduous forest,

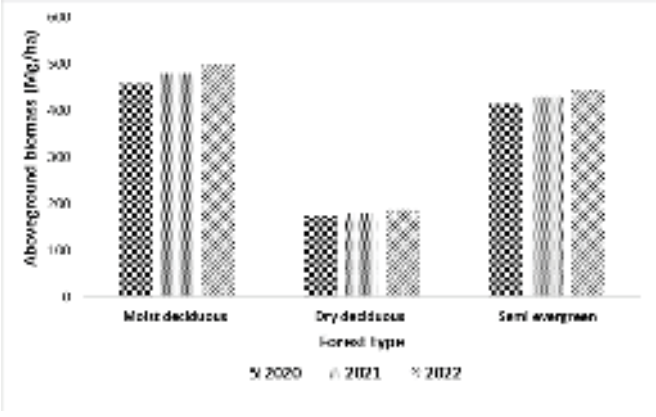

Fig. 1. Aboveground biomass patterns in three forest types of Similipal Biosphere Reserve, Odisha.

Terminalia tomentosa, Protium serratum, Anogeissus latifolia, Schleichera oleosa and *Croton persimilis* together contributed major proportion of total biomass. In dry deciduous forest, *Shorea robusta, Xylia xylocarpa, Lannea coromandelica, Croton persimilis* and *Cleistanthus collinus* dominated with their biomass contribution as compared to other species in the stand.

Assessment of carbon sequestration potential of tropical tree species for urban greening

Urban, peri urban and patch forests play a critical role in climate change mitigation through increased carbon storage. The present study aims to assess the biomass production and carboxylation efficiency of three native tropical tree species to identify the high carbon sequestering species, which will enhance the carbon stocks under urban green spaces. Above-ground biomass, carbon stock and physiological performance of three native tropical tree species (*Tectona grandis*, *Mallotus nudiflorus* and *Syzygium cumini*) were measured in Botanical Garden of CSIR-National Botanical Research Institute, Lucknow for eight years old tree stands.

Above-ground biomass (AGB, Mg/ha) was measured using a non-destructive method by applying allometric equations. Tree height, diameter at breast height (DBH) and leaf area index (LAI) was maximum in *Tectona grandis (T. grandis)* stand (10.43

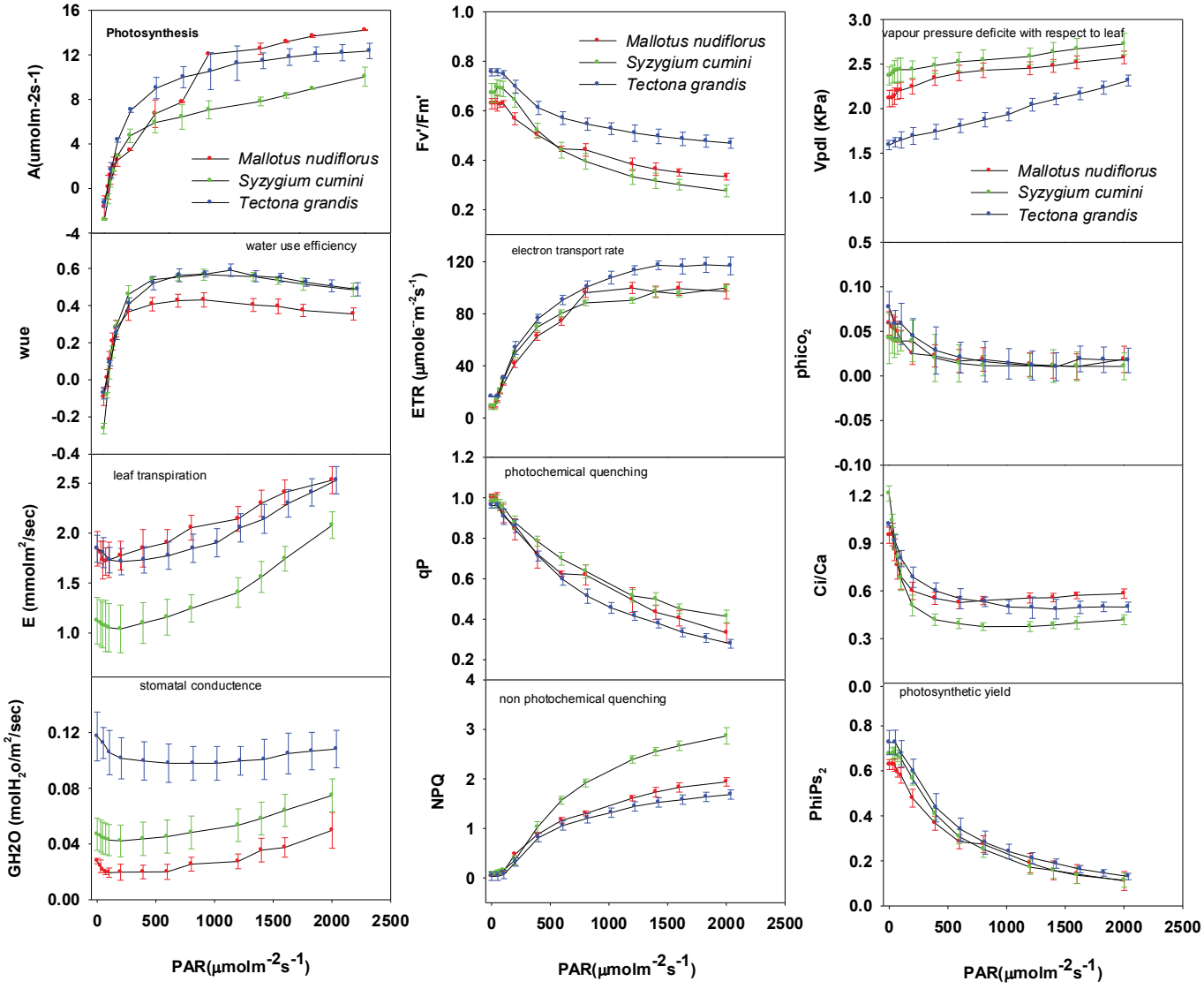

Fig. 2: Patterns of different physiological variables among three tropical tree species (*Tectona grandis, Mallotus nudiflorus* and *Syzygium cumini*) at Botanical Garden of CSIR-National Botanical Research Institute, Lucknow, India.

m, 29.21 cm, 1.95, respectively). Maximum AGB (71.94 Mg/ha) and carbon stock (25.54 Mg/ha) was observed in *T. grandis* plantations among the three tree stands. *T. grandis* stand also had maximum litter fall (5.82 Mg/ha). Highest diurnal photosynthesis rate, water use efficiency and stomatal conductance were also observed in *Tectona grandis* stand (Fig. 2). However, maximum photosynthetic rate was observed in *Mallotus nudiflorus*. Physiological parameters such as transpiration rate (E), electron transport rate (ETR), stomatal conductance (GH_2O) and water use efficiency (WUE) observed strong positive correlation with biomass production and carbon sequestration in three species. Maximum quantum yield (Fv/Fm) was highest in *T. grandis* (0.75) among three species, resulting in higher diurnal carboxylation efficiency and biomass accumulation. Highest electron transport rate (ETR), stomatal conductance (GH_2O, mol $H_2O/m^{2/}$sec), Fv'/Fm', and water use efficiency (WUE) (Fig. 2) were observed in *T. grandis* among the three species, making it most suitable for urban forestry and greenbelt plantation in urban landscape.

Pearson's Correlation matrix established the positive relationship between growth-performance and physiological traits of species with their capacity to sequester carbon. *T. grandis* can be promoted for urban greening projects for achieving carbon sequestration targets with short time span

Characterizing Patterns and Processes of Alpine Ecosystem in Indian Himalaya

Due to the compression of thermal zones and isolation caused by low temperature, the alpine landscape has the highest level of sensitivity to climatic changes. A long-term monitoring network known as HIMADRI (Himalayan Alpine Dynamics Research Initiative) was established by Space Application Centre (SAC), Indian Space Research Organization (ISRO) in collaborations with other participating national organizations. Under HIMADRI initiatives, six long-term monitoring sites were established having 20 summits in India.

In the alpine ecosystems, the ecotones are the most sensitive transition zones for monitoring the micro-scale variations to understand the ecological processes in response to climatic changes. The present study primarily focused on microclimate characterization of Alpine ecosystem ecotone vis-a-vis cryptogam

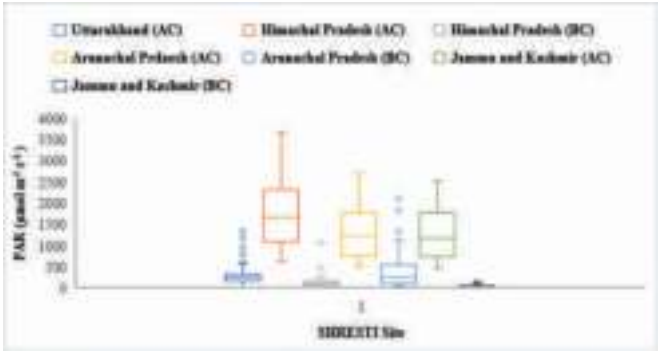

Fig. 3: Diurnal pattern of photosynthetically active radiation (PAR) (µmol m^{-2} s^{-1}) in above canopy (AC) and below canopy (BC) at alpine treeline ecotone at four different SHRESTI sites across Indian Himalaya.

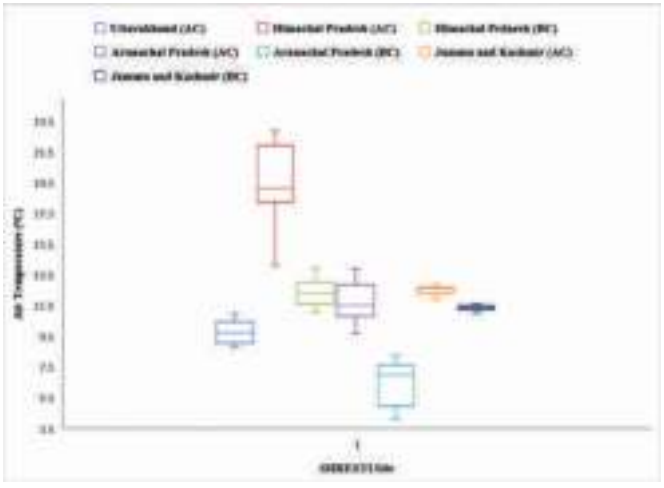

Fig. 4: Diurnal pattern of air temperature (ºC) in above canopy (AC) and below canopy (BC) at alpine treeline ecotone at four different SHRESTI sites across Indian Himalaya.

diversity assessment in Indian Himalayas, jointly with the plant diversity division.

The data on microclimate were collected at Tungnath (Uttarakhand), Chansal pass (Himanchal Pradesh), Tawang (Arunachal Pradesh) and Khilanmarg (Jammu and Kashmir) to understand the site-specific micrometeorological patterns at various HIMADRI long-term monitoring sites to understand how vegetation structure affects microclimate and vice-versa at alpine ecosystems across Indian Himalaya. Diurnal variations in five microclimatic variables (photosynthetically active radiation (PAR), air temperature, soil temperature, ambient CO_2, air absolute humidity) were measured. All the microclimate variables were measured in treeline (under-canopy) and immediately after the treeline/ shrub line (in the ecotone of alpine ecosystems. The

diurnal trend in microclimatic parameters showed wide variations among four measured sites (Tungnath, Chansal, Tawang and Khilanmarg) (Fig. 3 and Fig. 4). PAR at Chansal sites ranged from 641 to 3687 (µmol $m^{-2}s^{-1}$) in open areas without any canopy cover and 47 to 1068 (µmol $m^{-2}s^{-1}$) in treeline (under forest-canopy) (Fig. 3). PAR at Tawang sites ranged from 501 to 2730 (µmol $m^{-2}s^{-1}$) in open areas without any canopy cover and 58 to 1421 (µmol $m^{-2}s^{-1}$) in treeline (under forest-canopy). PAR at Khilanmarg site ranged from 482 to 2523 (µmol $m^{-2}s^{-1}$) in open areas without any canopy cover and 9 to 187 (µmol $m^{-2}s^{-1}$) in treeline (under forest-canopy). The ambient air temperature (AT) ranged from 14.1 to 22.9^{0}C in open areas without any canopy cover and 11.1 to 13.9^{0}C in treeline (under forest-canopy) at Chansal site (Fig. 4). The ambient air temperature (AT) ranged from 10.4 to 13.9^{0}C in open areas without any canopy cover at Tawang site. The ambient air temperature (AT) ranged from 11.8 to 12.9^{0}C in open areas without any canopy cover at Khilanmarg site. Soil temperature ranged from 18.6 to 38.6^{0}C in open areas without any canopy cover and 11.3 to 16.6^{0}C in treeline (under forest-canopy) at Chansal site. Soil temperature ranged from 6.27 to 14.94^{0}C in open at Tawang site. Chansal Pass received maximum amount of PAR among all the four studied sites, therefore resulting in higher ambient air and soil temperature among all sites. Lowest amount of PAR is received in Khilanmarg site resulting in lower ambient air temperature. Soil temperature ranged from 6.27 to 14.94 ^{0}C in open areas without any canopy cover at Tawang site. The results will be further compared with other HIMADRI sites to have a detailed suit of microclimate across Indian Himalayas in Alpine ecosystems. The study will be utilized to understand the functional role of microclimate on cryptogams (particularly lichens and bryophytes) community structure and functioning at Alpine ecotones in Indian Himalayas.

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Plant-microbe interaction, Microbial genetics, Bioremediation and Agri-waste management

Microbial formulations applicable for the biological control of *Fusarium* diseases

Comparative efficacy of the selected strains against *Fusarium* wilt disease in different crops has been monitored under greenhouse conditions with different host plants using their specific *Fusarium* pathogen. Elucidation of antagonistic interaction mechanism by the monitoring of different cell wall degrading and defence enzymes activities and metabolic profiling was performed. Microplot experiment at Distant Research Centre, Banthara against host specific *Fusarium* showed their potency for the control of wilt disease in Chickpea. Bioefficacy data at three different agroclimatic zones was coordinated at ICAR institutions (IIPR, Kanpur; IIPR, Bhopal and IIPR, Dharwad and toxicity data at CSIR-IITR has been performed for its registration at Central Insecticides Board and Registration Committee CIB-RC for its commercialization.

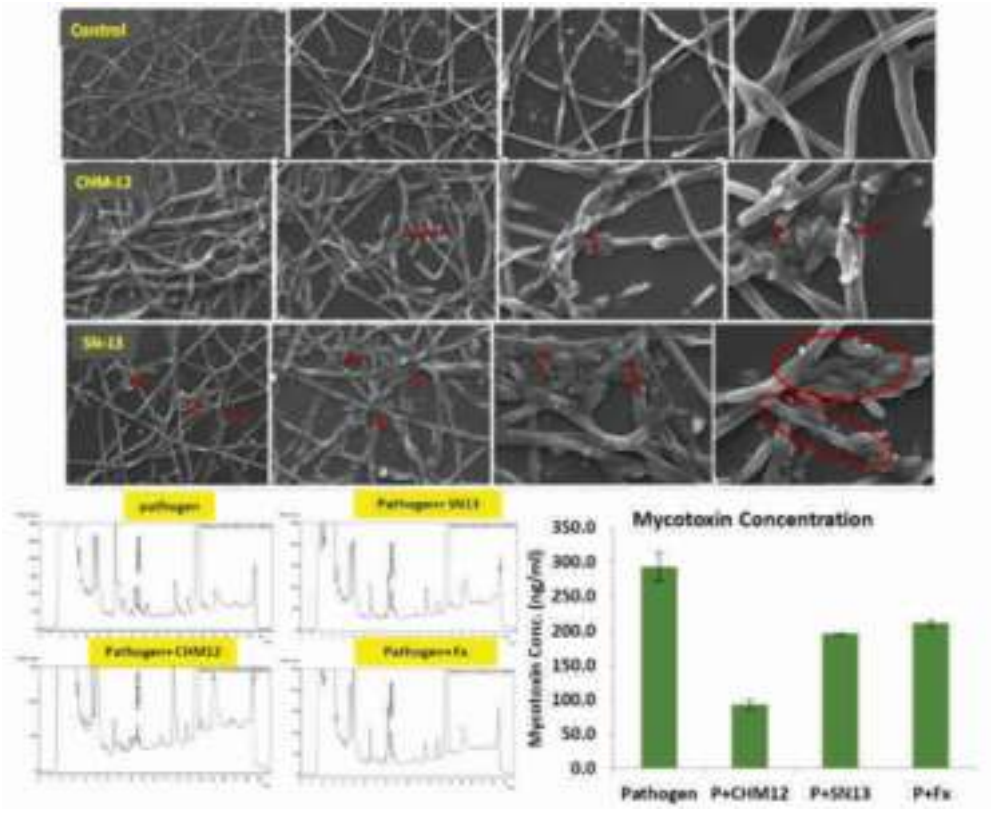

Fig. 1: Effect of different biocontrol agents against Fusarium oxysporium and their effect on reduction of mycotoxin content.

Elucidation of molecular mechanism of interaction of necrotrophic fungi *Rhizoctonia solani* responsible for sheath blight disease in rice with biocontrol agent *Bacillus amyloliquefaciens*

During bipartite interaction of *Rhizoctonia solani* with *Bacillus amyloliquefaciens* and tripartite interactions of *Rhizoctonia solani* and *Bacillus amyloliquefaciens* was used to study the interaction mechanism. Transcriptome analysis of *Rhizoctonia solani* during interaction with *Bacillus amyloliquefaciens* showed the role of different defence responsive genes and secondary metabolites for the control of *Rhizoctonia solani*.

Microbial formulation for arsenic stress amelioration in rice and vegetable crops

Microbes with different arsenic biotransformation potential were characterized for their arsenic tolerance and reducing the arsenic uptake in rice and vegetable crops. Bacterial strain identified as *Pseudomonas* sp. containing arsenite methyl transferase activity were found to reduce the arsenic uptake in leafy vegetable Spinach. Gene sequence analysis confirms the presence of methyl transferase

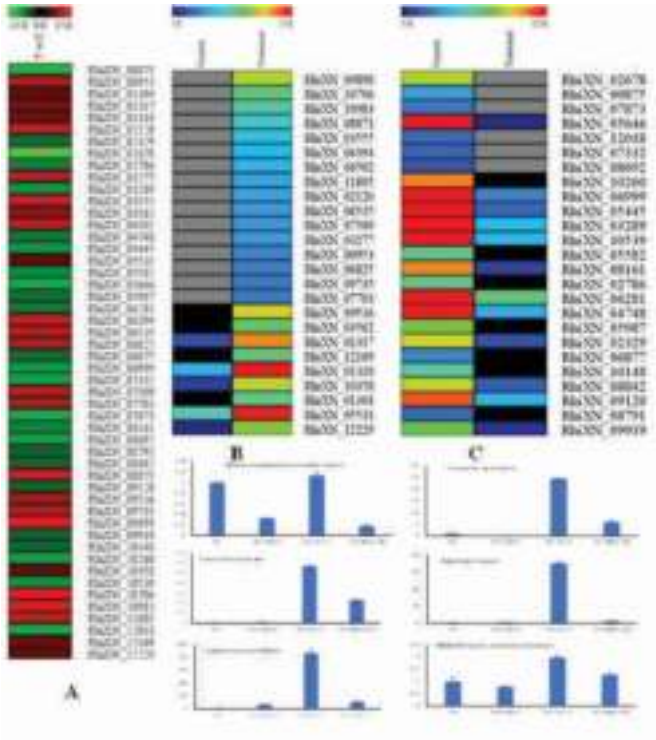

Fig. 2: Heatmap analysis representing different expression of genes involved in control as well as treatment of bacteria in *Rhizoctonia solani* (A, B, C) and relative expression of selected genes in presence of different biocontrol agents.

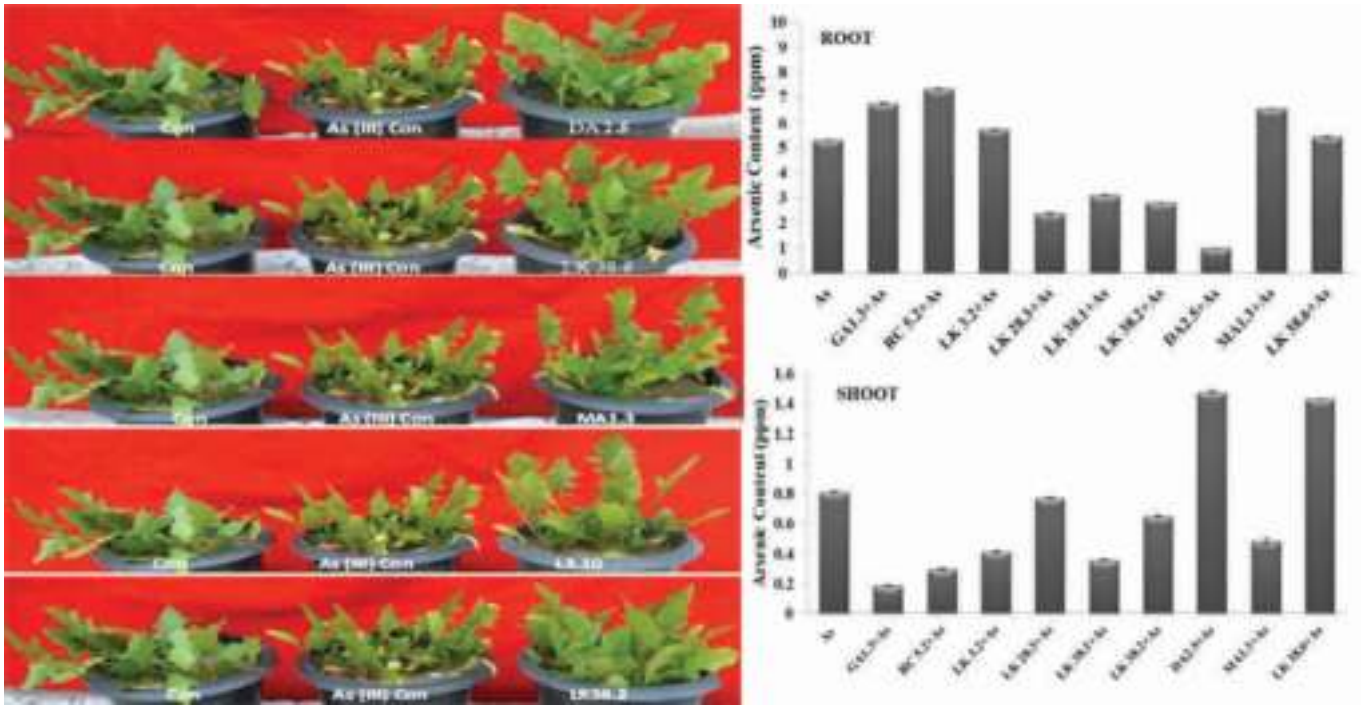

Fig. 3: Effect of inoculation of methyl transferase containing MA 1.3 bacterial strain on plant growth under Arsenic stress and its uptake through ICP-MS in spinach.

gene in the selected strain MA1.3 with higher arsenic volatilization potential.

Agriwaste management

Tribal farmers of Dudhawa regions of Uttar Pradesh were sensitized for on-farm utilization of rice straw for better soil health and productivity by conducting awareness cum demonstration program at Parsiya, Bandar Barari and Pipraula Villages, District Lakhimpur, Uttar Pradesh of Dudhawa region under National Academy of Sciences, Allahabad (NASI) sponsored project. Along with those deliberations for the use of biofertilzers and dried flower technologies were made to create awareness among them regarding different technologies developed by CSIR-NBRI. Preparation of more efficient microbial formulation devoid of Trichoderma strain is under process as per the objective of DBT funded project.

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Abiotic-Biotic stress management of plants & Potential of green nanotechnology herbal nano emulsion against phytopathogen: The research group focuses on disease management of commercially valuable crop and developing sustainable eco-friendly remedies. The microbial techniques are also explored to combat with rising CO2 conditions. Green nano-technological approach is involved in suppression of human and phytopathogens by herbal lipid-based nanomaterials.

Bacillus subtilis suppresses the charcoal rot disease by inducing defence responses and physiological attributes in soybean

Endophytes can induce the defence responses and modulates physiological attributes in host plants during pathogen attacks. In the present study, 127 bacterial endophytes (BEs) were isolated from different parts of healthy soybean plant. Among them, two BEs (M-2 and M-4) showed a significant antagonistic property against *Macrophomina phaseolina,* which causes charcoal rot disease in soybean. The antagonistic potential was evaluated through dual culture plate assay, where M-4 expressed higher antifungal activity than M-2 against *M. phaseolina*. The M-4 produces cell wall degrading enzymes viz. cellulase (145.71 ± 1.34 μgmL^{-1}), chitinase (0.168 ± 0.0009 $unitmL^{-1}$) and β,1–3 endoglucanase (162.14 ± 2.5 μgmL^{-1}), which helps in cell wall disintegration of pathogens. Additionally, M-4 also can produce siderophores, indole-3-acetic acid (IAA) (17.03 ± 1.10 μgmL^{-1}) and had a phosphate solubilization potential (19.89 ± 0.26 μgmL^{-1}). Further, GC–MS profiling of M-4 has been carried out to demonstrate the production of lipophilic secondary metabolites which efficiently suppress the *M. phaseolina* defensive compounds under co-culture conditions. Bio-efficacy study of M-4 strain showed a significant reduction in disease incidence around 60 and 80% in resistant and susceptible varieties of soybean, respectively. The inoculation of M-4 potentially enhances the physiological attributes and triggers various defence responsive enzymes viz. superoxide dismutase (SOD), phenol peroxidase (PPO), peroxidase (PO) and catalase (CAT). The histopathological study also confirmed that M-4 can reduce the persistence of microsclerotia in root and shoot tissue. Conclusively, M-4 revealed as an efficient biocontrol agent that can use multifaceted measures for charcoal rot disease management, by suppressing the *M. phaseolina* infection and enhance the physiological attributes of soybean (Fig. 1).

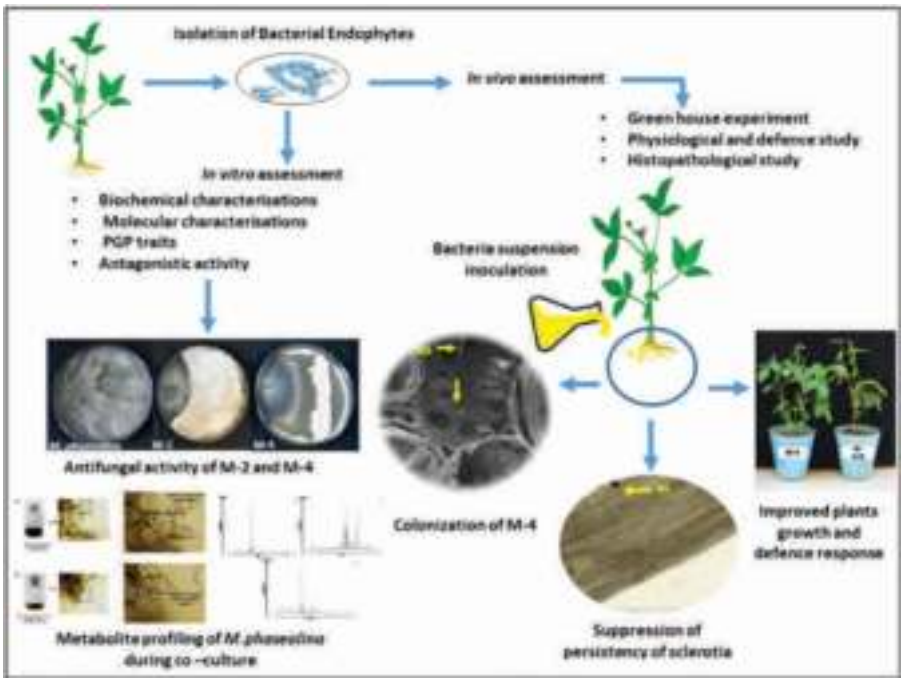

Fig. 1: Graphical representation of *Bacillus subtilis* suppressing charcoal rot disease in soybean.

Hybridization of Chitosan and Biosynthesized Silver Nanoparticles to enhance antimicrobial activity against Phytopathogens in Tomato (*Solanum lycopersicum*)

Chitosan-hybridized biogenic silver nanoparticles (Ch@BSNP) were synthesized with the extracellular metabolites of *Trichoderma viride*. Chitosan hybridization- and *T. viride*-derived compounds associated with the particles were confirmed by X-ray diffraction (XRD), transmission electron microscopy (TEM), scanning electron microscopy (SEM)-energy dispersive X-ray analysis (EDX), and gas chromatography–mass spectrometry (GC–MS) analysis. The particles had a ζ-potential 19.2 mV and a hydrodynamic size of 97.74 nm with apolydispersity index (PDI) of 0.198. TEM analysis revealed particles of spherical shape and actual size range between 30 and 35 nm. The antimicrobial activity of these particles was compared to chitosan alone and nonhybridized particles against three bacterial phytopathogens, *viz*, *Pseudomonas syringae*, *Erwinia chrysanthemi*, and *Xanthomonas campestris*. The zone size was 50.0, 29.75, and 34.00 mm with Ch@BSNP, respectively, while the corresponding values for BSNP were 29.75, 23.5, and 18.00 mm. In a liquid culture assay, exposure to Ch@BSNP significantly decreased the size of bacterial cells from 3905.00 to 2711.00 nm for *P. syringae*, from 3484.00 to 3386.00 nm for *E. chrysanthemi*, and from 7823.33 to 5956.33 nm for *X. campestris*. Similar increased activity of Ch@BSNP was also observed against four fungal plant pathogens, *viz*, *Sclerotium rolfsii*, *Rhizoctonia solani*, *Alternaria alternata*, and *Alternaria brassicicola*. The Ch@BSNP also demonstrated lower toxicity on noncancerous human cell lines than antimicrobial efficacy. In a greenhouse study, Ch@BSNP reduced the leaf spot disease incidence in tomato by up to 60% and also enhanced several physical and physiological attributes, *viz*, root and shoot lengths, fresh and dry weights, and chlorophyll and carotenoid contents compared to the diseased plant. These observed beneficial effects and overall biocompatibility of Ch@BSNP suggest that this material may be a safe and effective antimicrobial bioagent for sustainable nano-enabled agriculture (Fig. 2).

Comparative study of the development and characterization of ecofriendly oil and water Nanoemulsions for improving antifungal activity

Present work aimed to synthesize peppermint and eucalyptus oil-based nanoemulsions by a high-energy sonication process having potent antifungal activity. Tween 80 was used as the most suitable emulsifier by increasing interaction and stability of the system. A relative study was done among eucalyptus oil (ENE) and peppermint oil (PNE) nano-emulsions. PNE had a smaller droplet size (20–40 nm) than ENE (60–100 nm). Because of the smaller droplet size, higher surface area, lower surface tension, and presence of antimicrobial metabolites, PNE exhibited a higher antifungal efficacy as compared to ENE. 1% PNE showed complete inhibition of four fungal phytopathogens, while ENE showed partial inhibition. Stability of ENE was also a limiting factor along with increasing droplet size and resulted in decreased antimicrobial activity (Fig. 3). Conclusively, peppermint oil-based nanoemulsion (PNE) proved to be a promising antimicrobial agent against fungal pathogens; it can be used for sustainable disease management in crop plants.

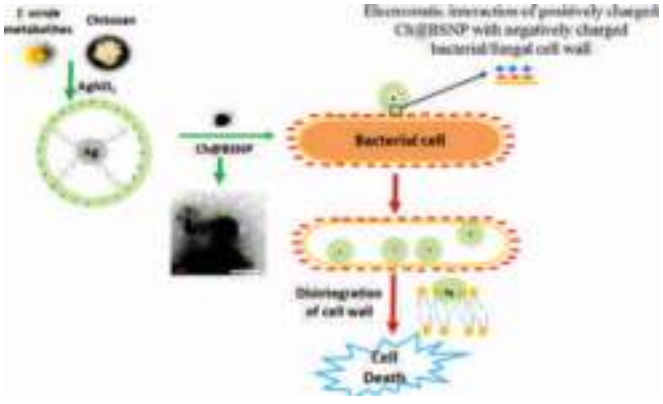

Fig. 2: Graphical representation showing antimicrobial activity of CH@BSNP against phytopathogens in tomato.

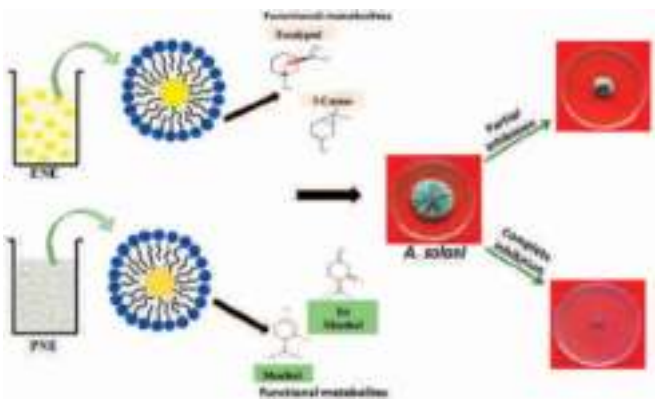

Fig. 3: Comparative study of development and characterization of oil and water nanoemulsions with antifungal activity.

Isolation and characterization of endophytic fungi having plant growth promotion traits that biosynthesizes bacosides and withanolides under *in vitro* conditions

Endophytes are regarded with immense potentials in terms of plant growth promoting (PGP) elicitors and mimicking secondary metabolites of medicinal importance. In the present study, we explored *Bacopa monnieri* plants to isolate, identify fungal endophytes with PGP elicitation potentials, and investigate secretion of secondary metabolites such as bacoside and withanolide content under *in vitro* conditions. Three fungal endophytes isolated (out of 40 saponin producing isolates) from leaves of *B. monnieri* were examined for *in vitro* biosynthesis of bacosides. On morphological, biochemical, and molecular identification (ITS gene sequencing), the isolated strains SUBL33, SUBL51, and SUBL206 were identified as *Nigrospora oryzae* (MH071153), *Alternaria alternata* (MH071155), and *Aspergillus terreus* (MH071154) respectively. Among these strains, SUBL33 produced highest quantity of Bacoside A_3 (4093 µg mL^{-1}), Jujubogenin isomer of Bacopasaponin C (65,339 µg mL^{-1}), and Bacopasaponin C (1325 µg mL^{-1}) while Bacopaside II (13,030 µg mL^{-1}) was produced by SUBL51 maximally. Moreover, these aforementioned strains also produced detectable concentration of withanolides—Withaferrin A, Withanolide A (480 µg mL^{-1}), and Withanolide B (1024 µg mL^{-1}) respectively. However, Withanolide A was not detected in the secondary metabolites of strain SUBL51 (Fig. 4). To best of our knowledge, the present study is the first report of *Nigrospora oryzae* as an endophyte in *B. monnieri* with potentials of biosynthesis of economically important phytomolecules under *in vitro* conditions.

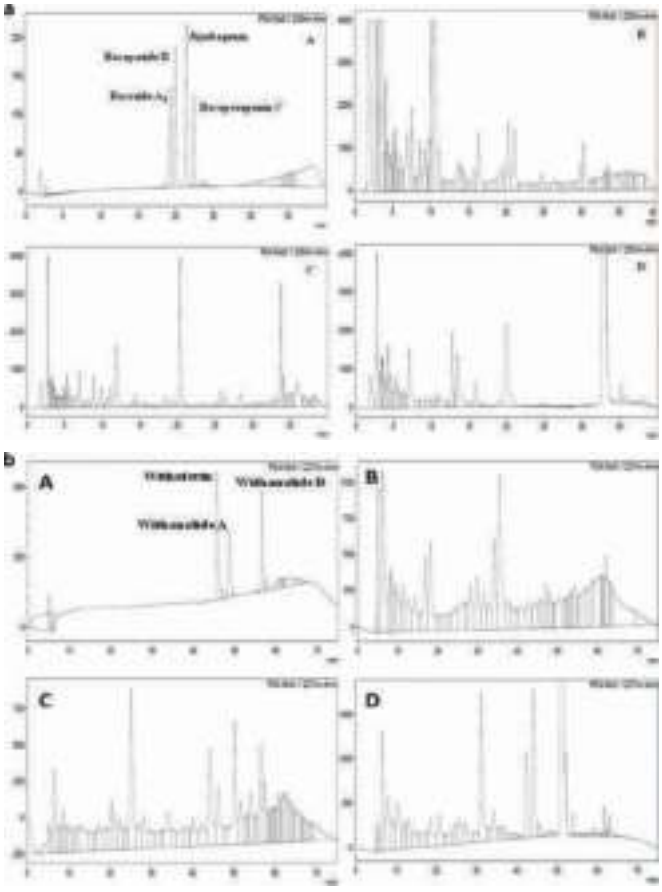

Fig. 4: (a) HPLC chromatograms of (A) Bacoside A (B) Crude extract of *Nigrosporaoryzae* (strain SUBL33). (C) Crude extract of *Alternaria alternata* (strain SUBL51). (D) Crude extract of *Aspergillus terreus* (strain SUBL206).

(b) HPLC chromatograms of (A) withanolides (mixtures of Withanolide A, Withanolide B and withaferin). (B) Crude extract of *Nigrosporaoryzae* (strain SUBL33). (C) Crude extract of *Alternaria alternata* (strain SUBL51). (D) Crude extract of *Aspergillus terreus* (strain SUBL206).

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Plant-microbe interaction for disease management, microbial interventions in management of Arsenic detoxification from crops, micro-plastics & agri-waste management, development of microbial formulations for applications in agriculture and environment

Development of biocontrol and biostimulant agents

Bacillus subtilis strain NBRI-W9 (MTCC-25374) is a potent biocontrol agent of Fusarium in different crops such as gladiolus, tomato and betelvine (Figure 1). Bio-efficacy, toxicity and environment safety data were generated for registration of the strain with Central Insecticide Board, Faridabad (Haryana). The strain is also acting as a biostimulant that can enhance plant growth after spray application and soil treatment. The strain is under field trial (second year) at five different agro-climatic zones of India under ACRIP program of ICAR for the bio-stimulant activity in mustard and rapeseed (Fig. 1).

Microplastic degradation

Microplastic is a new emerging threat for all the ecosystems including soil, freshwater, marine water and air. The harmful effect of microplastics has been documented on microbes, invertebrates, vertebrates including human. The application of plastics in agriculture is gradually increasing (Fig. 2). However, their impact on soil microbes and physico-chemical properties is un-known. Work was initiated on micro-

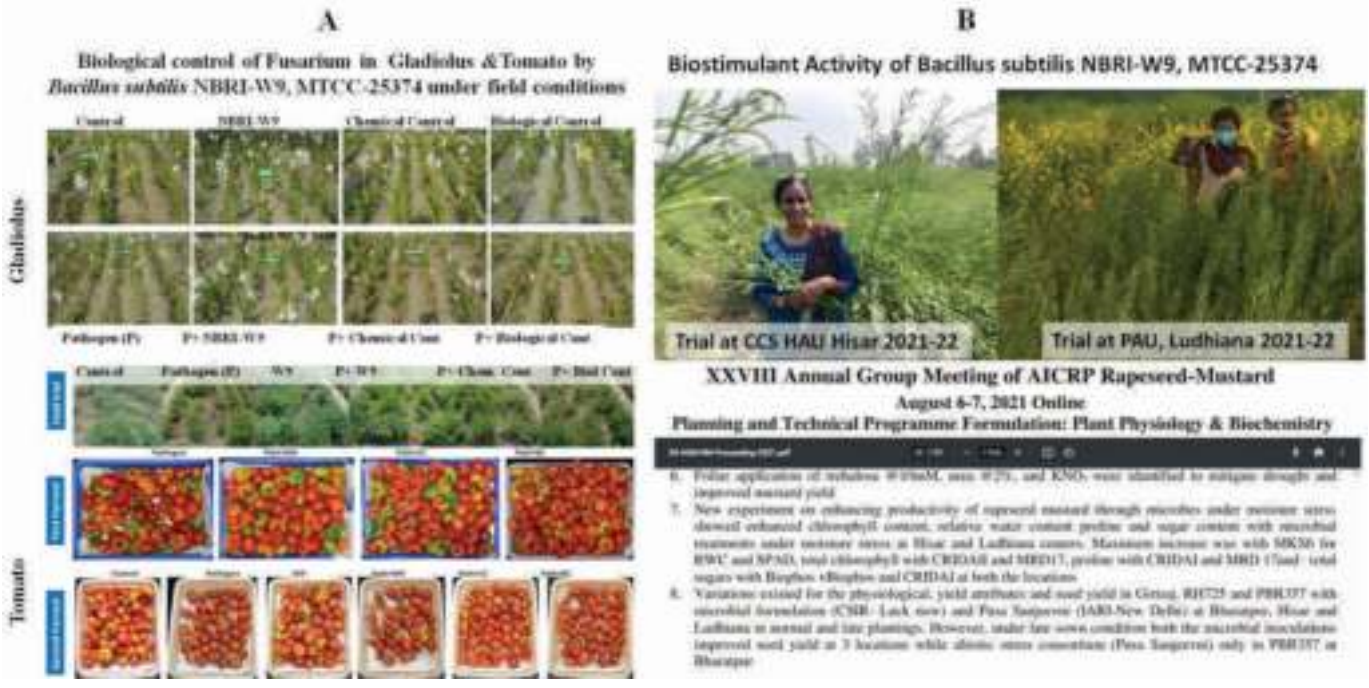

Fig. 1: (A).Biological control of fusarium in gladiolus and tomato by *Bacillus subtilis* NBRI-W9, MTCC-25374 under field conditions, (B). ACRIP field trials showing biostimulant activity of NBRI-W9 on mustard at CCS HAU, Hisar and PAU, Ludhiana.

plastic degradation for future applications in soil and waste water treatment. Microbes were isolated using samples collected from waste dumping land-fills at Lucknow, Varanasi and Delhi; preserved soil samples of Antarctic region, soil samples collected from harsh regions of Chambal valley and plastic recycling units at Lucknow (Fig. 2). Based on various enzyme activities reported to be involved in plastic degradation such as laccase, cutinase and lipase activities approximately 125 bacterial and fungal isolates have been screened. Further isolation and screening is in progress.

Agri-waste management: The metagenomic diversity of microbes in the fields treated with trichoderma amended rice straw (TrichoRS)

Trichoderma is a ubiquitous soil fungi often associated with biological control and a source of industrial enzymes. It is known to produce cellulolytic and hemicellulolytic enzymes, therefore, it plays important role in biological decomposition of organic matter. The potential of *Trichoderma* spp. in hastening the decomposition of straw has been reported. In a previous work we have reported sequestration of organic matter in sodic soil after application of residual rice straw (RS) fortified with two *Trichoderma* strains, *T. koningiopsis* NBRI-PR5 MTCC25372 and *T. asperellum* NBRI-K14 MTCC25373 (TrichoRS) for improving wheat and paddy productivity in a sustainable way. Although trichoderma is a widely used microbial inoculum which is commercially produced and used world-wide, its implications on soil microfloral diversity has been debated. To study the impact of *Trichoderma* fortified RS (TrichoRS) on the soil microflora, the soil metagenome was analyzed after two years of application in field conditions. Here, the diversity of the Trichoderma strains in the fields is depicted in Fig. 3. The observations showed enhanced abundance and diversity of microbes including Fungi in the TrichoRS treated soil. These fungi included beneficial microbes such as *Trichoderma*, *Metarhizium* and *Beauvaria bassiana*.

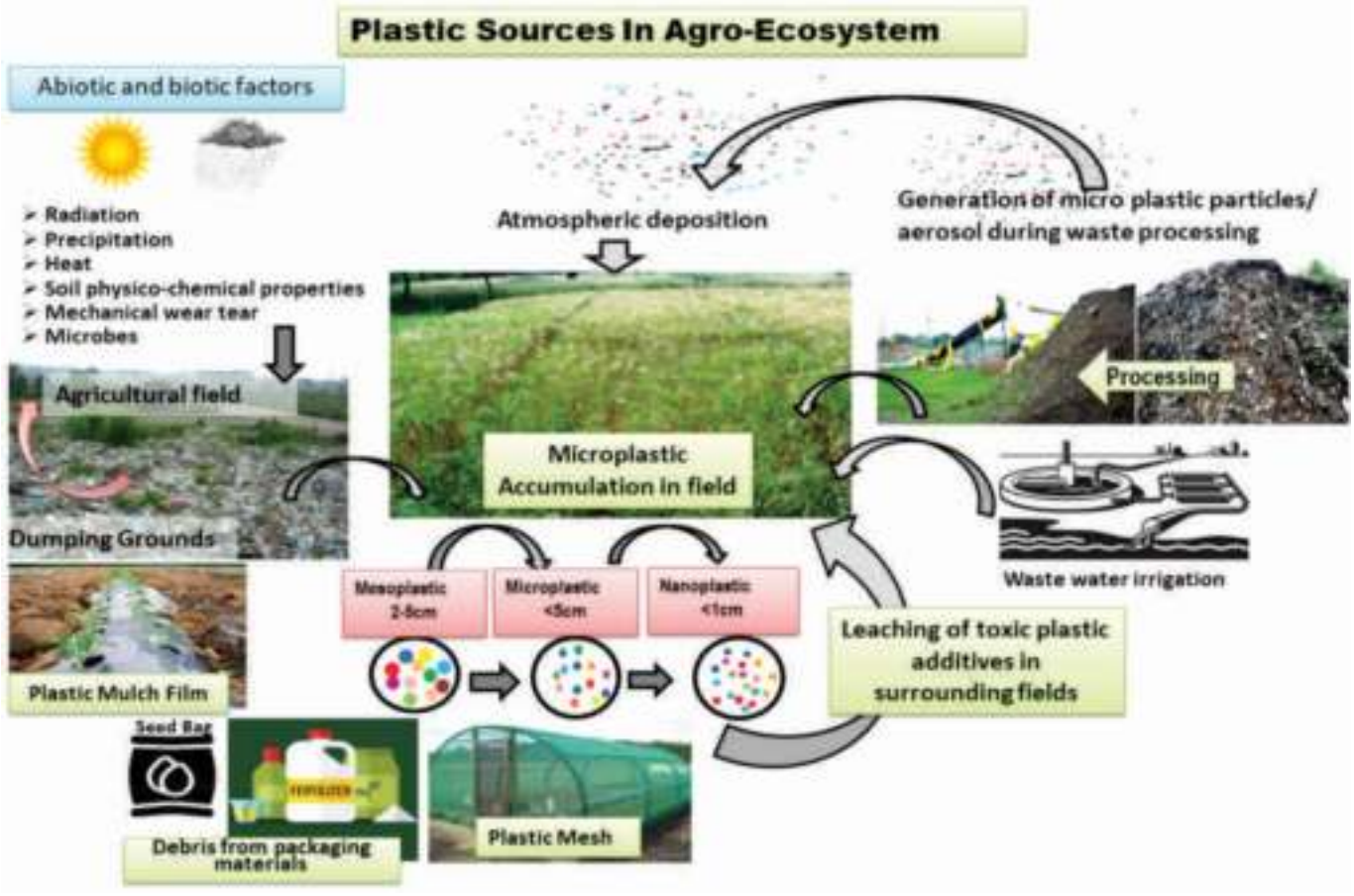

Fig. 2: Different sources of microplastics in the agro-ecosystem.

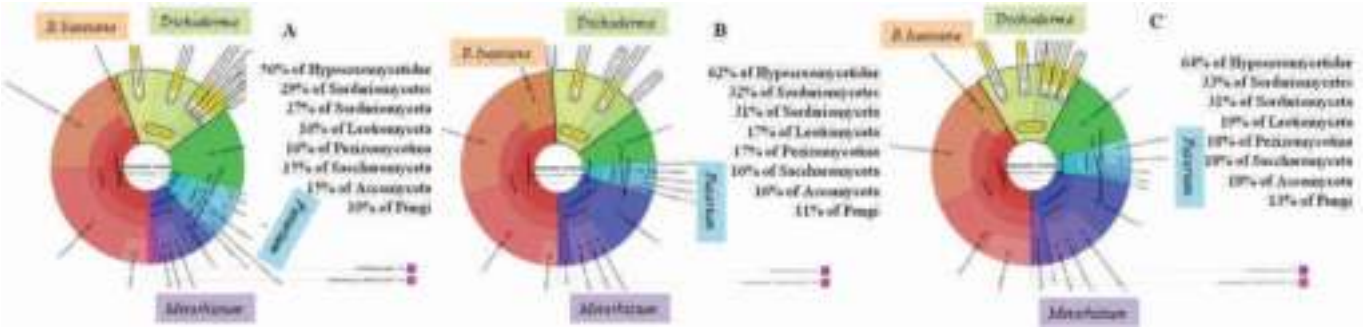

Fig. 3: Diversity and abundance of beneficial fungi such as Trichoderma, Metarhizium and Beauvaria bassiana after two years of TrichoRS (Trichoderma fortified rice straw) amendment in farmer's field. (A). Uncultivated control field, (B). Untreated mustard field, (C): Treated mustard field.

The Fungi Magnaporthe, which is associated with Rice Blast decreased in presence of the TrichoRS treatment.

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Modeling climatically stable areas for *Citrus* species

The potential impact of climate change on the geographic distribution of horticultural species and their wild relatives is relatively less studied compared to cereal crops. Though it is assumed that such species are resilient to the negative impact of climate change, assessing its impact can help in developing long-term strategies for their conservation and management. Identifying climatically stable areas for such species using a consensus of multi-model projections may help in delineating stable climate zones and prioritize conservation areas. Such areas are expected to maintain suitable conditions for species for long time periods. Technically, such consensus maps may help identify climatic stability gradients for individual species that may be useful for decision-makers.

We elucidate this using 130 occurrence records for six species of the genus *Citrus* (Rutaceae) viz., *C. indica* Tanaka, *C. karna* Rafin., *C. latipes* (Swingle) Tanaka, *C. macroptera* Montrouz., *C. medica* L., and *C. sinensis* (L.) Osbeck. Occurrence data on the species were collected through field surveys, and from scientific available literature. The geographical coordinates of occurrence of the selected species were recorded using a Geographical Positioning System (GPS) device. In the absence of specific geographical coordinates for the locality names in the secondary sources, Google Earth was used to assign geocoordinates. The compiled occurrence records were used to model the climatic niche and predict the potential distribution areas for each species.

Climatic predictors

Nineteen bioclimatic variables downloaded from www.worldclim.org that represent the current conditions were used to reconstruct the climatic niche of the selected species. They describe the annual climatic trends on temperature and precipitation including their seasonality and extremities, and are relevant to the persistence, phenology, and physiology that affect their geographical distribution.

Two global general circulation climate models viz., IPSL-CM5A-LR and NIMR-HADGEM2-AO with four Representative Concentration Pathways (RCPs), i.e., 2.6, 4.5, 6.0, and 8.5 for 2050s were used to predict the future distribution in India of the above mentioned six species. Nineteen bioclimatic variables pertaining to each of these factors with a resolution of 2.5 minutes were downloaded from CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) website (http://ccafs-climate.org/). These variables were resampled to a spatial resolution of 0.04° to match with the data resolution of the current climatic conditions, and were used as projection layers that represented the future scenarios.

Species distribution modeling

The climatic niches were modeled using maximum entropy species distribution modeling software MaxEnt version 3.4.3. The Maxent model was run with 10,000 background points used, 5000 iterations, a convergence threshold of 0.00001, and a regularization multiplier of one. We executed ten replicated runs for each species by using the bootstrap option to derive the optimized model. Model evaluation was done based on AUC as well as partial AUC measures.

Identifying climatically stable areas

Delineating potentially stable environments i.e., areas

that can conserve suitable climates in the long term, can help in averting economic losses due to improper conservation investments. We defined climatically stable areas as the consensus of all the threshold predicted areas under current as well as the future scenarios. Thresholding of the averaged probabilistic cloglog model outputs for each species were done by applying the 10 percentile training presence cloglog threshold rule in MaxEnt to generate species-specific binary maps representing climatic suitability and unsuitability. Climatically stable areas were identified by summing the scenario-specific binary maps for each species. Here, the areas with higher model agreements were considered as those with greater climatic stability, while the areas under lower model agreements were considered climatically less stable. Potential distribution area mapping was done using Q-GIS version 3.24.3 software.

The present study shows that climatically stable areas for the selected species are mainly distributed in northeast India and coincides with the existing distributional range of the selected species (**Fig. 1**). However, the species-specific stable areas varied in different states. For example, highly suitable areas for *C. indica* and *C. medica* were distributed in Arunachal Pradesh, Meghalaya, and Assam, while for *C. macroptera* it was distributed in Meghalaya, Mizoram, Tripura, and Manipur. Highly suitable areas for *C. karna* and *C. sinensis* were distributed in the foothills of Arunachal Pradesh and Assam, while for *C. latipes* they were mainly distributed in Meghalaya. It is interesting to note that most of the identified areas coincide with the current *Citrus* growing areas and have a heterogeneous topography comprising of hills, foothills, plateaus, slopes, river valleys, and floodplains, with a cover of tropical evergreen forests, tropical semi-evergreen forests, and subtropical evergreen forests. Degraded forests, abandoned shifting cultivation areas and irrigated agricultural lands were also represented. The identified areas with potentially stable climates may be helpful for the cultivation of commercially important *Citrus* species and varieties.

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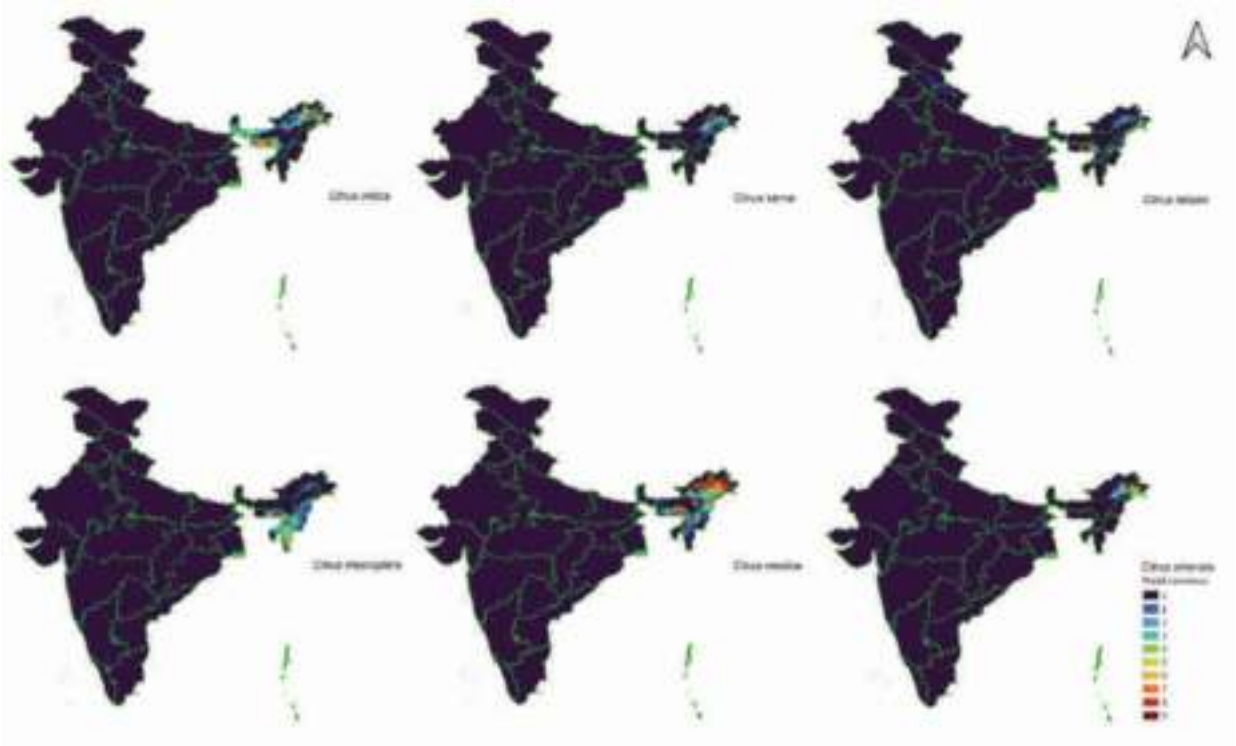

Fig. 1: Maps showing the distribution of the areas with stable climate for six Citrus species in India. The model consensus levels correspond to climatic stability, where areas with a higher consensus represent areas with more stable climates for the respective species. The maps for each species were generated by summing the threshold ENM outputs for the current scenario as well as outputs for the respective RCPs of the IPSL-CM5A-LR and NIMR-HADGEM2-AO climate models for the year 2050.

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Impact assessment of climate change and air pollution on plants

Differential defence responses of tolerant and sensitive wheat cultivars to ambient and futuristic concentrations of O_3, CO_2 and temperature

Food security in the 21st century faces multi-faceted challenges to feed the ever-increasing population with changing consumption patterns and changing climatic scenarios. India is the second largest wheat-producing country in the world. The strong correlation between elevated O_3-CO_2- temperature relationships in the future may influence crop responses. Tropospheric O_3 and high temperature induce oxidative stress. The objectives of the present study were to study the differential response of ROS scavenging mechanism in sensitive and tolerant wheat cultivars exposed to future climate change scenarios.

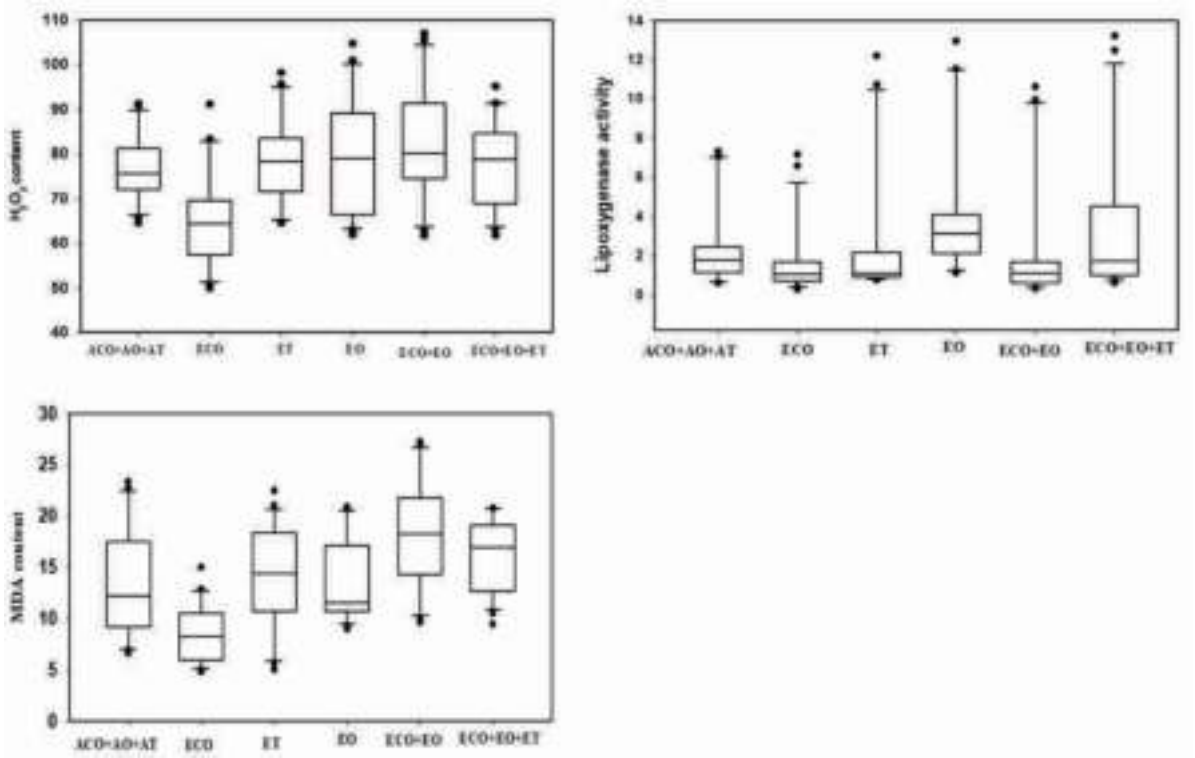

Fig. 1: Variation in H_2O_2 content, lipoxygenase activity and lipid peroxidation in wheat cultivars exposed to ambient (CO_2+O_3+temperature), elevated CO_2 (ECO), elevated temperature (ET), elevated O_3 (EO), elevated CO_2+elevated O_3 (ECO+EO) and elevated CO_2+elevated O_3+elevated temperature (ECO+EO+ET).

Experimental set up and design: A factorial design with two levels of ozone (ambient and elevated), two levels of CO_2 ambient and elevated CO_2 (550 ppm), and two levels of heat stress (ambient and elevated temperature (+2°C above ambient). The experiments were conducted in specially designed Free Air CO_2/O_3 enrichment chambers allowed us to control the movement of air inside the chambers thus enabling the plants to grow in near natural conditions. Continuous concentrations of O_3 and CO_2 were monitored and the temperature was recorded through sensors installed within FACE setup. Sensors also checked when the required dose of O3, CO2, and temperature was achieved

1st treatment: Ambient O_3+ambient CO_2+ ambient temperature will serve as "control" in the experiment (ACO+AO+AT)

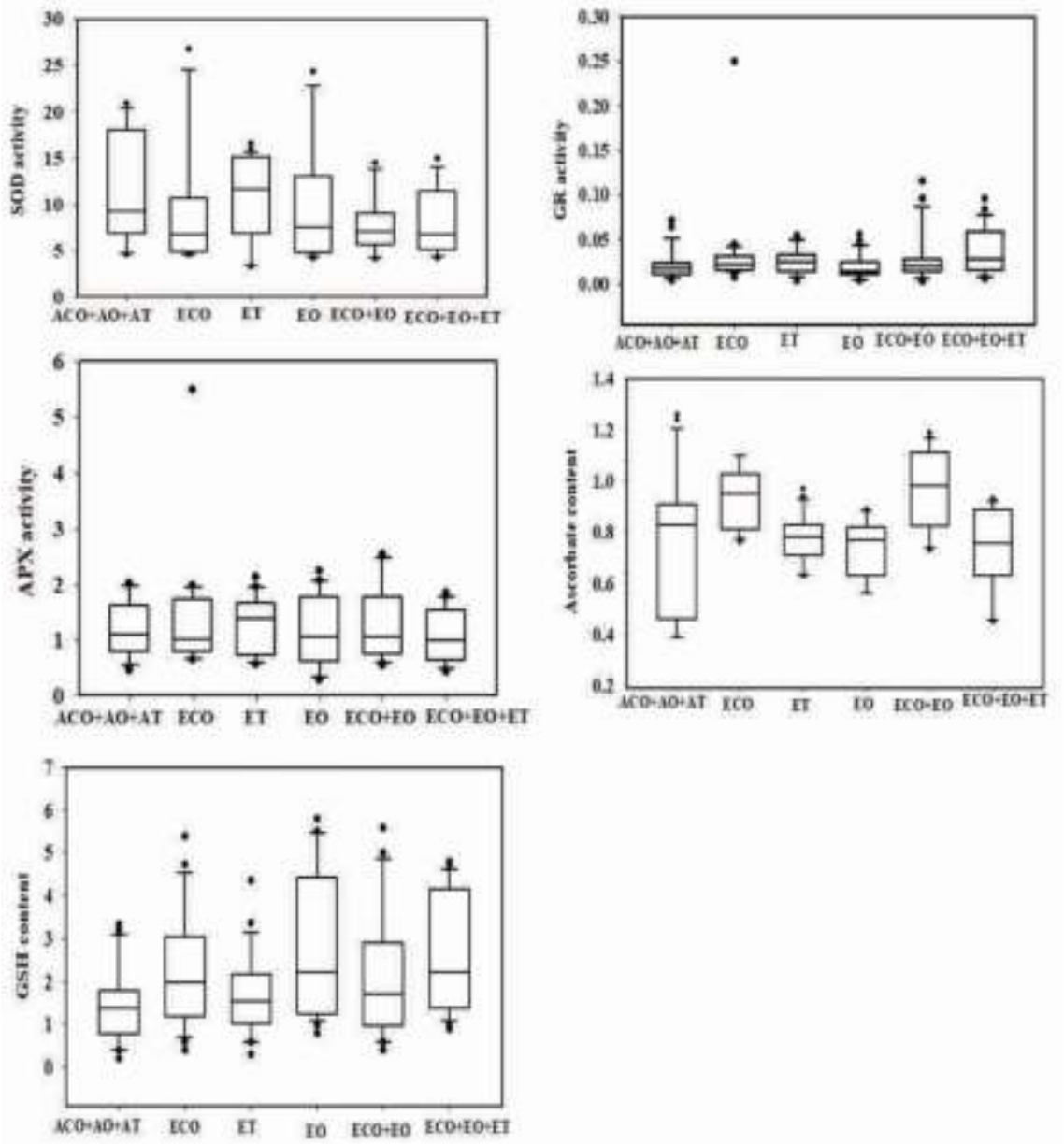

Fig. 2: Variation in superoxide dismutase (SOD), ascorbate peroxidase (APX) and glutathion reductase (GR) activities and ascorbate and glutathione content in wheat cultivars exposed to ambient (CO_2+O_3+temperature), elevated CO_2 (ECO), elevated temperature (ET), elevated O_3 (EO), elevated CO_2+elevated O_3 (ECO+EO) and elevated CO_2+elevated O_3+elevated temperature (ECO+EO+ET).

2nd treatment: Elevated O_3 (Ambient +20 ppb) + ambient temperature+ ambient CO_2 (EO)

3rd treatment: elevated temperature (2°C) (ET)

4th treatment: elevated CO_2 (550 ppm) (ECO2)

5th treatment: Elevated O_3 (ambient+ 20ppb O_3) + elevated CO_2 (ECO+EO)

6th treatment: Elevated O_3+ elevated CO_2+ elevated temperature (ECO+ET+EO)

Experimental plants: Eight wheat cultivars were taken PBW 154, WB-02, HD 2967, HD-3086, DBW 184, DBW 222, DBW 187, and HD 2329. Before sowing the seeds in recommended doses of N, P and K (N: in the form of urea, P: in the form of single super phosphate and K: as muriate of potash) will be added. The seeds will be shown in rows 15 cm apart. Required hand weeding was done at time to time.

Plant Sampling: Flag leaves were chosen for H_2O_2 content, lipid peroxidation, lipoxygenase activity, and antioxidative enzymes measurement like superoxide dismutase (SOD), ascorbate peroxidase (APX), glutathione reductase (GR) and non-enzymatic antioxidants ascorbate and glutathione was measured.

In the present study, H_2O_2 content was higher in all the cultivars exposed to a higher temperature (ET) compared to the control (ACO+AO+AT). Lipid peroxidation was measured in terms of MDA content and it increased for HD 2329, HD 2967, and PBW 154 in EO_3 and ECO+EO+ET treatment while it decreased in DBW 184, and DBW 222. MDA content and H_2O_2 content were lower in elevated CO_2 treatment. Lipoxygenase activity was higher in EO_3, ET, and in combination ECO+EO+ET treatment compared to control (ACO+AO+AT). Among wheat cultivars, higher LOX activity was recorded in PBW 154, HD 2329, DBW 222, and DBW 187 (Fig. 1).

Elevated O_3 and temperature are known to induce ROS formation. Plants have enzymatic and non-enzymatic antioxidants to scavenge ROS. SOD activity increased in HD 3086, HD 2967, DBW 184, and HD 2329, and reduced in WB 02, HD 2329, DBW 187, and PBW 154. Higher Ascorbate peroxidase (APX) activity was recorded in cultivars DBW 184, WB 02, HD 3086, and HD 2329 compared to control (ACO+AT+AO). GR activity increased for HD 3086, HD 2329, HD 2967, DBW 187, and DBW 184 in ECO+ET+EO (Fig. 2). Higher ascorbate and glutathione content was recorded in HD 2329 exposed to ECO+EO+ET treatment. Therefore it could be concluded based on ROS scavenging potential cultivar HD 2967 to be tolerant and DBW 184 as sensitive cultivars under future climate change scenarios.

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Virus identification and characterization, virus-management, understanding Host-Virus-Vector relationship, identification of phytoplasma

Identification of tomato infecting virus

In tomato growing plots at CSIR-NBRI, Lucknow, severe leaf mosaic disease was observed on a number of tomato plants, *Solanum lycopersicon*. The virus culture from the infected tomato plant was mechanically sap-transmitted to seedlings of tobacco, capsicum, and tomato. After 15 dpi, the virus caused chlorotic dots and mosaic on capsicum, mosaic accompanied by leaf deformation on tomato, and chlorotic lesions on tobacco plants. The virus is subsequently being maintained on tomato plants in broad daylight glass-house conditions. The biological and molecular characterization of the tomato virus is under progress (Fig. 1).

Biologically synthesized nanoparticles for virus management

Rivina humilis is a species of flowering plant in the family *Petiveriaceae*. It is commonly known as pigeon berry, baby peppers, and blood berry. Biological synthesized silver nanoparticles was prepared with the leaves of *R. humilis* and its properties are being investigated (Fig. 2).

Fig. 1: Tomato plant exhibiting severe mosaic disease of leaf in the field. Biological characterization of tomato virus on different test species, *Nicotiana tabacum* cv. White Burley, *Capsicum annuum* (PusaJwala) and *S. lycopersicon* (cv. S-22). Test plants revealed initial mild symptoms at 15 days of post inoculation (dpi) whereas symptoms get severe after 30 dpi.

Fig. 2: Biologically synthesized silver nanoparticles using leaf extract of *R. humilis* plant.

PGPR-based viral disease amelioration in tomato

The uncharacterized tomato virus and Punjab chuhara cultivar, a sensitive variety of tomato was used for the assessment of plant growth promoting rhizobacteria (PGPR)-based amelioration of viral disease (Fig. 3).

Six rows of plants, each row containing three plants, were adjusted for each treatment and experiments were conducted as shown below:

Control plants: The 3-4 leaf stage seedlings were inoculated with buffer only (mock-inoculated) and used as a control reference.

Control+virus: The 3-4 leaf stage seedlings were inoculated with uncharacterized tomato virus. Symptoms developed after 15 dpi on upper un-inoculated leaves were considered for diagnosis.

PGPR: The 3-4 leaf stage seedlings were soil drenched with PGPR suspension and considered as PGPR-treated tomato.

PGPR+virus: The above PGPR-treated plants were inoculated with tomato virus and symptoms developed after 15 dpi on upper un-inoculated leaves were considered for diagnosis.

PGPR+Foliar spray: The 3-4 leaf stage seedlings were soil drenched and also foliar sprayed twice at 3 days intervals with PGPR suspension before virus inoculations.

Fig. 3: 60 days old tomato plants (from all treatments) displaying growth related attributes. From left to right are the control plants, virus inoculated control plants, PGPR-treated plants, PGPR following virus inoculated plants, PGPR and Foliar sprayed plants, and PGPR and Foliar sprayed virus inoculated plants.

PGPR+Virus+Foliar spray: The above PGPR-treated plants were inoculated with tomato virus and symptoms developed after 15 dpi on upper un-inoculated leaves were considered for diagnosis.

Further assessment of plant vigor related attributes is under process.

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Phyto-hormonal cross talk, environmental signalling

The major focus of my research is to identify and characterize novel molecular players at the junction of phytohormones and environmental signalling (temperature, light, water availability, and CO_2) networks to generate climate resilient plants without yield and nutritional value impairment.

Plants stress responses and adaptability to adverse climate usually comes at the expense of yield and nutritional value. The need to engineer plant systems that can harness the maximum photosynthetic potential under future climate change scenarios, avoid the harmful effects of adverse environment on nutrition quality and survival, and fine-tune cellular metabolism and resource allocation efficiently, becomes urgent. Therefore, in-depth understanding of the underlying molecular mechanisms of plant response(s) to sub-optimal growth conditions as well as functional characterisation of key players of trade-off between growth and stress responses will help the search of innovative solutions to make future climate-ready smart crops and ensure food and nutritional sustainability.

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Quantification of microplastics in agricultural soil, modified biochar to adsorb arsenic from contaminated soil and also to enhance crop productivity, mitigation of Chromium load from tannery sludge by using biochar

Data compilation of samples collected from 18 districts of Uttar Pradesh with reference to Arsenic contamination in soil, water, and crop samples. Completed a geo-tagged web portal of arsenic mapping in the arsenic-contaminated zones in collaboration with RSAC, Lucknow.

Soil samples have been collected from agricultural fields in Lucknow to quantify the microplastics present in the samples. Various steps have been involved in the quantification viz., density separation, digestion and analysis of the samples through FTIR and Raman spectroscopy.

Table 1: Proximate, Ultimate and Chemical parameters of various types of Biochar

Analysis	Parameters	JLBC	JBBC	CRBC	TLBC	JLMBC	JBMBC	CRMBC	TLMBC
Chemical analysis	pH	8.5	10.5	8.3	9.5	2.5	2.0	2.0	2.4
	Electrical conductivity	0.337	0.118	0.105	0.108	0.080	0.019	0.069	0.054
	Yield (%)	65.80	66.80	67.77	61.92	39.19	30.77	19.84	26.42
	Cation Exchange capacity (CEC) (meq/100g)	27.88	21.39	30.47	55.58	26.59	34.14	35.60	49.35
	Mg (ppm)	11.63	13.22	10.86	7.49	2.43	2.95	4.43	10.84
	Cr (ppm)	0.69	0.36	0.29	0.42	0.38	0.31	0.29	0.22
	Fe (ppm)	12.55	9.72	20.37	17.85	73.28	55.83	55.54	64.08
	Co (ppm)	0.44	0.57	0.66	0.75	0.77	0.89	0.48	0.59
	Ni (ppm)	0.27	0.21	0.16	0.22	0.99	0.61	0.41	0.57
	Zn (ppm)	41.01	22.03	37.52	42.40	16.83	37.18	51.16	62.80
	As (ppm)	0.29	0.23	0.35	0.17	0.25	0.39	0.11	0.18
	Pb (ppm)	0.26	0.15	0.29	0.39	0.25	0.22	0.29	0.32
Ultimate/ Elemental analysis	C %	51.188	54.546	42.02	49.403	50.864	52.354	57.926	56.22
	H %	3.315	0.574	--	--	3.059	6.62	2.028	0.387
	N %	4.65	2.25	2.425	2.396	--	--	0.664	-
	S %	--	2.647	--	0.991	3.917	-	1.759	-
	O %	40.847	39.983	55.555	47.21	42.16	41.026	37.623	43.393
Proximate analysis	Moisture Content %	7.66	5.19	7.5	6.89	32.17	22.18	16.70	26.56
	Volatile Matter %	6.3	6.3	10.2	9.8	11.1	16.0	8.5	6.7
	Ash Content %	11.7	7.7	7.5	26.1	21.3	21.7	26.8	37.7
	Fixed Carbon %	82.0	86.1	82.2	64.1	67.5	62.4	64.6	55.6

Prepared biochar and modified biochar by various feedstocks like leaves and roots of juniper, turmeric, cyperus and eichhornia and mentha distillation waste (Fig.1). Different Batch experiments were performed to identify the potential biochar which showed maximum adsorption. Experiments have also been set up to check the maximum adsorption of sewage wastewater (Fig.2)

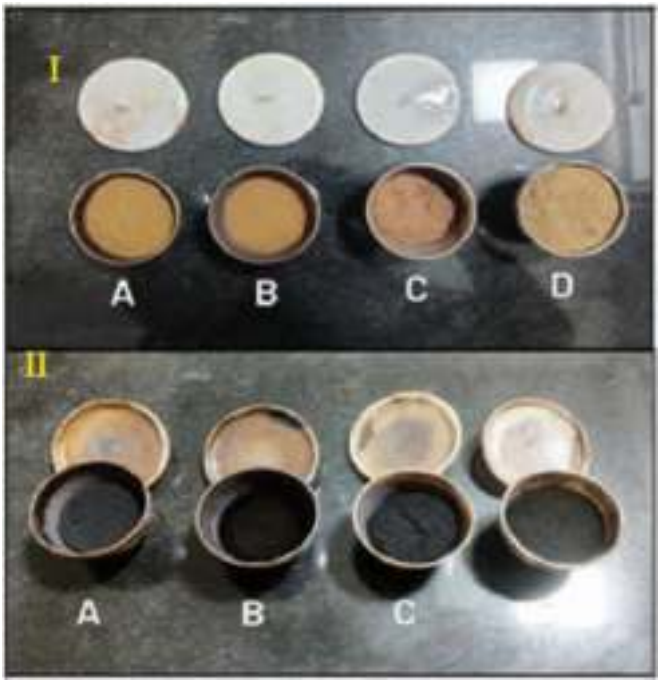

Fig. 1: Biochar from different feed stock (I). Raw material (II). Biochar prepared from (A). Juniper leaves, (B). Juniper berry, (C). Cyperus root, (D). Turmeric leaf

The yield percentage of pristine and magnetic biochar prepared at 500°C was found to be in the following order:

Cyperus root (CRBC) (67.77%) > Juniper Berry (JBBC) (66.86%) > Juniper Leaves (JLBC) (65.80%) > Turmeric leaves (TLBC) (61.92%) and Juniper leaves magnetic (JLMBC) (39.19%) > Juniper berry magnetic (JBMBC) (30.77%) > Turmeric leaves (TLMBC) (26.42%) 4 > Cyperus roots (CRMBC) (19.84%).

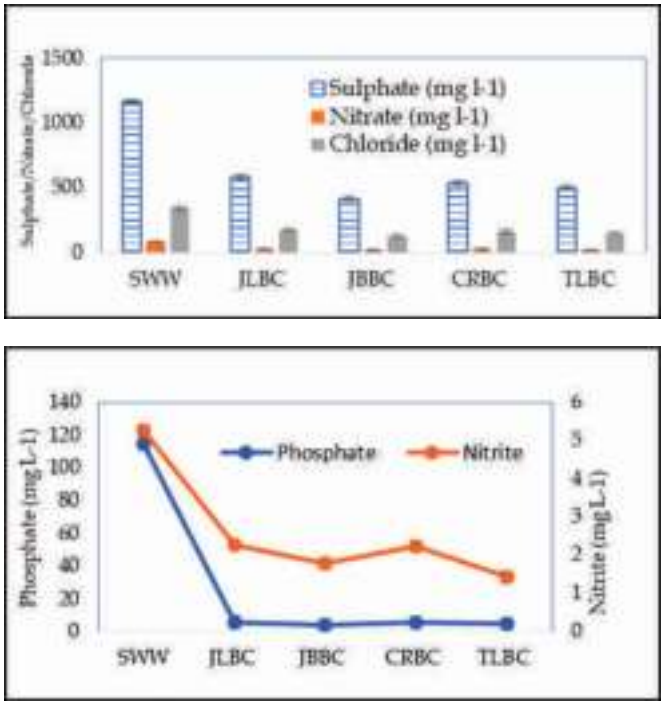

Fig. 2: Graph showing concentrations of sulphate, nitrate, chloride, phosphate, and nitrite in sewage wastewater, and after the incorporation of different biochar, contaminants level reduced in the sewage wastewater.

Isolation and characterization of arsenic tolerant fungal strains to ameliorate arsenic toxicity in contaminated agricultural soil.

Collected tannery sludge from Jajmau and isolated microbes (64 bacterial strains and 108 fungal Strains) from the tannery sludge.

Research Group Member

- Mr. Sampurna Nand, ICMR-SRF

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Molecular diagnosis and management of plant diseases caused by viruses

Currently, our laboratory is focussing on molecular characterization, diversity analysis and development of farmer friendly diagnostic kits for commercially important crop viruses.

Molecular characterization and on-site diagnosis of *Papaya Ringspot Virus*

Papaya (*Carica papaya*) is a tropical, commercial fruit with high nutritive and medicinal value. *Papaya ringspot virus* (PRSV) causes destructive disease in papaya and cucurbit cultivation worldwide. The complete genome of a *Papaya ringspot virus* (PRSV) Palampur isolate (MW030522) from foot hills of Himalayan region in northern India was characterized. The PRSV-Palampur showed close identity of 89.7 % to Indian isolate (MH311882). The phylogenetic analysis revealed that the PRSV isolates are found in seven groups (G). The PRSV isolates

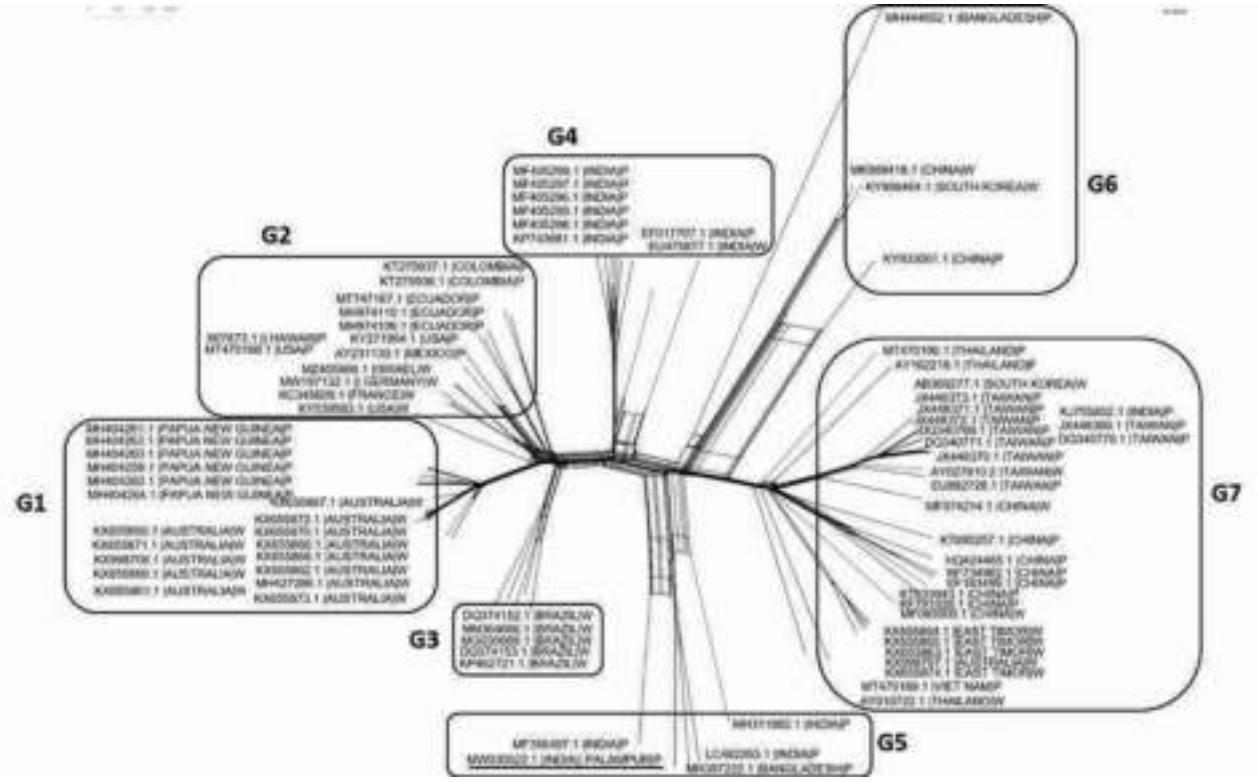

Fig. 1: Evolutionary analysis of 83 full length *Papaya ringspot virus* (PRSV) genome sequences. The PRSV-Palampur isolate from this study is underlined.

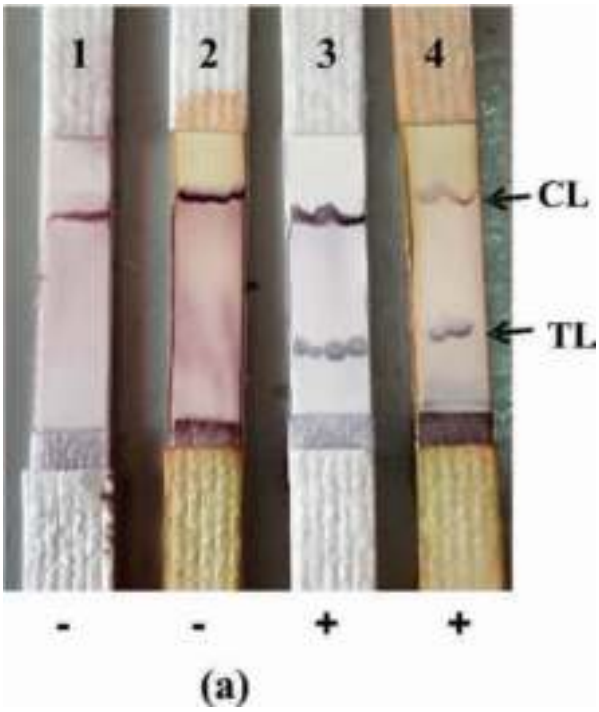

Fig. 2: Lateral flow immunoassay showing the specificity and sensitivity of the immunostrip. Strip 1: *Potato virus Y* infected plant sample, Strip 2: Healthy papaya sample, Strip 3: PRSV expressed coat protein, Strip 4: PRSV infected papaya sample.

in G5 and G6 showed more diversity compared to PRSV isolates in other groups, whereas the isolates in other groups are more conserved within their geographical region (Fig. 1). For development of onsite-diagnostics, PRSV truncated coat protein (CP) gene was expressed in *Escherichia coli* and used to generate polyclonal antibody (PAb) in rabbit. The PRSV - PAb specifically detected PRSV up to 2,04,800 dilution in ELISA. The PAb was further utilized for development of rapid and field-deployed lateral flow immunoassay (LFIA). The sensitivity of LFIA for detection of PRSV was up to 1:40 dilution of plant sap. The diagnostic specificity of LFIA with ELISA was 100% and showed no cross reaction with other potyvirus, *Potato virus Y* (Fig. 2). The availability of the immunostrip will encourage farmers, breeders, horticulturists and other researchers to readily detect the virus in the field for effective crop management.

Research Group Members

- Dr. Yogita Maheshwari, DST-INSPIRE Faculty
- Ms. Swati Bhuria, Research Scholar
- Ms. AbhilashaSingh, Research Scholar
- Ms. Niranjana Prem MP, Research Scholar

Molecular Biology and Biotechnology

WHERE PLANT-BASED RESEARCH TOUCHES LIFE THROUGH INNOVATION
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MOLECULAR BIOLOGY AND BIOTECHNOLOGY

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- Mr. Om Pal Sharma, Senior Technician

Research Scholar Statistics

Sr. No.	Position Name	Numbers
1.	Project Scientist/Consultant	04
2.	Research Associate	03
3.	JRF/SRF	55
4.	Project Staff	46

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.

In Molecular Biology and Biotechnology Division, major objective is to understand about 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 fulfil these objectives, gene-mining, transgenic plant development and genome-editing technologies are being used on various crops.

Major R&D Highlights

Cotton R&D

Fourth-year performance evaluation trial of Msc14 guard cotton for the protection of tomato, papaya, and chili against whitefly vectored viral diseases was carried out at CSIR-NBRI, Lucknow. Consistent protection of the target crops and a high level of control of the whitefly population were recorded.

First-year performance evaluation trial of Tma12 GM cotton against the challenge of a field population of whitefly at Faridkot, Punjab (in collaboration with PAU, Ludhiana) and Sirsa, Haryana (in collaboration with CICR, Nagpur) was carried out.

First-year performance evaluation trial of Msc14 GM guard cotton for the protection of tomato and papaya against whitefly vectored viral diseases at CISH, Lucknow, and IIVR Varanasi was carried out.

Dhi31 GM cotton lines that express insecticidal protein under the regulation of PCD promoter in T1 generation were developed and these lines are being used for insect bioassay against the cotton aphids and whitefly. Developed 18 Cry1EC GM cotton lines that express Cry1EC under regulation of PCD promoter. Nine GM cotton lines showed remarkable toxicity to Pink Bollworm and Cotton Leaf Worm.

The effect of cotton miPEP828a^1 and miPEP828a^2 on fibre development was checked by using the cotton ovule culture. Fibre growth was observed to be affected by the microRNA828a-encoded peptides (miPEP828a^1 and miPEP828a^2).

We remapped approximately 380 cotton RNAseq data points using consistent mapping techniques with 400-fold coverage of the genome. We revealed stage-specific aspects of fibre cell commitment, initiation, elongation, and Secondary Cell Wall (SCW) production, as well as probable cis-regulatory elements for the unique control of fibre development. As a result, our data-mining investigation uncovers numerous essential factors connected to cotton fibre development and enhancement, which are compiled in the "Cotton Express-omics" database.

GhNAC2 expression was shown to confer drougt tolerance by the group. To understand its function cotton transgenic lines with antisense construct were developed and T1 lines are being studied.

The group established a robust protocol for the recombinant expression of Tma12 and Msc14 proteins in *E. coli* and yeast. These were necessary steps toward large-scale protein production for acute toxicity study and deregulation.

Tomato R&D

In the project on understanding root development and architecture in tomato, an analysis of the heat shock factor family in roots was carried out. Expression levels of several members of the family were found to increase during root growth at later stages and were responsive to different hormones. Manipulation of one of the HSFs of the B type (expressed predominantly in roots) greatly increased lateral root branching leading to higher root biomass while its CRISPR knockout showed reciprocal changes leading to suppressed root branching and reduced root biomass.

In the project on understanding the molecular basis of fruit ripening in tomato, the *SlERF6* gene from tomato (that alters ABA responses) was previously shown to delay ripening upon expression but reduced plant growth and fruit size as well as fruit set. To overcome these problems, the gene was expressed under the fruit specific 2A11 promoter. Four independent transgenic lines, studied under homozygous conditions, showed normal vegetative growth without any deleterious effects. Fruit ripening was nevertheless delayed by about 6 days compared to control suggesting that *SlERF6* could be used for delayed ripening in tomato.

In order to improve fruit shelf-life of tomato, CRISPR lines of two HSP90 chaperone-like genes have been developed and validated through sequencing. The plants are being raised for generation advancement and ripening-related studies.

Rose R&D

In the project on understanding the molecular basis of abscission in the fragrant rose, four members of the *INFLORESCENCE DEFICIENT IN ABSCISSION* family were identified. This family, identified as a key regulator of abscission in Arabidopsis and other plants, encodes peptides that interact with receptor-like kinases to activate abscission. Loss of function *ida* mutants show abscission deficiency in Arabidopsis. All four members in rose were conserved in sequence and expression of three of these, namely *RbIDL1*, *RbIDL2* and *RbIDL4* increased 3-4 fold in petal abscission zones (AZ) during ethylene-induced petal abscission as well as natural abscission. *RbIDL1* and *RbIDL4*, the more prominently expressed genes, could complement the abscission defect of the Arabidopsis *ida-2* mutant. Moreover, promoters of both genes could drive AZ-specific expression in an ethylene-responsive manner even in Arabidopsis silique AZs indicating recognition of AZ-specific and ethylene responsive *cis* elements in their promoters by the abscission machinery of rose as well as Arabidopsis.

Chickpea R&D

In the project on understanding the signals of early wound-responses in chickpea, at least 14 WRKY genes that showed 5-50 fold increase in expression within 5-20 minutes of wounding were identified. While studying the contribution of individual chemical cues in the early wound response it was observed that contrary to their collective effects upon wounding, individual chemical cues showed distinct and often opposite effects in absence of wounding. In particular, Jasmonic acid, reduced transcripts of most WRKY genes by >50% upon treatment of unwounded chickpea leaves as did salicylic acid. Neomycin (a JA biosynthesis inhibitor) delayed and also reduced early wound expression. H_2O_2 transiently activated several genes within 5-20 minutes by 5-8 fold while ethylene activated only a few WRKY genes by 2-5 fold. The summation of the individual effects of these chemical cues does not explain the strong increase in transcript levels upon wounding suggesting complex interaction.

The enhanced expression of the *CAMTA* gene in all transgenic lines of chickpea showed tolerance against drought and salt stress. The increased antioxidant enzyme activities and reduced level of stress markers (TBARS and H_2O_2) enhanced the overall performance of the transgenic plants and overcame oxidative stress caused by both drought & salt stress. The increased level of photosynthesis (*PN*), stomatal conductance, and non-photochemical quenching (qN) enhanced the physiological performance of chickpea under drought and salinity stress.

R&D on Rice and Vegetables

Based on our study, we proposed that the tau class glutathione-S-transferase (OsGSTU5) interacts with VirE2 protein and modulates the efficiency of *Agrobacterium*-mediated gene transfer in rice.

In addition to rice, vegetables grown in arsenic contaminated groundwater can add many fold daily arsenic intake through human food. Our research group studied on various aspects of arsenic entry into human food chain. We have selected WB, Bihar and U.P. for the collection of vegetables from highly arsenic affected districts. Up to now, total ten districts have been covered, among them four from WB and three from both U.P. and Bihar. Arsenic data analysis of these vegetables showed that the accumulation of arsenic has been high in leafy vegetables followed by tubers/roots and fruity vegetables. Therefore, arsenic accumulation order is fruity < tubers/roots < leafy vegetables. The level of arsenic was highest in spinach 367-1970 μgkg^{-1} in affected villages, being maximum up to 1970 μgkg^{-1} in Chain Chhapra, block Belhari of Ballia district, U.P., which is about two fold higher than the permissible limit i.e. 1000μgkg^{-1} set by WHO and FAO.

Arabidopsis R&D

Small RNAs such as microRNAs (miRNAs) and small interfering (si)RNAs are short 20-24-nucleotide non-coding RNAs. They are key regulators of gene expression in plants and other organisms. The group showed that in Himalayan *Arabidopsis thaliana* accessions having natural mutations in miR158 locus exhibit robust cascade silencing in pentatricopeptide (*PPR*)-like locus. These sRNAs trigger tertiary silencing of a gene involved in transpiration and stomatal opening. The natural variants of *MIR158* having deletions or insertions led to improper processing of miR158 precursors thereby blocking synthesis of mature miR158. Reduced miR158 led to increased level of its target, a pseudo-pentatricopeptide gene that is otherwise targeted by ta-siRNAs generated by miR173 cascade in other accessions. Using small RNA datasets derived from Indian Himalayan accessions, as well as overexpression and knockout lines of miR158, we show that absence of miR158 led to build up of pseudo-*PPR* derived tertiary small RNAs. These tertiary sRNAs mediated robust silencing of a gene involved in stomatal closure in Himalayan accessions lacking miR158 expression. We functionally validated the tertiary phasiRNA that targets *NHX2* thereby regulating transpiration and stomatal conductance. Overall, we deciphered a new module of sRNA network, miRNA-*TAS*-siRNA-pseudogene-tertiary phasiRNA-*NHX2* in plant adaptation.

Arabidopsis lines over-expressing the chickpea *MT1* gene showed enhanced tolerance against toxic heavy metals [As (III), As (V), Cr (VI) & Cd]. The defense system responsible for metal tolerance was elevated in the transgenic lines over-expressing *MT1*, compared to the WT plants. The levels of cysteine were higher in transgenic lines, suggesting that *MT1* actively regulates the thiol-dependent mechanism to reduce the heavy metals toxicity in plants.

In the area of computational biology the stress tolerance of plants in response to drought, salt, heavy metals and pathogen attack was studied. The transcriptome meta-analysis of the salt and drought stressed cotton was carried out. The analysis revealed key regulatory hub genes of drought and salt stress conditions. There were 5,962 and 3,510 differentially expressed genes (DEGs) in drought and salt stress data.

The pan genome analysis of Musa sp was carried out to identify the evolution of the ripening responsive genes. The ripening related ERS gene was analyzed in detail and significant differences in relation to ripening was identified in different Musa species. The combined stress of arsenic and sulphur results in higher sensitivity to stress. The transcriptome and miRNA sequencing analysis in *Arabidopsis thaliana* revealed the regulation of arsenic and Sulphur stress by several miRNAs.

Others

Screening of plant extracts for SAR-CoV-2 Main Protease inhibition activity; *Andrographis panniculatas* (Kalmegh) and its various formulations procured from the market showed good inhibition activity, CIM-MEG-19 (a preparation of CSIR-CIMAP) found the best among the tested formulation.

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Transcription and epigenetics regulation studies

Exploring the role of CAMTAs in drought tolerance and fibre development in cotton

Calmodulin-binding transcription activators (CAMTAs) are calcium-dependent transcriptional activators that play crucial roles in diverse stress signaling and plant growth and development. We identified several CAMTAs crucial for root development, drought stress tolerance (*AtCAMTA1*, *AtCAMTA5*, *GheCAMTA*,) and fibre development (*GhCAMTA2A*.2 and *GhCAMTA7A*) for cotton (Fig. 1). To validate *GheCAMTA's* role in root development and its impact on drought tolerance in cotton, we generated over-expression cotton (*Gossypium hirsutum* c.v.312) transgenic line. Overexpression of *GheCAMTA* improves the root biomass in cotton. For the functional validation, we are also generating *GhCAMTA7A* over-expression transgenic lines, and molecular characterization of transgenic lines is in progress.

Role of Epigenetic modifiers in cotton fibre development

A limited investigation has been done to know the epigenetic regulation of fibre development; in this respect, the role of *HDA5* in cotton fibre initiation has been established. Interestingly, positively co-expressed genes with *GhHDA5* exhibited a protein interaction network with *HDA6 and SUVH1*. Therefore, several constructs were developed, to make RNAi and overexpression transgenic lines with CaMV35S promoter and native promoter, to unravel the mechanistic roles of the histone methyltransferase *GhSUVHI* and histone deacetylase *GhHDA5* in the fibre initiation. Furthermore, to identify the genome-wide binding sites of *GhSUVH1* in cotton, we fused these genes with Myc-tag and developed the transgenic lines.

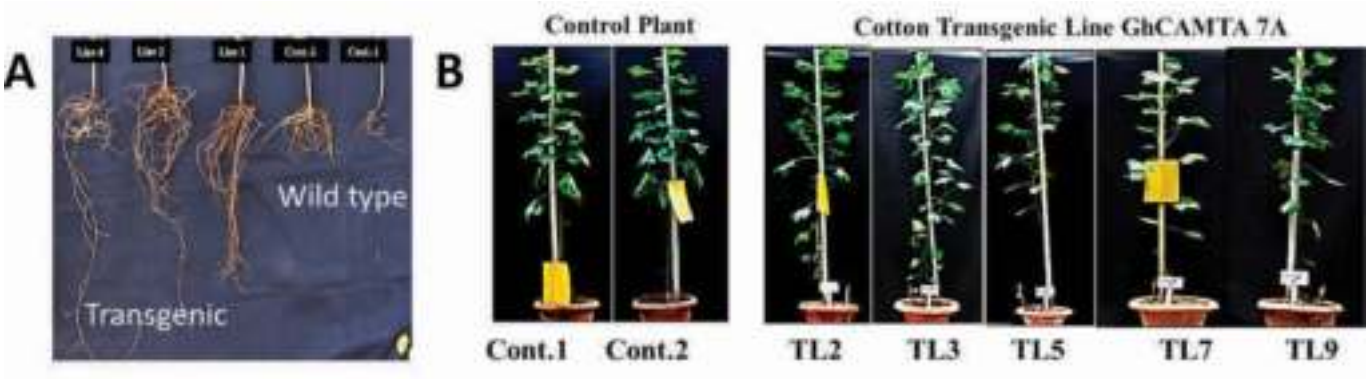

Fig. 1: **(A).** Enhanced root biomass in overexpression of *GheCAMTA* in cotton, **(B).** *GhCAMTA7A* over-expression transgenic cotton plants.

Investigation of the roles of MYB1 transcription factor and its regulatory microRNAs in secondary cell wall biosynthesis in cotton

Cotton MYB1 transcription factor (TF) shows higher expression during the secondary cell wall biosynthesis stage at 19 days post-anthesis (DPA). Therefore, a chIP experiment was carried out to identify the genome-wide DNA binding sites of MYB1 TF at the 19 DPA fibre stage. In addition, the effect of cotton miPEP828a[1] and miPEP828a[2] on fibre development was checked by using the cotton ovule culture. Fibre growth was observed to be affected by the microRNA828a-encoded peptides (miPEP828a[1] and miPEP828a[2]).

Identification and analysis of Arabidopsis wound-inducible promoters

A wound-inducible promoter facilitates the regulated gene expression at the targeted site during mechanical stress or infestation by the pathogen. The computational analysis of microarray data (GSE5627) resulted in identifying five early inducible genes, viz., AT1G17380, AT1G80440, AT2G43530, AT3G48360, and AT5G13220. In addition, the promoter of the highly induced and early expressed wound-inducible gene, AT5G13220 (named PW220), was characterized by fusing with *â-glucuronidase* (*gusA*) reporter or *Cry1EC* genes, which provides an excellent alternative for developing insect-tolerant transgenic crops in the future (Fig. 2).

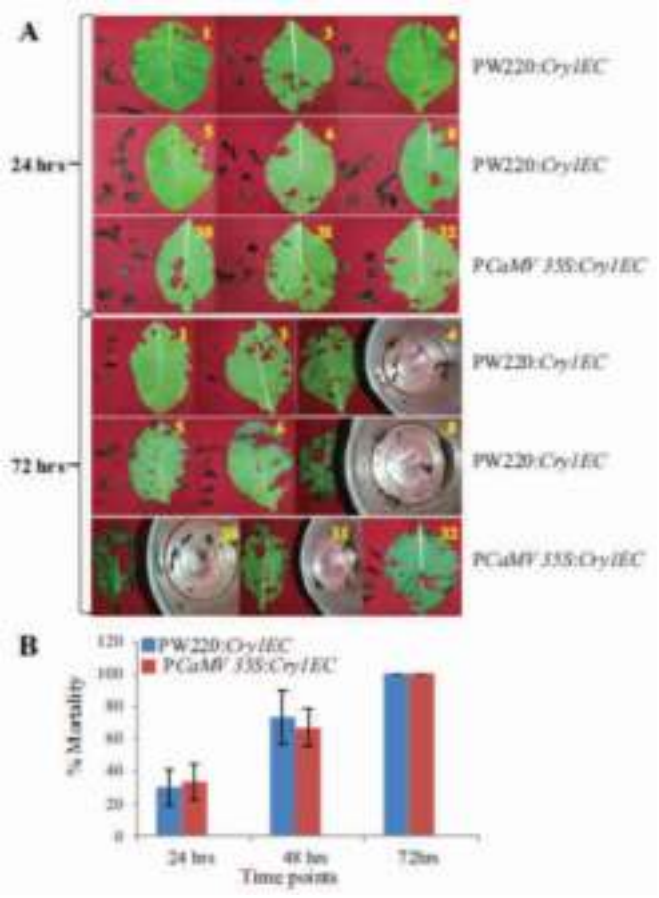

Fig. 2: Comparative third instar insect mortality analysis of wound-inducible PW220 and constitutive PCaMV 35S promoters in the transgenic plants: (A). Insect bioassay with third instar larvae of the *Spodoptera litura* at 24 and 72 h, (B). Mortality assay of the third instar larvae of the *S. litura* at 24, 48, and 72 h. The values above the bars indicate the SD from the means of three independent experiments.

A novel male sterility-fertility restoration system for the commercial hybrid seed production in cotton

A novel male sterility-fertility restoration system has been developed for hybrid seed production. In this system, a construct comprising a novel Arabidopsis *BECLIN1* gene was expressed under a two-component expression system (ES) to achieve complete male sterility in tobacco. The novel reversible ES in *Nicotiana tabacum* drives high-level and stringent expression of the *AtBECLIN1*gene in post-meiotic tapetal cells rendering them male sterile. The reversible ES principally works on functional complementation of mutated TATA-Box (TGTA) and TATA-binding protein-mutant-3 (TBPm3). In contrast, the fertility of F1-hybrid was restored by limiting TBPm3 availability through Constitutive-photo-morphogenesis-1 (COP1)-mediated degradation of Long Hypocotyle-in-Far-Red1 (HFR1) fused protein HFR1NT131-TB-Pm3. We introduced this proven ES in cotton by developing male sterility-fertility restoration transgenic lines using somatic embryogenesis methods in the Cocker-312 genotype of *G. hirsutum*. We performed the detailed phenotypic and molecular characterization of developed transgenic male and female lines and F1-hybrids. To confirm that the abnormal tapetal growth and delayed degeneration lead to the non-viable pollen in the male sterile parent, which is due to the *BECLIN1* expression, the anther cross-sections of the control confirm that the tapetal abnormality and pollen abortion in female (1374). Furthermore, the cross-section of F1- hybrid (female x male) showed normal development of tapetum and pollen similar to the control due to the abolished expression of

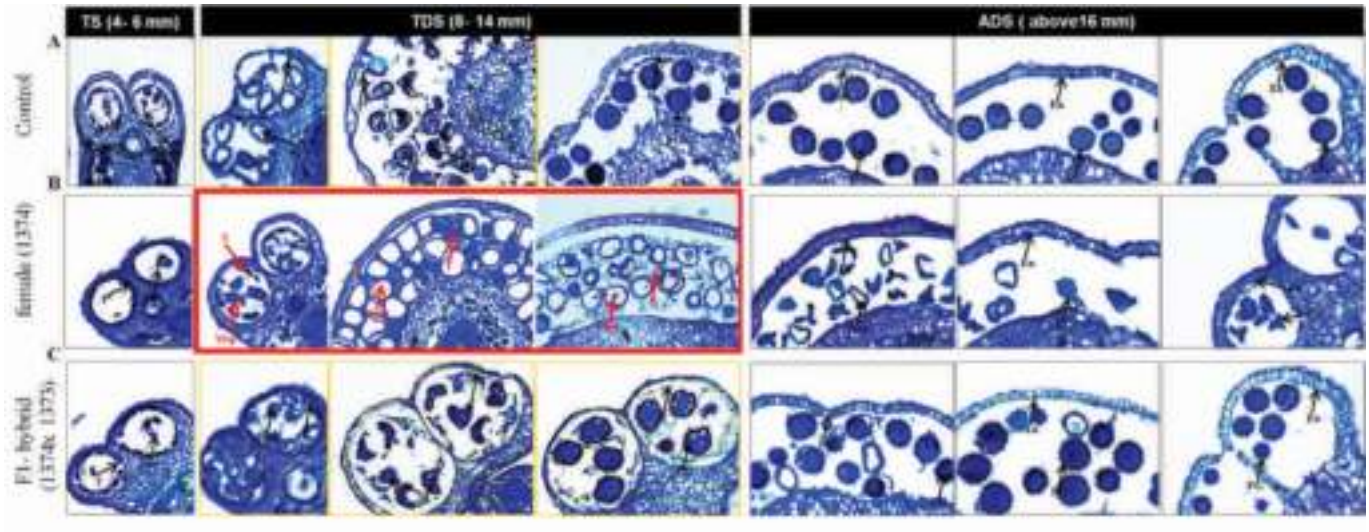

Fig. 3: Transverse anatomical comparison of anther development in wild type (control), *BECLIN1* transgenic (1374) and F1- hybrid anther cross sections of control (A), female (1374) (B). and F1 transgenic (C). at different anther developmental stages from TS (tetrad stage), TDS (tapetum degradation stage) to ADS (anther dehiscence stage). T, Tapetum; Tds, Tetrad ; Msp, Microspore; PG, Pollen grain; En, Endothecium ; Bars= 50um.

Beclin1 (Fig. 3). Thus, this work translates proofs of concept to technology for efficient F1-hybrid production in cotton.

Role of RabGTPase in Arabidopsis plant growth and seed development

Rab GTPases act as a molecular switch, and their activation and inactivation govern numerous processes. Arabidopsis consists of 57 Rab GTPases. Based on high expression levels, preferentially in seed tissues, we selected RabC for further characterization in plant growth and seed development. A loss-of-function of RabC (*rab-1* and *rab-2*) led to shorter roots, delayed flowering, and smaller seed size (Fig. 4). Furthermore, DIC microscopy of developing seeds revealed a smaller endosperm cavity and reduced integument cell length. Altogether, our work demonstrates the crucial role of Rab GTPase signaling in plant growth and seed development.

Cotton (*Gossypium* sp.) genome editing to develop determinate/semi-determinate sympodial varieties for synchronized fibre yield and quality

The cultivated cotton varieties are perennial; thus, flowering, boll setup, and mature fibre production continues throughout the year. We want to develop cotton varieties that can give the production in one go, and preferably in a shorter time frame. In cotton,

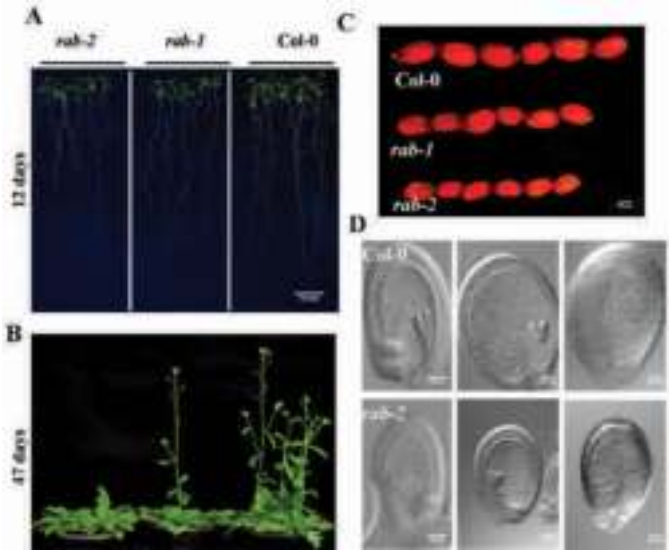

Fig. 4: RabGTPase signalling in plant growth and seed development: (A). Comparative study of Col-0, *rab-1*, and *rab-2* at 12 days old seedling, (B). Delayed flowering in mutants (*rab-1*, and *rab-2*) as compared to Col-0, (C). Comparative seed size analysis in *rab-1*, *rab-2*, and Col-0, (D). Whole-mount comparative DIC microscopy of developing seed (3 DAP, 5DAP, and 9 DAP) in Col-0 and *rab-2*.

the SELF-PRUNING (GhSP) and SINGLE FLOWER TRUSS (GhSFT) genes have been identified whose local balance (GhSP and GhSFT ratio) and antagonistic actions in shoots apical meristem regulate growth habit and flowering. Studies showed that the constitutive expression and knockout/down of

either GhSP or GhSFT showed an extreme phenotype which is not beneficial for agricultural purposes. To develop agronomically superior cotton varieties, we have identified crucial cis-regulatory elements in their promoter as well as a few regulatory regions in these genes for precise editing of the expression pattern of GhSP and GhSFT. Now, we are developing CRISPR-edited lines to select the improved lines.

Data mining of cotton RNAseq repositories for different cotton fibre development stages

We remapped > 380 cotton RNAseq data with uniform mapping strategies that span ~400-fold coverage to the genome. We identified stage-specific features related to fibre cell commitment, initiation, elongation, and Secondary Cell Wall (SCW) synthesis and their putative cis-regulatory elements for the specific regulation in fibre development. Thus, our data-mining study reveals several important features related to cotton fibre development and improvement, consolidated in the "Cotton Express-omics" database.

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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 *SlERF6*-mediated changes in ABA levels and responses during fruit ripening

Previous studies had identified *SlERF6* as a negative regulator of ABA responses in tomato and shown how its expression delayed fruit ripening. Further analysis revealed that SlERF6 action affected the basal levels of ABA as a result of which there was a shift in the pre-ripening associated increase in ABA that precedes ethylene. Thus suppression lines that had high sensitivity to ABA showed a peak in ABA levels at least 3 days earlier at 37 DPA (days post-anthesis) compared to control (at 40 days) and *SlERF36* OEx lines (43 days). The intensity of the peak nevertheless remained the same in all the lines (including the OEx lines and suppressions). The data not only confirmed that ripening in tomato is preceded by an ABA increase at breaker stage but also that alteration in sensitivity to ABA by SlERF6 affects the timing of the ABA peak and thereby ripening (Fig. 1).

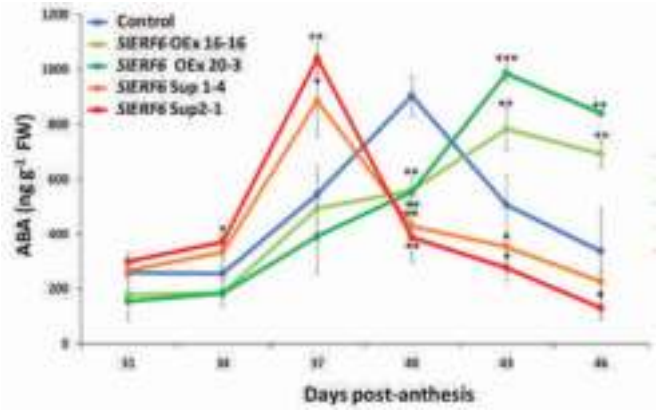

Fig. 1. *SlERF6* manipulation alters the timing of peak ABA accumulation prior to ripening. ABA was estimated in fruit pulp of control and transgenic *SlERF6* OEx and suppression lines at different stages of ripening (31-46 DPA) using an HPLC. Values are average ± SD of three replicate per line. *, indicates P < 0.05, **, indicates P < 0.01, ***, indicates P < 0.001 (one-way ANOVA).

Over-expression of *SlERF6* under the constitutive CaMV35S promoter delayed ripening. However, the phenotype of SlERF6 over-expression, although beneficial for improving shelf life of tomatoes, was associated with several deleterious characters such as poor germination, slow growth, reduced flowering and poor fruit set and yield. In order to overcome these defects, the gene was introduced in tomato under the fruit specific 2A11 promoter. Four independent lines expressing the 2A11pro:SlERF6 construct were generated and studied in the homozygous T3 generation. All four lines showed normal germination, vegetative growth, leaf number and leaf area as observed in control. None of the deleterious effects in vegetative growth (including high seedling mortality) were observed in the 2A11 promoter unlike when the gene was expressed constitutively. However the plants showed a clear difference (and delay) in ripening. Compared to the control (Arka Vikas) fruits which achieved breaker at 45 DPA, turning stage at 48 DPA and the red ripe stage at 54 DPA, all the over-expression lines attained the breaker at 51 DPA, turning stage at 54 DPA and the red ripe stage at 60 DPA thus showing a delay of 6-7 days as compared to control (Fig. 2). Thus, Arka Vikas varieties showing delayed ripening and better shelf life have been generated.

Early wound-responsive cues regulate the expression of WRKY family genes in chickpea differently under wounded and unwounded conditions

Insect wounding activates a large number of signals

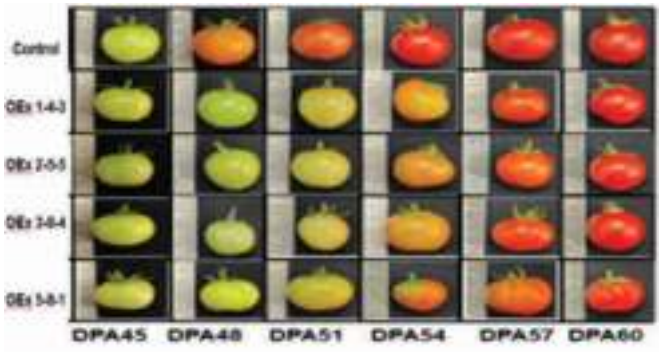

Fig. 2. Manipulation of *SlERF6* levels affects fruit ripening. Pictorial representation of delayed ripening in *SlERF6* transgenic lines (expressed under the fruit-specific 2A11 promoter) at different days of growth compared to control Arka Vikas.

that function co-ordinately to modulate gene expression and elicit defence responses. How each signal influences gene expression in absence of wounding is also important since it can shed light on changes occurring during the shift to wound response. Using simulated *Helicoverpa* herbivory on chickpea, we identified 14 WRKY genes that showed 5-50 fold increase in expression within 5-20 minutes of wounding. The ability of these genes to respond to different wound-associated chemical cues such as jasmonic acid (JA), ethylene, *Salicylic acid* (SA), hydrogen peroxide was studied individually, in absence of wounding. Our studies showed that contrary to their collective effects upon wounding, individual chemical cues have distinct and often opposite effects in absence of wounding.

Treatment with jasmonic acid (100 µM), a key early defence hormone, reduced transcript levels of 10/14 genes by 50-75 % within 20-60 minutes of treatment, in absence of wounding. This suggested that the early wound response of most of the WRKY genes was either repressed by JA or, more likely, regulated differentially by JA depending on the presence or absence of wound-responsive factors. To identify the extent of contribution by JA, leaves were pre-treated with neomycin (a JA biosynthesis inhibitor) prior to simulated herbivory. Any transcript reduction in presence of neomycin would indicate the involvement of JA while any wound-induced up-regulation in its presence would indicate JA-independent regulation. Neomycin treatment substantially reduced the rapid wound-responsive up-regulation at 5 min by 50-70% in 9/14 WRKY genes although levels rose again by 20 min in most cases. The delay in the transcriptional response from 5 to 20 min indicated that JA biosynthesis did contribute in the up-regulation of most WRKY genes upon wounding, partly or substantially depending on the gene. Some, like *WRKY33A,* were entirely dependent on JA while others like *WRKYs 40B, 40C* and *70B,* were independent of JA (Fig. 3).

Ethylene induced only a moderate increase in 6/14 genes that was limited to 1.5-5 folds compared to the 5-50 fold increase upon simulated herbivory. The two exceptions were *WRKY70B* and *WKRY72* where a 10-20 fold increase was observed that matched in scale with simulated herbivory. SA treatment, like

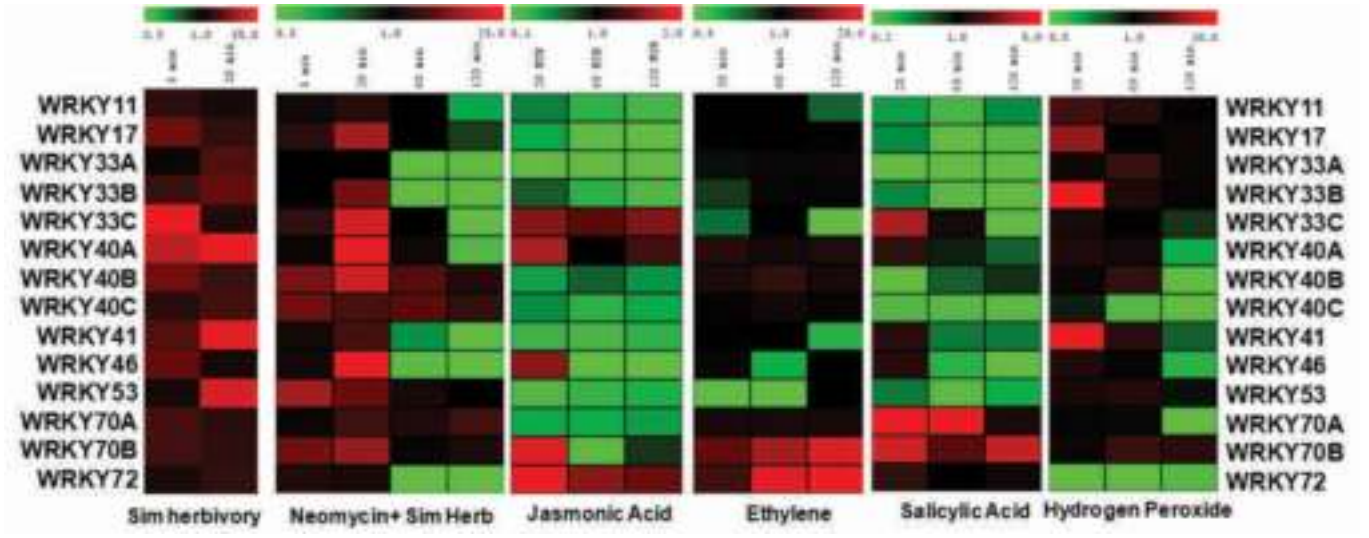

Fig. 3: Heat map summarizing the expression changes in different WRKYs in response to various treatments. (Sim Herbivory = simulated herbivory; neomycin + Sim herb = simulated herbivory after neomycin pretreatment).

JA, strongly reduced transcript levels. In contrast, treatment with H_2O_2 strongly but transiently up-regulated 11/14 WRKY genes by 3-8 fold even under unwounded conditions within 20-60 min indicating that early wound-induced transcription of at least some WRKY genes could be attributed to ROS like H_2O_2 (Fig. 3).

The studies show that summation of the individual effects of the primary chemical cues under unwounded conditions does not explain the large wound-responsive increase in transcript levels. Instead, wounding may bring about changes that alter the sensitivity of the genes to the chemical cues/ hormones leading to a completely different response compared to that in absence of wounding.

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Hormonal cross talk in root architecture: molecular basis of mango ripening

Role of HSFs in root development

Heat Shock transcription Factors (HSFs) function under heat and other abiotic stresses to combat stress. Few HSFs have been reported to function in plant development under unstressed conditions. HSFs are not extensively characterized for their function in root growth and development hence, we attempted to decipher *SlHSFs* contribution in root development under unstressed/normal environmental conditions. In tomato, 26 HSFs were identified based on highly conserved functional domains. The HSF gene family expansion in tomato is attributed to segmental and tandem duplication. Syntenic analysis revealed strong genetic evolutionary relationship between tomato HSFs and dicots and weak relationship with monocots. Abundant transcript levels of *SlHSFs* were seen in initial (15 days) as well as later (30 and 60 days) root stages. *SlHSFA5* and *SlHSFB1* exhibited highest transcript levels in mature root tissues. Overall, 42.3% of tomato HSFs showed upregulated transcript levels in 60 days root suggesting probable role in mature root growth. A heatmap (Fig.1) depicting the expression for 25 *SlHSFs* (*SlHSFA7a* was not identified in our transcriptome data) in five organs; root, shoot, leaf, fruit and flower constructed using the RNA seq transcriptome data. Fruit and root tissues exhibited the involvement of major number of *SlHSFs* as compared to leaf, flower and stem tissues. Interestingly, majority of class A HSFs showed high transcript levels in all five plant organs/tissues, while only three class B HSFs (*SlHSFB1, SlHSFB2a* and *SlHSFB2b*) showed prominent expression in all five tissues/organs suggesting their limited involvement in plant development. The heatmap data suggested significant gene expression in roots of *Ailsa craig* cultivar. *SlHSFA7, SlHSFB1, SlHSFB2b, SlHSFB3a* and *SlHSFB3b* are highly expressed in root tissues in comparison to other tissues hinting at its exclusive role in root development.

qRT-PCR validation of the *SlHSFs* in root developmental stages confirmed gene expression patterns in the 15, 30 and 60 days old root tissues (Fig. 2). *SlHSFA7* and *SlHSFB1* displayed rapid increase in

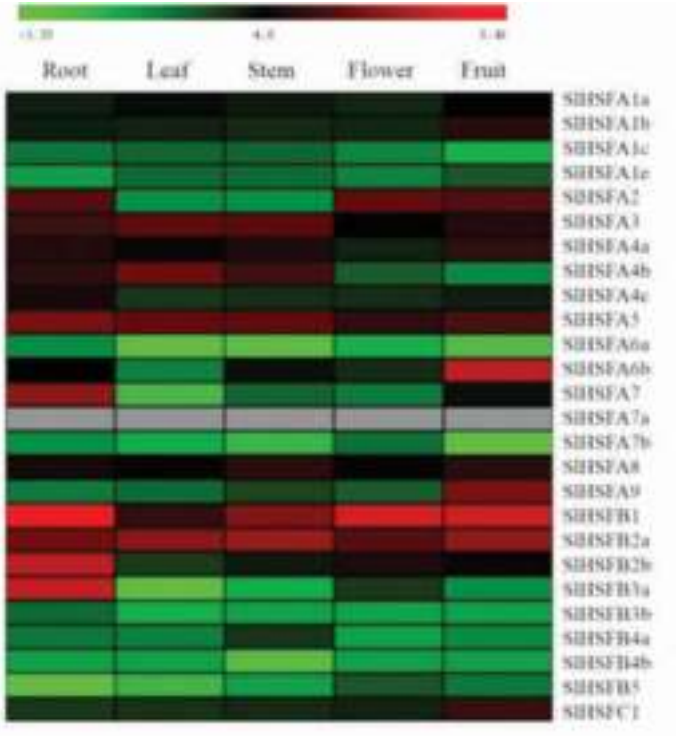

Fig. 1: Heatmap of the expression profile of *SlHSFs* gene among different tomato tissues. The transcript levels of *SlHSF* genes in root, leaf, stem, flower and fruit tissue based on Log_2(FPKM). Green, black and red colour squares in heatmap indicate low, medium and high expression, respectively.

expression during root maturation period (60 days) implying probable contributions in developmental mechanisms of tomato root architecture. Also, *SlHSFA4c* and *SlHSFB3a* displayed moderate expression in 60 days old root tissue. *SlHSFA4c* was steadily expressed throughout root elongation and development time period (15-60 days). Altogether, *SlHSFs* are significantly expressed in tomato root tissues and their role in root growth was indubitable (Fig. 2).

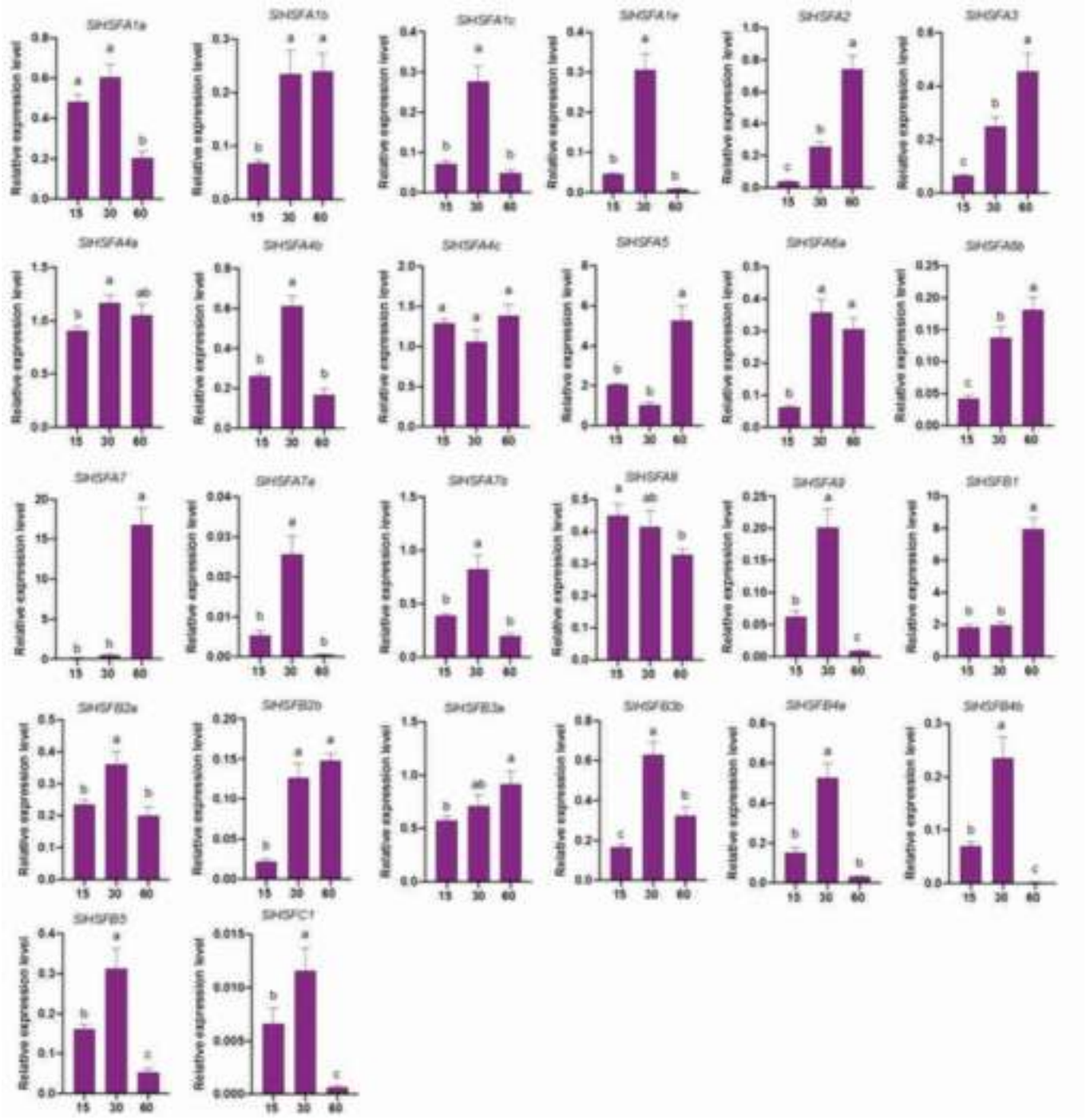

Fig. 2: Gene expression patterns of *SlHSFs* in age-dependent root tissues. The expression levels all *SlHSFs* were analysed in 15, 30 and 60 days old root tissues using qRT-PCR analysis. Error bars represent ± SE (n = 3). The statistically significant differences in transcript level are indicated by different letters.

The cis-acting regulatory motifs present in the promoter regions of 26 *SlHSFs* hinted at the role of phytohormones in regulating HSF family gene function in tomato. Hormonal profiling was executed to understand the roles of HSF TF family members, qRT-PCR validation confirmed the role of six phytohormones in regulating *SlHSFs* expression profiles in root tissues. The results showed that 88% (23/26) *SlHSFs* showed significant change in gene expression levels on exposure to ABA, 17 genes

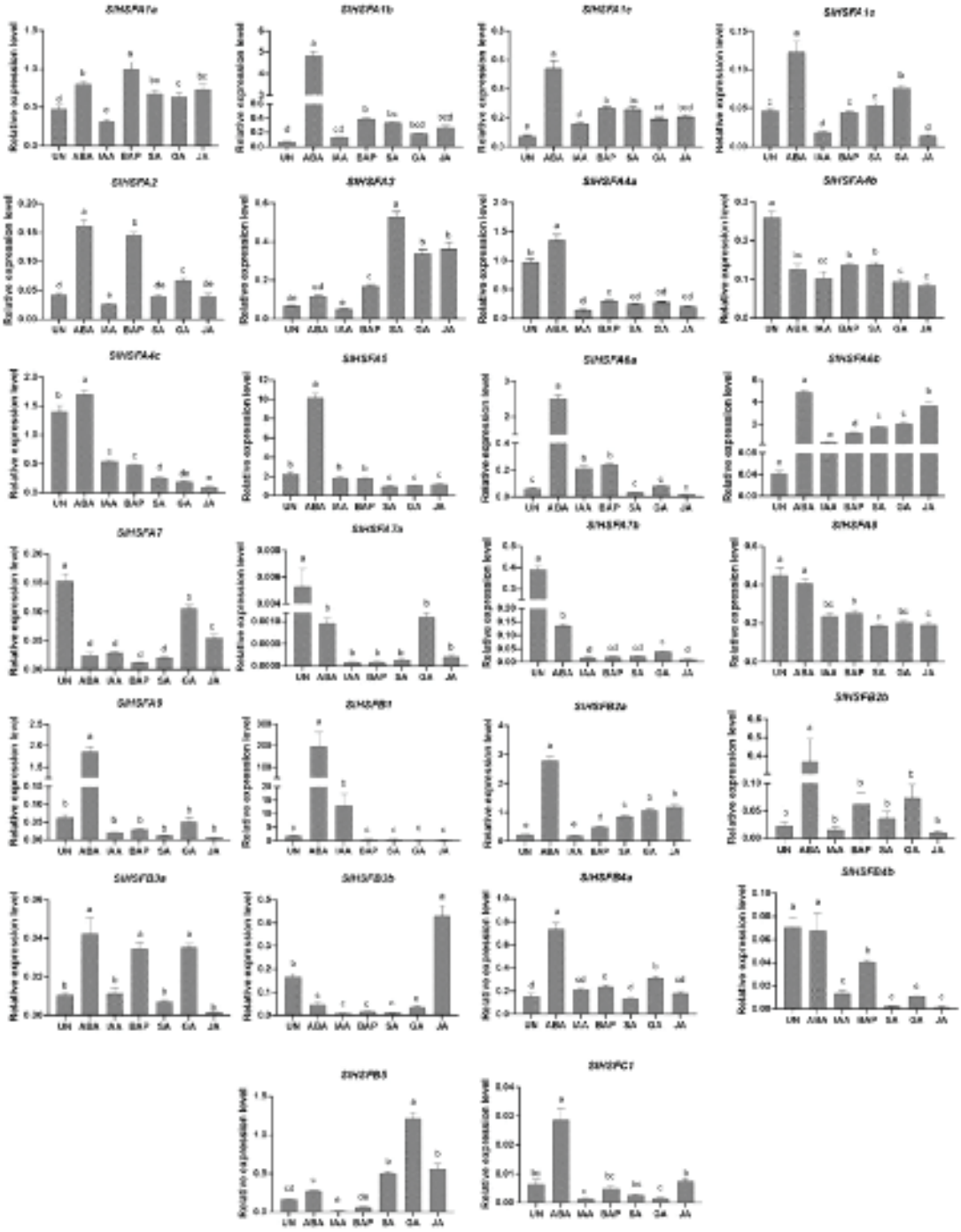

Fig. 3: The transcript profile of *SlHSFs* in root tissue upon different plant hormones treatment. 2-week-old seedlings were subjected to ABA (50 µM), IAA (1 µM), BAP (1 µM), SA (10 µM), GA (100 µM) and JA (10 µM) for 4h. The horizontal and vertical axes marks for different hormones and the relative expression levels, respectively and error bars represent ± SE (n = 3). The statistically significant differences in transcript level are indicated by different letters.

amongst 23 showed induced gene expression and the rest showed supressed transcript levels. 65.4% (17/26) tomato HSFs showed significant transcript variation upon 1µM IAA treatment, 14 *SlHSFs* out of 17 showed downregulated gene expression in presence of IAA (Fig. 3). On SA treatment, 69% genes showed significant variation amongst which majority showed a downregulation in transcript levels (Fig. 3). Exogenous BAP, GA and MeJA treatment caused significant changes in the transcript levels of 74%, 77% and 66% of tomato HSFs respectively. *SlHSFB1* showed highest transcript abundance upon ABA exposure in comparison to rest of *SlHSFs* (Fig. 3). Subclass *SlHSFA7*, *SlHSFA7a* and *SlHSFA7b* demonstrated a steady reduction in transcript levels on exposure to all six phytohormones (Fig. 3). Decreased expression levels of *SlHSFA4a, SlHSFA4b, SlHSFA4c, SlHSFA8* and *SlHSFA9* were observed on the samples treated with BAP, GA, SA, MeJA and IAA (Fig. 3). Two subclass A1 *HSFs*, *SlHSFA1a* and *SlHSFA1e,* were highly up-regulated on auxin, ABA, GA and MeJA treatments (Fig. 3). Interestingly, *SlHSFB2b* and *SlHSFB3b* showed enhanced gene expression on exposure only to ABA and MeJA but no or insignificant expression on exposure to other phytohormones. The data supports involvement of *SlHSFs* in regulating hormonal pathways in roots.

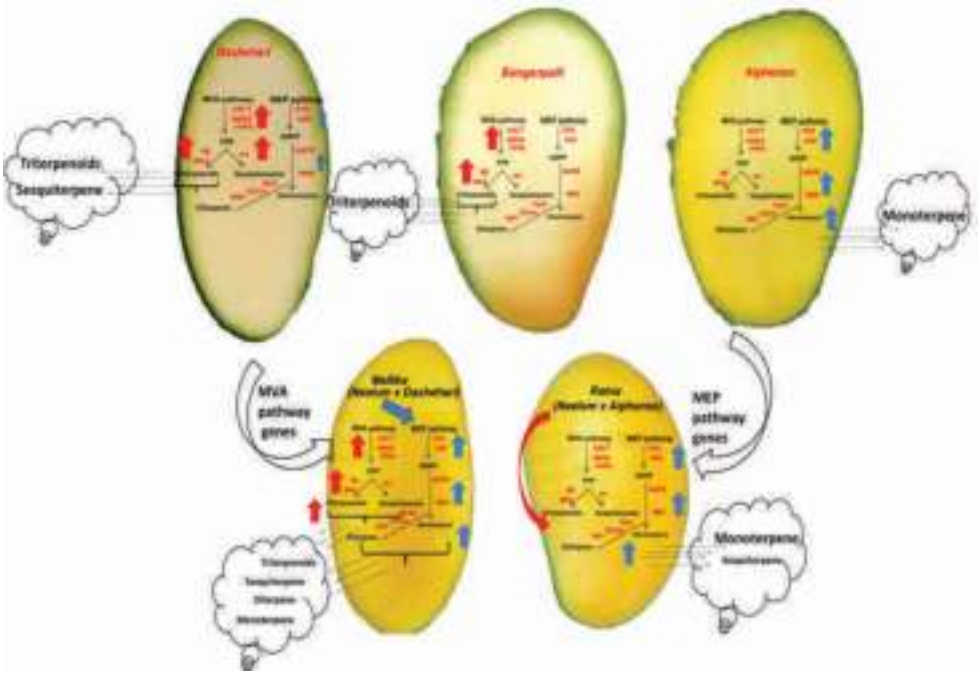

Fig. 4: A cartoon of gene expression of MVA and MEP pathway genes in different mango varieties.

Two *SlHSFs (SlHSFB3a* and *SlHSFA7)* are being studied in detail for their role in root development. Over-expression and CRISPR lines in tomato are developed and studies are under progress.

Transcriptomic insight into aroma pathway genes in different mango cultivars

Mango is flavour rich fruit and considered as king of fruit in India. About 578 volatile compounds have so far been identified in various cultivars. These are believed to accumulate differentially during the course of ripening. In order to understand the molecular mechanism of aroma in mango, *de novo* transcriptome assembly and analysis of *M. indica (Dashehari)* was performed by Illumina sequencing. Mining of transcriptome data led to identification of major genes related to most of the genes of terpenoid, carotenoid, flavonoid, lactone, lipoxygenase, aromatic amino acid, alkaloid, phenylpropanoid pathways, which are potentially involved in aroma biosynthesis. Comparative mRNA expression analysis in five Mango varieties (*Dashehari, Banganpalli, Ratna, Mallika and Alphonso)* revealed varietal and ripening related differences. To gain further insight into the terpenoid pathway, these genes were further studied in different tissues and developmental stages in *Dashehari* mango. Our results suggest a differential expression of MVA and MEP pathway genes in tested varieties, but it was challenging to make a direct correlation with aroma metabolites. This study is stepping stone to understand aroma pathways in different varieties of mango fruit.

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Improvement in cotton varieties for the broad-spectrum insect tolerance, protection of vegetables and horticultural crops from whitefly-vectored viral diseases in India

Whitefly tolerant cotton

We had developed the transgenic cotton expressing insecticidal protein Tma12. In continuation of our study, a total of 4 whitefly tolerant cotton (Tma12 cotton) events viz; Events 14, 384, 402, and 403 have been identified as promising lines. These events have been provided to ICAR-Central Institute of Cotton Research for the performance evaluation under contained conditions.

Two partner institutions namely Punjab Agricultural University, Regional Research Station Faridkot, ICAR-CICR, Nagpur and Sirsa Station are evaluating the whitefly tolerance in the Tma12 events at the cotton hot-spots. The whitefly tolerant cotton requires a single spray of pesticide as compared to 8-10 sprays on other susceptible cotton varieties grown in cotton hot spots in the country. Cultivation of whitefly tolerant cotton may save Rs. 3500-4500 per acre (the cost of pesticide application) of a cotton grower along with an additional advantage of high-quality lint with higher market value.

Efficacy of Cry1EC protein against the pink bollworm (PBW)

The pink bollworm is a serious insect pest of cotton. Toxicity of Cry1EC protein against PBW has been investigated. A culture of PBW on an artificial diet (as per the recommendation of Insecticide Resistance Action Committee) has been established at CSIR-NBRI. The insect completes its life cycle on the artificial diet in approximately 45 days (Fig. 1). Cry1EC protein was produced in *E. coli* and mixed with the diet. The neonate larvae of the PBW fed on artificial diet mixed with recombinant Cry1EC (at 100/gram of diet) exhibited severe growth retardation followed by 100 % mortality in 5 days (Fig. 2). The LC_{50} values of rCry1EC against the PBW and the leaf armyworm was determined to be 74 ng/g and 26 ng/g of diet, respectively. The result advocates possible use of Cry1EC protein for PBW along with LAW.

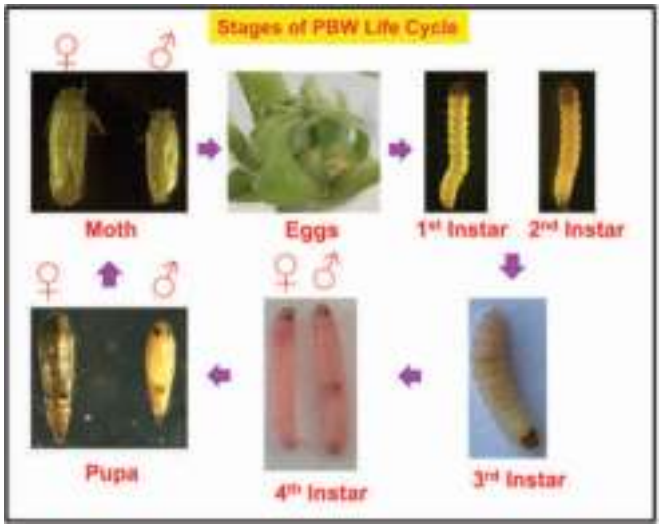

Fig. 1: Photographs showing different life stages of pink bollworm cultured on artificial diet.

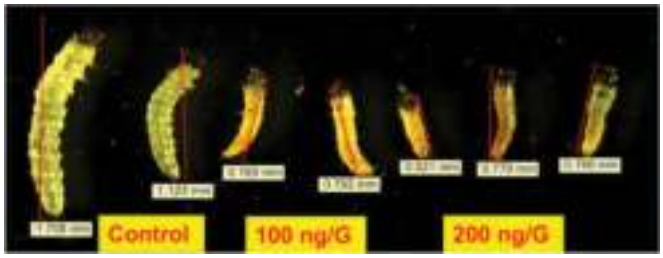

Fig. 2: Toxicity of recombinant Cry1EC protein on larvae of PBW. Larvae exhibited server growth stunting followed by 100% mortality in 5 days.

Development of GM cotton lines expressing Cry1EC

The gene encoding Cry1EC protein was cloned at downstream of a wound inducible promoter viz; RbPCD1 (origin *Rosa bourboniana*, 542 bp) for regulated expression (Fig. 3) upon wounding by the chewing insect pests. The promoter gets activated within 5 min of wounding and increases the transcript levels up to 150-fold. A total of 48 GM plants have been developed upon transformation of Coker 312 variety of cotton. Out of these 48 lines, T1 seeds could be obtained from 20 lines. Seed setting in other lines are under progress (Fig. 4).

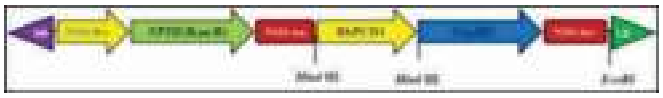

Fig. 3: Expression cassette pPK723 for the wound inducible expression of Cry1EC protein.

Fig. 4: A photograph showing representative GM cotton (Cry1EC) plants.

Guard Cotton Technology

We have developed a GM cotton event expressing Msc14 insecticidal protein that lures whitefly and kills them. The GM cotton event termed as *whitefly trap-cum-death-sink* cotton or the Guard cotton. Seeds of the guard cotton have been provided to ICAR-Central Institute of Sub-tropical Horticulture, Lucknow for the performance evaluation against the whitefly vectored viral disease in papaya.

Two partner institutions namely ICAR-Indian Institute of Vegetable Research, Varanasi and ICAR-CISH, Lucknow are evaluating the *whitefly trap-cum-death-sink* potential in the guard cotton to protect the tomato and papaya crop, respectively. The technology will enable farmers growing crops without application for pesticides leading to organic cultivation. This will not only increase the crop productivity but also reduce the pesticide load in field and increase the market value of produce.

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Heavy metal tolerance in Arabidopsis; Salinity and drought tolerance in chickpea

Metal tolerance in Arabidopsis

The role of the chickpea *metallothionein* 1 (*MT1*) gene was investigated against the major toxic heavy metals, As [As(III) and As(V)], Cr(VI), and Cd toxicity. MT1 over-expressing transgenic lines had reduced As(V) and Cr(VI) accumulation, whereas Cd accumulation was enhanced in the L3 line (Fig. 1). The physiological responses of photosynthesis, transpiration, stomatal conductance and water use efficiency were noted to be enhanced in transgenic plants. Similarly, the antioxidant molecules and enzymatic activities (GSH/GSSG, Asc/DHA, APX, GPX, and GRX) were higher in the transgenic plants. The activity of antioxidant enzymes, i.e., SOD, APX, GPX, and POD, were highest in the Cd-treated lines, whereas higher CAT activity was observed in As(V)-L1 and GRX in Cr-L3 line. The stress markers TBARS, H_2O_2, and electrolyte leakage were lower in transgenic lines in comparison to WT, while relative water content was enhanced in the transgenic lines. Similarly, the level of stress-responsive amino acid cysteine was higher in transgenic plants as compared to WT plants. Among all the heavy metals, *MT1* over-expressing lines showed a highly increased accumulation of Cd, whereas a non-significant effect was observed with As(III) treatment. Overall, the results demonstrate that *Arabidopsis thaliana* transformed with the *MT1* gene mitigates heavy metal stress by regulating the defense mechanisms in plants.

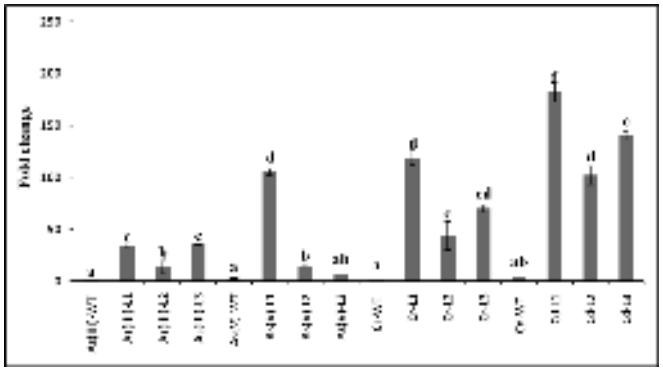

Fig. 1: ***The total transcript level of the MT1 gene.*** Relative expression of *MT1* gene in transgenic *Arabidopsis* under metal stress. The treatment abbreviation is treatment-genotype/line: Arsenite to WT (As(III)-WT); arsenate to WT (As(V)-WT), chromium to WT (Cr-WT); cadmium to WT (Cd-WT); arsenite to L1, L2,L3 (As(III)-L1, As(III)-L2, As(III)-L3); arsenate to L1, L2,L3 (As(V)-L1, As(V)-L2, As(V)-L3);chromium to L1, L2,L3 (Cr-L1, Cr-L2, Cr-L3);cadmium to L1, L2,L3 (Cd-L1, Cd-L2, Cd-L3). The significance of the mean values has been compared for each parameter separately (Duncan's test, $p<0.05$) where bars marked with the same letters are not significantly different.

Salinity and drought tolerance in chickpea

The role of the *CAMTA* gene was assessed by its over-expression in chickpea (*Cicer arietinum* L.) in response to drought and salinity stress. The over-expressing lines of chickpea harbouring the *CAMTA* gene have shown enhanced activities of various antioxidant enzymes (ascorbate peroxidase (APX), catalase (CAT), glutathione S-transferase (GST), superoxide dismutase (SOD), monodehydroascorbate reductase (MDHAR)) (Fig. 2). The reduced stress markers TBARS and H_2O_2 enhanced the survival of plants against both stresses. The physiological parameters (net photosynthesis; *P*N, transpiration; *E*, stomatal conductance; *g*s, photochemical quenching; *q*P, non-photochemical quenching; *q*N, and electron transport rate; ETR) were improved in the transgenics under both the stresses that protected the plants from damage. This investigation verified that the *CAMTA* gene provides tolerance against drought and salinity

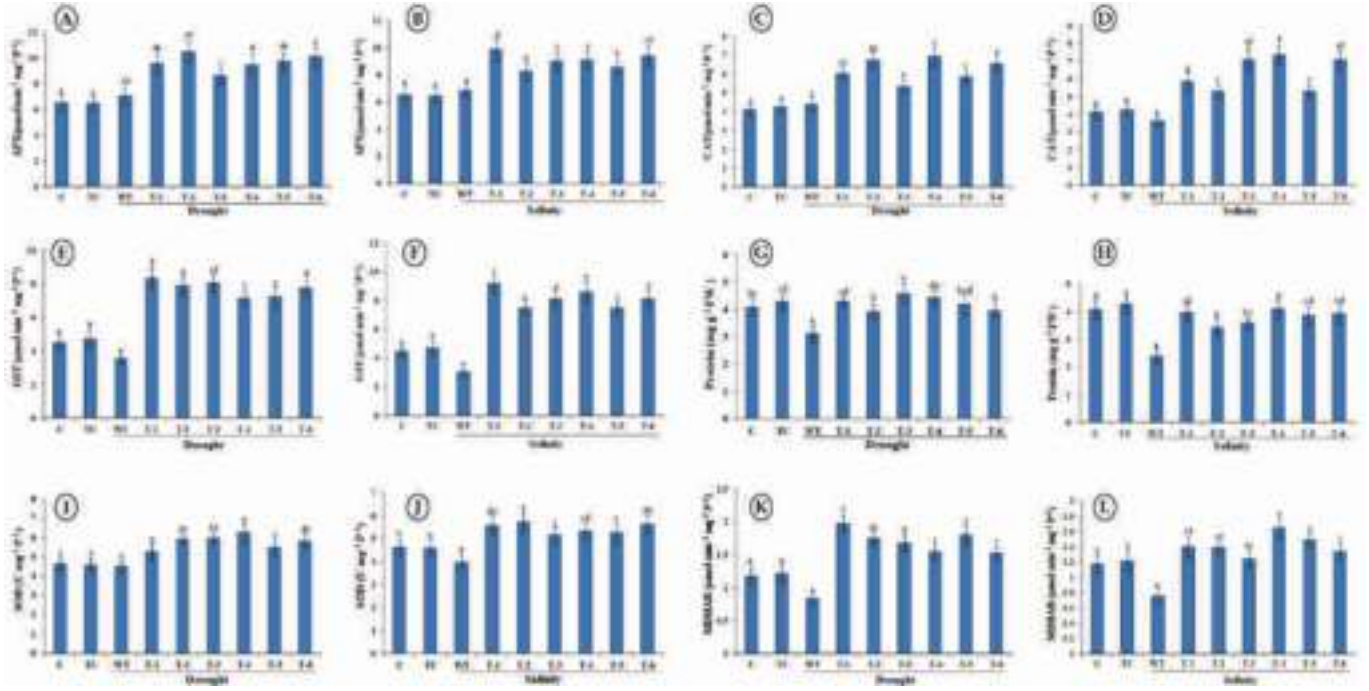

Fig. 2: Over-expressing lines of *CAMTA* gene showed enhanced activities of antioxidant enzymes under drought and salinity. **(A** & **B)** Ascorbate peroxidase (APX), **(C** & **D)** Catalase (CAT), **(E** & **F)** glutathione S-transferase (GST), **(G** & **H)** Protein content, **(I** & **J)** Superoxide dismutase (SOD), **(K** & **L)** Monodehydoascorbate reductase (MDHAR). 'C' represents Control, 'TC' represents Transgenic Control, and 'WT' represents treated Wild-Type plants. The control (C) and transgenic control (TC) plants were taken under well-watered controlled conditions. Duncan's Multiple Range Test (DMRT) was used for the analysis of the significant difference between the mean ($p < 0.05$) has been compared. All the values are the means of three replicates ± SD.

by maintaining the biochemical, physiological, and morphological performances and could be exploited for genetic engineering strategies to overcome the stresses in other economically important crops.

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Arsenic contamination, consequences and remediation techniques; *in vitro* culture of different ornamental and medicinal plants; Gene editing

Arsenic (As) risk assessment in vegetable crops in arsenic affected areas and mitigation through microbial consortia containing AsMT activity

According to the recent report eighteen Indian states and three union territories have been found to be As contaminated to different extents through natural or anthropogenic origin. The gravity of problem is high in West Bengal (WB) followed by Bihar and Uttar Pradesh (UP). Therefore, we have selected WB, Bihar and UP for the collection of vegetables from highly arsenic affected districts. Up to now, total ten districts have been covered, among them four from WB and three from both UP and Bihar. Total forty six villages of ten districts from three states have been surveyed to assess the level of arsenic in irrigation water and its accumulation in soil and subsequently in vegetables. The collected vegetables have been segregated as tubers/roots, leafy and fruity. After acid digestion the level of total arsenic was determined in water, soil and vegetables. After analysis of the data it has been found that the level of arsenic in irrigation water was 60-118µg l^{-1} in arsenic affected villages of district Lakhimpur Kheri, 33-103µg l^{-1} in Prayagraj and 54-284µg l^{-1} in Ballia. The Chain Chhapra village, block Belhari of Ballia district has high level of arsenic in irrigation water. The range of arsenic in irrigation water was 75-197µg l^{-1} in arsenic affected villages of Buxar district of Bihar state. The range of arsenic accumulation was in the range of 21-27mgkg^{-1} in Lakhimpur Kheri, 21-32mgkg^{-1} in Prayagraj, 18-33mgkg^{-1} in Ballia and 16-29mgkg^{-1} in Buxar. Arsenic levels were measured in common tubers/roots i.e. Potato (*Solanum tuberosum* L.), Raddish (*Raphanus sativus* L.), Garlic (*Allium sativum* L.), Beetroot (Beta vulgaris L.) and Onion (*Allium cepa* L.); leafy vegetables i.e. Spinach (*Spinacia oleracea* L.), Goosefoot (*Chenopodium album* L.), Coriander (*Coriandrum sativum* L.), Cabbage (*Brassica oleracea* L.) and Fenugreek (*Trigonellafoenum-graecum* L.) and fruity vegetables i.e. Tomato (*Solanum lycopersicum* L.), Kidney beans (*Phaseolus vulgaris* L.), Fava beans (*Vicia faba* L.), Common beans (*Phaseolus vulgaris* L.) and Pea (*Pisum sativum* L.). Arsenic data analysis of these vegetables showed that the accumulation of arsenic has been high in leafy vegetables followed by tubers/roots and fruity vegetables. The level of arsenic was highest in spinach 367-1970 µgkg^{-1} in affected villages, being maximum up to 1970 µgkg^{-1} in Chain Chhapra, block Belhari of Ballia district, UP, which is about two fold higher than the permissible limit i.e. 1000 µgkg^{-1} set by WHO and FAO. Among the tubers/roots, arsenic accumulation was high in potato and least in garlic except in the villages of Lakhimpur Kheri where the range of arsenic accumulation in garlic was 641-1393 µgkg^{-1}. The accumulation of arsenic in kidney beans was below the permissible limit set by WHO and FAO. Further analysis of other different villages is in progress.

FLORICULTURE MISSION

Production and distribution of quality plant material among prospective farmers

Plant Tissue Culture Laboratory, NBRI Lucknow is working on *in vitro* establishment and commercial propagation of following flowering and ornamental plants with domestication of wild ornamental plants (Fig. 1).

Fig. 1: (A-C), *In vitro* shoot cultures for mass propagation of ornamental plants, (D-E), Acclimatized plants, (F-K), Distribution of plants saplings to the beneficiaries.

Flower Plants: Carnation (Kiliyosh, Liberty, Purple, Master, and Pink); Gerbera (Silvester, Sunway, Balance, Dune, Ankur, Dana Allen, and Pink); Gladiolus; (Tiger, Amethyst, Prosperity, Blue Isle, Yellow stone, Kalima, and Melody) Chrysanthemum (Himani, Kundan)

Ornamental Plants: *Iris laevigata*; *Hoya Carnosa*; *Begonia dipetala* var. hydrophila

A tau class GST, OsGSTU5, interacts with VirE2 and modulates the *Agrobacterium*-mediated transformation in rice

Agrobacterium, in nature, cannot infect the monocot plants but *Agrobacterium*-mediated transformation (AMT) has been well established in large group of plants. During AMT, the journey of T-complex through cytoplasm of the plant cell is a key regulatory event that is governed by both virulence and host proteins. Although, the role of virulence protein has been well known, there is limited information on the host protein participation, especially in monocots. In our study, we identified eight clones including *Os09g20220* from a cDNA library of rice that interact with VirE2 protein of *Agrobacterium* (Fig. 2 A&B). One of the identified clone, i.e., *Os09g20220* encodes for glutathione-S-transferase (GST) protein. Detailed analysis of *Os09g20220* showed the two conserved domains with GSH and substrate binding sites (Fig.2 C&D). In general, tau class GST possess two exons and one intron in the ORF. Interestingly, through gene structure display server (GSDS 2.0), it was identified that OsGSTU5 possess only one exon. (Fig. 2 E). The transcript abundance of OsGSTU5 during *Agrobacterium*-rice interaction was demonstrated via the relative expression profile of *OsGSTU5*. In comparison to the negative control, *OsGSTU5* was up-regulated in *Agrobacterium* treated rice calli (Fig. 2 F&G). VirE2 and GSTU5 interaction was further tested by one-to-one Y2H mating taking GSTU5 as bait and VirE2 as prey that confirms its interaction by growing on appropriate selection media (Fig. 2H). The confocal microscopy analysis of GSTU5-YFP fusion proteins gave a signal in the cytoplasm (Fig. 2I, panel 2), suggesting its probable role in the cytoplasm of the plant cell. GSTU5-VirE2 interaction further validated via His-pull down assay (Fig. 2K). GSTU5 over-expressing and knockdown lines were generated and confirmed via GSTU5 relative expression, GSTU5 protein formation and stem loop PCR (Fig. 2 L-N). These lines showed similar seed physiology (Fig.2 O&P), however under *Agrobacterium* infection KD lines were prone for infection in contrast to OE lines (Fig. 2 Q-S). Also, KD lines had higher GUS expressing calli as well as GUS activity in comparison to EV. In contrast, the OE lines had reduced GUS expressing calli as well as GUS activity compared to EV (Fig. 2T). The percent Agroinfiltration rate was also calculated by number of GUS expressing leaves out of total Agroinfiltered leaves. The KD lines with higher Agroinfiltration rate suggested having higher transient transformation efficiency compared to OE lines (Fig. 2U). VirE2 was found to get glutathionylated via GSTU5 (Fig. 2 V). Based on RMSD analysis, it was confirmed that "gVirE2+ssDNA" complex showed higher deviation and fluctuation as compared to "VirE2+ssDNA" complex, confirming that "gVirE2+ssDNA" complex had perturbed protein conformation in comparison to "VirE2+ssDNA" complex (Fig. 2W). By comparing the intensities of the shift, we found that gVirE2 subsequently decreases its SSB activity while increasing the GSH concentration (Fig. 2X). Based on our study we proposed that the tau class glutathione-S-transferase (OsGSTU5) interacts with VirE2 protein

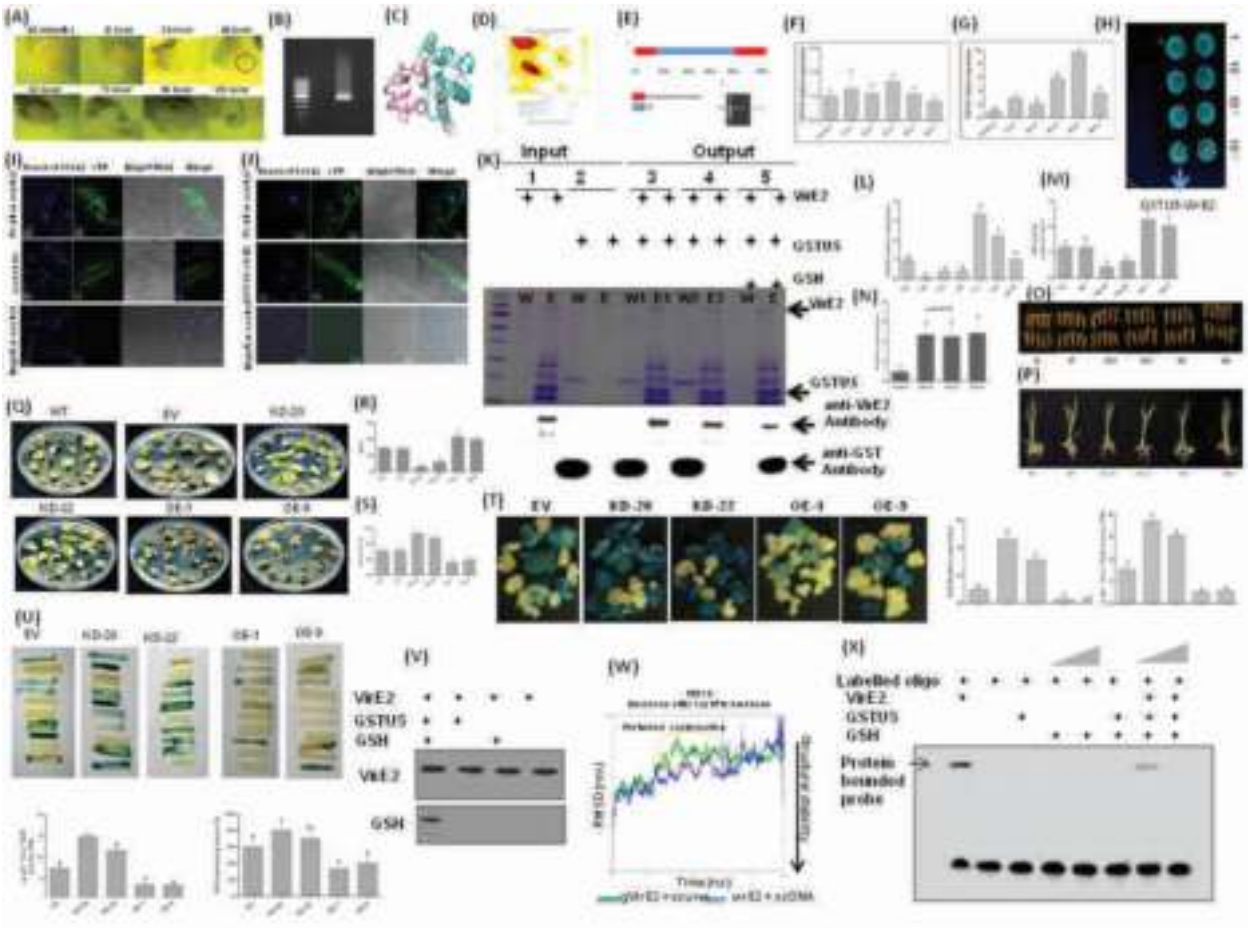

Fig. 2: Screening and confirmation of VirE2 interacting protein in rice and i*n planta* role of GSTU5 during *Agrobacterium* mediated gene transfer- (**A).** Analysis of GUS (T-DNA) expression in rice calli at different time intervals after infected with *Agrobacterium*, (**B).** purified cDNA library on agarose gel, (**C-D).** GSTU5 protein structure showing two domains, (**E).** *OsGSTU5* gene structure display showing no intron, (**F-G).** *GSTU5* transcript abundance in *Agrobacterium* non-infected and infected calli, (**H).** One-to-One Y2H of GSTU5 and VirE2, (**I).** GSTU5 localization, (**J).** VirE2-GSTU5 localization, (**K).** SDS-PAGE and western blot after His-pull down assay, Confirmation of Overexpressing (OE) and Knockdown (KD) lines in rice via (**L).** qRT-PCR, (**M).** GST activity, (**N).** Stem loop PCR, (**O-P).** Comparison of seed germination and seedling morphology in WT, EV, OE and KD lines, (**Q-S).** Testing of *Agrobacterium* infectivity in WT, EV, OE and KD lines, (**T).** GUS (T-DNA) expression analysis in rice calli after *Agrobacterium* infection in all lines, (**U).** GUS (T-DNA) expression in leaves after Agroinfiteration in all lines, (**V).** S-glutathionylation assay- western blot showing glutathionylated VirE2, (**W).** RMSD plot showing glutathionylated VirE2+ssDNA perturbed conformation, (**X).** EMSA- Blot showing attenuated ssDNA binding activity Of VirE2 protein.

and modulates the efficiency of *Agrobacterium*-mediated gene transfer in rice.

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Computational Biology; Genomics; Transcriptomics; Molecular modelling and simulation analyses

Pan-genomic evidences of evolution of ethylene machinery in climacteric fruit ripening

Fruit ripening is an important developmental process in angiosperms, which involves several tightly synchronized molecular and biochemical processes. The gaseous plant hormone 'ethylene' plays a major role in initiation of fruit ripening, especially in ethylene dependent fruits (climacteric fruits). How the ethylene sensing and response machinery evolved in fruits is itself an interesting question. To understand the functional evolution of ethylene machinery in climacteric fruits, the banana genome was selected as climacteric fruit representative. The recently available banana genomes and the Musa-Ensete pan-genome were analysed for the pan-genomic presence-absence chromosome-wide syntenic conservedness of ERS and ETR genes. The analysis revealed that even after more than 60% collinear region, the functional transcripts of ERS were absent in *Ensete glaucum* and *Musa balbisiana* genomes (Fig 1). The analysis also revealed that the mapped region of ERS and ETR genes were having significant changes in nucleotide patterns as well as in translated amino acids. The pan-genome was further analysed for conserved SNP pattern in genomic regions of selected genes and related phylogeny. The selected regions for SNP analysis were also analysed for conserve codon selection patterns in comparison with algal, bryophytic, pteridophytic and gymnospermic representatives to understand the substitutions and amino acid preference. The study indicates genomic adaptations in ethylene machinery genes for selective function.

Regulation of Arsenic and low-sulphur combined stress by miRNA in *Arabidopsis thaliana*

Heavy metal stress and nutrient limitation are major concerns across the globe that drastically impair plant growth and development. Among the several heavy metals known so far, Arsenic (As) is a naturally occurring toxic metalloid found in water, soil and rocks in the environment. Both natural and anthropogenic activities like mining, industrialization and pesticide increase As contamination in the food. The effects of As include skin cancer in humans whereas, in plants such as Rice, it accumulates in the grains eventually making the crop unsuitable for consumption. Arsenite [As(III)] and arsenate [As(V)] are two predominant inorganic forms of arsenic which are readily inter-convertible. As detoxification is known to be alleviated by Sulphur (S) mediated detoxification in plant cells. Sulphur being an important macronutrient not only leads to the synthesis of the two amino acids cysteine and methionine but also produces glutathione (GSH) and Phytochelatins (PCs) essential in combating As stress. Previous reports have illustrated the important role of GSH in regulating reactive oxygen species (ROS) accumulation induced by different stresses.

Small RNA sequence analysis concluded that 55 miRNAs are differentially regulated in As and LS conditions, out of which only 18 miRNAs were common in these stresses. Of common differentially expressed miRNAs, miR408 was the most responsive miRNA towards As and LS conditions. The expression of miR408 is differentially regulated in various plant systems in response to different abiotic stresses, like

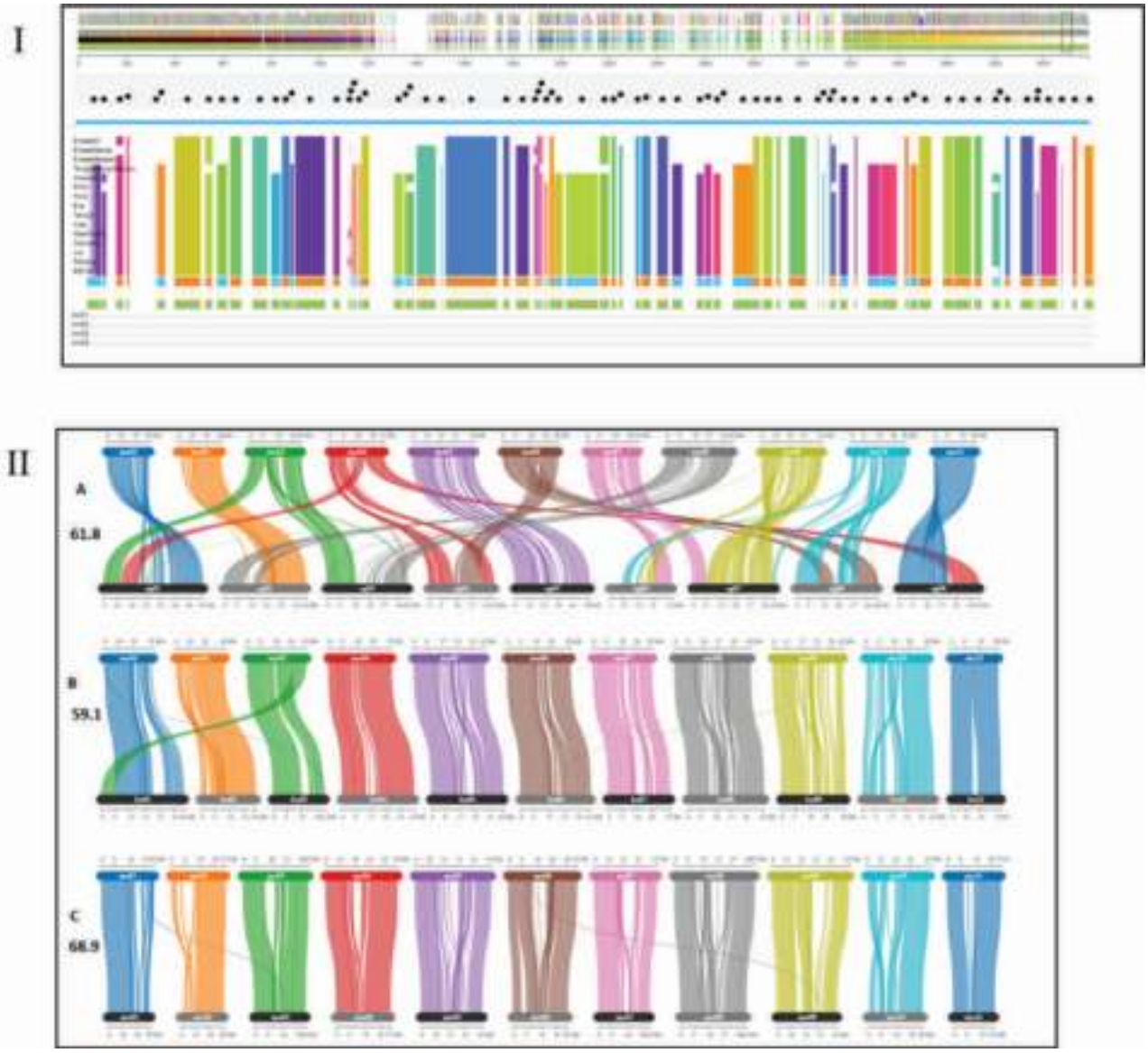

Fig. 1: (Panel I). Ripening specific ERS2 gene in *Musa* genomes and *Musa-Ensete* pangenome. Figure represents the presence of functional transcripts of ERS2 with significant nucleotide changes. The colour bars representing the conserved sequence while the black and white space show the absence of functionally conserved transcript. (Panel II). Genome –wide synteny between Ma-Eg, Ma-Mb and Ma-Ms genomes representing the percentage of collinearity and sharing of ancestral gene blocks between them. *Musa acuminata* (Ma), *Ensete galucum* (Eg), *Musa balbisiana* (Mb) and *Musa schizocarpa* (Ms).

drought, As and nutrient deficiencies. We analysed the involvement of miR408 towards LS, As(III), [LS+As(III)] stress and observed significant down-regulation in the expression of miR408 and vice-versa of its targets, ARPN and LAC3. Plants over-expressing miR408 showed severe sensitivity under low sulphur (LS), Arsenite As(III) and LS+As(III) stress while miR408 mutant developed through the CRISPR/Cas9 approach showed tolerance. Transgenic lines showed phenotypic alteration and modulation in the expression of genes involved in the sulphur reduction pathway and affect sulphate and glutathione accumulation. Similar to miR408 overexpressing lines, the exogenous application of synthetic miPEP408 and miPEP408OX lines led to sensitivity in plants under LS, As(III) and combined LS+As(III) stress compared to control. This study suggests the involvement of miR408 and miPEP408 in heavy metal and nutrient deficiency responses.

Pathway elucidation and identification of genes involved in guggulsterone biosynthesis in Commiphora species

Many of the plant secondary metabolites are economically and medicinally important. They are produced in very low quantities in the plants and large amount of raw material is required for their production. The identification of the pathways for the production of these phytomolecules is important and will pave a way for their production via the synthetic biology approach. *Commiphora wightii* commonly known as guggul is a medicinally and commercially important plant. The gum resin from this plant is commercially important and is used for the treatment of various ailments. It is a complex mixture of lignans, lipids, diterpenoids and steroids. Guggulsterones have been reported as a naturally occurring hypolipaemic agent. The medicinal importance of *C. wightii* resin is because of the two ketosteroids 4,17(20)-(trans)-pregnadiene-3,16-dione (guggulsterone-Z) and 4,17(20)-(cis)-pregnadiene-3,16-dione (guggulsterone-E) present in gum-resin of this plant. Recently, these ketosteroids have been reported to have potential anti-carcinogenic and antitumor properties. The accumulation of guggulsterones varies in the various chemotypes and understanding the pathway for the biosynthesis of the various sterols is important for its commercial production.

The transcriptome of leaves of *Commiphora wightii* and *Commiphora agolacha* were sequenced and analysed. Many genes differentially expressing in *C. wightii* and *C. agolacha* were identified. The genes of the steroid biosynthesis pathway, MEV and MEP pathway were identified. The findings are preliminary and the qRT-PCR validation is under progress.

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Plant-pest interaction and strategies to improve crop yield

Over-expression of *Pectin Methylesterase* gene in cotton for insect resistance

Pectin Methylesterases (PMEs) demethylesterifies the cell-wall pectin, leading to methanol release. PMEs are regulated in a highly specific manner, and are involved in vegetative and reproductive processes, in addition to involvement in biotic stress. Methanol is naturally emitted as a volatile organic compound, and is toxic to insect pests, but the quantity emitted is inadequate to protect against invading pests.

In our previous study, we demonstrated that the over-expression of Pectin Methylesterase, derived from *Arabidopsis thaliana* and *Aspergillus niger*, in transgenic tobacco plants enhances methanol production and resistance to polyphagous insect pests. Over expressing the PME gene results in higher methanol emission. *AnPME* gene was further over-expressed in cotton via *Agrobacterium*-mediated genetic transformation under the control of constitutive and wound-inducible promoter. Transgenic plants comprising constitutive and inducible *AnPME* expression system have shown 90-95% mortality against both the chewing (*Spodoptera litura & Helicoverpa armigera*) pests and 70-80% mortality in sap sucking (Aphid and Whitefly) pests, respectively. Further, it was observed that the surviving chewing pests had delayed life cycles completion and there were abnormalities in the pupa and flies. Thus over-expression of *AnPME* provides broad-spectrum resistance against chewing and sap-sucking insect pests through enhanced methanol emission (Fig. 1).

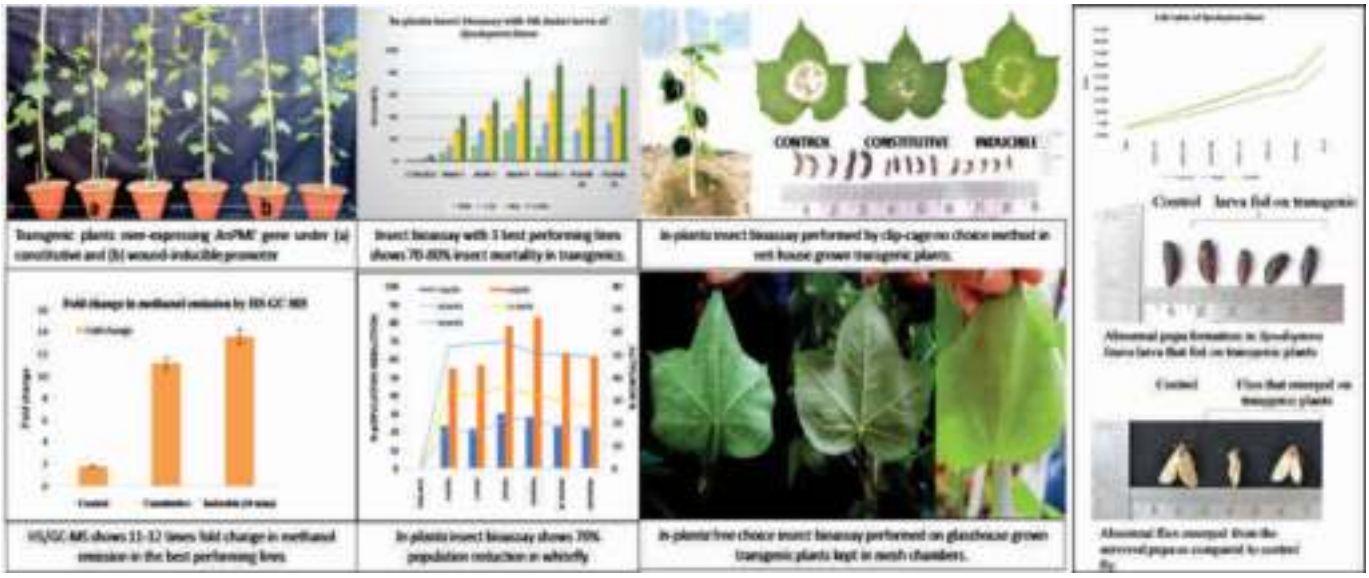

Fig. 1: Studies on Overexpression of *Pectin Methylesterase* gene in cotton.

CRISPR/Cas9 mediated genome editing in tomato for manipulating fruit shelf-life

Tomato makes a substantial contribution to nutrition in the human diet. It is also an excellent model plant for research in fruit biology. The tomato fruits have a limited shelf life and are highly perishable. As a result of this, a large fraction is lost to post-harvest due to poor shelf life and rapid deterioration following ripening, leading to considerable economic losses to the farmers. There are many postharvest technologies that extend the marketable life of fruits and help reduce these losses. We studied various ripening-related genes with the revolutionary genome editing technology i.e., CRISPR/Cas9. We targeted two HSP90 chaperone-like genes up-regulated during the early ripening stages. The putative genome-edited plants were screened for mutation and a number of indels were found. The indels are shown in Table 1 and 2. The plants are presently being raised for generation advancement and ripening studies.

Table 1: Indels generated in HSP90 chaperone-like 1 CRISPR lines.

HSP90 chaperone-like 1 CRISPER lines	Indels generated
Line1	4b deletion
Line2	4b deletion
Line3	2b deletion
Line4	1b deletion
Line5	5b deletion
Line6	1b deletion

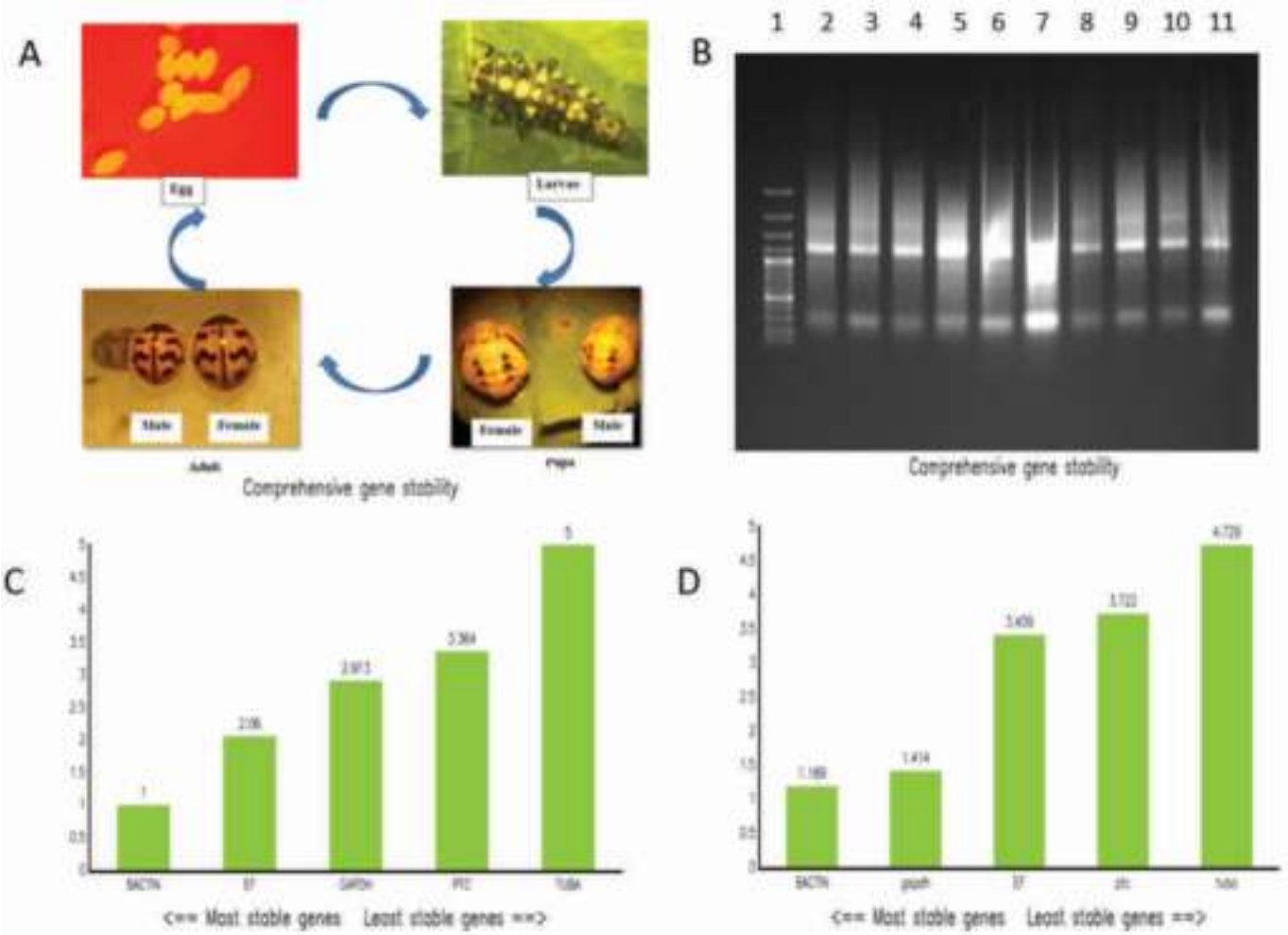

Fig. 2 (A) Life cycle of *Menochilus sexmaculatus*. **(B)** Gel images: (1) 100 bp ladder (2) 0 hr. C, (3) 0 hr. A, (4) 24 hr. C (5) 24 hr. A (6) 72 hr. C (7) 72 hr. A (8) 96 hr. C (9) 96 hr. A (10) adult C (11) adult A. **(C)** Geomean of Ranking values Control. **(D)** Geomean of ranking values Amputated. (C-Control, A-Amputated).

Table 2: Indels generated in HSP90 chaperone-like 2 CRISPR lines.

HSP90 chaperone-like 2 CRISPER lines	Indels generated
Line1	1b deletion
Line2	1b deletion
Line3	1b deletion
Line4	1b substitution and 4b deletion
Line5	11b deletion

Deciphering limb regeneration potential in ladybird beetles

Regeneration of lost body parts is one of the most fascinating and intriguing phenomena in the living world. Ladybird beetles (Coleoptera: Coccinellidae) feed on aphids, therefore act as a good bio-control agent. They also share high degree of similarity to *Tribolium* which in turn shares many conserved sequences with vertebrates and thus may be used as an alternative model. Therefore, there is a significant chance that the study of regeneration signaling pathways in coccinellids might lend to a greater understanding of process of regeneration in general and in vertebrates in particular. This study thus proposes the identification of target genes and signaling pathways during limb regeneration in coccinellid, *Menochilus sexmaculatus* and its modulation under stress conditions. Transcriptome analysis is being done to identify the genes and pathways involved in regeneration.

As no prior work has been done on the molecular aspects of the insect the reference genes needed to be selected and validated. Expression stability of the candidate reference genes i.e., β-Actin (β-ACT), Elongation factor (EF), Glyceraldehyde-3-phosphate dehydrogenase (GAPDH), Tubulin A (TUBA), Patched (PTC) were evaluated by geNorm (expression stability values M), NormFinder, RefFinder, Bestkeeper which calculated the stability values of each reference gene using the Ct values across all the experimental sets. The results indicated that, β-Actin was the most stable, while Tubulin A was the least stable reference gene in both control and regenerated stages. Once the genes are identified via transcriptome analysis, the functional validation of the genes will be done. Elucidation of putative pathways involved in limb regeneration will help to lay the groundwork for further exploration of evolutionary pathways of regeneration.

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Computational biology, genomics

Transcriptome meta-analysis associated targeting hub genes and pathways of drought and salt stress responses in cotton (*Gossypium hirsutum*): A network biology approach

Abiotic stress tolerance is an intricate feature controlled through several genes and networks in the plant system. In abiotic stress, salt, and drought are well known to limit cotton productivity. In order to understand drought and salt stress tolerance mechanisms, a meta-analysis of transcriptome studies is crucial. To confront these issues, here, we have given details of genes and networks associated with significant differential expression in response to salt and drought stress. The key regulatory hub genes of drought and salt stress conditions have notable associations with functional drought and salt stress-responsive (DSSR) genes. 5,962 and 3,510 differentially expressed genes (DEGs) were identified in drought and salt stress data. All genes from different tissue samples and stress responsive genes with expression patterns in the range of FPKM >1 and FPKM < 300 were evenly mapped onto 26 *Gossypium hirsutum* chromosomes using circus plot (Fig. 1) To make the summary of DSSR genes, which were expressed exclusively in drought or salt, DEGs were compared and found that 3,841 were unique in drought and 1,508 were unique in salt stress data (Fig. 2). To build the cotton-DSSR gene network, we have used the analyzed transcriptome data of cotton in two abiotic stress (drought and salt) conditions in different tissues. The protein-protein interaction network was constructed in a circular layout after co-expression calculation using the Expression Correlation module in the Cytoscape tool. Further, among the analyzed transcriptome data, the top 100 DEGs with FPKM values and significant p-value (< 0.05) were selected from each tissue for further co-expression network analysis using the PCC method. Based on correlation score calculation drought-

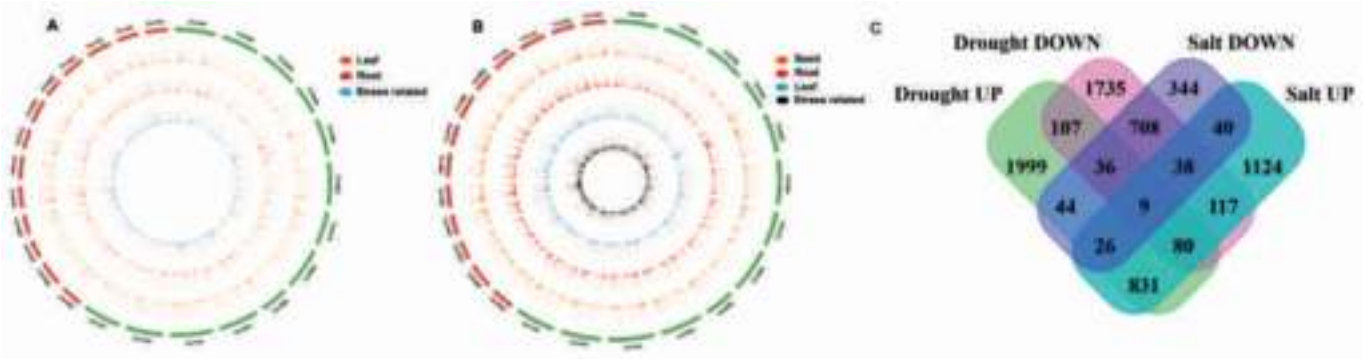

Fig. 1: Representation of expression histogram (FPKM) on 26 *G. hirsutum* chromosomes. A total of (A). 5962 in drought and (B). 3510 in salt stress genes mapped. (C). Venn diagram showing the number of shared and unique genes in differentially expressed genes (DEGs) of drought and salt stress data. In order to make drought and salt stress-responsive (DSSR) genes set compendium, we focused on 3,841 and 1,508 DSSR uniquely differentially expressed genes in drought and salt.

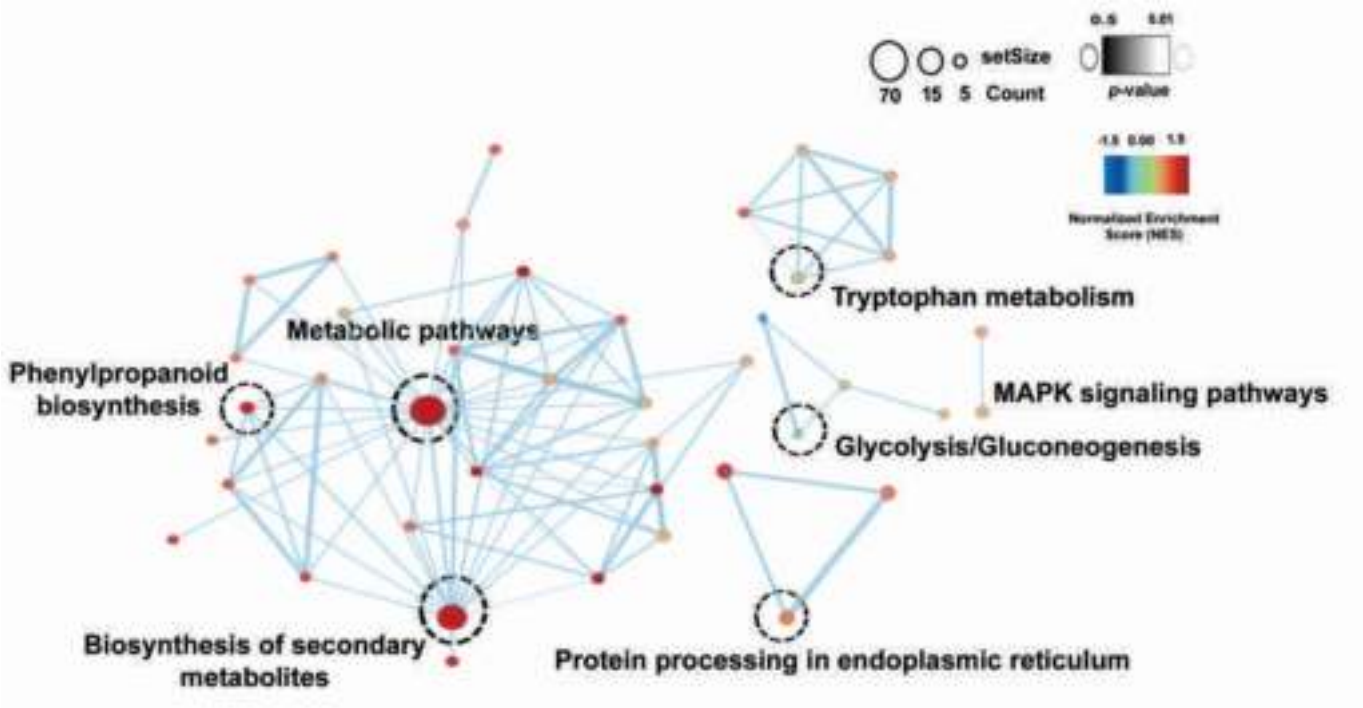

Fig. 2: Common enriched pathways in drought and salt dataset. Node colour shows the normalized enrichment score (NES) from the core enrichment genes. A positive score (red) shows gene set enrichment at the top of the ranked list, and a negative score (blue) indicates gene set enrichment at the bottom of the ranked list. The colour of the border represents the p-value of the enriched pathway.

responsive gene co-expression network (GCN) was generated which comprised 100 nodes connected by 1,704 and 2,747 co-expressed edges with minimum network density (ND) 0.34 and 0.55 in up- and down regulated genes of leaf tissue at PCC ≥ 0.95. Similarly, drought-responsive GCN of root tissue was generated which comprised 100 nodes connected by 1,505 and 2,314 co-expressed edges with minimum ND 0.30 and 0.46 in up and down regulated genes. Also, the salt responsive GCN of leaf tissue was generated which comprised 98 and 9 nodes connected by 4,565 and 45 co-expressed edges in up and down regulated genes, whereas 100 nodes connected with 3,252 and 2,604 co-expressed edges with minimum ND 0.65 and 0.52 in up and down regulated genes of salt root tissue. Similarly, salt responsive GCN of seed tissue was generated which comprised 27 and 74 nodes connected with 351 and 2,701 co-expressed edges in up and down regulated genes. Overall, this study highlights the key role of Ubiquinone and other terpenoid-quinone biosynthesis and MAPK signaling pathways with significant up-regulation of *TLP3, TLP5, TLP6, TLP, NCED1, EXLB1, PBS1, PCL1, BT2, TAR4, ITN1, ORG2, WRK54,* and *CAX3* genes in drought and phenylpropanoid biosynthesis and Isoquinoline alkaloid biosynthesis pathways with significant up-regulation of *LP1, TLP, GSTXA, NCS2, AKR1, LAC14, PDR1, ERD10, INV1, HSP70, DOX1, AOC, GPAT3, ATHB7, PER1, ELF4, EXLB1, RAV1, PER30,* and *CIPK6* in salt stress responses. By utilizing these genes the common enriched pathways were identified and represented through Cytoscape using the EnrichmentMap module (Fig. 2).

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Epigenetic regulation of plant response towards environmental change using natural populations of Indian *Arabidopsis thaliana*

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. 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, the expression of miR775 was relatively higher in stem, siliques and inflorescence as compared to other tissues, while in roots its expression was the least

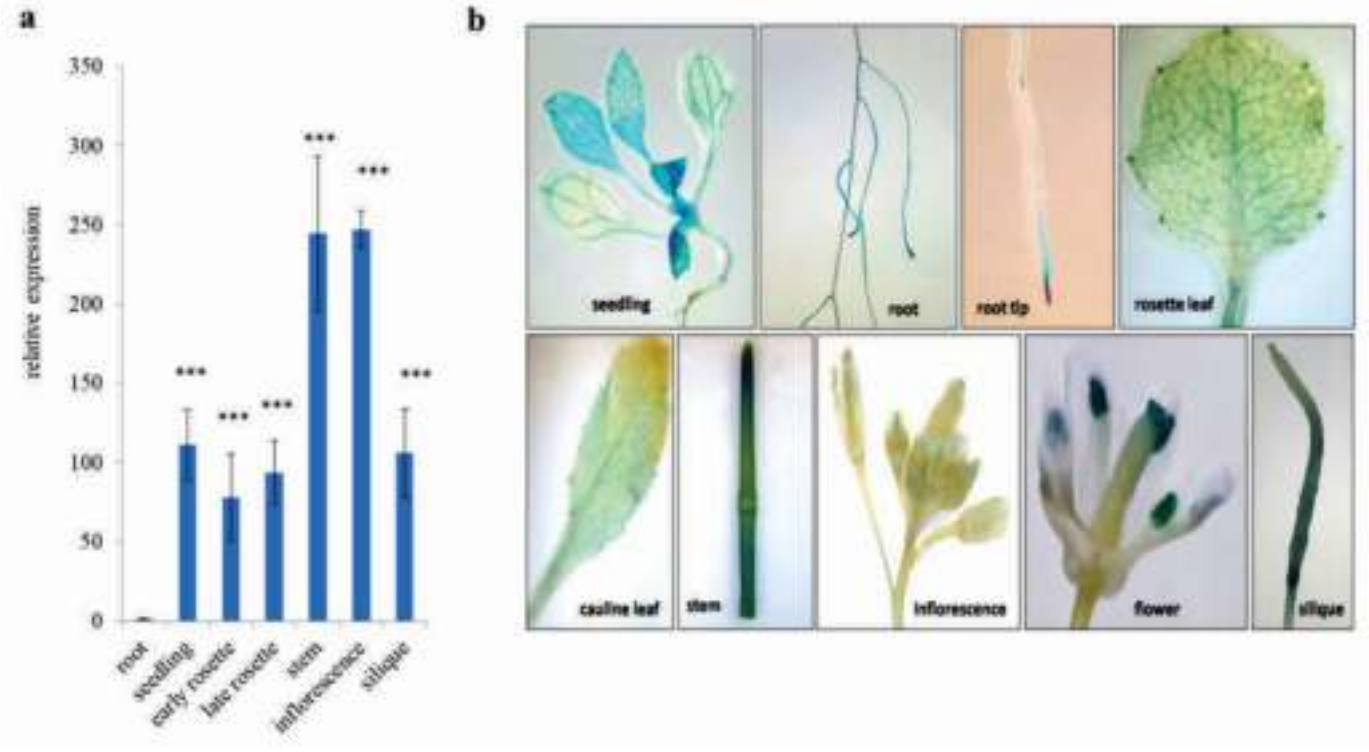

Fig. 1: Characterization of miR775 in *A. thaliana* (a). Relative expression of miR775 in different tissues of WT Col-0 as determined by qRT-PCR. Data represents mean of three replicates ±SE, *** indicate values which were significantly different at P value <0.001 (Student's t-test). (b). Histochemical GUS staining in different tissues of *MIR775*PRO-*GUS* transgenic lines.

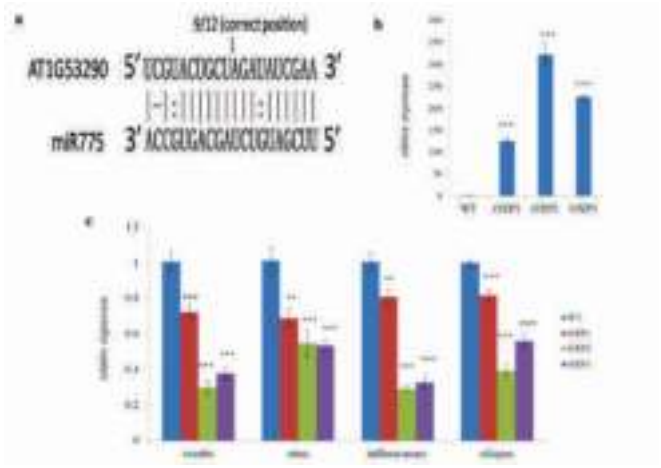

Fig. 2: Target of miR775 (a). Cleavage of AT1G53290 mRNA by miR775 as detected by modified 5'RLM-RACE is shown. The fraction of clones with cleavage at expected 5'end to the total number of clones sequenced is indicated above the target site, (b) qRT-PCR analyses of miR775 in rosette tissue of homozygous *MIR775*OXP lines and WT, (c). qRT-PCR analyses of *galactosyltransferase* target gene (AT1G53290) in rosette, stem, inflorescence and siliques of homozygous *MIR775*OXP lines and WT.Data is a mean of three replicates ±SE. **, *** indicate values which were significantly different from WT at P value <0.01,<0.001 respectively (Student's t-test).

(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*OXP) 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*OXP lines. qRT-PCR analyses suggested expression of *GALT* was down regulated in all the OXP lines as compared to the WT, in all the examined tissues (Fig. 2c). As expected, the OXP line having less expression of miR775 exhibited minimum target down regulation. Phylogenetic analysis with similar protein sequences revealed that the target GALT of miR775 was closely related to β-(1,3)-galactosyltransferases of *Camelina*

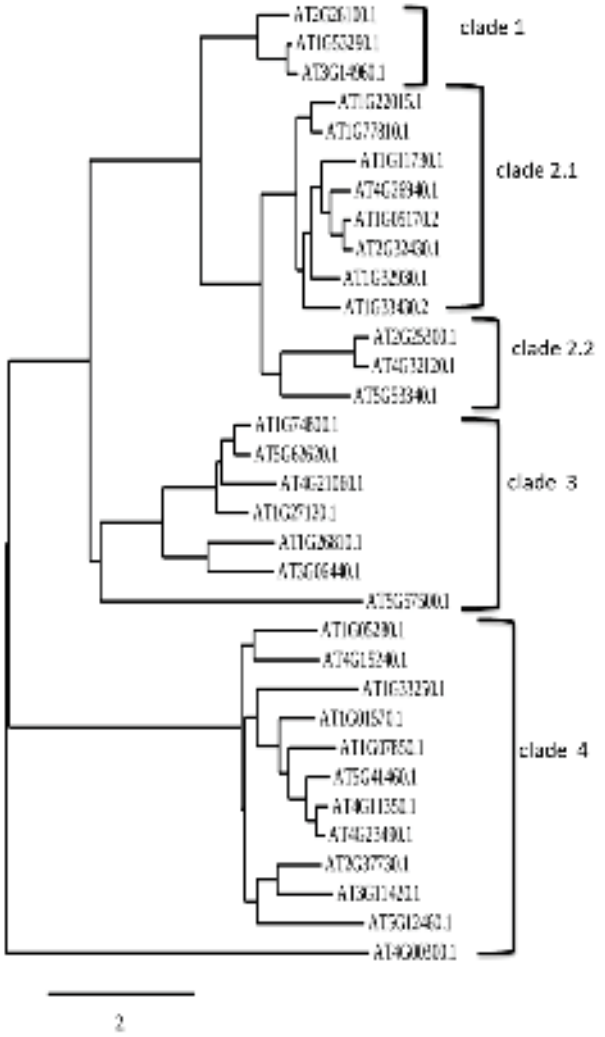

Fig. 3: Phylogenetic analysis of AT1G53290 with *A. thaliana* members of GT31 family.

sativa and *Arabidopsis lyrata* (Fig. 3).

Further, *In-silico* analysis of *MIR775* promoter revealed the presence of several regulatory motifs including light, hypoxia etc. However, when we exposed the WT plants to high light conditions (600µmol/m^2/s and 1000 µmol/m^2/s) for one hour, we could not detect any significant difference in expression level of miR775 (Fig.4a), 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 in UV-B treated plants. Interestingly, a significant increase in the expression of miR775 was observed in post UV-B treated plants (Fig. 4b). Subsequently, we tested the

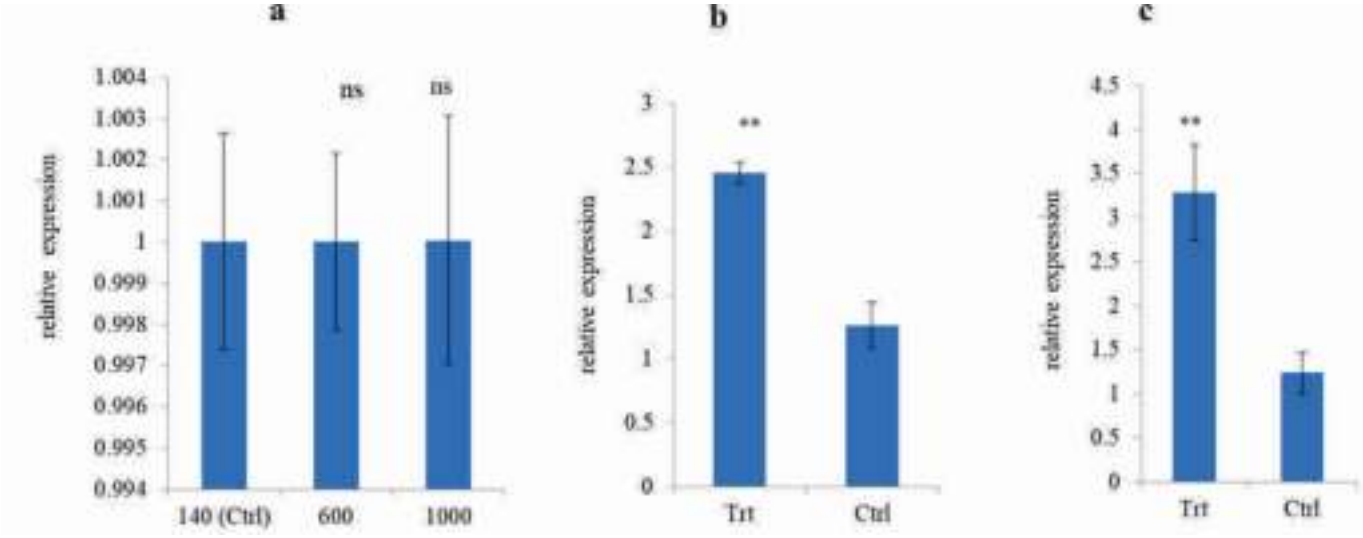

Fig 4: Expression of miR775 in response to environmental variables (a). after 1 hour of high light treatment, (b). after 1 hour of UV-B treatment, (c). after 3 hours of treatment with mitochondria inhibitors, Antimycin A and Salicylhydroxamic acid. Data is a mean of three replicates ±SE. ** indicate 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.

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.4c). 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 chickpea for drought and Fusarium wilt stresses; regeneration of Indian cotton cultivars

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.

Progeny advancement and expression analysis of chickpea transgenic for drought tolerance

Seeds (T_1) obtained from different T_0 transgenics were advanced to next filial generation and plants

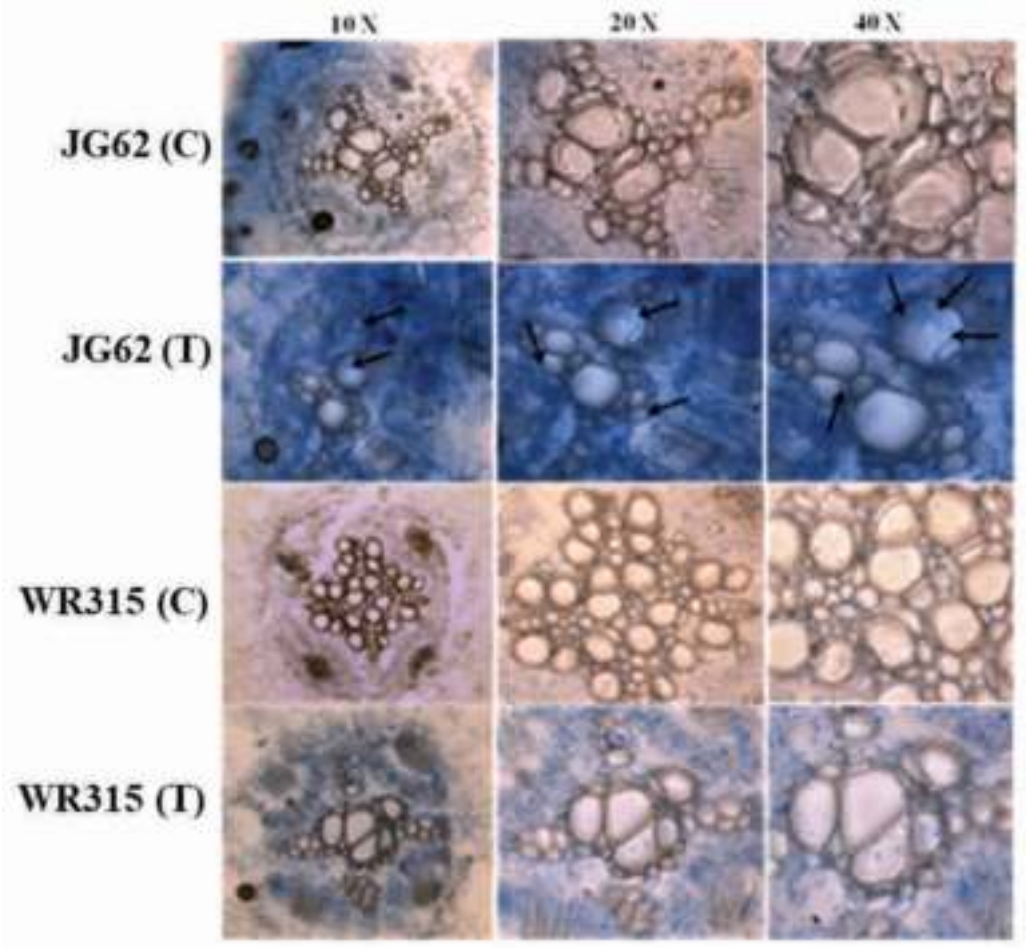

Fig. 1: Fusarium infection in chickpea roots (Lactophenol cotton blue stained T.S. of control and Foc2 infected chickpea root sections of wilt resistant WR315 and susceptible JG 62).

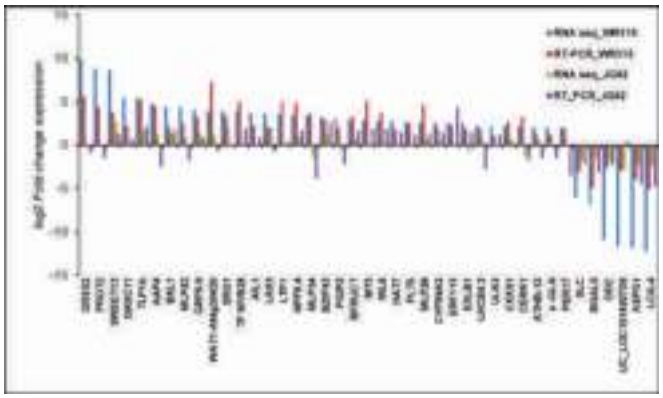

Fig. 2: Bar graphs depict the expression patterns of selected genes using qRT-PCR in wilt resistant (WR315) and susceptible (JG 62) cultivars under control and *Fusarium* stress.

were grown in Glass house with controlled condition under containment. For T_3 generation seeds derived T_2 Transgenic lines expressing CaCYP, CaMTD and CaWAT were used. Further molecular studies will be carried out in next generation for stable integration and drought analysis.

Transcriptome profiling of chickpea under Fusarium wilt

To understand host pathogen interaction in root tissue at molecular level in chickpea, we extracted xylem-specific RNA for the transcriptomics of wilt-susceptible JG-62 and wilt-resistant WR-315 cultivars under both *Fusarium oxysporum f.sp. ciceri r*ace2 (Foc2) challenged and unchallenged conditions (Fig. 1). We obtained 19,342 and 20,935 transcripts representing 16290 and 16442 genes loci in JG62 and WR315, respectively by reference-guided assembly with chickpea genome. The qRT–PCR analysis of some selected genes was done to validate the RNA seq data. qRT-PCR and RNA-seq data showed a good correlation (Fig. 2). We cloned four highly expressing genes (CaCERK1, CaLTP1, CaCXXS1, and CaPGIP2) in plant expression vector for functional validation.

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Studying the molecular mechanism of far-red light responses and high temperature on plants

Molecular mechanism of far-red light responses and high temperature on tomato

The present research in my group is to investigate the far red mediated downstream signaling networks in plants. How plants use the phytochromes and other photoreceptors to respond the vegetation proximity, and the signaling cascades that translate this information into adaptive responses. This knowledge will widen our understanding of shade avoidance response in model plant which may further be useful to grow crops at high density. Further, the long term goal of our research is to develop heat tolerant crop especially tomato variety through identification and manipulation of genes by using transgenic and gene editing technology.

To identify critical genes involved in high temperature adaptation, genome wide association study across tomato germplasms will be used. Till now, around 70 different tomato accessions have been collected.

Tomato accessions are growing in the field to know response of heat stress. Some tomato accessions display better performance under high temperature in field conditions. The molecular mechanism of heat/temperature perception is not much known in plants. Based on available previous transcriptome analyses, GWAS and QTL studies, we have identified a set of genes those may have important role in high temperature

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- Ms. Aditi Pathak, DBT-JRF

Plant Genetic Resources and Improvement

CSIR NBRI Estd. 1953

WHERE PLANT–BASED RESEARCH TOUCHES LIFE THROUGH INNOVATION

PLANT GENETIC RESOURCES AND IMPROVEMENT

Area Co-ordinator

Prof. SK Barik, Director

Scientific Staff

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- Dr. Arvind Jain, Principal Scientist
- Dr. HK Yadav, Principal Scientist
- Dr. SN Jena, Principal Scientist

Technical Staff

- Mr. Rajiv Kumar, Senior Technical Officer
- Dr. KN Maurya, Senior Technical Officer

Research Scholar Statistics

Sr. No.	Position Name	Numbers
1.	Women Scientist	01
2.	JRF/SRF	08
3.	Project Staff	16

Broad Areas of R&D

- Genomics-assisted breeding for crop improvement
- Genetic Improvement of ornamental & important narcotic crops, Mutation breeding, Molecular Genetics and Cytogenetics
- Genomic selection, pathway mapping of secondary metabolites for improvement of underutilized crops

Aims and Objectives

- Development and deployment of genetic and genomic resources for marker assisted breeding of industrial crops
- Development of new floricultural varieties with novel ornamental characteristics.
- Development of mutant varieties in Cannabis and Poppy for improved traits i.e. low-tetrahydrocannabinol (THC)/High cannabidiol (CBD) content and high Oripavine content, respectively.
- Selection, improvement and mainstreaming underutilized crops for providing nutrition and economic security

Major R&D Highlights

Genomics for varietal development

- Genome assembly of linseed was improvised with addition of HiC data. Second year phenotypic characterization of two RILs mapping population of linseed has been done for 10 important agronomic traits. These include RIL Pop. 1 for oil content derived from cross of RKY-14 (high) x KL-213 (Low) and RIL Pop. 2 for flowering/ maturity derived from cross of Padmini (Early) x KL-213 (Late).Genotyping by sequencing (GBS) was carried out for ~300 lines of two RILs for linkage/QTL mapping.Further, three bi-parental mapping populations for elite quantitative traits of linseed progressed to F_4 generation leading towards formation of Recombinant Inbred Lines (RILs). Approximately 1400 F_2 lines (~200 lines each of 7 MAGIC hybrids) of linseed were grown in field and selfed seed harvested.
- Comparative transcriptome analysis of guar genotypes RGC-936 and RGC-1066 during the early stage of *Alternaria* infection have been carried out and several differentially expressed genes have been identified.
- A subset of 300 accessions of grain amaranths have been identified as "core accessions" for SNP based association mapping.
- *Cestrum* is a genus of almost 300 species among these, two of the contrasting species are *Cestrum nocturnum* (night jasmine) and *Cestrum diurnum* (day jasmine). These plants are mostly domesticated for their fragrance and for ornamental purposes. Apart from that they possess many bioactive compounds to explore. These plants were analyzed for the presence of some bioactive compounds of medicinal importance.
- The silencing of anthocyanidin synthase gene in *P. tetragonolobus* has a regulatory effect on the condensed tannin biosynthesis in the underutilized *P. tetragonolobus*. Total proteome-analysis of the root-tuber of *P. tetragonolobus* resulted in the identification of 2678 proteins belonging to 154 families. Ninety-six percent of these proteins are associated with known biological, molecular and cellular activities.

Heat-shock proteins (HSPs) with 12-42 kDa monomeric size were the most abundant protein families constituting 13% of the total identified proteins

- The newly developed 'NBRI-Swadheen75' is a 'Decorative' type, late-blooming, gamma ray induced mutant variety. The variety was released by the Hon'ble, DG CSIR Dr. Shekhar C. Mande on Jan. 30, 2022. The new variety 'NBRI-Swadheen75' has been named to mark the 'Azadi Ka Amrut Mahotsava' during Platinum Jubilee celebration year of independence of India.
- New mutant lines have been induced through mutagenesis of vars. 'Kelvin Victory' & 'Hemant Singar' for desired novel cut-spray variety having pompon-type flowers & a dwarf variety with 'no-pinch-no-stake' characteristic, respectively.
- By removal of physical barriers to cross-pollination, fertile inter-varietal hybrids have also been produced from seedless, large-headed Chrysanthemum varieties in order to introduce novelty in such varieties that are otherwise propagated vegetatively. The hybrids are being raised that shall bloom during next season.
- Colchicine treatments were given to the Marigold seedlings (4 vars.) to induce polyploidy using cotton-swab method. The treated seedlings were slower in their growth than respective controls. Seeds have been harvested for raising next generation screening of polyploids, during the next season.
- Total 59 crosses (parental variety combinations) have been made using 21 parental varieties in order to raise hybrid Gladiolus varieties for introduction of desired traits i.e. better Spike length, compacter spike, no. of Florets/spike, floret size, attractive corolla colour or pattern, Disease tolerance, better corm multiplier & no. of spike/plant.
- **Mutation Breeding of Cannabis and Poppy:** Mutagenesis experiments were performed using both physical (gamma radiation) and chemical (EMS) mutagens with the aim to develop new lines rich in desired cannabinoids & Oripavine in Cannabis & Papaver, respectively.
- **Development of genomic resources for *Cannabis***: Biochemical analysis and screening for the secondary metabolites: phenols, flavonoids and terpenes of the different lines of *Cannabis* spp. was carried out.The contrasting lines were selected on the basis of phytochemical screening and morphological characters. *De novo* transcriptome analysis of the contrasting lines of *Cannabis* was carried out differential gene expression through qRT-PCR of selected molecular factors are underway.

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Selection, improvement and mainstreaming underutilized crops for providing nutrition and economic security

Identification and validation of miRNAs responsible for biosynthesis of proanthocyanidin (PA) in the underutilized legume *Psophocarpus tetragonolobus* (L.) DC.)

The underutilized legume winged bean (*Psophocarpus tetragonolobus* (L.) DC.) has various degrees or amounts of proanathocyanidin (PA) or condensed tannin (CT) on its seed-coat. PA content of two contrasting lines of *P. tetragonolobus* was estimated. The higher PA containing *P. tetragonolobus* contained 59.23 mg/g of total PA, with catechin and epigallocatechin gallate monomers identified by HPLC; while the low PA containing *P. tetragonolobus* line contained 8.68 mg/g of PA in its leaves. A comparative miRNA profiling of the leaf-tissues of these contrasting lines of *P. tetragonolobus* revealed a total of 139 mature miRNAs. Identification of differentially expressed miRNAs e.g. miR156, miR396, miR4414b, miR4416c, miR894, miR2111 and miR5139 might have role in proanthocyanidin metabolism (Fig.1).

Structural-monomeric unit catechin and epi-catechin were reported to be responsible for biosynthesis of condensed tannin in *P.tetragonolobus*. The enzyme anthocyanidin synthase (ANS) is involved in catechin biosynthesis. ANS transcript of *P. tetragonolobus* was silenced using virus-induced gene silencing (VIGS) to reduce the CT content. ANS silencing in *P. tetragonolobus* resulted in reduced CT levels (Fig 2, Fig 3). This preliminary study confirmed that the silencing of anthocyanidin synthase gene in *P. tetragonolobus* has a regulatory effect on the biosynthesis of condensed tannin. This study will pave way for manipulation of specific enzymes for reducing the biosynthesis of corresponding anti-nutrient.

Total proteome-analysis of the root-tuber of *P.tetragonolobus* resulted in the identification of 2678 proteins belonging to 154 families. Ninety-six percent of these proteins are associated with known biological, molecular and cellular activities. Heat-shock proteins (HSPs) with 12-42 kDa monomeric size were the most abundant protein families constituting 13% of the total identified proteins. This result is in coherence with the total metabolite

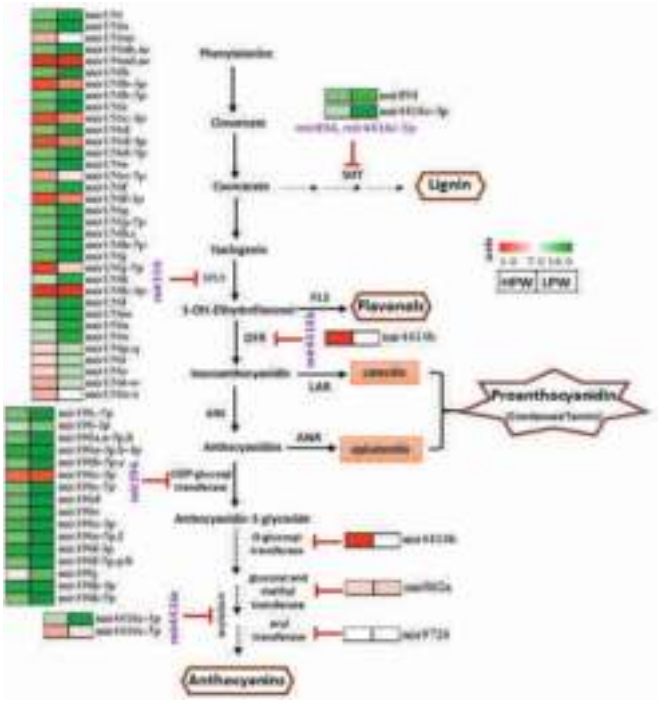

Fig. 1: Putative model that illustrates the role of specific miRNAs in proanthocyanidin metabolism in the contrasting lines of *P. tetragonolobus*. Continuous arrow lines display the known pathways, while broken arrows show some missing pathway links.

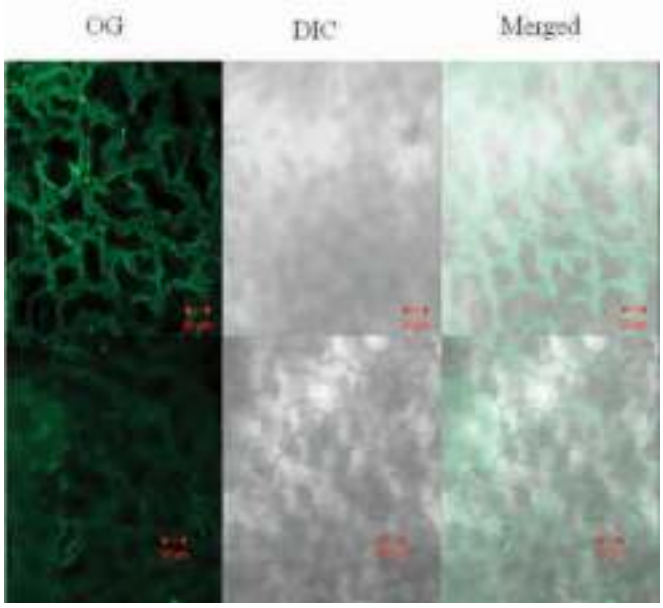

Fig. 2: Confocal microscopy of Control vs VIGS plant: (a)-Oregon green staining in the leaf of *P. tetragonolobus* in VIGS treated and control plant (*20X* magnifications on confocal microscope. Bars = 20 ìm). Upper lane of image is Control plant and lower one is VIGS treated plant *(1)*. OG: Oregon green stained (2) DIC and (3) merge of Oregon green and DIC (b) The degree of fluorescence calculated by IMAGE J software showed significant decrease in VIGS-ANS induced plant.

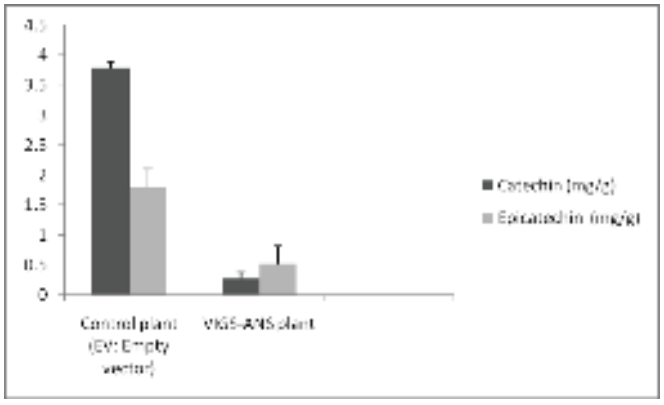

Fig. 3: Quantification of condensed tannin in monomeric unit (Catechin and epicatechin) of leaf tissues of *P. tetragonolobus* through HPLC.

analysis, where the enriched metabolite analysis indicates the maximum prevalence of amino acids as compared to other metabolites in the root-tuber of *P. tetragonolobus* (Fig 4). The presence of several proteins, particularly HSPs in the root-tuber with known function of providing self-defense and stress-resistance with anti-oxidative activities to plants, indicates the success of *P. tetragonolobus* in stressed environment and climate resilience.

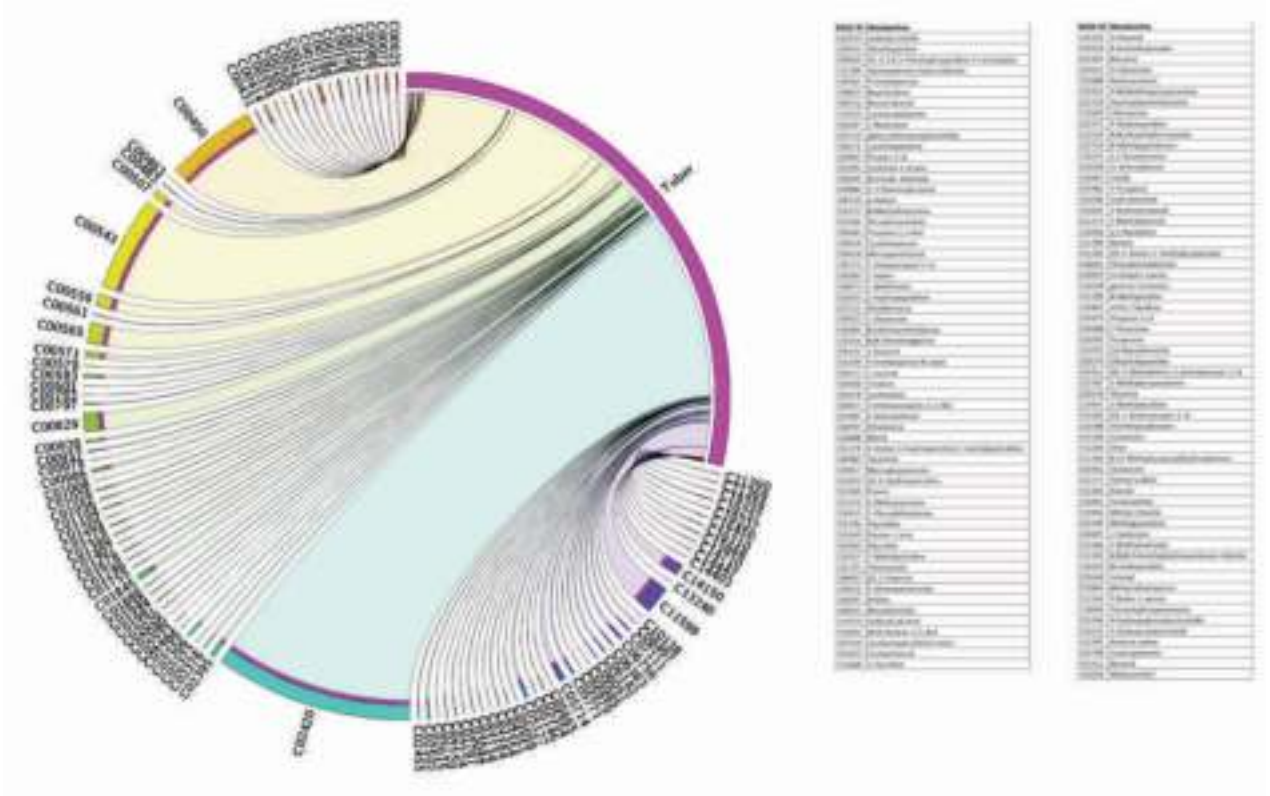

Fig. 4: Circos plot exhibiting the list of metabolites in the root-tuber of *P. tetragonolobus.*

Validation of miRNA expression and their targets in *Cestrum nocturnum* and *Cestrum diurnum*

Cestrum is a genus of almost 300 species; many of the plants of this genus are domesticated for their fragrance and for ornamental purposes. Two of the contrasting species of this genus namelyare *Cestrum nocturnum* (night jasmine) and *Cestrum diurnum* (day jasmine) bloom at night and day time respectively. The molecular factors responsible for flower anthesis at day and night time were deciphered through comparative transcriptome approach. The expression and validation of these factors were carried out by qRT-PCR analysis. Apart from the circadian rhythm of flower anthesis, factors of drough tolerance and pathogen resistance were also reported in the analysis. Seven miRNA families were validated along with their targets. As per the target prediction results, miR815a, miR849 and miR5205a, targeted PIF1 helicase, ubiquitin-specific protease 12 (UBP12) genes, and PATATIN-like protein 6 (PLP6), respectively. The expression of miR815a and miR849 with their target genes PIF1 helicase and UBP12 have been reported to enhance drought tolerance and control over dehydration stress in *C. nocturnum* and miR5205a with its target gene PATATIN-like protein 6 (PLP6) has regulatory control over pathogen resistance in *C. diurnum* (Fig 5).

Moreover, miR1089 and miR172 target leucine-rich repeat (LRR) protein kinase family protein, GRAS family transcription factor in *C. nocturnum* and miR1436, and miR5303 targets PHD finger transcription factor and Myb domain protein 48 in *C. diurnum*. Leucine-rich repeat protein kinase family protein and GRAS family transcription factor genes were reported to have an important role in biotic and abiotic stress responses. PHD finger transcription factor and Myb domain protein 48 target genes were regulated through miR1436 and miR5303 and also have important roles in biotic and abiotic stresses.

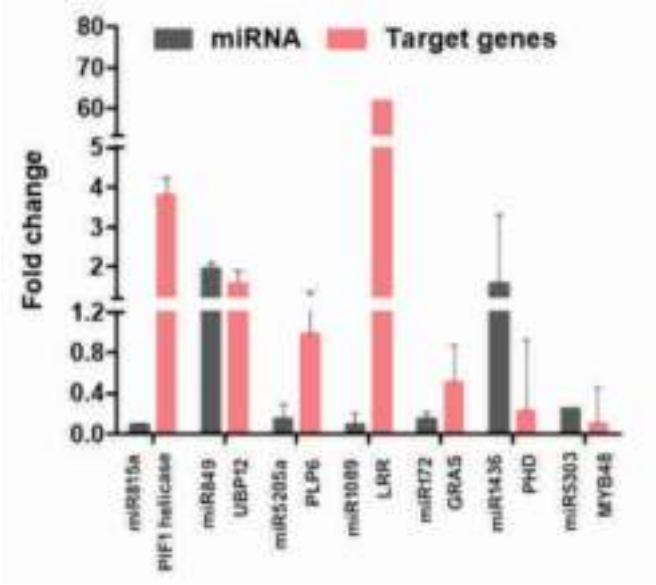

Fig. 5: Expression levels of selected miRNAs and their targets were determined by qRT-PCR. The error bars indicate the standard deviation obtained from biological and technical replicates.

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Genetic Improvement of ornamental and important narcotic crops; Mutation breeding; Molecular Genetics and Cytogenetics

Development of new variety of *Chrysanthemum* 'NBRI-Swadheen 75'

Somatic Parent: *Chrysanthemum morifolium* var. 'Puja'

Description

The 'NBRI-Swadheen75' is a new late-blooming, 'Decorative' type, highly floriferous, small chrysanthemum variety which bears vivid greenish yellow flowers (RHS Fan-1: Yellow Group 2A) that bloom during late-December to mid-February (Fig. 1). It takes ~125 days to raise the new variety from rooted cutting stage to full bloom stage. The new variety has been developed by physical mutagenesis using gamma radiation. The variety was released by Hon'ble Dr. Shekhar C Mande, the then DG, CSIR, New Delhi.

Novelty

A novel late-blooming chrysanthemum variety; improved ornamental characteristics include new floral colour, bigger flowers (≥20%), increased floral weight and better yield of flowers/plant (≥2X) compared to its somatic parent variety.

Uses: Excellent as potted-plant, in beds- and can be used as cut-spray and as loose flowers.

Fig. 1: A newly developed *Chrysanthemum* variety 'NBRI-Swadheen 75'

Induction of new mutant lines in *C. morifolium*

New mutant lines have been induced using gamma radiation in vars. 'Kelvin Victory' and 'Hemant Singar' for desired novel cut-spray variety having 'pompon'-type flowers and a dwarf variety with 'no-pinch-no-stake'-type, respectively (Fig. 2).

Fig. 2: Mutation induction in Chrysanthemum vars. 'Kelvin Victory' & 'Hemant Singar'.

Overcoming barriers to hybridization in Large-headed ('Standard') *Chrysanthemum*

In order to introduce novelty in otherwise seedless large-headed ('Standard') *Chrysanthemum* varieties, inter-varietal crosses were made after removing the physical barriers to expose pistils for hybridization (Fig. 3). Few fertile hybrid seeds have been obtained and germinated which are growing well and will bloom during next flowering season.

Joy', 'Garden Beauty', 'Punjab Gold', 'Autumn Eyes', 'Kalpana', 'Kurume' were procured from GBPUAT, Pantnagar and added to Chrysanthemum genetic resources collection.

Ten (10) varieties of Gladiolus viz. 'Urmi', 'Mohini', 'Pusa Red Valentine', 'Pusa Shanti', 'Chandni', 'P-16-1' x 'Eurovision', 'Shweta', 'Creamy Green', 'Canada X Green Finch' 'Suchitra' were procured from ICAR-IARI, New Delhi; Besides, six (6) varieties of Rose viz.

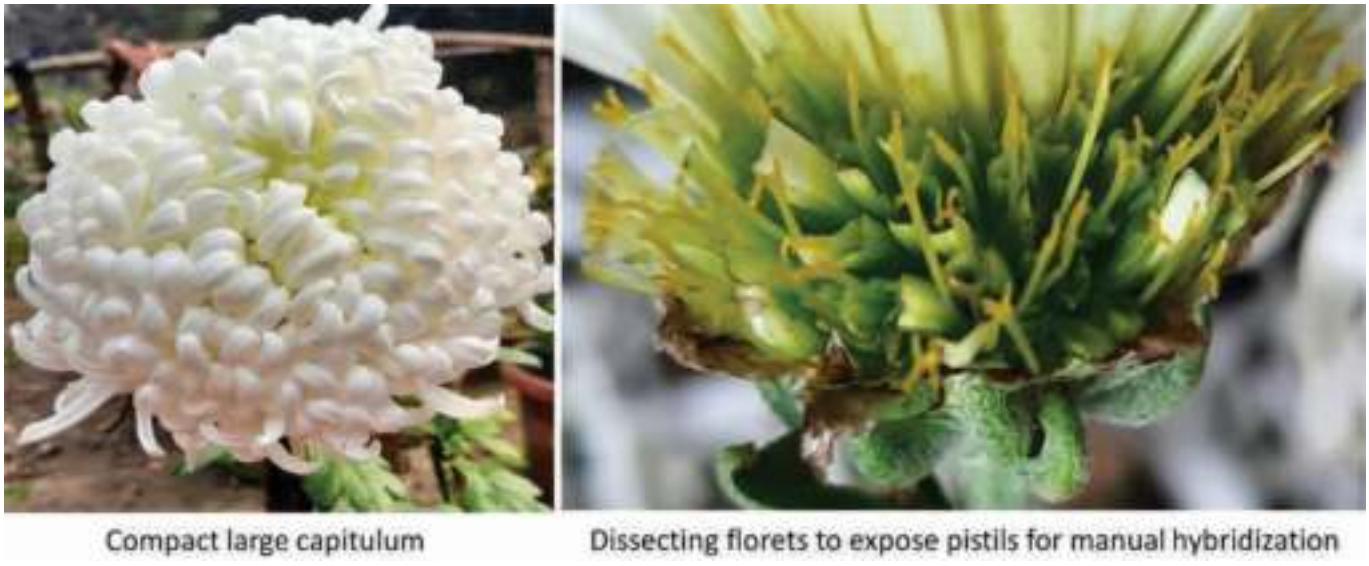

Fig. 3: Exposing pistils for crossing large-headed ('Standard') Chrysanthemums.

Breeding in Gladiolus

Total 59 crosses (parental variety combinations) have been made using 21 parental varieties in order to raise hybrid Gladiolus varieties for introduction of desired traits i.e. better spike length, compacter spike, no. of Florets/spike, floret size, attractive corolla colour or pattern, disease tolerance, better corm multiplier and no. of spike/plant. Seeds have been harvested from 28 successful crosses. These crosses may yield many new hybrid varieties with improved ornamental characteristics that will have immediate market potential as there is ever-increasing demand and market for Gladiolus spikes.

New Germplasm introduced

Twenty (20) varieties of *Chrysanthemum* viz. 'Neelima', 'Ravi Kiran', 'UHFS-CHR 117', 'UHFS-CHR 122', 'DFRC-1', 'DFRC-2', 'Pithica', 'Star White', 'Punjab Shingar', 'Bidhan Madhuri', 'Bidhan Purna', 'Yellow Delight', 'Royal Purple', 'Anmol', 'Autumn

'Pusa Mahek', 'Pusa Sharbet', 'Pusa Alpana', 'Queen Elizabeth', 'Sheer Delight', 'Rosa chinesis' were also procured from ICAR-IARI, New Delhi and added to genetic resource collections.

Mutation breeding of Cannabis and Opium Poppy

Mutagenesis experiments were performed using both physical (gamma radiation) and chemical (EMS) mutagens with the aim to develop new lines rich in desired cannabinoids and Oripavine in Cannabis and Papaver, respectively.

Cannabis

Four Cannabis accessions i.e. NBRI-137, NBRI-108, NBRI-107 and a local accession were mutagenized using both physical (Gamma irradiation) as well as chemical mutagenesis (EMS) treatments. For gamma irradiation treatment, mature seeds were irradiated with 300-350 Gy (Gray) after optimization using LD_{50}

value which was determined to be at 400Gy (40 kr), (Fig. 4). However, for tender seedlings, a dose range 10-30 Gy was decided.

Fig. 4: Optimization of LD_{50} value in *Cannabis sativa*

For chemical mutagenesis, different treatments of EMS were used for mature seeds and seedlings (for seeds, 150mM for 5hr and for seedlings, 75 mM for 1 and 2 hr) which were decided on the basis of the earlier reports with some modifications.

The mutagenized seeds (M_1 generation) of different accessions were put in pore-trays and kept at 25ºC for germination. After germination, seedlings were transferred to Cannabis field at Banthra station. In case of seedlings treated with EMS, treated M_1 seedlings of the local accession were directly transferred to the field and grown.

The male and female individuals belonging to same accession and treatment were later crossed to raise M_2 generation level seeds which shall be germinated during next season to screen for desired cannabinoids content.

Opium Poppy

The seeds of *Papaver somniferum* were given mutagenic treatments using physical mutagen (gamma radiation) alone as well as along with chemical mutagen (EMS). For physical mutagenesis, 300 Gy dose of gamma irradiation was given to seeds. In another set of mutagenic treatments, seeds were treated with combinations of gamma irradiation and EMS i.e. 100 Gy+ 40mM (6 hr) and 100 Gy+60mM(6hr). After the mutagenic treatments, the seeds were planted 'treatment-wise' in the poppy field to raise respective M_1 plants along with respective controls. The respective M_1 plants were grown further and during flowering season, self-pollination in each flower was performed to raise M_2 seeds. Lancing was also performed on each developing young capsule for latex collection. After latex collection, M_2 seeds were harvested at maturity from each capsule. The M_2 progeny shall be later screened for higher relative Oripavine content among other opioids to select promising lines.

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Molecular markers; development of genetic resources; linkage analysis and genomics assisted breeding for variety development of industrially important crops

Genetic and genomics resources in linseed for varietal developments

Linseed *(Linum usitatissimum* L.*)* is an important oilseed as well as fibre crop and has great potential for making industrial products. Linseed is a rich source of digestible protein, dietary fibres as well as an abundance of micro-nutrient, lignin and Omega-3 and Omega-6 fatty acids.

In continuation of previous work, the reference genome of linseed (IC 0526166) was improvised to a better assembly using Hi-C (chromosome conformation capture with next-generation sequencing) data to produce hybrid ONT-Hi-C assembly. It provides accurate orientation and ultimately reduces contig/scaffold numbers to chromosomal level. The nanopore long read assembled primary assembly of linseed was scaffolded with the help of Hi-C data using SALSA tool. SALSA performs large scaffold construction using graph construction and link scoring function. Misjoin detection and correction were performed repeatedly until the best final scaffolds was achieved. As compared to the primary assembly the present assembly comprised of 662 contigs. The Hi-C data further enhanced assembly almost by two-fold and resulted in 376 contigs. The N50 value and largest contig of this hybrid assembly was also improved by almost two-fold i.e 7.2 Mbp and 21.14 Mbp as compared to primary assembly. Further, this Hi-C and ONT based hybrid assembly will be used to achieve chromosome level assembly through different tools.

In addition to genome assembly, two bi-parental RILs mapping populations of linseed were evaluated for their phenotypic characters during cropping season of 2021-22. These include RIL Pop. 1 for oil content derived from cross of RKY-14 (high) x KL-213 (Low) and RIL Pop. 2 for flowering/maturity derived from cross of Padmini (Early) x KL-213 (Late). The oil from seeds of these RILs has been extracted using Soxhlet method for fatty acid profiling. In order to construct linkage/QTL map based on these two RILs, the genomic DNA were isolated (~300) and subjected to Illumina sequencing following Genotyping by sequencing (GBS) approach). Further, three bi-parental mapping populations (~700 lines) also progressed to F_4 generation leading towards formation of Recombinant Inbred Lines (RILs). The single seed descend (SSD) approach was followed to advance these populations for RIL development and seeds for next generation (F_5 generation) have been harvested. In addition to RILs mapping populations, the generation advancement for another set of mapping population i.e., MAGIC population had been made. Approximately 1400 F_2 lines (~200 lines each of 7 MAGIC hybrids) were grown in field and selfed and the seed harvested. To create further genetic variability 40 new crosses with different breeding design were made and hybrid seeds harvested. Flax fibre is considered as one of the quality fibres used for linen clothing. Fifty-four fibre type accessions have been evaluated for fibre quality and yield parameters. Out of 54, data on 25 accessions have been obtained for technical plant length and fiber yield/plant (Fig. 1). The technical plant length ranged from 65.0 cm (POLF37) to 100.0 cm (GP2891) and fibre yield varied from 0.62 g/plant (POLF37) to 2.5 g/plant (VIKING). The accessions VIKING, LC2023, GP2892 and RLU found to be promising lines for fibre.

Comparative transcriptome analysis of guar genotypes RGC-936 and RGC-1066 during the early stage of *Alternaria* infection

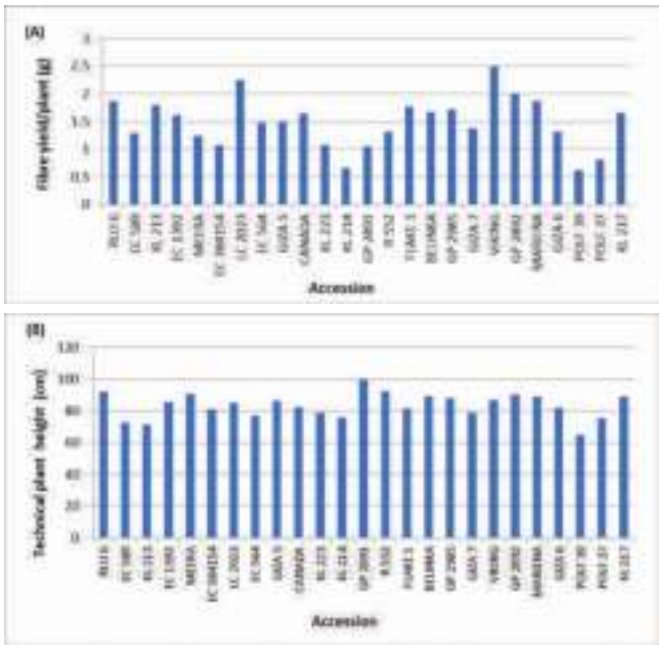
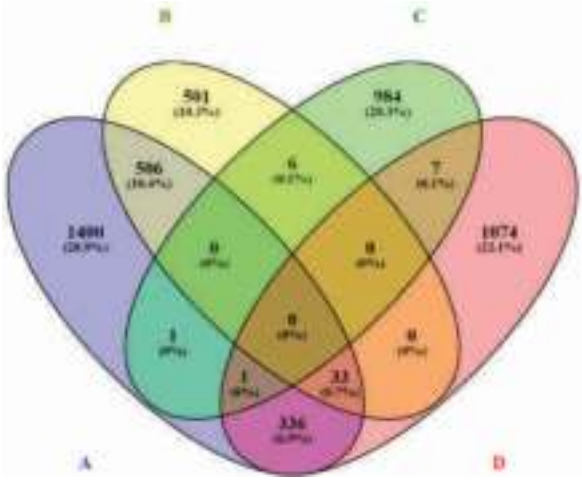


Fig. 1 Graph showing variability in (A). fibre yield/plant (g) and (B). technical plant length (cm).

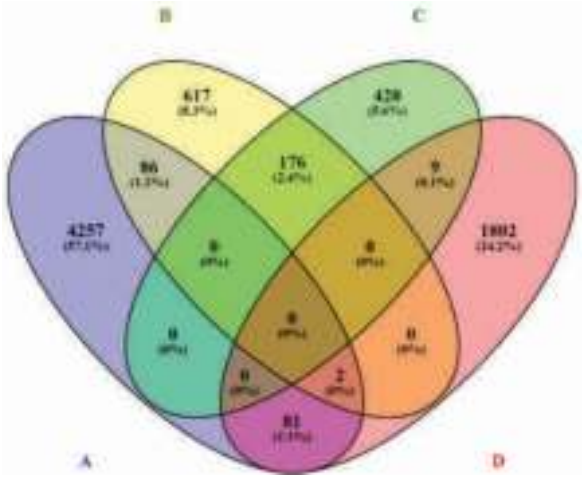
The *Cyamopsis tetragonoloba* L. Taub is an economically important drought tolerant legume crop. Due to the presence of galactomannan or guar gum it has tremendous potential in the industrial sector, ranging from pharmaceutical to textile and cosmetic to chemical industries.

In recent years blight or leaf spot caused by *Alternaria* sps. 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 gaur to identify key components of resistance pathways. Two popular guar genotypes (RGC-1066 and RGC-936) showing resistance and susceptibility to *Alternaria* were selected for comparative transcriptome analysis during the early stage of infection (72 hapi). After pre-processing, all the high-quality reads were used to generate *de-novo* assembly using Trinity Pipeline and generated a total of 181270 transcripts. The aligned transcripts were annotated using blastx against different databases such as TAIR10, *Glycine max* and *P. vulgaris*. To study the gene function, a Gene Ontology (GO) study of DEGs was carried out and KEGG (Kyoto Encyclopedia of Genes and Genomes) analysis was performed for metabolic pathways of significant genes.

The detailed pathway analysis was performed with PageMan using the up and down-regulated genes which were annotated with the TAIR10 protein database. Further, MapMan analysis was also performed to show the differential expression of genes in biotic stress pathways. Guar transcripts with putative functions related to biotic stress tolerance and defence against pathogens were up-regulated and may play a role in defence against *Alternaria* infection. *A. alternata* transcripts encoding putative pathogenicity factors, such as cell wall degrading enzymes and metabolic processes may



UP Regulated genes



Down Regulated genes

Fig. 2: Venn diagram of the differential expressed A) up-regulated genes B) and downregulated genes in A) RGC-936 mock-inoculated vs RGC-936 inoculated B) RGC-1066 mock-inoculated vs RGC-1066 inoculated C) RGC-936 mock-inoculated vs RGC-1066 mock-inoculated D) RGC-936 inoculated vs RGC-1066 inoculated.

be important for infection. We, therefore, identified the differential expression of several guar transcripts against *Alternaria* infection that present a group of valuable candidates for further studies for their roles in immunity or disease development (Fig. 2).

Exploitation of grain amaranth genetic resources for accelerated genetic improvement

The grain amaranth is known for its excellent nutritional and therapeutic value. It is well fortified with high contents of vitamins, minerals, phenolic acids, and oil (squalene, linoleic acid, ω-6-fatty acids, etc.). It has C4 mechanism suited to survive in adverse environmental conditions.

The genetic resources and knowledge of available variability serve as the raw material for devising suitable breeding strategies for further genetic improvement and development of new and trait specific varieties. The assessment of the phenotypic diversity that exists among the selected grain amaranth accessions was carried out by germplasm evaluation with respect to morphological characterization using standard descriptors for grain amaranth. Phenotypic data of 900 accessions of grain amaranths was analysed for genetic variability. Further, based on these phenotypic data a subset of

Fig. 3: Representative image from field showing variability in plant architecture.

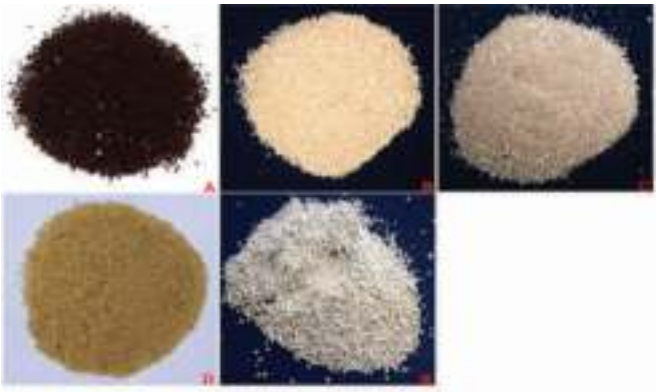


Fig. 4: Variability in seed color

300 accessions has been isolated as core accession for the purpose of identification of marker-trait relationship through association mapping. The data of core accessions showed almost similar genetic variability as of whole 900 accessions for most of the traits. This showed that the constructed core accessions are suitable for further evaluation and QTL identification through association mapping. The phenotypic traits variability can be easily observed in field as some of the representative images (Fig 3-4) which reveals existence of considerable variability among the germplasm resource of grain amaranths evaluated.

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Genomics, quantitative genetics and molecular plant breeding

Stable QTLs and candidate genes for fibre productive trait using intraspecific RILs of *G. hirsutum* MCU5 X TCH1218

A genetic map of *G. hirsutum* with 504 SNPs with a total span length of 4,416 cM and an average inter-marker distance of 8.76 cM was created. The researchers employed 181 intra-specific recombinant inbred lines (RILs) produced from a hybrid between *G. hirsutum* var. MCU5 and TCH1218. Although the CottonSNP50K assay discovered 2,457 polymorphic SNPs between the parents, only 504 SNPs were found to be helpful for the development of the genetic map. A substantial number of SNPs in the genotyping exhibited either greater% missing data, duplication, or segregation distortion. The mapped SNPs in this investigation, however, displayed collinearity with the physical map of the reference genome (*G. hirsutum* var.TM-1), indicating that no chromosomal rearrangement occurred within the examined mapping population. RILs were examined in a variety of settings and seasons, and phenotypic data were collected. QTL analysis dissected 53 QTL influencing plant height (PH), number of sympodial branches, boll number (BN), and boll weight (BW) under irrigated and water stress circumstances. Furthermore, nine QTL hot spots were discovered to be not only co-localized for more than one examined trait, but also stable with large QTL, i.e., with > 10% phenotypic variation. One QTL hotspot on chromosome 22 bordered by AX-182254626-AX-182264770 with an 89.4 cM span length co-localized with seven large and stable QTL related to a

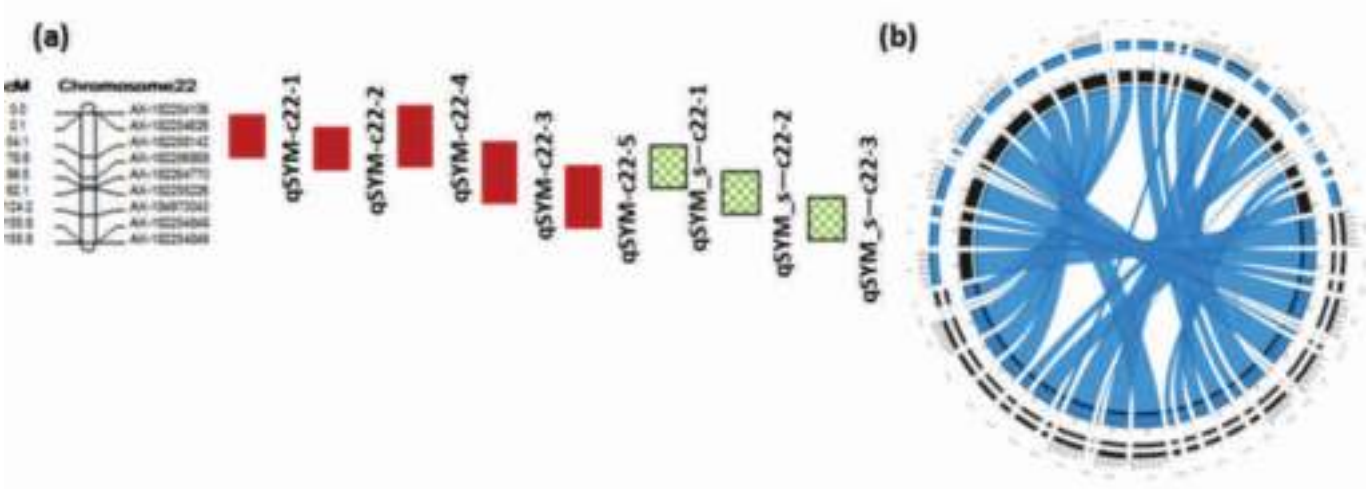

Fig. 1: (a) Linkage map showing the relative positions of quantitative trait loci (QTL) identified in chromosome number 22 (b) Collinearity of the TM-1 sequence based physical map (https://www.cottongen.org/analysis/251) corresponding to SNP-based genetic map constructed in this study. Chr1–Chr26 (represented in black color segment) is chromosome number of intraspecific map developed in this study. A01–A13 and D01–D13 (represented in blue color segment) is physical map of TM-1 taken from the CottonGen public database.

number of sympodial branches under both irrigated and water stress circumstances. In addition, potential candidate genes linked with water stress were discovered in the QTL hotspots. Furthermore, a few QTL from the hotspots had previously been reported across other cotton genetic architectures, confirming the potential applicability of these QTLs for cotton breeding and improvement.

Genome Wide Association Study (GWAS) for oripavine in opium poppy

Genomic DNA was isolated with Plant DNAeasy Kit (Qiagen) and quantified by Qubit ds HS assay (Thermo Fisher Scientific, MA, USA). In summary, illumina raw reads were pre-processed using Trimgalore. Processing steps includes removal of adapters and low-quality bases with cut off Q30 and minimum of read length of 20. All the samples were aligned to the reference genome of opium poppy (https://www.ncbi.nlm.nih.gov/genome/12819) and the resultant alignment file was used as input for genotype calling by stacks pipeline. The alignment file from Bowtie II was processed through Stacks GBS pipeline. This plugin took the data from each individual and grouped them into loci. Then loci were grouped together across individuals and a database was made. Further, loci from each individual were matched against the database to determine the allelic state at each locus in each individual and finally allelic state was subjected to population genetic statistics via population and polymorphic nucleotide sites were reported in variant calling file format (VCF). A total of 9,912 significant SNPs in 60 samples were identified and Hapmap result contained all the genotype information for all the sites.

Marker trait association (MTA) using all SNP markers were evaluated based on the average values for Opiod. MAF threshold of 6% was used to remove rare variants and avoid false–positive associations. Multiple algorithms were applied for GWAS. For all SNP loci and phenotypic data, we applied the generalized linear model (GLM) and MLM. Further, GWAS was conducted using Fixed and random model Circulating Probability Unification (FarmCPU) algorithm that takes into account the confounding problem between covariates and test marker by using both fixed effect model (FEM) and a random effect model (REM). GWAS was also conducted using Bayesian information content (BIC) in a FEM and replaces the bin approach used in FarmCPU with LD. Five principal components were used as covariates to control for population structure and Manhattan plots were drawn using package qqman in R statistical package.

Our analysis suggest that one loci from chr-10 was significantly associated with Oripavine in all models, thereby it signifies that it is closely associated with oripavine (Fig. 2).

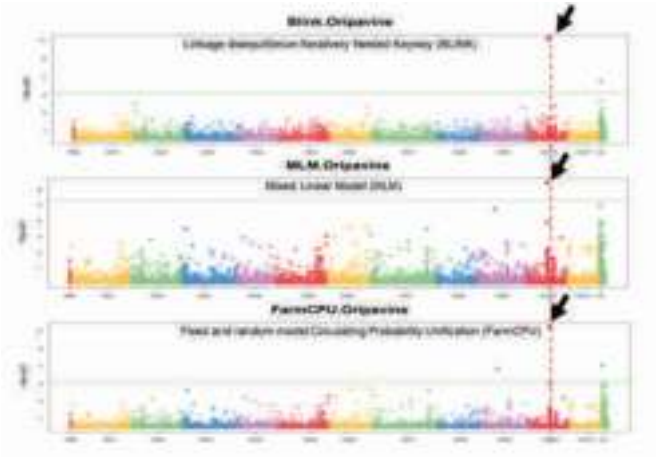

Fig. 2: Manhattan plot for Oripavine in GWAS analysis using various models with stringent setting

HPLC based cannabinoid profiling

Cannabis is an important crop with high economic importance due to presence of several phytomolecules with medical properties, and ifber content. However, due to the presence of tetrahydrocannabinol (THC), a psychoactive compound, its cultivation is strictly controlled by law enforcement agencies.

We at CSIR-NBRI, have collected and maintained a large collection of Cannabis germplasm. We aim to select promising germplasm through HPLC-based Chemotypic profiling for low THC content. We found four germplasms with low THC range (0.06% to 0.23%) and four germplasms with high CBD range (2.0% to 2.8%). All these low THC and high cannabidiol (CBD) lines were found to have high fiber content (Fig. 3)

Chloroplast genome of *Lithocarpus dealbatus* and its mutation hotspots for potential taxon delimitation

To resolve the phylogeny in Quercoideae, we sequenced and assembled the 161,476 bp chloroplast genome of *L. dealbatus*, which has a large single-copy section of 90,732 bp and a small single-copy

region of 18,987 bp, separated by a pair of inverted repeat regions of 25,879 bp. The chloroplast genome contained 133 genes, of which 86 were protein-coding genes, 39 were transfer RNAs, and eight were ribosomal RNAs. Analysis of repeat elements and RNA editing sites revealed interspecific similarities within the *Lithocarpus* genus. DNA diversity analysis identified five highly diverged coding and noncoding hotspot regions in the four genera, which can

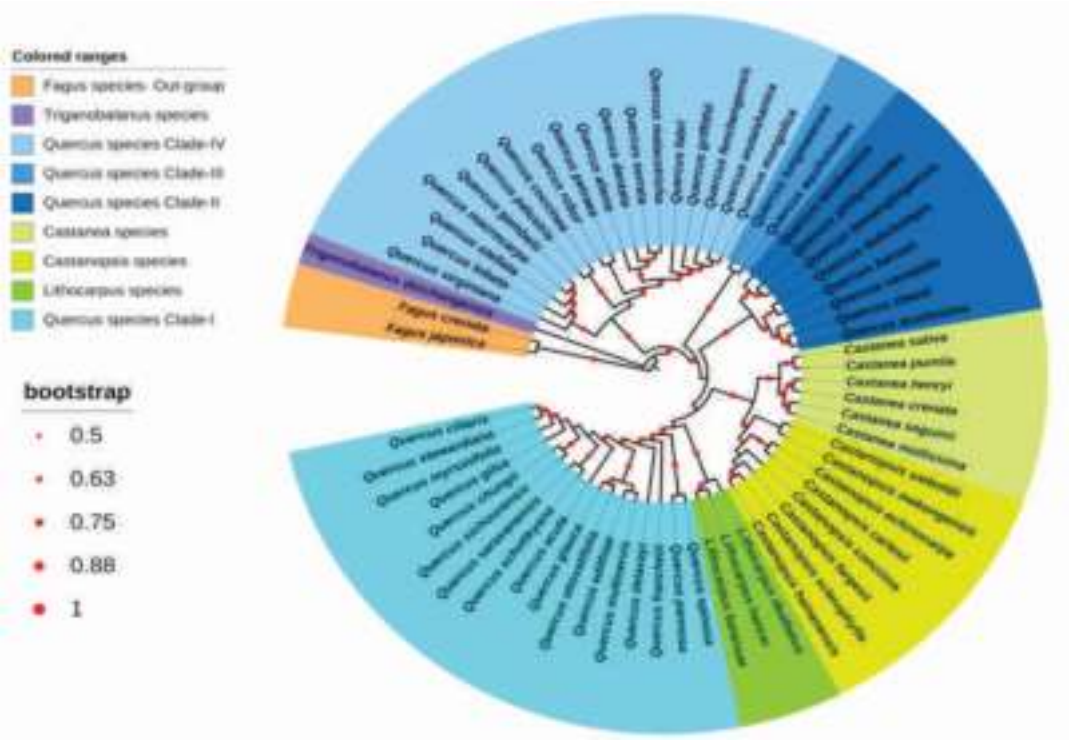

Fig. 4: ML phylogenetic-tree construction based on the whole chloroplast genome of Quercoideae species by keeping *Fagus* species as outgroup.

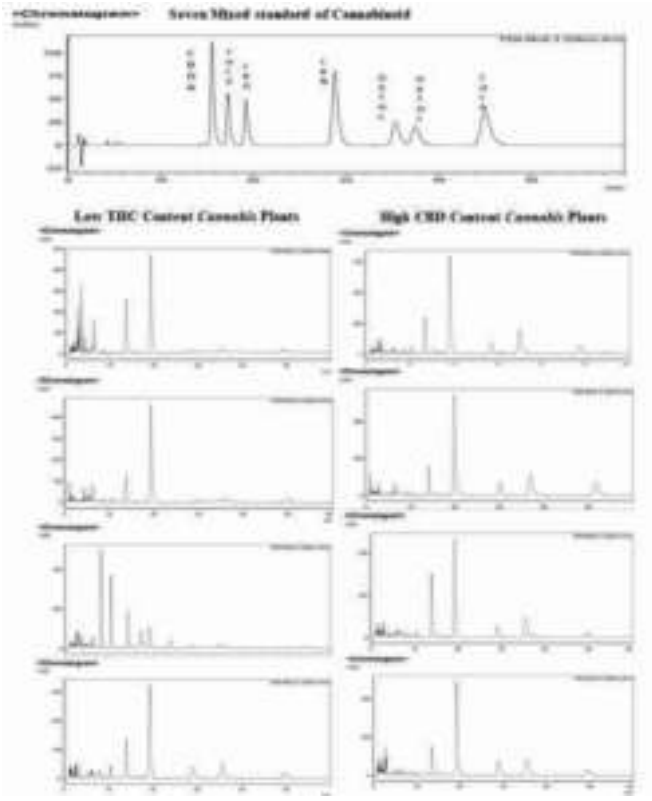

Fig. 3: Chromatogram of low THC, high CBD with reference to seven mix Cannabinoid standards.

be used as polymorphic markers for species/taxon delimitation across the four genera of Quercoideae viz., *Lithocarpus, Quercus, Castanea,* and *Castanopsis*. The chloroplast-based phylogenetic analysis among the Quercoideae established a monophyletic origin of Lithocarpus, and a closer evolutionary lineage with a few *Quercus* species (Fig. 4). Besides providing insights into the chloroplast genome architecture of *L. dealbatus*, the study identified five mutational hotspots having high taxon-delimitation potential across four genera of Quercoideae.

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Botanic Garden, Plant Conservation and Agro-Technology

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

BOTANIC GARDEN, PLANT CONSERVATION AND AGRO-TECHNOLOGY

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5.	Project Staff	11

Broad Areas of R&D

- Plant Conservation
- Agro-technology
- Aroma Mission
- Floriculture Mission
- Skill Development and Outreach Activities

Aims and Objectives

- The Botanic Garden of CSIR-NBRI serves as a repository of diversified groups of taxa with special reference to rare, endangered and threatened plants. Enriching the germplasm collection, domestication of wild plant species of ornamental significance, development of new and novel cultivars of ornamental plants, and awareness and education on garden related activities are the major objectives. The conservation of plants in specially designed houses, specially pteridophytes, bryophytes and cycades are the major attractions.
- The main purpose of Plant Conservation and Agro-technologies group is to develop agronomic package for sustainable development and economic utilization of sodic wastelands. The group has developed improved varieties of Bixa and Curcuma and evaluation of germplasm of other medicinal and aromatic plants is in progress for identifying elite germplasm. Field experiments are also conducted for development of agro-technologies of lesser-known, but important crop plants. Under outreach programme, the efforts are made towards popularizing CSIR-NBRI green technologies.

Major R&D Highlights

Botanic Garden

- Indian *Cycas* Garden and Waterlily-Lotus Conservation Centre are two new facilities created to serve as National Reference Centres. These developments are a part of the R&D activity for the establishment of *Cycas* as a model plant for *ex-situ* conservation of threatened plants and future restoration of natural populations, and conservation of various Indian species of *Nymphaea* and Lotus.
- Fieldwork were carried out in Eastern Ghats (Andhra Pradesh and Odisha), and Northeast India to collect plant samples for morphological and molecular characterization of Cycas. Observations on the reproductive plant parts were also made to understand the bottlenecks of reproduction in wild populations.

- Several seedlings were also collected and planted in Cycad House and Indian *Cycas* Garden for further studies in *ex-situ* at CSIR-NBRI Botanic Garden.
- New species, *Pyrrosia sarthalensis* (Polypodiaceae) and *Swertia patnitopiansis* (Gentianaceae) were described from Jammu & Kashmir.
- Varietal developments of floricultural and ornamental plants like *Canna*, *Nymphaea* and *Nelumbo* using the techniques of hybridization and mutation breeding through gamma radiation and chemical mutagens have been undertaken.
- Successfully domesticated ornamentals from our wild collection in the garden include *Iris* sp., *Hoya* sp., *Barleria* sp., *Begonia* sp., *Impatiens* sp., Orchids, *Nymphaea*, lotus, etc.
- A CSIR-NBRI online database has been created for enlisting the plant species that are threatened in India. The current database includes species from all groups of plant taxa and provides their IUCN conservation status.
- Several field trips were undertaken to various parts of India and numerous plant species were collected in the form of cuttings, saplings, live plants and seeds for *ex-situ* conservation in the garden. The collections include *Victoria amazonica*, 38 varieties of lotus including rare 108 petal lotus of Manipur, 15 species/varieties of *Nymphaea*, 17 varieties of Canna, 8 varieties of *Hoya*, 5 varieties of *Rhynchostylis*, 5 varieties of *Tolumnia*, 50 varieties of *Dendrobium, Dischidia pectinoides*, *Oxystelma seculentum, Ludwigia adscendens, Ultricularia aurea, Marsilea minuta, Nuphar lutea, Hydrocleys nymphoides*, 2 varieties of Rose, 5 varieties of *Heliconia, Costus insignis* and several other ornamental and threatened plants.
- A research topic was formulated to study the floristic composition of these regions. From Bani valley, a total of 196 plant species were identified, whereas 266 plant species were collected from Sarthal hills.
- Vegetation composition of Bani valley and Sarthal hill, Jammu and Kashmir comprised of (*Trillium govanianum* Wall. ex D.Don, *Bergenia ciliata* (Haw.) Sternb., *Daphne oleoides* Schreb., *Berberis lycium* Royle, *Arnebia benthamii* (Wall. ex G.Don) I.M.Johnst., *Morchella esculenta* (L.) Persoon., *Salivia hians* Royle ex Benth.).
- For promotion of NBRI developed floricultural crops and varieties, creation of new facility in the form establishing a floriculture garden in schools and colleges were undertaken in many states of the country.

Plant Conservation and Agro-technology

- For standardizing the agro-practices of Kalmegh (*Andrographis paniculata*), field experiment was conducted with various doses of press mud.
- To identify the potential *Aloe* species for cultivation in salt affected soils, twenty-five *Aloe* species and accessions were evaluated.
- Twelve more species were added to the Bambusetum at Banthra, making it a conservation plot of 67 spp. of Bamboo from different regions/ parts of India. The grain amaranth germplasm repository was further enriched to 1223 accessions which are being evaluated for various agronomical and quality traits.
- Collection, conservation and evaluation of 52 accessions of Nagarmotha (*Cyperus scariosus*) was done under sodic waste land conditions for their commercial cultivation and extraction of root essential oil. Total 139 samples of *Juniperus* were collected from four Himalayan states. Extraction and characterization of essential oil has been done from four populations from western Himalaya.
- A systematic exploration of application of carbon dots in agricultural crops was done. The effect of carbon dots on crop physiology and yield are being measured. The study aims to evaluate the efficacy of the mode of carbon dots application (induction) into the plant system vis-a-vis their effectiveness.
- Field experiments are being carried out to study the response of Zeolites on growth and yield performance of rice-wheat cropping system of Indo-Gangetic plains.
- The plant population (sowing distance) showed significant effect on growth parameters of Cannabis and maximum values of growth parameters were observed at 45x30 cm spacing and minimum in 30x30 cm spacing. Nitrogen levels significantly affected the growth parameters. Maximum test weight of seed (10.73 g) and seed yield/plant (9.87g) were significantly higher at 60X30 cm. Among nitrogen levels,

maximum yield attributes and test weight (9.54 g) were significantly higher under 125% nitrogen level, and seed yield per plant (8.88g) was higher under 100% nitrogen level 100 % than others.

Out-reach/Skill Development

- Under the UNIDO Neem project, different agroforestry models were developed with medicinal and aromatic plants. The multi-location trials were planted at five different agroclimatic zones to evaluate comparative adapttation of four different Neem cultivars.
- Under CSIR-Aroma Mission, 253 quintals rhizomes of turmeric variety 'Kesari' has been distributed among 59 farmers in nine states, which act as seed farmers, covering 387 ha area.
- Total 22 awareness cum training programmes were organized at different location for popularization of turmeric cultivation for essential oil extraction from senescing leaves, training 863 farmers.

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Botanic Garden; Plant Conservation; Floriculture; Agro-technology; Skill Development and Outreach Activities

Botanic Garden

The mutation 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. Species of ornamental/economic/ conservation importance, collected from different locations of Andhra Pradesh have been introduced and are being maintained at NBRI Botanic Garden. These are *Boswellia ovalifoliolata, Commiphora caudate, Cycas sphaerica, Decaschistia crotonifolia, Embelia tsjeriam-cottom, Gardenia gummifera, Hildegardia populifolia, Jasminum angustifolium, Melastoma malabathricum, Pterocarpus marsupium, Syzigium alternifolium, Terminalia pallid, Cycas seshachalamensis, Hibiscus platanifolium, Indigofera tinctoria, Orthosiphon aristatus.* The collection of Bougainvillea, Rose, Gladiolus and Chrysanthemum were further enriched by adding new varieties.

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. A total of 38 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 rhizome yield, leaf and rhizome oil yield and quality in large field experiments. A field experiment was also conducted to evaluate the improvement in curcumin content with nutrient management.

Promotion of new dwarf cultivars with early maturity and higher limonoids yield

Multi-location trials of four neem cultivars were planted at five locations (Shillong, Lucknow, Chandigarh, Bengaluru, and Bhubaneswar). Agroforestry models have been developed at Banthra Research Station of CSIR-NBRI, Lucknow. The land was slightly sodic with ~8.0 pH. Rehabilitation of such kind of problematic land can be possible by establishing agro forestry models, which also maintains ecological balance.

Establishment of a DUS Test Centre at CSIR-NBRI, Lucknow for Bougainvillea, Gladiolus and Canna crops

CSIR-NBRI is DUS Test Centre of PPV & FRA for Bougainvillea, Canna and Gladiolus. Characterizations by recording morphological characters (both vegetative and floral) of some varieties/ cultivars of Bougainvillea, Canna and Gladiolus were done for identifying morphological variations and developing descriptors.

Farm based S&T interventions for socio-economic development in the aspirational district of Nabrangpur, Odisha

To improve the socio-economic conditions of Nabarangpur, Odisha; the rhizomes of CSIR-NBRI turmeric variety 'Kesari' was provided to farmers along with technical information on leaf essential oil. Our well tested efficient strains of bio-inoculants were provided to the farmers with training and demonstration. In October 2021, the biofertilizer production unit was set-up in technical collaboration with CSIR-NBRI. The efficient microbial strains

Begonia dipetala *Strobilanthes heyneana* *Bauninia hoenicea*

Fig. 1: New plants introduced to CSIR-NBRI Botanic Garden.

were also provided by CSIR-NBRI with an MoU to technically support the unit. The art of Dehydrated flowers and foliage-based products has also been disseminated to the tribal women of district. Seedlings of marigold and tuberose were provided to the farmers.

Aroma Mission Phase II

The turmeric variety Kesari of CSIR-NBRI was popularized for cultivation as inter-crop in orchards, with additional advantage of leaf essential oil. The area expansion reached 387 ha under Kesari variety. Field trips were conducted for collection of leaf and berry samples from distinct populations of *Juniper* in Uttarakhand and Himanchal Pradesh. The germplam collection of *Nagarmotha* was further enriched (07 accessions) and growth, tuber yield and oil content were evaluated in existing germplasm.

CSIR Integrated Skill Initiative Programme

Under CSIR Integrated Skill Initiative, CSIR-NBRI has developed eight courses in its core competency areas. Total 18 employment-oriented skill development programmes were organized under the project.

New plants introduced and maintained at Botanic Garden

Over 50 taxa were successfully introduced to CSIR-NBRI Botanic Garden from Karnataka, Kerala, Tamil Nadu and Andhra Pradesh. The collections include wild ornamentals, threatened plants, economic plants and other ornamentals. The notable species are *Alstonia venenata, Amorphophallus* sp., *Angelonia angustifolia, Argyreia pilosa, Artamesia nilagirica, Asesticia* sp., *Barleria acuminate, Barleria cristata, Barleria prionitis, Bauninia phoenicea, Begonia dipetala, Begonia dipetala* var. *hydrophila, Berbesis tinctoria, Cestrum aurantiacum, Coleus* sp., *Curcuma inodora, Dendrobium* sp., *Dillenia* sp., *Dipterocarpus indicus, Ecbolium* sp., *Ensete superbum, Garcinia gummi-gutta, Heterotis rotundifolia, Hopea ponga, Hypoestes phyllostachya, Impatiens fruticosa, Impatiens gardeneriana, Impatiens tomentosa, Ixora arborea, Jasminum malabaricum, Jasminum trichotomum, Justicia santapui, Magnolia nilagirica, Malaxis* sp., *Melastoma malabathricum, Memecylon malabaricum, Musa kattuvazhana, Nervilia* sp., *Ophiorrhiza* sp., *Osbeckia leschenaultiana, Piper umbellatum, Plectranthes* sp., *Strobilanthes heyneana, Syzigium gardneri, Syzigium travancoricum, Vanda* sp., *Wedelia* sp., *Zingiber* sp., etc. Apart from these, ornamental varieties of *Fuchsia, Coleus, Begonia* and *Jasminum* from Ooty Botanic Garden (Tamil Nadu) were also introduced (Fig. 1).

Beside this, few other plants were also procured for enrichment of Garden viz. Chironji (*Buchanania cochinchinensis*), Hanuman phal (*Annona cherimola*), Mahua (*Madhuka longifolia*), Cheeku (*Manilkara zapota*), Tendu (Diospyros melanoxylon), Rakhi bel (Passiflora), Mausammi (*Citrus limetta*), and Mali (*Jasminum polyanthus*).

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Germplasm conservation and evaluation of non-traditional economic plants and development of their agro-technology; Outreach Programmes/ Extension Activities

CSIR Aroma Mission

Under Aroma Mission Project the main objective was development of agro-technologies for cultivation of turmeric for essential oil extraction from senescing leaves, and increasing area under turmeric cultivation in different states. About 253 quintals of promising turmeric variety 'Keasri' has been distributed among 59 farmers in nine states with an area coverage reaching 387 ha. We have also developed agro-technology and agri-economics for improved Curcuma variety(ies) which would be optimized under the shade of orchards, multi-location assessment for their suitability in different agro-climatic regions, agro-technology including post-harvest optimization for different agro-climate zones, capacity building and training programmes on agro-techniques, distillation and value addition and making public aware of mission activities and achievements using appropriate interface. A total of 22 awareness cum training programme have been organized at different location of India for popularization of turmeric cultivation for essential oil extraction from senescing leaves under Aroma Mission Project and trained about 863 farmers (Fig. 1)

Fig. 1: Glimpses of training cum awareness programmes organized under Aroma Mission.

Plant Conservation and Agro-technologies (Distant Research Centres, Banthra)

Collection, conservation, evaluation and propagation of plants spp. under partially sodic waste land condition for their commercial cultivation and income generation of the farmers is the major objective of our in-house project. Seven accessions of *Cyperus scariosus* (Nagarmotha) were conserved at Distant Research Centres, Banthra in field gene banks for their evaluation (Fig. 2). The growth parameters of 11 Nagarmotha germplasm from different locations of India (ACC No. 1 to ACC No. 13) were studied and identified by growth parameters. The growth parameters like plant height (120.33±11.2 cm), no of nodes/ 20 cm (12.00±2.6), stem diameter (6.27±1.2 cm), internodal distance (1.42±0.6 cm), fresh root wt./plant (140.30±2.5g) were found highest in ACC No. 3 while lowest in ACC No. 13.

Phenotypic & Chemotypic characterization *Juniperus* for the identification of elite germplasm for different habitat

Juniper is a genus of about 60 to 70 species of aromatic evergreen trees or shrubs of the cypress family (*Cupressaceae*), distributed throughout the Northern Hemisphere, cultivated as ornamentals and useful for their timber. But some species also have medicinal value and are important for pharmaceutical and cosmetic industry.

Total 139 samples of Juniperus collected from 5 states (Himanchal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh). The extraction of essential oil from 4 populations collected from western Himalayas was been done by hydro distillation method using Clevenger type apparatus. The essential oil was characterized by Gas Chromatography Mass Spectrometric (GC/MS) analysis (Fig. 3). From GC-MS analysis of berry oil of 04 samples, it was observed that α-Sabinene, 4-Terpinen and Limonene were major compounds. The compound Sabinene was found only in HP 3 (89.7%) and not found in others, 4-Terpineol was highest in JK 1 (37.6%) while lowest in HP 3 (0.51), Limonene was highest in HP 1 (56.16%) followed by HP 2 (40.73) while absent in others.

Agro-technology based enhancement of targeted cannabinoids

The sowing spacing showed significant effect on growth parameters of cannabis (Fig. 4) and maximum values of growth parameters (plant height- 238 cm, number of branches plant^{-1} -37.59, stem diameter -12.61 mm) were observed at 45x30 cm spacing while minimum in 30x30 cm spacing. Maximum test weight of seed (10.73 g) and seed yield/plant (9.87/10.73 g) is significantly higher under the spacing 60X30 cm. Nitrogen levels significantly affected the growth parameters. Maximum values of growth parameters were observed at 100% RDF (recommended dose of fertilizer) nitrogen level and minimum in 75% RDF.

Among nitrogen levels, maximum yield attributes, test weight (9.54 gm) was significantly higher under the nitrogen level 125%, while seed yield per plant (8.88 gm) was higher under the nitrogen level 100% than others.

Outreach Programmes/ Extension Activities

For popularization of CSIR-NBRI green technologies, various extension/outreach activities such as 05 training programmes were conducted on *Betelvine*

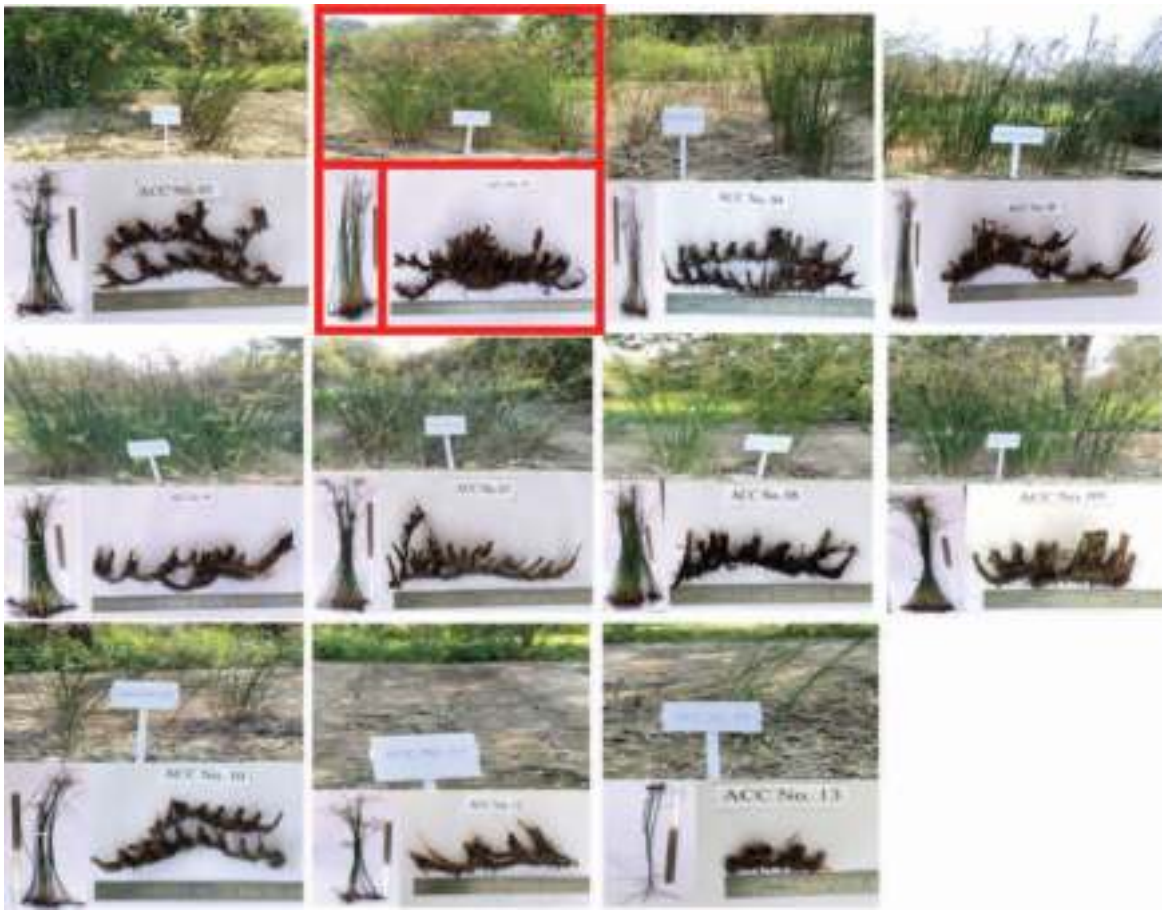

Fig. 2: Eleven germplasm of Nagarmotha growing at CSIR-NBRI Banthra Research Centre (low land). The accession no. 3 shows the best growth (in red).

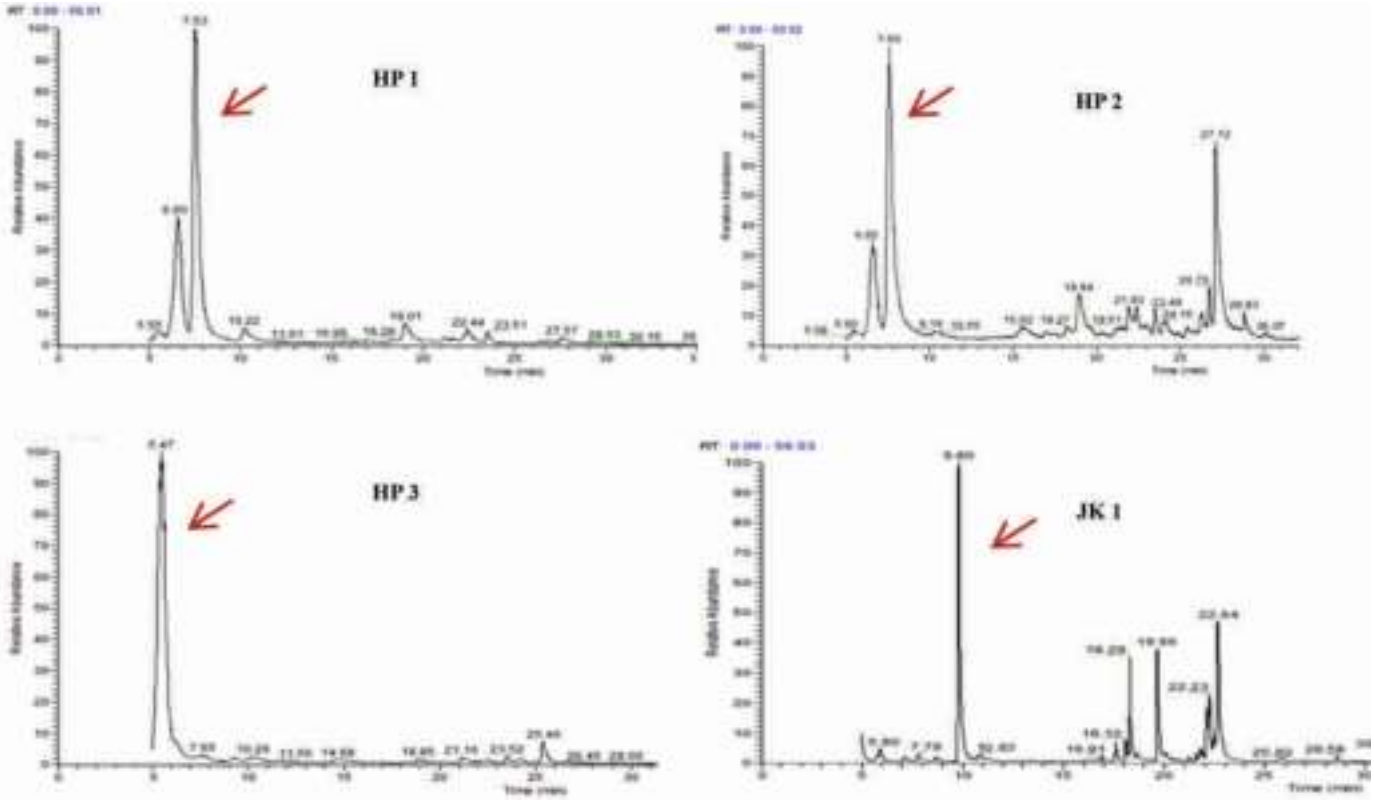

Fig. 3: GC-MS analysis of Juniper oil for major composition (location wise).

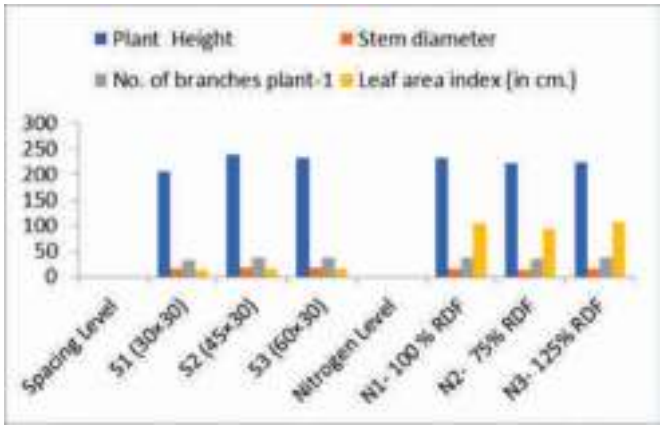

Fig. 4: Evaluation of different qualitative and quantitative parameters in Cannabis. Plant height (cm), Stem diameter (mm).

cultivation where 225 farmer participated. 22 training programme were conducted on cultivation of turmeric for extraction of essential oil from leaf waste and about 863 farmers were trained. There field visits were organized at Distant Research Centre (Banthra) for students and teachers from various schools and colleges.

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Standardization of Press-mud (an industrial waste) for organic cultivation of *Andrographis paniculata*

The standardization of the package of various practices for organic cultivation of *Andrographis paniculata* after application of pressmud, is as following-

Growth parameters and biomass yield

The results indicated that plant height, number of branches, and stem diameter increased with increasing levels of press-mud from control (without press-mud) to 15 t ha^{-1}. The economic part of the *A. paniculata* is biomass, which significantly increased up to 7.5 t ha^{-1} showing the value of 21.79 q ha^{-1} (Fig. 1). Further increase in doses of press mud did not affect the plant height, number of branches, stem diameter, and biomass yield of the *A. paniculata*.

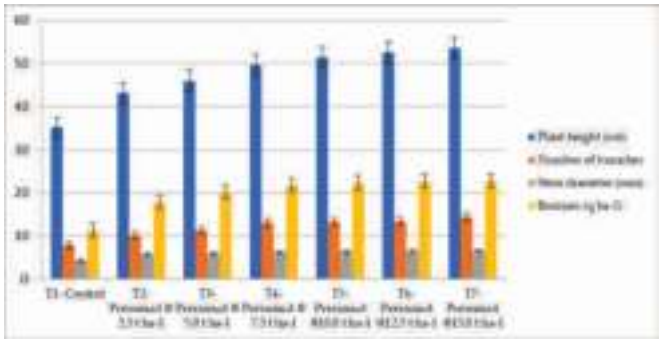

Fig. 1: Effect of different doses of pressmud on biomass yield and attributing characteristics of *Andrographis paniculata*

Nutrient content

Nitrogen (N) content significantly increased corresponding to an increase in press-mud doses. The minimum nitrogen content was recorded in control while maximum content was observed with higher doses of press mud @15 t ha^{-1} for the root and leaf and 12.5 t ha^{-1} press mud for the stem. No trend was observed for phosphorus (P) content in the root of the *A. paniculata*, however, phosphorus content significantly increased in stem and leaf with increasing doses of press mud up to 15 t ha^{-1}. No trend was observed for Sodium (Na) and potassium (K) content in the root, stem and leaf respectively. The increasing trend of calcium (Ca) and magnesium (Mg) content was observed in the root and leaf of the plant with increasing doses of the press mud. However, no trend was observed for calcium and magnesium content in the stem of the *A. paniculata* (Fig. 2).

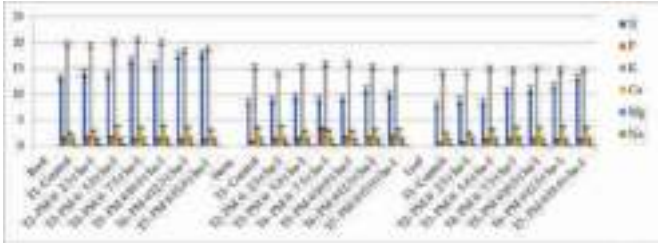

Fig. 2: Nutritional contents in biomass of *Andrographis paniculata* (g Kg^{-1} FW)

Micronutrients content

Zinc (Zn) content significantly increased in root and stem. However, no trend was observed for the zinc content leaves of the plant. A significant increment in iron (Fe) content was recorded with all doses of press mud application in comparison to control in root, stem, or leaf. Maximum iron content was recorded in stem followed by root and leaf respectively by the application of press mud. Copper (Cu) content

increased with increasing doses of press mud. Similar trend was also recorded in the case of manganese (Mn) and molybdenum (Mo) content in plants (Fig. 3).

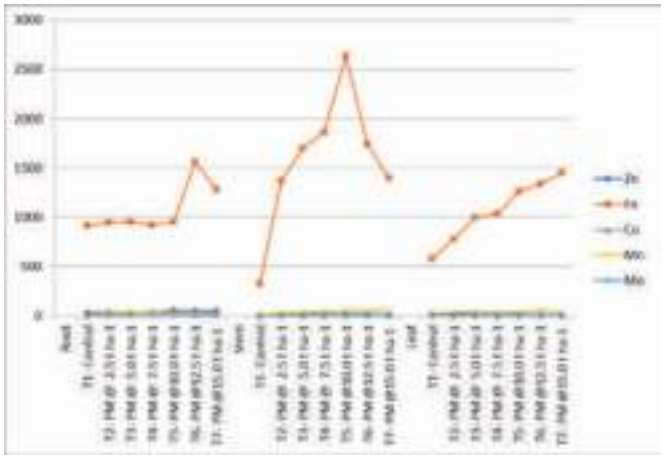

Fig. 3: Micro-nutrient contents (mg Kg^{-1} FW) in biomass of *Andrographis paniculata* at different doses of press mud application.

Heavy metals content

The high chromium (Cr) content was recorded in the leaf followed by the stem and root. The chromium content significantly increased corresponding to press mud application over control. Similar trend was also recorded in the case of Nickel (Ni) content in the plant. The selenium (Se) content increased in the root and stem of the plant with increasing press mud doses. However, no trend was noted in the leaf of the plant. The selenium was absorbed by the plant in a higher amount, but it was not translocated in the leaf of the plant. The maximum content of the selenium was recorded in the root followed by the stem and leaf. The arsenic (As) content was increased in the press mud treatments, but no trend was recorded either in root, stem, or leaf. No trend was recorded in lead (Pb) either in root, stem, or leaf, as well as in cobalt (Co) and cadmium (Cd) content in plants (Fig. 4).

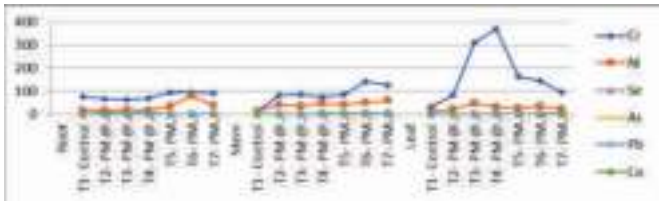

Fig. 4: Heavy metal content (mg Kg^{-1} FW) in different tissues of *Andrographis paniculata* corresponding to press mud application over control.

Quantification of plant extract and Secondary metabolites (andrographolide and neo-andrographolide, wogonin)

Secondary metabolites, andrographolide, neo-andrographolide, and wogonin were quantified from *A. paniculata* plant extract with respect to the press mud doses. Andrographolide and neo-andrographolide are a labdane diterpenoid. Andrographolide, an extremely bitter substance, is the main secondary metabolite of *A. paniculata*. The andrographolide content in plant extract ranged from 86.51 to 98.58 mg kg^{-1} with a minimum in press mud @ 15 t ha^{-1} and maximum in press mud @ 2.5 t ha^{-1}. The neo-andrographolide ranged from 39.89 to 58.69 mg kg^{-1} with the lowest in press mud @10.0 t ha^{-1} and highest in the control treatment.

Wogonin is an O-methylated flavone, quantified in the biomass of *A. paniculata*. The wogonin content was found very less in *A. paniculta*. It ranged from 0.003 to 0.004 mg kg^{-1} in the plant extract of *A. paniculata*.

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Plant Conservation and Agro-technology

Bambusetum

A Bambusetum**,** with a collection of sixty seven (67) spp. of Bamboo from different regions/parts of India, was established at Distant Research Centre (DRC) of CSIR-NBRI, at Banthra, Lucknow for display, education, conservation and related studies. The aim is to have an exhaustive collection of bamboos that can be successfully grown in partially sodic waste land and development of integrated value chains for bamboo products. Appropriate training and technology, access to capital, business development services and practical government policies are required for the poor to access markets and transform poverty in to prosperity through providing income generation opportunities.

The Bambusetum was enriched with introduction of 12 more bamboo species including *Bambusa nutans*, *B. glaucescens*, *B. vulgaris*, *B. mizorameana*, *Ochlandra travancoria*, *Dendrocalamus latiflorus*, *Melocanna bambusoides*, *Melocalamus compactiflorus*, *Cephalostachyum pergracile*, *Guadua angustifolia*, *Schizostachyum polymorphum* and *S. dulloa* (Fig. 1).

Fig. 1: Field view of Bambusetum at Distant Research Centre, Banthra.

Amaranthus

The amaranth germplasm repository was enriched by 1223 accessions of Amaranth spp. (consisting *A. hypochondriacus, A. cruentus* and *A. caudatus*) and evaluated them for various agronomically important quality traits and identification of trait specific lines as well as preparation of core set for further marker studies. This will lead to development of high yielding protein rich varieties in an accelerated manner through marker assisted breeding. The Improved lines of grain amaranth will help the farmers to fetch good prices in local market. The aim of the study is to explore the importance of grain amaranth as a climate resilient crop, as the yield per plant by grain amaranths is much impressive even under drought-stress, conditions of salinity, heavy metals and pests due to presence of high phenolic content which helps in tolerating the biotic and abiotic stress. The work will be focusing on collection of grain amaranth germplasm across country, its maintenance and phenotypic characterization for major agronomic and quality traits.

Screening of Tuberose variety for cultivation in partially sodic land

The work on collection, conservation and evaluation of tuberose (*Polianthes tuberosa* L.), including single type and double type flower is ongoing. Among these varieties, screening of the suitable one for production of long-lasting flower spikes for economically and sustainable utilization of sodic waste land is in

progress. Total 30 varieties, including single and double type flower, have been collected and planted during the period (Fig. 2). Some varieties of tuberose were also exposed to gamma induced radiation for mutation to obtain the new mutant variety. During the period 04 new varieties has been added to the collection.

Fig. 2: Field view of Tuberose varieties at Distant Research Centre, Banthra.

Application of Carbon Dots as Growth Enhancers in Agriculture system

A systematic exploration of application of carbon dots in agricultural crops was done. The effect of carbon dots on the crop physiology, photosynthesis and yield attributes along with the crop yield and biomass yield are being measured. 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, are kind of nanotechnology-based plant growth regulators or enhancers, which are not much explored for increasing agricultural production in a sustainable manner (Fig. 3). 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. These carbon

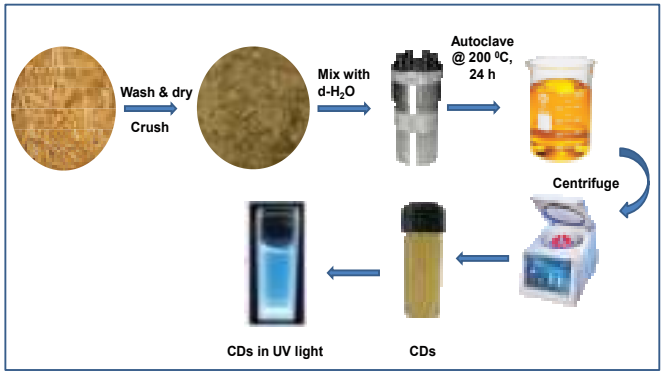


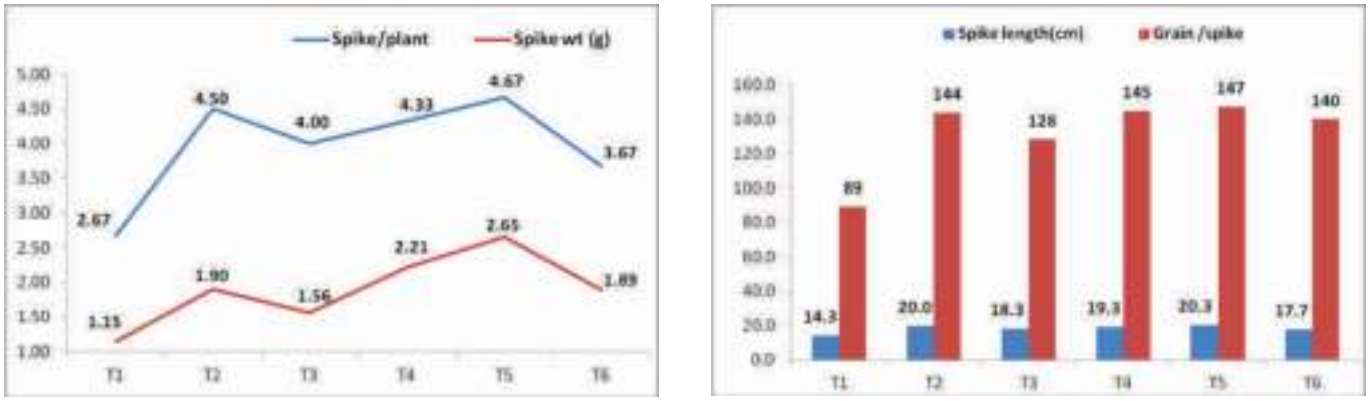
Fig. 3: Synthesis of CDs from wheat straw though hydrothermal approach.

dots are known to induce fluorescence and activate photosynthesis in the plant system, which has a direct bearing on the agricultural production.

To study the efficacy of these carbon dots on plant growth and their yield performance, field experiments were conducted at distant research centre, Banthra. The effect of CDs on yield of paddy crop (Grain) and biomass (Straw) showed a strong positive correlation with the increase in CDs dosage. The experiments showed that the Seedlings treatments (ST) and Foliar spray (FS) of CDs application are both equally effective in increasing the paddy crop yield. The combined effect of ST & FS is more pronounced as compared to the ST alone. All the yield attributes were significantly affected by the seedling treatment and foliar spray. Data revealed that spike per plant and grain per spike were 37.9 and 35.9 % increased respectively however, spike length was marginally increased (11.3%) as compared to control. Spike weight and grain weight per spike was also increased up to 51.2% and 51.6% respectively.

Synthesis of Zeolites from Fly Ash for Agriculture Application

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 power-plants are also known as "intelligent fertilizers" because of the ion exchange capacity (CEC) and high porosity. They have improved fertilizer efficiency resulting in increased productivity and reduced nutrients being leached to the environment. Zeolite application along with recommended dose of fertilizer (RDF) has significant effect on plant growth attributes of paddy. Application of 2% zeolite along with RDF (T5) recorded significantly higher plant fresh weight at all the growth stages i.e., 30, 60 and 90 days after transplanting (DAT). The higher values for average growth rate of the plant recorded at diverse time interval also confirmed the same trend. Spike length and its weight, number of grains per spike and 1000 grain weight are the important yield attributes recorded during harvesting of the crop, and were significantly influenced by all different sources and levels of fertilizers along with zeolite. Significantly higher values for yield attributes like Spike length and its weight, number of grains per spike and 1000 grain weight, were obtained by application of 2% zeolite



[A] **[B]**

Fig. 4: Effects of zeolite application on paddy field. (A) Average spike/plant and spike weight. (B) Average spike length and grain/ spike.

along with RDF (Fig. 4). Higher values of these yield parameters significantly influenced the biomass yield and grain yield obtained in these treatments. Further study on response of zeolite on other agricultural crops like wheat chickpea are under progress.

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Plant Taxonomy; Evolution and diversification of gymnosperms; Plant diversity and conservation; Improvement of floricultural crops and ornamental plants; Domestication of wild ornamental plants

Cycad Research

Fieldworks were carried out in Eastern Ghats (Andhra Pradesh and Odisha), and Northeast India to collect plant samples for morphological and molecular characterization. This activity will help in the ongoing research on diversification and evolution of Cycas in South and Southeast Asia. Observations on the reproductive plant parts were also made to understand the bottlenecks of reproduction in wild populations. Several seedlings were also collected and planted in Cycad House and Indian *Cycas* Garden for further studies in *ex-situ* at CSIR-NBRI Botanic Garden.

Floral Variety Development

Mutants of Canna 'Bengal Tiger' and Nymphaea 'Colorado' showing variegated flower characters have been isolated and morphological characterization has been done. Stability test is being carried in all the mutants.

Domestication of Wild Ornamental

Successfully domesticated ornamentals from our wild collection in the garden include *Iris* sp., *Hoya* sp., *Barleria* sp., *Begonia* sp., *Impatiens* sp., Orchids, *Nymphaea*, lotus, etc.

Plant Introduction and Conservation

Victoria amazonica, 25 varieties of lotus including rare 108 petal lotus from Manipur, 15 species/varieties of *Nymphaea*, 17 varieties of Canna, 8 varieties of *Hoya*, 5 varieties of *Rhynchostylis*, 5 varieties of *Tolumnia*, 50 varieties of *Dendrobium, Dischidia pectinoides*, *Oxystelma seculentum, Ludwigia adscendens, Ultricularia aurea, Marsilea minuta, Nuphar lutea, Hydrocleys nymphoides*, 2 varieties of Rose, 5 varieties of *Heliconia, Costus insignis* and several other ornamental and threatened plants were introduced in the Botanical Garden.

Fig. 1: Some of the newly introduced Lotus varieties in Botanic Garden.

New Facility Created

Indian *Cycas* Garden and Waterlily-Lotus Conservation Centre are two new attractive facilities created at CSIR-NBRI to serve as a national reference centres for these important plant groups. These developments are a part of the R&D activity for the establishment of *Cycas* as a model plant for *ex-situ* conservation of threatened plants and future restoration of natural populations, and conservation of various Indian species of *Nymphaea* and Lotus.

Threatened Plants of India Database

A CSIR-NBRI online database has been created for enlisting the plant species that are threatened in India. The current database includes species from all groups of plant taxa and provides their IUCN conservation status.

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New plant species discovered

Pyrrosia sarthalensis (Polypodiaceae) was described as a new species from Kathua district, Jammu & Kashmir (Bani valley, North-Western Himalaya), India. *P. sarthalensis markedly differs from its allied species P. flocculosa* in smaller plant height, having basifixed, entire rhizome scales (vs. pseudopeltate, margin ciliate) and lacking hydathodes (vs. hydathodes present). This new species recorded as epiphyte whose elevation varies from 1400–1500 m above mean sea level, having brown sori, formed only on the upper half of the frond. Other diagnostic features include grooved rhizomes, rhizome scales, lamina size and structure, sori placement, size and structure, and spore characters (Fig. 1).

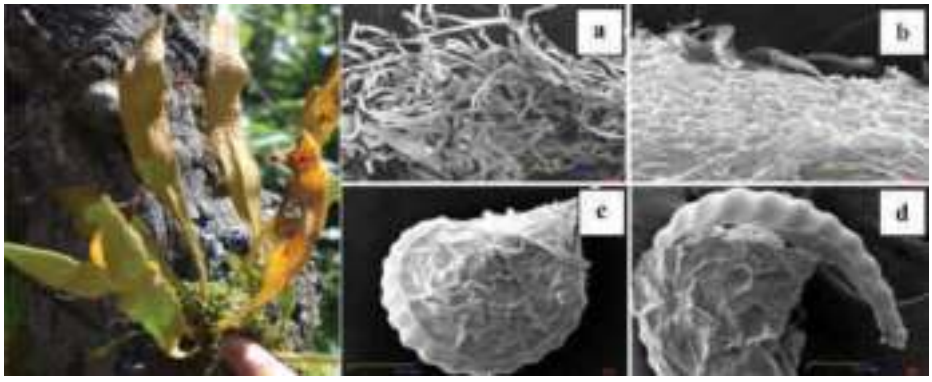

Fig. 1: Newly discovered *Pyrrosia sarthalensis* (habit and scanning electron microscope (SEM) micro-morphology of rhizome (a), lamina (b) and sporangia (c-d).

Swertia patnitopiansis (Gentianaceae) was described from Jammu and Kashmir (Patnitop Hill, North-Western Himalaya), India as a new species endemic to Himalaya. *S. patnitopiansis* is morphologically similar to *S. cordata* but differs in biennial habit (vs. annual), plant height 10–20 cm (*vs* 30–70 cm), 1 or 2 branches (*vs* 8–25), leaf base rounded, obtuse or cuneate, 4–12 × 3–10 mm (*vs* base cordate, 14–56 × 8–33 mm), 3–6 flowered inflorescence (*vs* 8–12 flowered), 4–5 mm diam. pure white flowers (*vs* 7–10 mm diam. yellowish-white), nectaries globose, fimbriate (*vs* orbicular or rhomboid, membranous dentate) and polyhedral seeds with minutely thorny seed coats (*vs* ellipsoid to globose, winged, Fig. 2). *S. patnitopiansis* is threatened due to tourism, habitat fragmentation, road construction and other developmental activities.

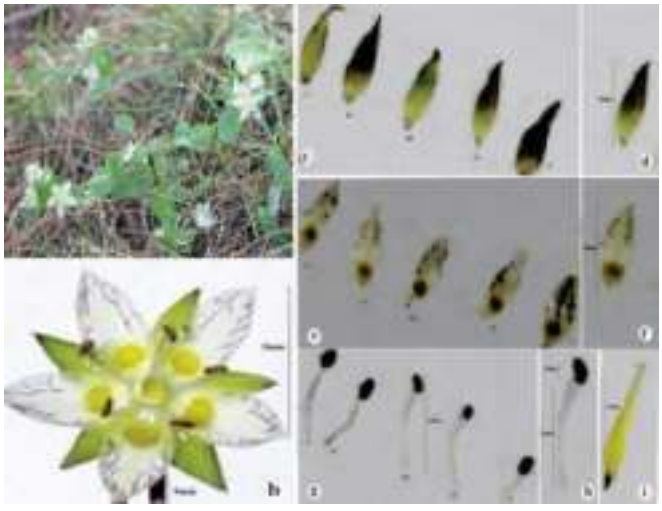

Fig. 2: Newly discovered *Swertia patnitopiansis Bikarma Singh* (*a.* plant habit, b. complete flower, c. five number sepals, d. a single sepal, e. five number petals with nectaries, f. a single petal, g. five numbers stamens, h. a single stamen with filament and anther, i. carpel with ovary, style and bifid stigma).

The wild forest area where species grows is characterised by typical Himalayan coniferous vegetations and categorized as endangered species (categories: B1b(i,ii,iii,v) c(i,ii,iii,iv);C2a(i);D; IUCN 2019).

Field Expedition in Valley of Flowers and Hemkund Glacier, Uttarakhand Himalaya

A field expedition tour programme was undertaken to investigate and collect important flowering plants from the Valley of Flowers and Hemkund Glacier of Uttarakhand. During field visit and while studying the floral component of these regions, it was found that the region is very rich in different varieties of plants which has medicinal as well as ornamental potentials. *Hedychium spicatum* (Zingiberaceae), *Imaptiens devendre* (Balsaminaceae), *Imaptiens sulcata* (Balsaminaceae), *Sassurea obovallata* (Asteraceae), *Rhodolia heterodonta* (Crassulaceae), *Tagetes minuta* (Asteraceae), *Dendrobium fimbriatum* (Orchidaceae), *Dendrobium amoenum* (Orchidaceae), *Coelogyne cristata* (Orchidaceae), *Bulbophyllum umbelatum* (Orchidaceae), *Geranium nepalense* (Geraniaceae), *Pepromia tetraphyllum* (Piperaceae) and *Hoya parasitica* (Asclepidiaceae) (Fig. 3) were collected as a live plants and introduced in NBRI Botanic Garden for the first time from Uttarakhand. Besides, several seeds of *Pyracantha crenulata, Ribes orientales, Rosa sericea, Rosa macrophylla, Impatiens sulcata, Acer laevigatum,*

Fig. 4: Plant enrichment in NBRI Botanic Garden from Uttarakhand Himalaya (a & d. *Begonia* sp., b. *Tagetes minuta*, c. Datura and *Saussurea* sp., e. *Hoya parasitica*, f. different species of orchids, g. Juniperus sp., h. *Pyracantha* sp.).

Fig. 3: Natural beauty and plant composition in Valley of Flowers and Hemkund, Uttarakhand Himalaya (a-c: site views, d. *Pyracantha crenulata* (D.Don) M.Roem., e. *Impatiens sulcata* Wall., f. *Saussurea obvallata* (DC.) Sch.Bip., g. *Bistorta affinis* (D.Don) Greene, h. *Potentilla atrosanguinea* G.Lodd.)

Himalayan Datura, Polygonatum verticillatum and *Heraculum glucum* were also collected for introduction in the NBRI Botanic garden as a new germplasm of Himalaya (Fig. 4). During field tour, different accessions of *Juniperus communis* were also collected for extraction of essential oils and value additions.

Collection of Indian Lotus (*Nelumbo nucifera* Gaertn.) accession for R&D and living germplasm for NBRI Botanic Garden

According to the World Checklist of Vascular Plants (WCVP), only two species of *Nelumbo* Adans. (Nelumbonaceae), viz. (1) *Nelumbo lutea* (Willd.) Pers. (American Lotus) and *Nelumbo nucifera* Gaertn. (Indian Lotus), are described. Under NBRI lotus mission project, 13 accessions of lotus were collected from different geographic locations. This includes accessions of Uttar Pradesh (5 acc. Moradabad, 1 acc. Saharanpur, 1 acc. Itawah, 2 acc. Chitrakoot, 1 acc. Banda, 1 acc. Fatehpur, 1 acc. Mujjaffarnagar) and Uttarakhand (1 acc. Kashipur) [Fig. 5]. The living germplasm/accessions collected from these locations were planted in NBRI Botanic Garden and Banthra Research Station for genepool maintenance and conservation. Conservation of these germplasm is still continuing in the planted area. The molecular profiling, chemistry and pharmacological activities of these accessions are underway.

Fig. 5: Lotus collection from different geographic locations of Uttar Pradesh and Uttarakhand.

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R & D Outputs

CSIR NBRI Estd. 1953

WHERE PLANT-BASED RESEARCH TOUCHES LIFE THROUGH INNOVATION

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PATENTS GRANTED/FILED

Patents Granted (International)

Sr. No.	Title	Inventors	Country	Grant Date	Patent No.
1.	A process for preparation of a novel insecticidal chitinase toxic against whiteflies, it's encoding nucleotides and application there off	PK Singh, SK Upadhyay, K Chandrashekar, Sharad Saurabh, Rahul Singh, Preeti Rai, Harpal Singh, Manisha Mishra, AP Singh, PC Verma, KN Nair, Rakesh Tuli	Brazil	July 06, 2021	BR112014 0159300
2.	Herbal composition for the management of diabetes	CS Nautiyal, ChV Rao, SK Ojha, AKS Rawat, D Mani, Anirban Pal, Dinesh Kumar	Sri Lanka	November 08, 2021	18977
3.	A method for production of transgenic cotton plant.	SV Sawant, RK Tripathi, Asif Idris	Brazil	March 29, 2022	BR 11 2016 008009-2

Patents Granted (National)

Title	Inventors	Application No.	Grant Date	Patent No.
Natural hair dye and its applications	Mahesh Pal, Manjoosha Srivastava, Ranjan Banerji	0776DEL2010	September 08, 2021	376653

Patents Filed (National)

Sr. No.	Title	Inventors	Application No.	Filed Date
1.	A curcumin rich nano-formulation for enhancing bioavailability of curcumin and method of preparation thereof	BN Singh, SK Barik, Prateeksha, SC Gupta, VK Sharma, ChV Rao	202111045277	October 04, 2021
2.	A nanocomposition of flavonoids and method of its preparation thereof	BN Singh, SK Barik Prateeksha, SC Gupta, VK Sharma, NK Nagpoore, ChV Rao	202111052185	November 12, 2021
3.	Synergistic microbial formulation for arsenic removal	PK Srivastava, Poonam C Singh, S Srivastava, M Sharma, Anshu, M Naseem, S Chauhan, P Dubey, J Kaur, P Tripathi, V Srivastava, RD Tripathi, SK Barik	202211013360	March 11, 2022

HUMAN RESOURCE DEVELOPMENT

Trainings Received by Individual

Sr. No.	Name of Person (s)	Subject of Training Course	Organizer/ Place	Date/ Period
1.	Dr. Manjoosha Srivastava	National Accreditation Board for Testing and Calibration Laboratories	NABL, Gurugram (Online Mode)	August 30-31, 2021
2.	Dr. Manish Tiwari, Dr. MH Asif, Dr. VV Wagh and Dr. Manish Bhoyar	Training Programme on Enhancing Accountability and Responsiveness in Scientific Organizations	Institute of Public Enterprise, Hyderabad	September 27-October 01, 2021
3.	Dr. GK Mishra and Dr. Vijay Anandraj S	Induction Programme for Newly Recruited Scientist	CSIR-HRDC, Ghaziabad at CSIR-IHBT, Palampur	October 23-29, 2021
4.	Dr. Anju Patel	Laboratory Management System and Internal Audit as per ISO/IEC 17025: 2017	CIPET, Lucknow	December 20-23, 2021
5.	Dr. SK Rath and Dr. BN Singh	Science, Technology and Emerging Trends in Governance for Scientists and Technologists of the S & T Departments, Government of India	Indian Institute of Public Administration, New Delhi	December 20-24, 2021
6.	Dr. Anju Patel and Dr. Richa Rai	Workshop on "Basic Statistical tools in Research and Data Analysis"	CSIR-HRDC, Ghaziabad	February 1-4, 2022
7.	Dr. Anju Patel and Dr. Aradhana Mishra	Training Programme on Science and Technology for Rural Societies for Women Scientist & Technologist	Indian Institute of Public Administration, New Delhi	February 21-25, 2022
8.	Dr. Devendra Singh, Dr. Lal Bahadur and Dr. RC Nainwal	Training Programme on Science & Technology for Rural Societies	Indian Institute of Public Administration, New Delhi	March 07-11, 2022

Trainings Imparted to Groups

E-trainings organized by Botanic Garden, CSIR-NBRI, Lucknow

Sr. No.	Subject of Training	No. of Participants	Date/Period
1.	Home Gardening	207	July 06-08, 2021
2.	Bonsai Technque	193	July 13, 2021
3.	Dehydrated Floral Crafts	127	July 20, 2021
4.	Biofertilizer Production and Application Techniques for Farmers of Nabrangpur, Odisha	40	October 19-20, 2021

Other Group Trainings Imparted

Sr. No.	Co-ordinating Division	Subject	No. of participants	Place	Date
1.	Distant Research Centre, Banthra	Training programmes on Betelvine cultivation	29	DRC, Banthra, CSIR-NBRI	September 24, 2021
			37		December 13, 2021
			34		December 17, 2021
			33		December 20, 2021
			47		December 27, 2021
			26		December 31, 2021
			36		March 15-16, 2022
2.	Botanic Garden	Dehydrated Floral Crafts	99	CSIR-NBRI, Lucknow	July 29, 2021
			44		July 16, 2021
			39		September 10, 2021
			59		November 24, 2021
			42		November 25, 2021
3.	Botanic Garden	Home Gardening	11		March 23-25, 2022
4.	Botanic Garden	Bonsai technique	19		March 28, 2022
5.	Botanic Garden	Dehydrated Floral Crafts	10		March 29, 2022

Trainings Imparted Under CSIR-Aroma Mission

Subject of the Training: Cultivation of turmeric for essential oil from leaf			
Sr. No.	**No. of Participants**	**Place**	**Date**
1.	81	Deendayal Research Institute, Chitrakoot	July 15, 2021
2.	57	Bhagaulitirtha, Barabanki	August 09, 2021
3.	48	Krishi Vikas Kendra, Ayodhya	August 16, 2021
4.	44	SAGE University, Bhopal	September 03, 2021
5.	28	Nawabganj, Unnao	September 09, 2021
6.	26	Dubauilya, Basti	September 10, 2021
7.	29	Banthra Lucknow	September 24, 2021
8.	58	Mavaiya, Hardoi	October 08, 2021
9.	31	Ol, Mathura, UP	November 25, 2021
10.	37	Banthra, Lucknow	December 13, 2021
11.	34	Banthra, Lucknow	December 17, 2021
12.	33	Banthra, Lucknow	December 20, 2021
13.	47	Banthra, Lucknow	December 27, 2021

14.	26	Banthra, Lucknow	December 31, 2021
15.	08	Seoni, Barghat, MP	February 08, 2022
16.	35	Govindpitaujiya, Muzaffarpur, Bihar	February 12, 2022
17.	35	Sahbazpur, Kanti, Muzaffarpur, Bihar	February 13, 2022
18.	93	Tetariya, Bhojpur, Bihar	February 17, 2022
19.	33	Bokaro, Jahrkhand	March 03, 2022
20.	29	Deoghar, Jharkahnd	March 04, 2022
21.	15	Integral University, Lucknow	March 12, 2022
22.	36	Banthra, Lucknow	March 15, 2022

Skill Development Programmes Organized

Sr. No.	Name of the Programme and title	Date/period	Number of the candidates
1.	Training Programme under the UGC STRIDE scheme (Quality Analysts in herbal drug industries)	March 31, 2022	30
Under CSIR Integrated Skill Initiative			
2.	Quality Analyst for herbal industry	August 31-September 28, 2021	07
		November 07-December 08, 2021	07
		March 27, 2022-April 01, 2022	30
3.	Phytochemicals Analysis Technician	August 05-September 17, 2021	06
4.	Biofertilizer Production and Application Techniques	August 16-September 25, 2021	14
5.	Plant Tissue Culture Technician	September 14, 2021-October 13, 2021	11
6.	Bioinoculant Producer for agriculture	September 16- October 28, 2021	13
7.	Biofertilizer Production and Application	October 11-13, 2021	30
8.	Fractionation, Separation & Detection of Adulteration in Essential Oils and Product Development	March 07-11, 2022	13

HONOURS/AWARDS/DISTINCTIONS

Honours/Awards/Recognitions Received by Individual

Sr. No.	Name of the Person	Designation	Award (s)
1.	Dr. GK Mishra	Scientist	Fellow of Linnean Society of London (FLS)
2.	Dr. KM Prabhukumar	Senior Scientist	• Kerala State Biodiversity Award for the **Best Taxonomist** for the year 2021 • Fellow of Linnean Society (FLS), London (2021) • Dr. P.D. Sethi National Award (2nd Prize) for the paper "Identification of validated substitutes for Asoka (*Saraca asoca* (Roxb.) Willd.) by phytochemical and pharmacological evaluations" • **Eponymy Achievement:** A new species, *Neanotis prabhuii* (Rubiaceae) from India, have been named in recognition of contribution to the field of Angiosperm Taxonomy and Systematics.
3.	Mr. AK Maurya	DBT JRF	Best Poster Presentation Award in the National Seminar on *Recent developments in science & technology* organized by the Utkarsh School of management and technology, Bareilly, Uttar Pradesh, India
4.	Dr. SK Ojha	Senior Principal Scientist	B.N. Mehrotra Medal- 2020 by society of ethnobotanists
5.	Dr. VV Wagh	Senior Scientist	• Dr. D.C. Pal Medal for the year 2020 by Society of Ethnobotanist • Fellow of Society of Ethnobotanist (FES) • Fellow of Indian Association for Plant Taxonomy (FAPT)

Member, Editor, Referee, Expert, Reviewer, Judge etc. (selected, recognized, enrolled, empaneled, nominated)

Sr. No.	Name of the person	Details
1.	Dr. Aditi Gupta	Life Membership for International Society of Environmental Botanists (ISEB), Lucknow
2.	Dr. Anju Patel	Life Membership of National Environmental Science Academy, New Delhi
3.	Dr. Aradhana Mishra	• Editor of the PLoS One • Life membership of International Society of Environmental Botanists (ISEB). • Member of Scientific Advisory Board of Journal of Complementary Medicine Research • Member, Indian Science Congress Association (ISCA), Kolkata.

4.	Dr. AP Sane	Expert Member of Teachers Associateship for Research Excellence (TARE), SERB, Government of India.
5.	Dr. BN Singh	Editor of 'Frontiers in Fungal Biology', 'Surgery Insights Cancer Biology Journal' 'Ocean Journal of Biotechnology and Bioengineering'
6.	Dr. ChV Rao	• CPCSEA Nominee by Ministry of Environment and Forest, New Delhi • Research council member of Dr. APJ Adbul Kalam Technical University, Amity University and Integral University, Lucknow
7.	Dr. GK Mishra	• Reviewer of Journal of '*Threatened Taxa*', '*Phytotaxa*', '*Lichenologist*' and '*Taiwania*' • Life Member of Mycological Society of India
8.	Dr. KJ Singh	• Member of *International Waterlily* & *Water Gardening Society,* Royal Horticulture Society, Indian Society of Ornamental Horticulture, Bougainvillea Society of India • Joint Secretary, Society of Ethnobotanists
9.	Dr. KM Prabhukumar	• Member of The Society of Herbarium Curators, United State • Member of IUCN Species Survival Commission • Member of IUCN SSC Medicinal Plants Specialist Group 2021-2025 • Member of IUCN SSC Western Ghats Specialist Group 2021-2025 • Section Editors of journals 'Phytotaxa' & 'Webbia'
10.	Dr. Manish Tiwari	Review Editor on the Editorial Board of Plant Abiotic Stress are in Journal Frontiers in Plant Sciences
11.	Dr. PK Srivastava	• Life Member of National Environmental Science Academy, New Delhi • Fellow of International Society of Environmental Botanists, Lucknow
12.	Dr. Poonam C Singh	• Associate Editor, BMC Microbiology • Member, Association of Microbiologists of India
13.	Dr. Priyanka Agnihotri	Editorial board member of 'Yogayu Research' journal, Patanjali Research Institute, Haridwar
14.	Dr. Richa Rai	Life Membership for International Society of Environmental Botanists (ISEB), Lucknow
15.	Dr. SK Behera	Reviewer of Ecological Engineering, Environmental Monitoring and Assessment
16.	Dr. SV Sawant	• Editorial Board manager in Nature Scientific Reports • Associate Editor of Frontiers in Genetics
17.	Dr. Sanjeeva Nayaka	Membership of International Association for the years 2021-2025
18.	Dr. Susheel Kumar	Review Editor in Frontiers in Plant Sciences
19.	Dr. TS Rana	• Member of IUCN Species Survival Commission • Member of IUCN SSC Western Ghats Specialist Group 2021-2025
20.	Dr. Vijay Anandraj S	Reviewer Editor of Frontiers in microbiology

PHDs AWARDED AND SUBMITTED

Ph.D Theses Awarded

Sr. No	Name of the Student	Title of Thesis	Guides	University
1.	Mr. Ambedkar Gautam	Study on role of sucrose in amelioration of arsenic toxicity in C_3 and C_4 plants	Dr. Shekhar Mallick, Principal Scientist/ Prof. Kavita Sah	BHU, Varanasi
2.	Mr. Anil Kumar	Over-expression of glutaredoxin (*Grx*) gene and its role in drought stress.	Dr. Indraneel Sanyal, Senior Principal Scientist/Prof. Veena Pande	Kumaun University, Nainital
3.	Mr. Ankesh Pandey	Expression of *Cocculus hirsutus* trypsin inhibitor (*ChTI*) for resistance to *Helicoverpa armigera* and *Spodoptera litura*.	Dr. Indraneel Sanyal, Senior Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
4.	Mr. Akram Ansari	Morphological, biochemical and molecular responses of Guar (*Cyamopsis tetragonoloba* (L.) Taub.) to drought stress	Dr. Vivek Pandey, Chief Scientist/Prof. Veena Pande	Kumaun University, Nainital
5.	Mr. Danish Husain	Systematic studies in the genus *Aconitum* L. (Ranunculaceae) from India	Dr. Priyanka Agnihotri, Principal Scientist/Dr. T Husain, Former Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
6.	Ms. Nasreen Bano	Transcriptome meta-analysis and genome-wide identification of Tubby-like protein (TLP) gene family in Gossypium species	Dr. SK Bag, Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
7.	Ms. Neha Agrawal	Role of NPR1 in global nucleosomal remodeling in *Arabidopsis thaliana*	Dr. Samir V Sawant, Chief Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
8.	Ms. Nishtha Mishra	Deciphering the interaction strategiesof rice and Trichoderma under elevated CO_2 condition	Dr. Aradhana Mishra, Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
9.	Ms. Poorwa Badola	Molecular components involved in miR858-dependent plant growth and development	Dr. PK Trivedi, Former Chief Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.

10.	Ms. Preeti Patel	Deciphering the role of stress/elicitor on the differential modulation of gene expression and subsequent production of secondary metabolites in *Solanum virum* Dunal	Dr. Debasis Chakrabarty, Senior Principal Scientist & Prof. Satya Shila Singh	BHU, Varanasi
11.	Ms. Radha Shivhare	Transcript profiling of pearl millet (*Pennisetum galucum* L.) under drought stress and functional characterization of a stress-responsive gene	Dr. Charu Lata, Former Scientist/ Dr. PS Chauhan, Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
12.	Mr. Raghvendra Dubey	Physiological behavior of stomata towards exogenous and endogenous stimuli in cotton	Dr. PA Shirke, Chief Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
13.	Mr. Rahul Michael	Light-mediated transcriptional regulation of terpenoid biosynthetic pathway in *Arabidopsis thaliana*	Dr. PK Trivedi, Former Chief Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
14.	Mr. Ram Jatan	Identification and characterization of plant growth romoting rhizobacteria-responsive microRNA(s) from plants	Dr. Charu Lata, Former Senior Scientist/ Dr. PS Chauhan, Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
15.	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, Chief Scientist/ Prof. Vivek Prasad	Lucknow University
16.	Ms. Ria Khare	Molecular mechanisms involved in arsenic stress response under limiting sulphur condition in *Arabidopsis thaliana* natural variation	Dr. PK Trivedi, Former Chief Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
17.	Ms. Sonali Mehrotra	Effect of elevated CO_2 on leguminous edible crop under free air concentration enrichment (FACE) system	Dr. PA Shirke, Chief Scientist/ Dr. KP Tripathi	Uttarakhand Technical University, Dehradun
18.	Ms. Suchita Lade	Genetic diversity assessment and gender distinction among indigenous collections of *Tinospora cordifolia*	Dr. HK Yadav, Senior Principal Scientist/	Kumaun University, Nainital

19.	Ms. Swati Gupta	Unravel the mechanism(s) of PGPR mediated drought stress amelioration in *Cicer arietinum* L. by proteomics approach	Dr. PS Chauhan, Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
20.	Ms. Vidisha Bisht	Characterization of microbial formulation for rice straw management	Dr. Suchi Srivastava, Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
21.	Mr. Vinay Kumar	Molecular marker and phenotypic trait based genetic diversity analysis in *Lepidium sativum* Linn	Dr. HK Yadav, Senior Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
22.	Mr. Umesh Kumar	Development and characterization of TILLING population of *Gossypium herbaceum* L.	Dr. HK Yadav, Senior Principal Scientist/ Prof. Veena Pande	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
23.	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.

Ph.D. Theses Submitted

Sr. No.	Name of the student	Title	Guides	University
1.	Mr. Balwant Singh Paliwal	Enhancement of anti-quorum sensing property of selected phytochemicals using nanotechnology	Dr. BN Singh, Senior Scientist/ Dr. Jos Mathew	Bundelkhand University, Jhansi
2.	Ms. Isha Pathak	*In-vitro* Studies on Some Selected Endemic, Threatened and Potential Bryophytes and their e*x-situ* Conservation	Dr. AK Asthana, Senior Principal Scientist/ Prof. Geeta Asthana	Lucknow University, Lucknow
3.	Ms. Meenakshi	Functional validation of *CAMTA* gene against drought stress in chickpea	Dr. Indraneel Sanyal, Senior Principal Scientist/ Prof. Veena Pande	Kumaun University, Nainital
4.	Mr. Mithlesh Singh	Analysis of transgenic cotton lines expressing *Tma12* under control of inducible promoters	Dr. PK Singh, Senior Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.

5.	Ms. Nikita Bisht	Plant growth promoting rhizobacteria mediated nutrient stress management in *Oryza sativa* L.	Dr. PS Chauhan, Principal Scientist/ Dr. Poonam C Singh, Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
6.	Ms. Priti Prasad	Data mining of fiber specific features in cotton at different cotton fiber development stages	Dr. SV Sawant, Chief Scientist/Dr. SK Bag, Principal Scientist	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
7.	Ms. Priyanka Upreti	Physiological and biochemical performance of Guar (*Cyamopsis tetragonoloba* (L.) Taub) plant varieties in response to drought stress	Dr. PA Shirke, Chief Scientist/ Dr. LM Pandey	Kumaun University, Nainital
8.	Mr. Priyanshu Srivastava	Studies on Bryophytes of selected areas in Eastern Ghats, India	Dr. AK Asthana, Senior Principal Scientist/ Prof. Neerja Pande	Kumaun University, Nainital
9.	Ms. Shobha Singh	Phytochemical investigation of Sesbania seed with emphasis on modification and functional properties of its gum	Dr. Manjoosha Srivastava, Principal Scientist/ Dr. Karuna Shanker	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.
10.	Mr. Sumit Singh	Floristic inventory through eco-taxonomy and eth-nobotanical studies in Bani valley and Sarthal hill of Kathua district (J&K)	Dr. Bikarma Singh, Senior Scientist/ Dr. Rajendra Bhanwaria	Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P.

S & T Support

CSIR NBRI Estd. 1953

WHERE PLANT-BASED RESEARCH TOUCHES LIFE THROUGH INNOVATION

Vivek Srivastava
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Divisional Head, Planning, Monitoring and Evaluation and Technology Transfer and Business Development

Planning, Monitoring and Evaluation Division

Planning, Monitoring and Evaluation Division plays vital role in smooth management of different R&D activities of the Institute by efficient and effective project management. From project conceptualization its implementation and till its' completion different activities are coordinated smoothly for scientists. Monitoring activities by way of Research Council (RC) meetings, experts meeting is facilitated by the division. It acts as a central point where various activities are managed: Mapping of new Contract R&D Projects in R&D Project module, technical manpower planning and human resource development. The necessary project receipts of the FY 2021-22 of ongoing projects were processed in the CVR, database maintenance for R&D projects (in-house, sponsored, Grant-in-aid, Consultancy, Plan Projects & Network Projects) and Interface with auditors. The division interacted and provided supporting information for submission of internal and external audit parties of CSIR in the auditing of R&D projects, examination, evaluation and processing of indents, parliament question reply, report for PAB, RUD, providing information to CSIR HQ., processing of foreign deputation cases of researchers for various R&D purposes. During the reporting period, a total number of 18 projects including 17 Government Aided Projects (GAP) and 03 Mega Lab Projects (MLP) were initiated.

Projects initiated during April 01, 2021 to March 31, 2022

Sr. No.	Project Number	Project Title	Funding Agency	Principal Investigator/ Co-Principal Investigator / Coordinator / Mentor	Duration
CSIR Funded and In-house projects					
1.	MLP 0054	CSIR Multi- centric Genome Surveilance for COVID-19	CSIR, New Delhi	Dr. SV Sawant	*w.e.f.* 27-Aug-2021 to 26-Feb-2022
2.	MLP 0055	Unraveling the post-translational control of ripening by the MAP kinase pathways in mango	CSIR, New Delhi	Dr. VA Sane	*w.e.f.* 30-Dec-2021 to 31-Mar-2023

3.	MLP 0168	Understanding food energy water nexus in dynamics of critical zone WRJ-1 critical zone observatory	CSIR, New Delhi	Dr. Aradhana Mishra	*w.e.f.* 17-Jan-2022 to 31-Mar-2023
Projects funded by outside agencies					
4.	GAP 3496	Development of Cost effective and iron fortified herbal supplement for dysmenorrheal (menstrual disorder)	DST, New Delhi	PC: Dr. Sharad K Srivastava / PI: Dr. Ankita Mishra	*w.e.f.* 08-Apr-2021 to 07-Apr-2024
5.	GAP 3497	Evaluation of nutritional and anti-nutritional properties and neurotoxicity of *Cycassphaerica* (Cycadaceae) - a food plant used by the tribals of Eastern Ghats of India	DST, New Delhi	PC: Dr. SN Jena / PI: Dr. Pankajini Bal	*w.e.f.* 01-Apr-2021 to 31-Jan-2023
6.	GAP 3498	Seasonal impact on the phyto constituents of *Moringa oleifera* Lam. and their shelf life study	UPCST, Lucknow	Dr. MM Pandey	*w.e.f.* 18-Aug-2021 to 17-Aug-2024
7.	GAP 3499	Elevated CO_2 induced small RNA directed DNA methylation regulation and miRNA expression in low and high-altitude populations of *Arabidopsis thaliana* for adaptive advantages	SERB, New Delhi	Dr. Sribash Roy	*w.e.f.* 18-Oct-2021 to 17-Oct-2024
8.	GAP 3500	Development of rapid and cost effective 'on-farm' diagnostics for plant viruses	DST, New Delhi	PC: Dr. PS Chauhan/ PI: Dr. Yogita Maheshwari	*w.e.f.* 01-Sep-2021 to 07-Oct-2023
9.	GAP 3501	Did most Cycas species originate from India? Genetic evidence through phylogenetic and phylogeographic studies	SERB, New Delhi	Dr. KJ Singh	*w.e.f.* 22-Dec-2021 to 21-Dec-2023
10.	GAP 3502	Systematic study in the family Poaceae from Western Himalaya	SERB, New Delhi	Dr. Priyanka Agnihotri	*w.e.f.* 29-Dec-2021 to 28-Dec-2024
11.	GAP 3503	Unravelling the induced defense response in the neighbouring crops as a consequences of over-expressed methanol	SERB, New Delhi	Dr. PC Verma	*w.e.f.* 27-Dec-2021 to 26-Dec-2024
12.	GAP 3504	Development of novel microbial formulation to bioremediate Cr(VI) toxicity in hexavalent chromium contaminated sites	SERB, New Delhi	PC: Dr. PK Srivastava/PI: Dr. Sandhya Mishra	*w.e.f.* 07-Feb-2022 to 06-Feb-2024

13.	GAP 3505	Taxonomy and ecology of lichenicolous fungi in Eastern Himalaya	SERB, New Delhi	Dr. Sanjeeva Nayaka	*w.e.f.* 21-Feb-2022 to 20-Feb-2025
14.	GAP 3506	Systematic studies of the tribe *Boehmerieae Gaud.* (Utricaceae) in India	SERB, New Delhi	Dr. VV Wagh	*w.e.f.* 21-Feb-2022 to 20-Feb-2025
15.	GAP 3507	Assessment of Pteridophytic diversity in Kotgarh Wildlife Sanctuary, Odisha	SERB, New Delhi	Dr. Sandip Kumar Behera	*w.e.f.* 05-Mar-2022 to 04-Mar-2025
16.	GAP 3508	Taxonomic and Phylogenetic Studies on *Impateins sect. Annuae* (Balsaminaceae)	SERB, New Delhi	Dr. KM Prabhu Kumar	*w.e.f.* 18-Feb-2022 to 17-Feb-2025
17.	GAP 3509	Dehydrated Flowers and Foliages for Women Empowerment	DSIR, New Delhi	Dr. SK Tewari	*w.e.f.* 17-Mar-2022 to 16-Mar-2025
18.	GAP 3510	Exploration of native legumes and characterization of associated nitrogen fixing microsymbionts in North-Eastern India for development of biofertilizers	DBT, New Delhi	Dr. Suchi Srivastava and Dr. SN Jena	*w.e.f.* 09-Mar-2022 to 08-Mar-2025
19.	GAP 3511	An integrative revision of the genus *Swertia* L (Gentianaceae) in India and threat assessment of its species	SERB, New Delhi	PC: Dr. KJ Singh / PI: Dr. Amber Srivastava	*w.e.f.* 02-Mar-2022 to 01-Mar-2024
20.	GAP 3512	Development of high laccase producing mutants of *Trichoderma asperellum* strain NBRI-K14 using Gamma	DAE, Mumbai	Dr. Poonam C. Singh	*w.e.f.* 19-May-2022 to 18-May-2025

Technology Transfer & Business Development Division

The division is 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 Jigyasa 2.0 Programme: Virtual Lab Integration (HCP0101) were also undertaken to give exposure of laboratory and research problem solving to students. Diverse areas of institute were selected for developing novel and interesting content for Virtual Lab.

Technologies Transferred

Sr. No.	Name of the Technology	Client	Date
1.	Anti-dandruff herbal hair oil	Marc Laboratories Limited, New Delhi - 110088	September 26, 2021
2.	Alcohol based liquid herbal hand sanitizer		

MoUs/MoAs/MTAs/MoCs/Secrecy Agreements Signed

Sr. No.	Details	Client	Date	National/ International
1.	To associate with party for sharing of planting materials and Agro-technology	M/S Vishvaksenah Herbs and Aromatic Pvt. Ltd., Muzaffarpur	April 13, 2021	National
2.	For collaborative research in the interest of producing quality planting material of medicinal plants and herbs	National Medicinal Plants Board, Ministry of AYUSH, New Delhi	May 21, 2021	National
3.	For evaluation of Herbal Nano Serum	M/s Alkush Industries Pvt. Ltd., Daman	June 04, 2021	National
4.	For promoting technologies and their commercialization in India together	North East Centre for Technology Application and Reach (NECTAR), Shillong - 793001	June 17, 2021	National
5.	For work together towards promoting of floriculture and apiculture for the benefit of farmers	Tirhut Honey FED Producer Cmpany Ltd., Muzaffarpur, Bihar	June 29, 2021	National
6.	For material transfer (Tma12 protein)	Amity University, Noida U.P.	July 09, 2021	National
7.	For procurement of germplasm (palak seeds)	ICAR-IIVR, Varanasi	August 28, 2021	National
8.	For evaluating the developed knowledgebase having the utility in Agricultural applications	M/S J.K. Agri Genetics Ltd., Hyderabad	August 31, 2021	National
9.	For floriculture mission	SAGE University, Bhopal	September 03, 2021	National
10.	For facilitation of R&D work at Raipur along with field trials for various bioformulations	Indira Gandhi krishi Vishwavidyalaya, Raipur	September 08, 2021	National
11.	For evaluation of Fermented herbal drink, herbal soft drink, herbal dental cream and herbal formulation for toothache	Transformative Learning Solution Pvt. Ltd., New Delhi	September 17, 2021	National

12.	For working together to give impetus to Innovations & Technological Transfer which will help in achieving modern agriculture system beneficial for farmers of country	Indian Farmers Fertilizers Cooperative limited (IFFCO), IFFCO Sadan, C-1, District Centre, Saket Place,New Delhi-110017	September 26, 2021	National
13.	For mutual cooperation with field of agriculture and development of herbal formulation against grain pest to enhance the shelf life of grains	KALOB ORGANICS L.L.P., Kalra Mansion, 46/1, first floor, Wazir Hasan Road, Lucknow, Uttar Pradesh 226001	September 26, 2021	National
14.	For work together towards attaining common objectives of development of useful products and gives us market feed-back also	M/S Tansukh Herbals Pvt. Ltd., 133 KA/196, Aminabad Road, Lucknow - 226018	September 26, 2021	National
15.	For working together for the development of Certified Reference Materials (CRMs), transferring process and knowhow of developed CRMs and sale facilitation	Aashvi Technology, LLP, E-14Madhavpura Market, Shahibaug, Ahmedabad, 380004	September 26, 2022	National
16.	For procurement of tomato germplasm	ICAR-Indian Institute of Vegetable Research (IIVR), Varanasi	October 11, 2021	National
17.	For providing gene encoding anti-insect proteins Tma12, Cry1EC, ASAL and Pr1a promoter	ICAR-IIPR, Kanpur	October 12, 2021	National
18.	For the working together for urban floriculture under floriculture mission	Lucknow Development Authority (LDA), Lucknow	October 25, 2021	National
19.	For evaluation of Herbal Hair Colour, herbal lipstick, herbal Lip care, herbal sanitizer, Lip balm, Dental Cream and Zenthodent	Transformative Learning Solution Pvt. Ltd., New Delhi	November 01, 2021	National
20.	For the procurement of Plasmids for the research work under project –MLP-07	ADDGENE, USA	December 01, 2021	International
21.	For the project entitled "Poverty alleviation through popularization of locally available medicinal-dietary plants for the prevention of malnutrition among the SC/ ST children and women"	DBT, New Delhi	December 06, 2021	National

22.	For evaluation of plant based biodegradable films	M/S Varsya Eco Solutions Pvt. Ltd., Trivandrum, Kerala	December 24, 2021	National
23.	For working jointly towards different areas of expertise leading to advancement in research and development	Fragrance and Flavour Development Centre (FFDC), Industrial Estate, Makarand Nafar, Kannauj - 209726	January 18, 2021	National
24.	For jointly working towards horticultural work in AMRUT BIODIVERSITY PARK for an area of 108 Ha.	Delhi Development Authority (DDA), Vikas sadan, INA, New Delhi	March 23, 2022	National

Training for Post Graduate Students

The division also coordinated and managed the research trainings imparted to post graduate students for their short-term training/project work/dissertations. During the reporting period a total number of 55 students were imparted research training in different disciplines of the plant science and applied science.

A revenue of Rupees nine lakh thirty-two thousand was generated as training fee during the year 2021-22.

School Visits

Due to Covid 19 pandemic restrictions, the division coordinated the visits of only 266 individuals including school students, teachers to the various laboratories and facilities of the institute.

Team Members

Planning, Monitoring and Evaluation	Technology Transfer and Business Development
• Dr. RN Gupta, Senior Technical Officer • Mr. VK Gupta, Technical Officer • Mrs. Sandhya Srivastava, Senior Stenographer • Mr. Atul Srivastava, Senior Stenographer • Mr. ShubhamTandon, Technician • Mr. Sagar Kumar, MTS	• Dr. Manish Bhoyar, Senior Scientist • Mrs. Swati Sharma Senior Technical Officer • Mr. BL Meena, Technical Officer • Mr. YC Tiwari, Sr. Stenographer

Manish Bhoyar
manish.bs@nbri.res.in

Intellectual property management, technology transfer & business development, trainings, popularization of science among students

IPR and Business Development

- Technology transfer process (finalization of the technology cost, dealt negotiation, preparation of agreement and execution of the technology transfer) of two herbal products (Alcohol based liquid herbal hand sanitizer and Anti-dandruff herbal hair oil) was facilitated.
- Two patents' applications for filing in India were finalized and processed.
- A total number 18 MoUs/MTAs/Secrecy Agreements were supported and facilitated for signing with the party.

Trainings, Outreach programmes, Exhibitions

- The research trainings to 48 post graduate students and school visits of 206 students were coordinated during the reporting period.
- Participated and showcased technologies and products developed by the CSIR-NBRI in following events/programmes:
  1. CEO roundtable jointly organized by CSIR-NBRI and CSIR-IITR, Lucknow on September 26 2021.
  2. Shining Uttar Pradesh 2021 at Varanasi" during 19-21 October 2021.
  3. Coordinated A series of trainings and outreach programmes on cultivation of floriculture crops, apiculture and opportunities of entrepreneurship in associated industries under CSIR Floriculture Mission for farmers and entrepreneurs from different districts of Maharashtra during 15-19 November 2021.
  4. Agrovision 2021 at Nagpur, Maharashtra during 24-27 December 2021.
  5. IISF 2021 Curtain Raiser and Outreach Programme at CSIR-IITR on December 02, 2021.
  6. India International Science Festival-2021 (IISF-2021) at Panaji, Goa during 10-13 December 2021.
  7. Pradeshik Fal Shak Sabji Pradarshani at Governor House Raj Bhawan, Lucknow during March 04-06, 2022.

Glimpses of programmes, exhibitions, training programmes coordinated during the reporting period

NBRI JIGYASA CORNER

Mission Objective

- To develop interesting content for students in the area of plant science.
- Convert this content into impactful audio-visual or reading material.
- Interaction with students and teachers for making them abreast with latest scientific development at laboratory.

Mode of Engagements

Under the Jigyasa programme, CSIR-NBRI has provided quality exposure to promote scientific temperament among the students under following models:

- School visit on CSIR Foundation Day
- Lab specific activities / Visits of students
- Online Programmes for School Children
- Popular Lecture Series
- Scientists as Teachers and Teachers as Scientists
- Important Awareness Days like: Environment Day, World Health Day, National Science Day etc.

Major Activities

Sr. No.	Name of the programme	Place	Date
1.	Awareness programme on Say no to single use plastic	Kendriya Vidyalaya (KV), AMC cantt. Lucknow	October 07, 2022
2.	Programme on World Soil Day	Jawahar Navodaya Vidyalaya, Pipersand, Lucknow	December 05, 2022
3.	Scientist–students interaction programme on Fundamentals of Intellectual Property Rights: Indian perspective	Online Mode	
4.	Vigyan Sarvatra Pujyate	CSIR-NBRI, Lucknow	February 22-28, 2022
5.	Two days' workshop under Scientist – students interaction programme	CSIR-NBRI, Lucknow	January 17-18, 2022
6.	Scientist–students interaction programme	Online Mode	February 03, 2022
7.	Lecture on Health-related issues and uses of important herbs	Online Mode	February 10, 2022
8.	Lecture on Air Pollution and Climate Changes	KV, CRPF, Binaur, Lucknow	February 14, 2022
9.	Lecture on 'Water Pollution and Its Impacts'	KV, IIT Kanpur	February 25, 2022
10.	Lecture on 'The Secret life of plants: Lessons for climate-smart agriculture'	Kendriya Vidyalaya Barabanki	March 04, 2022
11.	Climate-Smart Agriculture and their prospects in future	Kendriya Vidyalaya Chakeri no. 01, Kanpur	March 09, 2022

Virtual Contents Developed

Under Jigyasa initiative, CSIR-NBRI created following short science films and science comics for the students during the year 2021-22.

Short Science Films Created

- Floral variety development through gamma radiation.
- Threats of indoor air pollution.
- Importance of essential oils, its sources methods of isolation.
- CSIR-NBRI efforts on increasing shelf life of fruits.
- Electron microscopy
- Role of HPLC in quantification of chemical compound

Science Comics

A comic to generate interest about plants among school students.

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

Glimpses of programmes organized under the Jigyasa Project

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, it 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 the nation. It also bears the public relation to the press and media for promoting and showcasing institute's achievements to the scientific 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 2020-21 was compiled and released on the occasion of Annual Day of the Institute on October 25, 2021.

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 2020-21.

Sale of Publications: Rs. 5,925/-

Parliament Questions: Thirty-Three parliament questions received from CSIR HQ were answered.

Section-In-charge

Dr. ChV Rao

Senior Principal Scientist

Email ID: info-nbri@nbri.res.in

Team Members

- Dr. KN Nair, Chief 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 29626 books and 31525 bound journals. It currently subscribes a total of 554 journals, including 60 print and 482 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	29626
Journals Bound Volumes	31525
Total No. of Books and Bound Journals	**61151**
Theses	
• **AcSIR**	**78**
• **Other Universities**	**83**
Annual Reports	
• **CSIR Institutes**	**44**
• **Other Organizations**	**137**

Additions in KRC holding during the year 2021-22	
Books:	
• Purchased	**32**
• Received as Complimentary copies/Gifts	**32**
Bound journals	**00**
Total number of books and bound journals added during 2020-21	**64**
Current Periodicals Subscribed:	
• Print only	**60**
• Print + Online	**01**
• Online subscribed directly by CSIR-NBRI	**09**
• Online subscribed through CSIR Consortium (NKRC) on share basis	**469**
• Complimentary /Gifts	**10**
Total number of Periodicals (titles)	**489**
Databases subscribed:	
• Subscribed direct by KRC, CSIR-NBRI.	**Nil**
• 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 in Library Science every year under the Apprentice Scheme of Government of India. In the current year training was imparted to 2 trainees.

Sectional In-charge

Dr. ChV Rao
Senior Principal Scientist
Email ID: chvrao72@nbri.res.in

Team Members

- 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

Preparation of Certified Reference Material of Important Phytomolecules

Five CRMs/RMs (2 aromatic and three medicinal) were prepared. A total nine certified reference materials/ reference materials (6 CRMs and 3 RMs) have been prepared.

New Facility Created

Nuclear Magnetic Resonance (NMR) 600 MHz

A facility of NMR 600 MHz has been successfully installed at CIF. Nuclear Magnetic Resonance (NMR) Spectroscopy is one of the powerful analytical techniques used to determine the structure of organic compounds. NMR spectroscopy used in the field of metabolomics and also to determine the effect of Geographical and climatic condition in plant metabolites.

Newly Created NMR Facility at CIF

Analytical Testing Services Provided (2021-22)
External Samples • No. of samples analyzed-**58** • Revenue generated- Rs. **1,17,174.00**
No. of industries/organizations/entrepreneurs/individual benefitted - **11**
Internal Samples No. of samples analyzed-**7082** Estimated revenue generated-**58,32,750.00** @ 50% of current testing charges
Maintenance and repairing of instruments Number of jobs of maintenance and repairing of instruments -197
NABL Accreditation of the Institute NABL-Gurugram after reassessment audit held in October 2021 recommended for continuation of NABL-Accreditation of the institute up to Jan. 2024. Certificate Number: TC-7972; Validity- 17.01.2024 Scope: Ayush Product, Cosmetics & Essential Oils, Food & Agriculture Products, Pesticide Formulation, Pollution & Environment, Residues in Water, Chemical Water Institute is also NABL Accredited as reference material producer based on the requirement of ISO 17034:2016 since 31.03.2021 and valid up to 30.03.2023
Training Imparted and Special Demonstration programmes Held Skill development programme on Phytochemical Analysis Technicians August 05-September 17, 2021 Skill development Program for Fractionation, Separation & Detection of Adulteration in Essential Oils and Product Development during March 07-11, 2022

Scientist In-charge

KN Kaul Block
Dr. Vivek Pandey
Chief Scientist

TN Khoshoo Block
Dr. Alok Lehri
Senior Principal Scientist

Team Members

- Dr. Anil Kumar, Senior Technical Officer
- Dr. Sanjay Dwivedi, Senior Technical Officer
- Dr. Abhishek Niranjan, Senior Technical Officer
- Dr. Babita Kumari, 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. The following activities were performed by ICT during the reporting year.

- Maintenance of CSIR-NBRI website www.nbri.res.in
- Maintenance of CSIR-NBRI Intranet site.
- Maintenance of several servers including Web Server, Library Server etc.
- Management of Network Security – UTM
- Upgrading Antivirus on all nodes of CSIR-NBRI LAN.

Facilitating day to day troubleshooting, antivirus updates, projection facilities & other ICT related work.

New Facility Installed

- Upgradation of existing UTM Firewall.
- Installation of LED Display at Conference Room, Genetic Block
- Installation of USB Video Conference Camera for online meetings.
- Upgradation of NKN (NIC) Lease Line Bandwidth from 100 Mbps to 1Gbps.
- Extension of LAN network to Horticulture, Ram Jharokhe and Security Gate No. 1.
- Extension of Fiber Connectivity to Auditorium and Ram Jharokhe.
- Removal of old Switches with new Switches for smooth LAN Connectivity.
- Upgradation of Servers to Windows Server 2019.
- IT support was provided in Recruitment Portal and payment gateway integration.

Scientist In-charge

Dr. SK Bag, Principal Scientist
Email ID: sumit.bag@nbri.res.in

Team Members

- Mr. Prashant Srivastava, Technical Officer
- Mr. Dev Ranjan, Technical Assistant

ENGINEERING AND ESSENTIAL DIVISION

Divisional Head: Er. Lalit Kumar Srivastava

The division mainly provides following facilities to the institute:

- Civil Engineering & section works
- Electrical and Essential Services
- Mechanical and Allied Services
- Transportation facility

Civil Engineering Section

Civil engineering section looks after the construction and maintenance works of the institute and staff quarters as and when required.

During the reporting year, the section provided its services for following infrastructure developments:

- Establishment of processing shed in Botanic Garden.
- Modernization of plant houses in garden.
- Renovation and extension of hall and canteen facility at CSIR Colony Nirala Nagar.

Section In-charge:

Er. Lalit Kumar Srivastava, Executive Engineer (Civil)

Email ID: l.srivastav@nbri.res.in

Team Members

- Mr. Moinuddin Khan
- Mr. Harish Chand
- Mr. Om Prakesh
- Mr. Sapan Kumar
- Mr. Saral Ram

Electrical and Essential Services Section

The Electrical and Essential services division primarily manages the electrical operation and supply works, maintenance of electrical equipments, functioning of gen-sets, etc.

Section In-charge-

Er. Somanath Swain, Assistant Engineer (Electrical)

Email ID: somanathswain@nbri.res.in

Team Members

- Mr. Ajay Kumar
- Mr. Rakesh Kumar

Mechanical and Allied Services Section

The Mechanical and Allied services manage the refrigeration and air conditioning services in the institute. It also manages the telephonic system in the institute.

Mechanical & Allied Services Division

Section In-charge

Er. Jai Chand, Assistant Executive Engineer (Mech.)

Email ID: jaichand@nbri.res.in

Team Members

- Mr. Dinesh Singh
- Mr. Raj Singh
- Mr. Anoop Kumar
- Mr. Surjeet Kumar
- Mr. Pawan Kumar

Transport and protocol Section

The section manages the vehicle requirement as and when required in the institute along with the transportation services for the guests/staff/students etc.

Section In-charge

Mr. Jyoti Tandon

Email ID: j.tandon@nbri.res.in

राजभाषा यूनिट

संस्थान में राजभाषा कार्यान्वयन समिति के तत्वाधान में हिंदी के प्रगामी प्रयोग संबंधी निम्नांकित गतिविधियाँ वर्ष 2021–2022 में की गयीं –

- संस्थान द्वारा प्रकाशित की जाने वाली राजभाषा गृह–पत्रिका 'विज्ञानवाणी अंक 26 वर्ष 2020' को जून 2021 में ई–पत्रिका के रूप में प्रकाशित किया गया।
- संस्थान में दिनांकः 18.08.2021 को आयोजित हिंदी कार्यशाला में प्रो. ज्ञान चंद्र एम0बी0बी0एस0, एम.एस. इंडोक्राइन सर्जरी विभाग, संजय गांधी स्नातकोत्तर आयुर्विज्ञान संस्थान, लखनऊ को को मुख्य अतिथि के रूप में आमंत्रित किया गया, जिन्होंने आनलाइन एम.एस.टीम्स के माध्यम से हिंदी में 'थायराइड कैंसर' विषयक विस्तृत व्याख्यान प्रस्तुत किया।
- संस्थान में दिनाँक 28/12/2021 को एम एस टीम्स के माध्यम से हिंदी कार्यशाला का आयोजन किया गया। उक्त कार्यशाला में मुख्य अतिथि के रूप में डॉ. चन्द्र मोहन नौटियाल, सेवानिवृत्त वरिष्ठ वैज्ञानिक एवं रेडियोकार्बन प्रयोगशाला प्रमुख, बीरबल साहनी पुराविज्ञान संस्थान, लखनऊ को आमंत्रित किया गया, जिन्होंने 'हिंदी में विज्ञान लेखन में स्पष्टता : क्यो और कैसे' विषयक विस्तृत व्याख्यान दिया। कार्यशाला में संस्थान के लगभग 50 अधिकारियों/कर्मचारियों ने प्रतिभागिता की।
- संस्थान के अधिकारियों तथा कर्मचारियों के लिए हिंदी के प्रगामी प्रयोग में और भी अधिक वृद्धि लाने हेतु संस्थान के निदेशक महोदय द्वारा व्यक्तिशः आदेश जारी किये गये।
- संस्थान से प्रकाशित होने वाली राजभाषा गृह पत्रिका 'विज्ञानवाणी' के 27 वें अंक वर्ष 2021 का विमोचन किया गया, जिसमें संस्थान में होने वाले क्रिया–कलापों से सम्बंधित वैज्ञानिक, तकनीकी तथा जनप्रिय लेखों को प्रकाशित किया गया।

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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.	वित्त एवं लेखा अधिकारी	सदस्य
10.	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

fganh vf/kdkjh– श्री बिजेंद्र सिंह

bZesy vkbZMh– brijesh-singh@nbri.res.in

सहयोगी– श्री शैलेन्द्र कुमार

EVENTS

National Technology Day Celebration

Glimpses of webinar organized on the occasion of National Technology Day

CSIR-NBRI and CSIR IITR, Lucknow jointly organized a webinar on the occasion of National Technology Day on May 11, 2021. Dr. Anant Narayan Bhatt, Senior Scientist, Institute of Nuclear Medicine and Allied Sciences (INMAS), Defence Research Development Organization (DRDO), Ministry of Defence, Government of India was the guest speaker and delivered the lecture on "Development of indigenous anti-Covid medicine". Dr. Bhatt is one of the lead member of the team who discovered 2-DG (2- Di-oxy Glucose) drug against the COVID 19.

World Environment Day Celebrations

- CSIR-NBRI and International Society of Environmental Botanists (ISEB), Lucknow jointly organized a webinar on the occasion of World Environment Day on June 05, 2021. Professor Agepati S. Raghavendra, Institution of Eminence Research Chair, School of Life Sciences, Department of Plant Sciences, University of Hyderabad, Hyderabad was the guest speaker and delivered the lecture on "Response of Photosynthesis to Global Warming and Possible Strategies to Sustain Crop Growth".

Glimpses of webinar organized on the occasion of World Environment Day

- On the occasion, a MoU was also signed between CSIR-NBRI, Lucknow and National Medicinal Plant Board, Ministry of Ayush, New Delhi for collaborative research on various aspects of medicinal plants, quality checking, development of mobile testing units of medicinal plant materials.

One Day Webinar' on IPR Protection & Access and Benefit Sharing under Biodiversity Act, 2002

One Day Webinar' on IPR Protection & Access and Benefit Sharing under Biodiversity Act, 2002 was organized virtually on August 02, 2021. Dr. V. Balakrishnan, Former Member Secretary, Kerala State Biodiversity Board, Dr. Shikha Rastogi, Sr. Pr. Scientist, and Dr. Lipika Patnaik, Pr. Scientist from CSIR-Innovation Protection Unit were the key speakers. The webinar was focused to create awareness regarding biodiversity laws, rules and regulation of access & benefit sharing and obtaining IPR.

75th Independence Day Celebrations

CSIR-NBRI, Lucknow celebrated 75th Independence Day on August 15, 2021. Prof. SK Barik, Director hoisted the flag at main building as well as distant research centre, Banthra.

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हिंदी सप्ताह समारोह के अंतर्गत आयोजित कार्यक्रमों की कुछ झलकियाँ

संस्थान द्वारा हिंदी सप्ताह का आयोजन दिनांक 14 सितम्बर से सितम्बर 20, 2021 के मध्य किया गया। समारोह का उदघाटन सितम्बर 14, 2021 को हिंदी दिवस के अवसर पर किया जिसमे मुख्य अतिथि के रूप में प्रो. विजय कुमार कर्ण, नव नालंदा महाविहार, नालंदा, बिहार, (सम विश्वविद्यालय संस्कृति मंत्रालय, भारत सरकार) उपस्थित थे। हिंदी सप्ताह आयोजन के अंतर्गत संस्थान के पुस्तकालय में हिंदी पुस्तकों की प्रदर्शनी का भी आयोजन किया गया था हिंदी सप्ताह समारोह का समापन दिनांक सितम्बर 20, 2021 को किया गया जिसमे मुख्य अतिथि के रूप में डॉ. नीतू कुमारी नवगीत, प्रसिद्ध भोजपुरी लोकगीत गायिका मौजूद थी।

CEO Round Table Meet on the occasion of 80th CSIR Foundation Day Celebration

Glimpses of CEO Round Table Meet organized on the occasion of 80th CSIR Foundation Day

CSIR-NBRI and CSIR-IITR jointly organized a CEO Round Table Meet on the occasion of its parent organization's (CSIR) 80th Foundation Day on September 26, 2021. Dr. Mahendra Singh, Hon'ble Minister of Jal Shakti Department, Government of Uttar Pradesh was the chief guest and inaugurated the programme. A total of 12 MoUs were signed on the occasion by different companies for product and technologies developed by CSIR-IITR and CSIR-NBRI. NBRI signed 6 MoUs with, Mark Laboratories, M21 Breweries Pvt Ltd and Tansukh Herbal Pvt Ltd.

68th Annual Day of CSIR-NBRI

Glimpses of 68th Annual Day Celebrations of CSIR-NBRI

CSIR- National Botanical Research Institute, Lucknow celebrated its 68th Annual Day on October 25, 2021 through online mode. Prof. KP Gopinathan, Honorary Professor, Indian Institute of Science, Bengaluru was the Chief Guest of the function and delivered the Annual Day Lecture on 'Hanging by the Silk Thread'. On this occasion, the institute's Annual Report 2020-21 was released by the dignitaries and an agreement was also signed by the institute with Lucknow Development Authority to jointly work on development of parks located in Lucknow city as green lungs.

Vigilance Awareness Week-2021

Glimpses of Vigilance Awareness Week

CSIR-NBRI, Lucknow observed Vigilance Awareness Week from October 26-November 01, 2021. Prof. SK Barik, Director administered the Integrity Pledge to all the staff on the occasion.

National MSME Expedition Meet 2021

Glimpses of National MSME Expedition Meet

Under CSIR-Floriculture Mission and as a part of the celebration of Azadi ka Amrit Mahotsav, CSIR-NBRI, Lucknow hosted National MSME Expedition Meet 2021 on 6th December 2021. The programme was organized in collaboration with the Ministry of Micro, Small and Medium Enterprises (MSME) and Fragrance and Flavour Development Centre (FFDC) was Kannauj. The main objective of the programme to create awareness about MSME activities and its various schemes. Potential floriculture entrepreneurs and farmer clusters from different parts of the country under CSIR Floriculture Mission participated in the programme.

73rd Republic Day Celebrations

The 73rd Republic Day was celebrated at CSIR-NBRI with great joy on January 26, 2022. Prof. SK Barik, Director unfurled the flag at CSIR-NBRI campuses (KN Kaul Block and DRC Banthra)

Vigyan Sarvatra Pujyate Festival

Glimpses of Vigyan Sarvatra Pujyate Festival

'Vigyan Sarvatra Pujyate', the great festival of science celebrated across the country to showcase the contribution of Indian science and technology under Azadi Ka Amrit Mahotsav was organized at CSIR-NBRI, Lucknow, during February 22-28, 2022. Prof. Pramod Tandon, CEO, Biotech Park, Lucknow inaugurated the programme on February 22, 2022. The main attractions of the festival included the poster exhibition showcasing achievements of the nation in science and technology during 75 years of independence, science model competition, science photography competition, rangoli competition, fancy dress competition, science essay competition, art competition, science quiz competition, science drama by students etc. The festival concluded on National Science Day (February 28, 2022). A total number of 350 individuals including school & college students, researchers, teachers and general public participated in the festival.

International Women's Day

Glimpses of International Women's Day Celebrations

CSIR-NBRI celebrated International Women's Day on March 08, 2022. On the occasion, social worker Dr. Shachi Singh, Founder, Ehsaas (NGO) Lucknow was the chief guest. Dr. Shachi Singh, while sharing her social work done for destitute children on railway platforms, said that we all used to visit the railway platform, but there is different world out there, which we barely realized.

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.

RM Module Courses (AcSIR-25-RM)		
Sr. No.	**Course Name**	**Expert Name**
1.	Research Methodology Module 1 & 2	Dr. KN Nair, Dr. TS Rana & Dr. AP Sane
2.	Research Methodology Module 3	Dr. SK Tewari & Dr. RC Nainwal
3.	Research Methodology Module 4 & 5	Dr. Vivek Srivastava
4.	Research Methodology Module 6	Dr. Alok Lehri & Dr. PK Singh
RPE Course (AcSIR-25-RPE)		
1.	Research Publication & Ethics	Dr KN Nair and Dr. Silijo Joseph
1 Credit Courses		
1.	Basic Chemistry for Biologist (AcSIR-25-ID-001	Dr. ChV Rao, Dr. BN Singh, Dr. Manjoosha Srivastava, Dr. Mahesh Pal
2.	Cell and tissue engineering (AcSIR-25-ID-002)	Dr. PC Verma and Dr. Manoj Kumar
3.	Climate change and plants (AcSIR-25-ID-003)	Dr. PA Shirke, Dr. Vivek Pandey Dr. S Behera, Dr. Richa Rai
4.	Genomics assisted breeding of plants (AcSIR-25-ID-004)	Dr. Hemant Yadav, Dr. SN Jena Dr. Arvind Jain
5.	Introduction to bioinformatics (AcSIR-25-ID-005)	Dr. MH Asif, Dr. SK Bag
6.	Phylogenomics (AcSIR-25-ID-006)	Dr. KN Nair, Dr. TS Rana Dr. Mehar H. Asif, Dr. Sumit K. Bag
7.	Soil fertility and nutrient management (AcSIR-25-ID-007)	Dr. Lal Bahadur, Dr. SK Behera Dr. Suchi Srivastava, Dr. Shekhar Mallick

3 Credit courses		
1.	Agro-Horticulture Technology (AcSIR-25-BS-AD-001)	Dr. SK Tewari, Dr. Lal Bahadur Dr. Rakesh Nainwal, Dr. D Singh, Dr. Arvind Jain
2.	Cell Signaling (AcSIR-25-BS-AD-002)	Dr. AP Sane and Dr. VA Sane
3.	Developmental Biology-Plants (AcSIR-25-BS-AD-003)	Dr. Indraneel Sanyal, Dr. Debasis Chakrabarty, Dr. CS Mohanty, Dr. Samir V. Sawant
4.	Environmental Biochemistry and Biotechnology (AcSIR-25-BS-AD-004)	Dr. RD Tripathi, Dr. Shekhar Mallick, Dr. Sanjay Dwivedi
5.	Genomics and Epigenomics (AcSIR-25-BS-AD-005)	Dr. Samir V. Sawant, Dr. Sribash Roy Dr. Manish and Dr. Rakesh
6.	Phytochemistry and their utilization (AcSIR-25-BS-AD-006)	Dr. Sharad Srivastava, Dr. Sanjeev Ojha Dr.CHV Rao, Dr. BN Singh
7.	Plant Biodiversity and Systematics (AcSIR-25-BS-AD-007)	Dr. Sanjeev Nayaka, Dr. AK Asthana, Dr. AP Singh, Dr. Baleshwar, Dr. Vijay V. Wagh, Dr. Priyanka Agnihotri, Dr. KM Prabhu, Dr. Gaurav Mishra, Dr. Bikarma Singh,
8.	Plant Microbe interaction (AcSIR-25-BS-AD-008)	Dr. Suchi Srivastava, Dr. PS Chauhan, Dr. P Singh, Dr. Aradhana Mishra, Dr. S Vijay Anandraj
4 Credit Courses		
1.	Societal Program	Dr SK Tewari (Program Coordinator)

Number of Students enrolled for Ph.D until March 31, 2022	
Ph.Ds. awarded during 2021-22	16
Ph.Ds. theses submitted during 2021-22	04

Coordinator

Dr. Vidhu A Sane, Senior Principal Scientist

Executive Consultant

Ms. Harshita Nag

RESEARCH COUNCIL (AS ON 31.03.2022)

1.	**Prof. Paramjit Khurana** Head, Department of Plant Molecular Biology University of Delhi South Campus Benito Juarez Marg, New Delhi - 110 021	Chairperson
2.	**Dr. SK Apte** DST J C Bose National Fellow & Distinguished Professor, University of Mumbai-Department of Atomic Energy-Centre of Excellence in Basic Science, Vidyanagari, Mumbai - 400 098	Member
3.	**Prof. Madhoolika Agarwal** Professor & Head, Department of Botany, Banaras Hindu University, Varanasi - 221 005	Member
4.	**Prof. SR Yadav** Department of Botany, Shivaji University Kolhapur - 416 004	Member
5.	**Dr. Anil Prakash Joshi** Himalayan Environmental Studies & Conservation Organization (HESCO) Dehradun - 248 001	Member
6.	**Dr. Usha Barwale Zehr** Director and Chief Technology Mahyco Private Limited Jalna - Aurangabad Road, Post Box No. 76, Dawalwadi	Member
7.	**Dr. KV Prasad** Director, ICAR-Directorate of Floriculture, College of Agriculture Campus Shivajinagar Pune - 411 005	Member (Agency Representative)
8.	**Dr. Utpal Nath** Associate Professor, Department of Microbiology and Cell Biology, Indian Institute of Science, Bangalore - 560 012	DG's Nominee
9.	**Dr. DS Reddy** Director, CSIR-Indian Institute of Integrative Medicine Canal Road, Jammu - 180 001	Member (Sister Laboratory)
10.	**Dr. SK Barik** Director, CSIR-National Botanical Research Institute, Rana Pratap Marg, Lucknow – 226 001	Member
11.	**Dr. Vibha Malhotra Sawhney** Head, Technology Management Directorate, (Socio-economic Ministry Interface) CSIR-HQ, Rafi Marg, New Delhi - 110 001	Member (CSIR HQ Invitee)
12.	**Dr. PK Srivastava** Principal Scientist, CSIR-National Botanical Research Institute, Rana Pratap Marg, Lucknow – 226 001	Member -Secretary

MANAGEMENT COUNCIL (AS ON 31.03.2022)

Prof. SK Barik Director CSIR-National Botanical Research Institute Lucknow - 226 001	Chairman
Dr. Vivek Pandey Chief Scientist CSIR-National Botanical Research Institute Lucknow - 226 001	Member (Upto June, 2021)
Dr. Sharad Srivastava Senior Principal Scientist CSIR-National Botanical Research Institute Lucknow - 226 001	Member
Dr. Poonam C Singh Principal Scientist CSIR-National Botanical Research Institute Lucknow - 226 001	Member
Dr. Richa Rai Senior Scientist CSIR-National Botanical Research Institute Lucknow - 226 001	Member
Mr. Yogendra Nath Principal Technical Officer CSIR-National Botanical Research Institute Lucknow - 226 001	Member
Dr. PK Trivedi Director CSIR-Central Institute of Medicinal & Aromatic Plants Lucknow-226031	Member
Dr. Vivek Srivastava Senior Principal Scientist CSIR-National Botanical Research Institute Lucknow - 226 001	Member (w.e.f. July 2021)
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 2021-22

I. EXPENDITURE	Figure in Lakhs of Rupees
A. Revenue	
1. Salary & Salary Linked Allowances	2948.743
2. Other Allowances	
a. Reimbursement of Medical Expenses/CGHS/Medical Charges	122.958
b. Overtime Allowance	
c. Honorarium	1.908
d. Leave Travel Concession	7.592
e. Travel Allowances (India)	15.667
f. Travel Allowances (Foreign)	
g. Professional Update Allowance	
h. Total Other Allowances (a to g)	105.765
3. Total Salaries (1+2h)	**3093.868**
4. P-04 Contingencies	593.372
5. P-05 H.R.D.	
6. P-06 Lab. Maintenance	478.655
7. P-701 Staff Qrs. Maintenance	73.832
8. P07 Chemical/Consumables & Other Research Expenses	466.431
9. Total Revenue (3 to 8)	**4709.158**
B. Capital	
a) P-50 Land Cost	
b) (i) P-50 Works & Services/ Electrical Installations (Lumpsum)	82.575
b) (ii) P-50 Works & Services/ Electrical Installations (Other)	27.783
c) P-50 App. & Equip./Computer Equipments	250.850
d) P-50 Workshop Machinery	
e) P-50 Office Equipments	
f) P-50 Furniture & Fittings	
g) P-50 Library (Books/ Journals/ e-Journal)	56.35
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)	17.975
m) (ii) P-702 Staff Quarters (Construction) (Other)	
Total Capital (a to m)	**436.359**
Total A+B	**5145.517**
C. Special Project FBR/NCP/FTC/FTT/RSP/HCP/ HARIT/Lab Projects etc.	
1. Revenue	
(i) Travel Allowances (India)	35.39
(ii) Travel Allowances (Foreign)	
(iii) Contingencies	45.694
(iv) Maintenance	110.000
(v) Chemical, Consumables & Other Research Expenses	1842.758
Total Rev.(C1)	**2033.491**
2. Capital	
(i) Work's & Services	30.210
(ii) Apparatus & Equipment	166.737
(iii) Other Capitals	
Total Capital(C2)	**196.947**
C. Total allocation FBR/NCP/ FTC/FTT/RSP/HCP/HARIT/ Lab Projects etc. (C1+C2)	**2230.438**
Total National Labs. (A+B+C)	**7375.955**
D. OTHERS	
P-804 Pension & Other retirement benefits	3046.067
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.	**3046.067**

II. Earnings	
RECEIPTS	
R04 Donation	30.400
R05 Contribution	103.519
R06 Miscellaneous Receipts	15.586
R906 Recovery of Advances	1.161
TOTAL R06+R906	150.666

R071 LAB RESERVE	
a) Royalty Premia	9.920
b) Testing & Analytical Charges	2.751
c) Other Technical Service	4.751
d) Job Work	4.953
e) Rest of R 071 heads	40.833
Total Lab Reserve(R-071)	**63.208**
R909 EXTERNAL CASH FLOW	
a) Government departments/PSU's	658.649
b) Private agencies	
c) Foreign government/agencies	2.639
TOTAL ECF (a+b+c)	**661.288**
Royalty & Premia for distribution (R907)	

PERSONNEL (AS ON 31.03.22)

Director

SK Barik

Chief Scientists

PA Shirke
SK Tewari
TS Rana
KN Nair
Vivek Pandey
Samir V Sawant
AP Sane

Sr. Principal Scientists

Anand Prakash
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
Subha Rastogi
Debasis Chakrabarty
CS Mohanty

Principal Scientists

HK Yadav
MH Asif
Arvind Jain
PS Chauhan
Shekhar Mallick
PK Srivastava
SK Behera
SN Jena
PC Verma
SK Bag
Manjoosha Srivastava
Sribash Roy
Suchi Srivastava
AP Singh
Aradhana Mishra
Poonam C Singh
Dibyendu Adhikari
SK Rath
Priyanka Agnihotri

Senior

Devendra Singh
Lal Bahadur
BN Singh
VV Wagh
RC Nainwal
Manoj Kumar
KM Prabhukumar
KJ Singh
Bikarma Singh
Richa Rai
Manish Tiwari
SK Behera
Manish Bhoyar
Susheel Kumar
Aditi Gupta

Scientists

GK Mishra
Anju Patel
S Vijay Ananad Raj

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
SK Mishra
Komal K Ingle
Bharat Lal Meena
Vivek K Gupta

Technical Assistants

RR Rastogi
Devranjan
Vandana Tiwari
MG Prasad

Administration

BJ Deuri, CoA
Rakesh Shukla, AO
Bhasker Kumar Ravi, F&AO
Prasenjeet Mitra, SPO
Dheeraj Pathak, SO
Anil Kumar Upadhyay, SO
Sona Lamsal, SO
Gyasuddin, SO
Ram Naresh, PS
SK Pandey, Security Officer
Bijendra Singh, Hindi Officer

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