वार्षिक प्रतिवेदन
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2015-2016




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

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Data Collection, Compilation and Production
Yogendra Misra
RR Rastogi

Editors
SA Ranade
PA Shirke
KN Nair
Yogendra Misra

Cover Design and Photographs
A C Little

Hindi Translation
KK Rawat

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Editorial Committee

SA Ranade
PA Shirke
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Front Cover **: New plant varieties, product and technologies developed by CSIR-NBRI**

1. Bougainvillea 'A.P.J. Abdul Kalam' - a winter blooming variety with variegated leaves
2. *Curcuma longa* (Turmeric) 'Kesari', a variety tolerant to foliar diseases and low temperature
3. BGR 34 - a polyherbal formulation for diabetes management
4. Chrysanthemum 'Peetabh' – an ornamental variety with bright attractive florets
5. Whitefly - resistant transgenic cotton line expressing a fern protein

वार्षिक प्रतिवेदन
Annual Report
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With best compliments from :

Director
CSIR-NBRI
Lucknow

सीएसआईआर–राष्ट्रीय वनस्पति अनुसंधान संस्थान
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राणा प्रताप मार्ग, लखनऊ – 226 001, उ.प्र., भारत

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

Institute at a Glance

Publications	
Total Research Papers	197
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निदेशक की कलम से.....

मुझे सीएसआईआर-राष्ट्रीय वनस्पति अनुसन्धान संस्थान के 2015-16 का वार्षिक प्रतिवेदन प्रस्तुत करते हुए अपार प्रसन्नता हो रही है। मुझे अत्यंत गर्व है कि इस अवधि के दौरान संस्थान ने अपने आधारभूत विषयों के साथ साथ प्रायोगिक क्षेत्रो में भी बहुआयामी शोध, विकास, शिक्षा एवं विस्तार गतिविधियों से चौमुखी प्रगति की है।

वर्ष 2015-16 के दौरान संस्थान ने उच्च संस्थागत, निमिटली, आतंरिक एवं वाह्य पोषित परियोजनाओं के अंतर्गत कुल 98 परियोजनाओं पर अनुसन्धान व विकास कार्य किया गया। संस्थान के वैज्ञानिको ने कुल 197 शोध पत्र प्रतिष्ठित राष्ट्रीय एवं अंतर्राष्ट्रीय शोध पत्रिकाओं में प्रकाशित किये जिनमे से कुल 125 शोध पत्र SCI पत्रिकाओं में प्रकशित हुए जिनका प्रति वैज्ञानिक औसत इम्पैक्ट फैक्टर 2.345 रहा तथा कुल इम्पैक्ट फैक्टर 293.389 रहा। वर्तमान वर्ष में कुल तीन पेटेंट अनुमोदित हुए, छह पेटेंट दाखिल किये गए, 18 नई परियोजनाएं प्रारंभ हुयी तथा 10 समझौता पत्रों पर हस्ताक्षर किये गए। 15 छात्रों को पीएच.डी उपाधि प्रदत्त हुयी तथा 11 छात्रों ने अपने अनुसन्धान ग्रन्थ उपाधि हेतु प्रस्तुत किये।

प्रौद्योगिकी व व्यापार विकास के क्षेत्र में, हमारे संस्थान एवं सीएसआईआर-सीमैप द्वारा संयुक्त रूप से विकसित, मधुमेह नियंत्रण हेतु एक हर्बल दवा को BGR 34 के ट्रेड नाम से बाजार में उतारा गया जिसका वाणिज्यिक उत्पादन और वृहद स्तर पर व्यापार-विपणन मेसर्स ऐमिल फार्मास्यूटिकल्स लिमिटेड, नई दिल्ली के द्वारा किया जा रहा है। संस्थान द्वारा विकसित जैव-इनोकुलेंट की प्रौद्योगिकी, बड़े पैमाने पर उपयोग हेतु उत्तर प्रदेश के कृषि विभाग और निजी उद्योगों को स्थानांतरित करी गयी। कपास में एलील/जीन मैपिंग के कुशल विश्लेषण के लिए ऐफीमेट्रिक्स कंपनी के साथ मिलकर एक बेहतर तकनीकी 'कपास SNP-CHIP' को विकसित किया गया। इसके साथ-साथ संस्थान ने एक बहुत बड़ी उपलब्धि सफेद मक्खी प्रतिरोधी पारजीनी कपास के क्षेत्र परिक्षण में हासिल की है जिससे जीएम् फसलों की कई तकनीकी जानकरियां मिल सकेंगी। संस्थान को अन्य बहु-आयामी विषयों पर अनुसन्धान से कई महत्वपूर्ण सुराग मिले हैं जिन्हें संस्थान फास्ट ट्रैक प्रौद्योगिकी, औद्योगिक, सामाजिक और आर्थिक लाभ के लिए सतत प्रौद्योगिकियों, उत्पादों और सेवाओं हेतु परिवर्तित करने में शोधरत है।

समीक्षाधीन वर्ष में, संस्थान के विश्व विख्यात वनस्पति उद्यान ने अपने उद्देश्यों की प्रतिबद्धता के अंतर्गत दुर्लभ व दिलचस्प पौधों विशेषकर ऑर्किड, साईकेड, फर्न तथा सजावटी पौधों के परिचय, संवर्धन, संरक्षण एवं प्रसार को जारी रखा हैं। इस वर्ष सीएसआईआर-एनबीआरआई ने सजावटी पौधों बोगनविलिया एवं गुलदाउदी की दो नई किस्में क्रमशः 'एनबीआरआई-ऐपीजे अब्दुल कलाम' तथा 'एनबीआरआई-पीताभ' जारी की हैं। सीएसआईआर-एनबीआरआई ने भारत में एकमात्र स्थापित साईकेड संरक्षण केंद्र को विकसित किया है जिसमे भारतीय साईकस की 7 प्रजातियों सहित कुल 56 प्रजातियों को संरक्षित किया गया हैं। इसके अलावा दुर्लभ एवं संकटग्रस्त पौधों के लिए एक विशेष संरक्षण गृह को भी विकसित किया गया है। संरक्षण शिक्षा एवं उद्यान प्रेमियों के लिए सजावटी पौधों एवं फूलों से सुसज्जित एक कियोस्क को वनस्पति उद्यान में बनाया गया है।

संस्थान के बंथरा दूरस्थ अनुसंथान केंद्र ने सोडिक व बंजर भूमि पर आर्थिक रूप से महत्वपूर्ण कई पौधों जैसे हल्दी, एचटी गुलाब, पान, कैना, ग्लेडियोलस तथा औषधीय पौधों जैसे अश्वगंधा, कालमेघ, बिक्सा व एलोवेरा की सफल खेती और उनके गुणन का कार्य सफलतापूर्वक किया है। इस वर्ष संस्थान ने उत्तर भारत के मैदानों के अनुकूल हल्दी की एक नई किस्म '**केसरी**' को भी जारी किया है।

पादप विविधता, वर्गिकी एवं पादपालय समूह ने देश के पादप तथा लाइकेन संसाधनों के व्यवस्थित प्रलेखन, पूर्वेक्षण एवं विविधिता अध्ययन में विशेष उपलब्धियां प्राप्त की हैं जो इस प्रकार हैं: भारतीय हिमालय में अल्पाइन पारिस्थितिकी तंत्र की गतिशीलता के अध्ययन हेतु जैव-सूचक लाइकेन्स की पहचान; हिमालयों पर अधिक खराब मौसम की पूर्व जानकारी हेतु सर्वप्रथम

भारतीय साईनोलाइकेन में इमिनो माईकोस्पोरिन जैसे एमिनो एसिड का अभिलक्षणन; तीन शैवालों की संभावित बायोडीजल फीडस्टॉक के रूप में पहचान; लाईकेन की दो नयी प्रजातियों की खोज; ब्रायोफाइट्स की दो किस्मों एवं 29 प्रजातियों के भारत में क्रमशः नए राष्ट्रीय और क्षेत्रीय अभिलेख के रूप में रिपोर्ट; राष्ट्रीय स्वच्छ गंगा मिशन के अंतर्गत गंगा नदी के किनारे पश्चिम बंगाल, बिहार, उत्तराखंड व उत्तर प्रदेश के 13 स्थानों पर शैवाल, ब्रायोफाइट्स, टेरिडोफाइट और पुष्पी पौधों का मानसून पूर्व और मानसून के पश्चात् सर्वेक्षण एवं पारिस्थितिकीय निगरानी; गांगेय मैदानों से ***फाईकस*** की 38 प्रजातियों का पूर्ण अध्ययन; उत्तर प्रदेश के लगभग 150 वृक्षों के वर्गिकी आंकड़ों का संकलन; ***डेलफिनियम*** की 13 प्रजातियों, ***कोंसोलिडा*** की 1 प्रजाति और ***एकोनिटम*** की 11 प्रजातियों का वर्गिकी अध्ययन; भारतीय मॉस ***पोगोनेटम*** की 10 प्रजातियों का आकारिकीय-वर्गीकरण अध्ययन; डीएनए मार्कर्स की सहायता से दो महत्वपूर्व औषधीय पौधों ***ऐफेड्रा जीरारडियाना*** और ***बर्जीनिया स्ट्रेकायी*** में डीएनए मार्कर आधारित आनुवंशिक विविधता का आकलन; पार्मिलियेसी कुल की लाइकेन बनाने वाली 13 कवक प्रजातियों एवं 11 औषधीय पौधों के डीएनए बारकोड का विकास; ***वुडफोर्डीया फ्रुटीकोसा*** की प्रजनन जैविकी एवं विकास का अध्ययन; तीन दुर्लभ फर्न प्रजातियों (***ऐथीरियम पैक्टीनेटम, ड्रायोप्टेरिस कोक्लिएटा*** व ***ओनीकियम कंटीगुवम***) के *इन-विट्रो* बीजाणु संवर्धन एवं प्रजनन जैविकी का अध्ययन किया गया तथा दो ब्रायोफाइट प्रजातियों; एक देशज प्रजाति ***एनथोसेरोस मैक्रोस्पोरस*** एवं एक संकटग्रस्त प्रजाति ***क्रिप्टोमिट्रियम हिमालएन्से*** के *इन विट्रो* प्रोटोकाल का विकास किया गया। सीएसआईआर-राष्ट्रीय वनस्पति अनुसन्धान संस्थान के पादपालय में पुष्पीय और अपुष्पीय पौधों के 2298 नए नमूनों को सँजोया गया जिससे वर्तमान में इसमें कुल संग्रहीत नमूनों की संख्या 2,92,970 तक पहुच गयी है।

पारिस्थितिकी एवं पर्यावरण विज्ञान समूह द्वारा किए जा रहे मुख्य शोध कार्यों में गांगेय मैदाओं में कृषि एवं वन पारिस्थिकी तंत्रों पर जलवायु परिवर्तन के प्रभावों से संबन्धित नवीन जानकारियां; कार्बन जब्ती, कार्बनिक एवं अकार्बनिक प्रदूषकों का जैव-उपचार; एवं जैविक एवं अजैविक तनावों में वायुवीय एवं भूमिगत पादप अंगों में जैव-भार वितरण आदि रहे। समूह द्वारा किए जा रहे शोध कार्यों ने धान में As(V) एवं As(III) प्रेरित तनाव को कम करने में ग्लूटारेडोक्सिन एवं γ-अमीनो ब्यूटाइरिक अम्ल की भूमिका को समझा गया। धान की किस्म सरजू 52 में एक नवीन पृथक्कीकृत किए गए जीवाणु विभेद ***ब्रेवुण्डीमोनास डिमीन्यूटा*** (एनबीआरआई 012) द्वारा संखिया ग्रहण को स्थिर करता हुआ पाया गया। धान के खेतों में हरित शैवाल ***क्लोरेल्ला*** के प्रयोग को संखिया विषालुता को कम करने के लिए प्रभावी रणनीती के रूप में देखा गया। ताजे लाई ऐश ढेरों में वातावरणीय कार्बन डाईआक्साइड जब्ती के लिए ***सैक्रम स्पोंटेनियम*** एवं ***प्रोसोपिस जुलीलोरा*** के संघ को प्रभावी रूप से उपयुक्त पाया गया। दो शीतकालीन गेहूं की किस्मों (कुन्दन एवं लोक 1) में सैलीसिलिक अम्ल तनाव की स्थिति में शुष्कता-सहिष्णु लक्षणों को पहचाना गया जिनका प्रयोग तनाव के दौरान गेहूं की उपज को बढ़ाने में किया जा सकता है।

आनुवंशिकी एवं आणुविक जैविकी समूह ने पादप जीनोमिक्स, ट्रांसक्रिप्टोमिक्स एवं प्रोटियोमिक्स के क्षेत्र में अपने विभिन्न शोध कार्यक्रमों को जारी रखा। इस वर्ष कपास की किस्म 'कोकर 312' की पारजीनी नर बंध्य एवं रिस्टोरर लाइनों के विकास हेतु पादप आनुवांशिक रूपान्तरण प्रोटोकॉल को मानकीकृत किया गया। टमाटर के फल के cDNA से AP2/ERF डोमेन युक्त प्रोटीनों का संकेत करने वाले दो जीनों *SlERF6* एवं *SlERF8* को पहचाना गया एवं टमाटर में फल के विकास एवं पकने में उनकी भूमिका का अध्ययन किया गया। ***विथानिया सोम्नीफेरा*** में वीथैनोलाइड्स जैव-संश्लेषण में *WsSGTL1* जीन की भूमिका को जांचा गया। ***सोलेनम खसियानम*** में काँटों से संबन्धित विशेष संभावित कल्पित ट्रांसक्रिप्शनल नियंत्रकों को पहचाना गया। अलसी में ***अल्टेर्नेरिया*** झुलसा प्रतिरोध से संबन्धित दो कल्पित SSR मार्करों को पहचाना गया। विथैनोम डाटाबेस को विभिन्न कीमोटाइप के ट्रांसक्रिप्टोम डाटासेट पर अतिरिक्त जानकारी से संवर्धित किया गया एवं विशेष वीथैनोलाइड्स के लिए जैव-संश्लेषण पाथवे प्रस्तावित किए गए। कपास में *GhNAC2* के एक्स्प्रेशन द्वारा पानी युक्त एवं सूखे की स्थितियों में जड़ों की वृद्धि में सुधार प्रदर्शित किया गया जिससे पौधों में शुष्कता तनाव की स्थिति में शुष्कता सहिष्णुता उत्पन्न करने में *GhNAC2* की संभावित भूमिका के संकेत मिले। ***एग्रोबैक्टीरियम ट्यूमेफेशिएन्स*** आधारित रूपान्तरण का प्रयोग करते हुये कैना के रूपान्तरण के लिए एक प्रभावी प्रोटोकॉल तैयार किया गया। दो विपरीत रंग वाली ***कैना*** की किस्मों 'ट्रोपिकल सनराइस' एवं 'रेड प्रेसीडेंट' में पुष्प बनने, फेनिल प्रोपैनोइड एवं पिग्मेंट मेटाबोलिक प्रक्रियाओं में शामिल miRNAs वंशों के जीनों को खोजा गया। थीबेन प्रचुर अफीम की तीन लाइनों को विभिन्न कृषि-जलवायु परिस्थितियों में सर्वाधिक स्थायी एवं अनुकूलित लाइनों के रूप में चयनित किया गया। भारतीय अलसी की किस्म में उच्च ओमेगा -3- वसीय अम्ल लाइनों को पहचानने के लिए 10,057 SNPs के एक सेट को विविधता आंकलन एवं एसोसिएशन मैपिंग हेतु पहचाना गया।

पादप सूक्ष्म-जीव संबंध समूह ने देश भर में विभिन्न फसलों की उत्पादकता में सुधार हेतु जैव-इनोकूलेंट के गुणात्मक उत्पादन एवं प्रसार पर चल रहे अपने शोध कार्यक्रमों के साथ-साथ संभावित सूक्ष्म-जैविक संघ आधारित नवीन जैव-इनोकूलेंट, जैव-नियंत्रण एजेंट्स एवं जैव-उर्वरको की खोज में नई गतिविधियां प्रारंभ कीं। समूह ने ***ट्राइकोडर्मा एट्रोविरिडी, ट्राइकोडर्मा हर्जियानम, ट्राइकोडर्मा रीसियाई*** एवं ***ट्राइकोडर्मा वाइरेन्स*** में 12 बहुरूपी SSRs को पहचाना जिन्हें ***ट्राइकोडर्मा*** के विभिन्न प्रभेदों में आनुवांशिक संबंध स्थापित करने में प्रयोग किया जा सकता है। बाजरा में व्यक्तिगत एवं बहु-अजैविक तनावों के दौरान प्रथम बार दो संदर्भ जीन EF-1α एवं UBC-E2 को प्रमाणित किया गया। एक नवीन जैव-नियंत्रक एजेंट ***बेसीलस*** प्रजाति (NBRI-W9) को पहचाना गया एवं पान के एक रोगकारक कवक ***फ्यूजेरियम*** प्रजाति (NBRI-PMSF12) के विरुद्ध प्रभावी पाया गया।

भेषज विज्ञान समूह ने ***बाहुनिया परप्यूरिया*** एवं ***बाहुनिया वैरीगेटा*** के फूलों एवं कलियों में एंटी-आक्सीडेंट एवं एंटी-कैंसर क्षमताएँ देखीं जिससे इन पौधों के माइक्रो-न्यूट्रीएंट कुपोषण एवं प्रोस्ट्रेट कैंसर में खाद्य अनुपूरकों को बनाने में प्रयोग किए जा सकने के संकेत मिले। संजीवनी (***सिलैजिनेला ब्रायोप्टेरिस***) की क्षमताओं को परखने के लिए पौधे में पहचाने गए पादप-रसायनों के जैविक एवं भेषज अनुप्रयोगों को जांचा गया। भोजन के प्रभावी वितरण हेतु स्थायी मैट्रिक्स के रूप में प्रयोग हेतु पोषण से प्रचुर तीन गोंद इनकैप्सूलेंट को पहचाना गया तथा खाद्य तेलों एवं रंजक पदार्थों को कोर पदार्थ की तरह प्रयोग करते हुये मल्टी कोर इनकैप्सूलेशन हेतु प्रयोग किया गया। उत्तर प्रदेश के ग्रामीण क्षेत्रों में स्वास्थ्य एवं मासिक धर्म स्वच्छता समस्याओं के प्रति जागरूकता फैलाने के उद्देश्य से नवीन, कम लागत के सैनीटरी नैपकिन के विकास की दिशा में प्राकृतिक गोंदों के प्रयोग पर एक नया कार्यक्रम प्रारम्भ किया गया है। गुग्गुल (***कमीफोरा वाइटाइ***) के 9 नमूनों में गैर-लक्षित

मेटाबोलाइट प्रोफाइलिंग से गुग्गुलेस्ट्रोन E एवं Z में सार्थक मात्रात्मक एवं गुणात्मक अंतर पता चले। ***लाउनिया प्रोकंबेन्स*** के एथिल एसीटेट फ्रैक्शनों को सर्विक्स (HeLa), ल्यूकेमिया (K562) एवं स्तन (MCF-7) कैंसर सेल लाइनों के प्रति क्रियाशील देखा गया।

संस्थान ने सीएसआईआर-800 एवं अन्य कार्यक्रमों के अंतर्गत अनेक सामूहिक प्रशिक्षण एवं कार्यशालाएँ आयोजित कीं। विभिन्न विषयों जैसे वर्गिकी, बागबानी, पुष्प कृषि, कृषि प्रौद्योगिकी, जैव-उर्वरक, शुष्क पुष्प कला, पान की खेती, औषधीय एवं सगंध पौधों की खेती आदि के विषय में विभिन्न हितधारकों को प्रशिक्षण दिया गया। इन कार्यक्रमों से लाभ लेने वालों में किसान, शिक्षक, विद्यार्थी, उद्योगपति एवं जैव-उर्वरक ईकाइयों के अधिकारी शामिल रहे। विभिन्न विश्व-विद्यालयों/संस्थाओं के परास्नातक विद्यार्थियों को भी पादप विज्ञान के विभिन्न क्षेत्रों जैसे आणुविक जैविकी, सूक्ष्म-जीव विज्ञान, भेषज विज्ञान एवं जैव-प्रौद्योगिकी आदि के विषय में प्रशिक्षित किया गया।

संस्थान के प्रसिद्ध शोध योगदानों को देखते हुये इस वर्ष सीएसआईआर एवं संस्थान के वैज्ञानिकों को विभिन्न राष्ट्रीय पुरस्कारों एवं सम्मानों से सम्मानित किया गया। वर्ष 2015 के सीएसआईआर-प्रौद्योगिकी पुरस्कार 'दक्षिण के पठारी क्षेत्रों के अर्द्ध शुष्क इलाकों में छोटे किसानों के आर्थिक सुधार हेतु औषधीय रूप से महत्वपूर्ण पौधे अश्वगंधा की उन्नत किस्मों के विकास एवं प्रसार हेतु' संयुक्त रूप से सीएसआईआर-एनबीआरआई, सीएसआईआर-सीमैप, सीएसआईआर-सीडीआरआई एवं सीएसआईआर-आईआईसीबी को दिया गया। पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय, भारत सरकार, द्वारा डॉ डी के उप्रेती, मुख्य वैज्ञानिक को लाईकेन वर्गिकी में उनके उल्लेखनीय कार्य के लिए वर्ष 2015 के प्रतिष्ठित 'पादप वर्गिकी हेतु ई के जानकी अम्मल पुरस्कार' से सम्मानित किया गया। डॉ प्रियंका अग्निहोत्री, वैज्ञानिक को पादप विज्ञान के क्षेत्र में उल्लेखनीय योगदान हेतु भारतीय साइंस कांग्रेस एशोसिएशन द्वारा स्थापित वर्ष 2015-2016 के 'प्रो. हीरा लाल चक्रवर्ती मेमोरियल पुरस्कार' से सम्मानित किया गया। डॉ समीर सावंत, प्रमुख वैज्ञानिक को नेशनल एकेडमी ऑफ साइंस के द्वारा, इलाहाबाद द्वारा FNASc उपाधि प्रदत्त की गई एवं डॉ पी के त्रिवेदी, प्रमुख वैज्ञानिक, को नेशनल एकेडमी ऑफ एग्रीकल्चरल साइंसेस, नई दिल्ली द्वारा FNAAS उपाधि प्रदत्त की गई।

मैं इस अवसर पर संस्थान के सुचारु रूप से संचालन एवं अनुसंधान एवं विकास में निरंतर प्रगति के लिए किए जा रहे गंभीर प्रयासों के लिए अपने सभी सहयोगियों को बधाई एवं धन्यवाद देता हूँ। मैं अपने सभी वैज्ञानिक एवं प्रशासनिक सहयोगियों से अपील करना चाहूँगा कि वे हमारे सभी अनुसंधान एवं विकास तथा संबद्ध कार्यक्रमों की योजना निर्माण एवं क्रियान्वयन में और अधिक विवेकपूर्ण एवं उत्पादक हों ताकि हम सतत् कृषि विकास हेतु सस्ती प्रौद्योगिकियों एवं उत्पादों, स्वास्थ्य, पर्यावरण रक्षा, जलवायु परिवर्तन से सुरक्षा एवं देश व देश के लोगों के सामने आ रही अन्य महत्वपूर्ण समस्याओं से निपटने के लिए इच्छित परिणामों को प्राप्त कर सकें। मैं संस्थान के सफल वैज्ञानिक एवं तकनीकी प्रबंधन के लिए समय-समय पर मार्गदर्शन, सलाह व समर्थन हेतु सीएसआईआर के भूतपूर्व एवं वर्तमान महानिदेशकों क्रमशः डॉ एम ओ गर्ग एवं डॉ गिरीश साहनी का आभार व्यक्त करना चाहता हूँ। हम संस्थान के शोध एवं विकास कार्यक्रमों के सफलतापूर्वक कार्यान्वयन हेतु अमूल्य मार्गदर्शन हेतु शोध एवं प्रबंध परिषद के अध्यक्ष प्रो. एस के सोपोरी, एवं सभी सम्मानित सदस्यों के आभारी हैं। हम हमारी शोध एवं विकास तथा दूरस्थ गतिविधियों के सफलतापूर्वक सम्पन्न होने के लिए अपने वरिष्ठ-जनों, शुभ-चिंतकों एवं समर्थकों से प्राप्त सहायताओं के प्रति आभारी हैं। हम हमारे भविष्य के सभी क्रियाकलापों में आपके निरंतर मार्गदर्शन, सलाह एवं समर्थन के आकांक्षी हैं।

(दलीप कुमार उप्रेती)
कार्यवाहक निदेशक

From the Director's Desk .....

It gives me immense pleasure to present the Annual Report of CSIR-NBRI for the year 2015-16. I am glad that, during the period from April 2015 to March 2016, the Institute made all-round progress in its research, development, education, extension and outreach activities in a broad spectrum of disciplines in basic as well as applied plant sciences.

The Institute during the reporting year carried out 98 R&D projects under in-house, supra-institutional, network, NMITLI and other externally funded project categories. A total of 197 research papers were published by the scientists of the Institute in reputed national and international journals. Out of these, 125 were in SCI journals with an impact factor of 2.345 per scientist and total IF of 293.389. This year, three patents were granted, six patents were filed, 18 new projects received, 10 MoUs/ Agreements were signed, 15 students were awarded their Ph.D. degrees and 11 students submitted their research work for the Ph.D. degree.

In the domain of technology and business development, the Institute witnessed the launch of an antidiabetic herbal formulation - 'BGR-34' on the occasion of its 62nd Annual Day on 25th October 2015. This herbal formulation was jointly developed by CSIR-NBRI and CSIR-CIMAP as 'NBRMAP-DB' during 2013-14. The formulation has been now commercially produced and marketed under the trade name 'BGR-34' by M/S Aimil Pharmaceuticals Ltd., New Delhi. The bioinoculant technologies developed by CSIR-NBRI were transferred to Uttar Pradesh Agriculture Department and private industries for widespread application throughout the country. 'A Cotton SNP-chip' was developed in collaboration with Affymetrix, which proved to be an efficient tool for genotyping and allele/gene mapping in cotton. Another major breakthrough achievement in the reporting year was the contained field trials on 'whitefly resistant transgenic cotton lines expressing a fern protein' that can be deployed in GM crops to control whitefly and the viruses it carries. Several other significant leads were also obtained from the transdisciplinary researches that are now being transformed to fast track translational projects targeted at sustainable technologies, products and services for industrial, societal and economic benefits.

The Botanic Garden, the flagship of CSIR-NBRI, continued with its committed activities on introduction, enrichment, conservation, propagation and multiplication of interesting plants, notably orchids, cycads, ornamentals, ferns, mosses, and rare, endangered and threatened (RET) species. In this year two novel ornamental plant varieties, Bougainvillea 'NBRI-A.P.J. Abdul Kalam' and Chrysanthemum 'NBRI-Peetabh', were developed and released. The Cycad Conservation Centre, the only such centre in India, was enriched with 56 species of cycads including 7 species of Indian *Cycas*. A new 'Propagation House for RET Species' and a 'New Kisok Point' were established for conservation, education and aesthetic purposes. The Distant Research Centres of the Institute at Banthra successfully worked out various demonstrations projects on sustainable use of sodic wastelands for cultivation and multiplication of economically important plant resources such as Turmeric, Kalmegh, Ashwagandha, Aloes, Canna, Gladioli, HT Rose, Betel vine, Bixa, and several high value medicinal and aromatic plants. A new variety of turmeric named 'Kesari', suitable for cultivation in North Indian Plains was released this year.

The Plant Diversity, Systematics and Herbarium Group excelled in their efforts in conducting systematic documentation and bioprospecting the plant and lichen resources of the country. Some of the notable achievements include: Identification of bio-indicator lichens to monitor the alpine ecosystem dynamics in the Indian Himalayas, and the first ever characterization of Imino Mycosporine like Amino Acids (MAAs) in Indian cyanolichens that can help predict the extreme weather phenomenon in the Himalayas; Identification of three fresh water algal strains as potential biodiesel feedstock; Discovery of two new species of lichens and new geographic records of nine lichen species to India and 84 species to six states of India; Report of 29 species and two varieties of bryophytes as new national and regional records to India; Pre-monsoon and post-monsoon surveys and ecological monitoring of algae, lichens, bryophytes, pteridophytes and flowering plants in 13 sites along Ganga River in West Bengal, Bihar, Uttar Pradesh and Uttarakhand under the National Mission for Clean Ganga; Completion of taxonomic study on *Ficus* of the Gangetic Plains with documentation of 38 species; Comprehensive taxonomic data organization of about 150 tree species of Uttar Pradesh; Systematic studies on 13 species of *Delphinium*, 1 species of *Consolida* and 11 species of *Aconitum*; Morphotaxonomic studies on 10 Indian species of the moss genus *Pogonatum*; DNA marker -based genetic diversity assessment in two important medicinal plants, *Ephedra gerardiana* and *Bergenia stracheyi*; Development of DNA barcodes for 13 lichen-forming fungal species belonging to Parmeliaceae and 11 species of medicinal plants; Reproductive biological and regeneration studies on *Woodfordia fruticosa*; *In-vitro* spore culture and reproductive biological studies on three rare

ferns: *Athyrium pectinatum*, *Dryoperis cochleata*, and *Onychium contiguum*; Development of *in-vitro* propagation protocols for two bryophyte species: the endemic *Anthoceros macrosporus* and the endangered *Cryptomitrium himalayense*. The Herbarium of the Institute, which is a National Repository designated by the National Biodiversity Authority, was enriched with an addition of 2298 specimens, making up the total specimen holdings to 2,92,970.

Generating new knowledge on the impact of climate change on agriculture and forest ecosystems in the Indo-Gangetic Plains, carbon sequestration, bioremediation of organic and non-organic pollutants, and biomass partitioning among aerial and subterranean plant parts under abiotic and biotic stresses were the key themes of research undertaken by the Ecology and Environmental Sciences Group. The studies by the Group elucidated the role of glutaredoxins (OsGRXs) and γ-amino butyric acid (GABA) in ameliorating As (V) and As (III)–induced stresses in rice. A newly isolated bacterial strain, *Brevundimonas diminuta* (NBRI012) was shown to stabilize arsenic uptake in the rice variety- Sarju52. Application of the green alga, *Chlorella* was found to be a viable strategy to decrease Arsenic toxicity in rice fields. *Saccharum spontaneum* and *Prosopis juliflora* association was found potentially suitable for sequestering atmospheric CO_2 in the fresh Fly Ash deposited sites. Drought tolerant traits identified in two winter wheat cultivars (Kundan and Lok1) under interactive effect of stress and Salicylic Acid, which could be used for increasing yield potential in wheat under stress.

The Genetics and Molecular Biology Group continued with its various research programs in the areas of plant genomics, transcriptomics and proteomics. During the year *Agrobacterium* based plant genetic transformation protocols were standardized for developing transgenic male sterile and restorer lines of cotton variety – 'Coker-312'. Two genes, ***SlERF6*** and ***SlERF8***, encoding AP2/ERF domain containing proteins were identified from tomato fruit cDNA, and their role in development and fruit ripening in tomato was studied. The role of *WsSGTL1* gene in the withanolide biosynthesis in *Withania somnifera* was elucidated. Some prickle specific potential putative transcriptional regulators were identified in *Solanum khasianum*. Two SSR markers putatively linked to *Alternaria* blight resistance in linseed were identified. The Withanome Database was enriched with additional information on transcriptome datasets of different chemotpyes and proposed biosynthesis pathways for specific withanolides. ***GhNAC2*** expression was shown to improve root growth in cotton (*Gossypium herbaceum*) both under control and water stressed conditions, indicating possible role of ***GhNAC2*** in imparting drought tolerance to plants. An efficient protocol for canna transformation was developed using *Agrobacterium* mediated transformation. miRNAs families targetting genes involved in flower development, phenyl propanoid and pigment metabolic processes were identified in two Canna cultivars with contrasting flower colors, Tropical sunrise and Red president. Three thebaine rich lines of opium poppy were selected as highly stable and adaptable to different agro-climatic conditions. A set of 10,057 SNPs were identified for diversity analysis and association mapping to identify high omega -3- fatty acid lines of Indian linseed variety.

Besides its ongoing programs on quality production and popularization of bioinoculants for enhancing productivity in a variety of crops across the country, the Plant Microbe Interaction Group initiated new activities in search of new bioinoculants, biocontrol agents and biofertilzers based on potential microbial consortia. The Group identified 12 polymorphic SSRs in *Trichoderma atroviride*, *T. harzianum*, *T. reesei,* and *T. virens*, which will be utilized for establishing genetic relationships among different isolates of *Trichoderma*. Two reference genes, *EF-1α* and *UBC-E2* were validated for the first time under individual and multiple abiotic stresses in pearl millet. A new biocontrol agent, *Bacillus* sp. (NBRI-W9) was identified and found effective against the fungal pathogen *Fusarium* sp. (NBRI-PMSF12) infecting betel vine.

The Pharmacognosy and Phytochemistry Group detected antioxidant and anticancer properties of *Bauhinia purpurea* and *Bauhinia variegata* flowers and flower buds, indicating the utility of these plants as food supplements in micronutrient malnutrition and prostate cancer. The biological and pharmaceutical applications of the phytochemicals identified in sanjeevani, *Selaginella bryopetris* were examined to study the adaptogenic properties of the plant. Three nutraceutically rich gum encapsulants were identified and subjected to multi core encapsulation using edible oils and coloring principle/ pigments as core material for utilization as stable matrices for effective delivery of foods. A new program was initiated aimed at utilization of natural gums as low cost material for development of sanitary napkins and imparting awareness on health and menstrual hygiene issues in rural areas of Uttar Pradesh. Non-targeted metabolite profiling of nine samples of Gugul- *Commiphora wightii* revealed significant qualitative as well as quantitative variation in Guggulsterone E and Z. Ethyl acetate fraction of *Launaea procumbens* was reported to be active against cervix (HeLa), leukemia (K562) and breast (MCF-7) cancer cell lines.

The Institute during the year conducted a number group trainings and workshops under CSIR-800 and other projects. Training was imparted to various stakeholders

on different subjects, including taxonomy, gardening, floriculture, agrotechniques, biofertilizers, dehydration of flowers and floral crafts, betel vine cultivation, cultivation of medicinal and aromatic plants. The beneficiaries of these training programs included farmers, teachers, students, entrepreneurs and officers of Biofertilzers units. Post-graduate students of different universities/institutes were also imparted training on various topics in plant sciences, including molecular biology, microbiology, pharmacology, and biotechnology.

In recognition of the outstanding research contributions, CSIR-NBRI and scientists of the Institute were honored with national awards and recognitions during this year. CSIR-Technology Award-2015 was conferred jointly to CSIR-NBRI, CSIR-CIMAP, CSIR-CDRI and CSIR-IICB for 'Development of improved varieties and promotion of cultivation of medicinally important Ashwagandha for improving the economy of small and marginal farmers in Semi Arid-Tropical (SAT) Regions in Deccan Plateau'. Dr DK Upreti, Chief Scientist, was bestowed with the prestigious 'EK Janaki Ammal National Award for Plant Taxonomy 2015' by the Ministry of Environment, Forest and Climate Change, Government of India, for his contributions in the field of Lichen taxonomy. Dr. Priyanka Agnihotri, Scientist, received 'Prof. Hira Lal Chakravarty Memorial Award for the year 2015-2016' instituted by the Indian Science Congress Association for significant research contributions in the field of plant sciences. Dr. Samir V Sawant, Principal Scientist, was conferred FNASc by the National Academy of Sciences (NASI), Allahabad and Dr. PK Trivedi, Principal Scientist, was conferred FNAAS by the National Academy of Agricultural Sciences (NAAS), New Delhi.

I take this opportunity to congratulate and thank all my colleagues for the sincere efforts they made in steering the Institute towards steady and sustained progress in the R& D pursuits. I would also like to appeal my scientific and administrative colleagues to be far more prudent and productive in planning and executing our entire R&D and allied programs, so that we achieve the desired outputs in terms of affordable technologies and products for sustainable agriculture, health care, environmental protection, combating climate change, and other crucial problems faced by our nation and people. I wish to place on record my sincere gratitude to Dr. MO Garg and Dr. Girish Sahni, the Former and Present Director Generals of CSIR, respectively, for the timely guidance, advice and support they rendered to us for the successful S&T management of the Institute. We are grateful to Prof. SK Sopory, Chairman, Research Council and all the honorable members of the Research and Management Councils for their valuable guidance in successful implementation of the research and development programs of the Institute. We acknowledge greatly the unstinted help and assistance received from our peers, well wishers and supporters in successfully pursuing our R&D and outreach activities. We look forward to your continued guidance, advice and support in all our future endeavors.

DK Upreti
Acting Director

अनुसंधान एवं विकास

उच्च संस्थागत नेटवर्क परियोजनाएं

1. पादप संपदा एवं अन्य प्राकृतिक संसाधनों का पूर्वेक्षण

उत्तराखंड के गोविंद वन्य जीव अभयारण्य (GWLS) के जैविक संसाधनों के मापन कार्य के अंतर्गत ***थैलोट्रेमोइड*** लाइकेंस (121 प्रजातियाँ) एवं *कोरिडेलिस* (23 प्रजातियाँ) के वर्गीकरण का अध्ययन किया गया। कुल 637 एन्जिओस्पेर्म, 315 लाइकेन, 350 ब्रायोफाइट्स, 154 शैवाल और 85 टेरिडोफाइटस की प्रजातियों की सूची तैयार की गयी।

GWLS में नई क्षेत्रीय चार ब्रायोफाइटस प्रजातियों (***रिक्सिया बेरिचिअना*** हेम्पे, ***टेलोरिया होर्न्सचिची*** (Grev. & Arn.) Broth., ***लिंबर्जिया कोएल्जी*** Williams, एवं ***ब्रेकिथेसियम फल्केतुलम*** Broth.) की भी पहचान की गयी। GWLS में ***मर्केंसिया पेलेसिया*** Bertol. एवं ***प्लेजिओकेस्मा एपेंडीकुलेटम*** Lehm. के लिए कृत्रिम परिवेशिय प्रसारण विधियाँ विकसित की गयी तथा फर्न की तीन प्रजातियों ***एथाईरियम पेक्टिनेतम*** (Wall ex. Mett.), *टी. मूर,* ***ड्रोपटेरिस कोल्चियेता*** (Buch.Ham.ex. D.Don) C.ChrA एवं ***ओंकियम कोंटिगम*** Wall.ex Hope का स्पोर कल्चर के माध्यम से कृत्रिम परिवेशिय अध्ययन किया गया।

बर्जीनिया स्त्रेकायी की उत्तरी हिमालय की प्रजातियों में आनुवांशिक विभिन्नता के अध्ययन के अंतर्गत ***बर्जीनिया स्त्रेकायी*** की पश्चिमी हिमालय क्षेत्र (जम्मू व कश्मीर एवं हिमाचल प्रदेश से) एकत्रित 41 नमूनों में आनुवांशिक विभिन्नता के अध्ययन हेतु 10 DAMD एवं 16 ISSR मार्कर्रों का प्रयोग किया गया। संचित डाटा के अध्ययन से *बर्जीनिया स्त्रेकायी* के नमूनों में 87.14% बहुरूपता का पता चला।

GWLS के चयनित औषधीय पौधों की 11 प्रजातियों के 68 नमूनों की डीएनए बारकोडिंग का कार्य किया गया।

गांगेय मैदानों में ***फाइकस*** का वर्गिकी अध्ययन कार्य पूरा हो चुका है। ***फाइकस*** की 38 प्रजातियों को पूर्वी राजस्थान, उत्तर प्रदेश, बिहार, झारखंड और पश्चिम बंगाल के शामिल अध्ययन क्षेत्रो से सूचीबद्ध किया गया।

लाइकेन से घाव भरने के लिए नैनो एंटीमाइक्रोबियल फार्मुलेसन को एक प्रौद्योगिकी के रूप में विकसित करने हेतु अध्ययन अनुसन्धान किया गया। नैनो एंटीमाइक्रोबियल फार्मुलेसन से स्ट्रेप्टोमाइसिन सल्फेट और बीटाडाइन की तरह सकारात्मक नियंत्रण के बराबर प्रभावकारिता का पता चला।

GWLS से एकत्रित संभावित विरोधी कैंसर पौधों की मेटाबोलाइट फिंगरप्रिंटिंग कार्य के अंर्तगत भोजपत्र (***बेटूला उटैलिस***) से बायोएक्टिव यौगिकों का प्रथक्करण किया गया। जिनमे दस यौगिकों को भोजपत्र छाल से पृथक किया गया है एवं सात पहचान की गयी। दो यौगिकों (NBMP -6 और NBMP-7) को पहली बार इस पौधे से खोजा गया तथा प्राप्त यौगिकों को पांच विभिन्न प्रकार की कैंसर कोशिका लाइनों में तुलनात्मक *इन-विट्रो* साइटोटोक्सिक गतिविधियों के लिए परीक्षण किया गया। NBMP-7 में कोलोन और स्तन कैंसर कोशिका लाइनों के खिलाफ सबसे महत्वपूर्ण साइटोटोक्सिक एक्टिविटी पायी गयी।

मार्केंसिया पोलिमोर्फा से रासायनिक अंशों का चार कैंसर कोशिका लाइनों (स्तन, पेट, सिर व गर्दन और सामान्य उपकला कैंसर कोशिका लाइन) के विरूद्ध *इन-विट्रो* साइटोटोक्सिक गतिविधियों के लिए मूल्यांकित किया गया। ***मार्केंसिया पोलिमोर्फा*** के कल्चर से प्राप्त हेक्सेन अंश में भी अन्य निष्कर्षित अंशों की तुलना में स्तन, पेट और सिर व गर्दन के कैंसर कोशिका लाइनों के खिलाफ साइटोटोक्सिक एक्टिविटी पायी गयी।

संभावित औषधीय पौधों के पादप रसायानों की प्रोफाइलिंग का अध्ययन कार्य में ***बर्जीनिया सीलिएटा*** के नमूनों को विभिन्न ऊंचाइयों से एकत्रित कर उनके बर्जेनिन अंश का अध्ययन किया गया। दो हजार नौ मीटर की ऊंचाई से प्राप्त ***बर्जीनिया लिगुलाटा*** के 24 नमूनों में बर्जेनिन अंश सबसे अधिक (77.25 mg/g) पाया गया जबकि ***बर्जीनिया स्त्रेकायी*** एवं ***बर्जीनिया पर्पुरासेन्स*** में बर्जेनिन अंश 55.0 mg/g पाया गया।

भोजपत्र (***बेटुला उटैलिस***) से उच्च प्रदर्शन तरल क्रोमैटोग्राफी (एचपीएलसी) और उच्च संकल्प मैजिक कोण स्पिनिंग परमाणु चुंबकीय अनुनाद स्पेक्ट्रोस्कोपी (एचआर मास एनएमआर) द्वारा पेंटासाइक्लिक ट्राईटरपिंस के निर्धारण हेतु एक विश्वसनीय प्रोटोकॉल विकसित किया गया तथा हिमाचल प्रदेश और उत्तराखंड में हिमालय से 2013 में अलग अलग ऊंचाई से एकत्रित भोजपत्र की छाल के नमूनों को NBRI-1, NBRI-2, NBRI-3, NBRI-7 के रूप में चिह्नित किया गया। भोजपत्र के लायोंफीलाइजड छाल सैंपल की HR&MAS NMR स्पेक्ट्रोस्कोपी भी की गयी।

द्रोणपुष्पी (***लुकस सेफेलोटेस***) के जड़ों, पत्तियों, तनों और फल का इथेनॉल के साथ निष्कर्षण हेक्सेन, एथिल एसीटेट, क्लोरोफॉर्म में किया गया। सभी प्राप्त भागों में *इन-विट्रो* अल्फा एमिलेज व एंटी ऑक्सीडेंट एक्टिविटी टेस्ट किया गया। एथिल एसीटेट द्वारा निष्कर्षित भाग में स्केवेंजिंग एक्टिविटी सबसे ज्यादा पायी गयी।

अनंतमूल (***हेमीडेसमास इंडीकस***) की पत्तियों का इथेनॉल के साथ निष्कर्षण हेक्सेन, एथिल एसीटेट, क्लोरोफॉर्म में किया गया। सभी प्राप्त भागों में *इन-विट्रो* अल्फा एमिलेज व एंटी ऑक्सीडेंट एक्टिविटी टेस्ट किया गया। एथेनोलिक भाग से मानक दवा एकार्बोज की तुलना में सबसे अच्छा परिणाम प्राप्त हुआ। एथिल एसीटेट द्वारा निष्कर्षित भाग में स्केवेंजिंग एक्टिविटी सबसे ज्यादा पायी गयी।

जस्टिसिया एढेटोडा से प्राप्त तेल में प्रमुख घटक फाईटोल (57.8%) को निष्कर्षित किया गया हैं जो कि एक डाईटरपिंस व अत्यधिक जैविक रूप से सक्रिय यौगिक है। प्राप्त तेल को प्रतिरोधी मेथीसिलियम और संवेदनशील तनाव के खिलाफ जीवाणुरोधी गतिविधियों के लिए मूल्यांकित किया गया। तेल के घटकों ने उल्लेखित सूक्ष्मजीवों के खिलाफ अधिक रोगाणुरोधी गतिविधि प्रदर्शित की।

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

विशिष्ट एल्केलोइड के जैव संश्लेषण के अश्रेणीबद्ध चरणों में शामिल जीनो के cDNA को क्लोन किया गया। वायरस पोषित जीन साइलेंसिंग

द्वारा मेटाबोलाईटस के रूपांतरण का अध्ययन किया गया जिससे पाथवे में एल्केलोइड के उत्पादन हेतु शामिल जीन्स के संश्लेषण में आई कमी का पता चला। इसके साथ साथ पेपवेरिन संश्लेषण में शामिल एक जीन ***मिथाइल ट्रांसफेरेज*** की भूमिका अध्ययन स्थापित करने हेतु ***ई. कोलाई.*** बैक्टीरिया में एक्सप्रेस कराया गया।

AtMYB12 एक्स्प्रेस्सिंग टमाटर लाइनों के फल एवं पत्तियों में वैश्विक जीन अभिव्यक्ति विश्लेषण द्वारा विभिन्न ऊतकों में ***AtMYB12*** से अंतर मॉडुलन का अध्ययन किया गया। द्वितीयक पौध उत्पाद जैवसंश्लेषण में miRNAs की भागीदारी स्थापित करने के लिए, ***एरेबीडोप्सिस*** miR858a के कार्यात्मक लक्षण का वर्णन किया गया। ***एरेबीडोप्सिस*** miR858a के अधिक अभिव्यक्ति से कई MYB ट्रांसक्रिप्शन फैक्टर्स (जैसे फ्लेवोनोइड जैवसंश्लेषण में शामिल कारक) प्रभावित हुए। जिससे पौध विकास एवं फ्लेवोनोइड जैवसंश्लेषण में कई विनियमिताओं का पता चला।

ट्रांस क्रिप्टोम अनुक्रमण द्वारा केले के परिपक्व और अपरिपक्व होने की चरण-क्रिया में शामिल जीन परिवारों के सदस्यों की पहचान के लिए विश्लेषण किया गया। AP2 / ERF, HDZIV और WRKY जीन परिवारों सहित विभिन्न जीन परिवारों के विस्तृत विश्लेषण का अध्ययन किया गया। आम की दशेहरी व बेगानपाली किस्मो में बाहरी एवं भीतरी फलको के RNA की इल्लुमिना आधारित अनुक्रमण भी किया गया।

RNA की इल्लुमिना आधारित अनुक्रमण द्वारा ईथीलीन प्रभावित ***रोजा बोर्बोनियाना*** व ***रोजा हाईब्रीड़ा*** के विलगन क्षेत्रो से ईथीलीन जैवसंश्लेषण में शामिल जीन्स का अध्ययन किया गया।

कपास के जीनोमिक डाटा में कपास के रेशों की गुणवत्ता के नियंत्रकों को पहचानने एवं अभिलक्षण हेतु NBRI-समेकित कपास जीनोमिक डाटाबेस विकसित किया गया एवं ट्रांसक्रिप्शन फैक्टरों तथा एपिजेनिक मॉडुलन से संबन्धित जींस की पहचान की गई। कपास के रेशों के विकास में एपिजेनिक मोडीफायर्स के प्रभाव का पता लगाने हेतु प्रयोगशाला में अंडाणु संवर्धन द्वारा हिस्टोन रूपान्तरण के प्रभावों का अध्ययन किया गया।

धान की जेपोनिका एवं इंडिका किस्मों में भेदक सोमेटिक भ्रूण विकास को नियंत्रित करने वाले आनुवांशिक परिवर्तनों को समझने के लिए धान के कैलस की विभिन्न अवस्थाओं एवं पुर्नुत्पादन की जीनोम स्तर पर अभिव्यक्ति का विश्लेषण किया गया।

एक द्विलिंगी औषधीय पौधे ***टीनोस्पोरा कार्डीफोलिया*** में लिंग भेद के आणुविक आधार के अध्ययन के लिए पौधे को देश के विभिन्न स्थानों से एकत्रित किया गया तथा ट्रांस क्रिप्टोम डेटाबेस को स्थापित किया गया।

अजैविक तनाव जैसे भारी धातु तनाव सहिष्णुता एवं एकत्रीकरण हेतु बहुत से जींस एवं प्रोमोटर्स की भागीदारी के लिए क्रियात्मक अभिलक्षणन किया गया।

सफेद मक्खी प्रतिरोधी जीएम कपास का विकास

सफेद मक्खी दुनिया भर में कपास सहित कई फसलों के लिए एक आक्रामक कीट है। फसलों की उच्च तापमान, आर्द्रता, घने फसल और पॉलीहाउसेस में खेती सफेद मक्खी के फैलने को बढ़ाते हैं। सफेद मक्खी पौधों से रस चूस कर कवक संक्रमण करती हैं तथा फसलों में वायरस को प्रसारित करती हैं। सीएसआईआर-एनबीआरआई ने एक खाद्य फर्न में एक सफेद मक्खी प्रतिरोधी प्रोटीन की पहचान की है। इस प्रोटीन से सफेद मक्खी की प्रजनन प्रणाली में हस्तक्षेप हो जाता हैं और इस तरह से इसकी आबादी को बढ़ने से रोका जा सकता हैं। इसका प्रभावी जीन कपास में क्लोन किया गया है। ट्रांसजेनिक कपास के कई पीढ़ियों के संवर्धन के माध्यम से सफेद मक्खी की आबादी पर नियंत्रण करना संभव हो पाया हैं। सफेद मक्खी प्रतिरोधी प्रोटीन का स्रोत एक जातीय-वानस्पतिक खाद्य फर्न है जिसका बायोसेफ्टी अध्ययन से यह पता लगाया गया है कि यह प्रोटीन स्तनधारियों के लिए सुरक्षित है।

3. पादप विविधताः उपयोगी बायोएक्टिव हेतु औषधीय रूप से महत्त्वपूर्ण पौधों को समझने/दोहन करने हेतु अनुकूलन विज्ञान का अध्ययन

एक पारंपरिक औषधीय पौधे (NBRI-CHT1) की प्रजातियों की जीसी एमएस द्वारा मेटाबोलाईट प्रोफाइलिंग से प्राप्त क्लोरोफॉर्म भाग से जर्मक्रोंन को एक प्रमुख यौगिक के रूप में निष्कर्षित किया गया। पारंपरिक चिकित्सा में जर्मक्रोंन की कैंसर रोधी और विरोधी ट्यूमर गुण में प्रदर्शित हुए हैं।

ऊंचे स्थानों में अनुकूलन के अध्ययन कार्य में ***एरेबीडोप्सिस थैलियाना*** के पौधों को उत्तरी हिमालय में समुद्र तल से 700 मी. से लेकर 3400 मी. की विभिन्न ऊंचाईयों क्रमशः देहरादून (700 मी.), मुनस्यारी (1829 मी.) एवं छितकुल (3453 मी.) से एकत्र किया गया। इन सभी एकत्रित नमूनों में एकल न्यूकलोटाइड बहुरूपता का अध्ययन स्थानीय एवं वैश्विक स्तर पर किया गया।

शुष्क क्षेत्र में ***सायमोप्सिस टेट्रागोनोलोबेटा*** (ग्वार) का शरीर-क्रियात्मक प्रतिक्रिया अध्ययन हेतु ग्वार की तीन किस्मों (RGC-1002, RGC-1066 और RGC-936) को ग्रोथ चौम्बर में उगाया गया। चालीस दिन पुराने ग्वार के पौधों को शुष्क तनाव दिया गया। विभिन्न पिगमेंट के साथ-साथ पत्ती के ऑप्टिकल गुणों का भी विश्लेषण किया गया। पत्तियों के ऑप्टिकल गुणों में शुष्क तनाव की अवस्था में स्पेक्ट्रा के विजिबल और अवरक्त क्षेत्र में बड़े बदलाव दिखाई दिए। गर्मी के रूप में प्रकाश ऊर्जा के अपव्यय को RGC-1002 किस्म ने सबसे ज्यादा प्रदर्शित किया जिससे पता चला कि RGC-1002 सूखे के प्रति सर्वाधिक सूखा सहनशील है। ग्वार के प्रोटिओमिक्स अध्ययन शोध कार्य हेतु उच्च CO_2 की अवस्था में ग्वार की RGC 1066 किस्म में 50 विभिन्न व्यक्त प्रोटीनों में से 23 अपरेगुलेटेड एवं 27 डाउन रेगुलेटेड पाए गए जिनमे से 30 प्रोटीनों की मास स्पेक्ट्रोमेट्री (MALDI-TOF-TOF) के माध्यम से पहचान की गई। जबकि ग्वार की RGC 1002 किस्म में 32 विभिन्न व्यक्त प्रोटीनों में 19 अपरेगुलेटेड एवं 13 डाउन रेगुलेटेड पाए गए।

पत्ती क्षेत्र सूचकांक का अध्ययन LAI-2000 सिस्टम की सहायता से मानसून के बाद कतर्नियाघाट वन्यजीव अभयारण्य में तीन विभिन्न तरह के वृक्षों (ड्राई मिसलेनीयस, साल मिश्रित व टीक) पर किया गया। ग्राउंड पत्ती क्षेत्र सूचकांक इन तीन वृक्षों में क्रमशः 2.38-6.88, 1.47-7.32 व 180^0 द्रष्टिकोण के साथ 2.02-5.49 पाया गया।

QuadPOL alos Palsar डेटा का उपयोग कर ***शोरिया रोबस्टा*** एवं ***टेक्टोना*** के जंगलों में जीवित बायोमास तथा कार्बन एस्टिमेट्स का अध्ययन किया गया।

कतर्नियाघाट वन्यजीव अभयारण्य में विभिन पर्यावरण निचे क्षेत्रो में ***मेलोटस फिलिपेंसिस*** के प्रजनन जीव विज्ञान का अध्ययन किया गया। नर और मादा पौधों के उत्थान की क्षमता, उपज एवं प्रजनन की स्थिति का मूल्याकन किया गया। फूल और गैर फूल पौधों की अधिकतम संख्या क्रमशः ड्राई मिसलेनीयस एवं सागौन वृक्षों के समुदायों में पायी गई।

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

कैना, ग्लेडियोलस और अन्य बल्बस पौधों का चयन एवं विविधिता अध्ययन के अंतर्गत नई किस्मो के विकास हेतु कैना की गोल्डन गर्ल और रेड प्रेसिडेंट किस्मो पर गामा विकिरण के साथ विभिन्न स्तरों पर प्रयोग किये गए। चुने गए म्युटेंट पौधे को आगे के लक्षण अध्ययन के लिए संधारित किया गया। ग्लेडियोलस के 86 नमूनों में आणविक लक्षण वर्णन के अध्ययन हेतु क्लोरोप्लास्ट के स्पेसर क्षेत्र की PsbA-trnH इंटरजेनिक न्युक्लियोटाइड विविधता का आंकलन किया गया। जर्मप्लाज्म संवर्धन के अंतर्गत ग्लेडियोलस की बैंगलोर ब्यूटी व पंजाब एलेगंस किस्मो को वनस्पति उद्यान के संग्रह में जोड़ा गया।

पादप सुधार एवं जर्मप्लाज्म संग्रह का आंकलन उद्देश्य हेतु ***बिक्सा*** एवं ***करकुमा*** की किस्मो का अध्ययन किया गया। बिक्सा के 17 नमूनों को विभिन्न जैव-भौगोलिक क्षेत्रों से एकत्र करके दूरस्थ अनुसन्धान केंद्र, बंथरा में विकास, उपज एवं गुणवत्ता (बिक्सिन) के लिए मूल्यांकित किया गया। दमास्क रोजेज (रोजा डेमेसिना) की 6 नमूनों (NBRD-1, NBRD-2, NBRD-3, NBRD-4, NBRD-5 और NBRC-1) का सोडिक मिटटी में विकास एवं गुणवत्ता हेतु आंकलन किया गया।

चयनित पौधों के बहु स्थानीय क्षेत्र परिक्षण हेतु सीएसआईआर-एनबीआरआई द्वारा ग्लेडियोलस, कैना एवं बिक्सा की पौध सामग्री सीएसआईआर की सिस्टर प्रयोगशालयों (सीएसआईआर-आईआईआईएम, जम्मू एवं सीएसआईआर-आईएचबीटी, पालमपुर) को भी दी गयी जिनमे ग्लेडियोलस की 'नीलिमा', 'रोशनी', 'उषा' व अमेथिस्ट किस्म तथा कैना की 'रक्तिमा' व 'अग्निशिखा' किस्म शामिल है। इसके अलावा सीएसआईआर-आईएचबीटी, पालमपुर ने ग्लेडियोलस की 6 किस्मे (पालमपुर प्राइड, 'पालमपुर डिलाईट', 'पालमपुर क्वीन, 'तुषार मौली', 'सेंट' और 'सिलेक्शन नं 30') सीएसआईआर-एनबीआरआई को प्रदान की हैं।

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

जीवाणु द्वारा उच्च आणविक भार वाली एल्केनो जैसे एन- टेट्राकोसेन के जैविक अपघटन के अध्ययन में तीन पेट्रोलियम अपघटन करने वाली जीवाणु प्रजातियों ***पी. एरुजिनोसा, क्रोनोबक्टर*** एवं ***रोड़ोकोकस*** के साथ विभिन्न स्थितियों में प्रयोग किये गए। टेट्राकोसेन का ***पी. एरुजिनोसा*** द्वारा 91%, ***क्रोनोबक्टर*** द्वारा 88% तथा ***रोड़ोकोकस*** द्वारा 85% अपघटन हुआ।

कम आर्सेनिक वाली धान की प्रजाति विकसित करने के लिए सल्फर और सेलेनियम के साथ साथ अनुपूरण द्वारा विभिन्न प्रयोग किये गए। सल्फर पौधे की जड़ों में उपस्थित आर्सेनिक के साथ जुड़कर थिओल चिलेसन बना देता हैं जिससे आर्सेनिक का प्रवाह पौधे के तनों तक कम हो जाता हैं। सल्फर और सेलेनियम का एक साथ की पूरकता, पौधों में आर्सेनिक लोड को कम करने के लिए एक प्रभावी रणनीति हो सकती है।

धान की भूसी के अपघटन के द्वारा भूमि में कार्बन जब्ती हेतु माइक्रोबियल कवक और बैक्टीरिया का एक संयोजन विकसित किया गया है। विघटित भूसे को गमलों में उगाये हुए मक्के के पौधों के साथ मिला कर पौध वृद्धि का परिक्षण किया गया तथा फील्ड परिक्षण में इस फॉर्मुलेशन से गेहूं की बेहतर पैदावार का निष्कर्ष मिला हैं।

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

भारत में मक्का चावल और गेहूं के बाद तीसरी सबसे महत्वपूर्ण खाद्य फसल है। मक्का की दो किस्मे (PEHM2 व SMH 3031) जो समान विकास एवं वृद्धि अवस्था प्रदर्शित करती है, को उच्च CO_2 के लिए प्रतिक्रिया अध्ययन हेतु चयनित किया गया। अध्ययन के लिए 6 रिंग FACE सुविधा के 3 रिंग कार्बन डाइऑक्साइड (400 पीपीएम) तथा अन्य तीन को उसके संवर्धन हेतु (460 पीपीएम) इस्तेमाल किया गया। चयनित की गयी किस्मो ने उच्च CO_2 की अवस्था में फोटोसिंथेसिस में वृद्धि एवं कम रेसपिरेसन, कम रंध्र चालकता व कम ट्रांसपिरेसन को प्रदर्शित किया। दोनों किस्मो ने उच्च CO_2 की अवस्था में अधिक बायोमास प्रदर्शित किया जबकि कम लिपिड पेरोक्सीडेसन सिर्फ SMH 3031 में प्राप्त हुआ। PEHM 2 में कुल ग्लूटेथिओन् में कमी प्राप्त हुयी है जो किस्म SMH 3031 में वृद्धि में थी। सुपरऑक्साइड डिसम्युटेज के स्तर में वृद्धि सिर्फ PEHM 2 में प्राप्त हुयी। केटालेज और एपीएक्स के स्तरों में कमी दोनों किस्मो में प्राप्त हुयी ।

7. पादप सूक्ष्म जीव एवं मृदा संबंध

पेनीबेसिलस लेंतीमोर्बस B 3048 द्वारा उत्पादित 1-एमिनोसाइकलोप्रोपेन-1- कार्बोक्सिलेट (एसीसी) डीएमिनेज द्वारा टमाटर में लगने वाले साउथर्न ब्लाइट रोग (***इस्क्लेरोसियम रॉल्फसाईं***) की रोकथाम का अध्ययन किया गया। टमाटर की खेती में मिट्टी जनित रोगों की अत्यधिक संभावना रहती है और इस रोगों पर रासायनिक कवकनाशी भी अधिक प्रभाविकता से कार्य नहीं कर पातें हैं। ऐसे में राइजोबैक्टीरिया ***पेनीबेसिलस लेंतीमोर्बस*** B 3048 एक पर्यावरण अनुकूल विकल्प साबित हो सकता हैं। इस बैक्टीरिया से प्राप्त एंजाइम एसीसी डीएमिनेज का *इन-विट्रो* और *इन-विवो* परिस्थितियों में कवक के विरूद्ध परिक्षण के सकारात्मक नतीजें प्राप्त हुए हैं।

पेनीबेसिलस लेंतीमोर्बस B 30488 का एक जैव-इनोकुलेंट के रूप में प्रयोग कई महत्वपूर्ण वायरस जैसे कुकुम्बर मोजेक वायरस के खिलाफ किया जा सकता हैं। मिटटी के साथ B 30488 का जैव-इनोकुलेंट प्रभावी रूप से तम्बाकू में कुकुम्बर मोजेक वायरस को फैलने से रोकने में कारगर साबित हुआ हैं। इस जैव-इनोकुलेंट ने पौधे में वायरस के प्रवाह को 91% तक कम कर दिया। प्रयोग में लाए पौधे की पत्तियों के ऊतक विज्ञान से स्वस्थ ऊतकों या निम्न वायरस संक्रमण की पुष्टि की गयी हैं।

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

सीएसआईआर-एनबीआरआई द्वारा विकसित उत्पाद न्यूट्री-जैम के साथ वैज्ञानिक एवं तकनीकी के माध्यम से हस्तक्षेप द्वारा कुपोषण का मुकाबला करने हेतु करने के लिए दो गाँवों दाऊ (उन्नाव) एवं दफेदार का पुरवा (बाराबंकी) को चुना गया। ग्रामीण जनता में स्वास्थ्य के प्रति जागरूकता

फैलाने हेतु सब्जियों, फलों, अनाजों एवं औषधीय पौधों आदि के महत्त्व से संबन्धित विभिन्न पहलुओं पर आधारित पोस्टर तैयार किए गए तथा दाऊ गाँव के प्राथमिक विद्यालय के कक्षों में प्रदर्शित किए गए। स्कूल के बच्चों को सब्जियों, फलों आदि की पोषकता तथा महत्त्व एवं औषधीय पौधों और उनके प्रयोग के बारे में शिक्षित किया गया।

इस वर्ष के दौरान गावों में आयोजित चार से पांच स्वास्थ्य शिविरों में उत्पादों और पोस्टर को प्रदर्शित किया गया। सीएसआईआर-सीमैप के डॉक्टरों के साथ मिल कर, युवा लड़कियों, महिलाओं और पुरुषों की कुपोषण स्थिति का डेटा एकत्रित किया गया। इसके साथ साथ चयनित लोगो कुपोषण से निपटने के लिए को पोषण संबंधी उत्पादों को वितरित किया गया।

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

पौध वृद्धि को बढ़ावा देने वाले राइजोबैक्टीरिया ***स्यूडोमोनास पुटिडा*** NBRIRA और ***बेसिलस एमाईलोलिक्यीफेसियंस*** NBRISN13 के सहक्रियाशीलता के प्रभाव से चने में सूखे तनाव के प्रति सहनशीलता का अध्ययन किया गया। दोनों बैक्टीरिया पौधे में एंजाइम एसीसी डीएमिनेज की गतिविधि, खनिज घुलन, अजैविक तनाव को सहन करने की क्षमता, हार्मोन, साईडरोफोर की गतिविधि को बढ़ाते हैं। अतः इन दोनों बैक्टीरिया के मिश्रण को साथ साथ उपयोग से चने के पौधे को बेहतर विकास तथा अत्यधिक तनाव के प्रति सहनशील बनाया जा सकता हैं।

स्यूडोमोनास पुटिडा के जैव-इनोकुलेंट के रूप में प्रयोग से काबुली चने में सूखे तनाव की अवस्था में पौधे की जैव रासायनिक और आणविक प्रतिक्रियाओं को नियंत्रित किया जा सकता है।

वेटिवर (***क्रयीसोपागों जिजेनिओडस***) की दो मोर्फोटाइप्स (उत्तरी भारत एवं दक्षिणी भारत से प्राप्त) की ट्रांसक्रिप्टोम एनालिसिस से उनके तेल एवं जड़ की गुणवत्ता परखने के लिए करी गयी।

ट्रांसक्रिप्टोम एनालिसिस से धान की दो विरोधास्पद किस्मो (सूखा तनाव सहनशील व सूखा तनाव संवेदनशील) का तुलनात्मक अध्ययन किया गया। जिससे 22 अत्यधिक विविध व्यक्त जीन्स को चयनित कर उनके आपेक्षिक गतिविधियों का निर्धारण किया जा रहा हैं।

वानस्पतिक उद्यान एवं दूरस्थ अनुसंधान केंद्र

उत्तर प्रदेश में हल्दी (*कुर्कुमा लोंगा*) का मानकीकरण एवं ओर्गैनिक बीज उत्पादन का प्रसार

विश्व में ओर्गेनिक पदार्थों की बढ़ती मांग के चलते किसानों के लिए मुनाफा युक्त ओर्गेनिक खेती के तरीके की आवश्यकता भी पड़ेगी। अतः इस दिशा में हल्दी के वाणिज्यिक उत्पादन पर प्रयोगात्मक अध्ययन किए गए। प्राप्त नतीजों से पता चला कि विभिन्न जैव-नियंत्रकों के प्रयोग से हल्दी की फसल में पर्ण धब्बों को छोडकर अन्य बीमारियों के प्रति प्रतिरोधकता में बढ़त देखने को मिली। सामान्य स्थितियों में बीमारी होने की घटनाएँ 11.54% एवं *ट्राइकोडर्मा विरडी* उपचारित बीजों में 2.17% देखने को मिलीं। अन्य तुलनात्मक परीक्षणों में भी ऐसे ही नतीजे देखे गए।

विशेष क्लोनों तथा औषधीय एवं सगंध पौधों की नई किस्मों के त्वरित गुणन हेतु छोटी नर्सरी की स्थापना

राष्ट्रीय वनस्पति अनुसंधान संस्थान जर्मप्लाज्म एकत्रीकरण, संरक्षण, खेती एवं पौधों के उगाने के तरीकों के मानकीकरण तथा औषधीय, सगंध, रंजक उत्पादक पौधों के एकत्रित जर्मप्लाज्म के आंकलन के क्षेत्र में कार्यरत है। इस दिशा में औषधीय तथा सगंध पौधों के उत्पादन हेतु एक नई सुविधा की स्थापना की गई है। हमने ग्रामीण विकास को लक्ष्य करते हुये संस्थान की विभिन्न प्रौद्योगिकियों के लिए किसानों से संपर्क किया है, जिसके तहत किसानों ने संस्थान द्वारा आयोजित विभिन्न किसान मेलों में भाग लिया एवं विभिन्न पौधों को उगाने से संबन्धित जानकारी में रुचि प्रदर्शित की। सीएसआईआर के ग्रामीण विकास कार्यक्रम के तहत किसानों को हल्दी, सतावर आदि पौधों को उगाने से संबन्धित तकनीकों की जानकारी दी गई एवं साथ ही बीजों एवं पौधों का वितरण भी किया गया।

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

अश्वगंधा (***विथानिया सोम्नीफेरा***) एवं कालमेघ (***एंड्रोग्राफिस पैनीकुलेटा***) पर सोडीसिटी आंकलन किए गए एवं भविष्य में शोध हेतु अश्वगंधा की 7 किस्मों एवं नमूनों को व्यवस्थापित किया गया। यह पाया गया कि बिना फसल की गुणवत्ता एवं उपज को नुकसान पहुंचाए अश्वगंधा को 25ESP तक एवं कालमेघ को 16ESP तक उगाया जा सकता है। इस तरीके को सोडिक मृदा के विकास हेतु मानकीकृत किया गया।

कालमेघ की गुणवत्ता एवं जैव-भार उपज पर कार्बनिक पदार्थ के विभिन्न स्रोतों एवं स्तरों के प्रभावों का अध्ययन

गत वर्ष FYM (0-30 t ha^{-1}), प्रेसमड (0-15 t ha^{-1}) एवं वर्मी-कम्पोस्ट (0-15 t ha^{-1}) का प्रयोग किया गया एवं इस वर्ष डाली गई कार्बनिक खाद की अवशेषी प्रतिक्रियाओं का कालमेघ की वृद्धि एवं उपज पर अध्ययन किया गया। सर्वाधिक प्रतिक्रिया FYM के साथ वर्मी-कम्पोस्ट में न्यूनतम अवशेषी प्रतिक्रिया देखी गई। पौधों की औसत उपज एवं गुणवत्ता के आंकलन हेतु विभिन्न ओर्गनिक कार्बन स्तरों के विकास के लिए इस पद्धति का मानकीकरण किया गया।

संरक्षण, शिक्षा एवं जैविक-सुंदरता हेतु विभिन्न पादप समूहों एवं चुनिंदा सजावटी फसलों के जर्मप्लाज्म के संग्रह का विकास एवं व्यवस्था

वानस्पतिक उद्यान संस्थान की एक राष्ट्रीय सुविधा की भांति कार्य करता है। संस्थान की वनस्पति वाटिका एवं विभिन्न पौध गृहों में लगभग पाँच हजार पौधों के जर्मप्लाज्म को *एक्स-सीटू* रूप में संरक्षित किया गया है। यह जीवित जर्मप्लाज्म नमूने लैंडस्केपिंग में प्रयोग किए जाने के साथ साथ वानस्पतिक अध्ययनों एवं शोधों के लिए एक महत्वपूर्ण स्रोत हैं। वानस्पतिक उद्यान अपने वृहद आनुवांशिक स्रोतों के कारण विद्यार्थियों, शोधार्थियों एवं आम जन के लिए एक महत्वपूर्ण ज्ञान एवं शिक्षा का केंद्र है।

जर्मप्लाज्म समृद्धि

जर्मप्लाज्म समृद्धिकरण कार्यक्रम के तहत पौधों को एकत्र करने के लिए विभिन्न यात्राएं की गईं एवं निम्न पौधों को उद्यान में समाहित, गुणित एवं प्रचारित किया गया

आर्किड्स

आर्किड्स की लगभग 30 प्रजातियों को 6 राज्यों, असम, बिहार, झारखंड, मेघालय, मणिपुर एवं उड़ीसा से एकत्र किया गया एवं संस्थान के आर्किड गृह को पुनर्जीवित किया गया। कुछ प्रमुख प्रजातियाँ हैं: ***एकैम्पे प्रीमोर्सा, अरुंडिना ग्रैमीनीफोलिया, बल्बोफिल्लम क्रैसीपस, सीलोगाइन क्रिसटाटा, सिंबीडीयम प्रजाति, डेंड्रोबियम एफील्लम, डेंड्रोबियम हरबेसियम, डेंड्रोबियम मोसकेटम, गैस्ट्रोकाइलस इंकन्सेपीकुयस, लूसिया इंडिका, ओबेरोनिया*** प्रजाति, ***पेलाटैन्थेरिया इन्सेक्टीफेरा, रिंकोस्टाइलिस रेटचूसा, वैंडा सीरूलिया, वैंडा टेस्सेलाटा*** आदि। ***डेंड्रोबियम एफील्लम*** एवं ***वैंडा टेस्सेलाटा*** संकटग्रस्त होने के कारण आईयूसीएन की रेड लिस्ट में भी शामिल हैं। जबकि *वैंडा सीरूलिया* वन्यजीवन संरक्षण अधिनियम 1972 के अंतर्गत एक संरक्षित पादप है।

साइकेड्स

उड़ीसा से हाल ही में वर्णित की गई ***साइकस ओरिक्सेंसिस*** एवं ***साइकस नायगरेंसिस*** को उनके वर्णन के स्थान से एकत्र कर वानस्पतिक उद्यान में संरक्षित किया गया। अंगुल एवं नायगढ़ जिलों से युवा पौधों एवं बीजों को एकत्र किया गया। सायकेड गृह एवं संरक्षणशाला में ***जामिया लोड़ीगेशाई*** के 1000 से अधिक एवं ***जामिया पूमिला*** के 40 बीजों को कृत्रिम परागण के द्वारा विकसित किया गया।

वृक्ष

क्राइसोफील्लम सिनिटो एवं ***लैब्रोमा बाजोरी*** को भारतीय वानस्पतिक अनुसंधान, हावड़ा के वानस्पतिक उद्यान से एवं ***ब्राउनिया कोकसीनिया, गुस्ताविया अंगस्टा*** एवं ***मैग्नोलिया ग्रैंडेलोरा*** को कृषि-बागवानी सोसाइटी, कोलकाता से एकत्र किया गया।

फर्न

कृत्रिम रूप से प्रयोगशाला में उगाये गए ***डाईप्लैजियम एस्कूलेंटम*** को सफलतापूर्वक फर्न गृह में स्थानांतरित एवं स्थापित किया गया।

माँस एवं लीवरवर्ट

संस्थान के माँस गृह में 9 प्रजतियों ***प्लैजियोकाज्मा इंटरमीडियम, प्लैजियोकाज्मा कार्डेटम, ब्रायम कोरोनेटम, यूनेरिया हाइग्रोमेट्रीका, कोनोसेफैलम कोनिकम, रिबोलिया हेमीस्फेरिका, विसनेरेल्ला डेनूडेटा, मार्केन्शिया पोलीमोर्फा, टार्जीओनिया हाइपोफिल्ला*** को स्थापित किया गया।

संरक्षण एवं सामूहिक उत्पादन

सजावटी फर्न की 12 प्रजातियों का सामूहिक उत्पादन (लगभग 950 पौधे) किया गया जिनमें ***सिलैजिनेला ब्रायोप्टेरिस*** (संजीवनी) एवं ***डोरियोप्टेरिस लूडेन्स*** (एक संकटग्रस्त पौधा) शामिल हैं।

दुर्लभ साइकेडों का गुणन

संस्थान के वानस्पतिक उद्यान में साइकेडों के संरक्षण हेतु तीन गेंहरू साइकेड गृह, जुरासिक गैलेरी एवं संरक्षणशाला स्थापित हैं और इस प्रकार का भारत में यह एकमात्र केंद्र है। इस केंद्र में साइकेड्स की 56 प्रजातियाँ मौजूद हैं जिनमें 7 भारतीय प्रजातियाँ हैं। वर्तमान में ***जामिया*** की 3 एवं ***साइकस*** की 4 भारतीय प्रजातियों के गुणन एवं उत्पादन पर कार्य किया जा रहा है।

नई किस्मों का विकास एवं विमोचन

बोगेनविलिया

बोगेनविलिया के एक नई किस्म *'एनबीआरआई - एपीजे अब्दुल कलाम'*

विशेषता

तीन रंगों (हरा, पीला एवं धूसरित पीला) के संयोजन से उत्पन्न चक्कतों के कारण बहुत ही आकर्षक पत्तियाँय बड़ी, मुड़ी, ब्रैक्ट्स एवं शीत-पुष्पन।

उत्पादकः डॉ. आर. के. राय

गुलदाउदी

गुलदाउदी की एक नई किस्म 'एनबीआरआई - पीताभ'

विशेषता

फूल आसामनी रूप से बड़ा, अर्ध-कप के आकार का तथा अर्ध-क्विल्ड, बड़ी ट्यूब युक्त पंखुड़ियाँ साथ ही पंखुड़ियों पर केंद्र में बैंगनी धारियाँ एवं किनारों पर हल्के बैंगनी रंग का संयोजन। यह किस्म सजावटी प्रयोग हेतु गमलों में लगाने लायक है।

संकटग्रस्त प्रजातियों के लिए उत्पादन गृह

संकटग्रस्त प्रजातियों का संरक्षण एवं उत्पादन वानस्पतिक उद्यान की महत्वपूर्ण गतिविधियों में से एक हैं। संकटग्रस्त प्रजातियों की जनसंख्या बढ़ाने के लिए उनके संरक्षण एवं विनिमय हेतु एक विशेष उत्पादन गृह का निर्माण किया गया है। इस समय निम्न प्रजातियाँ उगाई जा रही हैं: ***साइकस बेडोमी, साइकस पेक्टीनाटा, साइकस रिवोल्यूटा, साइकस स्फेरिका, डायोस्पाइरोस डिस्कलर, होया वाइटाई, लुइसिया इंडिका, नेपेंथीस खासियाना, सैंटेलम अल्बम, सराका असोका, सीक्योडेंड्रोन जाइगैंटीयम, जामिया फरयूसिया, जामिया लोडीगेशाई*** एवं ***जामिया पूमिला***।

नवीन कियोस्क स्थल

वानस्पतिक उद्यान के सुधार कार्यक्रम के अंतर्गत कैना एवं ग्लैडिओलस उद्यान के समीप एक नए स्थल का विकास किया गया। यहाँ पर सुन्दर भू-दृश्य निर्मित करने के उद्देश्य के लिए इसे विभिन्न सजावटी पौधों से सजाया गया है। इस स्थल को आगंतुकों के लिए सेल्फी प्वाइंट के रूप में विकसित किया गया है।

दूरस्थ शोध केंद्र (बंथरा शोध स्टेशन)

यह संस्थान का सोडिक भूमि पर बना एक प्रायोगिक केंद्र है। इसमें पाँच फील्ड इकाइयां (बंथरा, जैव-भार, गेंहरू, औरावां, रानीपुर) हैं जिन्हें भूमि के विभिन्न प्रयोग-तंत्रों जैसे, पुष्पकृषि, बागवानी, शाक कृषि, ऊर्जा वृक्षारोपण, फील्ड जीन बैंक, आदि के द्वारा पुनर्स्थापित किया गया है।

उत्तर भारत के लिए हल्दी के नमूनों का आंकलन एवं सुधार

हल्दी के 34 नमूनों को देश के विभिन्न क्षेत्रों से एकत्र कर बंथरा शोध केंद्र में संरक्षित किया गया है। उत्तर भारत के मैदानों के लिए उपयुक्त एक हल्दी की एक नवीन किस्म **'केसरी'** को 7 फरवरी 2016 को जारी किया गया।

आंशिक रूप से सुधारित सोडिक मृदा के लिए कर्कुमा प्रजाति का आंकलन

कर्कुमा की चार प्रजातियों को उनकी उपज के लिए जांचा गया एवं जैव-रासायनिक प्राईक्षण भी किए गए। ***कर्कुमा लोंगा*** को छोडकर सभी में कुल कर्कुमोनोइड्स नगण्य मात्रा में पाए गए। GCMS अध्ययन ने सभी प्रजातियों के पत्ती एवं कंद के आवश्यक तेलों में मुख्य यौगिकों में भिन्नता प्रदर्शित की। ***कर्कुमा लोंगा*** (52.03%) एवं ***कर्कुमा सेसिया*** (21.03%) के पत्ती के तेलों में मुख्य यौगिक पी-साइमीन रहा जबकि *कर्कुमा अमाडा* (32.91%) एवं ***कर्कुमा ज्योडेओरिया*** (29.55%) में कपूर रहा। कंद के आवश्यक तेलों में ***कर्कुमा लोंगा*** में α-टर्पीनीन (443%) एवं ***कर्कुमा सेसिया*** में β-germacrone (30.45%) पाया गया।

सोडिक मृदा में बिक्सा का आंकलन

विभिन्न क्षेत्रों से एकत्र किए गए ***बिक्सा*** के 17 नमूनों को बंथरा केंद्र के सोडिक मृदा (pH 8.7 से 9.2) पर उनकी वृद्धि, उपज एवं गुणवत्ता के लिए परखा जा रहा है। पौधों ने आकारकीय लक्षणों (पत्ती आकार, पुष्प आकार, कैप्सूल आकार, नाप एवं रंग आदि), उपज (प्रति पौधा कैप्सूल संख्या, प्रति कैप्सूल बीजों की संख्या एवं वजन) एवं गुणवत्ता (बिक्सिन की मात्रा) में भिन्नता प्रदर्शित की है। भिन्नताओं के आधार पर पूरे संग्रह को 7 समूहों में विभक्त किया गया है।

आधुनिक पान उत्पादन तंत्र

पान उत्पादन की आधुनिक तकनीक के तहत आधुनिक प्रकार के 'बरेजा' का विकास किया गया एवं विभिन्न प्रशिक्षण कार्यक्रमों में विभिन्न स्थानों पर पान के गुणात्मक उत्पादन के लिए किसानों के समक्ष इसका प्रदर्शन किया गया। यह पान को गर्मी में अत्यधिक गर्मी एवं सर्दी में पाले से बचाता है।

धान की किस्मों में सूखा प्रतिरोधकता की छंटनी

धान की दो किस्मों 'हिना' एवं 'किरण' पर प्रयोग किए गए जिनमें एक में बिना सिंचाई के, एक प्रयोग में बाली बनते समय अधिकतम एक सिंचाई, एक प्रयोग में बाली बनते एवं पुष्पन के समय अधिकतम 2 सिंचाई, एवं एक प्रयोग में हर 4-5 दिन पर सिंचाई की गई। 'हिना' ने विभिन्न परीक्षणों में पानी की कमी में बेहतर प्रदर्शन करते हुये सूखे के प्रति अधिक प्रतिरोधकता प्रदर्शित की।

सूखे से तनाव के उन्मूलन में PGPR की प्रतिक्रिया

चने की दो किस्मों पूसा 362 (देशी) एवं पूसा 1003 (काबुली) को खेतों में पानी की भिन्न कमियों के बीच उगाया गया जिनमें विना सिंचाई, अधिकतम वृद्धि के दौरान एक सिंचाई एवं विभिन्न वृद्धि अवस्थाओं के मध्य सिंचाई शामिल हैं। इन किस्मों को भिन्न पादप वृद्धि नियामक एजेंट के साथ उपचारित किया गया। पूसा 1003 (काबुली) ने विभिन्न प्रयोगों में बेहतर प्रदर्शन किया।

विभिन्न *एलो* प्रजातियों का संग्रह, अनुकूलन, गुणन, पहचान एवं सोडिक मृदा में जर्मप्लाज्म बैंक की स्थापना

इस शोध का उद्देश्य अनुकूलन में सक्षम औद्योगिक महत्व के पौधों के द्वारा बेकार सोडिक भूमि का सुधार एवं प्रयोग है। इस संबंध में ***एलो*** प्रजातियाँ काफी सक्षम होती हैं अतः ***एलो*** की 15 प्रजातियों को एकत्र, अनूकूलित, गुणित, चिन्हित कर बंथरा शोध केंद्र में स्थापित किया गया है। कॉस्मेटिक्स एवं पोषण महत्व के उत्पादों के औद्योगिक उत्पादन को ध्यान में रखते हुए कुछ प्रजातियों की सोडिसिटी सहन क्षमता का अंकलन किया जा रहा है।

विभिन्न सोडिक स्तर पर *एलो* प्रजातियों की वृद्धि एवं जेल उत्पादकता का आंकलन

इस संबंध में ***एलो*** की तीन प्रजातियों, ***एलो वेरा*** (सामान्य कड़वा), ***एलो फोरेक्स*** (बहुत कड़वा) एवं ***एलो मैकुलेटा*** (कड़वा नहीं) को जेल के स्वाद के आधार पर चयनित कर विभिन्न सोडिक स्तरो पर उनके वृद्धि एवं जेल की उत्पादकता का आंकलन किया गया। सर्वाधिक पादप वृद्धि एवं जेल उत्पादकता ***एलो वेरा*** में देखी गई जबकि ***एलो मैकुलेटा*** दूसरे स्थान पर रही।

सोडिक मृदा में विभिन्न *एलो* प्रजातियों का पुष्पन

इस संबंध में ***एलो*** के 14 प्रजातियों की पुष्पन गतिविधियों का अध्ययन किया जा रहा है।

विभिन्न *एलो* प्रजातियों में फली निर्माण, बीज निर्माण एवं परिपक्वता

एलो की चार प्रजातियों ***एलो टेन्यूर, एलो ग्रियथेड़ाई, एलो फेरोक्स*** एवं ***एलो मैकुलेटा*** में फली निर्माण, बीज निर्माण एवं परिपक्वता का अध्ययन किया गया।

एलो वेरा के क्षतिग्रस्त पौधों में जड़ निर्माण

एलो वेरा कवक एवं जीवाणु जनित रोगों, पानी की अधिकता, अधिक एवं न्यून तापमान स्थितियों के प्रति संवेदनशील है। ऐसे में जीवाणु जनित रोग से ग्रस्त 6 पौधों को सूखे घास के ढेर में खुली हवा में बिना भूमि के संपर्क के 30 दिन छांव में रखा गया। एक माह के पश्चात सभी पौधों के क्षतिग्रस्त हिस्सों से जड़ों का विकास देखा गया।

एलो वेरा के बीजों से उत्पन्न पौधों में प्राकृतिक उत्परिवर्तन

भूस्तारियों से ***एलो*** के पौधों के उत्पादन में आने वाली अड़चनों को देखते हुए, ***एलो वेरा*** के पौधों को बीज से उत्पादन कराने के दिशा में प्रयोग किए गए एवं बीजों को वर्मी-कंपोस्ट युक्त क्यारियों मे बोया गया। 15 दिनों के पश्चात बीजों में सफलतापूर्वक अंकुरण देखा गया।

पादप विविधता, वर्गिकी एवं पादपालय

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

परियोजना के अंतर्गत उत्तराखंड, उत्तर प्रदेश, बिहार एवं पश्चिम बंगाल के विभिन्न स्थानों से पौधों के नमूने एकत्र किए गए। इन नमूनों में शैवालों की 37 प्रजातियों की पहचान की गई। शैवालों की अधिकतम विविधता क्रमशः कन्नौज, नरौरा, कानपुर एवं हुगली में देखी गई। नरोरा में शैक विभिन्नता पर उसके पास स्थित परमाणु बिजलीघर के संभावित प्रभाव दिखाई दिये वहीं फरक्का के नमूनों से पता लगा कि यहाँ सूक्ष्म जलवायु परिस्थितियाँ शैकों, विशेषकर फोलिओस एवं फ्रूटीकोस शैकों की वृद्धि के लिए उपयुक्त नहीं हैं। साथ ही मानसून पूर्व एवं बाद में विभिन्न क्षेत्रों में किए गए सर्वेक्षणों में ब्रायोफाइट्स की 19 प्रजातियों की उपस्थिती का पता चला। इनमें से ***आर्कीलेज्यूनिया माइन्यूटीलोबा*** को पहली बार गांगेय मैदान में देखा गया। इसी प्रकार टेरिडोफाइट्स के 215 नमूनों में 9 वंशों के 12 कुलों की 17 प्रजातियाँ देखी गईं।

शैवाली ब्लूम, इनके निरूपण एवं बनने को प्रभावित करने वाले कारकों का अध्ययन

प्राकृतिक रूप से उत्पन्न होने वाले शैवाल ब्लूम, जैव ईंधन उत्पादन हेतु एक सस्ता स्रोत हैं। ऐसे तीन शैवाल क्रमशः ***नियोक्लोरिस*** (NBRI 081), ***नैनोक्लोरोप्सिस*** (NBRI 082) एवं ***क्लोरेल्ला*** (NBRI 070) प्रजातियों के शैवालों को खुले एवं बंद तंत्रों में वृहद मात्रा में उगाने के लिए चुना गया। NBRI 082 में सर्वाधिक तेज वृद्धि एवं जैव भार प्राप्त किया गया। अध्ययन में यह भी पाया गया कि सभी तीनों शैवाल आर्थिक रूप से जैव ईंधन उत्पादन हेतु सक्षम हैं तथा जैवडीजल निर्माण एवं अन्य औद्योगिक प्रयोगों के लिए उपयोग हो सकते हैं।

सूक्ष्मजीवों से आनुवंशिकी सुधार एवं प्रक्रिया अनुकूलन के माध्यम से जैव-हाइड्रोजन उत्पादन में सुधार हेतु अध्ययन

आनुवांशिक रूप से परिष्कृत शैवाल विभिन्न प्रकार की जैव-ऊर्जाओं के उत्पादन को बढ़ा सकते हैं। इस अध्ययन हेतु ***सेनडेस्मस*** की प्रजाति NBRI-012 का आनुवांशिक सुधार हेतु चयन किया गया क्योंकि इसमें अन्य अध्ययन किए गए 16 शैवालों की तुलना में सर्वाधिक जैव-भार एवं जैव-हाइड्रोजन उत्पन्न करने की क्षमता देखी गई। ***सेनडेस्मस*** प्रजाति NBRI-012 के जैवभार-अवशेषों में प्राप्त वसीय अम्लों की गुणवत्ता अंतरराष्ट्रीय मानकों (IS 15607, ANP255, EN14214 एवं ASTM D6751) के अनुरूप पाई गई।

जैव-ईंधन उत्पादन हेतु सक्षम शैवाल प्रजातियों की पहचान

जैव-ईंधन उत्पादन हेतु सक्षम 16 शैवाल प्रभेदों पर अध्ययन किया गया। ***सेनडेस्मस अबंडंस, सेनडेस्मस क्वाड्रीकाडा, क्लैमाइडोमोनास एंगुलोसा*** एवं ***सेलेनैस्ट्रम माइन्यूटम*** में सर्वाधिक वृद्धि देखी गई। इनमें सर्वाधिक तीव्र गति से जैव-भार द्विगुणन (3 दिन) भी देखा गया जबकि अन्य में यह 6 से 7 दिन पाया गया। इसी प्रकार ***सेनडेस्मस अबंडंस*** में लिपिड की सर्वाधिक मात्रा भी देखी गई जो इसे जैव-ईंधन के लिए एक उपयोगी शैवाल सिद्ध करती है।

संभावना युक्त सूक्ष्मजैविक प्रभेदों का पृथक्कीकरण, चयन एवं न्यूट्रीएंट प्रोफाइलिंग

चार शैवालों क्रमशः ***क्लोरेल्ला वल्गेरिस, क्रोकोकस माईनर, हमेटोकाकस प्लुविएलिस, स्फेरोसिस्टिस श्रोटेराई*** के शुद्ध संवर्धनों को वृद्धि, जैव-भार उत्पादकता एवं पोषकता अध्ययनों हेतु 3 संवर्धन माध्यमों (BBM, BG-11 एवं TAP Media) में संवर्धन हेतु चुना गया। यह पाया गया की ये चारों शैवाल TAP माध्यम में अन्य दो माध्यमों की तुलना में अधिक जैव-भार उत्पादकता प्रदर्शित करते हैं। इन सभी में ***क्लोरेल्ला वल्गेरिस*** ने सर्वाधिक जैव-भार उत्पादकता प्रदर्शित की। सर्वाधिक प्रोटीन मात्रा ***क्लोरेल्ला वल्गेरिस*** में जबकि सर्वाधिक लिपिड मात्रा ***हमेटोकाकस प्लुविएलिस*** में देखी गई। सर्वाधिक क्लोरोफिल ***हमेटोकाकस प्लुविएलिस*** में पाया गया जबकि उच्च ऊर्जा युक्त जैव-भार ***क्लोरेल्ला वल्गेरिस*** में पाया गया।

कालीन उद्योग अपशिष्ट से प्राप्त सूक्ष्म शैवालों का सूक्ष्मजीव प्रतिरोधकता एवं जैव-ईंधन हेतु अभिलक्षणन

भदोही जिले के कालीन उद्योगों के अपशिष्ट से प्राप्त शैवालों को पृथक कर शोधित किया गया। इन संवर्धनों को BG11+ तरल संवर्धन माध्यम एवं BG11+ अगर स्लांट पर बनाए रखा गया है। संवर्धनों का उपयोग जीनोमिक डीएनए प्राप्त करने के लिए किया गया है। ***आसीलेटोरिया, फोर्मीडियम, नोस्टोक*** एवं ***एनाबीना*** की प्रजातियों के 16SrRNA के कंजर्वड़ सीकेवेंस को जबकि ***क्लोरेल्ला, नैनोक्लोरोप्सिस*** एवं ***क्लैमाइडोमोनास*** के 18S rRNA सीक्वेंस को पीसीआर तकनीक के जरिये बढ़ाया गया।

भारतीय हिमालय में अल्पाईन पारिस्थितिक गतिकी एवं जलवायु परिवर्तन प्रभाव का अध्ययन

अरुणाचल प्रदेश के तवांग जिले की पाँच महत्वपूर्ण जगहों से शैकों के 47 कुलों की 22 प्रजातियाँ वर्णित की गईं। अध्ययन के दौरान सभी उच्चतम शिखर बिन्दुओं पर ***जूनीपेरस*** एवं ***रोड़ोडेंड्रोन*** की झाड़ियों की बहुलता देखी गई जो शैकों की वृद्धि हेतु समुचित वातावरण प्रदान करती हैं। पार्मेलिएसी वंश 25 प्रजातियों के साथ इस क्षेत्र में सर्वाधिक व्याप्त देखा गया। इस क्षेत्र में बड़े शैकों की उपस्थिति यह बताती है कि यह क्षेत्र अप्रभावित क्षेत्र है एवं यहाँ मौजूद शैकों के समुदाय एवं प्रजातियाँ आने वाले भविष्य में पर्यावरण निगरानी संबंधित अध्ययनों में महत्वपूर्ण भूमिका निभा सकती हैं। विभिन्न उच्चतम शिखर बिन्दुओं पर शैकों की प्रजातियों में भिन्नता देखने को मिली। यहाँ यह महत्वपूर्ण है कि शैक प्रजातियाँ, वन संरचना एवं संगठन पर पड़ने वाले जलवायुवीय प्रभावों से अप्रत्यक्ष रूप से प्रभावित होती हैं। पर्यावरणीय प्रभावों के चलते आने वाले समय में उच्च शिखरों की ओर वनों के फैलाव के चलते वनों पर निर्भर शैक प्रजातियाँ वहाँ भी पाई जा सकती हैं जहां वह अभी नहीं पाई जाती हैं।

शैक प्रजातियाँ पर्यावरणीय परिवर्तनों के प्रति अत्यंत संवेदनशील होती हैं। इस कारण इनका प्रयोग सूचक के रूप में किया जा सकता है। ये प्रजातियाँ इन परिवर्तनों के प्रति तीन प्रकार से प्रतिक्रिया प्रदर्शित करती हैं - विस्थापन, समायोजन एवं अनुकूलन। वर्तमान अध्ययन में विभिन्न उच्चतम शिखर

बिन्दुओं पर पाये गए बड़ी शैक प्रजातियों को सूचक के रूप में प्रयुक्त किया जा सकता है ताकि उनके विस्थापन का अध्ययन कर भविष्य में जलवायु परिवर्तनों की समीक्षा किया जा सके।

उत्तर प्रदेश के संरक्षित क्षेत्रों में शैकों का अध्ययन एवं जनसामान्य में संरक्षण की भावना का प्रसार

पश्चिमी उत्तर प्रदेश के 35 जिलों का सर्वेक्षण कर लगभग 500 शैक नमूने एकत्र किए गए जिनमें 48 प्रजातियों की पहचान की गई। इनमें सर्वाधिक 31 क्रस्टोज शैक पाये गए। उत्तर प्रदेश से 8 नए शैक वर्णित किए गए।

उत्तर प्रदेश के विभिन्न क्षेत्रों में 10 ''जैव-विविधता जागरूकता सप्ताह'' आयोजित किए गए। इनमें कक्षा 9 से लेकर परास्नातक तक के विद्यार्थियों को जैव-विविधता के संबंध में जागरूक किया गया। इन कार्यशालाओं में 19 विशेषज्ञ परामर्शदाताओ ने भी भाग लिया।

शैकों पर राष्ट्रीय नेटवर्क कार्यक्रम - द्वितीयक यौगिकों का जैव-अभिलक्षणन एवं संवर्धनों तथा संग्रहों की स्थापना

शैकों से यौगिकों के निष्कर्षण हेतु प्रोटोकाल का मानकीकरण किया गया ताकि द्वितीयक यौगिकों एवं क्रियात्मक समूहों की पहचान आदि के लिए लक्षित की गई उच्चतम उत्पादकता वाले शैकों की पहचान की जा सके। दो विशेष शैक नमूनों (NBRI-LS8 - NBRI-LS9) का 5 विभिन्न पोलर एवं नान-पोलर विलायकों के माध्यमों से निष्कर्षण किया गया। द्वितीयक मार्करों की TLC प्रोफाइलिंग के माध्यम से पहचान की गई।

लाईकेन NBRI-LS6, NBRI-LS7 एवं NBRI-LS9 में P-TLC एवं कॉलम क्रोमैटोग्राफी के द्वारा 6 लाईकेन अम्लों का शोधन किया गया। इनकी पहचान एवं अभिलक्षणन का कार्य चल रहा है।

विलायक विशिष्ट अर्कों की पहचान के लिए यौगिकों का विखंडन एवं शोधन किया गया। NBRI-LS9 के एसीटोन अर्क से 28 अंशों एवं 50% एथेनोल अर्क से 10 अंशों को शोधित किया गया। इसी प्रकार NBRI-LS8 से कॉलम क्रोमैटोग्राफी के द्वारा 15 अंशों को अलग किया गया जिनके अभिलक्षणन का कार्य चल रहा है।

PTLC एवं कॉलम के द्वारा अलग किए गए 5 शुद्ध यौगिकों का LC-MS के द्वारा अभिलक्षणन किया गया।

चार लाईकेन अम्ल यौगिकों के साथ साथ कोडेड अर्कों (NBRI/L10/ae1 and MSSRF/L2ae2) में से यौगिकों का विखंडन, पृथक्करण एवं शोधन किया गया जिनका UV, IR एवं MS माध्यम से अभिलक्षणन किया जा रहा है।

शैकों के माध्यम से भारत में जलवायु परिवर्तन निगरानी तंत्र का विकास

पश्चिम बंगाल के दार्जीलिंग जिले में जलवायुवीय परिस्थितियों में परिवर्तन के आंकलन हेतु राष्ट्रीय वनस्पति अनुसंधान संस्थान के पादपालय में मौजूद दार्जिलिंग जिले के पाँच दशक पुराने शैक नमूनों का शैक वनस्पति, धातुओं एवं PAH के सान्द्रण, कार्बन आइसोटोप संगठन में बदलाव हेतु नवीन शैक नमूनों से तुलनात्मक अध्ययन किया गया। यह देखा गया कि वर्ष 1966 से 2015 के बीच क्षेत्र का माध्य तापमान 12 से बढ़कर 18°C (अधिकतम) एवं -2 से 8°C (न्यूनतम) हो गया है साथ ही माध्य सापेक्षिक आर्द्रता 84% से बढ़कर 95% हो गई है। इसके विपरीत माध्य वर्षा 2500 से 1800 एमएम हो गई है। इसके साथ साथ क्षेत्र में मानवीय गतिविधियां भी पिछले 5 दशक में बहुत बढ़ी है। इन सभी सम्मिलित प्रभावों के चलते क्षेत्र में पाये जाने वाले शैकों की विविधता पर स्पष्ट प्रभाव परिलक्षित हुये हैं। अस्निओइड समुदाय में स्पष्ट गिरावट जबकि फिसकोइड समुदाय में स्पष्ट बढ़त देखी गई। लाइकीनिओइड एवं कैल्सीओइड समुदाय इस क्षेत्र से पूरी तरह से समाप्त हो गए हैं जबकि लोबेरियन समुदाय का हाल ही में इस क्षेत्र में प्रवेश परिलक्षित हुआ है।

जलवायु परिवर्तनों के कारण बढ़ते तापमान एवं पराबैंगनी विकिरण के प्रति शैकों का व्यवहार

गढ़वाल हिमालय के कोटद्वार एवं लैंड्सडाउन क्षेत्रों में 400 से 1800 मी. की ऊंचाई के बीच 24 विभिन्न जगहों से 58 शैक नमूने एकत्र किए गए। हिमालय में स्थायी कार्बनिक प्रदूषकों के संग्रहण पर जलवायुवीय परिस्थितियों एवं स्थलाकृति के प्रभाव को देखने के लिए अध्ययन किए गए जिनसे हिमालय तंत्र में स्थायी कार्बनिक प्रदूषकों के लंबी दूरी तक प्रकीर्णन का प्रभाव दिखाई पड़ा।

भारत के पश्चिमी घाट की नीलगिरी पहाड़ियों के उष्णकटिबंधीय वर्षा वनों में पर्यावरणीय सततता हेतु शैकों का अध्ययन

नीलगिरी बायोस्फीयर रिजर्व एवं साइलेंट वैली राष्ट्रीय उद्यान में शैकों के अध्ययन से पता चला कि नीलगिरी के अन्य स्थानों की तुलना में साइलेंट वैली राष्ट्रीय उद्यान में शैक विविधता बिलकुल अलग है क्योंकि यहाँ वनों की सघनता के चलते सूर्य की किरणें नीचे कम पहुँच पाती हैं जो कि शैकों की वृद्धि के लिए अत्यंत आवश्यक है। इसी कारणवश नीलगिरी में साइलेंट वैली की तुलना में ग्रैफिडेसी वंश काफी विविधता में व्याप्त देखा गया।

हिमालय के शैकों की बारकोडिंग : शैकों की जैव-विविधता के अध्ययन हेतु आधुनिकतम तरीकों का प्रयोग एवं भारत में शैक-संरक्षण नीतियों की स्थापना

शैक वंश पार्मेलिएसी की 13 शैक बनाने वाली कवक प्रजातियों की न्यूक्लियर राइबोसोमल ITS एवं मानक बार कोड के माध्यम से मोनोफायली एवं आनुवांशिक दूरी का आंकलन किया गया। अध्ययनों में पाया गया कि भारत में पायी जाने वाली अस्निया की सभी प्रजातियों को न्यूक्लियर राइबोसोमल ITS के अध्ययन के द्वारा सफलतापूर्वक विभेदित किया जा सकता है।

जैव-प्रौद्योगिकीय उद्देश्यों हेतु टीलोसिस्टेसी (एस्कोमाइकोटा) के दक्षिण भारतीय शैकों का वंशावली समूहीकरण

यूक्रेन के शैक विशेषज्ञों के सानिध्य में आकारिकी, आंतरिक संरचना एवं रसायनिकी के आधार पर शैक कुल जैन्थोरिया का संशोधनात्मक अध्ययन प्रारम्भ किया गया। साथ ही वर्गिकी के आंकड़ों के समर्थन हेतु आणुविक आंकड़े एकत्र किए जाने का कार्य भी चल रहा है।

पूर्वी घाटों में ब्रायोफाइट विभिन्नता का अध्ययन

पूर्वी घाट में आंध्र प्रदेश के कृष्णा, प्रकाशम, कुरनूल एवं विशाखापत्तनम जिले के विभिन्न स्थानों से ब्रायोफाइट्स के 254 नमूने एकत्र किए गए जिनमें मोस की 54 प्रजातियों एवं लीवरवर्ट्स की 16 प्रजातियों की पुष्टि की गई। ***आर्कीडियम एकाइन्थोफिल्लम*** एवं ***लेज्यूनिया माइन्यूटीलोबा*** वर. ***हेटेरोगाइना*** को भारत में सर्वप्रथम खोजा गया। सात प्रजातियाँ दक्षिण भारत से पहली बार खोजी गईं जबकि 10 प्रजातियाँ पूर्वी घाट में पहली बार देखी गई।

चुनिंदा संकटग्रस्त एवं संभावित ब्रायोफाइट्स में आकारिकीय, प्रजनन जैविकी एवं संरक्षण अध्ययन

दो देशज, असामान्य एवं संकटग्रस्त पौधों ***एंथोसेरोस मैक्रोस्पोरस*** एवं ***क्रिप्टोमीट्रियम हिमालएंसे*** को प्रयोगशाला में कृत्रिम रूप से उगाया गया जिससे इन पर प्रजनन जैविकी एवं आकारिकीय अध्ययन किए जा सकें तथा इन्हें कृत्रिम रूप से उगाने की विधि का मानकीकरन किया जा सके। इन अध्ययनों से ज्ञात हुआ कि ***एंथोसेरोस मैक्रोस्पोरस*** की वृद्धि के लिए हाफ नोप्स मीडियम जबकि ***क्रिप्टोमीट्रियम हिमालएंसे*** के लिए हाफ नोप्स मीडियम एवं होगलैंड मीडियम उपयुक्त हैं।

भारत में रेननकुलेसी वंश की डेल्फीनी ट्राइब में शोध प्रबंधीय एवं वंशावली अध्ययन

पूर्वी एवं पश्चिमी हिमालय के विभिन्न क्षेत्रों से पौधों को एकत्र किया गया। एकोनिटम कुल की 19 प्रजातियाँ एकत्र की गईं। साथ ही विभिन्न राष्ट्रीय एवं अंतरराष्ट्रीय पादपालयों से भी अध्ययन हेतु नमूने मंगाए गए। इसी संबंध में हिमालय में संकटग्रस्त ***एकोनिटम*** प्रजातियों के कुछ नमूनों को भी ढूंढा गया। यह भी देखा गया कि डेल्फीनियम कुल के पौधे एकोनिटम से भी अधिक दुर्लभ होते जा रहे हैं। हालांकि ***एकोनिटम फेरोक्स,*** जो पहले मात्र पश्चिमी हिमालय से ज्ञात थी अब पूर्वी हिमालय में भी पाई गई।

भारत में पाई जाने वाली ***एकोनिटम, कोंसोलिडा*** एवं ***डेल्फीनियम*** की लगभग 50 प्रजातियों में से ***डेल्फीनियम*** की 13, ***कोंसोलिडा*** की 1 एवं ***एकोनिटम*** की 11 प्रजातियों का विस्तृत वर्गिकी अध्ययन पूर्ण किया गया। इसके अतिरिक्त ***डेल्फीनियम*** की 7 एवं ***एकोनिटम*** की 8 प्रजातियों का आणुविक वंशानुक्रम अध्ययन भी किया गया। ***एकोनिटम*** की एक नई प्रजाति ***एकोनिटम अरुणाई*** को सिक्किम से खोजा गया।

किशुनपुर वन्य जीव अभयारण्य में वनस्पति विविधता का मापन एवं पादप संसाधनों का संरक्षण अध्ययन

इस क्षेत्र से पौधों की 150 प्रजातियाँ एकत्र की गईं जिनके विस्तृत अध्ययन से पता चला कि इनमें से 63 प्रजातियों को स्थानीय निवासियों द्वारा औषधी, मसालों, हस्तकला एवं रेशों के लिए उपयोग में लाया जा रहा है। दो अत्यधिक दोहित पौधों ***कुरकुलीगो आर्कीओइडिस*** एवं ***हेल्मैन्थोस्टाइकिस जेलैनीका*** के संरक्षण स्तर का भी अध्ययन किया गया। इन सब के अतिरिक्त वन्य जीव अभयारण्य में विभिन्न स्थानों पर 20×20 मीटर के प्लाट डालकर पारिस्थितिक अध्ययन भी किए गए।

उत्तर प्रदेश के वृक्षों का वर्गिकी अध्ययन

उत्तर प्रदेश के 150 वृक्षों का वर्गिकी अध्ययन किया गया एवं सही नाम, मुख्य पर्यायवाची, वितरण एवं उपयोग से संबन्धित आंकड़े एकत्र किए गए।

भारत के गांगेय मैदानों में *फाइकस* (मोरेसी) का अध्ययन

भारत के गांगेय मैदानों में ***फाइकस*** के वर्गिकी अध्ययन को पूर्ण किया गया। इस क्षेत्र, जिसमें राजस्थान, उत्तर प्रदेश, बिहार, झारखंड एवं पश्चिम बंगाल सम्मिलित हैं, में ***फाइकस*** की 38 प्रजातियों के वितरण को देखा गया। गांगेय मैदानी क्षेत्र में इस पौधे पर यह हाल के समय में यह अकेला कार्य है।

उत्तर प्रदेश के गांगेय मैदानों में दो दलहनी फसलों में मृदा कार्बन जब्ती में सूक्ष्म-जलवायु की भूमिका

काबुली चने की 10 किस्मों को उनकी वृद्धि एवं कार्यिकी प्रदर्शन हेतु संस्थान के बंथरा जैव-भार शोध केंद्र पर परखा गया। सभी किस्मों की विभिन्न वृद्धि अवस्थाओं में आकारिकीय एवं कार्यिकी लक्षणों का विस्तृत तुलनात्मक अध्ययन किया गया। सभी 10 किस्मों में से 'उज्जवल' किस्म द्वारा सर्वश्रेष्ठ प्रदर्शन देखा गया।

भारत की वानस्पतिक विविधता अध्ययन एवं डिजिटलीकरण

राष्ट्रीय सुविधा के रूप में ख्यात संस्थान के पादपालय में उच्च पौधों के 762 नमूने एवं निम्न पौधों के 1536 नमूने संग्रहीत किए गए। भारत के विभिन्न क्षेत्रों से शैकों के 100 नमूने एकत्र किए गए जिनमें शैकों की 25 प्रजातियों को पहचाना गया जिनमें क्रसटोज शैकों की बहुतायत रही। इसी प्रकार ब्रायोफाइटा समूह के पोगोनेटम कुल की 10 प्रजातियों पर अध्ययन किया गया साथ ही सिक्किम से एक दुर्लभ ब्रायोफाइट पौधे ***होरिकावाएल्ला सबएक्यूटा*** की खोज की गई। पचमढ़ी बायोस्फीयर रिजर्व में ह र्नवर्ट विविधता पर अध्ययन के दौरान इस क्षेत्र से 5 प्रजातियों की पहचान की गई। 2 मोस पौधों ***स्लेकनम स्फेरिकम*** एवं ***यूनेरिया हाइग्रोमेट्रिका*** को प्रयोगशाला में कृत्रिम रूप से उगाने में सफलता प्राप्त की गई। संस्थान में बने मास गृह में 9 प्रजातियों को सम्मिलित किया गया।

टेरिडोफाइट के 251 नमूने पादपालय में जमा किए गए। प्रयोगशाला में कृत्रिम रूप से उगाये गए ***डाइप्लेजीयम एस्कूलेंटम*** को फर्न गृह में सफलतापूर्वक स्थानांतरित किया गया। सजावटी फर्न की 12 प्रजातियों के पौधों को बड़े स्तर पर (लगभग 950 पौधे) उत्पादन किया गया। पश्चिमी हिमालय में ***इफेड्रा जिरार्डियाना*** की 5 प्राकृतिक आबादियों से 55 नमूनों को एकत्र कर आनुवांशिक विविधता एवं आबादियों की आनुवंशिक संरचना का DAMD एवं ISSR विधि के द्वारा आंकलन किया गया।

एक औषधीय रूप से महत्वपूर्ण एवं रंजक उत्पादक संकटग्रस्त पौधे ***वुड्फोर्डिया फ्रूटीकोसा*** के नमूनों पर प्रजनन जैविकी अध्ययनों से मसूरी, उत्तराखंड के नमूनों में सर्वाधिक निषेचता जबकि कतर्नियघाट वन्य जीव अभयारण्य, उत्तर प्रदेश के नमूनों में उच्चतम पराग बंध्यता देखी गई। साथ ही परागकोष के भीतर ही परागकणों का अंकुरण देखा गया जो अभी तक इस पौधे में ज्ञात नहीं था। यह स्थिति सबसे अधिक उत्तराखंड के नमूने में देखी गई।

सीएसआईआर-राष्ट्रीय वनस्पति अनुसंधान संस्थान के पादपालय का गठन एवं डिजीटलीकरण

देश के विभिन्न क्षेत्रों से ब्रायोफाइट्स के 492 नमूने पादपालय में जमा किए गए जबकि 700 नमूनों को पहचानने एवं समाहित करने का कार्य सम्पन्न किया गया।

पादप पारिस्थितिकी एवं पर्यावरण विज्ञान

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

बेकार भूमि के पुर्नस्थापना हेतु उष्ण कटिबंधीय शुष्क वनों के कूड़े की प्रभावशीलता का अध्ययन

अम्लीय मृदा की पुर्नस्थापना हेतु प्रजातियों की जैविक क्षमता को निर्धारित करने हेतु कूड़े के उत्पादन, अस्थायी बदलाव, अपघटन की दर एवं पोषक तत्वों के निकलने को आंकना आवश्यक है। इस अध्ययन में हमने भारत के विंध्य क्षेत्र के उष्ण कटिबंधीय शुष्क वनों में चयनित बहुपयोगी वृक्षों जैसे ***शोरिया रोबस्टा, ब्यूटिया मोनोस्पर्मा, टेक्टोना ग्रैंडिस, हर्ड्विकिया बिन्नाटा*** आदि में कूड़े के गिरने की दर, गुणवत्ता, एवं अपघटन दर पैटर्नों को जांचा। इस अध्ययन से ज्ञात हुआ कि मृदा के जैविक पुर्नस्थापना हेतु मिश्रित पौधरोपण सबसे उपयुक्त है। वहीं ***हर्ड्विकिया बिन्नाटा*** एवं ***ब्यूटिया मोनोस्पर्मा*** ने व्यक्तिगत रूप से बेकार भूमि के शीघ्र सुधार में सर्वश्रेष्ठ नतीजे प्रदर्शित किए क्यूंकि ***टेक्टोना ग्रैंडिस*** एवं ***शोरिया रोबस्टा*** की तुलना में इनके कूड़े के अपघटन की दर काफी तेज है। हालांकि ***टेक्टोना ग्रैंडिस*** एवं ***शोरिया रोबस्टा*** अपेक्षाकृत अधिक कूड़ा उत्पन्न करते हैं किन्तु इससे मृदा में पोषक तत्वों के निकलने की दर काफी धीमी होती है। तेज अपघटन से मृदा में पोषक तत्वों के निकलने की दर भी तेज हो जाती है और इस प्रकार यह कार्बनिक पदार्थ की मात्रा को बढ़ाते हुये पोषक तत्वों के चक्र को भी बढ़ाता है।

भारत के गांगेय मैदानों में ग्लोमैलीन एवं मृदा में कार्बनिक कार्बन के फ्रैक्शंस पर लंबी अवधि के भू उपयोगों का प्रभाव

इस अध्ययन में 50 वर्ष पुराने अबाधित (***डेंड्रोकैलेमस कैलोस्टैकिस, मैंगीफेरा इंडिका*** एवं ***सैकेरम मुंजा***) एवं बाधित (***ओराइजा सैटाइवा*** खेत) मोनोकल्चर से छिछली मिट्टी एकत्र की गई। हमारे नतीजों से पता चला बाधित मृदा में अबाधित मृदा की तुलना में SOC, पर्टिकुलेट OC (POC), नान-पर्टिकुलेट OC (NPOC), GRSP, आसानी से निष्कर्षित होने वाले GRSP (EE-GRSP) एवं कठिनाई से निष्कर्षित होने वाले GRSP (DE-GRSP) तेजी से नष्ट होते है। अध्ययन क्षेत्र की बाधित कृषि मृदा में GRSP एवं SOC के मात्रा में बढ़त कार्बन जब्ती एवं सतत मृदा स्वास्थ्य के लिए तत्काल आवश्यकता है। यह शोध भू-परिदृश्य विविधता को उबारने की दिशा में बेकार भूमि के लिए प्रबंधन योजनाओं को प्रोत्साहित करेगा।

ओराइजा सैटाइवा में आर्सेनिक विषहरण में ग्लूटारेडाक्सिन की भूमिका का अध्ययन

आर्सेनिक एक तीक्ष्ण जहर एवं क्लास 1 कैंसरकारक है जो स्वास्थ्य के लिए गंभीर खतरा उत्पन्न कर सकता है। मुख्य फसलें जैसे धान (चावल), मानव भोजन में आर्सेनिक संदूषण का प्रमुख स्रोत हैं। आर्सेनिक संदूषित क्षेत्रों में उगाये जाने वाले धान के खाने योग्य हिस्सों में आर्सेनिक एकत्र होता है। ग्लूटारेडाक्सिन (GRXs) छोटी बहुकार्यात्मक प्रोटीनों का एक वंश है जो विभिन्न कोशिकीय कार्यों, जिनमें रीडोक्स नियंत्रण एवं ओक्सीडेटिव तनाव में बचाव शामिल हैं, में सम्मिलित होती हैं। पौधों के जीनोम में ***GRX*** जीनों की अधिक संख्या (धान में 48 ***GRX*** जीन) के बाद भी, इनके जैविक कार्य एवं शारीरिक भूमिकाएं, विशेषकर आर्सेनिक तनाव के प्रति, पूरी तरह से ज्ञात नहीं हैं।

इस अध्ययन में As (III) एवं As (V) के विरुद्ध GSH प्रचुर एवं GSH मुक्त परिस्थितियों में ओराइजा सैटाइवा की आर्सेनिक संवेदी (ऊसर-3) एवं सहिष्णु किस्मों (पंत धान 11) में विषहरण तंत्रों में GRX एवं संबंधित एंटीओक्सीडेंट एंजाइमों की भूमिका का अध्ययन किया गया। As(III) एवं As(V) के विभिन्न उपचारों के विरुद्ध संवेदी किस्मों में कुल मिलाकर वृद्धि एवं शारीरिक मानक सहिष्णु किस्मों से निम्न थे। As (III) एवं As (V) की उपस्थिति में सहिष्णु किस्मों की तुलना में संवेदी किस्मों में आर्सेनिक संग्रहण निम्न रहा।

पौधों में आर्सेनिक तनाव की भूमिका को समझने के लिए पारजीनी पौधे एरबिडोप्सिस थैलियाना में धान की दो आर्सेनिक-अनुक्रियाशील ***GRX*** वंश की प्रोटीनों, OsGRX_C7 एवं OsGRX_C2 का अभिलक्षणन किया गया। जिससे आर्सेनिक सहिष्णुता को अंकुरण दर, जड़ वृद्धि एसे एवं संपूर्ण पादप वृद्धि के संबंध में निर्धारित किया गया।

दोनों ***OsGRX*** जीनों को क्लोन कर के ***इश्चेरिशिया कोलाइ*** एवं ***सैकेरोमाइसिस क्रेवेसी*** स्यूटेंट प्रभेदों में प्रदर्शित किया गया। शोध से स्पष्ट संकेत मिले कि As(III) एवं As(V) दोनों ही तनावों के दौरान कोशिका के रीडोक्स स्तर एवं अंतराकोशीय GSH पूल में OsGRX एक महत्वपूर्ण भूमिका निभाते हैं एवं संभवतः अंतराकोशीय As(III) के स्तरों को नियंत्रित करने में शामिल होते हैं।

उत्तर प्रदेश के गांगेय मैदानों में तो दलहनों में मृदा कार्बन जब्ती में सूक्ष्म-जलवायु की भूमिका

दलहानी फसलों में मृदा कार्बन जब्ती पर्यावरणीय एवं जैविक कारकों से प्रभावित होती है। इस संबंध में उत्तर प्रदेश के गांगेय मैदानों की दलहनी फसलों में वृद्धि एवं शारीरिक प्रदर्शनों में सूक्ष्म-जलवायु की भूमिका पर बहुत कम जानकारी उपलब्ध है। अतः चयनित फसलों (काबुली चना सीसर एरीटिनम) पर शोध किए गए।

- काबुली चने की 10 किस्मों को उनकी वृद्धि एवं शारीरिक प्रदर्शनों के लिए संस्थान के बंथरा जैव-भार शोध केंद्र पर जांचा गया।
- किस्म HK-94-134 में पौधे की सर्वाधिक ऊंचाई देखी गई जबकि पौधे के तने का व्यास सर्वाधिक शुभ्रा किस्म में देखा गया। सभी 10 किस्मों में सर्वाधिक जैव-भार (52-13±6-39 ग्रा.) उज्जवल किस्म में देखा गया।
- सर्वाधिक प्रकाश-संश्लेषण JG-11 एवं उज्जवल किस्मों व न्यूनतम PUSA-362 में देखा गया। कुल मिलाकर उज्जवल किस्म ने सभी 10 किस्मों में सर्वश्रेष्ठ प्रदर्शन किया।

कार्बनिक एवं अकार्बनिक प्रदूषकों का जैव-उपचार

लाई-ऐश के ढेरों में कार्बन जब्तीः तीन पादप संघों में तुलनात्मक अध्ययन

इस शोध का उद्देश्य आटोमेटेड CO_2 लक्स तंत्र के प्रयोग से कार्बन जब्ती के लिए सक्षम पादप प्रजातियों की पहचान के लिए लाई एश ढेरों की प्राकृतिक रूप से पादपाच्छादित एवं गैर पादपाच्छादित जगहों से CO_2 लक्स को मापना था। यह CO_2 लक्स, अधिक जड़ घनत्व एवं श्वसन के कारण गैर पादपाच्छादित जगहों की तुलना में पादपाच्छादित जगहों पर अधिक पाया गया। प्राकृतिक रूप से पादपाच्छादित जगहों पर CO_2 लक्स दर टूफा लैटीफोलिया संघ की तुलना में ***सैकेरम स्पोंटेनियम*** एवं ***प्रोसोपिस जुलिलोरा*** संघों में सबसे कम था। इस प्रकार यह पाया गया कि ***सैकेरम स्पोंटेनियम*** एवं ***प्रोसोपिस जुलिलोरा*** संघ ताजे लाई एश जमाव की जगहों पर वातावरणीय CO_2 जब्ती के लिए सर्वाधिक सक्षम हैं।

ओराइजा सैटाइवा में *ब्रेवुंडीमोनस डिमिन्यूटा* की मध्यस्थता से आर्सेनिक विषालुता का उन्मूलन एवं पादप वृद्धि को बढ़ावा

चावल (***ओराइजा सैटाइवा***) की किस्म सरजू में आर्सेनिक की दो भिन्न सान्द्रताओं में एक नवीन प्रभेद ***ब्रेवुंडीमोनस डिमिन्यूटा*** (NBRI012) के प्रयोग के माध्यम से आर्सेनिक के पादप-स्थिरीकरण में सुधार की संभावनाओं को आँका गया। इस शोध ने धान के पौधे में खाने योग्य हिस्सों में तनाव सहिष्णुता में मध्यस्थता एवं आर्सेनिक स्थानांतरण नियमन में ***ब्रेवुंडीमोनस डिमिन्यूटा*** की विविध भूमिकाओं पर प्रकाश डाला।

आर्सेनिक तनाव में धान के पौधों के GABA शंट पाथवे में जीन नियंत्रण का अध्ययन

अमीनो अम्ल, γ-अमीनो ब्यूटाइरिक अम्ल (GABA) को अजैविक तनाव में पौधों में प्रेरित तनाव के प्रति प्रतिक्रिया एवं तनाव मोडेरेटर के रूप में जाना जाता है। अतः बाह्य GABA का प्रयोग पौधों में तनाव प्रभावों का उन्मूलन किया जा सकता है। इस परिकल्पना के संदर्भ में धान के पौधों में GABA शंट पाथवे में लिप्त एंजाइमों के जीनों के नियंत्रण को समझने के लिए प्रयोग किए गए। यह पाया गया कि As (III) के साथ या सिर्फ GABA के बाह्य अनुप्रयोग से धान के पौधों में GABA शंट पाथवे के जीनों का नियंत्रण होता है। यह भी निर्धारित हुआ कि As(III) प्रेरित तनाव के सुधार में GABA महत्वपूर्ण भूमिका निभाते हैं।

शैवाल (*क्लोरेल्ला*) के सह-प्रयोग से धान की किस्मों में आर्सेनिक विषालुता में कमी

निम्न समूह के जीव, जीवाणु, कवक एवं सूक्ष्म-शैवाल अकार्बनिक विषाक्त धातुओं आदि को मेथीलेशन के द्वारा कार्बनिक रूप में बदलने की क्षमता रखते हैं। इस आधार पर धान की किस्म (सरजू-52) में शैवाल क्लोरेल्ला के सह-प्रयोग के द्वारा आर्सेनिक संबन्धित विषालुता में कमी को जाँचने हेतु प्रयोग किए गए। ***क्लोरेल्ला*** के प्रयोग से आर्सेनिक सान्द्रण में कमी देखी गई जिससे यह प्रदर्शित हुआ कि धान की जड़ों के आस पास ***क्लोरेल्ला*** की उपस्थिति से पौधों में आर्सेनिक विषालुता कम हो सकती है।

बीज युक्त पौधों में अजैविक तनाव के अंतर्गत पत्तियों, तनों, फलों एवं जड़ों के जैव-भार वितरण में परिवर्तन

कपास (***गासीपियम***) की दो प्रजातियों की चार भिन्न किस्मों में शारीरिक प्रदर्शन एवं जड़ ऊतकों में सूखा सहिष्णुता से संबन्धित जीनों की अंतर अभिव्यक्ति की रूपरेखा

सम्पूर्ण विश्व में पौधों की वृद्धि एवं फसल उत्पादकता के लिए सूखे को एक सीमित कारक माना जाता है। सूखा तनाव के अंतर्गत फसल उत्पादकता को बनाए रखने के लिए जड़ों की वृद्धि के महत्व को समझा जा रहा है एवं जो शोधकर्ताओं को आकर्षित कर रहा है। सूखी मृदा में जड़ों की वृद्धि अनेकों कारकों से प्रभावित होती है। ऐसे में इस विषय पर शोध हेतु कपास की चार किस्मों को सूखे की परिस्थितियाँ देकर जड़ के ऊतकों की आकारिकी, शारीरिकी, मेटाबोलाइट की मात्रा एवं जीनों के प्रदर्शन आदि का अध्ययन किया गया।

सूखे से ग्रस्त गेहूं (*ट्रीटिकम एस्टिवम*) पर सैलीसिलिक अम्ल का प्रभाव

सूखे से ग्रसित गेहूं की किस्मों (कुन्दन एवं लोक 1) की आकारिकी, शारीरिक, एवं जैव-रासायनिक स्तरों के साथ साथ पत्तियों के प्रोटियोम पैटर्न पर सैलीसिलिक अम्ल का प्रभाव देखा गया ताकि सैलीसिलिक अम्ल प्रेरित सूखा सहिष्णुता के आणुविक तंत्र को आगे समझा जा सके। प्रभावों को दो भिन्न विकास अवस्थाओंः कायिक एवं पुष्पीय अवस्थाओं में पानी युक्त एवं सूखे की स्थितियों में जांचा गया। आकारिकी स्तर पर सैलीसिलिक अम्ल द्वारा लोक 1 किस्म में दोनों विकास अवस्थाओं में जड़ एवं शाखाओं के अनुपात में बढ़ोत्तरी देखी गई। इसी के साथ साथ सैलीसिलिक अम्ल द्वारा प्रकाश संश्लेषण दर, रंध्र संवाहकता, जल उपयोग क्षमता एवं PSII की अधिकतम क्षमता में बढ़ोत्तरी देखी गई। कुन्दन किस्म में यह प्रभाव अधिक प्रदर्शित हुए। कुल मिलाकर कुन्दन किस्म द्वारा आकारिक, शारीरिक एवं जैव-रासायनिक स्तरों पर अधिक सहिष्णुता प्रदर्शित की गई।

पादप सूक्ष्म-जीव समन्वयन, भेषज विज्ञान एवं पादप रसायन

पादप सूक्ष्म-जीव समन्वयन

फसल उत्पादकता बढ़ाने के लिए जैव-इनोकूलेंट्स का गुणवत्तापूर्ण उत्पादन एवं प्रचार

फसल उत्पादकता मृदा में उपलब्ध पोषक तत्वों की मात्रा पर निर्भर होती है। इन पोषक तत्वों का एक महत्वपूर्ण हिस्सा मृदा सूक्ष्म जीवों के जैव भार के रूपान्तरण से प्राप्त होता है। पारंपरिक खेती की तुलना में आर्गेनिक खेती में फसल चक्रों, कृत्रिम पोषक तत्वों के कम प्रयोग एवं कीटनाशकों की अनुपस्थिती के चलते अधिक सूक्ष्मजीव गतिविधियों के कारण मृदा की गुणवत्ता में काफी सुधार होता है। पोषण प्रबंधन एवं मृदा उत्पादकता के लिए फसल अवशेष, पशु विष्ठा, वन पर्ण अवशेष, हड्डी का चूरा, कसाईखाने के अवशेष एवं हरित खाद आदि महत्वपूर्ण कार्बनिक स्रोत हैं। इन सभी कार्बनिक स्रोतों को उचित प्रभाव के लिए अच्छी तरह से खाद में बदलना होता है। मृदा उत्पादकता को बढ़ाने एवं रासायनिक उर्वरकों के प्रयोग को कम करने के लिए जैव-इनोकूलेंट्स जैसे जैव-उर्वरक, जैव-पीड़कनाशी एवं अन्य सूक्ष्मजैविक इनपुट (ऑर्गेनिक खाद, वर्मी-कम्पोस्ट, आदि) तथा पीड़कनाशी आदि ने काफी ध्यान आकर्षित किया है। इस ज्ञान को उत्तर प्रदेश के विभिन्न गाँवों के किसानों में प्रचारित एवं प्रसारित किया गया।

उत्तर प्रदेश के किसानों के लाभ तथा इस तकनीक को वृहद स्तर पर फैलाने हेतु प्रयोगशाला से खेतों तक परिकल्पना के तहत वाणिज्यिक उत्पादन एवं वृहद स्तर पर तकनीक के उपयोग के लिए कृषि विभाग, उत्तर प्रदेश सरकार के साथ एक सहयोगात्मक कार्य की परिकल्पना की गई। इसके अतिरिक्त देश में व्यापक उपयोग हेतु इस तकनीक को निजी उद्योगों को भी स्थानांतरित किया गया।

उच्चीकृत कार्बन डाई आक्साइड स्तर के प्रति पौधों की प्रतिक्रिया एवं जड़-मृदा-सूक्ष्मजीव क्रिया-प्रतिक्रिया पर इसके प्रभाव

ट्राइकोडर्मा कुल के सदस्य कवकपरजीवता के लिए विश्व-विख्यात हैं। इनके जीनोम के संगठन एवं विकास के बारे में अधिक जानकारी हेतु ***ट्राइकोडर्मा एट्रोविरिडी, ट्रा. हार्जियानम, ट्रा. रीसियाई*** एवं ***ट्रा. वाइरेन्स*** में SSR की उपस्थिती, सापेक्षिक बहुलता एवं घनत्व के तुलनात्मक अध्ययन का सहारा लिया गया। इस अध्ययन से ज्ञात हुआ कि अध्ययन किए गए चार जीनोम सीकेवेन्सों में उपस्थिती, सापेक्षिक बहुलता एवं माइक्रोसैटेलाइट की बहुलता भिन्न होती है एवं जीनोम के आकार से प्रभावित नहीं होती। इस अध्ययन में प्राप्त 12 बहुरूपी मार्करों ने ***ट्राइकोडर्मा*** के विभिन्न निष्कर्षणों में आनुवांशिक संबंधों को स्थापित करने में नवीन विकसित SSR मार्करों की उपयोगिता को प्रदर्शित किया

काबुली चने (*साइसर एराईटीनम*) में पादप वृद्धि को बढ़ावा देने वाले *राइजोबैक्टीरिया* की मध्यस्थता से सूखे के तनाव शमन में miRNA की भूमिका का अध्ययन

सूखे के प्रति पादप अनुकूलन एक जटिल प्रक्रिया है जिसमें कार्यिक, जैव-रासायनिक एवं आणुविक स्तरों पर परिवर्तनों की एक श्रृंखला निहित होती है। हाल ही में पोस्ट-ट्रांस्क्रिप्शनल जीन नियंत्रण में miRNA एक महत्वपूर्ण घटक के रूप में उभर कर आए हैं। काबुली चना वैश्विक स्तर पर दूसरी सबसे महत्वपूर्ण दलहनी फसल है। यह देखा गया कि ***स्यूडोमोनास पुटिडा*** PGPR सूखे के तनाव के शमन में सहायक है। अतः हमने काबुली चने में PGPR-मध्यस्थ सूखे के तनाव के प्रति प्रतिक्रियाशील तंत्र को समझने का लक्ष्य किया है। यह दलहनों में तनाव के प्रति सहिष्णुता को सुधारने हेतु बेहतर योजनाएँ बनाने में सहायक होगा।

फसल उत्पादकता को बढ़ाने के लिए पादप वृद्धि नियामक *राइजोबैक्टीरिया* की मध्यस्थता से सूखे के तनाव का प्रबंधन

बेसिलस प्रजाति NBRI-W9 के द्वारा पान में रोगकारी *यूसेरियम* प्रजाति का जैविक नियंत्रण

पान के खेतों में आद्र परिस्थितियों के मौजूद रहने के चलते ***यूसेरियम*** प्रजाति द्वारा पैदा किए जाने वाले अनेकों कवक रोगों जैसे पर्ण धब्बे, फुट एवं रूट रोट आदि के प्रति काफी संवेदनशील है। पान की खेती के लिए एक प्रभावी जैव-नियंत्रण योजना प्रदान करने के लिए विभिन्न पान किस्मों से निष्कर्षित किए नमूनों की विस्तृत जांच एवं छंटनी के पश्चात एक प्रभावी बैक्टीरियल एंडोफाइट एवं विषालु कवक रोगजनक का चयन किया गया। 16S rRNA सीक्वेंसिंग का प्रयोग करते हुये एक ***बेसिलस*** प्रजाति (NBRI-W9) को पहचाना गया। प्रयोगशाला एवं खेत की परिस्थियों में NBRI-W9 जड़ों के शीघ्र प्रस्फुटन, पादप वृद्धि को बढ़ावा देने, पत्तियों के आकार एवं उपज (पत्तियों की संख्या) को बढ़ाने में एवं ***यूसेरियम*** प्रजाति संक्रमण के प्रति जैव-नियंत्रण प्रदान करने में सफल रहा।

सूखे के तनाव में मुख्य मिलेट फसलों की ट्रांस्क्रिप्ट प्रोफाइलिंग एवं तनाव-उत्प्रेरित ट्रांसक्रिप्शन फैक्टर्स का क्लोनिंग-अभिलक्षणन

बाजरा एक बड़े स्तर पर प्रयोग की जाने वाली अनाज एवं चारा फसल है जो एक या अधिक अजैविक तनावों से ग्रस्त क्षेत्रों में उगाई जाती है तथा उच्च सूखा एवं ऊष्मा प्रतिरोधकता युक्त होने के कारण सहिष्णुता अध्ययनों में मॉडल फसल के रूप में देखी जाती है। लक्षित सूखा-प्रतिक्रियाशील जीन के परिमापन हेतु मात्रात्मक रियल-टाइम PCR के माध्यम से उपयुक्त संदर्भ जीनों का चयन, उन्नत सूखा-सहिष्णुता के आणुविक तंत्र की व्याख्या के लिए महत्वपूर्ण है। बाजरा में विभिन्न विकासात्मक ऊतकों में एवं विभिन्न व्यक्तिगत अजैविक तनावों एवं उनके संयोजनों के तहत 10 चयनित संदर्भ जीनों को जांचा गया। हमारे परिणामों से पता चला कि सभी नमूनों में से EF-1α एवं UBC-E2 सर्वश्रेष्ठ संदर्भ जीन रहे। ये अध्ययन भविष्य में इस महत्वपूर्ण तनाव-सहिष्णु फसल में तनाव-सहिष्णु जीनों की खोज में सहायक होगा।

भेषज विज्ञान

कुछ संकटग्रस्त औषधीय पौधों की सर्वोत्तम कीमोटाइप्स के मोड़ीफाइड कल्टीवेशन एवं *इन-विट्रो* उत्पादन तकनीकों द्वारा पादप-रसायनों का उत्पादन

ग्लोरीयोसा सुपर्बा के कुल 80 नमूनों एवं ***कोलियस फोर्स्खोलाई*** के

65 नमूनों को भारत के विभिन्न क्षेत्रों से एकत्र किया गया। इन प्रजातियों के प्राकृतिक वितरण के पूरी तरह से मापन हेतु एकत्र किए गए नमूनों का पादपालय डेटाबेस एवं पासपोर्ट डेटाशीट तैयार किया गया। इसके अतिरिक्त गुणवत्ता नियंत्रण हेतु वानस्पतिक एवं फिजियो-केमिकल डिस्क्रिप्टर भी स्थापित किए गए।

मवेशियों में प्रतिरोधी कैटिलटिक्स के नियंत्रण हेतु सक्षम फाइटोएकेरीसाइड की कीमोप्रोफाइलिंग एवं क्रियात्मक अभिलक्षणन

पाँच राज्यों मध्य प्रदेश, उत्तराखंड, महाराष्ट्र, सिक्किम तथा जम्मू एवं कश्मीर के 23 स्थानों से चयनित प्रजाति ***एजेरेटम कोनेज्चाएडिस*** के नमूने एकत्र किए गए। प्रत्येक नमूने के लिए अक्षांश, देशांतर, ऊंचाई, आदि सूचनाओं से युक्त पासपोर्ट डेटाशीट को तैयार किया गया एवं विभिन्न भौतिक-रासायनिक पैरामीटर का भी आंकलन किया गया।

कुपोषण के लिए कुछ कम ज्ञात पौधों की पहचान एवं मूल्यांकन तथा एक कम लागत वाले हर्बल संयोजन का विकास

बाहुनिया परप्यूरिया, बा. वैरीगेटा, बा. अक्यूमिनेटा, आक्सेलीस कोर्निकुलेटा एवं ***लफा सिलिंड्रिका*** की फाइटोकेमिकल, फिजियो-केमिकल, एंटीआक्सीडेंट क्रियाओं का आंकलन किया गया। इन सभी पौधों के हिस्सों में ICP-MS का प्रयोग करते हुये तात्विक आंकलन एवं साथ ही एंटीकैंसर क्रिया का भी आंकलन किया गया। ***बाहुनिया परप्यूरिया*** एवं ***बाहुनिया वैरीगेटा*** ने आक्सीडेटिव स्ट्रेस संबन्धित बीमारियों को रोकने में क्षमता प्रदर्शित की एवं कैंसर एवं सूक्ष्म-तत्व कुपोषण के लिए खाद्य सप्लीमेंट के रूप में प्रयोग किए जा सकते हैं।

सिलैजिनेला ब्रायोप्टेरिस (संजीवनी) से निकाले गए पालिफीनॉल का पादप-रासायनिक एवं भेषज अध्ययन

सिलैजिनेला ब्रायोप्टेरिस (संजीवनी) भारत के मिथकों में सर्वाधिक रहस्यमय एवं सर्वाधिक चर्चित पौधा है। इसके पुनर्जीवन प्रदान करने की कथित क्षमता के महत्व से जुड़े मिथकों के प्रति अवहेलना के बाद भी शताब्दियों से यह पौधा गंभीर चर्चाओं का विषय रहा है। अतः इस पौधे में पहचाने गए फाइटोकेमिकल्स के जैविक एवं भेषज उपयोगों के अध्ययन के लिए प्रायोगिक तनाव स्थितीयों का अध्ययन या गया।

पेप्टिक अल्सर में प्रयोग की जाने वाली शैक प्रजातियों: *अस्निया लोंगीसीमा* एवं *क्लैडोनिया फरकेटा* का मानकीकरण एवं पुष्टिकरण

शैक, कवक एवं शैवाल के सहयोजी संयोजन से बने जटिल जीव हैं। यह विशेष संयोजन संबंध इन्हें विशेष जैविक लक्षण प्रदान करता है जो इन्हें अन्य सामान्य कवक या शैवाल से अलग करते है। शैकों में ऑर्सेनिक अम्ल, लाइकेस्टेरिनिक अम्ल व अन्य पदार्थ होते हैं जिनमें विलक्षण एंटीसेप्टिक एवं जीवाणुरोधी क्षमताएँ होती हैं। म्यूकोसल डिफेंसिव फैक्टर के प्रति एंटी-अल्सर क्रिया की क्षमता को भी जांचा गया।

औद्योगिक महत्व के भारतीय औषधीय पौधों का गुणवत्ता मूल्यांकन एवं वैज्ञानिक रूप से पुष्टि एवं पारंपरिक ज्ञान आधारित हर्बल उत्पादों का विकास

HPTLC के प्रयोग के द्वारा 'शंखपुष्पी' के वाणिज्यिक नमूनों का प्रमाणन

शंखपुष्पी में शंख के आकार के पुष्प होते हैं। यह मेध रसायन की एक बहुचर्चित आयुर्वेदिक औषधि है तथा इसमें अनेकों औषधीय गुण जैसे कि तंत्रिका तंत्र ऊतकों का जीर्णोद्धार, आवाज के प्रति लाभप्रद, याददाश्त, रंग, ऊर्जा, एवं क्षुधा वर्धक आदि। दिल्ली, लखनऊ, वाराणसी, हिसार, जालंधर, देहरादून, मुंबई एवं जयपुर के बाजारों से प्राप्त नमूनों को HPTLC फिंगरप्रिंटिंग द्वारा प्रजाति स्तर तक प्रमाणित किया गया।

बेटुला यूटिलिस एवं *बेटुला अलनोइडिस* की तुलनात्मक कीमोप्रोफाइलिंग

भारत में पाये जाने वाले ***बेटुला यूटिलिस*** एवं ***बेटुला अलनोइडिस*** को क्रमशः भुर्ज एवं भोजपत्र के नाम से जाना जाता है एवं पारंपरिक औषधियों में प्रयोग किया जाता है। इन वृक्षों की छाल को आयुर्वेदिक एवम यूनानी पद्धतियों में विभिन्न बीमारियों जैसे की घाव भरने के लिए, चर्म विसंक्रमण, खांसी, कोढ़, रक्त विकारों आदि के लिए प्रयोग किया जाता है। इन वृक्षों की छाल में बेटुलिन, β-सीटोसेरोल, ल्यूपियोल एवं ओलेनोलिक अम्ल आदि के आंकलन के लिए प्रोटोकाल विकसित किए गए।

फसल कटाई के सर्वोत्तम समय को जानने के लिए *टेफ्रोसिया परप्यूरिया* (सर्पुंखा) में मौसमी विविधिता का अध्ययन

यकृत, तिल्ली एवं गुर्दे के विकारों एवं अवरोधों आदि के इलाज के लिए पारंपरिक औषधि के रूप में ***टेफ्रोसिया परप्यूरिया*** एक प्रचलित पौधा है। HPLC आंकलन से इसके अर्क में क्वेर्सटीन-3-O-रूटीनोसाईड, बायोकेनिन A-7-O-रैमनोग्लूकोसाइड एवं कम्फेरोल-3-O-रूटीनोसाईड पाए गए। पौधों को तीन भिन्न मौसमों में एकत्र किया गयाः ग्रीष्म (अप्रैल; 400C±2), वर्षा (अगस्त; 360C±2) एवं शीत (दिसंबर; 200C±2). इन लेवोनाईड ग्लाइकोसाइड पर मौसमी प्रभावों को निर्धारित करने के साथ साथ इनकी एंटी आक्सीडेंट क्रिया को निर्धारित किया गया। इनके संगठन एवं मात्रा पर स्पष्ट मौसमी बदलाव दिखाई दिये।

पादप रसायन

विभिन्न खाद्य मैट्रिक्स में प्रभावी न्यूट्रास्यूटिकल्स के वितरण हेतु निष्कर्षण एवं माइक्रोकैप्सूलेशन

पाँच न्यूट्रास्यूटिकेली प्रचुर गम एंकैप्सूलेंट पर वास्तविक घनत्व, टैप्ड घनत्व, कैर इंडेक्स आदि जैसे मैकेनिकल अध्ययन किए गए एवं वाणिज्यिक अर्ध-कृत्रिम एंकैप्सूलेंट से तुलना की गई। एंकैप्सूलेंट्स से बने स्थायी मैट्रिक्स की क्रियात्मक समूह पहचान की गई। विभिन्न सान्द्रताओं में पाँच एंकैप्सूलेंट्स के साथ विभिन्न कोर पदार्थों जैसे कुरकुमीन, बिक्सीन, β-कैरोटीन, आवश्यक तेल एवं वसीय तेलों से माइक्रो कैप्सूल फार्मूलेट किए गए। कैप्सूलेशन की

प्रक्रिया को सुधारने के लिए एक कैप्सूलेशन पद्धति को सुधारा गया। खाद्य की प्रभावी वितरण हेतु स्थायी मैट्रिक्स को बनाने के लिए उपयोग हेतु खाद्य तेलों एवं रंजक पदार्थों को कोर पदार्थ की भांति प्रयोग करते हूए मल्टी-कोर कैप्सूलेशन किया गया।

शैकों पर राष्ट्रीय कार्यक्रमः द्वितीयक यौगिकों का जैव-पूर्वेक्षण तथा कल्चरों की स्थापना एवं संग्रहण

HPLC के माध्यम से शैक अम्लों की पहचान हेतु 50% एथेनोल एवं एसीटोन में निष्कर्षित किए गए शैक अर्कों के विभिन्न कालम फ्रैक्शनों को प्राप्त करने के लिए तीन शैक प्रजातियों का निष्कर्षण, प्रथक्कीकरण एवं विखंडन किया गया। बायो-एक्टीविटी को जाँचने, संग्रहण एवं बड़ी मात्रा में कल्चर के लिए तीन शैक प्रजातियों से चार शुद्ध द्वितीयक यौगिक अलग किए गए।

कुछ अल्प ज्ञात प्राकृतिक गोंद के प्रथक्करण निष्कर्षण हेतु कम लागत तकनीक का विकास

विभिन्न फोर्मूलेशन्स के निर्माण हेतु उत्तर प्रदेश के सोनभद्र जिले के चयनित जनजातीय ग्रामों से एकत्र किए गए पौधों जैसे ***अकेसिया मैंजियम, मैंगिफेरा इंडिका, बुकनानिया, ब्यूटिया मोनोस्पेरमा,*** चिरौंजी एवं महुआ पर पादप-रसायनिक अध्ययन किए गए।

सेनेटरी नैपकिन के विकास हेतु कम लागत वाले पदार्थों के रूप में प्राकृतिक गोंदों का उपयोग एवं ग्रामीण क्षेत्रों में स्त्री स्वास्थ्य से संबन्धित जागरूकता का प्रसार

स्वच्छता के उद्देश्य से प्रयोग किए जाने वाले पदार्थों के मार्केट सर्वे एवं संदर्भों के आधार पर गोंदों का चयन किया गया। पाँच प्रचुर मात्रा में एवं आसानी से मिलने वाले गोंदों को एकत्रित/हासिल किया गया तथा उपयुक्त जैवपदार्थ के रूप वाणिज्यिक समूनों के साथ अध्ययन किया गया। स्वास्थ्य एवं स्वच्छता हेतु नवीन कम लागत के उत्पादों के विकास हेतु इनके जल्द सूखने, फूलने एवं घुलने की क्षमता का अध्ययन किया जा रहा है।

कैमीफोरा वीटाई (गुग्गुल) में गुगुल्स्टेरोन उत्पादन को बढ़ावा

ग्रीष्म काल में शुष्क क्षेत्रों (बाड़मेर, जैसलमर), अर्ध-शुष्क क्षेत्रों (कायलाना, जोधपुर) एवं उपोष्ण कटिबंधीय (लखनऊ) क्षेत्रों से गुग्गुल की पत्तियों, तनों एवं लेटेक्स को एकत्र किया गया एवं उनके जलीय एवं गैर-जलीय मेटाबोलाइट्स हेतु HPLC एवं GC-MS द्वारा जांचा गया। भीषण गर्म मौसम में शुष्क एवं अर्ध-शुष्क क्षेत्रों से एकत्र किए गए कमीफोरा वाइटाइ के विभिन्न नमूनों की HPLC एवं GC-MS के द्वारा गैर-लक्षित मेटाबोलाइट प्रोफाइलिंग की गई एवं 59 रासायनिक रूप से भिन्न मेटाबोलाइट्स जैसे अमीनो अम्ल, ऑर्गैनिक अम्ल, शर्कराएँ, वसीय अम्ल, फेनोल, स्टेरोइड्स, स्टेरोल्स, टर्पेनोइड्स आदि पहचाने गए जो प्राथमिक एवं द्वीतीयक मेटाबोलाइट पाथवे को प्रदर्शित करते हैं। गुग्गुल के विभिन्न नमूनों में जलीय एवं गैर-जलीय मेटाबोलाइट्स स्पष्ट मात्रात्मक एवं गुणात्मक भिन्नता देखी गई।

औषधीय एवं सगंध पौधों का पादप-रासायनिक अध्ययन

लाउनिया प्रोकंबेन्स की जड़ों एवं पत्तियों में वसीय अम्लों की पहचान एवं अर्क विषाक्तता के साथ-साथ यौगिकों का निष्कर्षण एवं पहचान

लाउनिया प्रोकंबेन्स से 15 यौगिक अलग किए गए एवं पहचाने गएः 1-H-पाइराजोल, 1-H-इमिडाजोल , आइनोसिटोल, स्टिग्मास्टेरोल, β-एमेरिन, α-एमेरिन, लूप-20(29)-एन-3-ऑल, जाइलिटोलस, रिबिटोल, D-ग्लूकोज, प्रोलीन, अराबीटोल, मैनीटोल, फ्रक्टोस, ट्रेहलोस, गैलेक्टिनोल एवं 3-α-मैनोबयोज. विभिन्न फ्रैक्शनों LPH (n-हेक्सेन), LPE (एथिल एसीटेट), LPW (जल) and LPB (n-ब्यूटेनोल) की कोशा विषाक्तता अध्ययन किए गए। इन अर्कों को विभिन्न सान्द्रताओं में SRB एसे के द्वारा IC_{50} वैल्यू निर्धारित करने के लिए मानव कैंसर कोशिकाओं की सेल लाइंस जैसे ल्यूकेमिया (K 562), सर्विक्स (HeLa), अग्नाशयी (MIA-Pa-Ca-2) एवं स्तन (MCF-7) के विरुद्ध जांचा गया। एथिल एसीटेट फ्रैक्शन को सर्विक्स (HeLa), ल्यूकेमिया (K 562), एवं स्तन (MCF-7) कैंसर सेल लाइंस के विरुद्ध 42, 56.70, एवं 64 माइक्रोग्रा./मिली IC_{50} वैल्यू के साथ प्रभावी पाया गया।

RESEARCH & DEVELOPMENT

SUPRA-INSTITUTIONAL NETWORK PROJECTS

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

Nodal Scientist: DK Upreti

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

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

Objectives:

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

Highlights:

Bioresource mapping of Govind Wildlife Sanctuary (GWLS)

Bioresource mapping in GWLS was further continued. Taxonomic studies on Thelotremoid lichens (121 spp.) and *Corydalis* (23 spp.) were carried out. An inventory of 637 species of angiosperms, 315 lichens, 350 bryophytes, 154 algae and 85 species of pteridophytes recorded so far from GWLS has been prepared.

The occurrence of four bryophyte species in GWLS, viz. *Riccia beyrichiana* Hampe, *Tayloria hornschuchii* (Grev. & Arn.) Broth., *Linbergia koelzii* Williams, and *Brachythecium falcatulum* (Broth.) Par., constituted new regional records for Uttarakhand (Fig. 1).

In -vitro propagation protocols have been developed for *Marchantia paleacea* Bertol., and *Plagiochasma appendiculatum* Lehm. *et* Lindenb. from freshly collected plants from GWLS. Axenic cultures have been established using spores as explants. A good population of plants has been acclimatized on soil for propagation and multiplication of germplasm.

Reproductive biology of three species of ferns, *Athyrium pectinatum* (Wall ex Mett.) T. Moore, *Dryoperis cochleata* (Buch.- Ham. ex D.Don) C.Chr. and *Onychium contiguum* Wall.ex Hope, has been studied *in vitro* through spore culture. Fully cordate gametophytes were obtained from the spores cultured in P&T media on the 50th, 56th and 64th day of sowing in *Onychium contiguum*, *Athyrium*

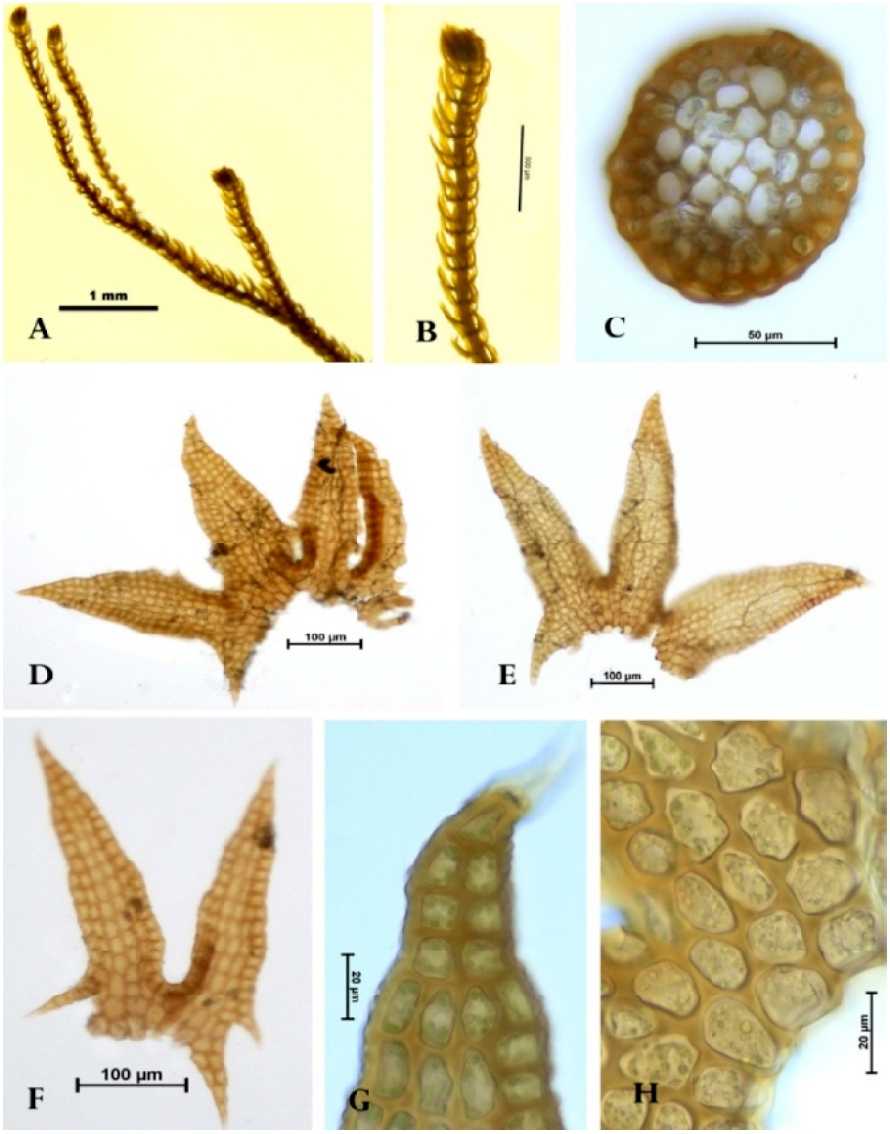


Fig. 1. *Tetralophozia filiformis* (Steph.) Urmi; A, B. Plants (a portion). C. Cross section of Stem. D, E Leaves. F. Under-leaf. G. Apical cells of Leaf. H. Basal cells of leaf.

pectinatum and *Dryoperis cochleata*, respectively. The gametangia development in all the three species showed a dioecious tendency with the male gametangia appearing first and the female gametangia later at a gap of 5 to 14 days interval on separate gametophytes. Sporophytes resulting from intergametangia fusion were started developing on 117th day in *Onychium contiguum*, 135th day in *Dryoperis cochleata* and on 160th day in *Athyrium pectinatum*. The dioecious sex expression, often with protrandry, seems to be one of the reasons for the poor colonization ability and population decline of these rare ferns. *In- vitro* spore culture is a viable method for multiplication and propagation of gametophytes/ sporophytes of such rare and threatened ferns and also for understanding their reproductive bottlenecks (Figs. 2 and 3).

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

Genetic diversity and population genetic structure of 41 accessions of *Bergenia stracheyi*, representing three populations from Jammu & Kashmir (J&K) and Himachal Pradesh (KULLU and JP) in the West Himalyas, was estimated using 10 DAMD and 16 ISSR markers. The cumulative data (DAMD+ISSR) analysis carried out showed 87.14% polymorphism across all accessions of *B. stracheyi*. The intra-population genetic diversity analysis revealed the highest value of Nei's genetic diversity (0.26), Shannon information index (0.38) and polymorphic loci (78.7%) in KULLU population and least value of Nei's genetic diversity (0.2), Shannon information index (0.3) and polymorphic loci (50%) in JP population. The maximum inter-population average genetic distance were in between J&K and JP population and minimum average genetic distance were in between KULLU and JP population. The hierarchical analysis of molecular variance (AMOVA) revealed maximum percentage of variation among individuals of populations (72%) followed by 16% among populations and 12% of variation among the regions. This study helped identify diverse accessions and populations of *Bergenia stracheyi* for further utilization and conservation in the Himalayan regions.

DNA barcoding of selected medicinal plants of GWLS

DNA barcoding of 11 species of medicinal plants comprising of 68 accessions has been completed.

Ficus L. (Moraceae) of the Gangetic Plains in India

The taxonomy of *Ficus* of the Gangetic Plain has been completed. The genus consists of 38 species from the study area which includes Eastern Rajasthan, Uttar Pradesh, Bihar, Jharkhand and W. Bengal. In addition to taxonomy, the detailed morphological diversity study has also been carried out on many variable species to define the species correctly. About 1600 herbarium specimens housed at various Indian herbaria such as BSA, BSD, CAL, DD, LWG and MH were studied to draw taxonomic conclusion. Several new information regarding status, distribution, identification and variation pattern of species have been generated in this study. This is the first study on the genus in the recent time from the Gangetic Plain.

Nanoformulation from Lichens

The lead available on nano-antimicribials for *in-vivo* wound healing is under development as a technology. The nano-antimicrobial material exhibits efficacy at par with positive control like Streptomycin sulphate and betadine.

Metabolite fingerprinting of potential anti-cancerous plants of GWLS

Isolation of bioactive compounds from *Betula utilis*

Ten compounds have been isolated from *Betula utilis* bark and seven of these have been identified. Two compounds, NBMP-6 and NBMP-7, were reported for the first time from this plant. Isolated compounds were tested for *in-vitro* cytotoxic activity against five different cancer cell lines (Fig. 4), where NBMP-7 found to have most significant cytotoxic activity against colon and breast cancer cell lines comparable to the standard drug-Doxorubicin. IC_{50} value is 4.68 µM/mL. Moreover it was found to be selective for breast cancer cells over non-tumorigenic breast epithelial cells (MCF 10A).

Anti-proliferative effect of NBMP-7 was determined. It was mediated by the generation of reactive oxygen species (ROS), the ROS level in MCF-7 cells was measured using DCFH-DA using fluorescent microscope (Fig. 5). Thus intracellular ROS generation and mitochondrial membrane potential disruptions are the major factors for the anticancer potential of NBMP-7. It also inhibits breast cancer cell migration.

Cytotoxic activity of *Marchantia polymorpha* fractions

The chemical fractions from *Marchantia polymorpha* have been evaluated for *in vitro* cytotoxic activity against four cancer cell lines, viz., Breast (MCF-7), Colon (DLD-1, SW-620), Head & Neck (FaDu) and normal epithelial cancer cell line. Hexane exract of wild plants has shown significant cell growth inhibition percentage against Colon (DLD-1, SW-620), Head & Neck (FaDu) and normal epithelial cancer cell line. In comparison to other extracts, the hexane extract of cultured *M. polymorpha* was also found to have significant cell growth inhibition against Breast (MCF-7), Colon (DLD-1) and Head & Neck (FaDu) cancer cell lines.

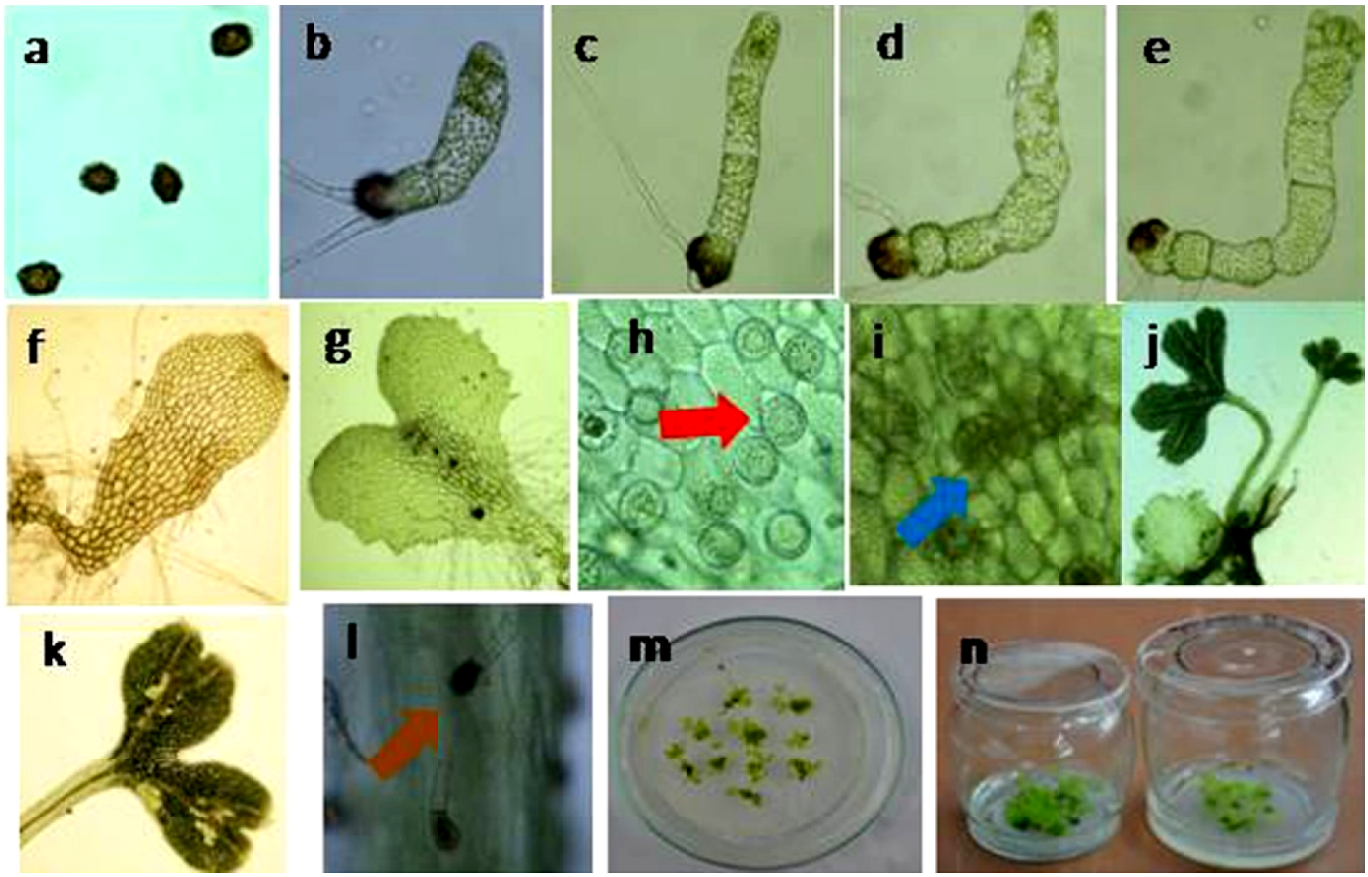


Fig. 2. Developmental stages of *Athyrium pectinatum*, a. Spores, b-d. Germinating spore with rhizoid and 4-5 celled filamentous gametophyte, e-f. Filamentous and spathulate gametophyte, g. Cordate gametophyte, h. Antheridia, i. Archegonia, j-k. Sporophyte and dichotomy, l. Hairs on sporophyte, m-n. In-vitro multiplication of sporophytes.

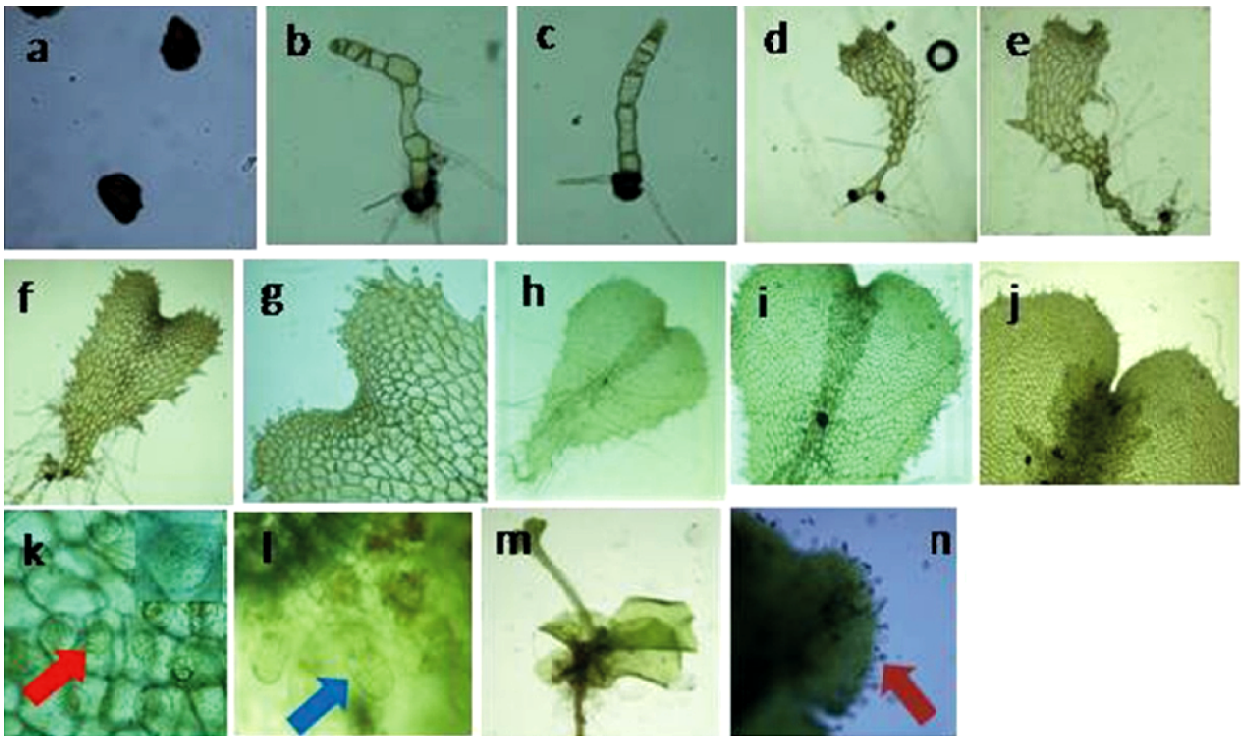


Fig. 3. Developmental stages of *Dryopteris cochleata*, a. Spores, b-c. Filamentous gametophyte, d-e. Spathulate gametophyte, f. Semi-cordate gametophyte, g. Hairs on gametophyte, h. Cordate gametophyte, i-j. Hairs on the margin of gametophyte, k. Antheridia, l. Archegonia, m. Sporophyte, n. Hairs on sporophyte.

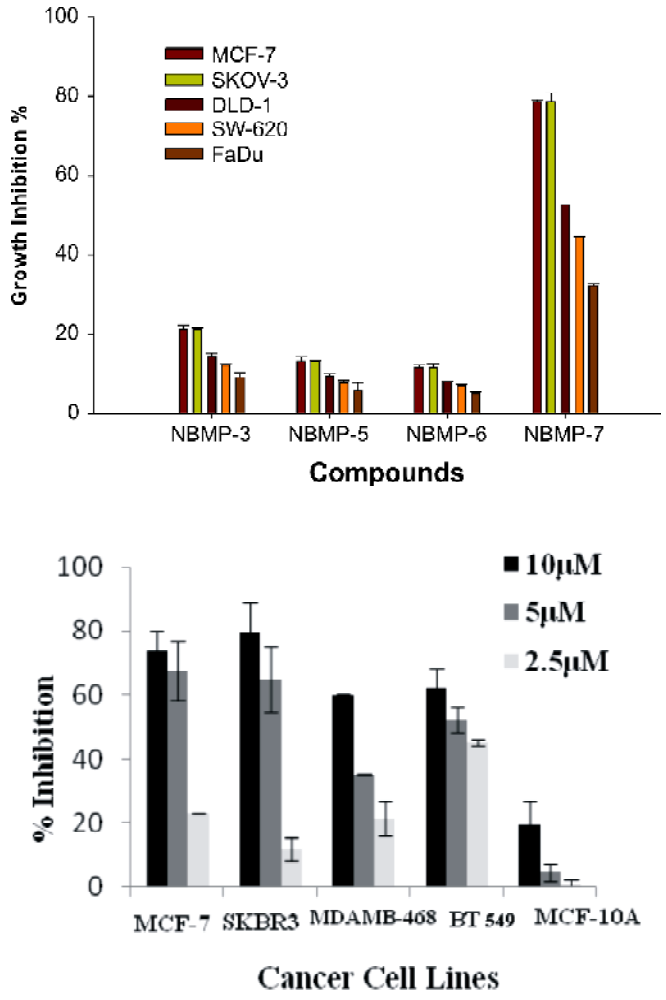


Fig. 4. Compounds isolated from *Betula utilis* bark were tested for *in-vitro* cytotoxic activity against five different cancer cell lines

Phytochemical profiling of potential medicinal plants

Bergenia ciliata

The berginin content in different populations of *Bergenia* species at varied altitudinal gradients was estimated. *Bergenia ligulata* comprising of 24 accessions at an altitude of 2009 meters have the maximum berginin content of 77.25 mg/g, followed by *B. stracheyi* (16 accessions) and *B. purpurascens* (7 accessions) with 55.0 mg/g berginin each. *B. ciliata* population in Sikkim at an elevation of 1645 meters has the maximum berginin between 8.28 to 72.10 mg/g, followed by Kullu with 22.4-39.50 mg/g at an altitude of 2086 m.

Betula utilis

A rapid and reliable method was developed for determination of Pentacyclic Triterpenes from *Betula utilis* by High Performance Liquid Chromatography (HPLC) and High Resolution Magic Angle Spinning Nuclear Magnetic Resonance Spectroscopy (HR MAS NMR).

Bark samples of *B. utilis* were collected from five locations during May 2013 from mature trees growing at different altitudes of Himalayas in Himachal Pradesh and Uttarakhand and the samples were labelled as NBRI-1, NBRI-2, NBRI-3, NBRI-7 and NBRI-8.

HPLC Analysis

Five grams of lyophilized powder of bark tissue from each accession was extracted with chloroform using a tissue homogenizer (Kinematica Polytron Homogenizer PT 6100) and the concentrated chloroform extracts were analyzed using HPLC. The peaks were confirmed and quantified against external standards of betulin and betulinic acid and the concentrations were expressed in µg/mg of dry weight basis of bark samples.

HR-MAS NMR spectroscopy

Lyophilized bark tissue samples were macerated to a fine powder in liquid nitrogen using a pestle and mortar for analysis. The powdered samples were analysed using HR-MAS NMR spectroscopy. The HR-MAS NMR spectra were recorded on Bruker Avance 400 MHz spectrometer

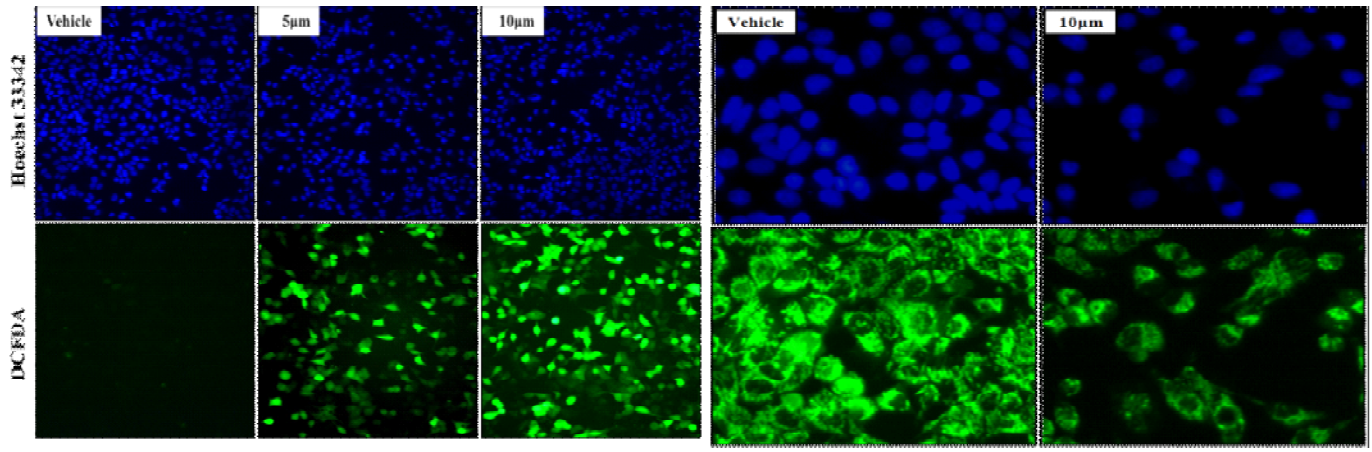


Fig. 5. Anti-proliferative effect of NBMP-7 mediated by the generation of reactive oxygen species (ROS), in MCF-7 cells measured using fluorescent microscopy

(Bruker Biospin AG, Fallendan, Switzerland) equipped with a 4 mm HR-MAS ^{1}H-^{13}C dual probehead with magic angle gradient. The HR-MAS NMR experiments were performed at 28 °C. Lyophilized powder of bark tissue (25 mg) was packed in a 50 µL capacity ZrO2 rotor for quantification of metabolites. About 10 µL of $CDCl_3$ containing 0.03% TMS as a chemical shift reference was filled in the rotor with the powdered sample for locking the spectrometer frequency, and to adjust the local field homogeneity. The HR-MAS NMR experiments were performed at magic angle spinning frequency of 4.0 kHz to expel the signals arising from rotation sidebands. One dimensional Carr–Purcell–Meiboom–Gill (CPMG) pulse sequence with water suppression (echo time of 40 ms) and relaxation delay of 3.99 s was performed to remove short T_2 components arising due to the presence of lipids as well as to obtain a good baseline for the quantitation as well as for multivariate analysis. The spectral width of 8,250.8 Hz and 128 transients were acquired with a total recording time of about 9 minutes.

HR-MAS NMR spectroscopy of lyophilized bark tissue of *B. utilis* distinguished the resonances of betulin and betulinic acid (Fig. 6). There was a wide variation in the betulin and betulinic acid content amongst the five accessions of *B. utilis* collected from various locations. Betulin content ranged from 0.34±0.05 to 3.9±0.42 µg/mg, the lowest being in NBRI-7 and the highest in NBRI-8. The range of betulinic acid was 0.29 to 1.98 µg/mg with an average of 1.09 µg/mg. The clusters observed in the principal component analysis (PCA) score plots of NMR and HPLC analysis classified individuals with very high as well as very low betulin and betulinic acid apart from a third group of accessions with moderate concentration of metabolites (Fig. 7). HR-MAS NMR protocol methods also minimize the drawbacks associated with the extraction of betulin and betulinic acid using different solvents.

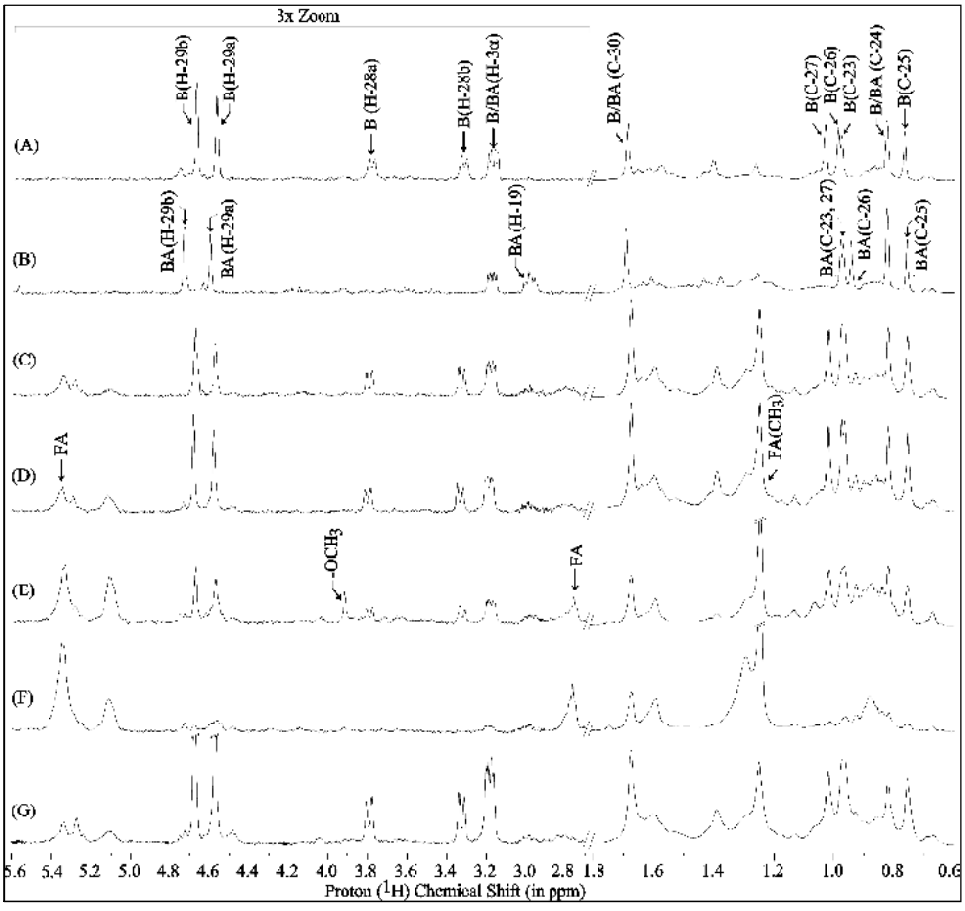


Fig. 6. Stack-plot of HR-MAS 1H NMR single pulse spectra (0.6-1.8 ppm and 2.70–5.60 ppm) of bark of *Betula utilis* (A) Betulin, (B) Betulinic acid, (C) NBRI-1, (D) NBRI-2, (E) NBRI-3, (F) NBRI-7 and (G) NBRI-8. B= Betulin; BA= Betulinic acid; FA= Fatty acid. All the five representative spectra were plotted on the same intensity.

UHPLC-MS

A simple, rapid, sensitive method was developed by UHPLC-MS and validated for simultaneous determination of triterpenoids, phenolics and flavonoids in stem bark of *Betula utilis* (24 accessions). The content of betulinic acid and oleanolic acid were detected higher among selected analytes in the sample collected from Himachal Pradesh (Fig. 8).

Leucas cephalotes

Leucas cephalotes (roots, leaves, stems and fruits) extracted with ethanol and further fractionated in hexane, ethyl acetate, chloroform and water. *In-vitro* á-amylase activity of all plant parts has been done in which ethanolic extract of fruits and leaves showed the highest á-amylase inhibition in comparison to standard drug. Anti-oxidant activity of all plant parts has been done and ethyl-acetate extract of leaves showed the highest scavenging activity.

Hemidesmus indicus

Hemidesmus indicus leaves extracted with ethanol and ethanolic extract was further subjected to fractionation

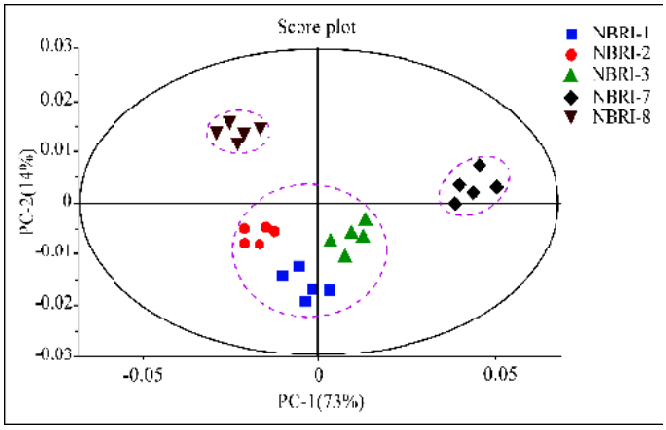


Fig. 7. PCA scores plot obtained from the PC analysis of HR-MAS 1H NMR spectra of *Betula utilis* bark.

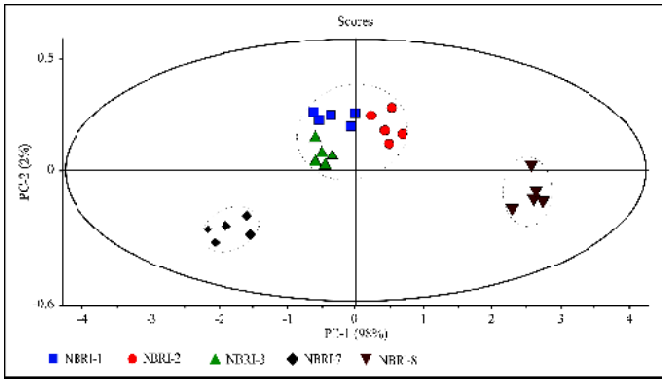


Fig. 8. PCA scores plot obtained from the PC analysis of quantified data of betulin and betulinic acid obtained from HPLC.

with hexane, ethylacetate, chloroform and water. In-vitro á-amylase activity and anti-oxidant activity of all the fractions of plants has been done. Ethanolic and water extract shown the best result in comparison with standard drug *acarbose*. Anti-oxidant activity of all plant parts has been done and ethyl-acetate extract of leaves showed the highest scavenging activity

Justicia adhatoda

The major constituent in the essential oil of *Justicia adhatoda* was Phytol (57.8%) (Fig. 9) which is a diterpene and highly biological active compound. Essential oil was evaluated for antibacterial activity against Methicillian Resistant and Sensitive Strain along with their Clinical Isolates. It showed a strong antimicrobial activity against the tested microorganisms (MIC: 62.5-250 µg/ml).

Caenorhabditis elegans

Chemical analysis of selected oils, chemicals and extracts were carried out for purity and composition. TPC, TFC, and antioxidant activities of various oils and aroma chemicals were carried out. Anti-aging effect of different oils on *Caenorhabditis elegans* using end point parameters like toxicity assay, life span assay, pharyngeal pumping, oxidative stress, thermal stress and reactive oxygen species assay are under progress.

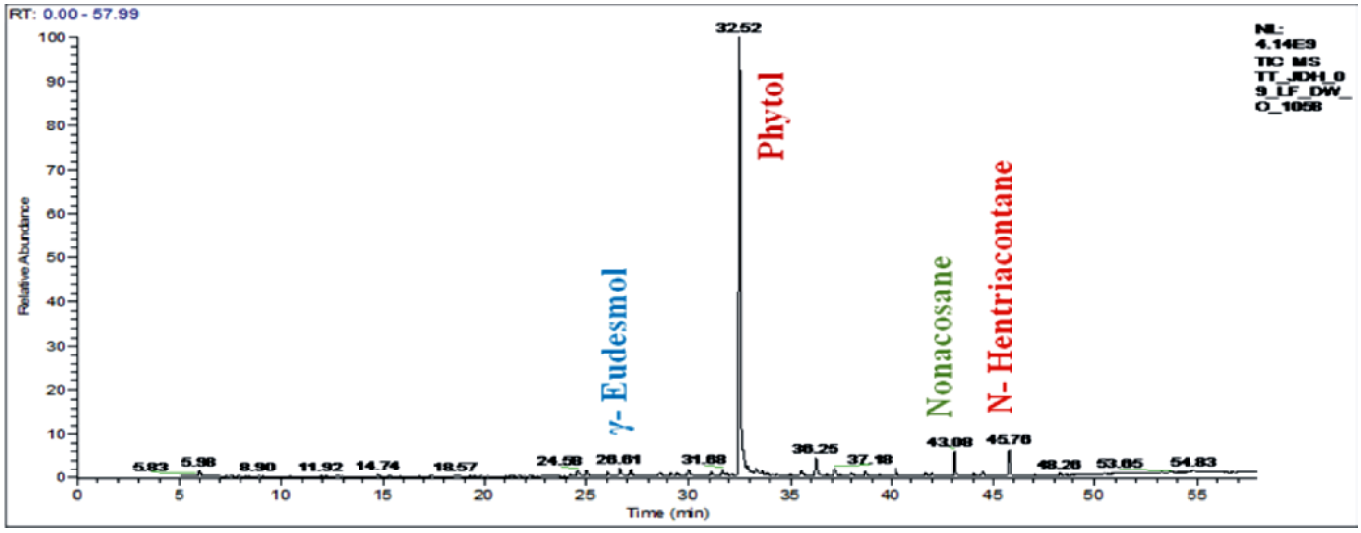


Fig. 9. Essential oil constituents in *Justicia adhatoda*

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

Nodal Scientist : PK Trivedi

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

Objectives:

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

Highlights

- Full-length cDNAs of putative genes involved in uncharacterized steps of specific alkoloid biosynthesis have been cloned. Various constructs have been developed and used for Virus Induced Gene Silencing (VIGS) to study the modulation of metabolite content. Transcript and alkaloid analysis suggest reduced metabolite content due to VIGS of the pathway genes. In addition, one methyl transferase has been expressed in *E.coli* to establish its role in papaverine biosynthesis. Transcriptome datasets of thebaine-rich (>10% of the latex) poppy lines and their parents as well as *Psoralea corylifolia* have been established and are being analysed.
- Global gene expression analysis in leaf and fruit of AtMYB12 expressing tomato lines suggests differential modulation of several processes by AtMYB12 in different tissues. Impact of enhanced flavonol content on animal health has been studied in collaboration with CSIR-CDRI. Pre-pubertal ovary intact BALB/c mice were orally administrated ethanolic extract of wild type (WT-TOM) and transgenic AtMYB12-tomato (MYB12-TOM) fruits for six weeks. MYB12-TOM extract significantly increased tibial and femoral growth and subsequently improved the bone length as compared to vehicle and WT-TOM. This study concluded that metabolic reprogramming of tomato by AtMYB12 has the potential to improve longitudinal bone growth thus helping in achievement of greater peak bone mass during adolescence.
- To establish involvement of miRNAs in secondary plant product biosynthesis, functional characterization of Arabidopsis miR858a was carried out. Over-expression of miR858a in Arabidopsis led to down-regulation of several MYB transcription factors regulating flavonoid biosynthesis. In contrast to the robust growth and early flowering of miR858OX plants, reduction of plant growth and delayed flowering was observed in Arabidopsis transgenic lines expressing artificial miRNA target mimic (MIM858) (Fig. 1). Genome-wide expression and metabolite analysis using transgenic lines suggested that miR858a targets a number of regulatory factors which modulate expression of down-stream genes involved in plant development as well as modulated flavonoid biosynthesis (Fig. 2). Further, higher expression of MYBs in MIM858 lines leads to the redirection of the metabolic flux towards the synthesis of flavonoids at the cost of lignin synthesis. This study also established the potential role of HY5-dependent light-regulated miR858a in flavonoids biosynthesis and plant growth and development.
- Transcriptome sequencing of ripe and unripe stages of banana was completed and analysed for the identification of members of genes families putatively involved in fruit ripening. Detailed analysis of various gene families including AP2/ERF, HDZIV and WRKY gene families has been carried out. Illumina based sequencing of RNA from inner and outer zones of Dashehari and Baganpalli varieties of mango was completed and analysed. A comparative analysis of the inner and outer zones of unripe and mid ripening stage of these varieties identified differentially expressing genes.
- An Illumina based sequencing of RNA from 0h and 8 h ethylene treated abscission zones of *Rosa bourboniana* (highly ethylene sensitive) and 8h ethylene treated *Rosa hybrida* (which shows reduced ethylene sensitivity) was carried out. A number of genes involved in ethylene biosynthesis, perception and other signaling processes showed differential expression in *Rosa bourboniana* and *Rosa hybrida.*
- In cotton, gene families involved in histone modifications related to fiber development were identified and characterized in detail. Transcriptome and ChIP- sequencing of the epigenetic modifiers treated ovule cultures suggest epigenetic regulation of fiber development. Role of Histone Acetylation in cotton fibre development has been demonstrated (Fig. 3).

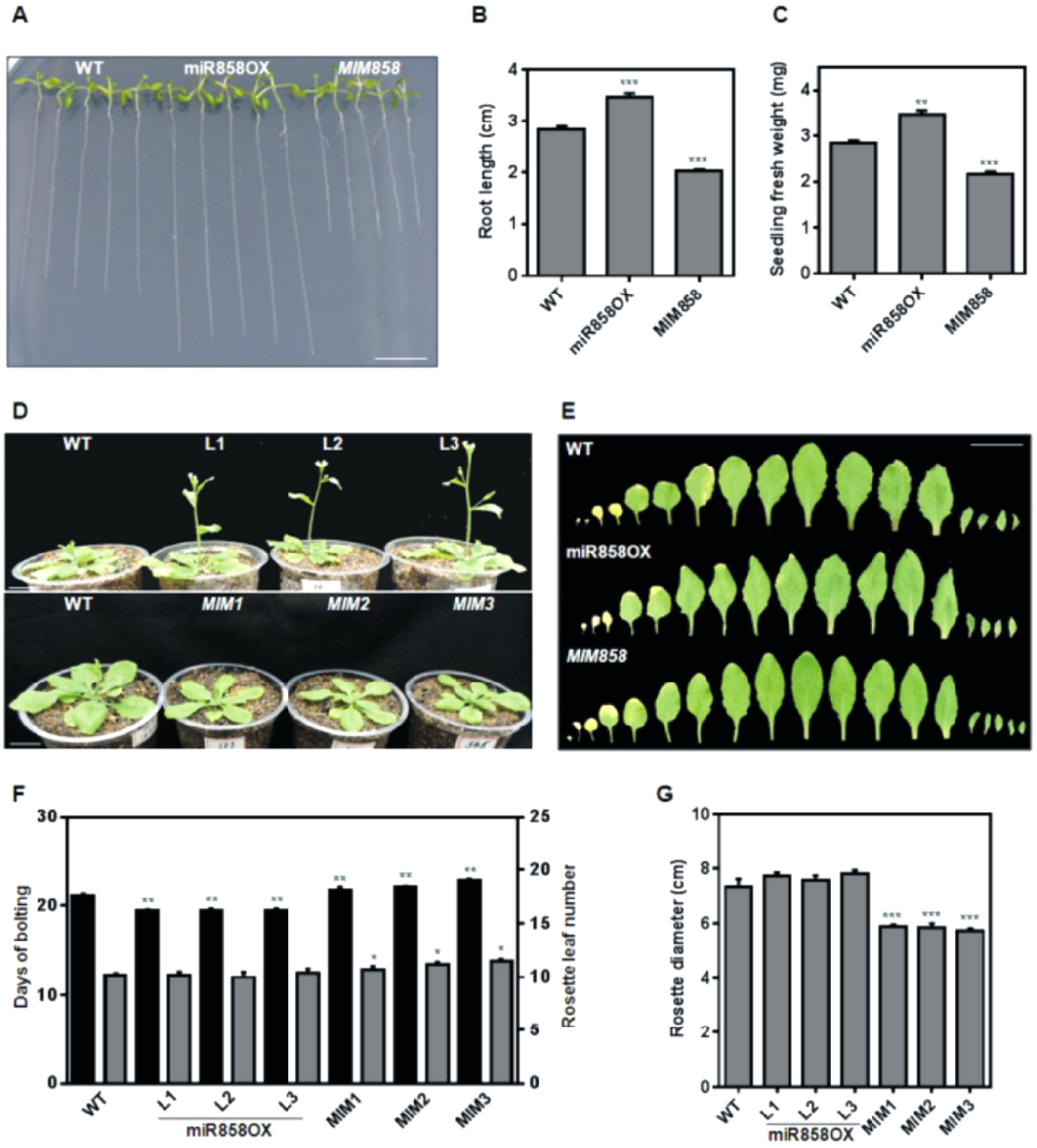


Fig. 1. Alteration of morphology in the miR858a transgenic lines. (A) The seedling phenotype of WT, miR858OX (L1) and *MIM858* (*MIM1*) transgenic lines grown on ½ MS media for 10 days. (B) Root length of the seedlings of WT, miR858OX (L1) and *MIM858 (MIM1)* after growth of 10 days on ½ MS media. (C) Seedling fresh weight (mg) of the WT, miR858OX (L1) and *MIM858* (*MIM1*) after growth of 10 days on ½ MS media. (D) Rosette phenotypes of WT, miR858OX and *MIM858* transgenic lines. (E) Leaf sizes and pattern of each rosette leaf beginning from the oldest one of WT, miR858OX and *MIM858* transgenic plants. (F) Number of rosette leaves (black bars) and days at bolting (gray bars) of WT and transgenic lines of the miR858OX and *MIM858* grown under LD conditions (16 hr light-8 hr dark cycles). (G) Rosette diameter of transgenic lines and WT. Plants were grown for 3 weeks under 16 hr light-8 hr dark photoperiod before photograph. Error bars represent +SE of 8-10 individual plants. The level of significance was evaluated by One-way ANOVA (Newman-Keuls used as post hoc test). ***Significantly different from WT ($P < 0.0001$). White line indicates the scale bar (1 cm). L1, L2 and L3 are miR858OX transgenic lines whereas *MIM1*, *MIM2* and *MIM3* represent *MIM858* transgenic lines.

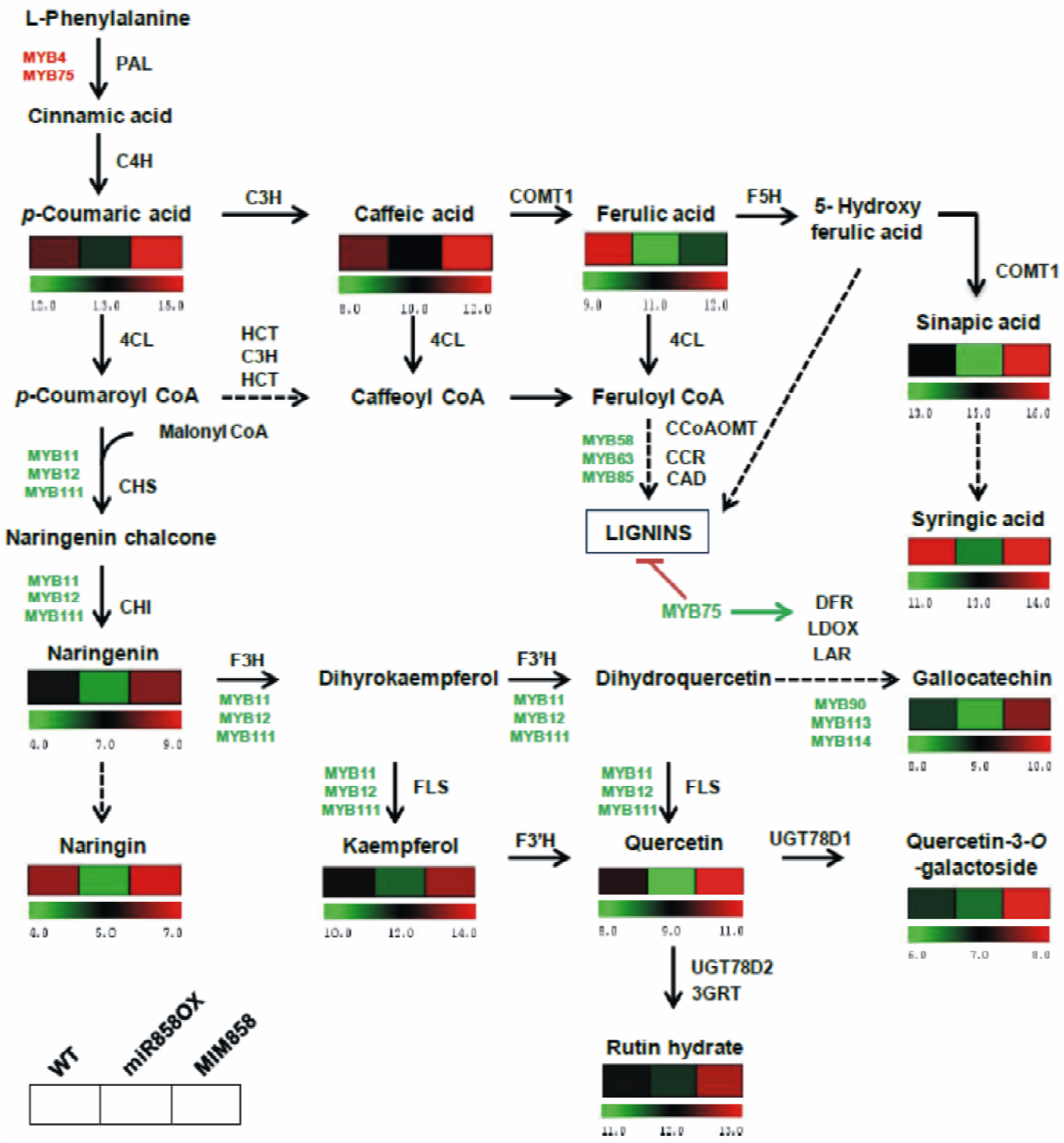


Fig. 2. Metabolic profiling of miR858OX and *MIM858* transgenic lines. Schematic diagram of the phenylpropanoid pathway. Heat maps indicate $\log_2$ transformed values of the concentrations of metabolites in rosette tissue of WT, miR858OX and *MIM858* transgenic lines. LC-MS-MS analysis was performed with the methanolic extracts of dried rosette tissues. Arrows indicate the order of steps in the pathway; dashed arrows represent multiple enzymatic steps. The main enzymes included PAL, phenylalanine ammonia lyase; C4H cinnamate 4-hydroxylase; 4CL, 4-coumaroyl CoA ligase; CHS, chalcone synthase; CHI, chalcone isomerase; F3H, flavanone 3-hydroxylase; F3'H, flavonoid 3' hydroxylase; FLS, flavonol synthase; DFR, dihydro flavonol 4-reductase; LDOX, Leucoanthocyanidin dioxygenase; LAR, leucoanthocyanidin reductase; UGT78D1, flavonol 3-O-rhamnosyltransferase; UGT78D2, flavonoid 3-O-glucosyltransferase; 3GRT, flavonol-3-O-glucoside L-rhamnosyltransferase; HCT, p-hydroxycinnamoyl-CoA:quinate shikimate p–hydroxycinnamoyltransferase; C3H, p-coumaroyl ester 3-hydroxylase; COMT I, caffeic acid O-methyltransferase of class I; CAD, cinnamyl alcohol dehydrogenase; CCoAOMT, caffeoyl-CoA O-methyltransferase; CCR, cinnamoyl-CoA reductase; F5H, ferulic acid 5-hydroxylase. MYB transcription factors are shown in green and red colours (Green for activation and red for inhibition). Likewise green arrow is for activation and red arrow for inhibition.

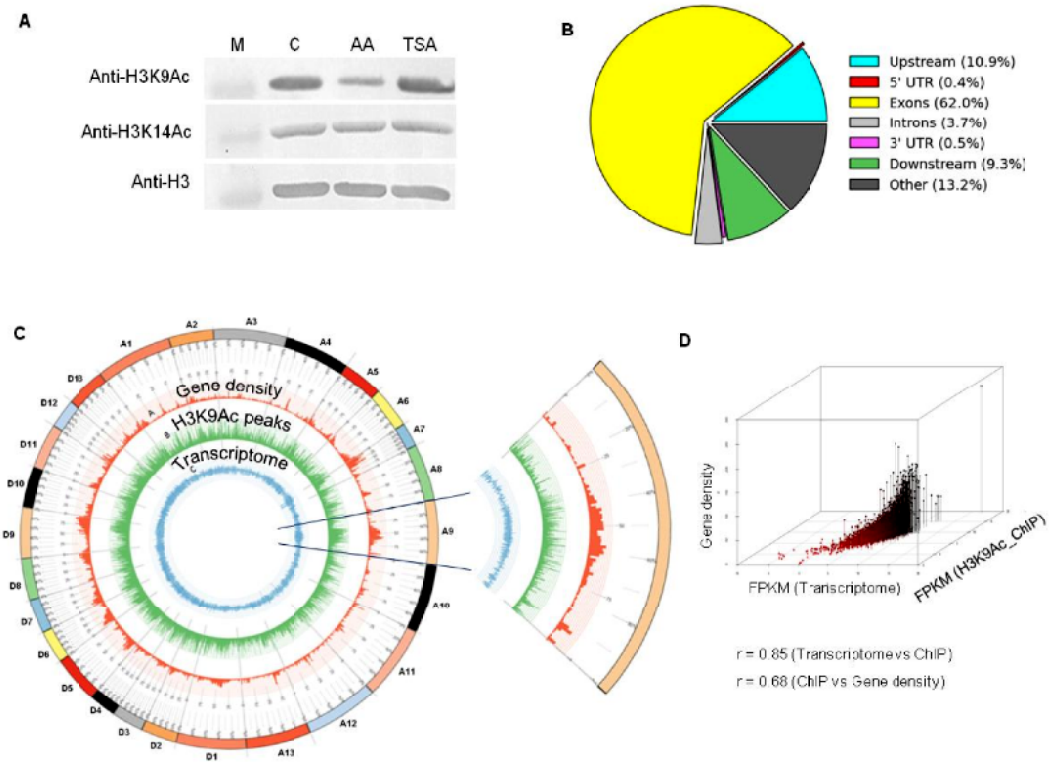


Fig. 3. Genome-wide H3K9Ac landscape in cultured cotton ovules. (A) Immuno-blotting of histone protein from control, AA, and TSA treated ovules at 6 DPA using anti-H3, anti-H3K9Ac, and anti-H3K14Ac antibodies reflects the decrease in H3K9Ac in AA treated ovules and increased in TSA treated ovules . Lane M represents pre-stained marker. (B) Distribution of H3K9Ac peak positions with reference to *G. hirsutum* genome. (C) Genome-wide H3K9Ac peak pattern (green) and corresponding gene expression (blue; $\log_{10}$ FPKM) in control ovules. Red peaks represent gene density per Mb genome. Inset shows enlarged view of H3K9Ac peaks, corresponding gene expression, and gene density at chromosome A9. (D) Genome-wide correlation between gene density, transcriptome, and H3K9Ac peaks in *Gossypium hirsutum* (r represents Pearson's correlation coefficient).

- Transcriptome of callus culture from different developmental stages of Indica and Japonica rice established and analysed. Dynamic transcriptome landscape during somatic embryo development suggested differential stem cell maintenance programming among japonica and indica rice sub-species.
- To understand molecular basis of gender distinction in a dioecious medicinal plant, *Tinospora cordifolia* plants from different parts of the country have been collected, grown in the institute. Transcriptome datasets of male and female were established and being analysed.
- Several genes and promoters have been functionally characterized for their involvement in abiotic stress response including heavy metal stress tolerance and accumulation. The early wound responsive behavior of several promoters has been demonstrated in various plant systems and during insect infection.

Development of whitefly resistant GM cotton

Whitefly is an invasive insect pest of several crops including cotton across the world. High temperature, humidity, dense cropping and cultivation in polyhouses promote the outbreak of whitefly. The insect damages the crops by sucking sap from the host plant, causing fungal infection and spreading plant viruses. The most severely affected crops are cotton, eggplant, tomato, cassava causing a huge financial loss. GM technology for the control of whitefly is not yet available.

A novel anti-whitefly protein was identified in an edible fern. This protein interferes in the reproductive system of whitefly and thus restricts its population. The gene has been cloned and introduced in cotton. The transgenic cotton shows remarkable control of whitefly population through several generations (Fig. 4). The transgenic cotton also shows protection against whitely vectored viral diseases. A patent has been filed on this gene in 8 countries, based on potential market prospects for the technology.

The source of the anti-whitefly-protein is an edible fern of ethno-botanical importance. Critical biosaftey studies were made and established that the protein is safe to mammals. It is digested easily in the stomach and do not harm the tested animals. It does not contain any allergenic property. It is also non-toxic to beneficial insects.

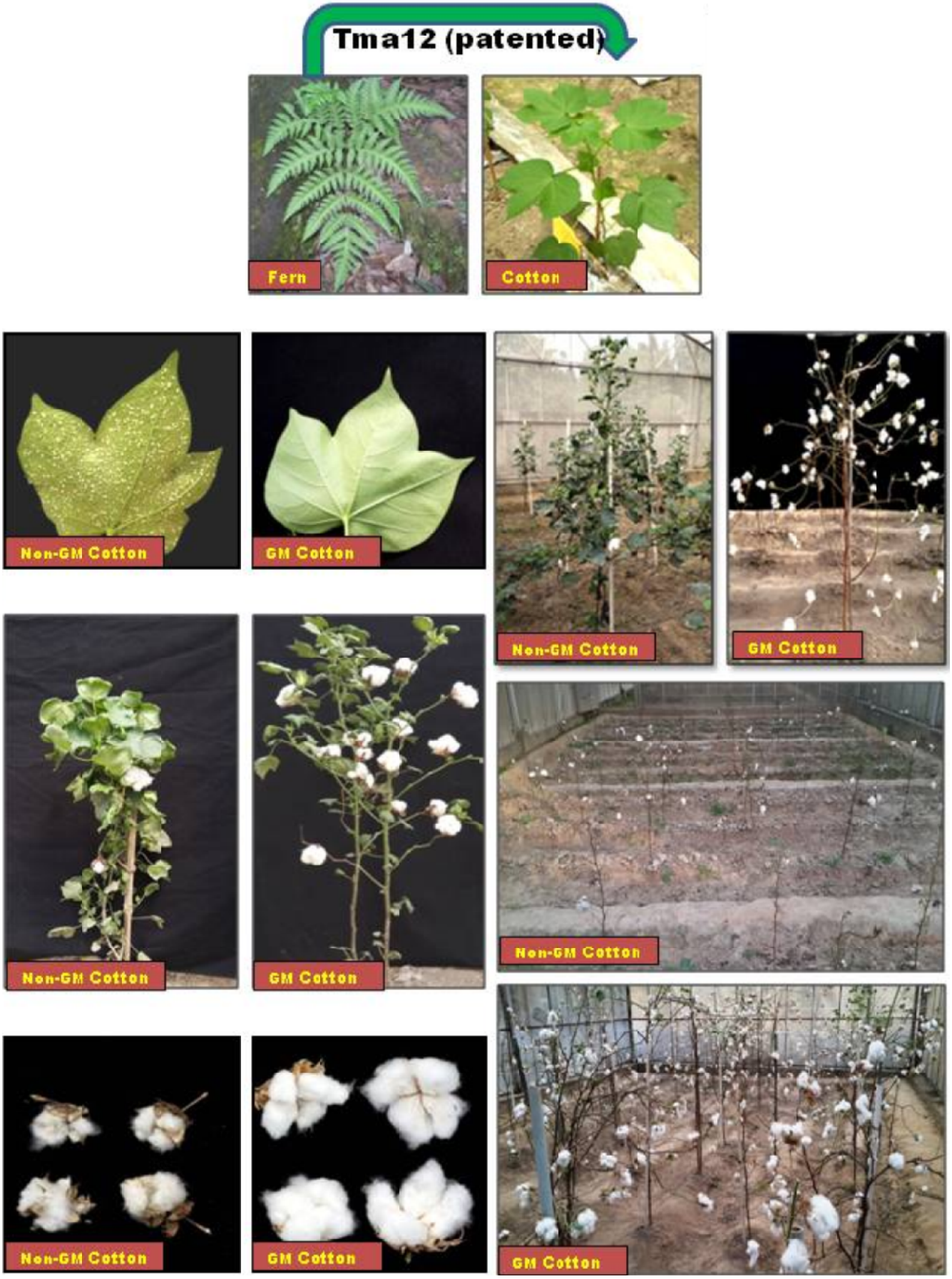


Fig. 4. Schematic presentation of development of whitefly resistant GM cotton

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

Nodal Scientist: N Singh

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

Technical Staff: S Jamil, Anil Kumar, KK Rawat

Objectives:

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

Highlights

A traditional medicinal plant - rich source of germacrone

Metabolite profiling of a traditional medicinal plant species (NBRI-CHT1) through GC-MS resulted in identifying germacrone as one of the major metabolites of chloroform extract. The anti-cancer and anti-tumor properties of germacrone are reported in traditional medicine. The percent peak area of germacrone in the chloroform extract was 23% of the total crude extract. Germacrone was isolated and purified from plant using column chromatography. Purified fraction of germacrone was analysed by GC-MS and analytical HPLC (Figs. 1 & 2). Structure determination and characterization of germacrone by NMR spectroscopy is under progress.

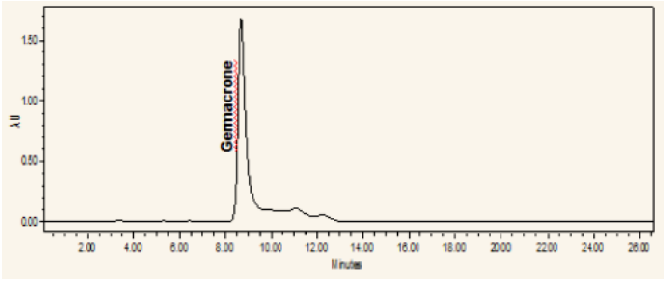


Fig. 2. HPLC Chromatogram of purified fraction of Germacrone

Ten different accessions of NBRI-CHT plants were investigated for variability in their germacrone content. The germacrone content varied from 44 µg g-1 to 186 µg g-1 dried latex, the lowest being in NBRI-CHT173 and highest in NBRI-CHT113 (Fig 3). HPLC analysis of germacrone content of 10 more accessions is under progress.

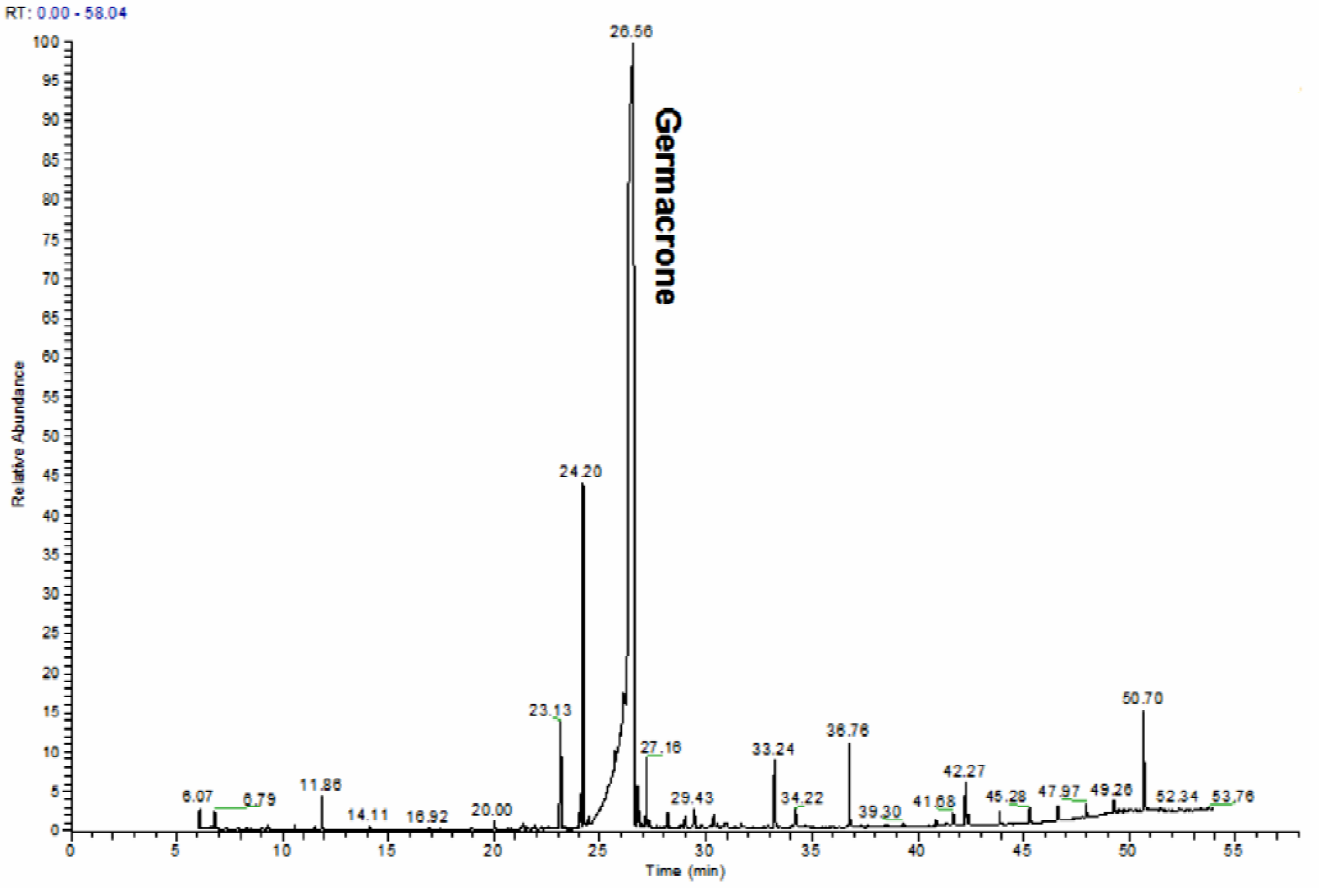


Fig. 1. GC-MS Chromatogram of purified fraction of Germacrone

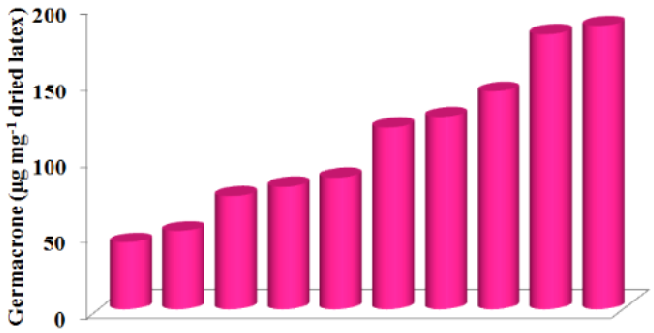


Fig. 3. Variations in germacrone content among different accessions of NBRI-CHT plants

Altitudinal adaptation in *Arabidopsis thaliana*

Identified genome-wide patterns of nucleotide variations in the coding regions of four natural *Arabidopsis thaliana* populations (Deh, Mun, San, Chi). These populations originated from 700 m to 3400 m a.m.s.l. in the Western Himalaya. Local and global level population-specific SNPs were identified. The biological functions of the SNP-containing genes were primarily related to the high light intensity prevalent at high-altitude regions. A total of 340258 SNPs were identified in the four populations. 11.21% of these were of synonymous, and 7.38% were non-synonymous amino acid variants. The various patterns of SNPs were consistent in each population. There was a significant decrease in the SNP density in populations with the increase in altitude (Pearson's r = 0.82, p<0.001). The Transition/ Transversion ratio (1.37) was consistent among all the four populations. In all the populations a large proportion (83%) of the amino acid changes was of the non-deleterious type and only 14.7-15.7% were of the deleterious type. The rest of amino acid changes did not fall in either of the categories. In the non-deleterious category, the percentage of known changes varied from 83.6% (Mun) to 95% in (Chi) whereas, in the deleterious category, the known changes varied from 59.8% (Mun) to 83.5% (Chi). It was notable that in all the populations, the percentage of the known changes was higher in the non-deleterious category as compared to that of the deleterious category (Fig. 4).

There were 8188, 8237, 8245 and 6271 genes containing non-deleterious but non-synonymous SNPs in Deh, Mun, San and Chi populations, respectively. Amongst these, 5016 genes were common in all the four populations. There was no difference in the enriched GO-terms (biological processes) among the four populations. Deh, Mun, San and Chi had 300, 558, 219 and 212 local-level population-specific SNP-containing genes, respectively. The GO-term enrichment analysis with local population-specific SNP-containing genes resulted in a variety of GO-terms (biological process) enriched in the four populations (Fig.5). The Mun and Chi populations showed a significant enrichment of genes related to stress responses. In Mun 85 genes (15.2%) were abiotic stress responsive, out of which 50 (58.8%) were light/radiation responsive. In Chi 'pigment metabolic process' (14 genes) and 'glucosinolate metabolic process' (9 genes) were found to be significantly enriched GO-terms that could be related to the known abiotic stresses prevailing at high altitudes. Deh showed no GO-term enrichment and San showed no stress responsive GO-term. In San 'catabolic process' was the only significantly enriched GO-term, which included two genes related to protection against high light intensity stress *viz*. FAR-RED ELONGATED HYPOCOTYLS 3 (FHY3) and ULTRAVIOLET HYPERSENSITIVE 1 (UVH1). The local-level population-specific SNP-containing genes of the combined dataset of San and Chi did not show any significant enrichment in abiotic stress related categories.

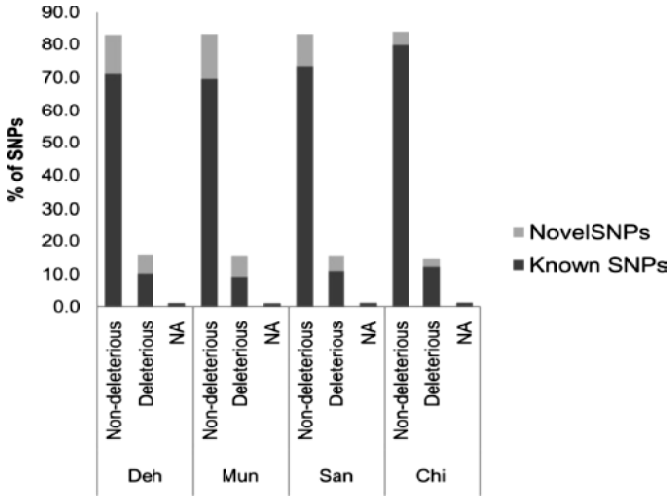


Fig. 4. Percentage of the non-deleterious and deleterious SNPs (including known and novel) in the four populations. NA indicates the SNPs which did not fall in either of the two categories.

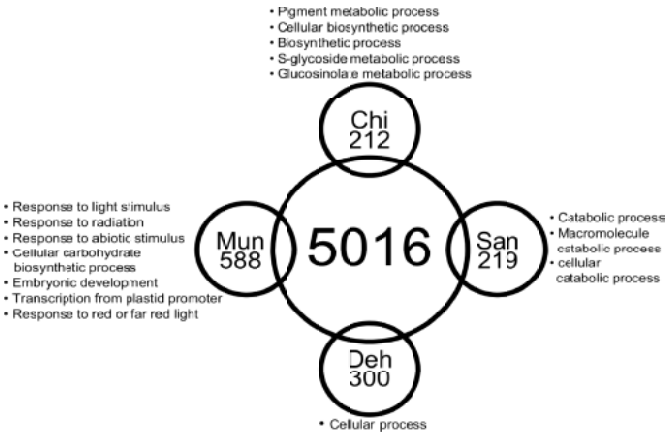


Fig. 5. The GO-term enrichment analysis with local population-specific SNP-containing genes resulted in a variety of GO-terms (biological process) enriched in the four populations.

Physiological Performance in *Cyamopsis tetragonoloba* (Guar) Under Drought Stress

Three varieties (RGC-1002, RGC-1066 and RGC-936) of *Cyamopsis tetragonoloba* were grown in pots in growth chamber. The temperature variation was maintained between 25-32 °C and relative humidity was in the range of 40-60%. The light intensity i.e. photosynthetic photon flux density increased gradually from 6:00 to 12:00 h which ranged from (50–1300 ìmol $m^{-2} s^{-1}$) and then decreased till 6:00 pm to maintain light and dark cycle for the plants. Forty days old plants were subjected to drought by withdrawal of water. The drought continued for eight days and then were re-watered. The leaf optical properties along with different pigments were studied. The reflectance in the control and drought stressed leaves was monitored with Spectroradiometer (400-1100 nm). Leaf optical properties showed major changes in visible and near infrared region of the spectra under drought stress. Reflectance and absorbance increased in the visible range of spectra under drought in all three guar varieties (Fig. 6). Normalized Difference Vegetation Index (NDVI), $NDVI_{705}$, which is an estimate of the photosynthetically absorbed radiation over the leaf surface, while $mNDVI_{705}$ is the Modified Red Edge Normalized Difference Vegetation Index. All varieties showed increase in $NDVI_{705}$ and $mNDVI_{705}$ under drought stress. Reflectance at 696, 727, 731 and 770 nm reflects the pigmentation of the leaf (Fig. 7). All these indices decreased in all three guar varieties under water stress condition. Carotenoid Reflectance Index (CRI) is sensitive to carotenoid pigments of plant foliage (Fig. 8). Higher CRI values mean greater caratenoid concentration relative to chlorophyll. CRI decreased in all three varieties under drought. Anthocyanin Reflectance Index (ARI) is a reflectance measurement that is sensitive to anthocynanins in plant foliage (Fig. 9). Increase in ARI indicates canopy changes in foliage. ARI increased in all three varieties under drought. RGC-1002 was most drought tolerant variety. Although reduction in photochemical quantum yield was maximum but enhancement in non photochemical quenching was also higher. Thus dissipation of light energy in the form of heat is highest in RGC-1002 variety and this phenomenon also protects the leaf from the photo inhibition under drought stress condition.

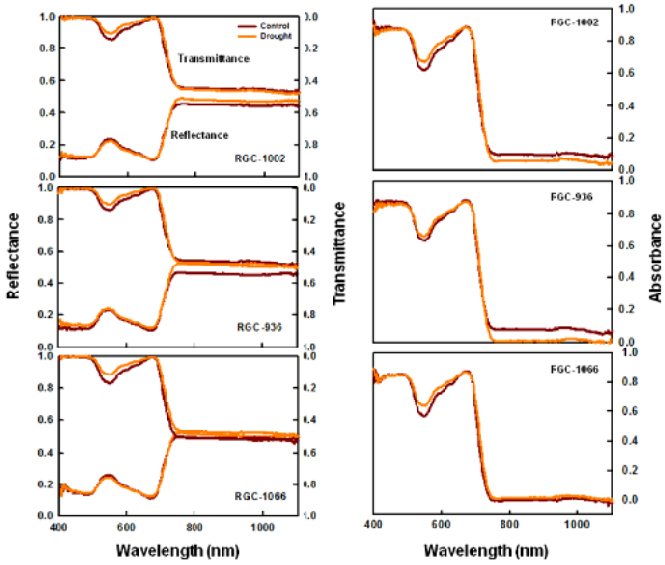


Fig. 6. The optical properties of Reflectance, Transmittance and Absorbance in the leaves of three varieties (RGC-1002, RGC-1066 and RGC-936) of *Cyamopsis tetragonoloba* under control and drought conditions.

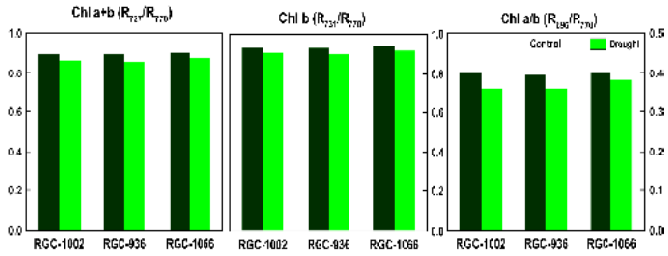


Fig. 7. The leaf Pigment Indices calculated from the values of reflectance at 696, 727, 731 and 770 nm in the leaves of three varieties (RGC-1002, RGC-1066 and RGC-936) of *Cyamopsis tetragonoloba* under control and drought conditions.

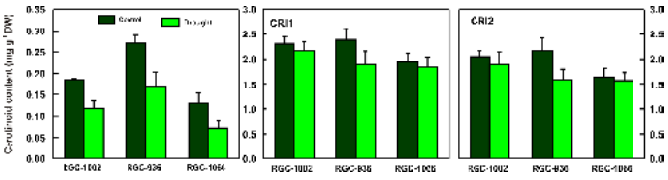


Fig. 8. Carotenoid pigment content and the Carotenoid Reflectance Index (CRI) 1 and 2 in the leaves of three varieties (RGC-1002, RGC-1066 and RGC-936) of Cyamopsis tetragonoloba under control and drought conditions.

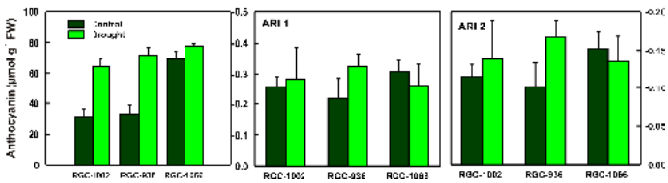


Fig. 9. Anthocyanin pigment content and the Anthocyanin Reflectance Index (CRI) 1 and 2 in the leaves of three varieties (RGC-1002, RGC-1066 and RGC-936) of Cyamopsis tetragonoloba under control and drought conditions.

Proteomics Study of Guar

Out of 50 differentially expressed proteins, 23 were upregulated and 27 downregulated in Guar RGC 1066 variety under elevated CO_2 and 30 were identified through Mass Spectrometry (Maldi-TOF-TOF). In RGC 1002 variety, out of 32 differentially expressed proteins, 19 were upregulated and 13 downregulated under elevated CO_2. The functional categorization revealed that the positive influence on electron transport and energy metabolism was more pronounced in Guar 1066 than Guar 1002 (Fig. 10).

The increased carbon gain and energy production can be predicted to increase polysaccharide galactomannan (guar gum) in endosperm through increased availability of carbon skeleton and energy. The shift of carbon pool was also correlated to the decreased amino acid metabolism and flavonoid biosynthesis. Guar 1066 shifted the cell metabolism and energy more towards carbon gain for gum production.

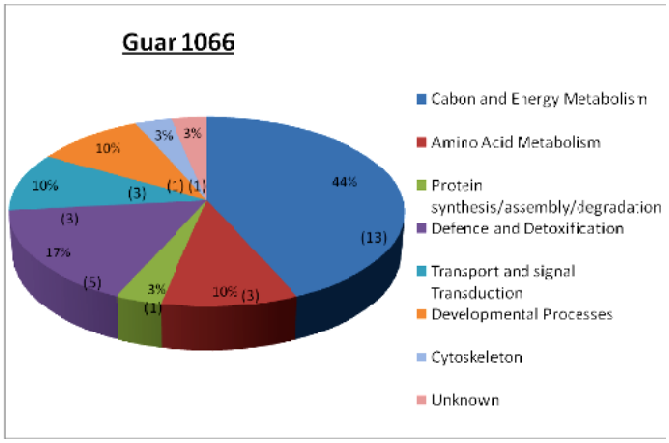


Fig. 10. Functional categorization of proteins in two varieties of Guar.

LAI measurement at Katerniaghat Wildlife Sanctuary, Uttar Pradesh

LAI with LAI-2000 PCA in post monsoon season in three plant functional types (PFTs) (dry miscellaneous, sal mixed and teak plantations) at Katerniaghat WLS were measured during October 2015. Ground LAI values ranged between 2.38 - 6.88, 1.47 - 7.32 and 2.02 - 5.49 with 180^0 view angles in dry miscellaneous, sal mixed forests and teak plantations during post monsoon season, respectively. Dry miscellaneous PFT showed lower LAI_{max} values compared to Sal PFT stands in post monsoon stage due to canopy gaps in the top storey layer. Although, dry miscellaneous forests show high tree density, but the top storey does not form a continuous canopy. One way ANOVA analysis among PFTs showed significant difference ($P<0.0001$) among LAI value in 2015 for post monsoon seasons. This clearly indicates that all 3 PFTs are having distinct LAI representations based on different tree species composition, stem density and different vertical stratification and canopy structure (Fig. 11).

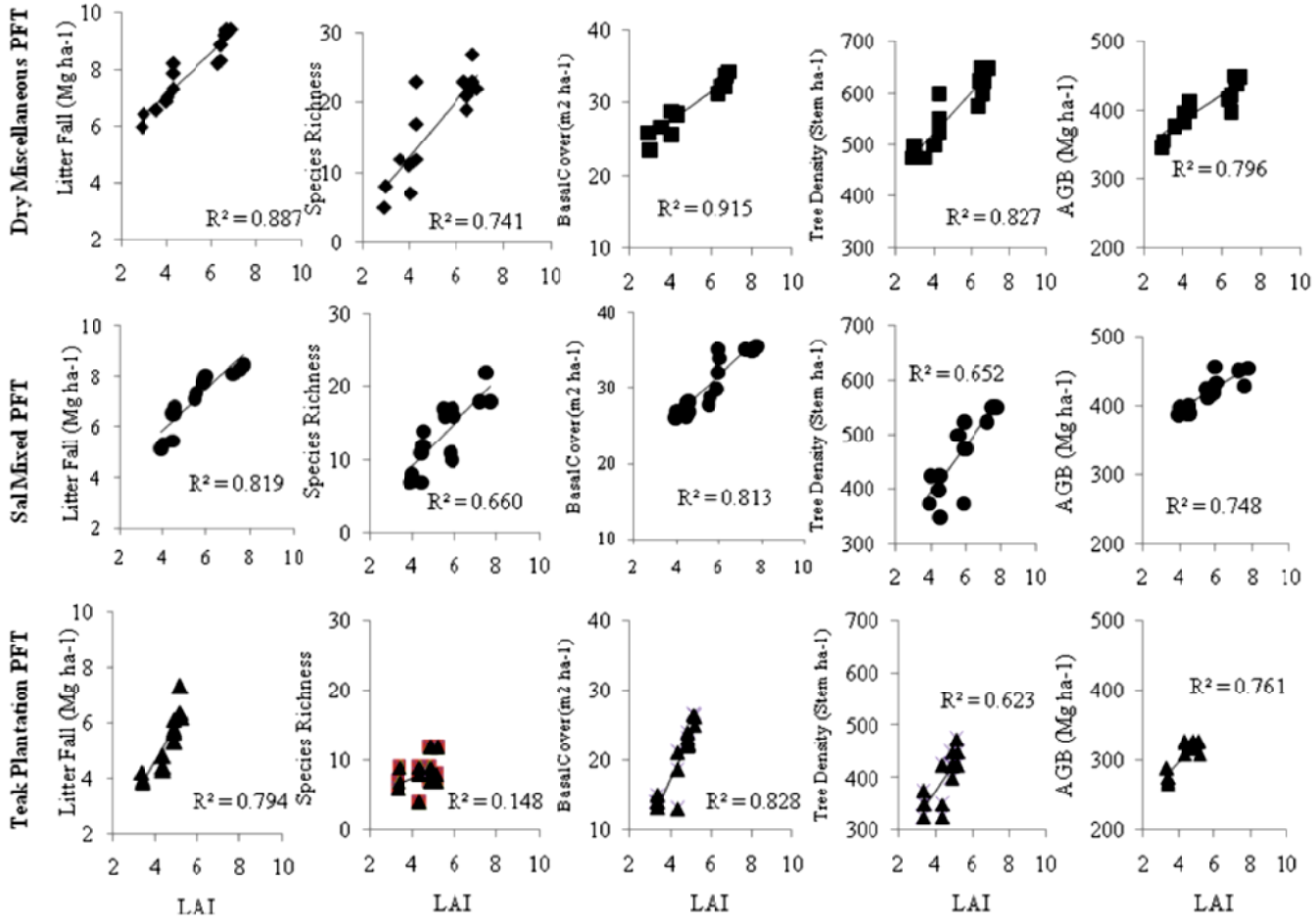


Fig. 11. Scatter analysis between the Indirect LAI against the litter fall, species richness, tree basal cover, tree density and AGB among the three PFTs.

Above-ground biomass and carbon estimates of *Shorea robusta* and *Tectona grandis* forests using QuadPOL ALOS PALSAR data

The above ground biomass (AGB) of two major forest types, i.e., *S. robusta* (Sal forest) and *T. grandis* (Teak plantations) were calculated based on ground inventory, and further estimated using SAR-imagery derived information through water cloud model. We investigated the potential use of a one time, QuadPOL ALOS PALSAR L-band 25 m data to estimate above-ground biomass (AGB) using a water cloud model (WCM) in Kateniaghat WLS. A significant correlation was obtained between the SAR-derived backscatter coefficient (r) and the field measured AGB, with the maximum coefficient of determination for cross-polarized (HV) for Sal, and the weakest correlation was observed with co-polarized (HH) for Teak forests (Fig. 12). Field-measured biomass of Sal and Teak forests were estimated to 444.7 ± 170.4 Mg/ha and 451 ± 179.4 Mg/ha, respectively. The mean biomass values estimated using the WCM varied between 562 and 660 Mg/ha for *S. robusta*; between 590 and 710 Mg/ha for *T. grandis* using various polarized data. Our results highlighted the efficacy of one time, fully polarized PALSAR data for biomass and carbon estimate in a dense forest. The regression analysis revealed a very significant positive polynomial correlation between all forms of polarized backscatter and the biomass values of *S. robusta* and *T. grandis*. HH polarized backscatter was much less correlated with the biomass of *T. grandis*.

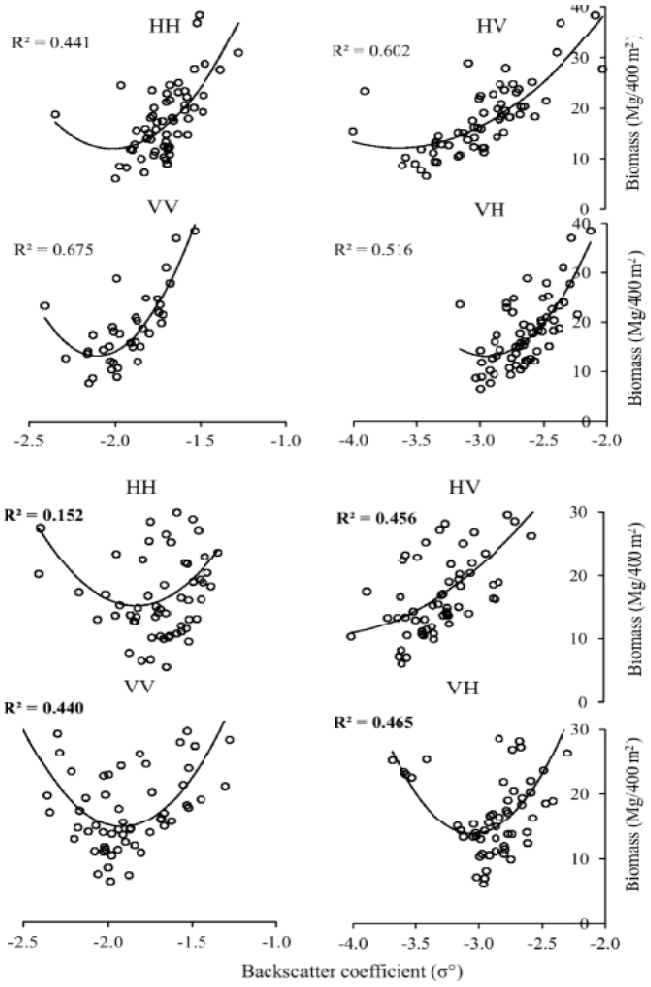


Fig. 12. Correlations with PALSAR co-polarised and cross-polarized backscatter co-efficient vs AGB for (a) *Shorea robusta* (b) *Tectona grandis*.

Reproductive biology of *Mallotus philippensis* in different niche environments

Reproductive status of male and female plants, regeneration potential and biotic threat to yield of *Mallotus philippensis* was assessed in different forest communities of Kateniaghat Wildlife Sanctuary. Maximum number of flowering and non-flowering (vegetative) plants were screened out from Dry miscellaneous and Teak plantation, respectively. Though all the three forest communities are male plant dominated, highest number (4 ♂ : 1 ♀) of male plants were observed in Dry Miscellaneous Forest. Maximum male and female flowering units / inflorescence were recorded from Dry Miscellaneous Forest and Sal forest, respectively. Highest and lowest fruit set / inflorescence were recorded from Dry Miscellaneous Forest and Teak plantation, respectively. *Mallotus phillipensis* had a very short seed viability duration i.e. up to 2 months (from seed harvesting) at room temperature (28±2°C – 40±2°C). However, seed storage at 4°C had increased viability duration up to 4 to 5 months with gradual decline in the viability potential. Seed germination potential of *Mallotus phillipensis* was very poor even within seed viability duration. It was due to seed coat imposed dormancy and high microbial infections as seeds are very prone to various types of such infections. Field observations on different forest types of KWLS showed a strong reliability of *Mallotus phillipensis* towards vegetative regeneration as the plant was found an efficient ramet producer through root suckers.

Mallotus philippensis is observed as the host plant of three main insect predators identified as *Physopelta schlanbuschii*, *Physopelta gutta* and *Cantao ocellatus* (Fig. 13). The life cycle of predators synchronized with fruiting period and caused quantitative and qualitative damage to fruits and seeds.

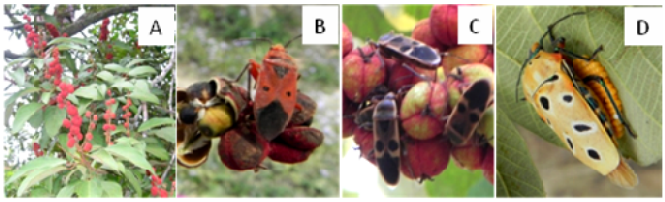


Fig. 13. Insect-fruit predators on *Mallotus philippensis* (A). *Physopelta schlanbuschii* (B) *Physopelta gutta* (C) and *Cantao ocellatus* (D)

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

Nodal Scientist: R.K. Roy

Scientists: PS Chauhan, RS Katiyar, RC Nainwal, TS Rana, D Singh, PC Singh, SK Tewari

Objectives:

- Characterization and development of improved varieties of *Canna, Gladiolus* and other bulbous crops.
- Evaluation of *Bixa* & *Curcuma* germplasm collection for plant improvement.
- Evaluation of Damask Rose for the sodic soils.
- Performance and evaluation of elite plant material and/or cultivars through multi-locational coordinated trials.
- Evaluation of performance of biofertilizers and biopesticides on plants.

Selection and characterization of diversity within mandate plants: *Canna*, Gladiolus and other bulbous crops.

Experiments on Canna Varieties

To develop new varieties of Canna, the rhizomes of Golden Girl and Red President varieties were treated with gamma radiation (10, 15 , 20 Gy) and planted in the field. Out of the treated plants of the two varieties, new mutants were detected and isolated (Fig. 1). The mutant showed stability with respect to change of flower colour and combination. The morphological characters were documented and the description is given below:

New Mutant -1:

Vegetative characteristics:

Plant height 120-130 cm, stem colour green (Yellow-green 146 C, Fan 3), leaf size 51.6 x 20.3 cm, non-variegated, leaf colour Green group 137-B, Fan 3.

Floral characteristics:

Length of inflorescence 55-65 cm, 10-15 no. of flower per inflorescence, flower size 13.9 x 10.5 cm, staminode Yellow (Yellow group 7-A Fan-1), have a blotches with red (Red 40 B Fan-1); staminode shape ovate, staminode size 9.3 x 7.1.

New Mutant -2:

Vegetative characteristics:

Plant height 120-135 cm, stem colour green (Yellow-green 144 A, Fan 3), leaf size 47.1 x 18.0 cm, non variegated, leaf colour Green group 137-B, Fan 3.

Floral characteristics:

Length of inflorescence 59-65 cm, 15-20 no. of flower per inflorescence, flower size 11.5 x 13.4 cm, staminode in two colours i.e. Yellow (Yellow group 5-A Fan-1) and red (Orange-red 34 A, Fan-1), blotches with red (Orange-red 34 A Fan-1); staminode shape ovate, staminode size 9.3 x 7.1.

Fig. 1. Two new Canna mutant varieties developed by gamma radiation from Golden Girl and Red President

Molecular Characterization of Gladiolus

Nucleotide diversity of PsbA-trnH Intergenic spacer region of chloroplast

The chloroplast sequences of 86 accessions were aligned using Clustal W program in MEGA6 software. The aligned cpDNA sequences of psbA-trnH region within *Gladiolus* cultivar varied from 556 bp to 583 bp with an average length of 579 bp. The average frequencies of Adenine (A) and thymine (T) were 30.3% and 33.4%, respectively, showing 63.7% mean A+T contents. Similarly, the average frequencies of Guanine (G) and Cytosine (C) were 18.3% and 17.9%, respectively, showing 36.2% mean G+C contents throughout the entire psbA-trnH sequences. The nucleotide pair frequencies like identical pairs (ii), transitional pairs (si), transversional pairs (sv) of psbA-trnH sequences were also calculated among the *Gladiolus* cultivars (Table 1). The average base substitutions recorded in *Gladiolus* cultivars was 8 (*i.e.*, si=3, sv=5). The basic statistics such as conserved sites, variable sites, parsimony informative sites and singleton sites were calculated after the complete deletion of the missing/gap sites from all the sequences. The aligned psbA-trnH sequences (including psbA gene and psbA-trnH intergenic spacer) formed a matrix of 583 nucleotide sites (after the deletion of missing/gap sites), of which 525 sites were conserved, 58 sites were variables, 37 sites were parsimony informative and 21 sites were singleton in *Gladiolus* cultivars. High level of

nucleotide diversity was found in *Gladiolus* cultivars with an estimated haplotype diversity (Hd) level of 0.65, and nucleotide diversity of 4.2×10^{-3} (π).

Nucleotide diversity of trnL-trnF Intergenic spacer region of chloroplast

The aligned cpDNA sequences of trnL-trnF region within 86 accessions ranged from 671bp to 678 bp with an average length of 672 bp. The average frequencies of Adenine (A) and Thymine (T) were 36.2% and 29.1% respectively, which showed 65.3% mean A+T contents in 672 bases average length of trnL-trnF sequences. Similarly, the average frequencies of Guanine (G) and Cytosine (C) were 18.5% and 16.2%, respectively, showing 34.7% mean G+C contents throughout the entire trnL-trnF sequences. The average base substitutions recorded in *Gladiolus* cultivars was 1 (*i.e.*, si = 1, sv = 0).The aligned trnL-trnF sequences (including trnL gene and trnL-trnF intergenic spacer) formed a matrix of 680 nucleotide sites, of which 669 sites were conserved, 6 sites were variables, 5 sites were parsimony informative and 1 singleton site in *Gladiolus* cultivars. The estimated haplotype diversity (Hd) in *Gladiolus* cultivars was 0.77, and the nucleotide diversity was estimated as 1.78×10^{-3} (π).

Table 1. Showing the nucleotide diversity as revealed by intergenic spacers (psbA-trnH and trnL-trnF) regions of cpDNA.

S. No.	Parameters	psbA-trnH	trnL-trnF
1.	Total length (bp)	583	678
2.	Length range (bp)	556 - 583	671-678
3.	Haplotype (H)	17	10
4.	Haplotype gene diversity (Hd)	0.65	0.77
5.	Nucleotide diversity {π (10^{-3})}	4.2	1.78
6.	Nucleotide frequencies of Adenine (%)	30.3	36.2
7.	Nucleotide frequencies of Thymine (%)	33.4	29.1
8.	Nucleotide frequencies of Cytosine (%)	17.9	16.2
9.	Nucleotide frequencies of Guanine (%)	18.3	18.5
10.	No. of conserved sites (%)	90.1	98.4
11.	No. of variable sites (%)	9.9	0.9
12.	No. of Informative sites (%)	6.3	0.7
13.	No of Singleton sites (%)	3.6	0.1
14.	Identical pairs (ii)	566	670
15.	Transitionsal pairs (si)	3	1
16	Transversional pairs (sv)	5	0

Experiment on other Bulbous Plants

For developing variability with regard to leaf variegation and improving starch content for high value food, two field trials were conducted. The crop identified for this purpose was *Colocasia esculenta*. In the first experiment, *Colocasia* tubers were treated with gamma radiation (0, 1.0, 1.5, 2.0 Gy) and planted in beds. In second experiment, higher dose of gamma rays (2.5, 3.0, 3.5, 4.0 & 4.5) were applied to the tubers.

As no somatic mutation yielded, the above experiments were repeated. However, no somatic mutation occurred and no changes in morphological characters in terms of plant height, growth habit and rhizome production was observed.

Another bulbous plant (*Hemerocallis* sp.) was treated with gamma radiation (10, 15, 20 Gy.) for creating somatic mutation as well as change of flower colour. Rhizomes (25 nos.) were treated and planted in the bed for growth and flowering. The treated plant showed some germination initially up to 30 days but subsequently died. The experiments will be repeated.

Experiment on Gladiolus varieties

To develop new varieties in Gladiolus, the cormlets were treated with Gamma radiation (0, 3.0, 5.0, 7.0 Gy) and planted in beds.

Very poor performance was observed of the formation of daughter corms from cormlets. The doses of radiation was detrimental to the growth and development of the cormlets into corms.

New Collection

Two new varieties of Gladiolus added in the germplasm collection (Fig. 2).

'Bangalore Beauty'

Vegetative Characteristics:

Plant height 60-70 cm, leaf size 63 x 2.2 cm, leaf colour Yellow-green 146 A, Fan 3.

Floral Characteristics:

Spike length 72 cm long, 14 florets per spike, flower size 10.7 x 10.5 cm, flower colour creamy (Red 36 C, Fan 1) and red blotches (Red group 38 B, Fan 1).

'Punjab Elegance'

Vegetative Characteristics:

Plant height 50-60 cm, leaf size 48 x 3.1, leaf colour Yellow-green 146 B, Fan 3.

Floral Characteristics:

- Spike length 45 cm long, 10 florets per spike, flower size 9.8 x 9.5 cm, flower colour yellowish-orange (Yellow-orange 18 C, Fan-1) and red (Red group 37 B, Fan 1).

Bangalore Beauty Punjab Elegance

Fig. 2. Two new varieties of Gladiolus added to the germplasm collection of CSIR-NBRI

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

Turmeric (*Curcuma longa* L.)

The field evaluation of 34 turmeric accessions under sodic waste land condition of Indo-Gangetic plains for late senescing and early sprouting, shade loving, disease free germplasm was continued in the year 2015-16. The accessions are yet to be harvested for the repeat yield estimates and quality evaluations.

Response of PSB (Phosphorus Solubilising Bacteria) for facilitating phosphorus uptake of turmeric under partially reclaimed sodic soil condition with normal (8-9 months) and prolonged harvesting (18-20 months) cycles is being studied. One set harvested at 9th month, showed positive response to phosphorus application and PSB treatment. For standardization of protocols for organic seed production of turmeric in Uttar Pradesh, two field experiments have been initiated in the current season.

Domestication of an introduced cultivar NBH-22 from north east part of India, through diverse agro techniques under various growing conditions was tried (Fig. 3). The collection failed to grow satisfactorily in sodic soil conditions.

Turmeric productivity enhancement demonstrations in Meghalaya

Experiment Site	Laitmynsaw BRDC farm	**Altitude**	1714 m
Latitude	25°32′28.67″ N	**Longitude**	91°49′19.12″E
The application of PSB as seed treatment enhanced the germination rate of the crop as well as increased the rhizome yield by 54 %.			
Experiment Site	Ri Kanaan West Jaintia Hills District, Meghalaya	**Altitude**	963 m
Latitude	25°32′721″ N	**Longitude**	92°32′086″ E
Three varieties of turmeric Lakadong, Ladaw and Lashein were grown. The fastest rate of emergence was observed in Lashein + NADEP + PSB treated plots. Increase in plant height was observed in treated plots when compared to control which may be due to high absorption of nutrients in PSB treated plots (Fig. 4).			
The PSB treated plant showed healthy and vigorous health whereas leaf spot, a major disease of turmeric was seen in the control plots only.			
Yields of all three varieties were significantly higher in PSB treated plots in comparison to other treatments. The average yield of treated plots (28.34 t/ha) was much higher than control plots (16.27 t/ha).			

Fig. 3. Turmeric productivity enhancement demonstrations in Meghalaya using Phosphorus Solubilising Bacteria (PSB)

Fig. 4. Three varieties of turmeric, Lakadong, Ladaw and Lashein in control plots (a-c): treated with, Lashein + NADEP + PSB (d-f).

Three turmeric varieties, Lakadong, Lashein and Ladaw were obtained from Meghalaya. These are high quality accessions with poor rhizome yield. The materials are being tested for pathogenecity, quality and multiplication.

Development and Release of Turmeric Variety

Fig. 5. New variety of turmeric "Kesari"

A new variety of *Curcuma longa* L., named as Kesari (Fig. 5) was released on 8th Feb. 2016 by HE Sri Ram Naik, Governor of U.P. This variety is having specialty of cold tolerance, remains green up to the last week of January with high yield potential (~35 t/ha fresh weight) even under partially reclaimed sodic soil. The variety is tolerant to foliar diseases and has shade tolerance, showing good prospects as inter-crop in orchards. Following are the details of new variety:

Late senescence: Tolerance to low temperature

Growing period: 230-240 days against approx. 200 days of other varieties

- High yield potential (>35 t/ha fresh rhizomes)
- Optimum quality - 1.16% Total curcuminoids

Quality of Rhizomes

Total carotenoid (mg g^{-1} FW)	0.41±0.04
Rhizome Moisture %	82.74±0.26
AOA (IC_{50} mg mL^{-1})	0.12
EC_{50} (mg/mg DPPH)	5.32
TPC (mg g^{-1})	14.62 ± 0.30

Leaf essential oil (0.61%)

Sixteen compounds identified. á-phellandrene (34.04%), p-cymene (17.31%) and p-Mentha-1,4(8) diene (17.26%) are major compounds (Fig. 6).

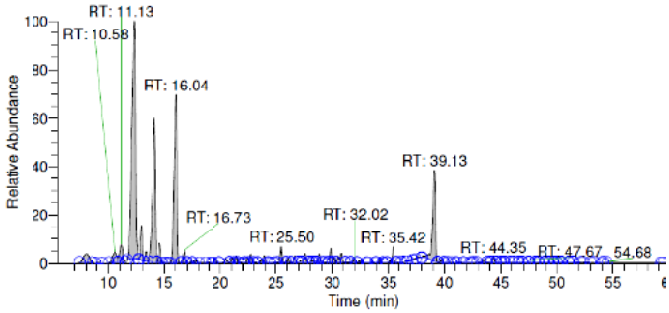


Fig. 6. GCMS chromatogram of leaf essential oil from the new turmeric variety, "Kesari"

Rhizome essential oil (1.92%)

Twentyone compounds identified. ar-tumerone (26.43%), â-tumerone (21.98%) and curlone (15.97%) are major constituents (Fig. 7).

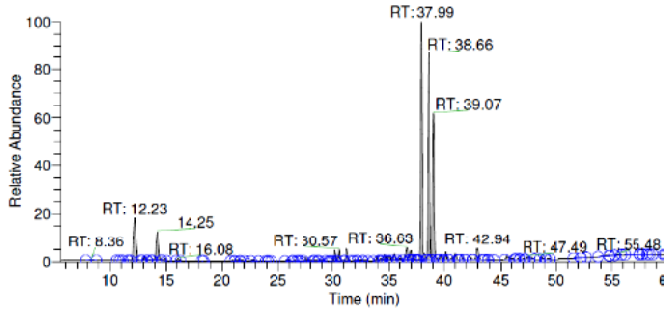


Fig. 7. GCMS chromatogram of rhizome essential oil from the new turmeric variety, "Kesari"

Genetic diversity assessment in *Curcuma* using SSR markers

Analyzed genetic variability in 29 accessions of *Curcuma* germplasm using SSR markers. A total of 13 SSR markers were considered which resulted into 70 DNA fragments, of which 68 (97.14%) were polymorphic in nature. The average polymorphic information content (PIC) was 0.42 and resolving power (RP) was in the range of 2.62-10.34. Average genetic distance was 0.86 across the 29 turmeric genotypes analyzed.

Number of effective alleles (Ne) were found maximum (1.94) in Cu02 and minimum value (1.64) in Cu08 with an average value of 1.79. Unbiased hetrozygosity (µHe) were higher (0.49 in Cu02; Cu07; Cu14) whereas Cu08 resulted in to a lower heterozygosity value, 0.35. The average heterogygosity value was, 0.42 across the different genotypes of *Curcum*a analyzed in the present study.

Evaluation of *Bixa* in sodic soils

Seventeen accessions of *Bixa* collected from different bio-geographical regions (Fig. 8) are being evaluated for growth, yield and quality at Banthra, having pH ranging from 8.7 to 9.2. The plants have shown variations in morphological characters (leaf shape, flower colour, capsule shape, size and colour etc.) yield (number of capsule per plant, number and weight of seeds per capsule) and quality (Bixin content). Based on morphological characterization, total collection has been arranged into seven groups.

Fig. 8. Accessions of *Bixa orellana* collected from different bio-geographical regions of India.

Evaluation of Damask Rose in Sodic Soils.

Damask Rose (*R. damascena*): Screening of the best suited variety in terms of growth and flowering among the collected varieties of Damask Rose (*Rosa damascena* and *Rosa centifolia*) in sodic soils was continued. Six accessions/ varieties of Damask Rose (NBRD-1, NBRD-2, NBRD-3, NBRD-4, NBRD-5 and NBRC-1) are being evaluated for growth, yield and quality at Gehru Research Centre of CSIR-NBRI, having high pH range (≈9.5).

An experiment is going on to find out the best suited variety out of 12 selected, for sodic soil along with integrated nutrient management approach including FYM and biofertilizers (PSB and *Trichoderma*).

Field Trails and Demonstrations on CSIR-NBRI Bio-inoculants in Meghalaya

S. No.	District	Village	Block	Crops
1	**North Garo Hills**	Balgito	Resubelpara	Chillies, Pumpkins, Beans, Tomatoes, Mustard, Cabbage.
2	**WJH**	Amlarem	Amlarem	Potatoes, Chillies, Pumpkins, Beans, Tomatoes, Maize, Mustard, Cabbage, Rice.
3		Laskein	Laskein	
4		Thadlaskein	Thadlaskein	
5	**Ri-Bhoi**	Jirang	Jirang	Ginger, Tomatoes, Chillies, Mustard, Maize, Beans, Rice, Pineapples.
6		Umsning	Umsning	
7		Umling	Umling	
8	**EJH**	Mutong	Khliehriat	Beans, Tomatoes, Maize, Mustard, Cabbage, Potatoes, Chillies, Pumpkins, Turmeric.
9		Saipung	Khliehriat	
10		Narwan	Khliehriat	
11	**SWKH**	Mawkyrwat	Mawkyrwat	Rice
12	**EKH**	Nongjrong	Mawkynrew	Orange
13		Mawklot	Mylliem	Cabbage, Cauliflower, Mustard, Peas, Radish, Carrot, Lettuce, Chillies, Beans, Turnip.
14		Laitmynsaw	Mylliem	
15		Nongkwai	Pynursla	Orange

WJH=West Jaintia Hills; EJH=East Jaintia Hills; SWKH=South West Khasi Hills; EKH= East Khasi Hills

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

Corms of four Gladiolus cvs. - 'Neelima', 'Roshani', 'Usha' and 'Amethyst' and rhizomes of Canna cultivars- 'Raktima' and 'Agnishikha' along with guidelines for *Gladiolus* and *Canna* cultivation were provided to CSIR-IHBT, Palampur and CSIR-IIIM, Jammu. Seeds of five accessions of *Bixa orellana* with experimental plan for their performance evaluation were also provided from NBRI.

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

Seeds of best five Bixa accessions, along with the technical details has been provided to CSIR-CIMAP, CSIR-IHBT and CSIR-NEIST for their multi-location trials.

Research work on Gladiolus under sodic soil

To utilize the sodic soil, an experiment is going on at Gehru research centre of CSIR-NBRI Lucknow, comprising three different nutritional management practices as main factor and twelve gladiolus varieties as sub factor for evaluating the growth and performance and screening of most promising gladiolus variety to cultivate under such type of degraded sodic land. During the investigation, it was observed that the field provided well rotten organic manure supplemented with treated corms of gladiolus with phosphorus solublizing bacteria (PSB) and *Trichoderma* showed significantly higher growth and flowering with more number of spikes bearing florets per plant. Among the varieties, Tiger flame and Big time supreme showed significantly better growth performance in terms of plant height at 90 DAS, spike lentgh and florets/spike, which is most desirable trait for economic point of view. However, significantly higher corm yield/plant was obtained from Big time supreme, due to significantly higher corm weight and corm per plant, indicating the ultimately better peroformance of Big time supreme, among the all varieties evaluated under sodic land condition.

Training Programs

To increase awareness and promote the use of biofertilizers, training programs and Kisan melas were organized and farmers were provided free samples of PSB and *Trichoderma* along with extension manual and technical guidance.

Multilocational Trials

CSIR-NBRI developed *PSB/Trichoderma* culture were provided to Bio Resources Development Centre, Shillong (Meghalaya) for testing and evaluation in Meghalaya on various crops

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

Nodal Scientist: RD Tripathi/ S Mallick

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

Technical Staff : S Dwivedi, B Kumari

Objectives:

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

Biodegradation of hydrocarbon (n-tetracosane) using identified bacteria

An experimental study was undertaken under the INDEPTH project to evaluate the degradation of high molecular weight alkane i.e. tetracosane using three petroleum hydrocarbon degrading bacterial strains. During biodegradation study of tetracosane (500 ppm) in minimal salt media in presence of the three bacterial strains i.e. *P. aeruginosa* (PSA5), *Cronobacter* sp. (PSM10) and *Rhodococcus* sp. (NJ2), it was observed that, 91% of the tetracosane was degraded by *P. aeruginosa* PSA5, 88% by *Cronobacter* sp. PSM10 and the least (85%) was recorded by *Rhodococcus* sp. NJ2, in comparison to only 6% degradation in the control i.e. linked to abiotic factors (Fig. 1). The results of degradation pattern clearly depicted that all the bacterial strains were potential degraders of tetracosane. The specific degradation rate calculated was found to be 9.19 day $^{-1}$ for *P. aeruginosa* PSA5, 8.93 day^{-1} for *Cronobacter* sp. PSM10 and 8.6 day^{-1} for *Rhodococcus* sp. NJ2, in a decreasing order. The least specific degradation rate was observed in control (0.6 day^{-1}) due to absence of bacterial strains.

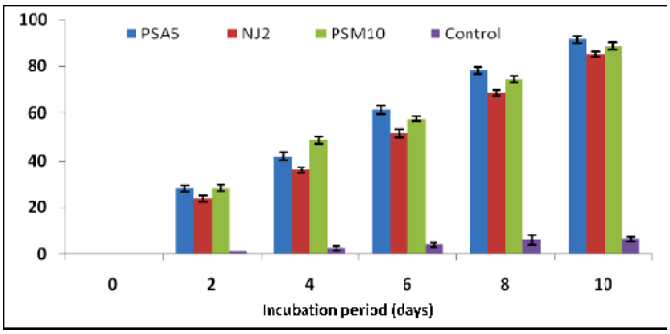


Fig. 1. Biodegradation of n-tetracosane by bacteria in MSM

The activities of four degradative enzymes, i.e., alkane hydroxylase, alcohol dehydrogenase, aldehyde dehydrogenase and lipase were monitored during the degradation of n-tetracosane metabolism. The specific activity of alkane hydroxylase was observed to be maximum in *Pseudomonas aeruginosa* (PSA5) and minimum in *Rhodococcus sp.* (NJ2). In case of *Pseudomonas aeruginosa* PSA5, the peak induction of alkane hydroxylase activity was recorded as high as 2539 µmol mg^{-1} protein, while in *Cronobacter* sp. (PSM10) and *Rhodococcus sp.* (NJ2), the maximum activity of this enzyme was recorded as 1838 and 1278 µmol mg^{-1} protein, respectively, after 8 days of incubation (Fig. 2a). Alcohol dehydrogenase activity was found invariably higher than alkane hydroxylase in all three bacterial strains *Pseudomonas aeruginosa* (PSA5), *Cronobacter* sp. (PSM10) and *Rhodococcus* sp. (NJ2), during tetracosane degradation. A maximum activity of alcohol dehydrogenase was attained by *Pseudomonas aeruginosa* PSA5 (4993µmol mg^{-1} protein), followed by *Cronobacter* sp. PSM10 (2730µmol mg-1 protein) and minimum was recorded in *Rhodococcus* sp. NJ2 (1515 µmol mg^{-1} protein) after 8 days of incubation period (Fig. 2b). Induction of aldehyde dehydrogenase was also observed in all the three bacteria during the tetracosane degradation. Among three degradative enzymes, aldehyde dehydrogenase was induced higher than alkane hydroxylase and alcohol dehydrogenase in these microbes. The maximum activities of aldehyde dehydrogenase i.e. 12922, 10161 and 5015 µmol mg^{-1} protein were recorded in *Pseudomonas aeruginosa* PSA5, *Cronobacter* sp. PSM10 and *Rhodococcus* sp. NJ2, respectively, after 8 days of incubation (Fig. 2c). During degradation of tetracosane, the highest lipase activity was observed in all three bacterial strains *Pseudomonas aeruginosa*, *Cronobacter* sp. and *Rhodococcus* sp. after 8 days of incubation and then declined. The maximum activity was attained by *Pseudomonas aeruginosa* (4684 µmol mg^{-1}

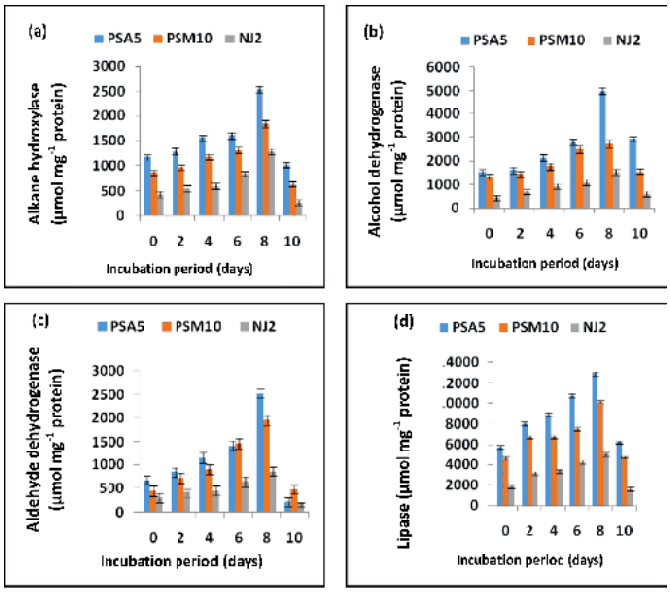


Fig. 2. Specific activities of alkane hydroxylase (a), alcohol dehydrogenase (b), aldehyde dehydrogenase (c) and lipase (d) during n-tetracosane metabolism by bacteria.

protein), followed by *Cronobacter* sp. PSM10 (3744 µmol mg^{-1} protein) and minimum activity (3615 µmol mg^{-1} protein) was found in *Rhodococcus* sp NJ2 (Fig. 2d).

Achieving low arsenic in grain rice by supplementing with sulphur and selenium

Arsenic (As) contamination in rice presents significant risk for the humans through dietary exposure. Sulphur (S) supplementation would lead to more chelation of As in roots through thiols, resulting in lesser As transport in shoot. Supplementation of S and Selenium (Se) may be an effective strategy for As tolerance and reducing As load in plants. Therefore, identification of biochemical and molecular mechanism for As tolerance during S and Se interaction would provide useful information leading to an improved understanding of As tolerance in plants.

Microbes for soil carbon sequestration through rice straw decomposition

Microbial formulation comprising of a combination of fungi and bacteria has been developed for faster decomposition of rice straw. The formulation has the ability to promote the plant growth of maize under pot trial conditions while the decomposed straw was mixed with soil. Experiments performed under field conditions exhibited better yield of wheat when the formulation was applied directly to the field where rice straw was amended (Fig. 3).

Soil control | Straw control | Urea control | Formulation control

Fig. 3. Effect of formulation on the growth of wheat plant under field conditions where rice straw was amended in field.

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

Nodal Scientist: V Pandey

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

Objectives:

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

In India, maize is the third most important food crop after rice and wheat. The response of maize, a C4 crop, to elevated CO_2 was studied. Two commonly grown maize varieties, PEHM 2 and SMH 3031 having similar growth condition, fertilizer requirement and maturation period were selected for the study. Among 6 FACE rings, 3 were used for ambient carbon dioxide (ca 400 ppm) and other 3 for carbon dioxide enrichment (ca 460 ppm). Each individual ring was divided in six subplots of 4.5m^{-2} areas. In randomize way each maize variety was sown in two plots per ring.

Both the selected varieties showed increased photosynthetic rate, decreased levels of stomatal conductance, respiration and transpiration under eCO_2 condition. Total plant biomass was found increased in both varieties in eCO_2 condition. SMH 3031 also showed less lipid peroxidation. Total glutathione content was found decreased in PEHM 2 while it was increased in SMH 3031 under eCO_2 condition. PEHM 2 showed increased while SMH 3031 showed decreased level of superoxide dismutase (SOD) in elevated carbon dioxide condition. Levels of catalase and APX were found to be decreased for both cultivars in elevated condition. Weight of 1000 grains was found increased in PEHM 2 and decreased SMH 3031 in elevated condition (Fig. 1). In eCO_2 condition harvest index for PEHM 2 was found decreased while it was increased for SMH 3031 cultivar (Fig. 1).

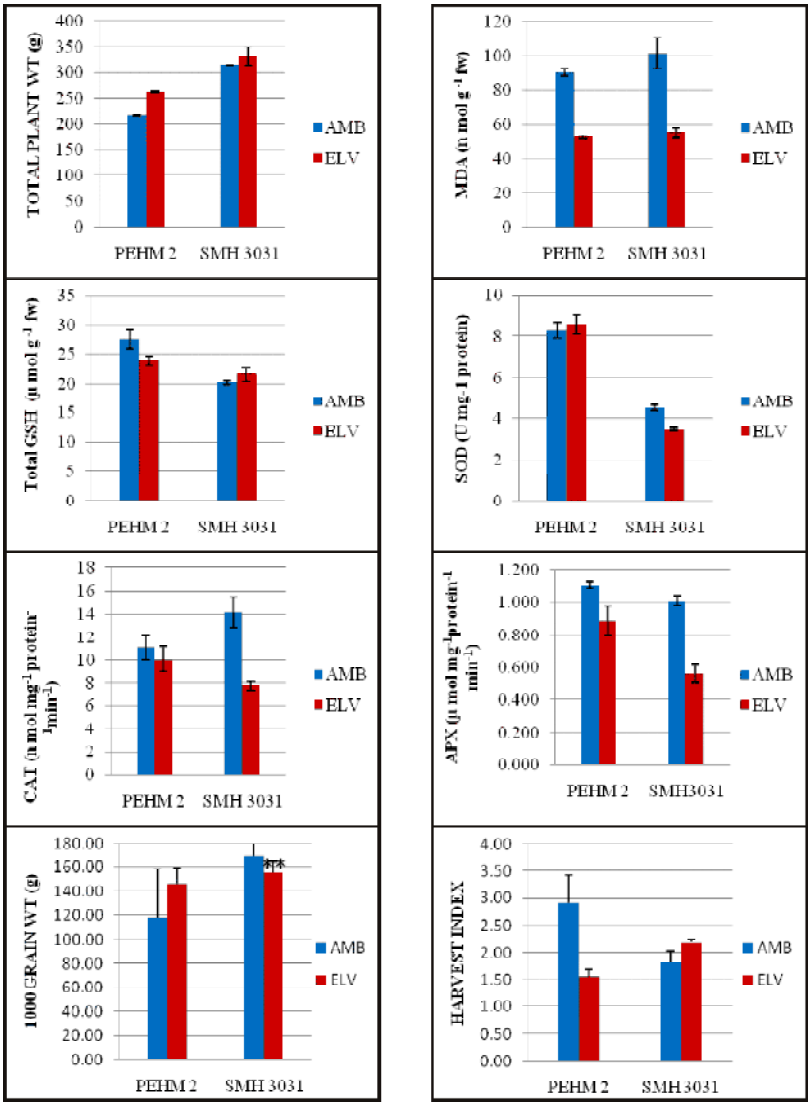


Fig. 1. Effect of elevated level of carbon dioxide on different parameters in two varieties of maize. Bars represents mean ± standard deviation (n = 5).

7. Plant-microbe and soil interactions (PMSI)

Nodal Scientist: CS Nautiyal

Scientists: PS Chauhan, M Kumar, Charu Lata, A Mishra, SK Raj

Objectives:

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

Highlights

Southern blight disease of tomato control by 1-aminocyclopropane-1-carboxylate (ACC) deaminase producing *Paenibacillus lentimorbus* B-3048

Tomato cultivation is highly susceptible for soil born diseases and among them southern blight disease caused by *Scelerotium rolfsii* is very common. For its management use of chemical fungicides is not very successful as their spores are able to survive for many years in the soil. As an alternative eco-friendly approach to control the disease antagonistic microbes are being characterized. Among them plant growth promoting rhizobacteria *Paenibacillus lentimorbus* B-30488 (B-30488) with antagonistic properties, multiple PGP attributes stress tolerance and ACC deaminase enzyme activity is characterized to decipher its mode of action against *S. rolfsii* under *in vitro* and *in vivo* conditions. *In vitro* results obtained from this study clearly demonstrate that B-30488 has ability to show antagonistic properties under different abiotic stresses against *S. rolfsii*. Similar results were also obtained from *in-vivo* experiments where B-30488 inoculation efficiently controlled the disease caused by *S. rolfsii* and improve the plant growth. Deleterious effect of enhanced ethylene levels in *S. rolfsii* infected plants was also ameliorated by inoculation of ACC deaminase producing B-30488 (Fig. 1). The ACC accumulation, ACO and ACS activities were also modulated in S. rolfsii infected plants. Results from defense enzymes and other biochemical attributes were also support the role of B-30488 inoculation in ameliorating the biotic stress caused by *S. rolfsii* in tomato plants. These results were further validated by pathogen related gene expression analysis by real time PCR. From the results of this study it may be concluded that ACC deaminase producing B-30488 has ability to control the southern blight disease caused by *S. rolfsii* and a commercial bioinoculant package may be developed.

Paenibacillus lentimorbus inoculation enhances tobacco growth and extenuates the virulence of Cucumber mosaic virus

This study investigated potential of B-30488 as a biocontrol agent against an economically important virus, Cucumber mosaic virus (CMV), in *Nicotiana tabacum* cv. White Burley. The study delineates the physical, biophysical, biochemical and molecular perturbations due to the trilateral interaction of PGPR-host-CMV. Soil inoculation of B-30488 enhanced the plant vigour and significantly decreased the CMV virulence and virus RNA accumulation by ~12 fold (91%) in systemic leaves of CMV infected tobacco plants as compared to the control ones. Histology of these leaves revealed improved healthy tissues and least aging signs in B-30488 inoculated tobacco plants, with or without CMV infection. B-30488 reduced intercellular spaces between collenchyma cells, reduced amount of xyloglucans and pectins in connecting primary cells, and increased polyphenol accumulation in hypodermis layer extending to collenchyma cells. B-30488 inoculation favourably manoeuvred the essential biophysical (ion leakage and photosynthetic efficiency) and biochemical (sugar, proline, chlorophyll, malondialdehyde, acid phosphatase and alkaline phosphatase) attributes of tobacco plants to positively regulate and release the virus stress. Moreover, activities of defense related enzymes (ascorbate peroxidase, guaiacol peroxidase, superoxide dismutase and catalase) induced due to CMV-infection were ameliorated with inoculation of B-30488, suggesting systemic induced resistance mediated protection against CMV in tobacco. The quantitative RT-PCR analyses of the genes related to normal plant development, stress and pathogenesis also corroborate well with the biochemical data and revealed the regulation (either up or down) of these genes in favor of plant to combat the CMV mediated stress (Fig. 2). These improvements led tobacco plant to produce more flowers and seeds with no negative impact on plant health.

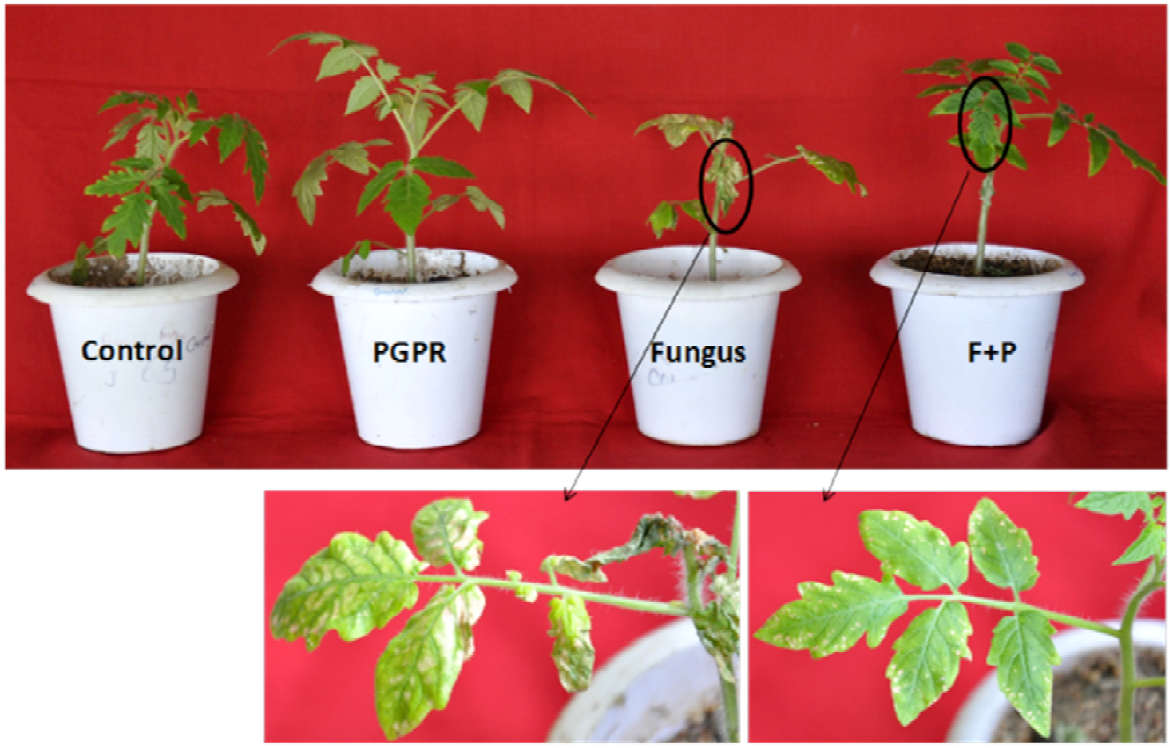


Fig. 1. *Paenibacillus lentimorbus* B-30488 inoculation enhances tomato growth promotion and biological control against *Sclerotium rolfsii*.

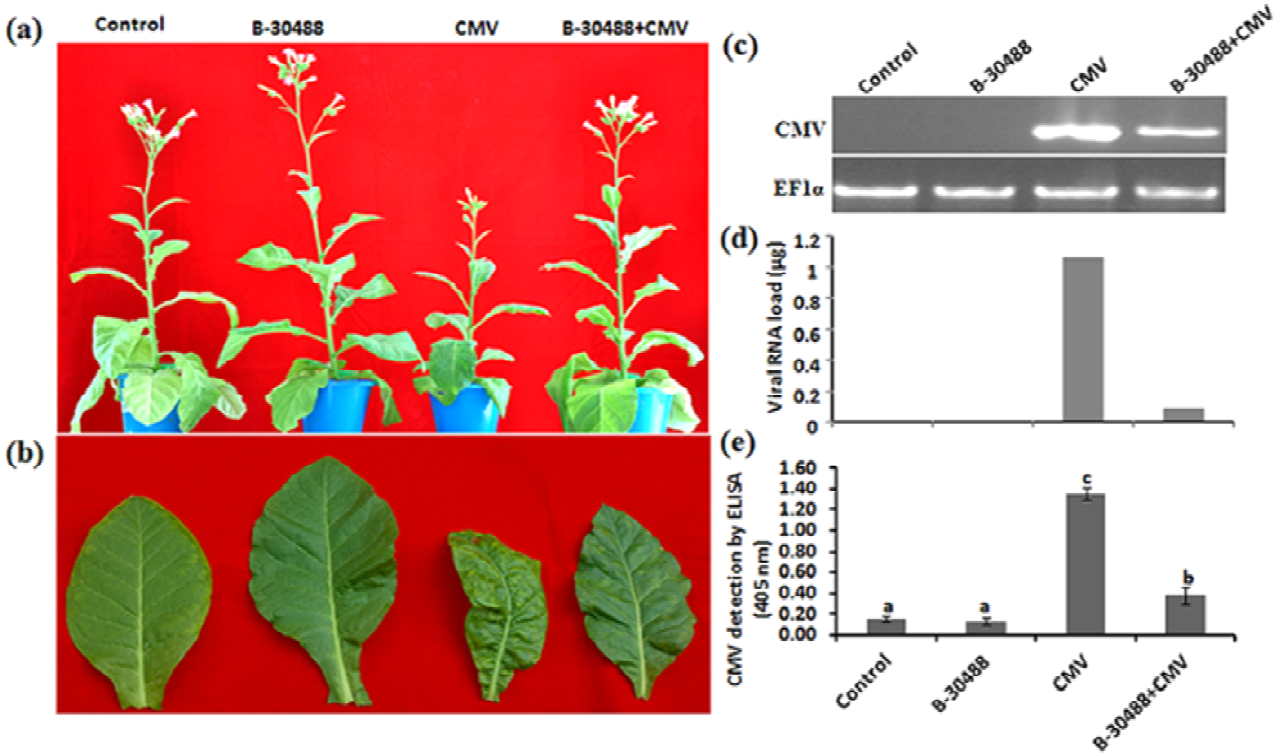


Fig. 2. PGPR promoted the tobacco health and reduced virus load. (a) *N. tabacum* cv. White Burley plants showing induced growth at 28 dpi in B-30488 treated plant with or without CMV infection as compared to healthy (control) and disease (CMV) plants. (b) A close view of 3rd tobacco leaf from top showing disease severity and chlorophyll differences. (c) Ethidium bromide stained agarose gel image showing high virus accumulation in leaf of CMV infected plant (CMV) as compared to B-30488 protected plant (B-30488+CMV). (d) Graphical representation of viral RNA load suggesting high CMV accumulation in infected tobacco (CMV) plant as compared to B-30488 protected plant (B-30488+CMV). Concentration of viral RNA was quantified by semi-quantitative PCR using CMV-coat protein (CP) gene specific internal primers and tobacco elongation factor 1alpha (EF1á) gene was used as an internal plant control. (e) Enzyme linked immunosorbent assay (ELISA) of upper leaves showing virus accumulation levels at 28 dpi. Plants were challenged with inoculum diluted ten times prepared from the leaves of tobacco infected with Cucumber mosaic virus (CMV)-A. Bar lines on each histogram indicate the standard error.

8. S&T interventions to combat malnutrition in women and children

Nodal Scientist : CS Nautiyal and AKS Rawat

Scientists : S Khatoon, SK Ojha, CV Rao, S Rastogi, S Srivastava, SK Tewari

Technical Staff : MM Pandey

Objectives:

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

Highlights

Three Tech-villages – Dua (Unnao), Dafedar Ka Purva (Barabanki) and Tulsipur (Amethi) have been selected and targeted for intervention through S&T to combat malnutrition with the developed product Nutri-Jam. Surveyed all the villages several time for collection of data, nutritional status, food and drinking water status of the individuals. Posters on various aspects related to the importance of vegetables, fruits, cereals and medicinal plants etc were prepared and displayed in the class rooms of Primary School of Daun village for creating health awareness among the rural masses. During this year, 4-5 visits were organized to these villages, during the Health camp the products and posters were exhibited and scientists interacted with the participants. Dr. Sanjeev Ojha along with the doctors of CSIR-CIMAP collected the data regarding malnutrition status of children, young girls, women and men. Blood samples were also collected from selected people for the selection of personals to which the nutritional products will be distributed to combat the malnutrition.

A View of a the health camp at Tulsipur (Amethi) village

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

Nodal Scientist: CS Nautiyal

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

Objectives:

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

Highlights

Synergistic effect of *Pseudomonas putida* and *Bacillus amyloliquefaciens* ameliorates drought stress in chickpea (*Cicer arietinum* L.)

Two plant growth promoting rhizobacteria (PGPR) *Pseudomonas putida* NBRIRA and *Bacillus amyloliquefaciens* NBRISN13 with ability to tolerate abiotic stress along with multiple PGP traits like ACC deaminase activity, minerals solubilisation, hormones production, biofilm formation, siderophore activity were evaluated for their synergistic effect to alleviate drought stress in chickpea. This study explores in detail the possibilities and benefits of utilizing these two PGPRs in consortium for improving the chickpea growth under control and drought stressed condition. *In-vitro* results clearly demonstrate that both the PGPR strains are compatible to each other and exhibit synergistic effects enhancing the PGP attributes. Greenhouse experiments were conducted to evaluate the effect of inoculation of both strains individually and in consortia under drought tolerant and sensitive cultivars (BG362 and P1003). The growth parameters were observed to be significantly higher in consortium as compared to individual PGPR (Table 1). Colonization of both the PGPRs in chickpea rhizosphere has been visualized by using gfp labeling (Fig. 1). Apart from plant growth parameters, defense enzymes, soil enzymes and microbial diversity were significantly modulated individually in consortia by the PGPRs. Negative effects of drought stress were relieved and was apparent by higher biomass and reversal of stress indicators in chickpea cultivars treated with PGPR individually or in consortia. It is concluded that synergistic application of the two PGPRs has better potential to improve plant growth promotion under drought stress conditions.

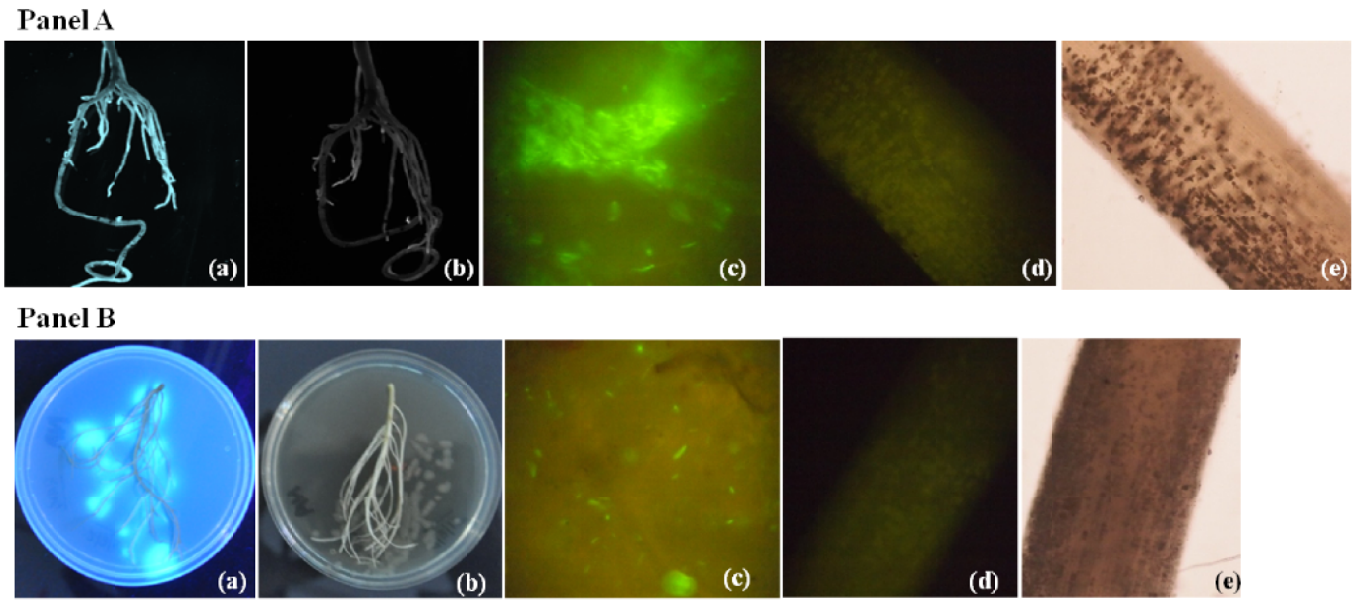


Fig. 1. Visualization of gfp tagged *Pseudomonas putida* RA and *Bacillus amyloliquefaciens* SN13 on chickpea roots. Panel A shows root adherence of gfp transformed in *Pseudomonas putida* (a), (c) and (d) showing gfp adherence on root whereas (b) and (e) are control without gfp label bacteria. Panel B shows *Bacillus amyloliquefaciens* (a), (d) showing gfp adherence on root whereas (b) and (e) are control without gfp label bacteria.

Pseudomonas putida attunes morphophysiological, biochemical and molecular responses in *Cicer arietinum* L. during drought stress and recovery

Role of *Pseudomonas putida* MTCC5279 (RA) in ameliorating drought stress on cv. BG-362 (desi) and cv. BG-1003 (kabuli) chickpea cultivars under *in-vitro* and greenhouse conditions was studied. Polyethylene glycol-(PEG 6000) induced drought stress severely affecting seed germination in both cultivars which was considerably improved on RA-inoculation. Drought stress significantly affected various growth parameters, water status, membrane integrity, osmolyte accumulation, ROS scavenging ability and stress-responsive gene expressions, which were positively modulated upon application of RA in both the chickpea cultivars. Quantitative real-time (qRT)-PCR analysis showed differential expression of genes involved in transcription activation (DREB1A and NAC1), stress response (LEA and DHN), ROS scavenging (CAT, APX, GST), ethylene biosynthesis (ACO and ACS), salicylic acid (PR1) and jasmonate (MYC2) signalling in both chickpea cultivars exposed to drought stress and recovery in the presence or absence of RA. The observations imply that RA confers drought tolerance in chickpea by altering various physical, physiological and biochemical parameters, as well as by modulating differential expression of at least 11 stress-responsive genes (Figs. 2 and 3).

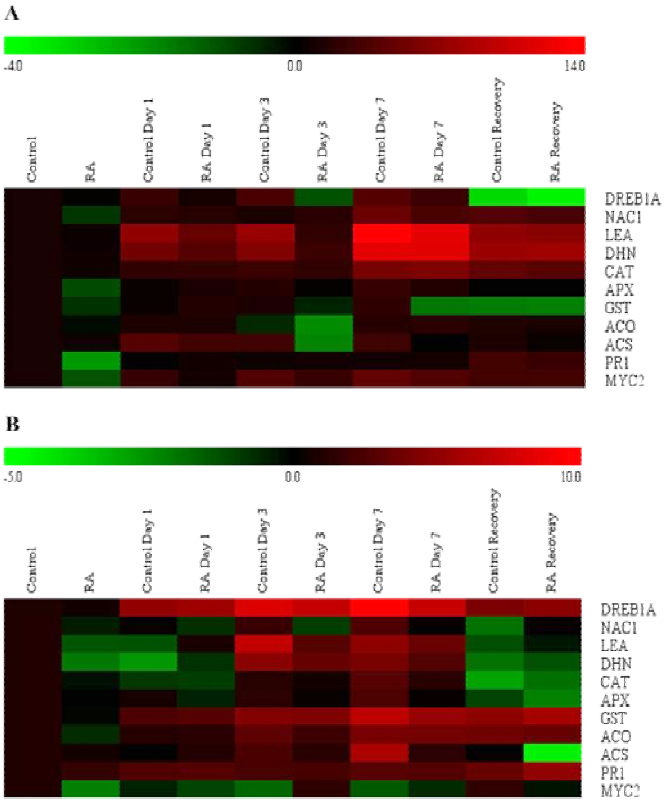


Fig. 2. Differential expression of genes in chickpea cultivars cv. BG-362 (A) and cv. BG-1003 (B) exposed to drought stress at 0, 1, 3 and 7 days and recovery in the presence or absence of RA. The heat map has been generated based on the fold-change values in the treated sample when compared with its unstressed control sample. The colour scale for fold-change values is shown at the top.

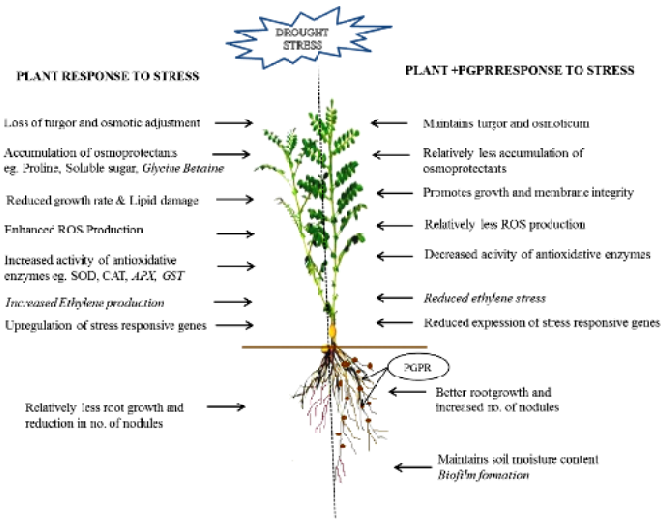


Fig. 3. A model of the physiological, biochemical, and molecular basis of drought stress tolerance operating in chickpea is created based on the differential response of both contrasting *desi* and *kabuli* cultivars. The enzyme assays and physiological parameters estimated in this study are indicated in normal font and well-known concepts reported in model species are shown in italics.

De novo assembly and characterization of root transcriptome in two distinct morphotypes of vetiver, *Chrysopogon zizaniodes* (L) Roberty

Vetiver, a perennial C4 grass, has long been known for its multifarious uses in perfumery, medicine and environmental protection. Two distinct vetiver morphotypes have been identified in India, i.e., A. North Indian type characterized by thick and smooth fast growing roots that produce superior quality of laevorotatory oil; and B. South Indian type with more number of thin and hairy roots that produce inferior quality of dextrorotatory oil (Fig. 4). The two morphotypes were targeted for transcriptome analysis to understand the contribution of

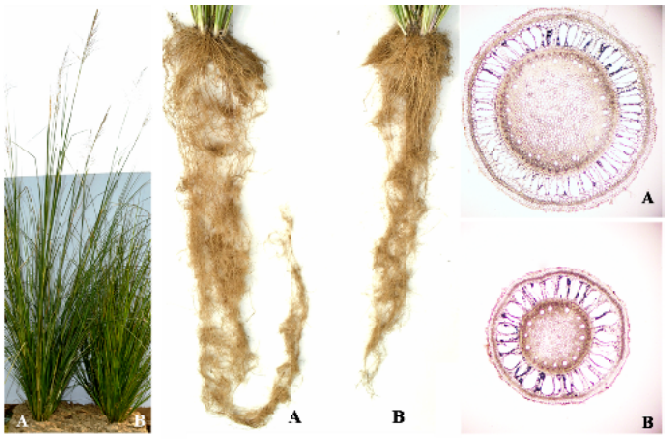


Fig. 4. Morphology of whole plants, root architecture and anatomy of two vetiver morphotypes, South Indian Type (A) and North Indian Type (B).

Table 1. Plant growth promotion in chickpea cultivars treated with *Pseudomonas putida* RA and *Bacillus amyloliquefaciens* SN13 individually and consortium under control and drought stress conditions.

Treat-ments	Root length (cm)	Shoot length (cm)	Fresh weight root (mg)	Fresh weight shoot (mg)	Dry weight root (mg)	Dry weight shoot (mg)	No. of Root nodules	R/S DW ratio
BC	16.7±1.3^{de}	12.3±0.7^{def}	321.66±19.56^{abcd}	808.00±31.05^{a}	90.00±12.60^{d}	80.00±5.10^{a}	44.67±3.05^{ef}	1.13
BC+D	13.3±1.3^{cd}	11.8±1.0^{d}	270.66±26.65^{abc}	707.34±74.45^{a}	27.57±2.24^{a}	75.13±8.64^{a}	40.67±3.79^{e}	0.37
BRA	20.1±3.4^{ef}	13.8±0.3^{fg}	595.33±64.39^{de}	899.67±64.01^{ab}	110.90±13.28e	110.00±10.13^{bc}	42.00±5.29^{e}	1.01
BRA+D	18.7±3.1^{e}	12.2±0.9^{de}	537.00±41.60^{cde}	818.67±84.28^{a}	40.60±4.68^{ab}	88.54±11.01^{ab}	35.00±5.00^{d}	0.46
BSN	24.1±3.8^{gh}	14.6±1.1^{gh}	457.66±91.15^{bcde}	809.34±51.98^{a}	130.40±6.42^{f}	100.34±8.90^{ab}	48.00±3.60^{fg}	1.30
BSN+D	22.4±3.4^{fg}	12.6±0.4^{ef}	440.66±93.30^{bcde}	793.34±43.31^{a}	31.63±6.66^{a}	79.81±3.99^{a}	44.34±4.93^{ef}	0.40
BRS	26.5±1.8^{h}	16.3±0.7^{i}	573.00±48.53^{de}	962.34±18.47^{ab}	180.90±14.35^{g}	129.69±13.20^{cd}	50.34±1.52^{g}	1.39
BRS+D	26.3±1.1^{h}	16.0±0.8^{hi}	560.33±60.45^{cde}	934.34±61.58^{ab}	46.63±6.76^{b}	128.34±12.74^{cd}	48.34±1.53^{fg}	0.36
PC	8.2±1.6^{ab}	6.1±1.2^{a}	174.33±37.07^{ab}	1270.00±101.48^{abc}	48.33±9.07^{b}	99.60±6.35^{ab}	18.67±3.05^{b}	0.49
PC+D	4.9±0.5^{a}	4.8±1.1^{a}	83.67±5.50^{a}	610.00±85.44^{a}	27.33±6.42^{a}	90.00±9.64^{ab}	11.34±1.52^{a}	0.30
PRA	11.6±0.4^{bc}	9.0±0.4^{bc}	206.67±15.27^{ab}	1893.34±120.5^{cde}	63.33±4.72^{c}	139.00±5.29^{b}	31.34±1.52^{d}	0.46
PRA+D	9.9±1.1^{bc}	7.8±0.9^{b}	180.00±12.12^{ab}	1653.34±177.85^{bcd}	47.00±2.64^{b}	224.00±42.55^{e}	24.00±1.00^{c}	0.21
PSN	10.1±0.5^{bc}	9.5±1.1^{c}	550.00±30.00^{cde}	2346.67±395.13^{de}	110.00±3.78^{e}	148.67±9.16^{b}	30.00±2.00^{d}	0.74
PSN+D	8.6±0.5^{bc}	7.9±0.5^{bc}	445.33±63.90^{bcde}	2176.67±70.23^{de}	87.67±5.13^{d}	140.67±18.02^{d}	21.67±1.52^{bc}	0.62
PRS	12.2±1.8^{bc}	11.5±0.8^{de}	661.33±81.39^{e}	2540.00±210.00^{e}	180.67±3.00^{g}	150.33±5.56^{d}	34.67±1.52^{d}	1.20
PRS+D	11.3±2.1^{bc}	10.9±0.8^{d}	321.66±19.56^{e}	808.00±31.05^{de}	117.50±11.60$_{ef}$	84.87±4.58^{d}	44.67±3.05^{d}	1.30

*values of root and shoot length taken 30 DAS, dry weight after drying at 45°C for 3 days.
RA (*P. putida*); SN13 (*B. amyloliquefaciens*); RS (consortia of RA and SN13).
"±: Standard errors (n=6)". Different letters within column represents significant difference at (P=0.05) by using DMRT.

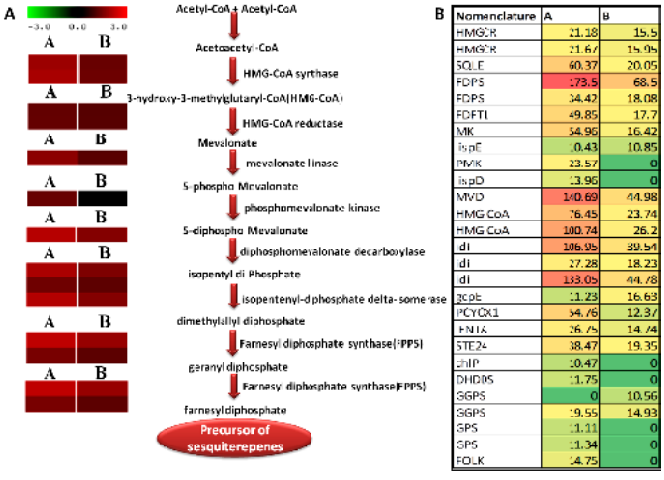


Fig. 5. Expression analysis of putative enzymes involved in terpene biosynthesis: A) Putative pathway for sesquiterpene biosynthesis in vetiver. All the enzymes found in this study related to different steps are shown between the reactions catalyzed. Expression of different transcripts related to these enzymes in sample A and Sample B is shown by heatmap. B) Names and expression value (FPKM) of enzymes related to terpene biosynthesis.

genetic background on oil quality and root morphology. Sample A showed enhanced activity of flavonoid and terpenoid biosynthesis related genes, i.e. ERF, MYB, bHLH, bZIP and WRKY (Fig. 5). Interestingly, expression analysis revealed that the genes involved in sesquiterpene biosynthesis pathway were up regulated in Sample A. Moreover, some of the genes involved in mevalonate pathway of sesquiterpene biosynthesis were unique to Sample A. Our results also demonstrated several transcripts involved in root development and hormonal regulation being up regulated in Sample A (Fig. 6). To

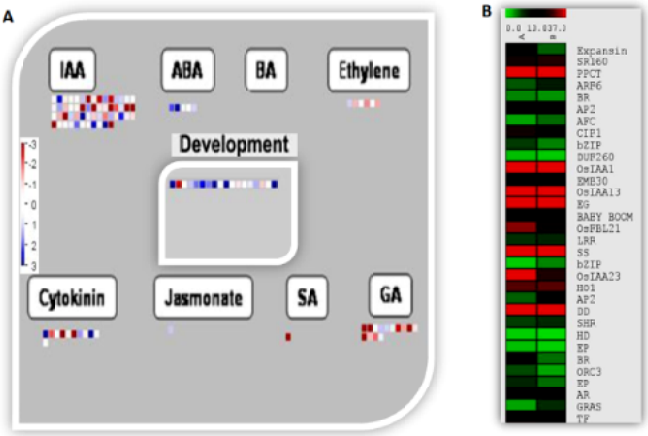


Fig. 6. Expression analysis of transcripts involved in regulation and root development. A) MapMan visualization showing the observed differential expression patterns of transcripts involve in hormonal regulation and development, based on the Log_2 FCs of transcript levels, in Sample B (South Indian Ecotype) compare to Sample A (North Indian Ecotype). In the display, each BIN or sub BIN is represented as a block where each transcript is displayed as a square. Red color indicate down regulation while blue colors showing up regulation in Sample B compare to Sample A. B) Heat map showing FPKM based expression of different transcripts involve in root development and regulation. Red and Green colors showing lower and higher expression of related transcripts, respectively.

validate gene expression results of RNA-seq data, 20 transcripts were validated by qRT-PCR experiment. This study provided an important start point for further discovery of genes related to root oil quality in different ecotypes of vetiver.

Comparative analysis of two contrasting rice cultivars for their drought tolerance, using transcriptome sequencing

Two contrasting rice varieties, one drought resistant and another drought sensitive, were selected. Seeds of both the varieties were germinated and grown on Hewitt media containing 20% Poly Ethylene Glycol (PEG 6000) at 16 hrs light and 8 hrs, dark photoperiod at 25 ±2°C. Roots were harvested after 24 hrs, 3 days and 7 days of PEG 6000 treatment and stored at -80°C. Total RNA was extracted from treated rice roots and transcriptome sequencing of 12 samples was done.

Based on sequencing results comparative expression analysis was done by using different sets and parameters. 22 highly differentially expressed genes were selected based on comparative analysis. Primers have been designed for further validation by quantitative real time PCR.

Four genes based on relative expression pattern and bioinformatics analysis were selected, WRKY, heat shock protein, and dehydrin. Full-length cDNAs have been cloned and confirmed in Arabidopsis expression vector pBI121. Transformation was performed for all the five genes. The selection of transformed T0 generation plants was made on 1/2 MS kanamycin plate. The overexpressing plants of above mentioned genes are in T2 stage.

Out of the four genes, dehydrin, OsIAA10 and express protein which have been transformed in rice for functional characterization showed phenotypic variation as compared to control. There is clear variation in root morphology (root length and number of lateral roots) of transgenic lines compared to control in all the cases. Plants overexpressing dehydrin and express protein are in T2 Stage and OsIAA10 in T3 generation. Further experiments are underway to test their role in drought stress.

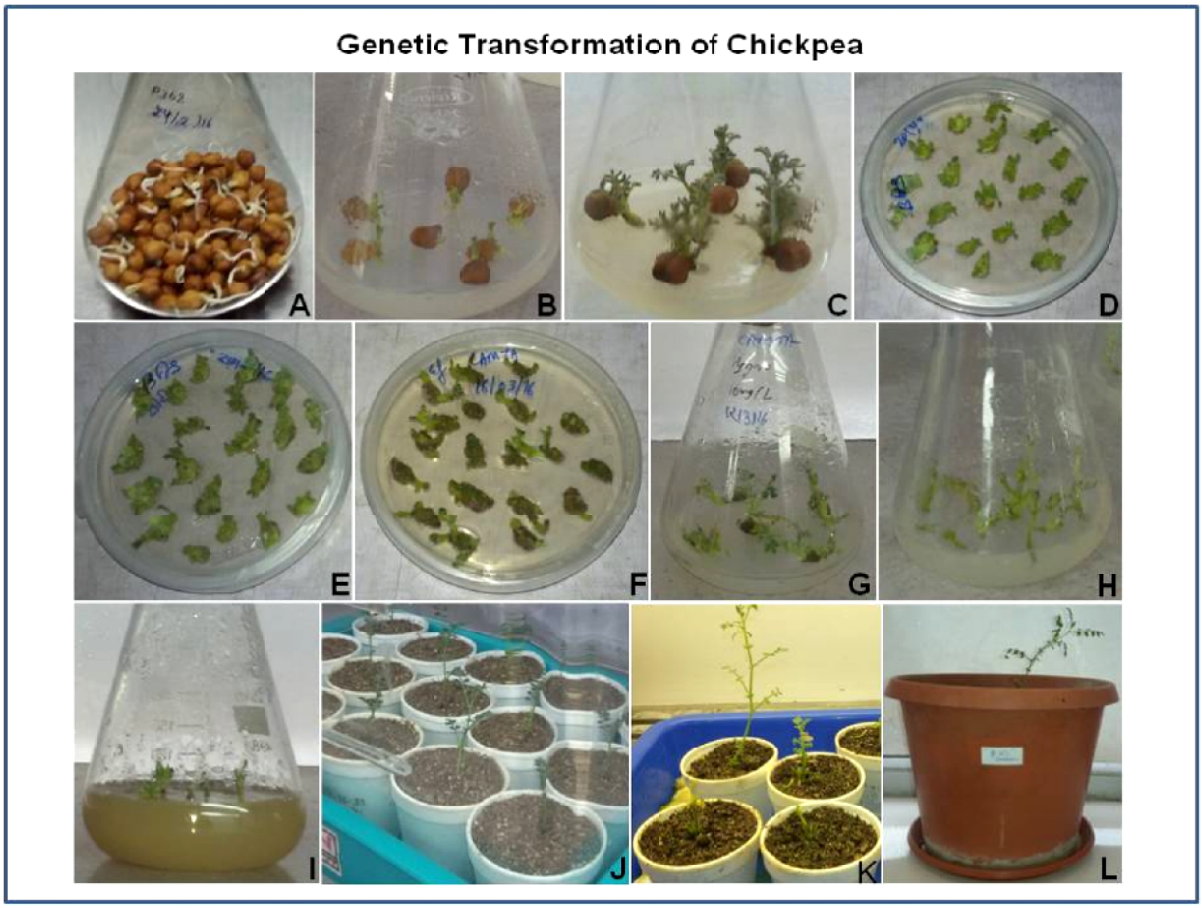


Fig. 7. A- Surface sterilization of seeds, B- Inoculation of seeds on BAP supplemented medium, C- Induction of multiple shoots from seeds, D- Preparation of cotyledonary node explants, E- Explants co-cultivated in the presence of Agrobacterium, F- Co-cultivated explants after 15 days of culture, G- Explants cultured on shoot induction medium, H- Individual shoots subjected to antibiotic selection, I- Shoots cultured on media supplemented with silver nitrate for elongation, J- Acclimatization of in vitro regenerated shoots grafted on seedling stocks, K- Successful hardening of transgenic shoots, L- Transfer of plantlet to pot under glasshouse conditions.

Soil metagenomics

Sixteen parameters namely pH, Electrical Conductivity (EC), Total organic carbon (TOC), Microbial Biomass Carbon, (MBC), Water Holding Capacity (WHC), Bulk Density (BD), Porosity, Particle Density (PD), Available P, Total P, Available K, Total K, Extractable sulphate, Soil Texture , Available N and metal analysis for quality assessment of 225 soil samples collected from 75 districts of UP have been completed.

Functional validation of *CAMTA* gene in chickpea in response to water stress

The aim was to develop drought tolerance in chickpea, by expression of *CAMTA* transcription factor in chickpea for drought tolerance. The following progress was made:

- Development of T_0 transgenic events of chickpea (Fig. 7).
- Characterization of transgene in the putative transgenic events.
- Establishment of these events under controlled environmental conditions.
- Collection of seeds of T_1 generation for genetic analysis.

BOTANIC GARDEN AND DISTANT RESEARCH CENTRES

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

Technical Staff: A Batra, B Das, A Kumar, R Kumar, S Kumar, G Sharma, SK Sharma, S Singh, RK Tripathi, SS Tripathi, Shankar Verma, Saurabh Verma, MG Prasad

Grant-in-Aid Projects

Standardization and promotion of organic seed production of Turmeric (*Curcuma longa* L.) in Uttar Pradesh

The increasing demand world over for organic material will require organic cultivation protocols for its profitable cultivation by the farmers. The project activities continued this year to study the production economics of turmeric.

Two experiments were conducted in randomized block design with three replications. The experiment-1 (Standardization of integrated organic farming approach to achieve optimum yield and quality), consisted of 11 treatments: T_1 - 100 % RDF (NPK+ Zink), T_2 - Vermicompost 20 tonnes/ha, T_3 - Coir compost (@ 5 t/ha), T_4 - 75 % Coir compost + 25 % Vermicompost, T_5 - 75 % Vermicompost + 25% coir compost, T_6 - 50% Coir compost + 50 % Vermicompost, T_7 - 100 % Vermicompost + PSB, T_8 - 100 % Coir compost + PSB, T_9 - 75 % Coir compost + 25 % Vermicompost + PSB, T_{10} - 75 % Vermicompost + 25% Coir compost + PSB, T_{11} - 50% Coir compost + *Azospirillum* + PSB. The experiment-2 (Organic inputs for disease control and standardization of the proper remediation for disease and insect management), consisted of nine treatments: T_1 – Control, T_2 - Mancozeb seed treatment, T_3 - Neem cake soil treatment, T_4 - *Trichoderma viride* seed treatment, T_5 - *Pochonia chlamydosporia* Bioagents, T_6 - Bordeaux mixture 1% spray, T_7 - Neem oil (0.5%) spray, T_8 - *Bacillus subtilis* seed treatment, T_9 - Neemgold (0.5%) spray.

In the first experiment different treatments significantly affected the growth attributing characters in comparison to the control. The maximum plant height, leaf length and leaf width per plant were recorded in the treatment T7 which was significantly higher than all the other treatments. The number of leaves per plant was found non-significant. The treatments T1 and T10 were found at par with T2, in all the growth characteristics. Minimum plant height, number of leaves, leaf length and leaf width was recorded in treatment T3 (Fig 1a).

Fig. 1a. Field view of organic nutrient management in turmeric

Fig. 1b. Field view of organic disease management in turmeric

In the second experiment, all the treatments of organic input significantly affected the growth attributing characteristics of turmeric. However, seed treatment with *Trichoderma viride* (T4) was found more effective in comparison to all other treatments, followed by seed treatment with Mancozeb (T2). Seed treatment with *Trichoderma viride* significantly affected the growth characteristics of the plant, like height, leaf length and leaf width per plant showing the value of 104.45 cm, 48.13 cm and 13.75 cm, respectively. Change in number of leaves per plant was found non-significant in all the treatments (Fig 1b).

The results indicated that application of different bio control treatments showed significant resistance against the disease infestation, except leaf spot disease in the turmeric crop. The disease incidence score (%) was showed up to 11.54 % in the control and minimum (2.17%) in the *Trichoderma viride* seed treatment.

Establishment of small nursery for fast multiplication of elite clones and new varieties of medicinal and aromatic plants

NBRI has been working in the area of germplasm collection, conservation, standardization of propagation and cultivation protocol, evaluation of collected germplasm for qualitative aspects of the crop plants from medicinal, aromatic, gum and dye yielding categories. During several years of such studies, the Institute now has elite germplasm of these categories of plants, domesticated in the edapho-climatic conditions with superior quality parameters. A few selected medicinal plant varieties released by CIMAP have also been procured and grown in the herbal garden, located at distant research centers, Banthara.

A new facility has been established and ready for use now for the propagation of medicinal and aromatic plants (MAPs) (Fig. 2). The farmers have been registered for various NBRI Technologies, aiming at rural development. The farmers visited the station on the occasion of Farmers Fair (Farmer-interaction programme) and showed interest in propagation of MAPs under protected conditions. The plantation of MAPs *viz.*, Haldi, Shatawar was promoted as intercrops. The seedlings and planting material of above plants were distributed to the farmers.

Fig. 2. Propagation unit for multiplication of elite clones of MAPs

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

Sodicity evaluations have been done on Ashwagandha (*Withania somnifera*) and Kalmegh (*Andrographis paniculata*) and maintained seven varieties and accessions of Ashwagandha (NMITLI-101, NMITLI-108, NMITLI-118, NMITLI-135, Poshita, WB-134 (DMAPR) and Gujarat Ashwagandha-1) for future research (Figs. 3 & 4).

It was found that Ashwagandha up to 25 ESP and Kalmegh up to 16 ESP can be cultivated without deteriorating the yield and quality of the crops. The method has been standardized for development of sodic soil and organic carbon for evaluation of optimum yields and quality of the plants. Residual response of sodicity was observed on Kalmegh. Above 8.7 pH the plant could not provide the desired economic yield.

Fig. 3. Sodicity evaluation in seven varieties of Ashwagandha

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

The FYM (0-30 t ha^{-1}), Pressmud (0-15 t ha^{-1}) and Vermi-compost (0-15 t ha^{-1}) applied during last year and the residual responses of added organic manures (FYM, Pressmud and Vermi-compost) were observed on growth and yield of Kalmegh during this year. Maximum residual response was observed with FYM followed by Pressmud and Vermi-compost. Vermi-compost showed minimum response in case of yield and quality at maturity stage of Kalmegh.

Fig. 4. Field view of the ongoing experiments on Kalmegh at DRC, Banthra

FYM-15 t ha^{-1}, Pressmud - 10 t ha^{-1} and Vermi-compost - 10 t ha^{-1} were standardized for economic yield of Kalmegh under organic farming system (Fig. 5).

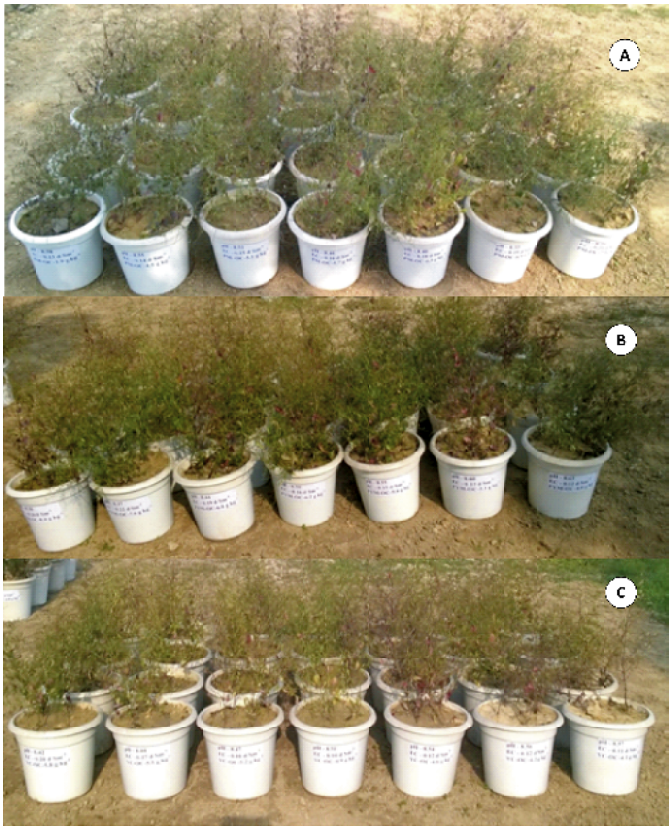


Fig.5 A-C. Residual Effects of different sources and organic matter on Kalmegh; A-FYM (4.8-8.4 g kg^{-1}); B-Pressmud (3.9-7.5 g kg^{-1}); C-Vermi-compost (4.1-5.8 g kg^{-1})

The residual response of FYM and Pressmud was found similar, while, vermi-compost showed the least effect on residual effect under organic farming. The method has been standardized for development of different organic carbon levels for evaluation of optimum yields and quality of the plants.

In-House Projects

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

The Botanic Garden serves as a National Facility of the Institute. A wide range of germplasm comprising of five thousand taxa are conserved *ex-situ* in the arboretum as well as plant houses. These live germplasm collections are an important resource for botanical study and research besides their use in landscaping for recreation purposes. The botanic garden with their vast genetic resource is an out of school education centre for the students, researchers and the public.

Enrichment of germplasms

As part of enrichment of germplasm collection in the Botanic Garden the following plant species were introduced, multiplied and popularized:

Orchids

Around 30 species of orchids were collected during plant collection tours for the enrichment of germplasm and revival of Orchidarium of the Botanic Garden. The orchids were collected from natural habitats of six states viz., Assam, Bihar, Jharkhand, Meghalaya, Manipur and Odisha. Some of the species are *Acampe praemorsa, Arundina graminifolia, Bulbophyllum crassipes, Coelogyne cristata, Cymbidium* sp., *Dendrobium aphyllum, D. herbaceum, D. moschatum, Gastrochilus inconspicuous, Luisia indica, Oberonia* sp., *Pelatantheria insectifera, Rhynchostylis retusa, Vanda coerulea, V. tessellata*, etc. *Dendrobium aphyllum* and *Vanda tessellata* are threatened in wild and included in the IUCN Redlist. *Vanda coerulea*, the Blue Vanda is protected under Schedule 2 (Appendix 2) of the Wildlife Protection Act, 1972 (Fig. 6A-D).

Cycads

Recently described *Cycas* species from Odisha, *Cycas orixensis* and *C. nayagarhensis* were collected from their type localities for *ex-situ* conservation at the Botanic Garden. Young plants and mature seeds were collected from Angul and Nayagarh districts. More than 1000 viable seeds of *Zamia loddigesii* and 40 seeds of *Zamia pumila* were

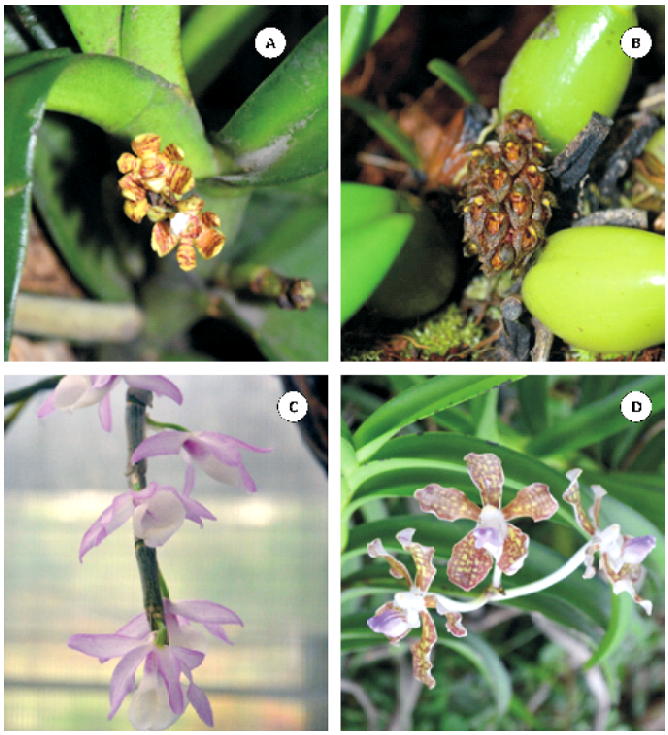


Fig. 6A-D. Orchids introduced to NBRI Botanic Garden. A- *Acampe praemorsa*. B-*Bulbophyllum crassipes*; C-*Dendrobium polyanthum*; D-*Vanda tessellata*

developed through hand pollination techniques in the Cycad House and Conservatory. Development of seed propagation techniques of the species are going on at RET Propagation House.

Trees

Chrysophyllum cinito, *Labroma bajori* collected from Indian Botanic Garden, BSI, Howrah, and *Brownea coccinea*, *Gustavia augusta*, *Magnolia grandiflora* from Agri-Horticultural Society, Kolkata.

Ferns

In-vitro raised *Diplazium esculentum* (Fig.7) plantlets have been successfully transferred and introduced to enrich the fern house of the Botanic Garden.

Fig. 7. *In-vitro* raised *Diplazium esculentum* introduced to enrich the fern house of CSIR-NBRI.

Mosses and Liverworts

The following nine species of mosses and liverworts were introduced to the Moss House in the Botanic Garden: *Plagiochasma intermedium, P. cordatum, Bryum coronatum, Funaria hygrometrica, Conocephalum conicum, Reboulia hemisphaerica, Wiesnerella denudata, Marchantia polymorpha, Targionia hypophylla.*

Conservation and Mass Propagation

Mass propagation (approximately 950 replicates) of 12 ornamental fern species viz. *Adiantum capillus-veneris, Colysis elliptica, Microsorum punctatum, M. alternifolium, Nephrolepes biserrata, N. cordifolia, N. exaltata, N. tuberosa, Pteris vittata, Tectaria macrodonta, Selaginella bryopteris* (Sanjeevani Booti) and *Doryopteris ludens* (a threatened fern, Fig.8) was made for conservation, sale and experimental studies.

Multiplication of Rare Cycads

Cycads are the oldest living seed plants and have survived three mass extinctions. They are known as living fossils and are the most threatened group of organisms on earth with almost 64% of cycads at the risk of extinction. *Ex-situ* conservation of cycads through a network of

Fig. 8. Multiplication of *Doryopteris ludens* to enrich the fern house of CSIR-NBRI.

botanic gardens played an important role in conservation of threatened cycad species. Some of the botanic gardens which maintain representative collections of cycads are Fairy Lake Botanical Garden (China), Montgomery Botanical Garden (United States), Nong Nooch Tropical Garden (Thailand), Lowveld National Botanic Garden (South Africa), Royal Botanic Gardens, Kew (United Kingdom) and Royal Botanic Gardens, Sydney (Australia). In India, only few botanic gardens carry out *ex-situ* conservation of cycads. Cycad Conservation Centre at CSIR-NBRI Botanic Garden, which comprises of three plant houses namely Cycad House, Jurassic Gallery and Conservatory, is the only such centre in India. The centre houses 56 species of cycads including 7 species of Indian *Cycas*.

At present, three species of *Zamia* and four Indian species of *Cycas* (*C. beddomei, C. pectinata, C. sphaerica* and *C. zeylanica*) are being propagated and multiplied in the Cycad Centre (Fig 9A-B). Through hand pollination around 700 viable seeds were developed and about 500 healthy seedlings of *Zamia loddigesii* were raised. Specialized seed germination technique was utilized to propagate. Hand pollination and seed setting of another species *Zamia pumila* is under study. The Conservation Centre aims to propagate all the nine species of Indian *Cycas* in next one year for *ex-situ* conservation purpose as well as exchange.

Release of New Varieties

Bougainvillea

A new variety of Bougainvillea **'NBRI-A.P.J. Abdul Kalam'** was released in the Annual Day Function held on 25.10.2015.

Parent: *Bougainvillea* 'Fantasy'

Description:

A bud sport (natural mutant); growth habit drooping; leaves variegated; medium-ovate; leaf size 6.0-7.5 × 4.5-6.0

Fig. 9A-B. Cycad propagation. A-Seed germination and development of seedlings in *Cycas beddomei*; B-Young seedlings of *Zamia loddigesii*

cm; thorns slightly curved; 0.6-1.0 cm long; 17 nos. of thorns in 30 cm length of shoot; floral bract size 2.5-3.0 × 1.8-2.3 cm; bract colour - young red (Red group 53-D, Fan-1); mature red-purple (Red purple 63-B, Fan-2); bract shape medium ovate; slightly twisted; star creamy colour (Green-yellow 1-C, Fan-1); 0.5-0.7 cm in diameter; flowering habit all along the branches (Fig. 10A&B).

Speciality:

Leaves are very attractive having variegation combining three colours- green, lemon yellow and ashy-yellow, bracts large, twisted, winter blooming.

Chrysanthemum

A new variety of Chrysanthemum **'NBRI-Peetabh'** was released during the Chrysanthemum and Coleus Flower Show held on December 12-13, 2015.

Parents: A natural hybridization and seedling selection of **Fairy x Unknown**

Description:

Plant bushy, semi-upright, 50-55 cm in height; leaves with shallow depth of sinus, leaf size 7.0-10.0 x 5.5-6.5 cm;

Fig.10A-B. New Bougainvillea variety 'NBRI Dr. A.P.J. Abdul Kalam'

flower - single korean type (semi-quilled), flower head large, flower size 7-8 cm in dia.; ray florets - anemone, 70-75 nos. per flower, 1.5-2.5 cm long with extra long basal tube, spatulate, upper surface having purple stripes (Red-purple group 72-B, Fan-2) at the centre, margins light-purple (Purple group 76-D, Fan-2); lower surface light-purple (Purple group 76-D, Fan-2); disc - 1.5-2.0 cm in dia., small head, convex, yellow (Yellow-orange group 14-B, Fan-1) (Fig. 11A&B).

Speciality: Flower head unusual large in semi-cup shape having unique semi-quilled ray florets with extra long basal tube. Attractive structural set-up and colour combination with purple stripes at the centre and light purple margins of the ray florets. The variety is suitable as decorative pot plant.

Propagation House for RET Species:

Conservation and propagation of Rare, Endangered & Threatened (RET) plant species are important activities of this Botanic Garden. In order to increase the number of population of the RET species for their *ex-situ* conservation and exchange, a propagation house for RET species has been created (Fig. 12 A & B).

The following RET species are under propagation: *Cycas beddomei*, *C. pectinata*, *C. revoluta*, *C. sphaerica*, *Diospyros discolor*, *Hoya wightii*, *Luisia indica*, *Nepenthese*

Fig. 11A-B : Chrysanthemum 'Peetabh'

khasiana (Fig. 12C), *Santalum album*, *Saraca asoca*, *Sequoiadendron giganteum*, *Zamia furfuacea*, *Z. loddigesii*, and *Z. pumilla*

New Kisok Point

As part of the ongoing improvement work in the Botanic Garden, a new area has been developed near Canna and Gladiolus gardens. This new garden has an exotic tree (*Tabebuia palmeri*), a Kiosk underneath connected with crazy path together with hanging baskets and potted flowering plants. As a whole, the area has now been converted into a selfie point for the visitors (Fig. 13). This was opened for the public during the Chrysanthemum & Coleus Flower Show held on Dec 12-13, 2015. This new addition has made the botanic garden more attractive and purposeful.

Fig.12 A-C : The RET propagation house –outer and interior views, with *Nepenthes khasiana* seedlings being propagated in the house.

Distant Research Centre (Banthra Research Station)

The Distant Research Centre (Banthra Research Station) is an experimental center of the institute, developed on sodic land. The centre has five field units (Banthra, Biomass, Gehru, Aurawan, Ranipur) rehabilitated under diverse land use systems viz. Floriculture, Herbiculture, Moriculture, Energy plantations, Field Gene Bank, Populatum, Bambusetum and a semi-natural forest. The centre is also working on conservation of economically important species in which exotic and indigenous poplar clones, varieties of Chrysanthemum, HT rose, *Canna* and ~200 species of medicinal and aromatic plants are being

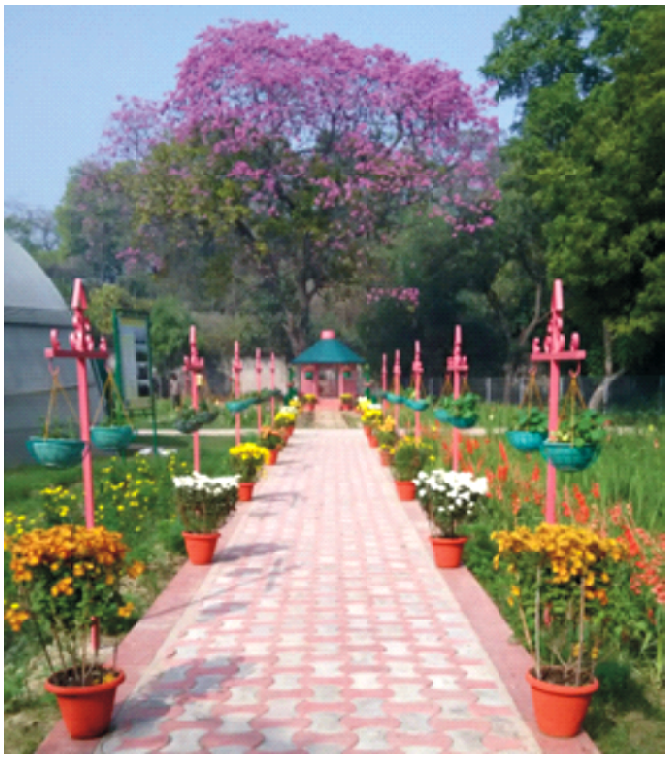


Fig. 13. The new kiosk point developed in the NBRI Botanic Garden

conserved. R&D experiments are carried out for standardization of agro-technology on degraded sites, with greater emphasis on non-traditional crop plants, including floriculture and medicinal and aromatic plants.

Evaluation and improvement of turmeric accessions for north India

Thirty four accessions of *Curcuma longa*, collected from various biogeographical regions are being conserved at Banthra Research Station. Biochemical analysis (total curcuminoids, total phenolic contents, Antioxidant activity) and molecular study of 29 accessions has been done. Among all the accessions three accessions (NBH-10, NBH-12 and NBH-18) were found to be best yielding and are cultivated for commercial purpose at Aurawan centre. Of these, "Kesari", a promising variety for shade conditions in northern plains was released on 7th February 2016.

Evaluation of *Curcuma* species for partially reclaimed sodic soil

Four species of *Curcuma* viz. *C. longa. C. caesia, C. zeodoaria* and *C. amada* were evaluated for their yield. Biochemical analysis (total curcuminoids, total phenolic contents, Antioxidant activity) was also done. Total curcuminoids was found in negligible amount in all the four species, except *C. longa*. GCMS study reveals variation in major constituents of leaf and rhizome essential oil in different species. The major constituent of leaf essential oil was p-cymene in *C. longa* (52.03%) and *C. caesia* (21.03%) and camphor in *C. amada* (32.91%) and *C. zeodoaria* (29.55%). The major constituents in rhizome essential oil were α-terpinene (443%) in *C. longa*, β-myrcene (76.09%) in *C. amada*, camphor (18.30%) in *C. zeodoaria* and germacrone (30.45%) in *C. caesia*.

Evaluation of *Bixa* in sodic soils

Seventeen accessions of *Bixa* collected from different bio-geographical regions are being evaluated for growth, yield and quality at Banthra, with the soil pH ranging from 8.7 to 9.2. The plants have shown variations in morphological characters (leaf shape, flower colour, capsule shape, size colour, etc.) yield (number of capsule per plant, number and weight of seeds per capsule) and quality (Bixin content). Based on morphological characterization, total collection has been arranged into seven groups.

Model Betelvine Production System

The advanced technique of cultivating betelvine in modern type of 'bareja' has been developed and is being demonstrated for the quality production of betelvine, saving the crop from excess heat during summer and low temperature and frost during winter. The model has been demonstrated and explained to farmers during various training programmes at the centre and other locations as well. Morphological characterization of Betelvine has been done for adventitious root production, first root initiation, vine diameter, orthotropic shoot internodal length (cm), orthotropic leaf length (cm), depth of lobe (cm), leaf lobe width (cm), orthotropic leaf L/B ratio, orthotropic leaf apex angle, shoot base colour (between 3-4 node) stripe colour and orthtropic leaf lamina.

Screening of drought tolerance in rice varieties

Field experiments were conducted with two rice varieties. Heena and Kiran, grown with no irrigation (control), one irrigation at maximum tillering stage (I_0), two irrigations at maximum tillering stage and flowering stage (I_1), irrigations at interval of 4-5 days to maintain the field at saturation level (I_2). During the investigation, Heena performed well during different water stress levels. Higher number of tillers per plant and spike length were obtained from Heena in irrigated condition. Among different water levels, combined treatment of *Trichoderma* and SN13, responded very well. In both the genotypes Heena and Kiran, moisture stress reduced the 100 seed weight, but the degree of reduction in 100 seed weight was different in different genotypes. Kiran was more influenced by moisture scarcity. Both of the genotypes produced higher biomass and grain yield in irrigated condition. Combined treatment with *Trichoderma* and SN_{13}, in different water levels performed better among other treatments to obtain grain and biomass yield.

Response of PGPRs for alleviating water stress

Two varieties of chickpea, Pusa 362 (desi) and Pusa 1003 (Kabuli) were sown in field at different water stress levels including no irrigation (I_0), one irrigation at maximum growth stage (I_1), and irrigations at different growth stages (I_2). Theses chickpea varieties were treated with different PGPRs viz., *Trichoderma*, PSB and their combination, to find out the performance of these PGPRs for growth and yield of chickpea, under water stress levels. During the investigation, Pusa 1003 (Kabuli) performed well during different water stress levels. At 90 DAS stage, the highest plant height and branches per plant of Pusa 1003 variety was obtained when grown in irrigated condition. Among the different water levels, combined treatment with *Trichoderma* and PSB, responded very well.

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

Amelioration and utilization of degraded sodic wastelands with adaptable plants of industrial importance is the target of this research. *Aloe* species are potentially viable to ameliorate degraded sodic wastelands. About 15 species of *Aloe* have been collected, acclimatized, multiplied, identified and established as germplasm bank at DRC Banthra (Fig. 14). These include *Aloe gracilis, A. tenuior, A. ortholopha, A. ammophila, A. saponaria, A. aageodonta, A. ferox, A. maculata, A. greatheadii , A. ambigens* and *A.vera* accession (to be identified). The screening for sodicity tolerance of some selected species is in progress.

Assessment of *Aloe* species growth and gel yield performance at various levels of sodicity

There highly demanded *Aloe* spp. as per taste of gel, *Aloe vera* (normally bitter), *A. ferox* (extremely bitter), and *A. maculata* (non bitter) were examined for their growth parameters and gel yield production at four levels of naturally existing soil pH as 8.5 (control), 9.0, 9.20, 9.5, and 9.70 at DRC Banthra.

The plant growth of all three *Aloe species* increased significantly with increasing pH levels up to pH 9.2 and decreased at pH 9. 50 and 9.70. But overall growth of all *Aloe* species were high upto pH 9.70 than that of control soil pH (8.50). The plant growth was considerably greatest in *A. vera* followed by *A. maculata* and comparatively slow growth occurred in *A. ferox* in control to highest sodic soil pH (9.70) level. The gel yield followed the same trend as in case of growth pattern of all three species (Fig. 15).

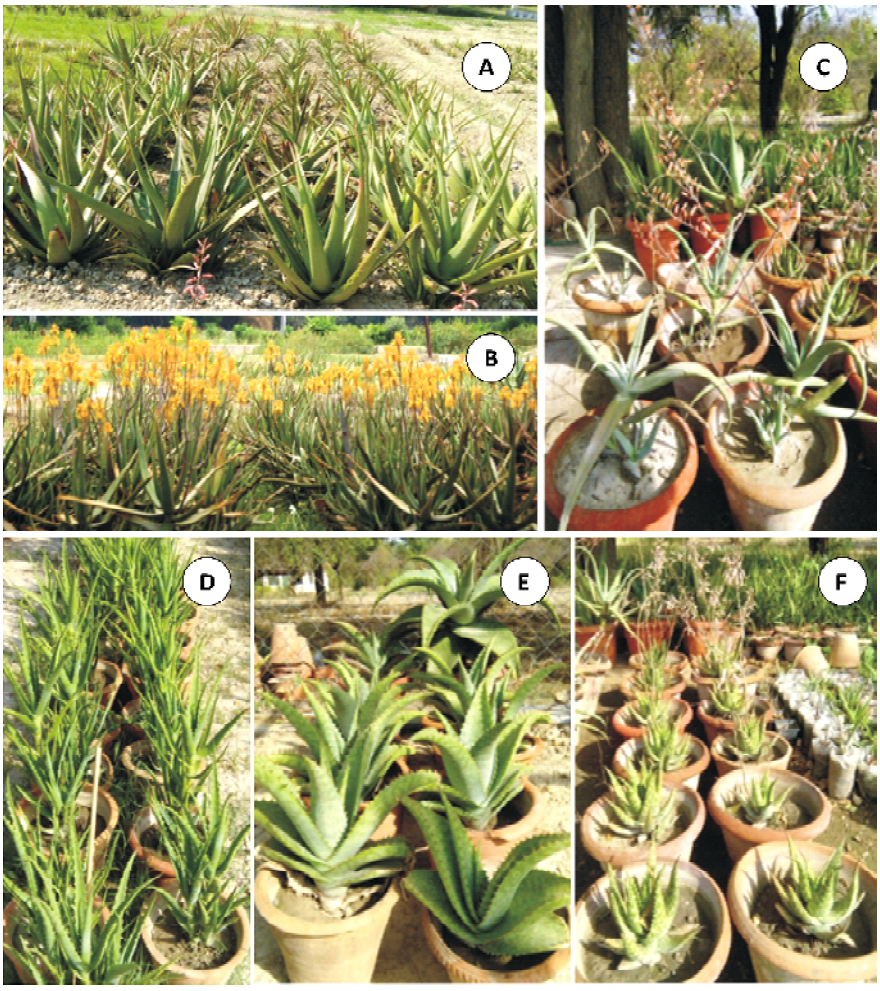


Fig.14 A-F. Field performance of different *Aloe species* at DRC Banthra: A. *Aloe vera* Accession No. IC281122 in field; B. *A. spicata*; C. *A. ambigens*; D. *A. gracilis*; E. *A. saponaria* f. *A. harlana*

Flowering behaviour of different *Aloe* species in sodic soil conditions

Phenological study was continued with observations on flowering behavior in 14 species viz. *Aloe ferox, A. greatheadii, A. harlana, A. ortholopha, A. spicata, A. ammophila, A.saponaria, A. maculata, A. vera* Accession No. IC281122, *A. tenuior, A. ambigens, A. vera* and two unknown *Aloe* species (Fig. 16).

Seed pod formation, seed setting and maturity in different Aloe

Formation of seed pod, seed setting and their maturity were investigated in four species, viz. *Aloe tenuior, A. greatheadii, A.ferox* and *A. maculata* (Fig. 17).

Seed pod formation generally starts in winter season from 2nd week of January in all the four species. The seed

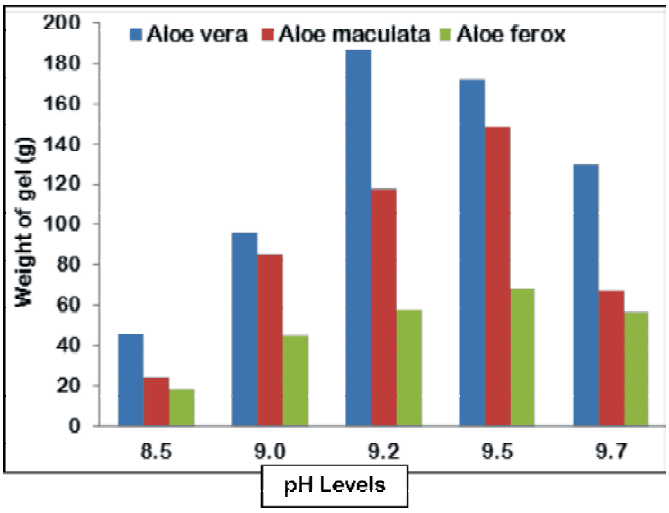


Fig. 15. Effect of sodicity on growth performance of three species of *Aloe* grown at various sodicity levels at DRC Banthra

pods attain proper growth and seed setting takes place in about one and half month period. The mature seeds pods become dry and crack and the seeds get scattered, if dry pods are not plucked timely. Size of seeds and their number in pods differ in each species. *Aloe greatheadii* produces more number of seeds of very small size while *A. tenuior* and *A. ferox* produce bigger pods with 4 to 6 seeds per pod. With big seed pod size *A. maculata* produces medium sized and more number of seeds per pod.

Root formation in damaged plants of *Aloe vera*

Aloe vera is very much sensitive to fungal, bacterial, water logging and extreme low and high temperature conditions. Sometimes whole planted area gets affected and no single plant survives. An experiment was conducted by collecting such damaged plants which had survived for raising the nursery of fresh suckers. Six plants

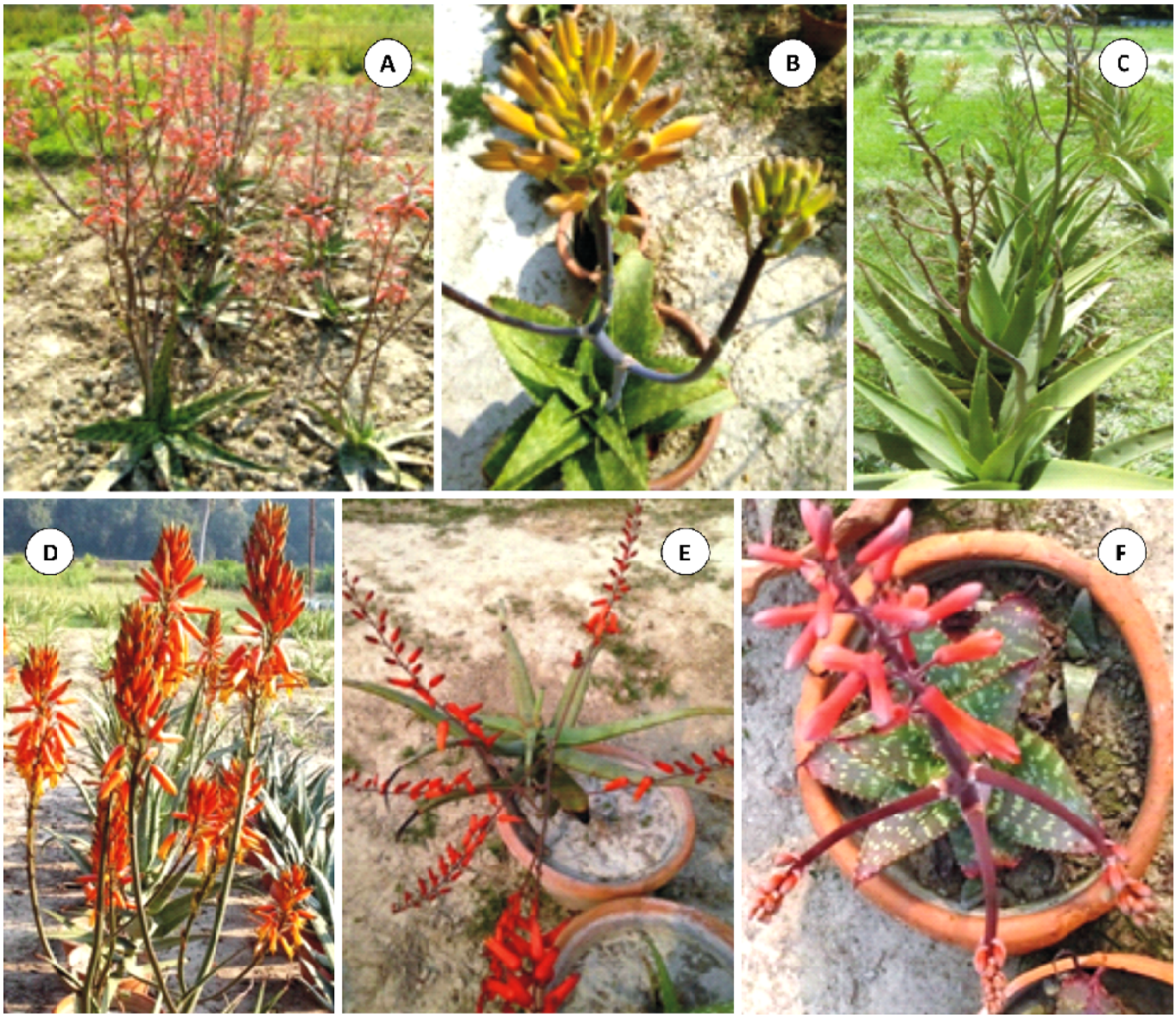


Fig. 16 A-F. Blooming in different species of *Aloe* A- *Aloe ammophila*; B- *A.saponaria*; C- Aloe vera Accession No. IC281122; D- *Aloe tenuior*; E- *Aloe ambigens*; F- An unidentified species of *Aloe*.

Fig.17 A-C : Seed pod formation in Aloes. a. *Aloe tenuior*; b. *Aloe greatheadii*; c. *Aloe ferox*

damaged with bacterial disease were kept under tree shade on dried grass heap in open air environment without contact with soil for 30 days in the month of January 2016. After after one month of open air incubation, root initiation was observed in all six damaged plants (Fig. 18).

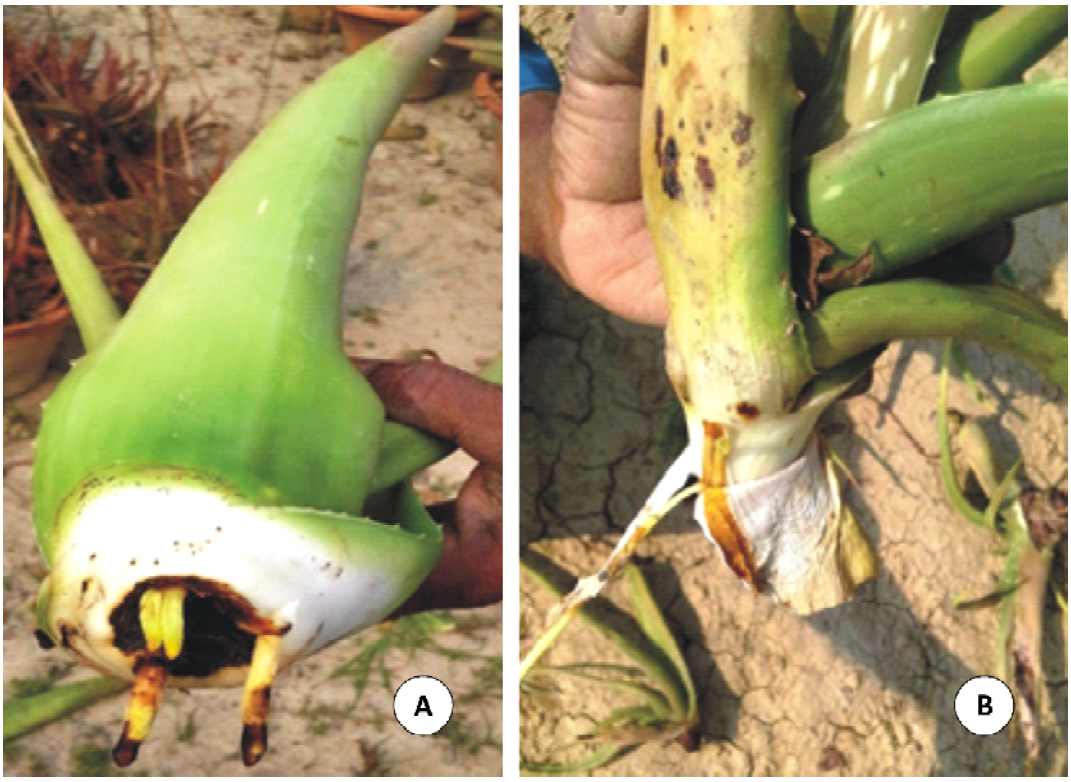


Fig. 18 A-B : Root initiation in damaged *Aloe vera* plants

PLANT DIVERSITY, SYSTEMATICS AND HERBARIUM

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

Technical Staff: Sandeep K Behera, B Datt, KK Ingle, KK Rawat, V Sahu, K Toppo, Sushma Verma

Grant-in-Aid Projects

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

The naturally occurring algal blooms are cost effective feed for biodiesel production. Three common bloom forming algal strains namely, *Neochloris* sp. (NBRI 081), *Nannochloropsis* sp. (NBRI 082) and *Chlorella* sp. (NBRI 070) were selected for mass culturing in close and open pond systems. In open pond culturing was carried out by adding urea and single superphosphate (SSP) as nutrient sources. The cultures were sedimented due to the process of auto-flocculation upon the consumption of nutrients, therefore, no external flocculating agent was required for harvesting the biomass. *Nannochloropsis* sp. (NBRI 082) was found to be the fastest growing and with the highest biomass content of 435 mg/L, followed by *Neochloris* sp. (359 mg/L) and *Chlorella* sp. (326 mg/L) during the stationary phase in open pond (Fig.1).

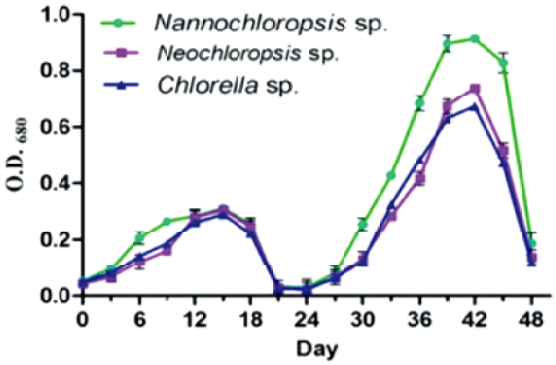


Fig.1. Growth curve of mass culture of algae in open pond

Many important fuel properties of biodiesel are highly influenced by the Fatty acid (FA) profile of the algae. FA profile showed the abundance of FA with carbon chain length of C16 and C18. Fatty acid profile of NBRI 081, NBRI 082 and NBRI 070 grown in photo-bioreactor (closed system) showed palmitic acid (16:0), palmitoleic acid (16:1) and oleic acid (18:1) as the dominant FAs. The study indicates that all the three algal strains were capable of economic biomass production that can be available as biodiesel feedstock and other industrial applications.

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

The agrobacterium based transformation, RNAi silencing of competitive pathways and overexpression of energy producing enzymes have been studied for metabolic divergence of energy producing pathways in *Scenedesmus* sp. (NBRI012) to ameliorate hydrogen. Gene sequences of Hydrogenase (Hyd), Alcohol dehydrogenase (Adh) and PEP carboxylase (PEPC) of related organisms such as *Chlamydomonas reinhardtii* (AJ620190.1 and XM_001703533.1), *Volvox carteri* f. *nagariensis* (XM_002958307.1), *Chlorella variabilis* (XM_005845555.1 and XM_005850201.1) and *Polytomella* sp. (AJ495765.2) were aligned through CLUSTAL-W and MultAlin programme. Conserved sequence motifs were chosen and primer has been designed. Amplied PCR product of ~2.3Kb and ~1.1Kb in size, expected to be Adh and Hyd respectively were purified from the gel and cloned into pBlueScript_II_SK(+)-cloning vector (Invitrogen). Vector was transformed in *Escherichia coli* DH5α and screened by blue-white selection. Plasmids were extracted and cloning was confirmed by restriction digestion. Sequencing of the plasmid clones is in progress.

Screening of potential algal species for bio fuel production

Algal biofuel, due to its renewable and ecofriendly nature, has gained huge popularity in the recent years. It is believed that, due to its huge diversity, it can completely replace the need of fossil fuels. In the present study a total of 16 unialgal strains were screened for their biofuel potential. The growth rate, doubling time and lipid concentration of algae are given in Table 1.

Higher growth rate was observed in *Scenedesmus abundans, S. quadricauda, Chlamydomonas angulosa* and *Selenastrum minutum*, whereas lowest growth rate was recorded in *Anabaena sphaerica, Phormidium tenue, Pediastrum duplex* and *Spirogyra plena*. Time required to double the biomass content is called as the doubling time of the algae. The doubling time of *S. abundans, C. angulosa, S. minutum* and *S. quadricauda* was approximately 3 days, whereas the doubling time of *A. sphaerica, P. tenue, P. duplex* and *S. plena* was 6 to 7 days.

Table. 1.Growth rate, doubling time and lipid concentration of the algae

Name of the algae	K (day^{-1})	T_d (d)	Lipid concentration (mg/L)
Scenedesmus abundans	0.206	3.364	222.08 ± 8.1
Scenedesmus quadricauda	0.175	3.953	91.14 ± 2.4
Scenedesmus dimorphus	0.172	4.035	127.74 ± 6.0
Nannochloropsis oculata	0.157	4.404	95.77 ± 1.7
Monoraphidium pusillum	0.139	4.993	73.53 ± 3.8
Golenkinia radiata	0.116	5.998	33.74 ± 0.9
Chlamydomonas angulosa	0.199	3.476	78.33 ± 2.2
Merismopedia punctata	0.127	5.444	19.68 ± 0.4
Phormidium tenue	0.095	7.273	15.62 ± 0.9
Selenastrum minutum	0.189	3.663	70.80 ± 1.9
Ankistrodesmus falcatus	0.135	5.134	76.0 ± 3.1
Chlorella vulgaris	0.150	4.619	70.37 ± 4.0
Pediastrum duplex	0.099	6.972	14.97 ± 0.6
Coelastrum proboscideum	0.154	4.508	20.52 ± 0.4
Spirogyra plena	0.104	6.697	25.52 ± 1.0
Anabaena sphaerica	0.095	7.273	14.25 ± 1.1

K, growth rate; T_d, doubling time

Biomass and lipid content of different algae are given in Figure 2. Highest biomass content was found in green alga *S. abundans* followed by *C. angulosa*, whereas the lowest biomass content was recorded in *A. sphaerica*. As far as lipid content was concerned, like the biomass content, highest lipid content was found in *S. abundans*. As a result it was concluded that, due to its high growth rate, biomass and lipid content, fresh water microalga *S. abundans* can serve as a potential feedstock for biofuel production.

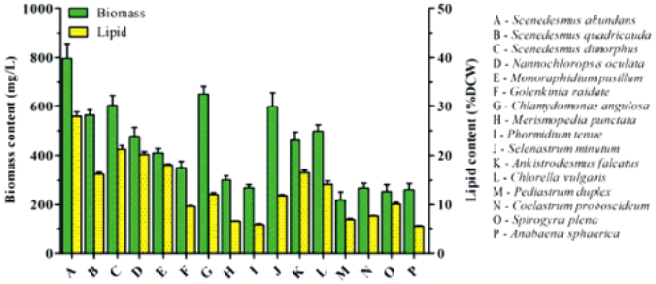


Fig. 2. Biomass and lipid content of the algae

Isolation, screening and nutritional profiling of promising microalgal strains

Four pure cultures of algae i.e. *Chlorella vulgaris* Beyerinck (Beijerinck), *Chroococcus minor* (Kutzing) Nageli, *Haematococcus pluvialis* Flotow and *Sphaerocystis schroeteri* Chodat were selected for the growth, biomass productivity and nutritional studies in three different media (BBM, BG-11 and TAP Media) (Fig. 3). It was found that all the four algal strains showed better biomass productivity in TAP media in comparison to the BG-11 and BBM, and *C. vulgaris* showed highest biomass productivity (0.80 mg/L). The protein content was highest in *C. vulgaris* (19.37 %) and lowest in *C. minor* (12.15%). Lipid content was found to be highest in *H. pluvialis* (8.42%), followed by *C. minor* (6.92%). The better results of the pigment content were found with the DMSO method as compared to the Acetone method. The highest chlorophyll content was found in *H. pluvialis* (1.86±0.023mg/g) and lowest in *C. vulgaris* (1.49±0.021mg/g).The high energy content of the biomass was found in *C. vulgaris* and *H. pluvialis* with 297.65 kJ per 100 gm and 295.02 kJ per100 gm, respectively.

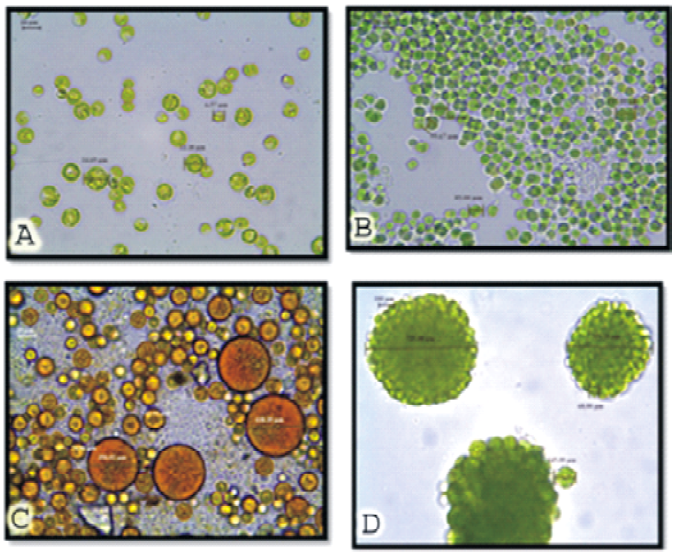


Fig.3. Algal taxa utilized for growth and nutritional study A- *Chlorella vulgaris;* B-*Chroococcus minor;* C-*Haematococcus pluvialis* and D-*Sphaerocystis schroeteri.*

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

Algal strains were isolated and purified from carpet effluent of Bhadohi district. They were identified based on microphotographs and standard manuals. The cultures were maintained in $BG11^+$ liquid growth medium and $BG11^+$ agar slants. The axenic algal cultures were used for genomic DNA isolation. PCR amplification of 16S rRNA gene in cyanobacteria (*Oscillatoria* sp., *Phormidium* sp.,

Nostoc sp. and *Anabaena* sp.) and 18S rRNA region in green algae (*Chlorella* sp., *Nannocloropsis* sp. and *Chlamydomonas* sp.) was carried out.

Alpine ecosystem dynamics and impact of climate change in Indian Himalaya

One hundred and twenty two species of lichens belonging to 47 genera and 24 families at five major sites of Tawang district of Arunanchal Pradesh were enumerated. Among the five localities Tawang exhibited maximum diversity of lichens, represented by 48 species followed by Highest Summit Point (HSP) 3, HSP 1, 2 with 48, 41 and 28 species, respectively. Most of the HSP sites exhibited dominance of Juniperous and Rhododendron shrubs which provided suitable habitat for different taxa of lichens. The species of lichens genus *Cladonia* exhibited maximum diversity in HSP 3 and HSP 2. Species of *Usnea* and *Bryoria* were common in HSP 3 together with crustose lichen species of the family Graphidiaceae. Parmeliaceae was the dominant lichen family in the study area, represented by 51 species, followed by Cladoniaceae and Lecanoraceae with 16 and 7 species, respectively. Each HSP site exhibited specific composition of different and individual lichen taxa and were grouped into 18 lichen bioindicator communities. The HSP 2 and 3 dominated with maximum number of lichen communities in comparison to HSP 1 whereas HSP 2 was represented only by Graphidioid, Pyrenulioid, Peltuliod and Physcioid lichen communities. The dominance of macro lichens present in the study area clearly indicates Tawang as an undisturbed site and the present records of communities as well as individual species will help as bioindicators for monitoring efforts in near future.

The lichen communities are indirectly affected by climate through its effects on forest composition and disturbance regimes. Expansion of forest extent would allow epiphytic macrolichens to expand into habitat that currently lacks suitable substrates. While climate appeared to be the strongest driver of community composition and individual species modelled, several species of *Ramalina*, *Parmotrema* and *Heterodermia* were favoured by hardwood substrates. The hardwoods were more abundant in the lower foothill area with luxuriant growth of such species.

The exceptionally diverse, abundant epiphytic lichen communities in the area comprised about 92 macrolichen and 30 microlichen taxa. The dominance of Parmeliaceae and Cladoniaceae in all the HSPs clearly indicates the undisturbed soil ecosystem and thinned out forest area. The crustose growth form of Lecanorioid lichens indicates well illuminated environmental conditions of the habitat. The communities rich in cyanolichens, Alectorioid and Usnioid forms often considered to air quality and forest continuity.

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

Nine field surveys were conducted in 35 districts of western Uttar Pradesh for documentation of lichen diversity. About 500 lichens samples were collected which were identified as belonging to 48 species in 25 genera and 16 families. The crustose lichens dominated the lichen biota with 31 species while foliose lichens were represented by only six species. A total of eight taxa (*Arthonia polymorpha, Arthothelium chiodectoides, Diorygma soozanum, Graphis pyrrhocheiloides, Opegrapha microspore, Porina internigrans, Pyrenula leucotrypa, Pyxine reticulata*) were reported for the first time from Uttar Pradesh.

A total of 10 'Biodiversity Awareness Workshops' were conducted in different parts of Uttar Pradesh, namely -1. Forest Training Centre, Hastinapur, Meerut; 2. Bareilly College, Bareilly; 3. Shri Gandhi Mahavidhyalaya, Sidhauli, Sitapur; 4. Dudhwa Tiger Reserve, Dudhwa; 5. Mewalal Ram Dulari Vidhya Mandir Inter College, Majhagain, Kheri; 6. Department of Botany, University of Allahabad, Allahabad; 7. Shri Shakti Degree College, Shankhahari, Ghatampur, Kanpur; 8. Department of Botany, Bappa Sri Narain Vocational P.G. College (KKV), Charbagh, Lucknow; 9. Sree Nagar Jee Vidhyalay Inter College, Krishna Nagar, Kanpur; 10. Sacred Heart Degree College, Sitapur. A total of 851 students from class IX to Post Graduate levels participated in these workshops.

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

Extraction of lichen natural thallus (NBRI-LS8 & NBRI-LS9) by cold and hot successive soxhlet methods was accomplished with five different non-polar to polar solvents. Percentage yield of each solvent extracts in these two species was calculated i.e. 19.96% in acetone and 16.66% in 50% EtOH for NBRI-LS8 and 10.22% in acetone and 14.92% in 50% EtOH for NBRI-LS9, respectively. Standardization of the protocol of extracting compounds was done to select the lichen specie having maximum solvent specific yields which was characterized for qualitative and quantitative assays/ detection of secondary compounds and functional groups. Development of compound specific solvent systems, fractionations of non-polar to polar compounds and their isolation was carried out. Secondary markers viz. fatty acids, flavanoid, sugar, cartetenoids, terpenoids, alkaloid and anthraquinones depsones, depsides and lichen acids/ were identified through TLC profiling. Six known lichen acids were purified and isolated using P-TLC & column chromatrography in lichens NBRI-LS6, NBRI-LS7, NBRI-LS9.

Twenty eight fractions from acetone extracts and 10 fractions from 50% ethanol extracts of NBRI-LS9 and 15 fractions of NBRI-LS8 through column chromatography were isolated. HPLC analysis of these fractions is in progress.

Five pure compounds isolated through PTLC and column chromatography were characterized through LC-MS. Chemical profiling of purified compounds i.e. fumarprotocetraric acid, usnic acid, diffractic acid alectoronic acid and collatronic acid through FTIR has been carried out in four lichen species. In addition chemical profiles of column fractionated and purified compounds of five lichen species extracts (NBRI/L10/ae1-CoFr_L6F3, L1CFp, L1-ECp, L1-LRp, L1FCp) were also obtained by FTIR.

Fractionation, isolation and purification of compounds in coded extracts (NBRI/L10/ae1 and MSSRF/L2ae2) along with four pure lichen acid compounds has been accomplished and compounds obtained are under characterization through UV, IR and MS. Specific codes are given specific to species, solvent, extracts, solvent systems, compounds at different purification level/fractions and analytical methods, to maintain the compound standards, comparison with commercial standards available, if any, and generate library of lichen compounds.

Develop a system to monitor climate change with lichens in India

During the reporting period, five decade old lichen specimens preserved in the herbarium from Darjeeling district were compared with recent collection with respect to change in lichen flora, metals and PAHs accumulation and carbon isotope composition ($\delta^{13}C$) to explore the changes in climatic conditions of the area. The temperature profile of the study area showed a continuous rise with temperature maxima having registered more increase over the years as compared to the temperature minima, indicating the mean temperature increase from 12 to 18°C (max.) and -2 to 8°C (min.) together with increase in mean relative humidity from 84% to 95%. In contrast, the mean precipitation decreased from 2500 to 1800 mm between the time periods 1966-2015 (data from IMD, Pune).

The observation of meteorological data indicated significant change in climatic condition in the study area over a period of nearly half a century. The study clearly demonstrates an increase in anthropogenic pollution and its impact on lichen communities that have changed significantly during the past five decades. Usnioid, a pollution sensitive community, drastically decreased, while Physcioid community increased significantly. Lichinioid and Calcioid communities were wipedout completely from the study area while Lobarian community got introduced in the recent past.

The carbon isotope composition ($\delta^{13}C$) of lichens showed that the ^{13}C has increased in the recent collections, which is in contrast to the assumption that anthropogenic emission leads to ^{13}C depletion in air and increased carbon discrimination in flora. Thus, post-industrial revolution, the abrupt changes in the environment have influenced CO_2 diffusion and/ C fixation of (lower) plants either as an adaptation strategy, such as resistance to water stress, or due to toxicity of pollutants.

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

A total of 58 lichen species were recorded from 24 locations in and around Kotdwar and Lansdowne area in Garhwal Himalayas at different altitudes ranging from 400 to 1850 m. Influence of climatic condition and topography on the uptake of Persistent Organic Pollutants (POP) in the Himalaya has been studied, which showed influence of long range transport of POPs in the Himalayan ecosystem.

Primary metabolites and the plausible environmental significance have been studied in some selected lichen species. Depending on the environmental condition, lichen species display different metabolite patterns, which appear to be an important contributing factor determining the ubiquity of the species.

Characterization of UV protecting compounds in Indian lichens has been carried out. Imino Mycosporine like Amino Acids (MAAs) has been characterized for the first time in Indian cyanolichens. Lichen biomonitoring data has been used as valuable proxy for predicting the reasons for increase in extreme weather phenomenon in the Himalayas.

The influence of aspect and altitudinal gradient on the quantitative profile of lichen metabolites-atranorin and salazinic acid in the three lichen species belonging to Parmeliaceae family collected from high altitude area was carried out using LC-MS/MS technique. Results indicated influence of incident radiation showing significant variation in the chemical content with the increasing altitude.

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

Ecological studies on lichens of Nilgiri Biosphere Reserve (NBR) and Silent Valley National Park (SVNP) were carried out and compared. The dense canopy of the forests in SVNP restricts the entrance of direct sunlight, which is an essential factor for lichen growth. Therefore, the observed pattern in the distribution of lichens in forests

patches of SVNP is totally different as compared with localities within NBR. Only a few species were found growing in totally undisturbed areas. *Acanthothecis*, *Ocellularia*, *Porina*, *Hemithecium*, *Graphis*, *Stirtonia*, *Cryptothecia*, *Phyllopsora* and few members of the family Pyrenulaceae were the common micro-lichen genera, showing their dominance in the forests. In macro-lichens only *Heterodermia* and *Leptogium* were the two genera commonly distributed in both the areas of the valley.

A comparative evaluation of lichens in SVNP and NBR revealed that NBR was rich in lichen diversity. The *Graphidaceae* flourish well and offer a remarkable diversity in NBR when compared with SVNP. Despite the variations in macro-habitat, tree species, trunk girth, bark texture, and other microclimate variables, it is noteworthy that thelotremoid and graphidioid group of taxa exhibit a uniform pattern of association with other lichens on different trees of tropical rain forests in the NBR. Taxa in their groups show ecological similarities and share habitats over a broad (300–2100 m) altitudinal range. Some members of thelotremoid group mostly inhabit the wide tree trunks and associate with other group of lichens in comparatively dry but shaded undisturbed to semi-disturbed mature secondary lowland forests. Considering the distribution and growth pattern of other indicator lichens, member of the family Graphidaceae is given particularly more emphasis due to its high species richness, broad distribution pattern and mostly corticolous (bark or tree inhabiting) habitat.

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

Monophyly and genetic distances in 13 lichen-forming fungal species belonging to Parmeliaceae were assessed through sequence analysis of the nuclear ribosomal internal transcribed spacer region (ITS). All *Usnea* species in India were successfully discriminated using the ITS sequence analysis. All phenotypically circumscribed species were recovered as well-supported, monophyletic clades. Furthermore, the data support a barcode gap among congeners (i.e., *Cornicularia, Usnea*, and the Cetrarioid clade) for all *Usnea* species investigated. However, high intraspecific genetic distances suggest the potential for previously unrecognized species lineages in at least five species: *Cornicularia normoerica, Usnea longissima, U. baileyi, U. subfloridana* and *U. himalayana.*

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

The revisionary studies on species of lichen genus *Xanthoria sensu lato* has been initiated in collaboration with Ukrainian Lichenologists. The study will examine segregation of different genera and species of *Xanthoria sensu lato* using morphological, anatomical, chemical and molecular studies.

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

In order to collect primary data on floristic diversity along river Ganga four collection trips were made during the pre-monsoon and post-monsoon period in the year 2015. Explorations in various habitats enabled to record 368 species of angiosperms, 17 species of pteridophytes, 19 species of bryophytes, 33 species of lichens and 37 taxa of algae from West Bengal (Kolkata, Hooghly, Gangasagar, Farakka, South 24 Parganas), Bihar (Patna, Bhagalpur), and Uttar Pradesh (Allahabad, Banaras, Kanpur, Kannauj and Narora) and Haridwar (Uttarakhand).

The algal samples collected from all these sites in West Bengal, Bihar and Uttar Pradesh represented 37 taxa belonging to 24 genera of five classes, namely Cyanophyceae, Chlorophyceae, Bacillariophyceae, Euglenophyceae and Rhodophyceae. The maximum diversity of algae was recorded from Kannauj and Narora sites followed by Kanpur and Hoogly.

Lichens specimens collected from the Narora and Kannauj sites revealed the occurrence of 12 species belonging to 11 genera and 9 families. The existing lichen diversity in Narora indicates eutrophic conditions. As the site is near to nuclear power plant, influence of radioactive compounds cannot be discarded, which may be influencing lichen diversity along with other microclimatic factors. The overall lichen diversity in Farakka region was represented by 10 families, 13 genera and 17 species. More than 100 lichen samples were collected from 12 localities along the riverside area of Kolkata, Hooghly and South 24 Parganas districts. The lichen diversity of the area was dominated with crustose lichens belonging to the genera *Graphis, Bacidia, Pertusaria, Lichenographa, Pyrenula, Opegrapha* and *Buellia.* Only two foliose lichens (*Pyxine* and *Dirinaria*) were recorded in this area. The most common lichens found in the area were *Graphis, Lecanographa* and *Pyxine.* Approximately 100 specimens were collected from Bhimgoda barrage, Haridwar. The lichen diversity of the area was dominated with crustose lichens genera, viz. *Bacidia, Lecanora, Buellia, Graphis* and *Opegrapha.* Few foliose lichens belonging to the genera *Dirinaria, Hyperphyscia, Physcia* and *Pyxine* were also recorded.

A total of 19 species of bryophytes (16 species in 13 genera of 9 families of Mosses and 3 species belonging to 3 genera of 3 families of Liverworts) were recorded from the Ganga river side. The survey and study revealed occurrence

of *Archilejeunea minutilobula* Udar *et* U.S. Awasthi (Fig. 4), as a new addition to the bryoflora of Gangetic Plains.

In all, 17 species of pteridophytes belonging to 12 genera under 9 families were recorded from all the study sites in West Bengal, Bihar and Uttarakhand during the pre and post monsoon period. This included 9 species belonging to 8 genera under 7 families from Gangasagar, Diamond Harbour, Srirampore and Hooghly; 11 species in 9 genera and 8 families from Farakka region; 11 species in 8 genera and 7 families from Haridwar region. The following five species were common in all the three sites: *Ampelopteris prolifera* (Retz.) Copel., *Christella dentata* (Forssk.) Brownsey & Jermy, *Diplazium esculentum* (Retz.) Sw., *Marsilea minuta* L., and *Pteris vittata* L. Among the species of *Adiantum*, *A. capillus-veneris* L. was recorded from the first and third sites, *A. philippense* L. from the first and second sites, and *Adiantum incisum* Forssk. from the second and third sites. *Drynaria quercifolia* (L.) J. Sm. was present in the first and third study sites. Eight species were found their occurrence only in any one of the three sites: *Phymatopteris evenipes* (Hook.) Pich. Ser. in the first, *Asplenium nidus* L., *Christella parasitica* (L.) Lev., *Pyrrosia mannii* (Gies.) Ching. in the second, and *Azolla pinnata*, *Christella* sp., *Christella appendiculata*, *Equisetum ramosissimum* in the third site.

Study of Bryophyte diversity in the Eastern Ghats

Explorations were made in Kondapali fort (Krishna), Bhairavkona, Nemaligunda Ranganayaka Swamigundam, Rajiv Gandhi Reserve Forest, Nagarjuna Sagar, Srisailam Tiger Reserve (Prakasam), Nallamalas Forest Reserve (Kurnool), Tribal museum, Sunkarmetta, Galikonda, Balluguda, Borra caves, Anantagiri, Katki Waterfall (Araku Valley, Vishakhapatnam) of Eastern Ghats in Andhra Pradesh. About 264 specimens were collected. A critical investigation and identification of the taxa of Eastern Ghats revealed the occurrence of 57 taxa of mosses belonging to families viz., Archidiaceae, Bartramiaceae, Brachythe-ciaceae, Bryaceae, Erpodiaceae, Fabroniaceae, Fissidentaceae Funariaceae, Hypnaceae, Meteoriaceae, Neckeraceae, Orthotrichaceae, Plagiothe-ciaceae Pottiaceae, Pterobryaceae, Racopilaceae, Sematophyllaceae, etc. and 16 taxa of liverworts belonging to families viz., Aytoniaceae Frullaniaceae, Geocalycaceae, Lejeuneaceae, Ricciaceae, Targioniaceae, etc. were identified. The morphotaxonomic details and illustrations of the taxa were prepared.

The study revealed *Archidium acanthophyllum* Snider as a new record to India. *Brachymenium sikkimense* Renauld & Cardot, *Frullania udarii* Nath et Singh, *Lejeunea minutiloba* A. Evans, *Fissidens taxifolius* Hedw., *Taxiphyllum maniae* (Renauld & Paris) M. Fleisch., *Frullania larjiana* Sushil K. Singh & D.K Singh and *Brotherella harveyana* (Mitt.) Dix. were new addition to south Indian bryoflora, while *Plagiochasma rupestre* (G. Forst.) Stephani, *Lophocolea heterophylla* (Schrad.) Dumort., *Meteoriopsis reclinata* (Müll. Hal.) M. Fleisch., *Homaliadelphus targionianus* (Mitt.) Dixon & P. de la Varde, *Lopholejeunea nilgiriensis* U.S. Awasthi, S.C. Srivast. & D. Sharma, *Erpodium mangiferae* Müll. Hal., *Pterobryopsis tumida* (Dicks. Ex Hook.) Dixon,

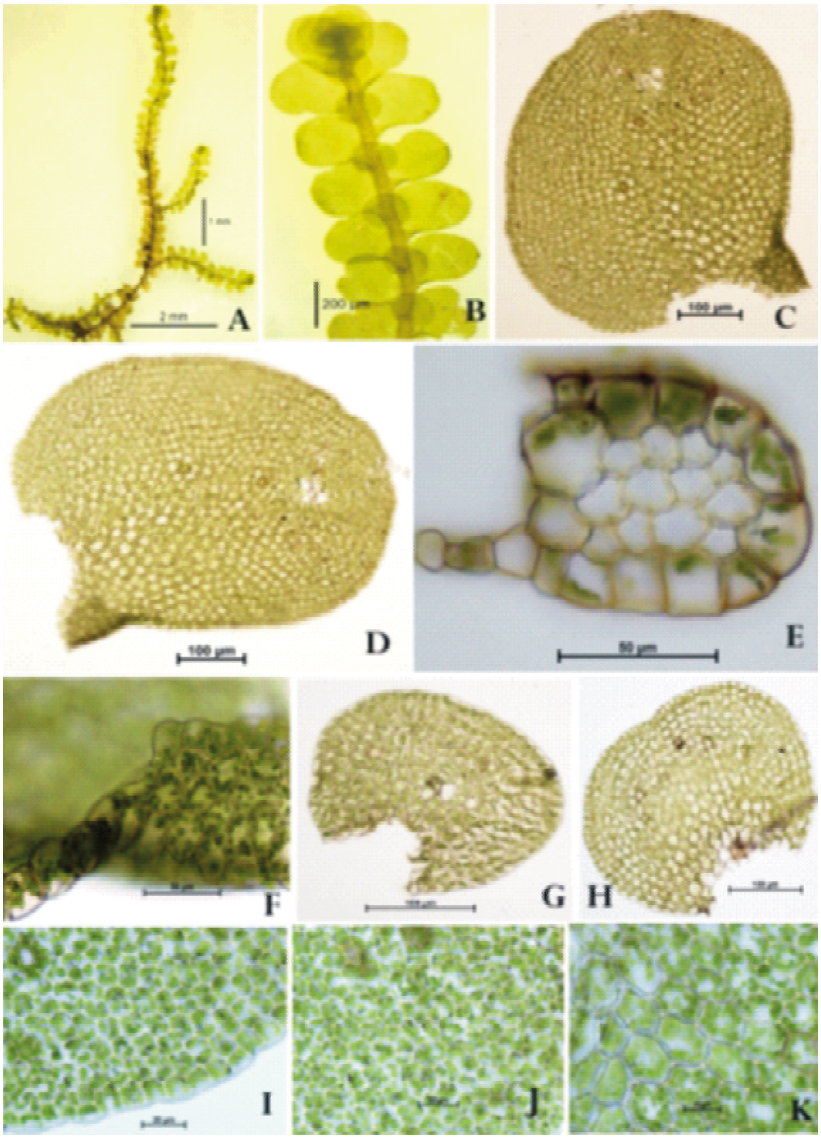


Fig.4A-K : ***Archilejeunea minutilobula*** Udar *et* U. S. Awasthi. A. Plant; B. A plant portion in Ventral view; C-D. Leaf lobes with lobule; E. Cross section of Stem; F. Leaf lobule; G-H. Amphigastria; I. Marginal cells of Leaf; J. Median cells of leaf; K. Basal cells of leaf.

Isopterygium albescens var. smallii (Sull. & Lesq.) Z. Iwats., *Barbula dharwarensis* Dixon and *Aulacopilum beccarii* (Müll. Hal.) Mitt. were new additions to Eastern Ghats.

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

In vitro propagation of two endemic and endangered bryophyte taxa viz., *Anthoceros macrosporus* Steph. and *Cryptomitrium himalayense* Kash., respectively, was carried out to study the morphogenesis and reproductive biology of these plants and also to standardize the protocol for propagation.

In case of hornwort *Anthoceros macrosporus*, spores were inoculated in Hoagland, KNOP's and Murashige and Skoog media. The spores germinated only in Half strength KNOP'S macronutrient medium. After 15 days of inoculation, spore coat dehisced along the triradiate mark and germ tubes were emerged (in *Anthoceros*, exosporous germination occurs). The germ tubes were enlarged slightly and divided vertically. Subsequently multicellular globose sporelings were directly developed by repeated transverse and longitudinal division. Smooth rhizoids were developed from cells of the sporeling. The spore coat remained intact and adherent at the base. Apical cells of the sporeling were dark green and contained dense cytoplasm and activated meristamatically to form young green thalli. These young thalli were further developed into mature thalli. The germination percentage remained very poor in case of this species.

Axenic culture of liverwort *Cryptomirium himalayense* was established from spores and propagated *in vitro* under a variety of culture media viz., half strength Knop's macronutrients as well as in Hoagland medium, MS, half strength Knop's macronutrients + Nitsch's trace elements, Gamborg B-5 medium without and with 1% sucrose under controlled physical conditions to determine the optimum conditions for the onset of sexual phase. Spores of *C. himalayense* germinated readily after 3-4 days of inoculation in half strength Knop's macronutrients medium and produced well differentiated fan shaped thalli in 70 days. When the thalli acclimatized on soil kept under long day regime with colder night (receiving 1200-2000 lux for 16 hours at 21°C and dark period of 8 hours at 15°C), induction of gametangiophore and gametangial disc took place. In about 20-25 days well developed umbrella shaped archegoniophores were developed in which archegonia and subsequently sporophyte formation took place.

Half Knop's macronutient medium was found best suited for the culture of *Anthoceros macrosporus* while half strength Knop's macronutrients and Hoagland medium were found the most suitable for *Cryptomitrium himalayense*.

Taxonomic study of tree flora of Uttar Pradesh

The purpose of the project was to provide a comprehensive taxonomy of all tree species, both in wild and cultivation, growing in Uttar Pradesh. During the reporting period, the detailed taxonomic information including correct name, important synonyms, local name, botanical characters, flowering and fruiting period, diagnostic features for identification, distribution and significant uses of about 150 tree species has been documented. Taxonomic data on each species has also been supplemented with colour photographs of habit, bark, blaze, leaves, inflorescence, flowers and fruits.

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

Systematic studies on *Aconitum*, *Consolida* and *Delphinium* of the tribe *Delphineae* were continued to comprehend the morphological and molecular evolution in these genera with respect to the Indian species.

Field surveys in Western Himalayas (Himachal Pradesh, Uttarakhand) and Eastern Himalayas (Sikkim) were undertaken and 19 species of the genus *Aconitum* were collected from natural habitat. Specimens of the target species housed in different national (CAL, DD, BSD) and international herbaria (BM, TH, K, E, NY and F) were also studied critically. Out of *ca.* 50 Indian species of the genera *Delphinium, Consolida* and *Aconitum,* critical studies on 13 species of *Delphinium,* 1 species of *Consolida* and 11 species of *Aconitum* have been completed with detailed taxonomic description of each species with their nomenclatural updates. Remarks on taxonomic affinities, phenotypic variability, and important notes were also documented along with live images and illustrations.

Cytological studies carried out in *Aconitum heterophyllum* and *A. violacium* showed irregular course of meiosis mainly in the pairing or segregation of chromosomes during cytokinesis. At diakinesis eight bivalents were discernible; three of these were with two chiasmata in each and five with a single chiasma. Such disturbances may be environmental, physiological, genetical or cytological. Irregular meiosis as observed in the two aconites may have a bearing on their genetic makeup and reproductive behavior.

Molecular phylogeny in seven species of *Delphinium* and eight species of *Aconitum* was examined using *trn*L-F sequence analysis. An MP tree generated from *trn*L-F sequence data segregated *Aconitum* and *Delphinium* in two distinct clades. In the *Aconitum* clade *A. leave*, *A. spicatum*, *A. palmatum*, *A. hookeri*, *A. heterophyllum*, *A. naviculare* and *A. laciniatum* formed a separate group distinct from *A. violaceum*. In case of *Delphinium* the *trn*L-F did not resolve

clear phylogenetic positions for the seven Indian species analyzed. The work is in progress with a combined analysis of ITS and *trn*L-F sequences of all target species of *Aconitum, Consolida* and *Delphinium* in India.

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

Established in the year 1972, the Kishanpur Wildlife Sanctuary (KWS) is located at 28^0 24'01" N and 80^{0}22'01" E in Uttar Pradesh. This project study aims at survey, collection and study of plants of KWS, so as to prepare a complete and up-to-date inventory of its floristic diversity with all the necessary information that would be of use in prioritizing conservation of RET, economically valuable and endemic plant taxa.

Extensive surveys carried out in KWS resulted in collection and identification of 150 plant species. Nomenclature has been updated for the identified plant species and specimens have been deposited in LWG. Ethnobotanical surveys revealed that a total of 63 plant species are used by local inhabitants for various uses like medicine, spices, condiments, handicraft and fibers. Conservation status has been assessed for two overexploited medicinal plant species, namely *Curculigo orchioides* and *Helminthostachys zeylanica*. Ecological studies were also conducted in the sanctuary at random by laying quadrates of 20 x 20 m.

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

Initiated in February 2016, this three year project envisages studying the systematics and molecular phylogeny of the Indian species of *Didymocarpus* (ca. 22 spp.) and *Henckelia* (ca. 32 spp.) using morphological as well as nuclear and chloroplast DNA sequence data. The main objectives of the project are: (i) Systematic revision of *Didymocarpus* and *Henckelia* in India, (ii) Molecular phylogenetic assessment of Indian *Didymocarpus* and *Henckelia* using nrDNA ITS and *trn*L-F spacer sequence data, and (iii) Elucidation of morphological character evolution in Indian species of *Didymocarpus* and *Henckelia*.

In-House Projects

Taxonomic studies and digitization of plant diversity of India

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

Algae

A total of 126 fresh water algal samples were collected from five districts of Uttar Pradesh Gangetic Plains, viz. Etawah, Sitapur, Fatehpur, Unnao and Lucknow. The algal samples were identified as 44 algal taxa under 33 genera and 6 classes. Class Cyanophyceae showed maximum diversity in the area with 16 taxa under 10 genera, followed by Chlorophyceae with 15 taxa (13 genera) and Bacillariophyceaewith 10 taxa (7 genera). The classes Xanthophyceae, Euglenophyceae and Chrysophyceae were poorly represented in the study area with only one taxon each.

Lichens

The flood zone areas along the river Ganga in Haridwar and Bhimgoda area were surveyed for collection of lichens. A total of 100 specimens of lichens were collected, which revealed the occurrence of 25 species of lichens with dominance of crustose lichens.

Bryophytes

Morphotaxonomic study on *Pogonatum* in India has been carried out with detailed account on 10 taxa *viz., Pogonatum cirratum* (Sw.) Brid. *P. contortum* (Brid.) Lesq. *P. microstomum* (Schwaegr.) Brid., *P. neesii* (Müll. Hal.) Dozy., *P. patulum* (Harv.) Mitt., *P. perichaetiale* (Mont.) A. Jaeger., *P. perichaetiale* subsp *thomsonii* (Mitt.) Hyvönen, *P. proliferum* (Griff.) Mitt., *P. subtortile* (Müll. Hal.) A. Jaeger, *P. urnigerum* (Hedw.) P. Beauv from different parts of India (Eastern Himalayas – Arunachal Pradesh, Darjeeling, Sikkim; NE- India: Western Himalaya – Uttarakhand, Meghalaya, Manipur, Kashmir, Himachal Pradesh) and South India (Eastern Ghats, Western Ghats).

Horikawaella subacuta (Herzog) S. Hatt. & Amakawa **(**Fig. 5**)**, a rare and endemic taxon of Indian bryoflora was recollected from Sikkim after a gap of about of 44 years since its original report in 1971. A complete morpho-taxonomic account of this species including fertile structures has been prepared and published.

A study on the hornwort diversity of Pachmarhi Biosphere Reserve has been undertaken and five taxa *viz., Anthoceros bharadwajii* Udar *et* Asthana, *Phaeoceros carolinianus* (Michx.) Prosk., *P. kashyapii* Asthana *et* Sriv., *P. laevis* (L.) Prosk. and *P. udarii* Asthana *et* Nath have been identified from this area.

In vitro propagation of the moss *Splachnum sphaericum* Hedw. and *Funaria hygrometrica* Hedw. was done.

Pteridophytes

Taxonomic study on 103 specimens Pteridophytes from Lakhimpur Kheri and Bahraich district revealed the occurrence of 23 species. Taxonomic studies on 204 herbarium specimens of Pteridophytes in LWG helped identify them at generic as well as species level. A checklist of Pteridophytes of Uttar Pradesh has been prepared.

Systematics and genetic diversity analysis in wild relatives of cucurbits

A revisit to the taxonomy and nomenclature of the *Trichosanthes tricuspidata- bracteata* complex in India has been made through herbarium and field studies. The study suggests that *T. tricuspidata* and *T. bracteata* are two distinct species and that *T. tricuspidata* does not occur in India. All the mainland Indian materials previously identified and reported as *T. tricuspidata* or *T. palmata* Roxb., belong to *T. bracteata*, and earlier reports of *T. tricuspidata* in the Andaman & Nicobar Islands represent *T. quinquangulata* A. Gray.

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

Ephedra gerardiana is an important medicinal plant known as 'soma' or 'somalata' in indigenous systems of medicine in India. Genetic diversity and population genetic structure in 55 accessions of *E. gerardiana* representing five populations from Western Himalyan region was analysed using DAMD and ISSR markers. Cumulative analysis of 25 markers (10 DAMD and 15 ISSR) revealed 90.34% polymorphism in *E. gerardiana*. The pair-wise genetic distances estimated among 55 individuals using Jaccard's coefficient ranged from 0.03 to 0.57. Mantel Z-statistics test between ISSR, DAMD and cumulative marker data matrices revealed best correlation coefficient (*r*) between cumulative v/s ISSR (0.83). The assignment of the assumed geographic populations revealed a strong population genetic structure. In the present study UPGMA, PCoA and Bayesian analyses revealed a strong geographical affiliation of the populations of *E. gerardiana*. AMOVA revealed that majority of the variations was restricted within populations (70%), whereas 30% variance was partitioned among populations and these values were highly significant (p <0.001). This pattern was further confirmed by genetic differentiation coefficient (Gst = 0.27) and the rate of gene flow (N_m = 1.35) among populations. The overall results indicate that the natural populations studied represented a single large population with high genetic diversity and moderate genetic differentiation.

Reproductive biology and regeneration potential of *Woodfordia fruticosa*

Highest pollen fertility (99.37%) was reported from plants growing near Yamuna Bridge, Mussoorie (Uttarakhand) while highest pollen sterility was recorded

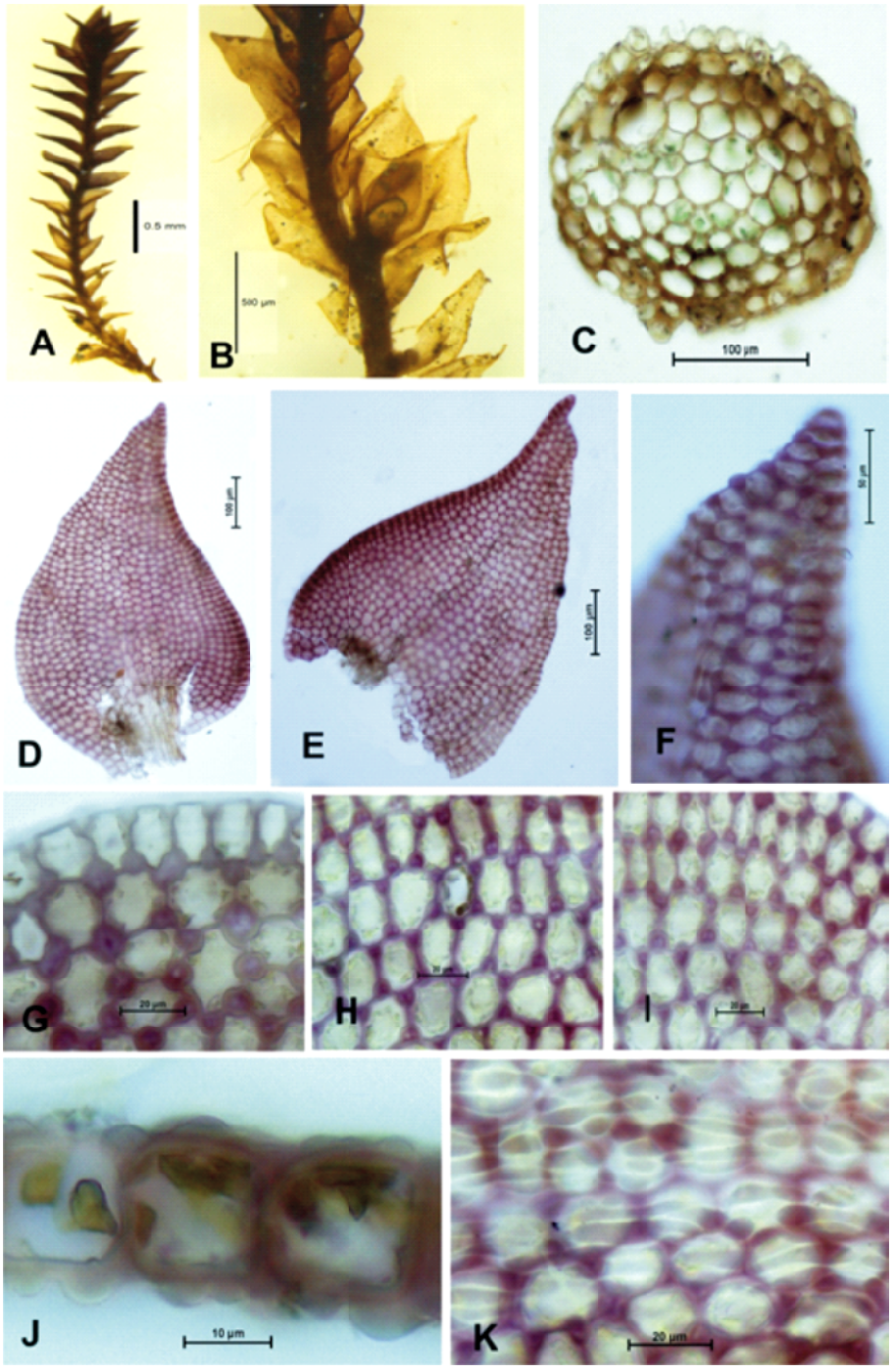


Fig. 5A-K : *Horikawaella subacuta* (Herzog.) Grolle. A. Plant habit. B. Plant portion, with female bracts and young perianth. C. Cross section of stem. D-E. Leaves. F. Apical cells of leaf.

from plants in Katerniaghat WLS (Uttar Pradesh). The percentage of unusual process of in-situ pollen germination (7.31%) was reported in *Woodfordia fruticosa* for the first time from Lansdown, Pauri Garhwal (Uttarakhand). The flowers from Katerniaghat WLS retained their stigma receptivity for a longest period even after the loss of pollen viability that can promote chances of cross pollination.

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

A total of 2298 specimens of algae, pteridophytes, bryophytes, lichens, gymnosperms and flowering plants collected from various parts of India have been processed and deposited in LWG to enrich the CSIR-NBRI Herbarium.

Herbarium- A National Facility

Under the National Facility-Herbarium, regular curatorial activities, such as general up-keep and maintenance were carried out, besides rendering technical assistance to visiting students and researchers from various R&D Institutes/Universities/Colleges, etc., particularly in identification of plants. Active link has been maintained through loan and exchange with other recognised herbaria of the country and abroad. The herbarium was enriched by incorporating fresh voucher specimens from different phytogeographic zones and states such as Andhra Pradesh, Bihar, Jammu & Kashmir, Himachal Pradesh, Madhya Pradesh, Sikkim, Uttarakhand, Uttar Pradesh and West Bengal.

The new additions included 762 specimens of seed plants and 1536 specimens of cryptogams (Pteridophytes-251, Bryophytes-492, Lichens-700, and Algae-93).

Herbarium Holdings	
Seed plants (Angiosperms & Gymnosperms)	1,01,826
Pteridophytes	5858
Bryophytes	16,306
Lichens	1,50, 350
Algae	2630
Carpological collections	16,000
TOTAL HERBARIUM HOLDINGS	**2,92,970**

PLANT ECOLOGY AND ENVIRONMENTAL SCIENCES

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

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

Grant-in-Aid Projects

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

Understanding the effectiveness of litter from tropical dry forests for the restoration of degraded lands

In order to determine the biological potential of species to aid soil restoration, it is necessary to evaluate litter production, its temporal variation, their rate of decomposition and nutrient release. This study examined patterns of litter fall production, quality of litter, and decomposition pattern of selected multipurpose tree species, viz., *Shorea robusta, Tectona grandis, Hardwickia binata, Butea monosperma* and dry mix trees in the dry tropical deciduous forest of Vindhyan highland, India. Average litter fall was 4.76 ± 1.21 Mg $ha^{-1}yr^{-1}$and varied significantly among species as follows: dry mix > *S. robusta* > *T. grandis* > *B. monosperma* > *H. binnata*. In the litter bag experiment, mass loss and mineralization rate were significantly different among the species and were assumed to be effected by the initial chemical composition of the litter. Annual relative mass loss was evidently higher in the dry mix trees, *H. binata* and *B. monosperma* followed by *T. grandis* and *S. robusta*. Nitrogen percentage increased significantly as decomposition progressed for all the species and a decrease was observed at the later stages of decomposition. The carbon percentage during decomposition showed a significant decrease throughout the study. Species with higher initial concentration of nitrogen and comparatively lower initial lignin decomposed at faster rate than the other selected species, viz., (dry mix > *H. binata* > *B. monosperma* > *T. grandis* > *S. robusta*). Mass loss showed significant positive correlation with N mineralization rate. Carbon, lignin, lignin:N and C:N showed significant negative correlations with decay rate (Fig. 1). The study recommended that for biological restoration of soil, mixed plantation would be most appropriate. While *H. binata* and *B. monosperma* individually shows the better results for the rapid recovery of degraded lands as their rate of litter decomposition is relatively faster than *T. grandis* and *S. robusta*. Although, *T. grandis* and S.*robusta* show higher litter production, their release of nutrient is slow into the soil. The faster the decomposition more is the release of nutrient in to the soil, thus increasing the rate of organic matter turnover and enhancing the nutrient cycling.

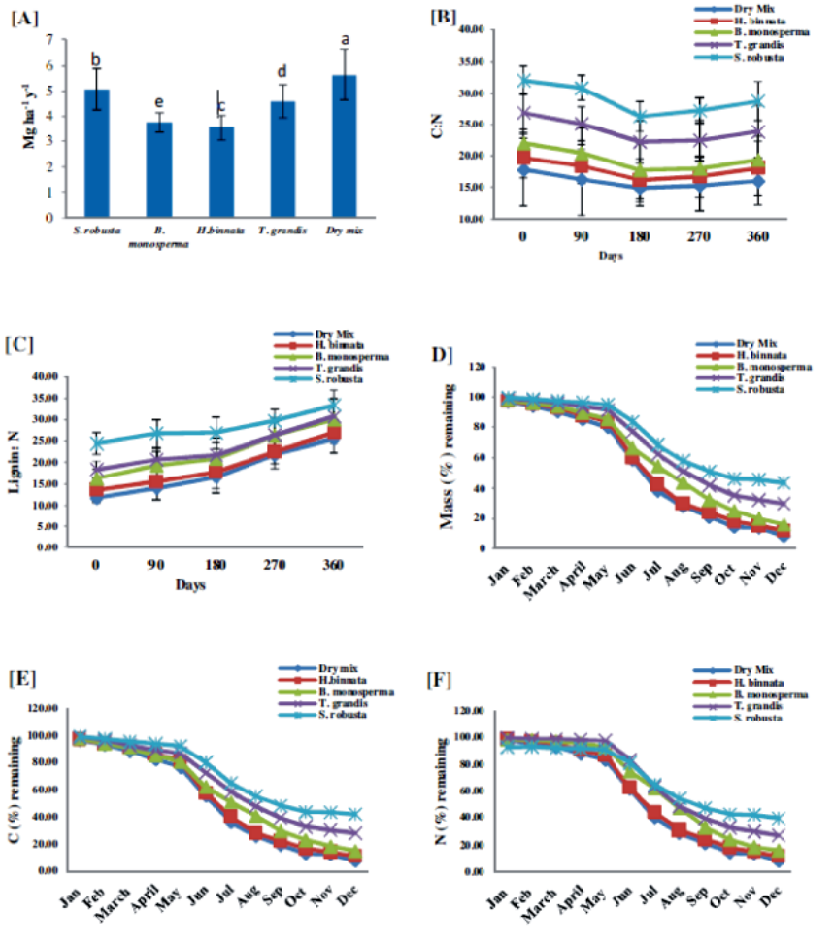


Fig.1. Litter dynamics of decomposing leaf litter in the tropical dry forests of India, Sonebhadra. Annual litter fall (Mg $ha^{-1}yr^{-1}$) [A] C:N [B] lignin:N [C] mass remaining [D]carbon (C) remaining percentage [E] nitrogen (N) remaining percentage [F]. Different lowercase letters indicate the significant differences between the different species.

Effect of long term land use systems on fractions of glomalin and soil organic carbon in the Indo-Gangetic plain

In this study, shallow soils were collected from 50-year-old monoculture treatments of undisturbed (*Dendrocalamus calostachyus, Mangifera indica* and *Saccharum munja*) and disturbed (*Oryza sativa* cultivated field) land use. Our results showed that compared to

undisturbed soils, soils under the disturbed use were dramatically depleted in soil organic carbon (SOC), particulate OC (POC), non-particulate OC (NPOC), GRSP, easily extractable GRSP (EE-GRSP) and difficult to extract GRSP (DE-GRSP) (Fig 2). The depletion in labile POC was found to be little higher than physically protected NPOC, and were almost similar among the fractions of GRSP (each decreased by 50%). Further, a linear correlation was found among the fractions of GRSP and SOC, and in turn resulted in the similar relationship with soils bulk density, porosity, pH, available phosphorus, total phosphorus, organic nitrogen, cations (calcium and potassium), arbuscular mycorrhizal (AM) abundance, and microbial activity (Fig 3). These results indicate that the factors involved in SOC accumulation simultaneously encourage AM proliferation and in turn GRSP enrichment. Apart from this, the higher contribution of GRSP-C in NPOC (13 to 17%), tended to increase with decreasing soil disturbance, suggesting the role of GRSP in accumulation and stabilization of SOC in this zone. A two component factor structure showed component 1 considerably occupied by fractions of GRSP, SOC and those other variables favouring GRSP and SOC, primarily scored by undisturbed (*M. Indica* and *D. calostachyus* treatments) soils. The second component which has fewer influence over soil variables, considerably occupied by microbial activity, electrical conductivity, cations and nutrients (available nitrogen, phosphorus), was also exemplified by undisturbed soils (except *D. calostachyus* treatment). Thus, improving GRSP and SOC stock in disturbed agricultural soil in studied area is of urgent requirement for the long-term goal of C sequestration and sustainable soil health. This finding should stimulate management plans for

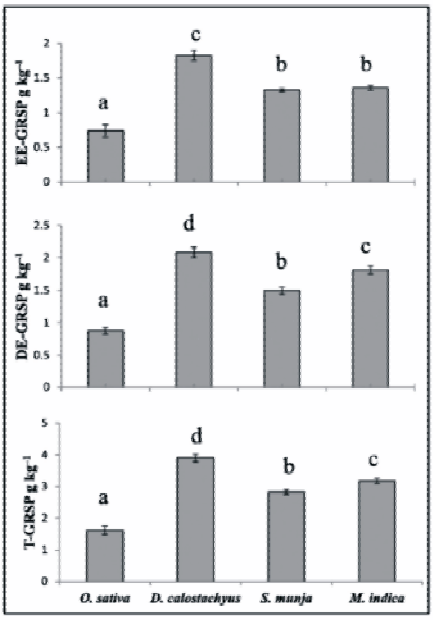


Fig.2. Fractions of glomalin related soil protein (GRSP) in studied Land-use System.

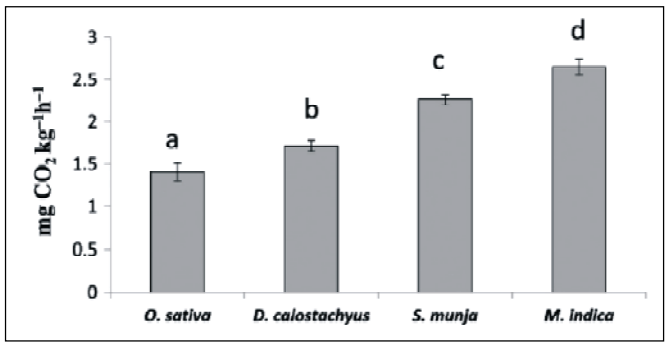


Fig. 3. Microbial activity in studied Land-use System

degraded lands aimed at recovering the landscape heterogeneity.

Study of the role of glutaredoxin in the arsenic detoxification in *Oryza sativa* L.

Arsenic (As) is an acute poison and class I carcinogen, can cause a serious health risk. Staple crops like rice are the primary source of As contamination in human food. Rice grown on As contaminated areas accumulates higher As in their edible parts. Glutaredoxins (GRXs) are a family of small multifunctional proteins involved in various cellular functions, including redox regulation and protection under oxidative stress. Despite the high number of GRX genes in plant genomes (48 GRXs in rice), their biological functions and physiological roles, particularly towards As stress, remain largely unknown.

The study investigated the role of GRX and associated antioxidant enzymes in the detoxification mechanism between arsenic (As) sensitive (Usar-3) and tolerant cultivar (Pant Dhan 11) of *Oryza sativa* against As(III) and As(V), under glutathione (GSH) enriched, and GSH deprived conditions. The overall growth and physiological parameters in sensitive cultivar were lower than the tolerant cultivar, against various treatments of As(III) and As(V). The As accumulation in sensitive cultivar was lower than in tolerant cultivar in presence of As(III) and As(V). However, the As translocation against As(V) was lower (35% and 64%, resp.) than that of As(III), in both the cultivars. In sensitive cultivar translocation of Zn and Cu was influenced by both As(V) and As(III) whereas, in tolerant one the translocation of Cu, Mn and Zn was influenced only by As(III). Translocation of Fe was negatively influenced by translocation of As in sensitive cultivar and positively in tolerant cultivar. Strong correlation between H_2O_2, SOD, GRX, GR, GST and GSH/GSSG in sensitive cultivar and between DHAR, APX, MDHAR and AsA in tolerant cultivar demonstrated the underlying preference of GSH as electron donor for detoxification of H_2O_2 in sensitive cultivar and AsA in tolerant cultivar. Higher expression of the four GRX and two GST genes in the sensitive cultivar than in tolerant

cultivar, suggests that under As stress, GRX are synthesized more in the sensitive cv than tolerant cv. Also, the expression of four GRX genes were observed to be higher against As(V) than As(III). The higher As accumulation in the tolerant cv is attributed to lower GST expression, due to the absence of thiolation and sequestration of As in roots, the translocation of As to shoots is higher.

Secondly, to understand the role of GRX against As stress in plants, functional characterization of the two arsenic-responsive rice GRX family proteins, OsGRX_C7 and OsGRX_C2.1 was carried out in transgenic *Arabidopsis thaliana*. Over-expression of OsGRX_C7 and OsGRX_C2.1 in transgenic *Arabidopsis thaliana* conferred arsenic (As) tolerance as quantified in terms of increase in germination rate, root growth assay, and whole plant growth. Also, the transgenic expression of OsGRXs displayed significantly reduced As accumulation in *A. thaliana* seeds and shoot tissues compared to WT plants during both AsIII and AsV stress. Thus, it is concluded that OsGRX_C7 and OsGRX_C2.1 seem to be an important determinant of As-stress response in plants. OsGRX_C7 and OsGRX_C2.1 transgenic showed to maintain intracellular GSH pool and involved in lowering AsIII accumulation either by extrusion or reducing uptake by altering the transcript of *A. thaliana* AtNIPs. Overall, OsGRX_C7 and OsGRX_C2.1 may represent a GRX family protein involved in As stress response and may allow a better understanding of the As induced stress pathways and the design of strategies for the improvement of stress tolerance as well as decreased As content in crops.

To understand the role of GRX to function as efflux proteins in order to avoid arsenic stress, functional characterization of the two arsenic-responsive rice GRX family proteins, i.e. GRX (OsGRX_C7and OsGRX_C2.1) were studied which were involved in the regulation of intracellular arsenite (AsIII) in *Saccharomyces cerevisiae* and *Escherichia coli* Both the OsGRXs genes were cloned and expressed in *E coli*. (Dars) and *S. cerevisiae* mutant strains (Dycf1, Dacr3). The expression of OsGRXs increased As tolerance in *E. coli* (Dars) mutant strain (up to 4 mM AsV and up to 0.6 mM AsIII). During AsIII exposure, *S. cerevisiae* (Dacr3) harboring OsGRX_C7and OsGRX_C2.1 have lower intracellular AsIII accumulation (up to 30.43% and 24.90%, respectively), compared to vector control. Arsenic accumulation in As-sensitive *S. cerevisiae* mutant (Dycf1) also reduced significantly on exposure to inorganic As. The expression of OsGRXs in yeast maintained intracellular GSH pool and increased extracellular GSH concentration. Purified OsGRXs displays in vitro GSH-disulfide oxidoreductase, glutathione reductase and arsenate reductase activities. Also, both OsGRXs are involved in AsIII extrusion by altering the Fps1 transcripts in yeast and protect the cell by maintaining cellular GSH pool. Thus, the results strongly suggest that OsGRXs play a crucial role in the maintenance of the intracellular GSH pool and redox status of the cell during both AsV and AsIII stress and might be involved in regulating intracellular AsIII levels by modulation of aquaporin expression and functions.

Role of micro-climate in soil Carbon sequestration in two pulses in Indo-Gangetic plains of Uttar Pradesh.

Soil carbon sequestration in pulse crops is influenced by environmental factors (e.g. soil temperature, soil moisture, etc.) and biological factors (e.g. soil organic matter content, above-ground canopy size and growth, etc.). There is little information available on the role of microclimate in growth and physiological performance in pluses in special reference to Indo-Gangetic Plains (IGP) of Uttar Pradesh. Therefore, the present study was carried out to assess the growth and physiological performance under experimental field trials in targeted pulse (Chickpea, *Cicer arietinum*).

Ten varieties of Chickpeas (HK94-134, JG-11, PANTG-186, JG-16, PUSA-362, Uday (KPG-59), Anubhav, Shubhra, Ujjawal, DCP-92-3) were tested for their growth and physiological performance at Biomass Research Centre, Banthra of CSIR-NBRI. All the varieties of Chickpeas were studied for their morphological characterization for plant height, stem diameter, number of branches, number of flowers and number of pods at different crop phenological stages. Leaf area index (LAI) was measured with LICOR-2000 Plant Canopy Analyzer in different vegetative, flowering, fruiting and senescence stage of the Chickpeas. Plants were harvested at full maturity stage, and aboveground biomass, belowground biomass, pod weight and total plant biomass were estimated. Different physiological parameters like photosynthesis rate, stomatal conductance, transpiration, water use efficiency (WUE) and vapor pressure deficit (VPD) were studied in detail for the above 10 targeted varieties.

Plant height was maximum in HK-94-134 followed by JG-11. Stem diameter was maximum in Shubhra followed by Ujjwal. Ujjwal variety observed maximum total biomass of 52.13±6.39 g among all 10 varieties followed by DCP-92-3 (29.6±4.86 g) and JG-11 (27.30±3.12 g). Maximum photosynthesis rate was observed in JG-11 and Ujjwal. Lowest photosynthesis rate was observed in PUSA-362, which also showed lowest total plant biomass. Overall Ujjwal performed best morphologically among 10 varieties.

In-House Projects

Bioremediation of organic and inorganic pollutants

Carbon sequestration in fly ash dumps: Comparative assessment of three plant association

The aim of the present study was to measure in-situ fly ash (FA) CO_2 flux from naturally vegetated and non-vegetated sites of FA dumps for identifying potential plant species for carbon sequestration by using an automated CO_2 flux system. The FA CO_2 flux was found to be higher in vegetated site than non-vegetated site due to higher root density and respiration. The presence of organic carbon, microbial activity and root biomass is important indicators for sequestration of atmospheric CO_2 in naturally vegetated site of FA dumps because of the fresh FA dumps are supposed to be initially free of organic carbon. Furthermore, in the naturally vegetated site, the FA CO_2 efflux rates were least in *Saccharum spontaneum* (lower by 84.29% and *Prosopis juliflora* (lower by 92.09%) association as compared to *Typha latifolia* association (Fig.4). Thus, the field results proved that *S. spontaneum* and *P. juliflora* association is potentially suitable for sequestering atmospheric CO_2 in the fresh FA deposited sites.

Brevundimonas diminuta mediated alleviation of arsenic toxicity and plant growth promotion in *Oryza sativa* L.

The present study, examined the possibility of improving phytostablization of arsenic through application of new isolated strain *Brevundimonas diminuta* (NBRI012) in rice plant [*Oryza sativa* (L.) Var.Sarju52] at two different concentrations 10ppm (low toxic) and 50ppm (high toxic)] of As. The plant growth promoting traits of bacterial strains revealed the inheritability of siderophores, phosphate solubilisation, indole acetic acid (IAA), 1-amino cyclopropane-1-carboxylic acid (ACC) demines production which may be associated with increased biomass, chlorophyll and MDA content of rice and thereby promoting plant growth (Fig. 5). The study also revealed the As accumulation property of NBRI012 strain which could play an important role in As removal from contaminated soil. Furthermore, NBRI012 inoculation significantly restored the hampered root epidermal and cortical cell growth of rice plant and root hair elimination. Altogether the study highlights the multifarious role of *B. diminuta* in mediating stress tolerance and modulating translocation of As in edible part of rice plant.

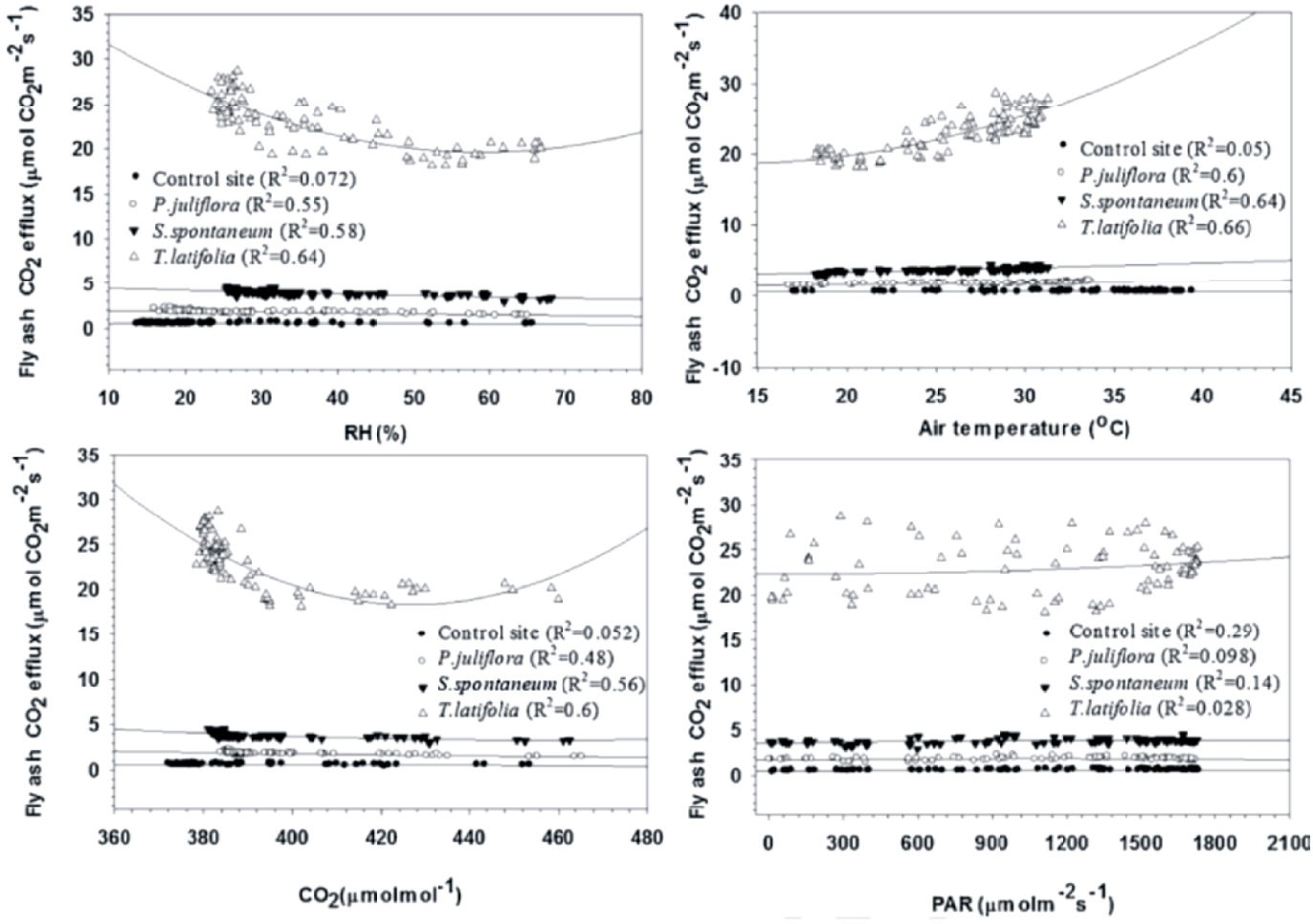


Fig. 4. Multiple linear regressions of FA CO_2 efflux against different parameters in three different plant species association

Study of the regulation of genes in the GABA shunt pathway of rice seedlings exposed to arsenite stress

The amino acid γ-amino butyric acid (GABA) is known to be induced in plants under abiotic stress as a stress response and also as stress modarator. Hence application of exogenous GABA can alleviate the stress effect in plants. With this hypothesis an experiment was conducted to investigate the regulation of genes of vital enzymes involved in GABA shunt pathway in rice seedlings exposed to GABA (i.e. 50 and 100 µM, abbreviated as GABA(L) and GABA(H), respectively and also in rice seedlings exposed to both 2 µg ml^{-1} of As(III) and GABA along with their respective controls. The treatment consisting of 2 µg ml^{-1} of As(III) supplimented with 50 and 100 µM GABA, which were abbreviated as As(III)+GABA(L) and As(III)+GABA(H), respectively. All the treatments were carried out in 4 replicates. Seedlings were harvested for analysis after 7d of treatments.

Glutamate decarboxylase (GAD), Glutamine synthetase (GS), Succinate dehydrogenase (SDH) and succinic semialdehyde dehydrogenase (SSADH) are the main enzymes of the GABA shunting pathway, which replenish the inhibited synthesis of succinate of the energy producing TCA cycle under abiotic stress condition. In the study, the results showed enhanced expression of the shoot GAD1 by 12.5 fold in plants receiving only GABA. On the contrary the expression of the gene in rice seedlings treated with As(III)+GABA(L) [2 µg ml^{-1} As(III)+50µM GABA], increased 7 fold, as compared to the control. In roots, the expression GAD1 decreased by 0.8 fold in GABA(H), as compared to the control. However, in the plant receiving only As(III), the expression of GAD1 increased by 1.5 fold, compared to the control. Similar to the regulation of GAD1, the expression of GAD2 increased in shoot of all the treatments receiving only GABA in a dose dependent manner, whereas, the expressions of GAD2 in shoots was down-regulated in all the treatments involving As(III). Whereas in roots, the expression increased by 2.5 and 1.8 fold in both the treatments of GABA(L) i.e. without As(III) and with As(III), respectively. On the other hand, the expression of GAD2 was down-

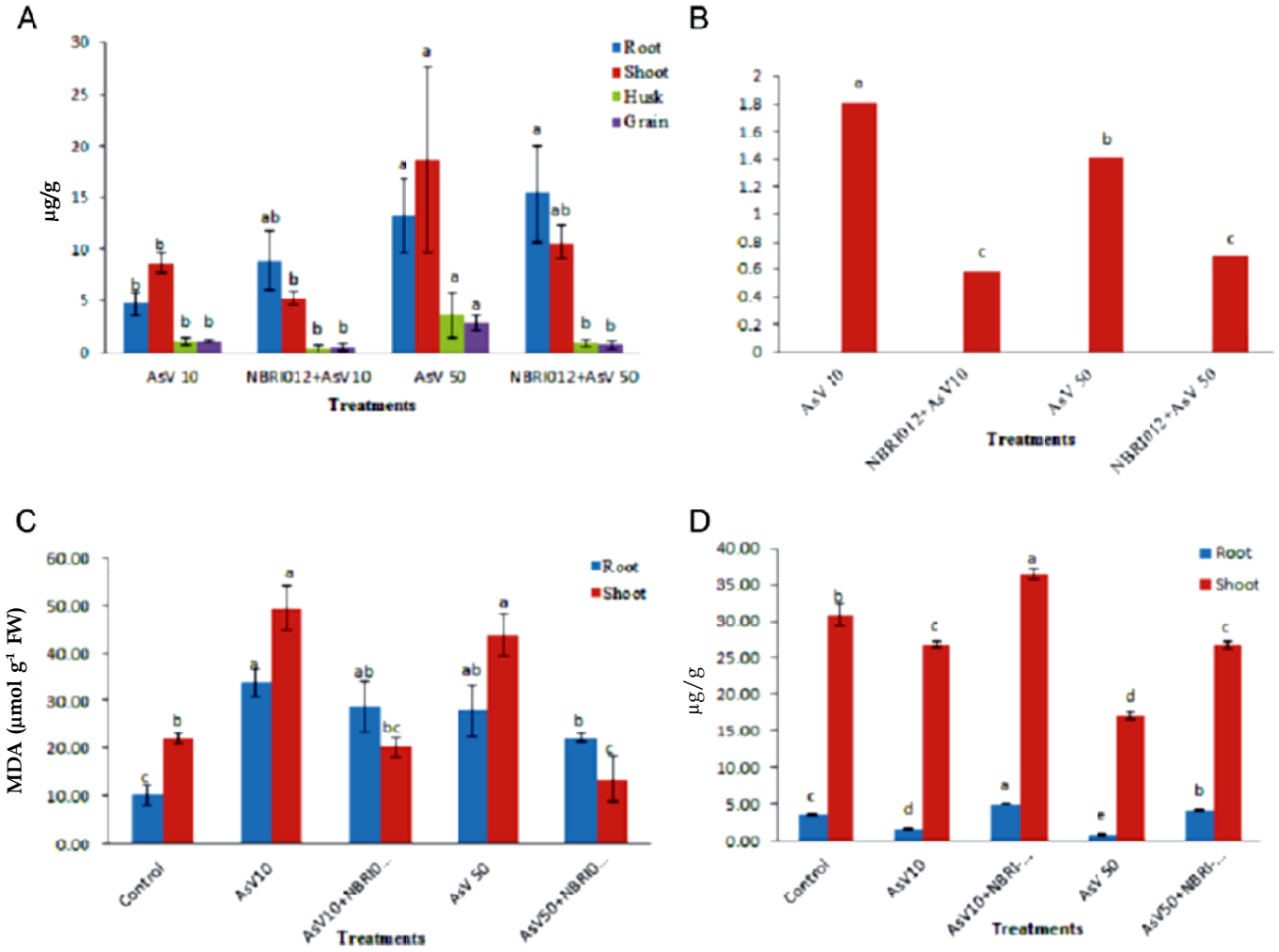


Fig.5. Distribution of arsenic in rice plant parts as a response of As amended soil (10 and 50 mg kg^{-1}) and bacterial inoculants (NBRI012). As concentration in root, shoot, husk and grain(A); (root to shoot) (B);effect of As on MDA content (C) and protein content (D)

regulated in the roots of plants exposed to higher level of GABA. The maximum down-regulation (0.5 fold) was observed in As+GABA(H), in comparison to the control. The expression of shoot and root GS was also highly upregulated in plants receiving only GABA [GABA(L) and GABA(H)]. The expression of GS in shoot of plant receiving higher GABA [GABA(H)] up-regulated by 3.7 folds, whereas, in the root of lower GABA [GABA(L)] the expression was up-regulated by 2.5 fold. As compared to the As(III), the expression of root GS was upregulated by 2.5 fold in As+GABA(L).

The function of SDH is conversion of succinate to the fumarate in TCA cycle. The expression SDH in shoots was down-regulated in all the treatments involving As(III), As(III)+GABA and GABA, compared to the control, except in GABA(H), where it increased. In contrary to the up-regulation of SDH in shoot SDH, exogenous application of GABA decreased the expression in the root SDH involving both the treatments with or without As(III), as compared to the control and A(III), except in root SDH where it was down-regulated by 0.85 fold in As(III)+GABA(H). Similar to the other gene expressions, shoot and root SSADH was also up-regulated with exogenous GABA treatments, and was down-regulated in As(III) treated rice seedlings, as compared to the control. However, the down-regulation of the expression of SSADH in shoot and root was recovered with the application of GABA and As(III) to the plants. The maximum increase was observed in shoot and root by 2.5 and 0.2 fold with the As(III)+GABA(L), in comparison to As(III) alone.

Overall the study concludes that the exogenous application of the GABA along or without As(III) treatment regulates gene expression of GABA shunt pathway enzymes in rice seedlings. The recovery of these gene expressions with the application of GABA against As(III) demonstrate that GABA plays a crucial role in the amelioration of As(III) induced stress.

Reduction of arsenic toxicity in rice cultivar through co-application of algae (Chlorella)

Lower group of organisms i.e. bacteria, fungi and microalgae has the property of conversion of inorganic toxic metals/metalloids to organic forms by methylation. While metals like Cd and Hg become toxic after methylation, organic arsenic or methylated arsenic becomes less toxic. An experiment was conducted to study the decrease in Arsenic (AsIII) related toxicity in a rice cultivar (Saryu-52) by the co-culture with alga *Chlorella* sp. Arsenic was applied as As(III) (30 µM) and As(V) (30 µM). In As(III) 30µM treated plants, the level of lipid peroxidation measured as thio-barbituric reactive substance (TBARS) content was observed to increase by

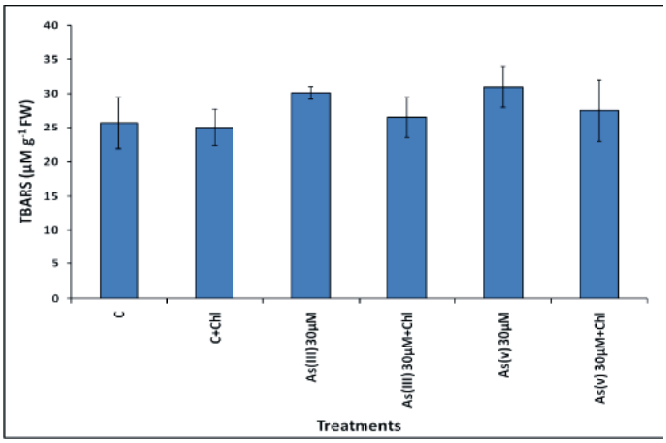


Fig. 6. TBARS (µM g^{-1} FW) of MDA in shoots of cv. Saryoo-52.

14.5%, as compared to the control. Similarly, TBARS content also increased (19%) in As(V) 30µM treated plants, as compared to the control (Fig 6). However, the TBARS content in seedlings grown with *Chlorella* [As(III) 30µM+Chl] decreased by 14.3%, as compared to the plants receiving only As(III) 30µM. Similarly, the content of TBARS also decreased in plants treated with As(V) 30µM and co-cultured with *Chlorella* by (15%), compared to the plants receiving only As(V). Application of *Chlorella* with As has also shown to decrease the As accumulation. Thus the preliminary results show that presence of alga (*Chlorella*) in the rhizosphere can decrease the As related toxicity in rice plants.

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

Physiological performance and differential expression profiling of genes associated with drought tolerance in root tissue of four contrasting varieties of two *Gossypium* species

Drought is considered as one of the limiting factors for plant growth and crop productivity around the world. The importance of root growth for maintaining crop yield under drought stress is becoming recognized and of increasing interest to plant researchers. The root elongation in parched soil is generally limited by a combination of mechanical impedance and water stress. The major function of root tissue is water and nutrient uptake so it imparts an important role in plant growth and stress management.

Four cotton varieties, JKC-770, drought tolerant and KC-2, drought sensitive [*Gossypium hirsutum*] and JKC-717, drought tolerant and RAHS-187, drought sensitive [*Gossypium herbaceum*] were imposed to drought stress and studied the changes in root tissue morphology (Fig. 7), physiology, metabolite content (Fig. 8) and differential/comparable genes expression (Fig. 9) which are responsible for tolerance or sensitivity of cotton varieties.

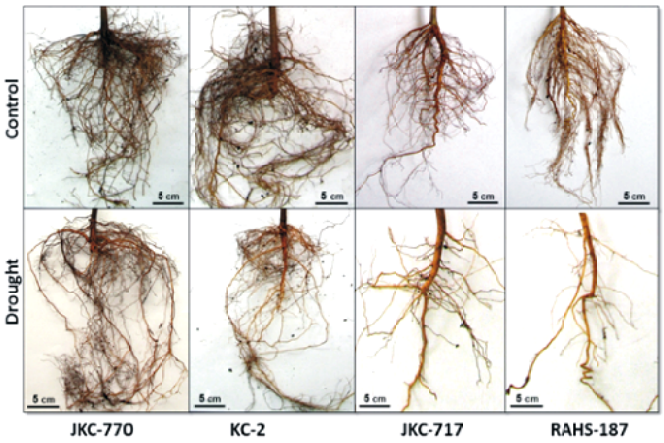


Fig. 8 Images of control (upper panel) and drought (lower panel) treated roots of four cotton varieties JKC-770 (a, b), KC-2 (c, d), JKC-717 (e, f) and RAHS-187 (g, h).

Cellulose synthase (CesA), pyrroline-5-carboxylase synthase (Δ^1P5CS), glutamate decarboxylase (GAD), xyloglucan:xyloglucosyl transferase (TCH4), squalene epoxidase (SqE), Ser/Thr PPase, Aux Res Ps, glutathione S-transferases (GST-8), heat-shock proteins (HSPs) and glycosyl hydrolases (GH) genes were selected to study their expression analysis under watering and water stress conditions in root tissues of cotton plants. To further define the physiological state of the plants that were subjected to expression profiling, the accumulation of two stress-inducible metabolites, proline and malondialdehyde (MDA) were monitored (Fig. 10). Proline works as osmolyte and MDA is known for oxidative damage of cell membrane. GST-8 is another gene which translates GST enzyme, used for scavenging the electophilic molecules produced during cell lipid peroxidation. High proline content under stress condition especially in root tissue helps plant having low water potential to facilitate water uptake from soil. Some triterpenoids, sterols and ã-amino butyric acid (GABA) were also estimated to observe the function of crucial genes CesA and GAD.

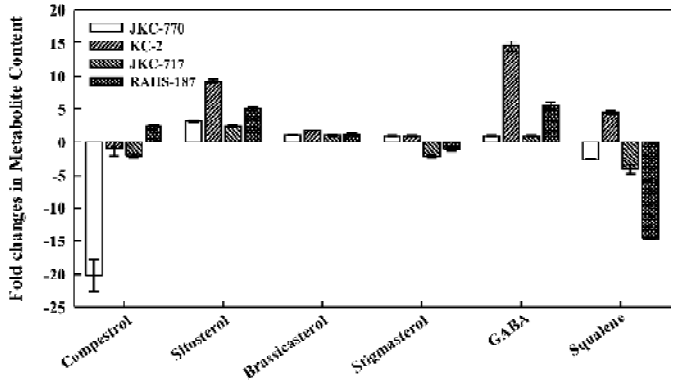


Fig. 8. Changes in sterols, γ-amino butyric acid (GABA) and squalene content in root tissues of drought treated cotton varieties with reference to root tissue of control plants.

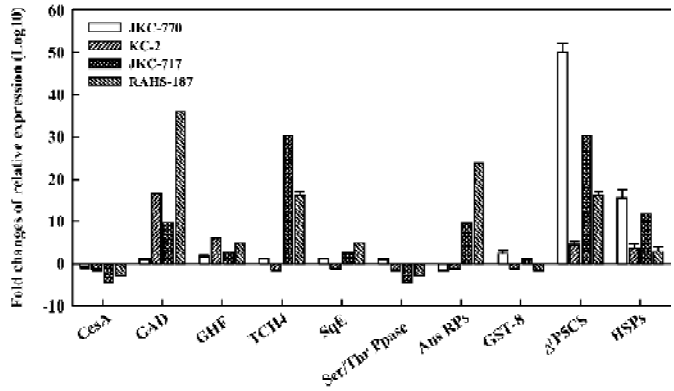


Fig. 9. Comparative expression profiling of genes associated with drought stress in, root tissue of four varieties of cotton plants.

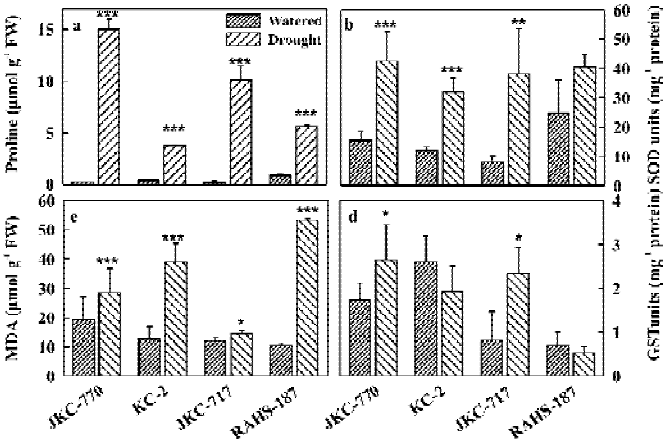


Fig. 10. Cellular content of proline (a), superoxide dismutase, SOD content (b), Lipid peroxidation expressed in the terms of malondialdehyde, MDA concentration (c) and cellular level of glutathione-S-transferase, GST activity (d), in root tissue of four contrasting cotton varieties under irrigated and drought treated condition.

JKC-770 and JKC-717 the drought tolerant varieties showed a comparatively high glutathione-S-transferase (GST), superoxide dismutase (SOD), proline along with their gene expression and low malondialdehyde (MDA) content indicating low membrane damage and better antioxidative defense under drought condition. The expression levels of cellulose synthase (CesA), xyloglucan:xyloglucosyl transferase (TCH4) and glycosyl hydrolases (GH) suggests modulation in cell wall structure and partitioning of sugars towards osmoprotectants instead of cell wall biosynthesis in tolerant varieties. Heat shock proteins (HSPs) and serine/threonine protein phosphotases (Ser/Thr PPase) show up-regulation under drought condition, which are responsible for temperature tolerance and protein phosphorylation respectively. These effects many metabolic processes and may be playing a key role in drought tolerance and adaptability of JKC-770 towards drought tolerance.

In the present study the root growth, root length, biomass of roots, % C and % N under watered and drought conditions was also studied (Fig. 12). Typically, well watered plants have a high C_i/C_a and are depleted in ^{13}C, whereas droughty plants have a low C_i/C_a and are

enriched in ^{13}C, reflecting the relationship between photosynthesis and transpiration or the water use efficiency and therefore the stable isotope carbon discrimination has been used as a tool for screening drought tolerant vs drought sensitive varieties. The long term water use efficiency (WUE) estimated in terms of carbon isotope discrimination ($\Delta^{13}C$) in the root tissues showed maximum depletion in the $\Delta^{13}C$ values in JKC-770 variety, while minimum in RAHS-187 under drought stress with reference to their respective control, suggesting a high WUE in JKC-770 variety (Fig. 11).

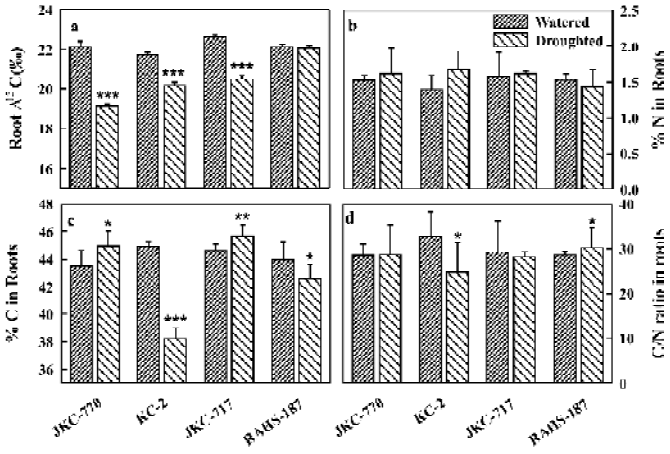


Fig. 11. Root carbon isotope discrimination, $\Delta^{13}C$ (a), % carbon content (b), % nitrogen content (c), and C/N ratio (d), in root tissue of watered and drought treated cotton plants.

Impact of salicylic acid (SA) on drought stressed wheat (*Triticum aestivum* L.)

Impact of salicylic acid (SA) on drought stressed wheat (*Triticum aestivum*) cultivars (Kundan and Lok1) was investigated at the morphological, physiological and biochemical levels along with changes in leaf proteome pattern to further explore the molecular mechanisms underlying SA-induced drought tolerance. The impact was studied at two different developmental stages: vegetative and flowering under well watered, water stressed (severe stress RWC 50% and moderate stress RWC 75%) and rehydration condition with their respective control. At the morphological level SA caused increase in root to shoot ratio in Lok1 under stress during both stages. The tolerant Kundan had highly developed root system, so biomass accumulation under stress and SA was more towards shoot. SA caused increase in rate of photosynthesis, stomatal conductance, water use efficiency and maximal efficiency of PSII in wheat cultivars with pronounced effect in Kundan than in Lok1. SA positively affected antioxidative metabolism in both cultivars under water deficit condition by enhancing the tolerant traits of Kundan and inducing tolerance in Lok1. Antioxidative enzymes like superoxide dismutase, catalase, ascorbate peroxidase and glutathione reductase with antioxidants like ascorbate and glutathione showed positive regulation under SA. Osmolytes like proline and total soluble sugars levels increased significantly under SA treatment. The tolerance was conferred to Kundan by these morphological, physiological and biochemical attributes which were further enhanced by SA treatment. Yield parameters, negatively impacted by water stress, like seed weight and number of seeds per plant, harvest index and seed starch were positively influenced in plants exposed to water deficit under SA treatment (Fig. 12).

The molecular mechanism underlying SA induced drought tolerance was studied through total leaf proteomics of plants under control, stress and rehydration. Proteomics revealed differential regulation of proteins related to metabolism, photosynthesis, defence, signal transduction and redox signaling (Fig 13). During early exposure to stress (vegetative stage) proteins related to carbon metabolism like fructose bisphosphate aldolase, phosphoglycerate kinase, glyceraldehyde dehydrogenase, malate dehydrogenase, etc. were upregulated in both cultivars but more significantly in Kundan. Carbon

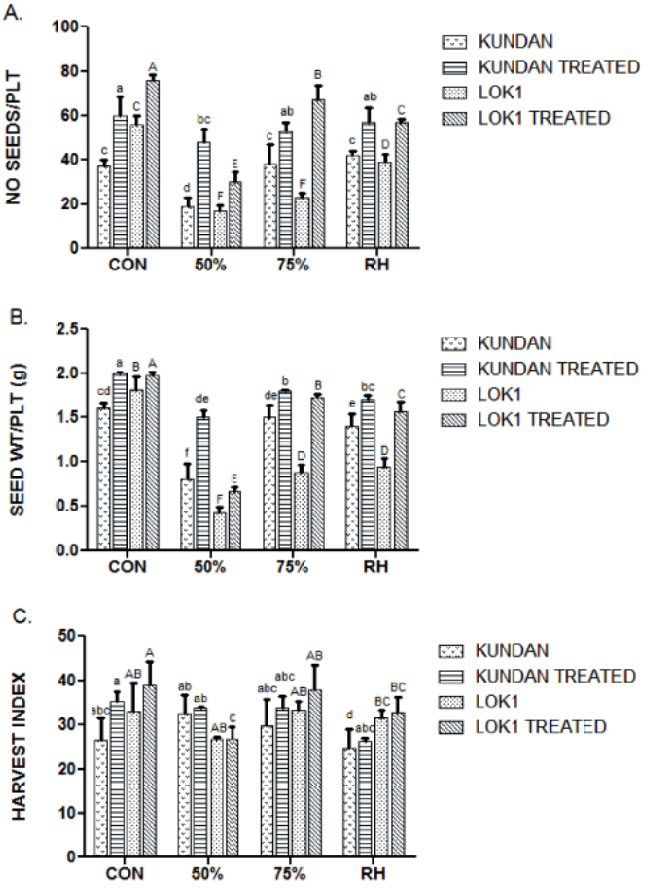


Fig. 12. Yield parameters A. Number of seeds per plant; B. Seed weight per plant; C. Harvest index (HI) under interaction of drought with SA in Kundan and Lok1. Bar represents mean ± standard deviation (n=3), letters (ABC) and (abc) represents level of significance for Lok1 and Kundan, respectively through one way ANOVA post hoc Duncan's test (pd"0.05).

metabolism in Lok1 was more diverted towards sucrose synthesis as observed by upregulation in UTP glucose-1-phosphate uridyl transferase and triose phosphate isomerase. Kundan showed shift of carbon metabolism towards starch accumulation due to negative regulation of transketolase. At later stage i.e., flowering stage, carbon metabolism proteins showed downregulation to provide building blocks for grain storage reserves and more of sucrose synthesis to be transported towards developing grain. The increased rate of photosynthesis under SA was supported by upregulation of RuBisCO, RuBisCO activase, carbonic anhydrase, ferredoxin NADP reductase and electron transport chloroplast membrane proteins at vegetative stage. During flowering, senescence caused downregulation in photosynthesis related proteins in Lok1 but in Kundan, plants strive to maintain rate with upregulated RuBisCO and RuBisCO activase. The recovered plants from stress maintained upregulation of these photosynthetic proteins at both stages to alleviate negative effect of water stress. The energy metabolism enhanced under SA clearly as observed through upregulation of ATP synthase which was diverted towards metabolism in Kundan and defence in Lok1 at vegetative stage. The energy metabolism during anthesis was diverted towards increase sink potential in both cultivars. Amino acid metabolism was positively regulated by SA and showed increase in glutamine synthase for accumulation of osmolytes like proline under stress for osmotic adjustment on early exposure in Kundan and Lok1.

Cysteine synthase and methionine synthase upregulation supported the increase in glutathione level in stressed leaves under SA. At anthesis, increase in sink potential by increased amino acid metabolism under SA to provide building blocks for seed storage proteins. Protein metabolism was under positive regulation by SA in both cultivars but more pronounced in Kundan. Defence proteins in Lok1 were more upregulated as compared to Kundan at vegetative stage observed through upregulation in ascorbate peroxidase, superoxide dismutase, germin like proteins, late embryogenesis protein etc. Redox signalling in Kundan was more affected than Lok1 by SA under stress through increased expression of thioredoxins and cys peredoxins. Redox signalling functions in redox activation of carbon metabolism enzyms like sedoheptulose 1,6 bisphosphatase, phosphoribulokinase, ATPase etc supporting the shift of metabolism more towards carbon gain in Kundan. The sensitivity of Lok1 towards water stress was higher causing the increase in defence, energy production and protective responses against stress under SA. This explains the SA induced drought tolerance in Lok1 by enhancing the protective responses and increased

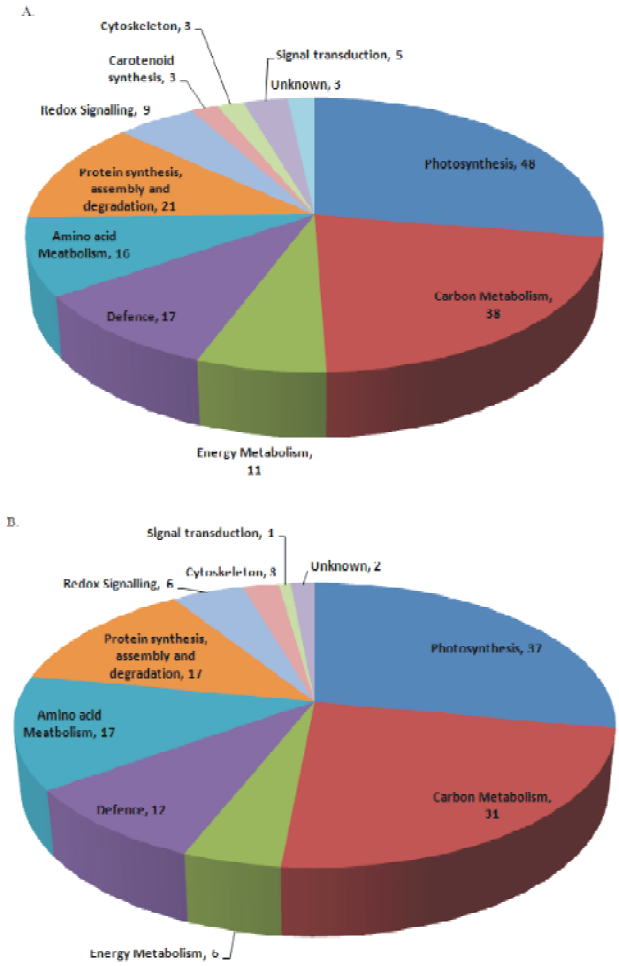


Fig. 13. Functional characterization of identified differentially expressed proteins under SA treatment A. Kundan, tolerant cultivar; B. Lok1, sensitive cultivar during both developmental stages (vegetative and flowering).

energy production to cope up with stress.

The ameliorating effect of SA under water stress was found to be higher in Kundan as compared to Lok1. SA conferred tolerance in Kundan even under severe stress but in Lok1 SA induced tolerance level was higher in moderate stress. In tolerant cultivar SA positively influenced metabolism and stress signaling to regulate drought tolerant responses which in sensitive cultivar shifted towards defense, energy production and protection against stress. Yield limitation by water stress was relieved by SA with increased yield parameters like grain number and weight per plant and starch. At anthesis, major influence of SA was in increasing sink potential with stress acclimation. The drought tolerant traits were identified for the two winter wheat cultivars under interactive effect of stress and SA which could be used in future for major goal of increasing yield potential under stress.

GENETICS AND MOLECULAR BIOLOGY

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

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

Grant-in-Aid Projects

Development of F1-hybrid cotton using novel reversible male sterility system

F1 hybrid cotton possesses superior agronomic traits including superior fibre quality, and hence has been of tremendous global demand. A commercially viable F1 hybrid cotton via invention of a novel protocol "reversible male sterility system" is being developed at this Institute. The *Agrobacterium* based plant genetic transformation protocols were standardised for achieving cotton transgenic male sterile (ms) and restorer (rs) lines of Coker-312 (Fig. 1). The transgenic male sterile (ms) lines carried autophagy related gene *BECLIN1* and selectable marker as herbicide resistance (H^R) gene BAR (35Sde:*BAR*:ocspA) assembled in binary vector pPZP200. Another binary vector pBI101 finally carried construct ms-H^R for transformation (Fig. 2). Transgenic cotton lines exhibiting the male-sterility character will be propagated by crossing with their wild-type parent followed by the progeny selection after herbicide spray.

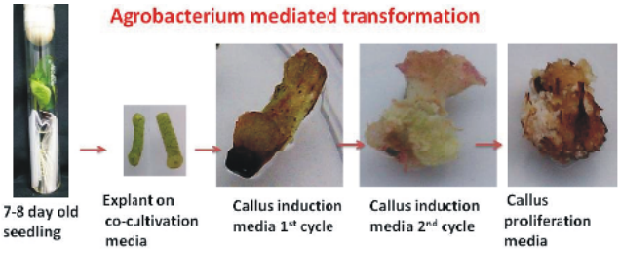


Fig. 1. Seedling explants were transferred to co-cultivation meidia along with Agrobacterium culture carrying pBI01 with constructs I370 or I373 at suceessive stages of callus formation and growth after co-cultivation are shown.

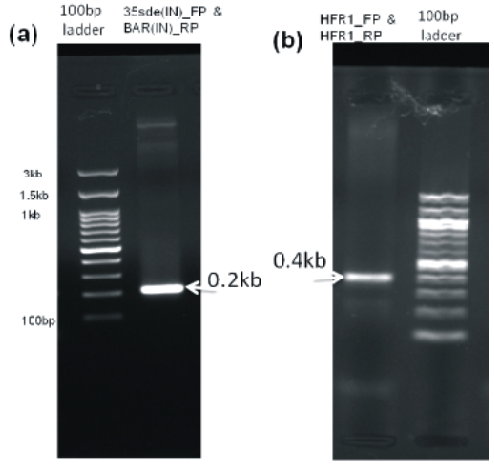


Fig. 2. PCR based screening and confirmation of construct ms-H^R. The herbicide resistance gene BAR was amplified and sequenced by gene specific internal primers (a), and gene HFR1 was amplified and sequenced by gene specific internal primers (b).

Role of Arabidopsis TBP-Associated Factors (TAFS) in plants defense

The TATA binding protein (TBP) associated factors (TAFs) are part of transcription complex TFIID and contribute in regulation of transcription. However, there is little knowledge about genome wide protein-protein interaction profile of TAF4b. The bait construct for Taf4b gene was prepared by cloning in $pGBKT_7$ vector. The yeast two hybrid screening was done using the Clontech mate and plate library and 44 interacting proteins were identified. Further, based on interaction strength, TAF4b interacting Proteins (TIP) were selected for further study. The vector switch experiment confirmed the TIP selections. The domain interaction studies demonstrated the non-redundant, sequence specific interaction of TIP protein with RST domain. The Reverse yeast two hybrid was done against TIP and additional 120 interacting proteins were identified. The TAF4b and TIP interaction was validated *in planta* using bimolecular florescence complementation technique. The possible roles of *Arabidopsis Taf4b* gene in conjunction with *Cpr*5 gene (constitutive expressor of PR5) in transcriptional regulation of plant innate immunity were also studied. Based on genetic mutant lines of *Cpr*5 and *taf4b*, it was observed that in *taf4b* genetic mutant *Arabidopsis* lines, the transcripts of Cpr5 regulated salicylic acid biosynthesis genes like Isochorismate synthase and Phenylalanine ammonia lyase by down regulating. This suggests that TAF4b interacts with CPR5 and positively regulates genes involved in innate immunity.

Development of saturated genetic linkage map for *Gossypium hirsutum* L. using SSR and SNP markers

Developing HMPR libraries for both parents, EL 958 and UPA 57-17, pyrosequencing the libraries and indentifying at least 1000 polymorphic SNPs between two parents

Hypo-methylated restriction libraries were prepared from genomic DNA of both parents of *G. hirsutum* using *Cla*I restriction endonucleases individually. DNA fragments ranging from 300 bp to 5 Kb DNA were excised and gel-eluted (Fig. 3).

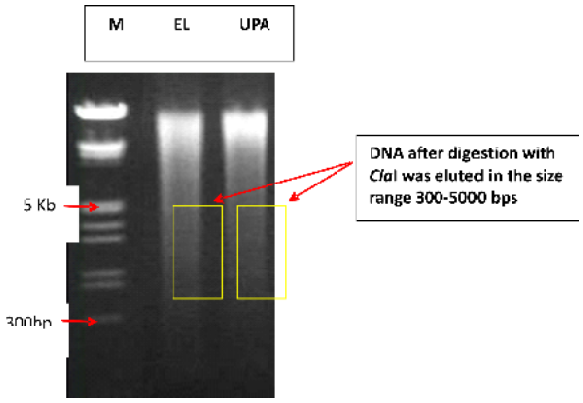


Fig. 3. Agarose gel image of digested DNA of both parents by *Cla*I

Sequencing library preparation and 454 sequencing was done using Roche GS-FLX Titanium sequencing kit. Signals were processed using gsRunBrowser v2.5.3, while the assemblies were made using parameter 40 bp overlap with minimum 95 percent identity and "large and complex genome" option. The sequencing results of the two parents and identification of SNPs from the data, where allelic SNPs were considered as true SNPs and non-allelic SNPs were discarded.

Cotton SNP Chip Development

The cotton SNP-chip was developed in collaboration with Affymetrix on the Axiom platform. A total of 110,095 SNPs (77,350 developed in-house and 32,745 from the public domain) were screened for different quality parameters and design score as recommended by Affymetrix. After screening, a total of 42,377 SNPs (34,985 in-house, 7392 from NCBI dbSNP) with 51,347 probes were finally selected. Out of total 42,377 SNPs selected for tiling on the chip, 5286 SNPs were identified from an interspecific (*G. hirsutum* x *G.barbadense*), while rest 37,091 SNPs were intra- *G. hirsutum* (Fig. 4).

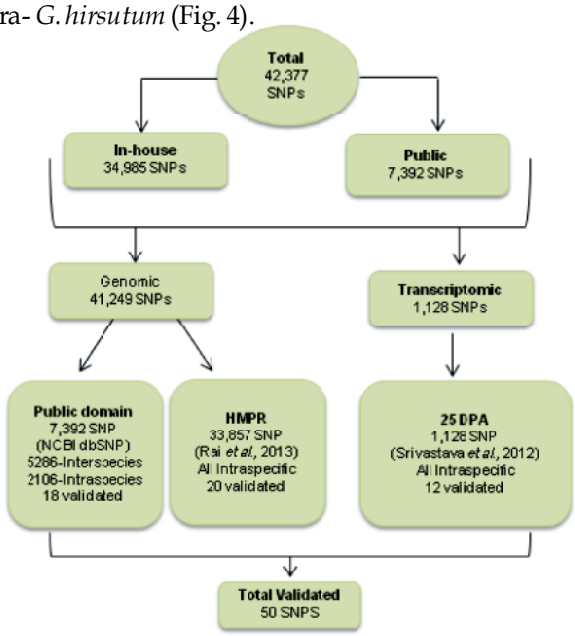


Fig. 4. Details of 42,377 SNPs present on SNP-chip, comprising SNPs taken from NCBI SNP database and others generated In-house. All the public domain SNPs were genomic SNPs, while In-house SNPs were selected from genomic HMPR data and transcriptome data of cotton fiber at 25 DPA.

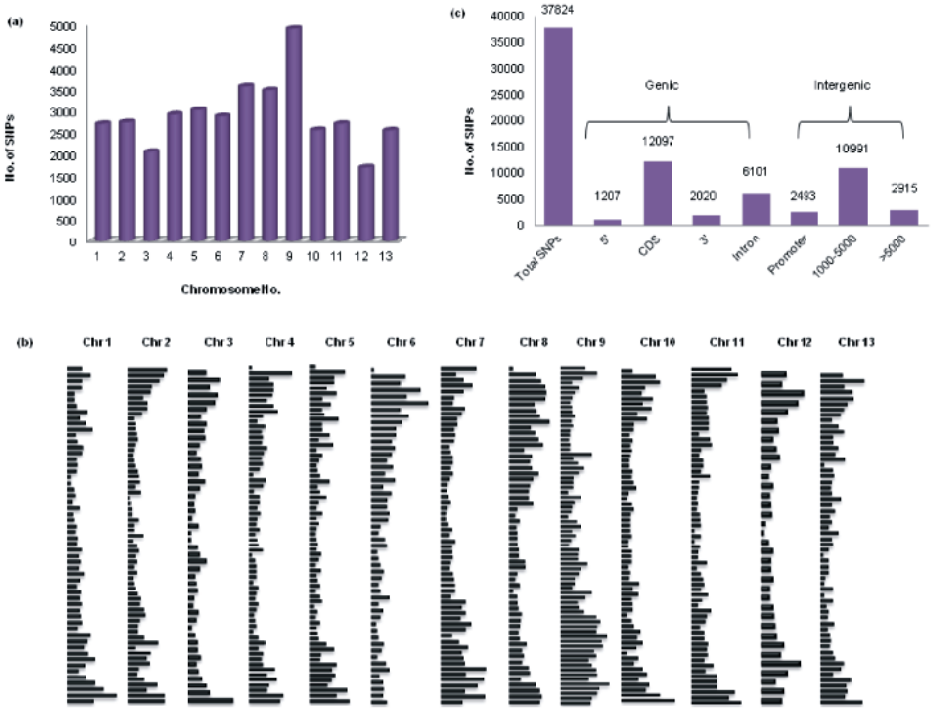


Fig. 5. Distribution and Characterization of Chip-SNPs through mapping on *G. raimondii* D-genome. (a) Distribution of 37,824 SNPs mapped on the 13 chromosomes of D-genome; (b) Distribution of mapped SNPs all along the chromosomes showing uniform coverage required for SNP chip. (c) Characterization of mapped SNPs in genic (5′, CDS, 3′ and Intron) and inter-genic (Promoter, 1000-5000 and >5000 bp) region.

The newly developed SNP chip (42,377 SNPs) was used for mapping on D-genome of *G. raimondii* (JGI version: ftp://.jgi-psf .org/pub/compgen/phytozome/v9.0/Graimondii/) using BLASTn programme. A total of 37,824 SNPs were mapped, which were found to be randomly distributed all along the 13 chromosomes of *G. raimondii* (Fig. 5a-c), indicating uniform coverage by the selected SNPs robustness of SNP-chip and genotyping.

Utilization of Cotton SNP Chip for genotyping of 192 RILs of (EL 959 X UPA57-17)

The new SNP-chip developed at NBRI was used for genotyping 190 RILs along with their parents, EL 95J9 and UPA 57-17 (total 192 lines). Fishers Linear Discriminant (FLD) was used for identifying high quality SNP clusters and all SNPs with an FLD value <3.6 were removed from downstream analysis. Similarly, Heterozygous cluster strength Offset (HetS0) with a threshold of <0.1 was used to minimize the incorrect calls. All the SNPs/ probe sets were further classified into six categories according to the SNP QC matrix (Fig.6a-f). The genotyping data represents three main clusters corresponding to AA homozygote, AB heterozygote and BB homozygote for each SNP. Out of the 42,377 SNPs, on cotton SNPs (5.6%) resulted into two clusters with no examples of homozygous for minor allele. A total of 23 SNPs (0.1%) were further confirmed to be off-target variants. Excluding outlier SNPs, a total of 39,101 SNPs showed clear clustering with our 172 RILs along with parental lines (total 174 lines) demonstrating a success rate of 92.3% for the Affymetrix Cotton SNP chip.

Development of genetic map in *Gossypium hirsutum* using SNPs

A total of 168 RILs and 2952 polymorphic markers were finalized for linkage group analysis *G. hirsutum* using NBRI developed cotton SNP chip. Out of 2952 polymorphic markers, 1867 were uniquely mapped on linkage groups, while 742 and 122 markers were mapped at duplicate and triplicate loci, respectively. Identical or co-segregating markers were also identified and shown in the linkage map. Thus, the linkage map contains 2731 markers placed in 29 linkage groups.

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

SlERF6 and SlERF8 were identified as two genes encoding AP2/ERF domain containing proteins from

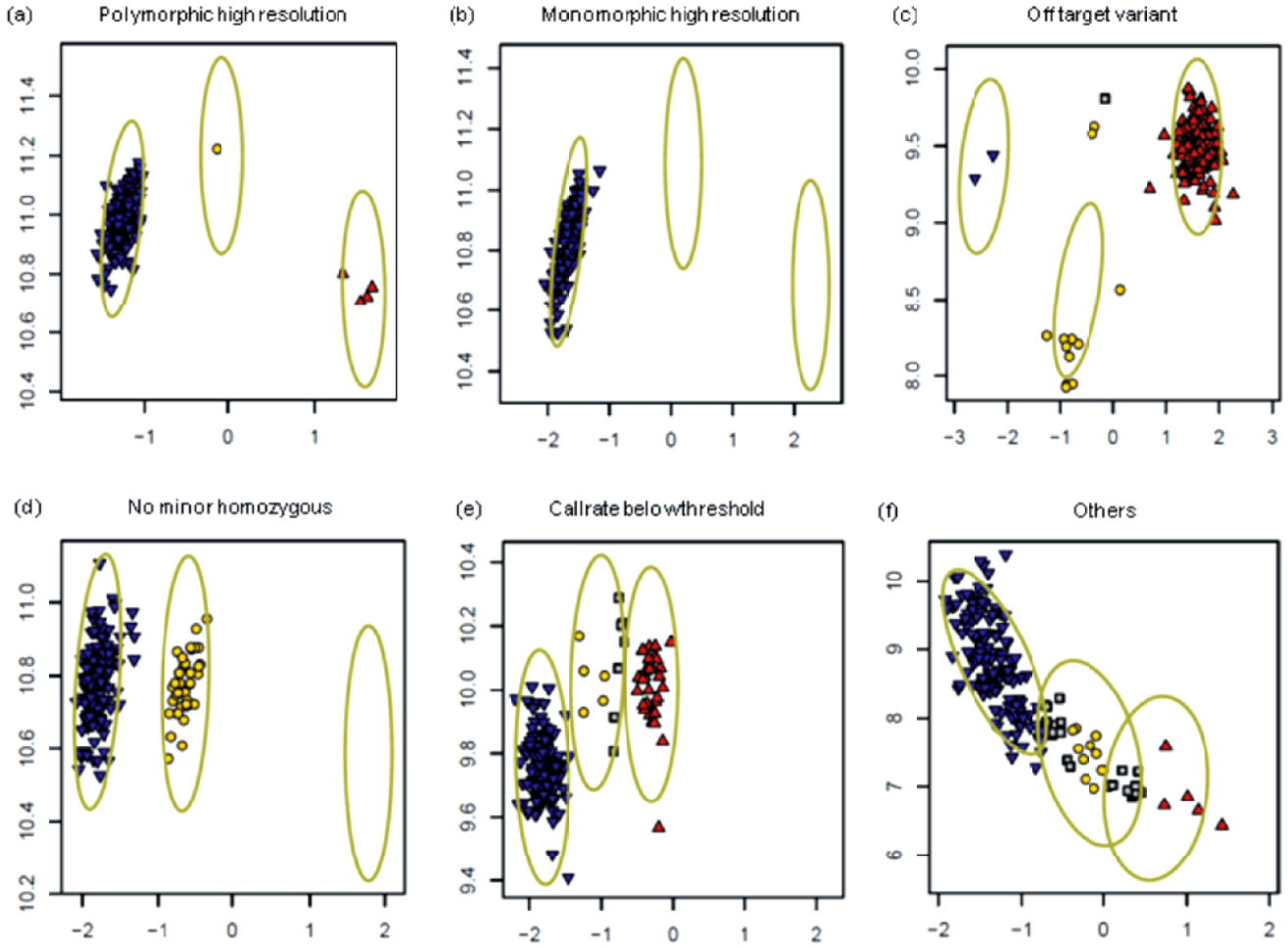


Fig. 6. SNP Genotyping (a-f) with six categories of Probesets according to SNP QC metrices.

tomato fruit cDNA. Their role in development and fruit ripening in tomato is being studied. To functionally characterize SlERF6, transgenic tobacco expressing *SlERF6* under the CaMV35S promoter were developed, and showed delayed flowering and senescence and an increase of 20 days in life cycle. Seeds of independent lines showed early germination both in absence and presence of 2 and 5µM ABA suggesting that SlERF6 reduced sensitivity to ABA (Figs. 7, 8). The reduction in sensitivity was not restricted to seed germination but also seen in other stages of plant development. Root growth was profoundly affected with transgenic lines showing higher root biomass in several independent experiments with most of the increase being due to increased lateral roots (Fig. 9). Leaf discs of transgenic lines showed delayed senescence in response to ABA. Stomatal closure was affected with transgenic lines showing 30-50% higher photosynthetic rates, and even higher conductance and transpiration both in absence and after ABA treatment (Fig. 10). A consequence of the reduced sensitivity to ABA and increased transpiration was increased sensitivity to water stress leading to rapid wilting of transgenic plants upon water stress (Fig. 11). However, under well watered conditions, transgenic plants produced larger number of capsules and greater number of seeds (Fig. 12). The increase in yield ranged from 18-35% in different experiments in years from 2011 to 2015. The gene has tremendous potential to increase yields by at least 18-30% in microirrigated conditions over the controls.

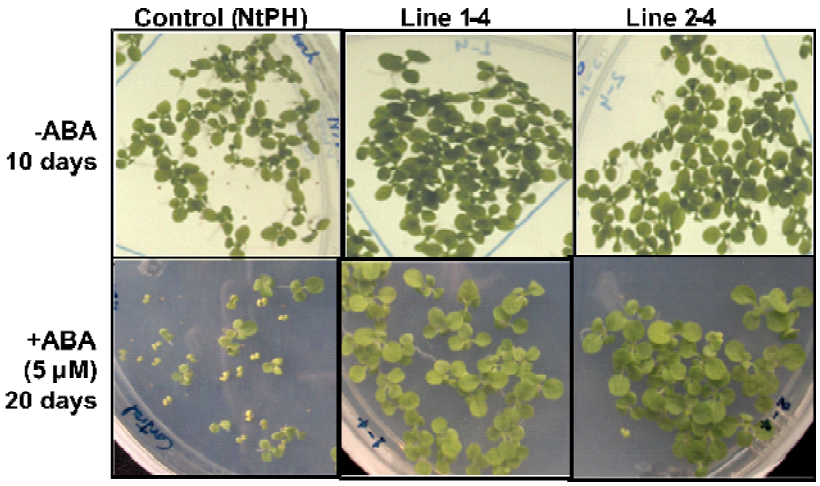


Fig. 8. Reduced sensitivity of seeds of transgenic *SlERF6* lines (1-4 and 2-4) to ABA

Expression of *SlERF6* expression appears to reduce sensitivity to ABA in several different ABA governed processes in different tissues and in different stages of plant growth and may encode a negative regulator that functions in the general ABA pathway.

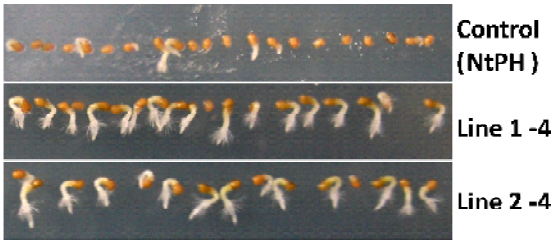


Fig.7. Early germination of transgenic tobacco seeds (Lines 1-4 and 2-4) expressing *SlERF6* on ½ strength MS medium.

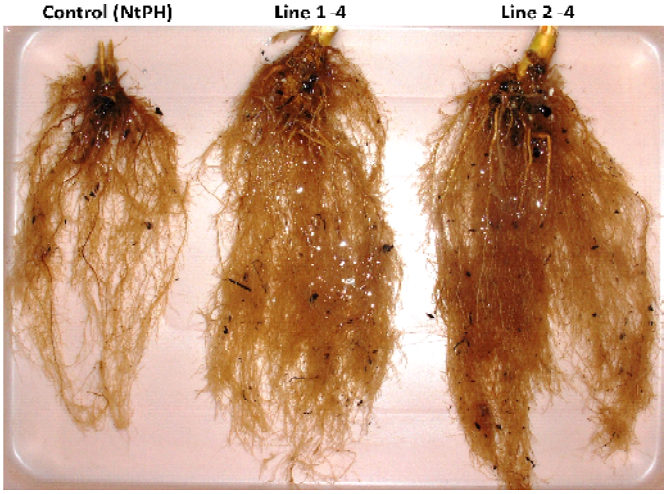


Fig. 9. Differences in root biomass and architecture in transgenic *SlERF6* over-expressing tobacco plants

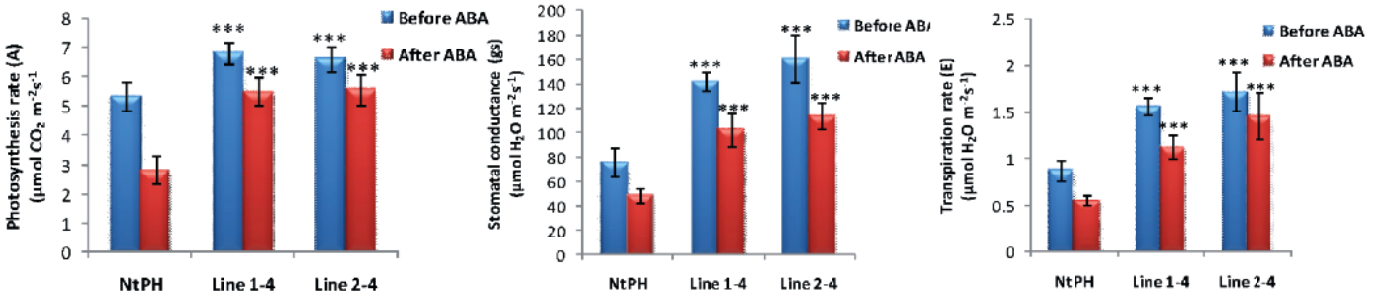


Fig. 10. Higher photosynthesis, conductance and transpiration rates in transgenic *SlERF6* over-expressing tobacco lines (1-4 and 2-4) before and after ABA (10ìM) treatment

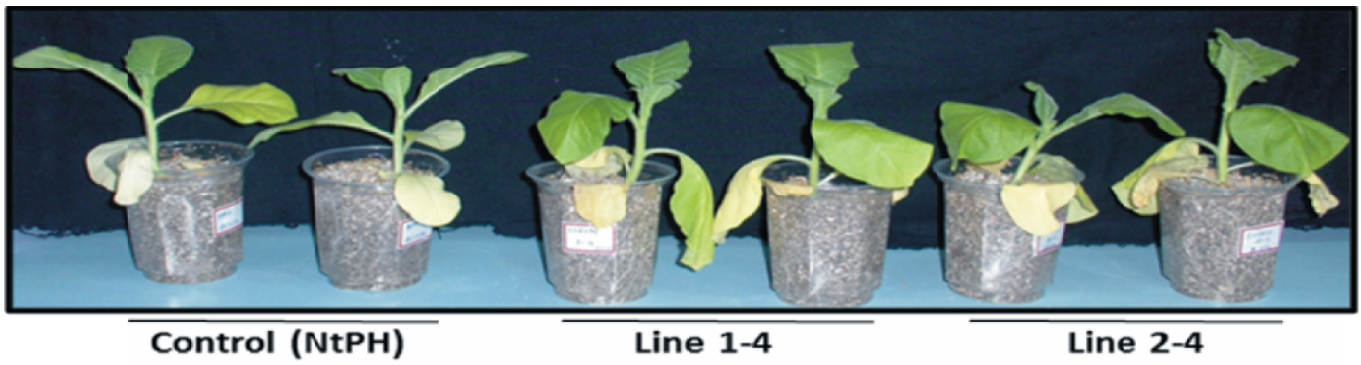


Fig. 11. Increased wilting in transgenic *SlERF6* over-expressing tobacco lines (1-4 and 2-4) after 8 days of withholding water

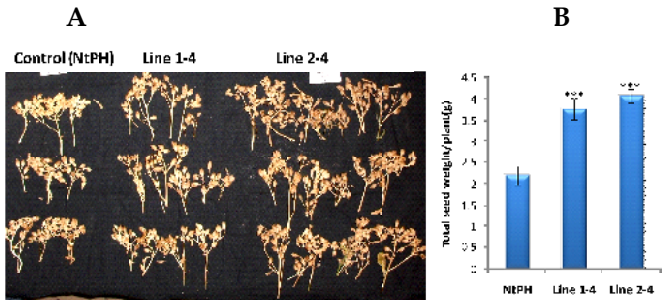


Fig. 12. Improved capsule number (A) and seed yield per plant (B) in transgenic tobacco over-expressing *SlERF6*

A comprehensive systematic analysis of stress responsive DHN gene family members in 11 *Oryza* cultivars: Is it lost or retained during course of domestication of rice?

Abiotic stresses adversely affect cellular homeostasis which ultimately impairs overall growth and development of the plant. These initial stress signals activate downstream signaling processes which in turn modulates stress-responsive mechanisms to re-establish homeostasis. One such mechanism is offered by Dehydrins (DHNs,) these are the key components of dehydration tolerance. Rice (*Oryza sativa* L.) being a paddy crop is mainly susceptible to drought-induced stress. As the rice crop survival might be a trait with strong evolutionary selection pressure, the functional role of DHNs in the light of domestication during the course of evolution was examined. Sixty five DHNs were identified by genome wide survey of 11 different rice germplasm, including wild relatives and cultivated varieties and 3 DHNs were found highly conserved during the course of domestication on the basis of their amino acid (aa) length, chromosomal localization and domain architecture. The correlation of conserved pattern of DHNs with domestication of wild to cultivated rice was validated by synonymous substitution rates, indicating that *Oryza rufipogon* and *Oryza sativa* ssp. *japonica* follow adaptive evolutionary pattern whereas *Oryza nivara* and *Oryza sativa* ssp. *indica* demonstrate conserved evolutionary pattern. A comprehensive analysis of tissue specific expressions of *DHN* genes in *japonica*, and their expression profiles in normal and different degree of drought conditions exhibited spatio-temporal expression pattern. This study offers identification and analysis of DHNs in 11 rice germplasm including wild type, domesticated, perennial, annual, upland, and lowland variety. The results obtained strongly indicated the importance of DHNs, as they are found to be conserved during the course of domestication and evolution.

Analysis of sterol glycosyltransferase (*SGT*) gene family of *Withania somnifera* using artificial miRNA technology in the glycosylation of secondary metabolite and using homologous expression system

The functions of *SGTLs* gene family members (*WsSGTL1*, *WsSGTL2* and *WsSGTL4*) of *Withania somnifera* were analyzed by developing transgenics of *W.somnifera* overexpressing *WsSGTL1* using *Agrobacterium tumefaciens*-mediated transformation and suppressing by the combination of artificial miRNA and Virus Induced gene silencing method. Later the VIGS vector with amiRNA was modified and developed amiRNA, based on virus induced gene silencing (aMIR-VIGS) system against *WsSGTLs* gene members. This aMIR-VIGS system helps avoid the off target gene silencing in plants. After silencing of *WsSGTLs* members biotic experiments were performed.

Silencing of the *WsSGTL* affected the leaf area and height of the plants. The ratio of free sitosterols and stigmasterol vs its glycosylated forms was measured by acid hydrolysis. The ratio of free phytosterol vs glycosylated phytosterols was higher in silenced lines than control plants (Fig. 13).

The infection of *Alternaria alternata* causes significant increase in salicylic acid, callose deposition, superoxide dismutase and H_2O_2 in silenced lines as compared to control plants.

Down-regulation of the *WsSGTL* gene family diminishes the plants tolerance against the *Alternaria alternata*. It was already reported that conversion of

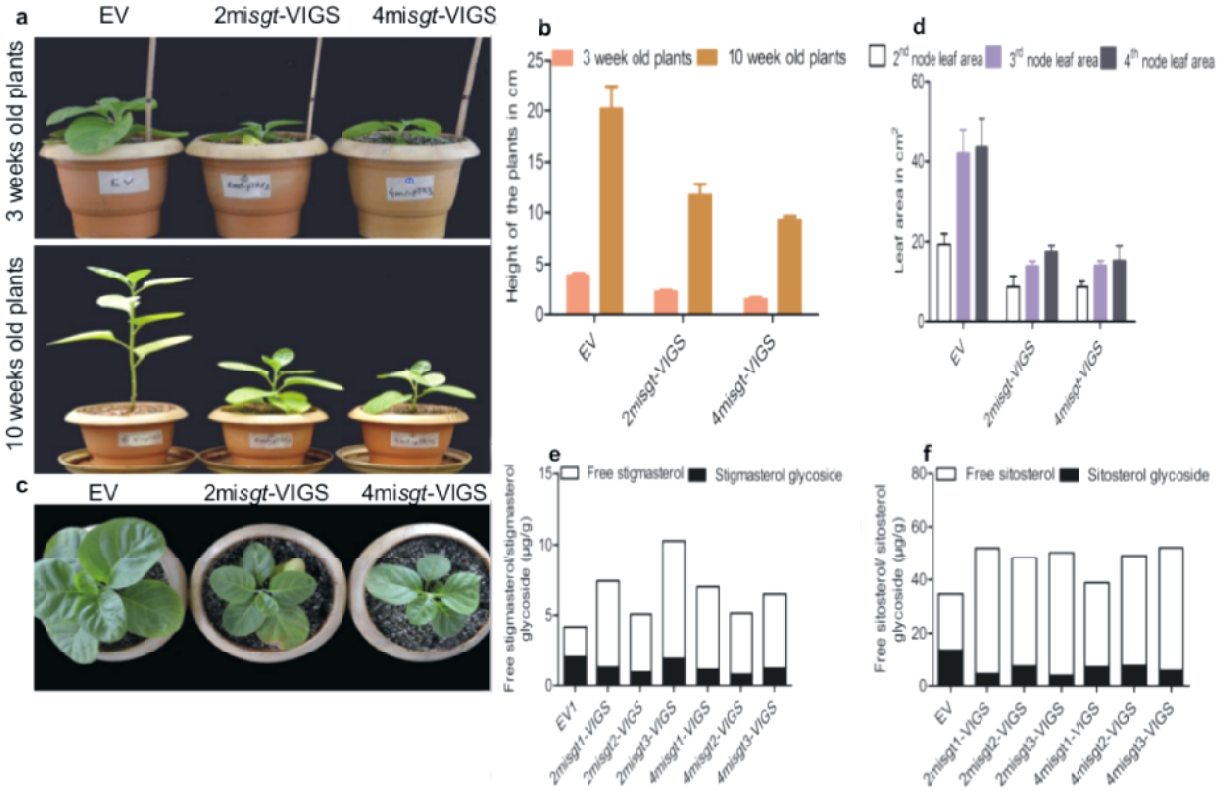


Fig. 13 (a-d) Down-regulation of *WsSGTL1, L2* and *L4* of *W. somnifera* significantly affects the height and leaf area of the plants. (e and f) ratio of free phytosterol to their respective glycoside.

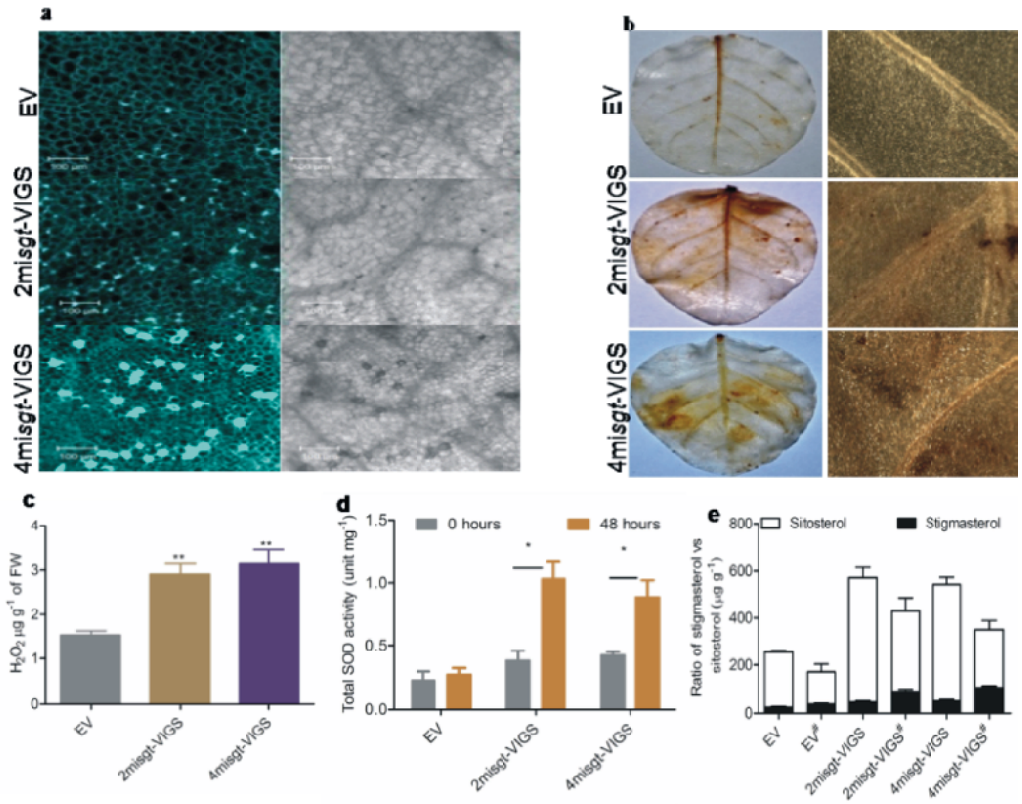


Fig. 14 (a) Aniline blue staining in the leaf of *W. somnifera* after the infection of *A. alternata* at 7 dpi at 20X magnifications on confocal microscope. Bars = 100 µm. (b and c) Hydrogen peroxide accumulation in leaves of *W. somnifera* were analysed after 48 h of infection by DAB staining, under light microscopy at 40 X magnification and spectroscopic analysis. (d)Total SOD has been measured after 48 h infection of *A. alternata* in control and silenced lines of *W. somnifera*. (e) Stigmasterol/sitosterol ratio in control and silenced lines before and after 7 days *A. alternata* infection.

sitosterol to stigmasterol increased after the biotic stress. We have checked the ratio of stigmasterol vs sitosterol after fungal stress. This ratio was higher in the silenced line than control plants (Fig. 14).

The expression of biotic stress related genes, namely, *WsPR1*, *WsDFS*, *WsSPI* and *WsPR10* were also enhanced in silenced lines in time dependent manner. Our observations revealed that a positive feedback regulation of withanolide biosynthesis occurred by silencing of *SGTLs* which resulted in reduced biotic tolerance (Fig. 15).

To understand the functional significance and potential of *WsSGTL1* gene, transgenics of *W.somnifera* overexpressing *WsSGTL1* were generated using *Agrobacterium tumefaciens* mediated transformation. Stable integration and overexpression of *WsSGTL1 gene* was confirmed by southern blot analysis followed by quantitative real time PCR.

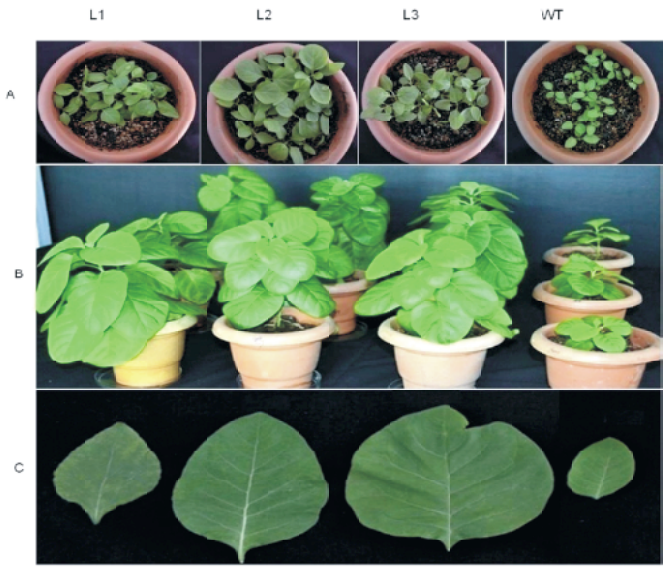


Fig. 16. Morphological characterization of T_1 transgenics of *W.somnifera*. A 8-weeks-old seedlings growing in the pot. B 4-months-old plants in the pot. C Morphological difference in the leaf size (L to R) of the transgenic lines and WT.

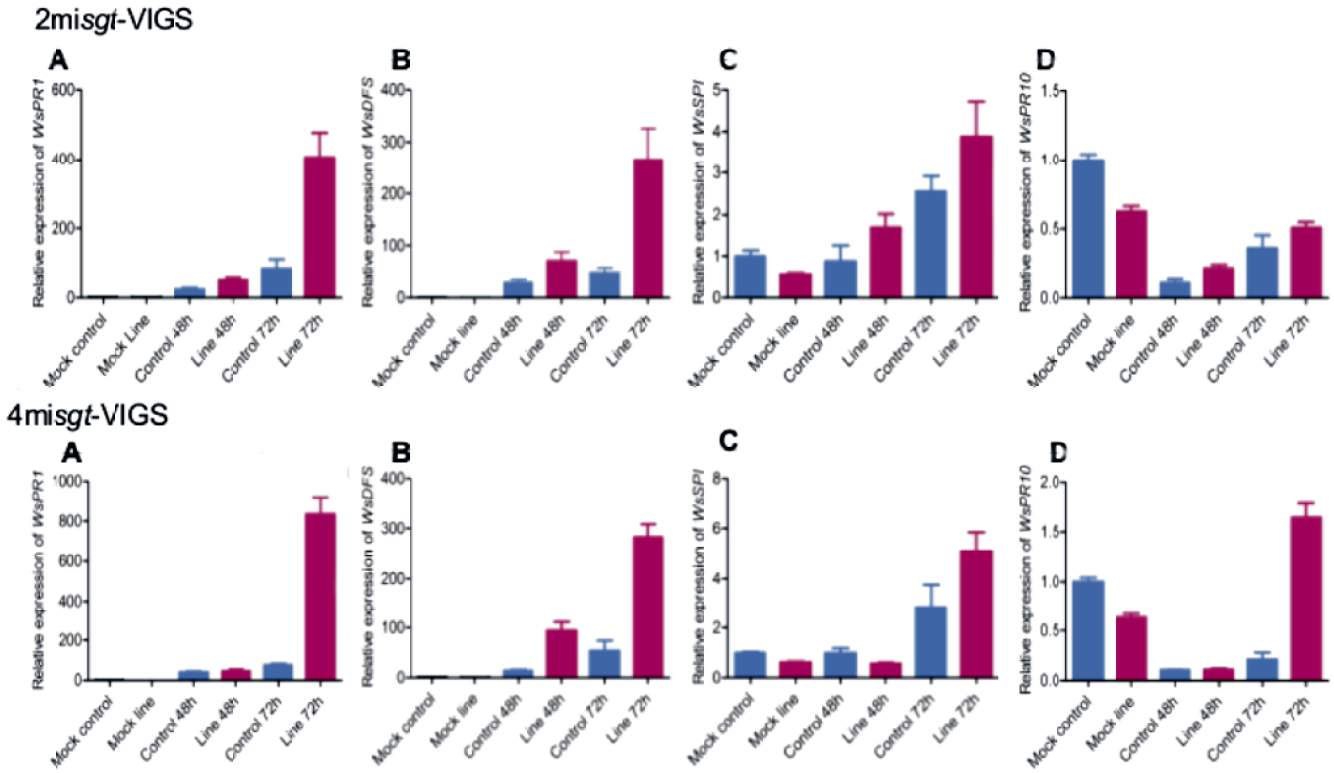


Fig. 15 (a and b) Expression level of different defense genes such as (A), *WsPR1* (B), *WsDFS* (C), *WsSPI* have significantly increased while (D), *WsPR10* showed delayed over-expression in silenced lines after 48 h and 72 h of fungal infection as compared to Mock, taken as control.

Transgenic Withania plants overexpressing *WsSGTL1* displayed number of alterations at phenotypic and metabolic level in comparison to wild type plants, which include early and enhanced growth with leaf expansion (Fig. 16) and increase in number of stomata.

Increased production of glycowithanolide (majorly withanoside V) and campesterol, stigmasterol and sitosterol in glycosylated forms with reduced accumulation of withanolides (withaferin A, withanolide A and withanone) in transgenic lines (Fig. 17). This resulted in tolerance towards biotic stress (100% mortality of *Spodoptera litura*), improved survival capacity under cold temperature stress (Fig. 18).

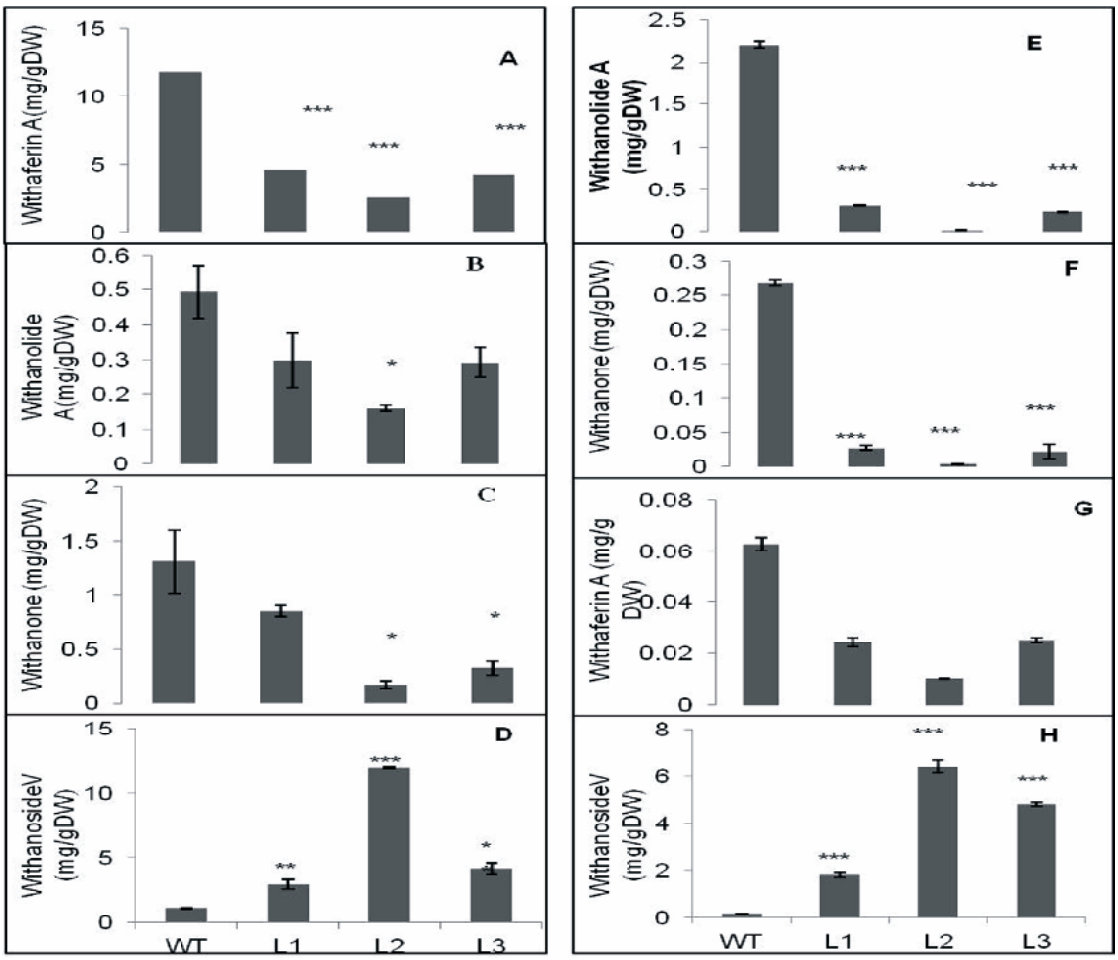


Fig. 17. Quantitative estimation of withanolides in WT and transgenic plants (L1, L2 and L3) illustrating enhanced glycosylation of withanolides A-D From samples of leaf extract. E-H From samples of root extract. I-L HPLC chromatogram.

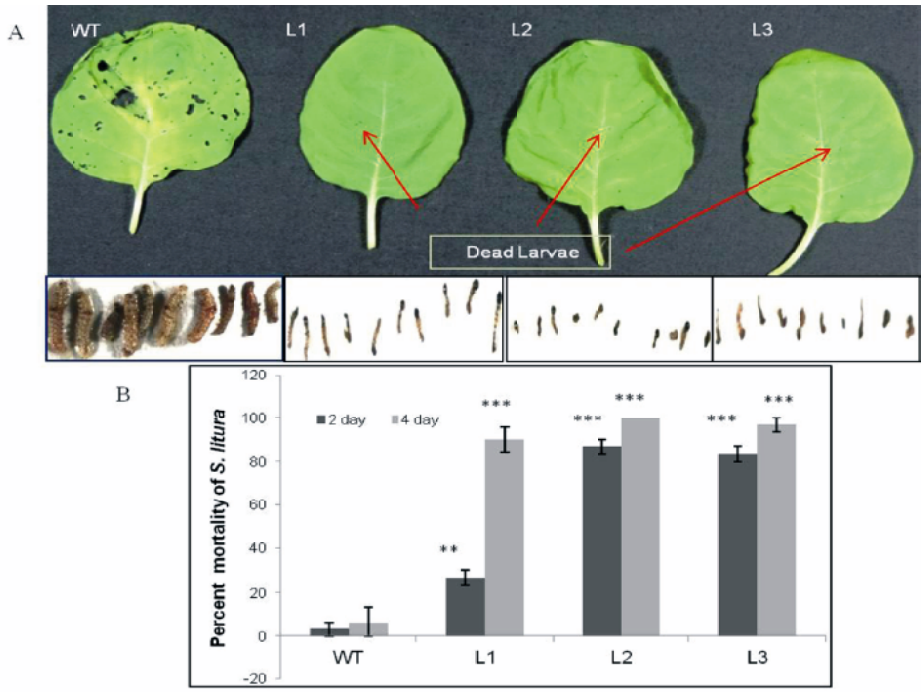


Fig. 18. Evaluation of transgenic plants against neonate larvae of *Spodoptera litura*. A Detached leaves of *W.somnifera*. B Percent mortality of *S.litura*. Asterisks indicate that mean values are significantly different between WT and transgenic plants (*, P < 0.05; **, P < 0.01; ***, P <0.001).

Further, the role of *WsSGTL1* was validated through RNAi silencing of *WsSGTL1* gene. For this RNAi construct (pFGC1008-*WsSGTL1*) was made and the genetic transformation was done by *Agrobacterium tumefaciens*. HPLC analysis depicts the reduction of *withanoside* V (the glycowithanolide of *W.somnifera*) and a large increase of withanolides (majorly withaferin A) content. Also, a significant decrease in the level of glycosylated sterols has been observed.

Hence, the obtained data provides an insight into the biological function of *WsSGTL1 gene in W.somnifera*. From the present study, it was observed that *WsSGTL1* is a key enzyme of withanolide biosynthetic pathway and is regulating the withanolide biosynthesis in *W. somnifera* predominantly by glycosylation of withanolides and sterols which in turn has a regulatory role in the growth and development and provides tolerance against biotic and abiotic stresses.

Enhancement of secondary metabolites with the use of biotic and abiotic elicitors in hairy root cultures of *Rauwolfia serpentina*, *Glycyrrhiza glabra* and *Solanum khasianum*

Glycyrrhiza glabra L. contains large amount of glycyrrhizin and saponins. Glycyrrhizin played important defensive role to protect the erythrocytes against the hemolysis. It has lots of medicinal values including its role in severe acute respiratory syndrome (SARS)-associated virus and effective remedial agent for acquired immunodeficiency syndrome (AIDS) and chronic hepatitis. Hairy root culture is an alternative method to save the biomass of the plant and enhancement of its alkaloids through elicitors is beneficial for humankind.

Hairy root cultures of *G. glabra* were subjected to biotic elicitation (Cellulase from *Aspergillus niger*) and (Mannan from *Saccharomyces cerevisiae*) as well as abiotic elicitation (Drought and heavy metal stress) to enhance the concentration of glycyrrhizin.

At 1% PEG concentration (drought stress), 5.4 fold enhancements in glycyrrhizin content was observed after 24 h of elicitation but treatment of heavy metal in the form $CdCl_2$ did not cause any significant enhancement in yield of glycyrrhizin. Mannan at 10 mg/l concentration and cellulase at 200µg/ml concentration, enhanced glycyrrhizin content upto 7.8 fold and 8.6 fold after 10 d and 7 d of stress respectively.

Proteomics changes were also reported in hairy root cultures in comparison to normal root cultures after 2-D electrophoresis. Eighty four protein spots were significantly differentially expressed, of which 64 spots were identified by MALDI-TOF/TOF analysis. The identified protein spots represented different categories such as Amino Acid Metabolism, Carbon Metabolism, Defense, Energy Metabolism, Flavonoid Biosynthesis, Protein Synthesis Assembly Degradation proteins and some Unknown proteins are categorised as unknown (Fig. 19).

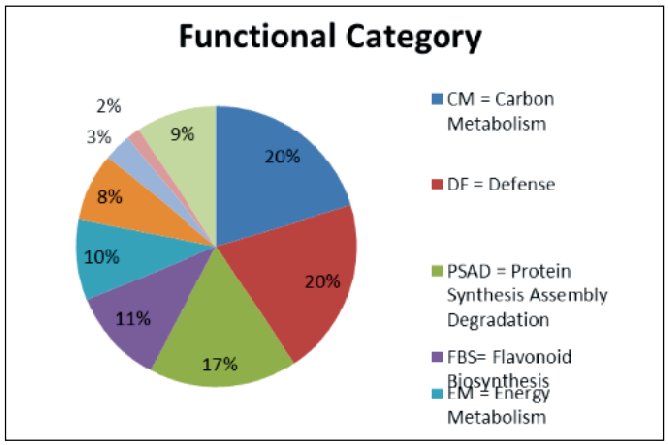


Fig. 19 - Functional categorisation of proteins identified through MALDI-TOF/TOF

Cellular characterization and transcriptome analysis of *Solanum khasianum* to identify the potential transcriptional regulators involved in prickle development

Prickles are very simple structures and can provide an ideal system for developmental studies like cellular differentiation, communication and growth. These can be defined as an outcropping of proliferated epidermal tissue, and very little is known about the molecular events in their development. We have prickly (WT) and prickleless (MT) strains of *S. khasianum* with the advantage of very close genetic similarity. This allows us to compare the mechanisms involved in prickle formation at the molecular level.

Morphological investigations of the stem of both the strain using scanning electron microscopy revealed that the prickle and trichomes of *S. khasianum* are structurally similar. Prickle development initiated only from the base of glandular trichome. Examination of the transverse section of stem of the prickly strain under light microscopy revealed that prickles of *S. khasianum* epidermal in origin but also contains hypodermal cells (Fig. 20).

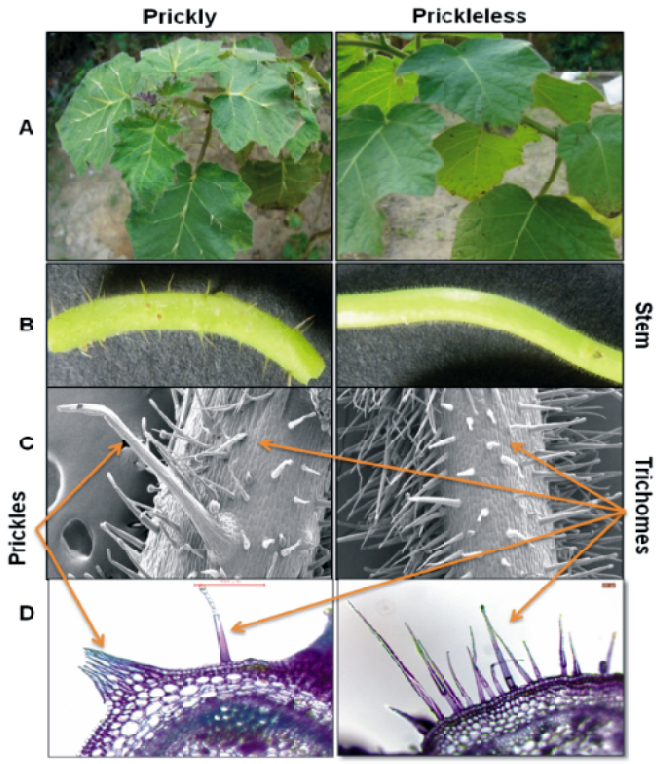


Fig. 20. Morphological difference in prickly and prickless *S. Khasianum*

In order to screen out the global transcriptional regulators involved in prickle development of *S. khasianum*, we have performed RNA-seq of the epidermal tissues of the stem of both strains. A total of 1,090 significantly differentially expressed unigenes were found. Pathways analysis of these unigenes indicated that secondary metabolite, stresses and development associated genes were differentially expressed. We have selected some prickle specific potential putative transcriptional regulators that are under investigation.

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

Linseed is an important oil seed crop having >65% omega-3- fatty acid (highest among the plants) and ~20% omega-6-fatty acid. This crop is prone to various biotic stresses such as rust, wilt, mildew and blight. The latter causing major losses. No systematic efforts have been made till date to develop blight resistant high yielding linseed varieties. Therefore, the project started to tag blight resistant loci using SSR markers and transferring QTLs from resistance source to high yielding linseed variety through marker assisted breeding.

A new set of 40 SSRs polymorphic among parental lines (JRF4 and Chambal) have been identified.

Genotyping of 140 F_2 mapping population segregating for *Alternaria* blight trait with 40 polymorphic SSRs have been carried out. Further genotyping is in progress to generate data for linkage/QTL mapping.

Bulk segregation analysis (BSA) was performed to identify the SSR associated with *Alternaria* blight in linseed, using 10 plants each from two extremes in F_2 population i.e. 10 highly susceptible plants and 10 highly resistant plants. Twenty five previously identified polymorphic SSRs were then used to differentiate the two bulk DNA. Out of 25, 2 SSRs i.e. LuSc_464_2_24 and LuSc_898_3_12 were able to differentiate the the resistant (BR) and susceptible bulks (BS). These 2 SSRs then used to amplify the individual DNA of each bulk and which successfully differentiated the susceptible and resistant plants and thus the markers LuSc_464_2_24 and LuSc_898_3_12 found to be putative linked markers for *Alternaria* blight resistancein linseed.

NMITLI Project

Genomics of *Withania somnifera*

Withania somnifera is one of the most valuable medicinal plants synthesizing secondary metabolites known as withanolides. Despite pharmaceutical importance, limited information is available about the biosynthesis of withanolides. Chemo-profiling of leaf and root tissues of Withania suggest differences in the content and/or nature of withanolides in different chemotypes. To identify genes involved in chemotype and/or tissue-specific withanolide biosynthesis, CSIR-NBRI established transcriptomes of leaf and root tissues of distinct chemotypes (NMITLI-101, NMITLI-118 and NMITLI-135). Genes encoding enzymes for intermediate steps of terpenoid backbone biosynthesis with their alternatively spliced forms and paralogues have been identified. Analysis suggests differential expression of large number of genes among leaf and root tissues of different chemotypes. Study also identified differentially expressing transcripts encoding cytochrome P450s, glycosyltransferases, methyltransferases and transcription factors which might be involved in chemodiversity in Withania. Virus induced gene silencing of the sterol "7-reductase (WsDWF5) involved in the synthesis of 24-methylene cholesterol, withanolide backbone, suggests role of this enzyme in biosynthesis of withanolides (Fig. 21). Information generated, provides a rich resource for functional analysis of withanolide-specific genes to elucidate chemotype- as well as tissue-specific withanolide biosynthesis. This genomic resource will also help in development of new tools for functional genomics and breeding in Withania. The information generated has been compiled in the form of database (Withanome). This database has comprehensive information about Withania in terms of medicinal properties, withanolides, different

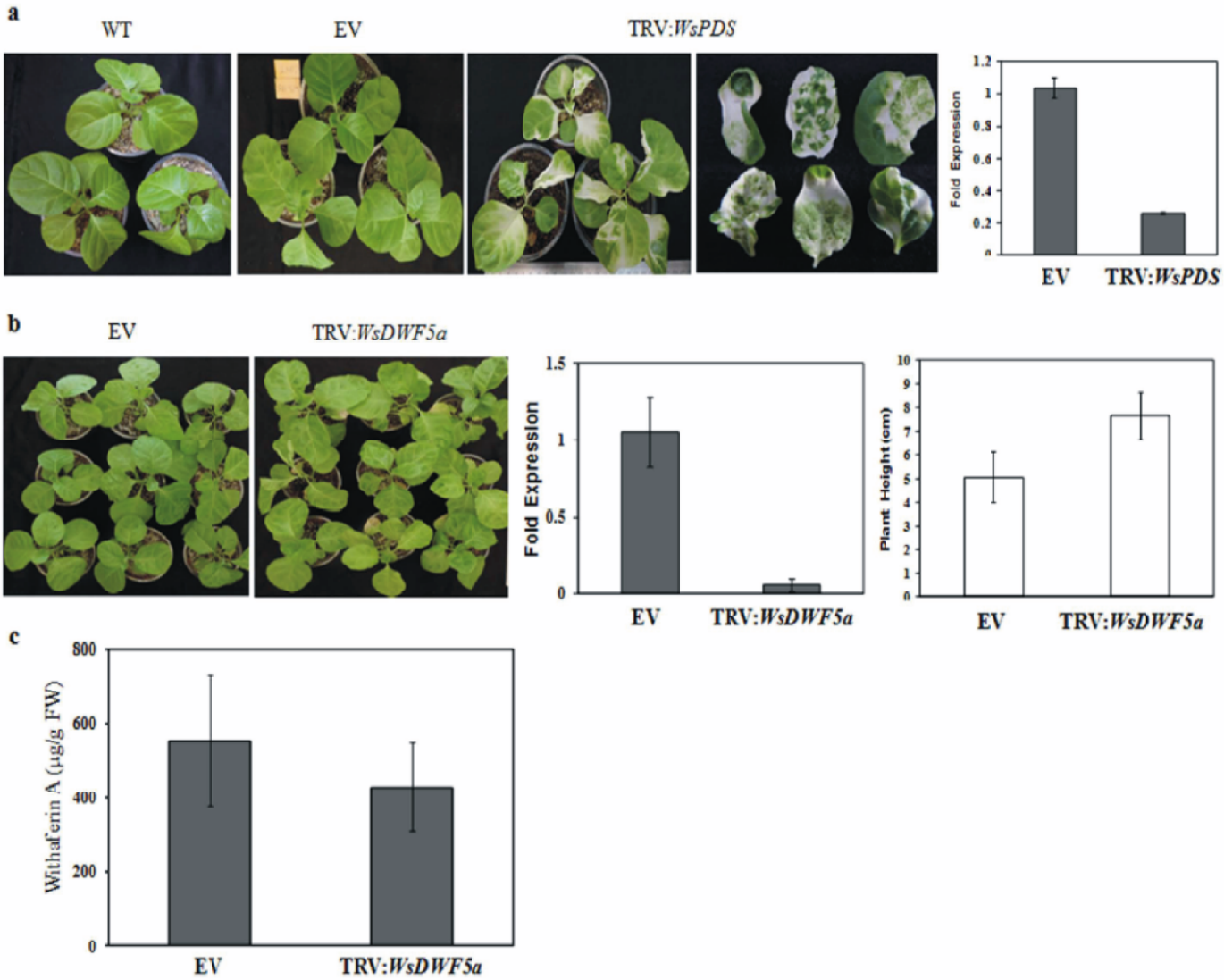


Figure 21: Virus induced gene silencing of WsPDS and WsDWF5a in Withania. (a) Phenotype of wild type (WT), TRV1 and TRV2 infected empty vector control (EV), TRV1 and TRV2:WsPDS infected (TRV:WsPDS) plants and reduced level of transcripts of WsPDS in PDS silenced plants. (b) Phenotype of EV and TRV1 and TRV2:WsDWF5a infected (TRV:WsDWF5a) plants, significantly decreased level of transcripts of WsDWF5a and increase in plant height in DWF5a silenced plants. (c) Reduced level of major withanolide in leaf (withaferin A) in DWF5a silenced plants as compared to EV.

chemotypes, transcriptome datasets and proposed pathway for biosynthesis of specific withanolides.

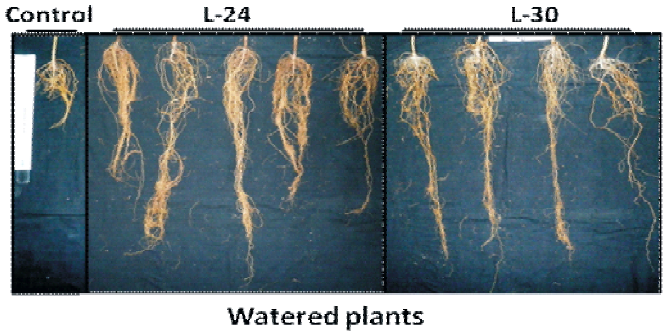
In-House Projects

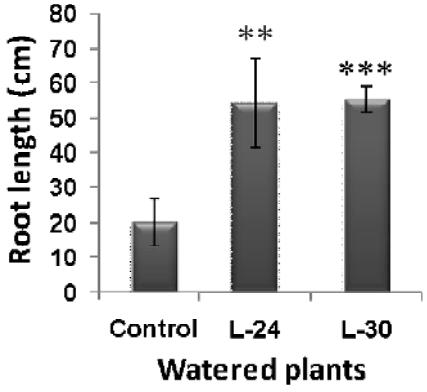
Functional analysis of *GhNAC2* from *Gossypium herbaceum*, and its role in root growth and drought tolerance in transgenic cotton

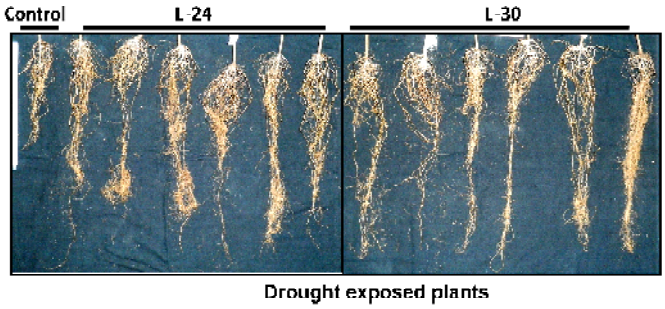
GhNAC2 was previously identified as a drought responsive NAC transcription factor from cotton. Its expression improved root growth in transgenic Arabidopsis and imparted drought tolerance. To study its role in cotton, transgenic lines expressing *GhNAC2* under the CaMV35S promoter were generated in cotton "Coker 310". A marked increase in root length (as seen in transgenic Arabidopsis lines) was also seen in all transgenic *GhNAC2* expressing cotton plants both under well watered and water stressed conditions. Under unstressed conditions, plants of transgenic lines of L-24 and L-30 showed a 2.5-2.75 fold increase in root length over control roots while under water stressed conditions plants of transgenic lines of L-24 and L-30 showed a 1.5-1.7 folds over control roots (Fig. 22).

Leaf abscission and wilting, which are common drought symptoms in cotton, were found to be reduced in transgenic plants subjected to 15 days water stress. While leaves of control cotton plants showed an average of 35% leaf abscission post 15 day water stress, the average leaf fall in plants of transgenic lines L-24 and L-30 was only 11.8% and 7.4% respectively. Of the leaves that remained, there was a greater degree of wilting in water stressed

control plants compared to transgenic lines. Leaf drooping measured as the angle between the leaf laminal plane and the petiole was 90.25°±8.2 in control leaves compared to 120-137° for lines L-24 and L-30 after 15 days of withholding water, indicating reduced wilting in transgenic plants (Fig. 23, 24).







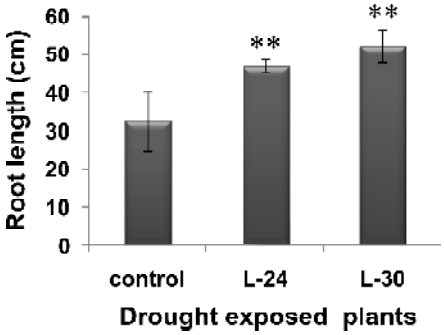


Fig. 22. Comparative root growths of control and transgenic cotton plants expressing *GhNAC2* under the CaMV35S promoter in well-watered (upper panel) and water-stressed (lower panel) conditions.

Notable conclusion: GhNAC2 expression improves root growth in cotton both under unstressed and water stressed conditions and imparts drought tolerance to plants.

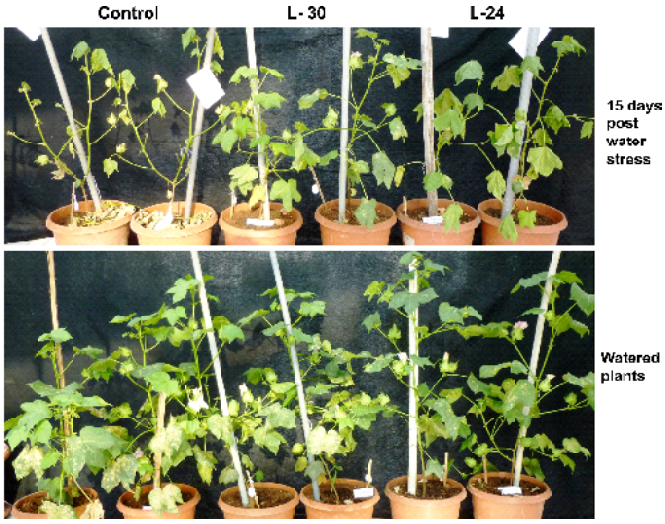


Fig. 23. Comparative plant growth phenotypes of control and transgenic *GhNAC2* expressing cotton plants described in Fig 1 under water-stressed (upper panel) and well-watered conditions (lower panel).

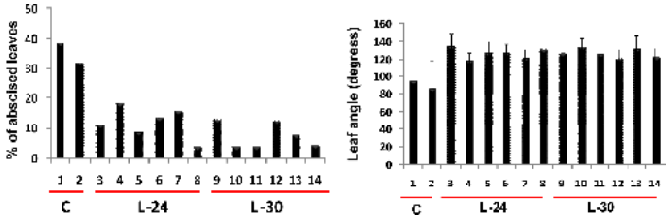


Fig. 24. A, Graphical representation of percent abscission of leaves in control and progeny of transgenic *GhNAC2* expressing cotton plants (Lines L-24 and L-30) after water stress (n=6). B, Graphical representation of leaf angle of leaves remaining in control and progeny of various transgenic *GhNAC2* expressing cotton plants (Lines L-24 and L-30) after water stress (n=6).

Canna Biology :Regeneration and genetic transformation of *Canna* spp.

Canna (*Canna indica* L.) is an ornamental landscape plant and was selected for genetic improvement. A foolproof tissue culture protocol is required for genetic transformation and for any genetic improvement. There is no report available in the literature. The reasons may be that it is a monocot, slow growing in culture, difficult to establish as bacterial contamination is carried through the soil-grown rhizome, hard seed coat etc.

The objective was to develop an efficient protocol for canna transformation using *Agrobacterium* mediated transformation by optimizing the concentration of the strain (GV3101), phenolic compound (acetosyringone), polyamine (Spermidine), inducer of somatic embryos from callus (PEG) and the duration of *Agrobacterium* incubation and infection time.

At lowest GV3101 concentration (OD_{600} = 0.2) it was observed that a high rate of untransformed callus was screened out at 1st cycle of kanamycin selection regenerating medium. Each cycle consists of 20 days. At higher GV3101 concentration (OD_{600} = 0.8) the callus experienced stress condition leading to cell death. At OD_{600} = 0.6, the callus showed growth in biomass in kanamycin selection medium and in selection free regeneration medium.

Transformation was best seen at 200 µM acetosyringone concentration compared to 100 µM and 150 µM. The best results were observed with 45 minutes incubation and 30 minutes infection time.

The transformed callus was screened till 3rd kanamycin selection cycle then transferred to selection-free regenerating medium. The callus divided and increased slightly in biomass. It did not show any development of somatic embryos or formation of plantlets. However few callus showed white hairy like outgrowth but it failed to differentiate in regeneration medium. Multiple shoots of three cultivars of canna are being maintained in optimized medium in liquid medium on glass beads. Transformed callus were checked by PCR analysis and showed positive lines.

miRNA analysis of two contrasting flower color Canna cultivars

miRNAs are endogenous small RNA (sRNA) and play critical roles in plant development processes. Total flavonoids as well as anthocyanin and carotenoids were estimated from the two contrasting flower color cultivars, of *Canna*, Tropical sunrise (TS) and Red president (RP). The total flaovonoids and anthocyanin content were much higher in RP than TS, where as carotenoids and xanthophyll contents were very less as compared to the total flavonoids and anhocyanin (Fig. 25). The small RNA sequencing was carried out from the flower tissues of these two cultivars. A total of 313 known miRNAs belonging to 78 miRNA families were identified from both the cultivars. Thirty one miRNAs (17 miRNA families) were specific to Tropical sunrise and 43 miRNAs (10 miRNA families) were specific to Red president. Thirty two and 18 putative new miRNAs were identified from Tropical sunrise and Red president, respectively (Fig. 26). 109 miRNAs were differentially expressed in two cultivars targeting 1343 genes. Amongst these, 16 miRNAs families targetting 60 genes were involved in flower development related traits and five miRNA families targetting five genes involved in phenyl propanoid and pigment metabolic processes. We further validated expression of a few miRNA and their target genes by qRT-PCR. Target validation of a few randomly selected miRNAs by RLM-RACE was performed but was sucessful with only miRNA162. In RLM-RACE experiment, we got only the target which was not perfcet complementary to the miRNA (Fig. 27). This

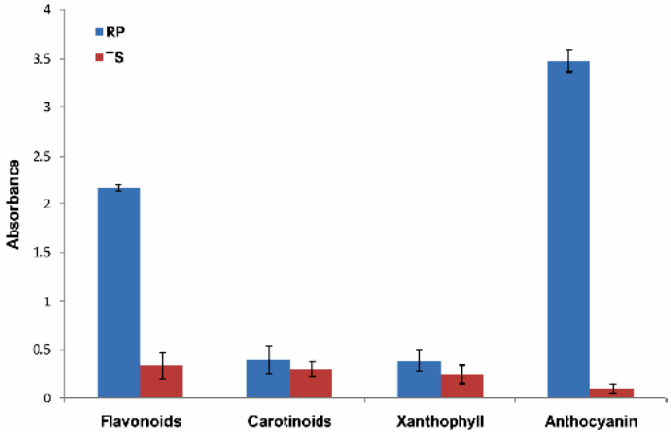


Fig. 25: Flavonoids, Carotenoids, Xanthophyll and Anthocyanin content of TS and RP.

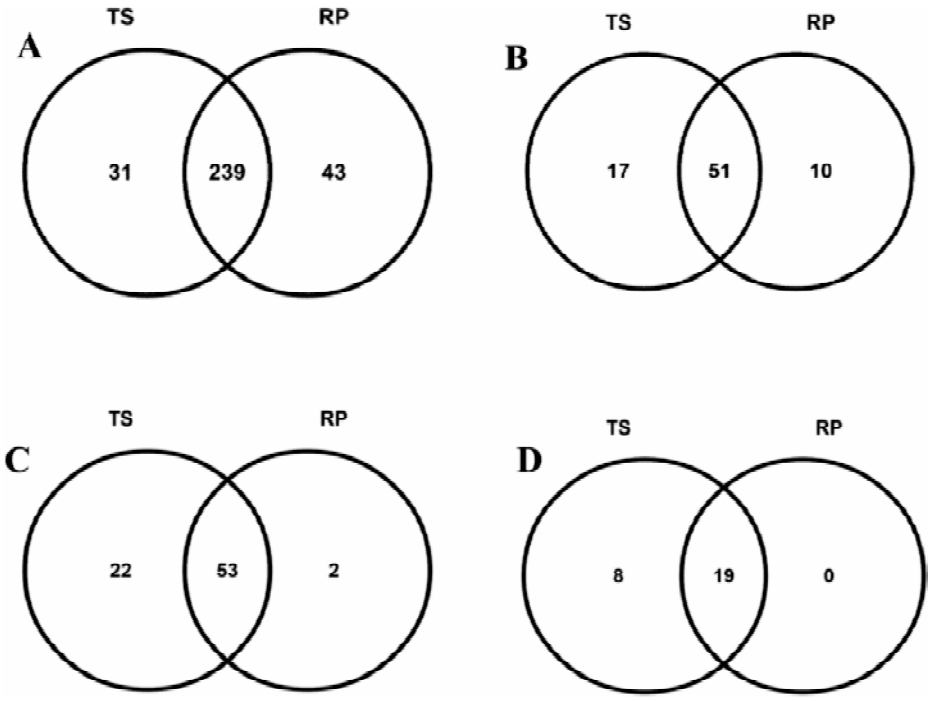


Fig. 26: Venn diagrams of conserved and unique miRNAs between TS and RP. (A) Total conserved and unique miRNAs between TS and RP, (B) Conserved and unique miRNA families between TS and RP, (C) Total conserved and unique miRNA* between TS and RP, (D) Conserved and unique miRNA* families between TS and RP.

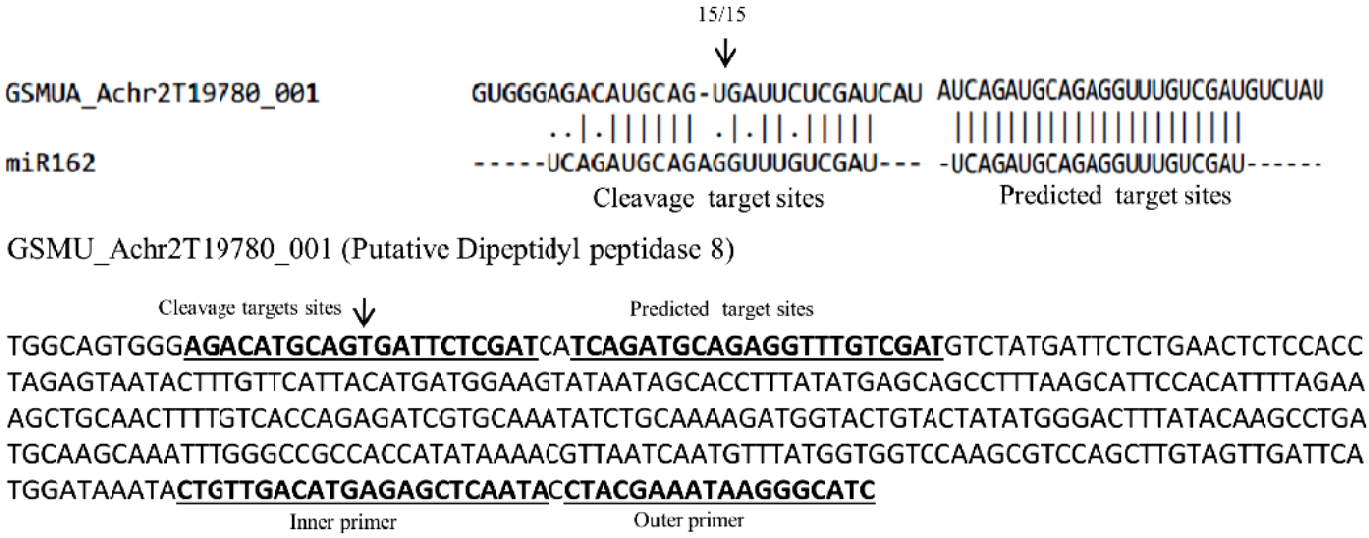


Fig. 27. Detection of cleavage site through RLM-RACE. 5' RLM RACE was used to map the cleavage sites. The partial mRNA sequence from the target genes were aligned with the miRNA. The arrow indicates the cleavage site, and the number above the arrow denotes the frequency of the sequenced clones.

type of miRNA target site is not very common for most of the validated plant miRNA targets but has been observed in some other cases. The differentially expressed and the putative novel miRNAs may provide insight into the molecular mechanisms of flower color as well as other development processes in *Canna*.

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

Introgression of high papaverine and thebaine content in Opium poppy (Papaver somniferum)

The introgression of high papaverine and thebaine content in high yielding varieties was continued to develop lines which are rich in these alkaloids along with the high opium yield. The thebaine and papaverine have high global demand for pharmaceutical purposes. Simultaneously, the global demand for codeine and narcotine alkaloids is also increasing due to use of codeine in cough syrups and narcotine in the treatments of cancers. The work for the development of high codeine and narcotine rich lines was undertaken.

The selected high narcotine and total alkaloid containing lines were further subjected for recurrent and pedigree selection.

The seeds of BC_3F_1 and transgressive segregants for recurrent selection of the crosses between high yielding varieties (NBRI-5 and NBRI-2) and high thebaine lines (NBIHT-1 and NBIHT-3) were obtained. BC_2F_1 and F_3 population for further back crossing and selection of transgressive segregants from the cross between high yielding variety (NBRI-5 and NBRI-2) and papaverine line were grown and seeds were obtained.

The recurrent selection was carried out from the population of the selected transgressive segregants of the cross between high yielding variety (NBRI-2) and papaverine line.

A study was conducted to find out the stable thebaine rich line out of the seven advanced breeding high thebaine lines which have been developed for the first time through rigrous selection from advance generations of interspecific population derived from cross between *Papaver somniferum* and *Papaver setigerum* based on the estimate of genotype × environment interaction (GEI). The overall stability analysis following different stability models (including regression and graphical models) concluded that the lines NBIHT-1, NBIHT-3 and NBIHT-4 were highly stable and adaptable for seed, opium and thebaine content in different agro-climatic conditions. The lines NBIHT-5 and NBIHT-6 can perform well in specific climatic conditions to obtain maximum gain. The study concluded that the GGE Biplot model proposed by Yan and Hunt is best suited for stability analysis than other different stability models due to ease in visualization of stable genotypes from the graphical representation.

Backcrossing programme in Linseed (*Linum usitatissimum*)

Linseed an important industrial oilseed crop can also be a substitute for edible oilseed crop. However, high level of linolenic acid in the oil makes it unsuitable for edible purposes. In this direction, the conversion of linseed oil from industrial to edible purposes can be a significant achievement to fulfill the demand of edible oil. An attempt was made to introgress low linolenic acid trait from the variety 'Linola' (a low linolenic acid <5% line) to high

yielding varieties through backcrossing programme. Simultaneously, characterization of linseed germplasm was completed on the basis of fatty acids profiling so as to facilitate proper utilization of available germplasm.

In linseed, the BC_5F_2 population of the crosses between Ajgan, Shweta and Surabhi with Linola (low linolenic acid) were grown and selection of the desired plants types was carried out.

The recurrent selections were initiated in the selected transgressive segregants of the crosses between high yielding varieties rich in linolenic acid (EC-110288, EC-112689, Mukta, A-993 and Ex-3-3). The gene actions for low linolenic acid and other fatty acids were also worked out in linseed through six parameter model.

The relationship among 12 phenotypic and five quality traits in a set of 151indigenous and exotic accessions of linseed (*Linum usitatissimum* L.) was worked out. Capsules per plant, harvest index and plant weight played a major role directly as well as indirectly towards seed yield. High heritability coupled with high genetic advance for plant weight, secondary branches per plant, capsules per plant and seed yield per plant. Based on *per se* performance, the accessions Shweta (5.41g), Gaurav (5.07g) and EX-3-3 (4.77g) for seed yield and Shubhra (45.09%) followed by Mukta (44.94%) and Laxmi-27 (45.06%) and Shweta (44.25%) for oil content were recommended for commercial cultivation. The chemo profiling of fatty acids in a large number of accessions was accomplished which can provide a platform to the researchers for selection of precise accession for the genetic improvement of linseed as a designer crop.

Marker assisted breeding to develop high omega -3- fatty acid Indian linseed variety

A project was initiated to tag QTLs (quantitative trait loci) for linolenic acid (omega-3-fatty acid) by using SSR makers and their application for marker assisted breeding to develop high omega -3- fatty acid Indian linseed variety. A set of new 25 SSRs polymorphic among parental lines (Neelum x Linola) have been identified. Till now, 193 SSRs polymorphic among parental lines (Neelum x Linola) have been identified.

Fifty highly polymorphic SSRs were deployed over 168 linseed accessions to explore the level of genetic diversity, population structure and also performed association mapping to identify markers for various quantitative traits. A total of 337 alleles were amplified by 50 SSRs ranging from 2 to 13 with an average of 6.74±2.8 alleles per loci. Neighbour-joining (NJ) analysis, model-based population structure and principal coordinate analysis (PCoA) were used to understand the genetic diversity among the 168 accessions of linseed. The NJ based clustering grouped all the accession into three major clusters which were also confirmed by scatter plot of PCoA. However, population structure determined four subpopulations. Further, AMOVA analysis showed that maximum variation (79%) was found within the population. The association mapping done for 9 quantitative traits showed that the only one marker (Lu_3043) was found to be linked with days to 50% flowering through both GLM and MLM analysis.

In order to enrich the marker data for linseed molecular breeding, genotyping by sequencing (GBS) approach was followed to develop SNP markers in a diverse set of 95 accessions of linseed. GBS of 95 accessions of linseed was carriedout and data analyzed for SNP identification. The GBS data resulted in identification of 22,985 SNPs in linseed. Out of 95, 9 accessions have SNP frequency less than 40% and thus removed from further analysis. In this way a total of 17,059 SNPs among 86 genotypes were found to be useful. Further, more stringent criteria were used and finally 10,057 SNPs were selected for further studies such as diversity analysis, AMOVA and association mapping.

PLANT MICROBE INTERACTION, PHARMACOGNOSY AND PHYTOCHEMISTRY

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

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

PLANT MICROBE INTERACTIONS

Grant-in-Aid Projects

Quality production and popularization of bioinoculants for enhancing crop productivity

Crop productivity greatly depends upon the amount of available nutrients in the soil. A significant portion of the available nutrients is derived from transformations of soil microbial biomass. Thus the growth and activity of microorganisms are functions of soil properties, such as nutrition, texture, pH, temperature, water content, which are also sensitive indicators of changes in soil properties. Several researchers have demonstrated that organic farming leads to improved soil quality with higher microbiological activity than in conventional farming, due to crop rotations, reduced application of synthetic nutrients, and the absence of pesticides. Supporting the choice of organic farming with credible science can be vital for improving the overall productivity, food security, food sovereignty and environmental impact of agriculture in the country. For conversion of a conventional field to organic field, first step is to build up the lost fertility of the soil. This can be achieved by complete restriction on the use of synthetic inputs and increased use of organic and biological inputs. For nutrient management and soil fertility build up crop residue, animal dung, forest leaf litter, bone meal, slaughter house waste, blood meal and green manures are important organic sources. All such organic material needs to be composted properly for appropriate impact. Nutrient value of the raw material and composting methodology determines the quality of produce. Bioinoculants such as biofertilizers, biopesticides and other microbiological inputs (organic manure, vermin-compost, etc.) to improve the soil fertility and reducing the use of chemical fertilizers and pesticides have also attracted lot of attention and are being promoted for popularization among farmers (Figs. 1 and 2).

Fig. 1: Training program on popularization of biofertilizer use at Pali, Gorakhpur.

Fig. 2 : Training program on popularization of biofertilizer use at Dafedar ka Purwa, Barabanki.

Uttar Pradesh, which is India's fifth largest state, with a total 243,286 km^2 area and 1,66,800 km^2 agricultural area. The U.P. state is divided in to 9 agro-climatic zones, and 18 divisions (Agra, Aligarh, Allahabad, Azamgarh, Bareilly, Basti, Chitrakoot, Gonda, Faizabad, Gorakhpur, Jhansi, Kanpur, Lucknow, Meerut, Mirzapur, Moradabad, Saharanpur and Varanasi). To ensure the dissemination of technology at massive scale for the benefit of farmers of U.P. a collaborative venture with the Dept. of Agriculture, Govt. of Uttar Pradesh was planned. This collaboration has ensured commercial production and wide spread application of the technology under Lab to Land concept. Besides the expansion through UP Agric Dept., the bio-inoculant technology has also been transferred to private industries for widespread application throughout the country.

Describing plant responses to elevated carbon dioxide and its implication for Root-Soil-Microbe Interactions

A comprehensive characterization of simple sequence repeats in the sequenced *Trichoderma* genomes to provide valuable resource for marker development

Members of genus *Trichoderma* are known worldwide for mycoparasitism. To gain a better insight into the organization and evolution of their genomes, we used an *in silico* approach to compare the occurrence, relative abundance and density of SSRs in *Trichoderma atroviride*, *T. harzianum*, *T. reesei*, and *T. virens*. Our analysis revealed that in all the four genome sequences studied, the occurrence, relative abundance, and density of microsatellites varied and was not influenced by genome sizes. The relative abundance and density of SSRs positively correlated with the G + C content of their genomes. The maximum frequency of SSRs was observed in the smallest genome of *T. reesei* whereas it was least in second smallest genome of *T. atroviride*. Among different classes of repeats, the tri-nucleotide repeats were abundant in all the genomes and accounts for ~38%, whereas hexa-nuceotide repeats were the least (~10.2%). Further evaluation of the conservation of motifs in the transcript sequences shows a 49.5% conservation among all the motifs. In order to study polymorphism in *Trichoderma* isolates, 12 polymorphic SSR markers were developed (Fig. 3). Of the 12 markers, 6 markers are from *T. atroviride* and remaining 6 belong to *T. harzianum*. SSR markers were found to be more polymorphic from *T. atroviride* with an average polymorphism information content value of 0.745 in comparison with *T. harzianum* (0.615). Twelve polymorphic markers obtained in this study clearly demonstrate the utility of newly developed SSR markers in establishing genetic relationships among different isolates of *Trichoderma*.

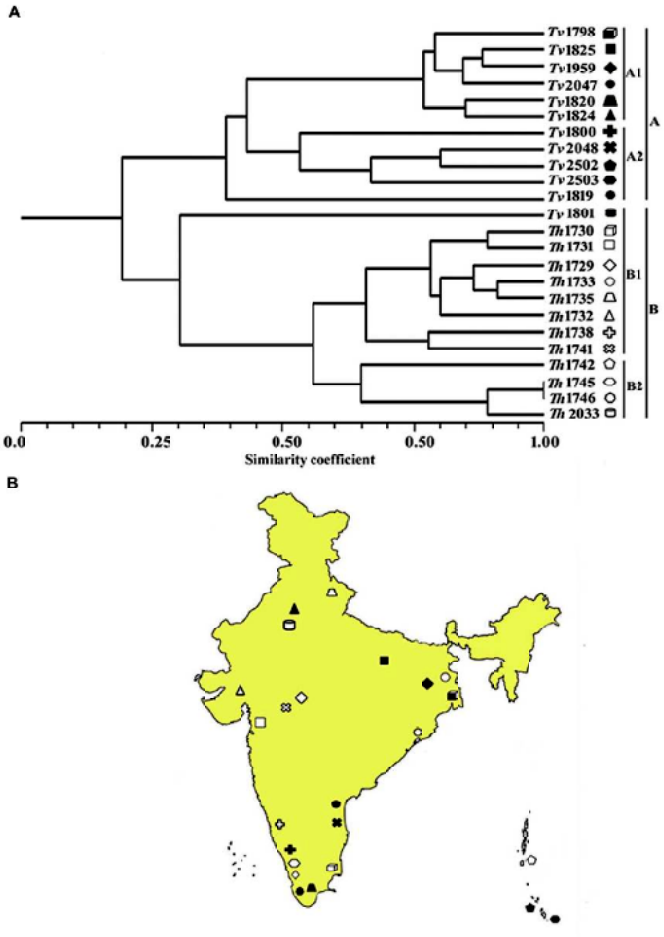


Fig. 3. (A) Dendrogram showing genetic relationship among the *Trichoderma* isolates based on 12 microsatellite markers. Scale indicates Jaccard's coefficient of similarity. A and B indicates main clusters. 1A, 2A, 1B, and 2B indicate sub-clusters within main cluster A and B. (B) Map of India showing the geographical location of different isolates used for diversity analysis in this study.

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

Plant adaptation to drought is a complex process that involves an array of changes at physiological, biochemical and molecular levels. Recently microRNAs (miRNAs) have emerged as key players in post transcriptional gene regulation. Chickpea is the second most important legume crop globally. It offers a unique advantage in understanding plant response(s) to drought stress owing to its hardiness. Further from our lab it has been shown that *Pseudomonas putida* PGPR (RAR) help in drought stress amelioration. Therefore, we aimed to understand the role of miRNAs in PGPR-mediated drought responsive mechanisms in chickpea. This will also help in designing better strategies aimed at improving stress tolerance of legumes. Out of 73 novel miRNAs, 2 and 24 miRNAs were up- and down- regulated ($e \geq 2$ or ≤ -2), respectively in RAR as compared to control. Twenty miRNAs were up- and 20 miRNAs were down- regulated in drought as compared to control whereas 4 and 23 miRNAs were up- and down-regulated, in drought + RAR as compared to control, respectively. Identification of conserved and novel chickpea miRNAs and their target genes from this study will help to assess their role in drought stress alleviation and/or tolerance mediated by PGPR.

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

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] a widely used grain and forage crop, is grown in areas frequented with one or more abiotic stresses, has superior drought and heat tolerance and considered a model crop for stress tolerance studies. Selection of suitable reference genes for quantification of target stress-responsive gene expression

through quantitative real-time (qRT)-PCR is important for elucidating the molecular mechanisms of improved stress tolerance. For precise normalization of gene expression data in pearl millet, ten candidate reference genes were examined in various developmental tissues as well as under different individual abiotic stresses and their combinations at 1 h (early) and 24 h (late) of stress using geNorm, NormFinder and RefFinder algorithms. Our results revealed EF-1α and UBC-E2 as the best reference genes across all samples, the specificity of which was confirmed by assessing the relative expression of a PgAP2 like-ERF gene that suggested use of these two reference genes is sufficient for accurate transcript normalization under different stress conditions. To our knowledge this is the first report on validation of reference genes under different individual and multiple abiotic stresses in pearl millet (Figs. 4 and 5). The study can further facilitate fastidious discovery of stress-tolerance genes in this important stress-tolerant crop.

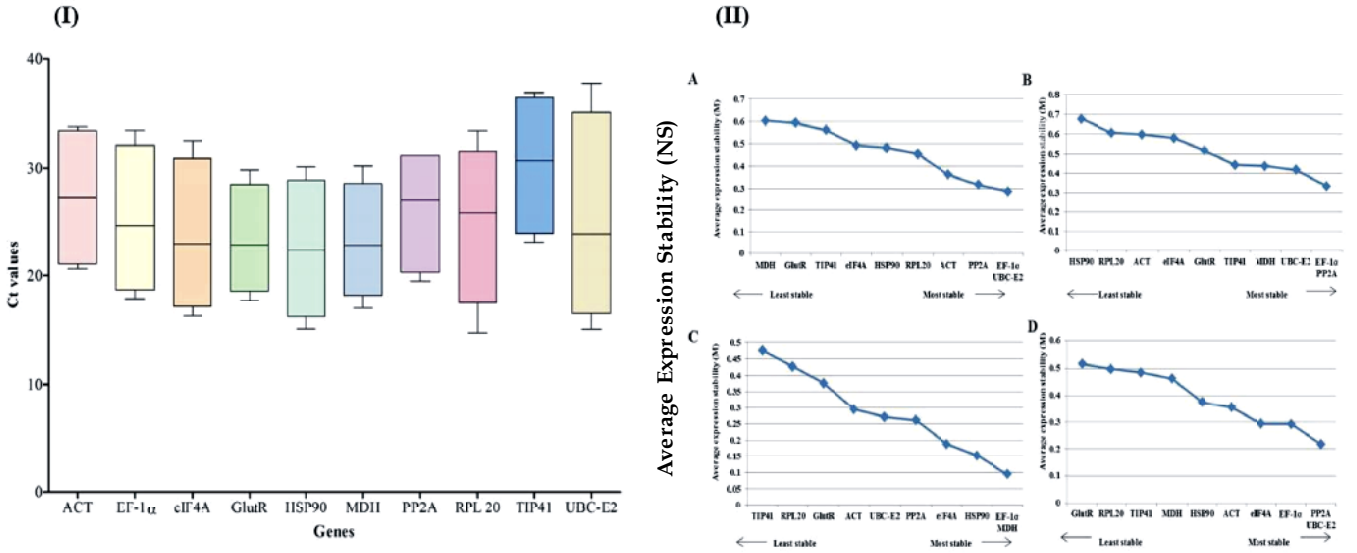


Fig. 4. Ct values of candidate reference genes across all samples (I). Line across the box depict the median value and inside the box show the Ct values. The top and bottom whiskers are determine by the 5th and 95th percentiles, respectively. Expression stability and ranking of 10 candidate reference genes as calculated by geNorm (II) in the individual stress samples set (A), multiple stress samples set (B), developmental tissue samples set (C) and all samples set (D). A lower value of average expression stability (M) indicates most stable expression.

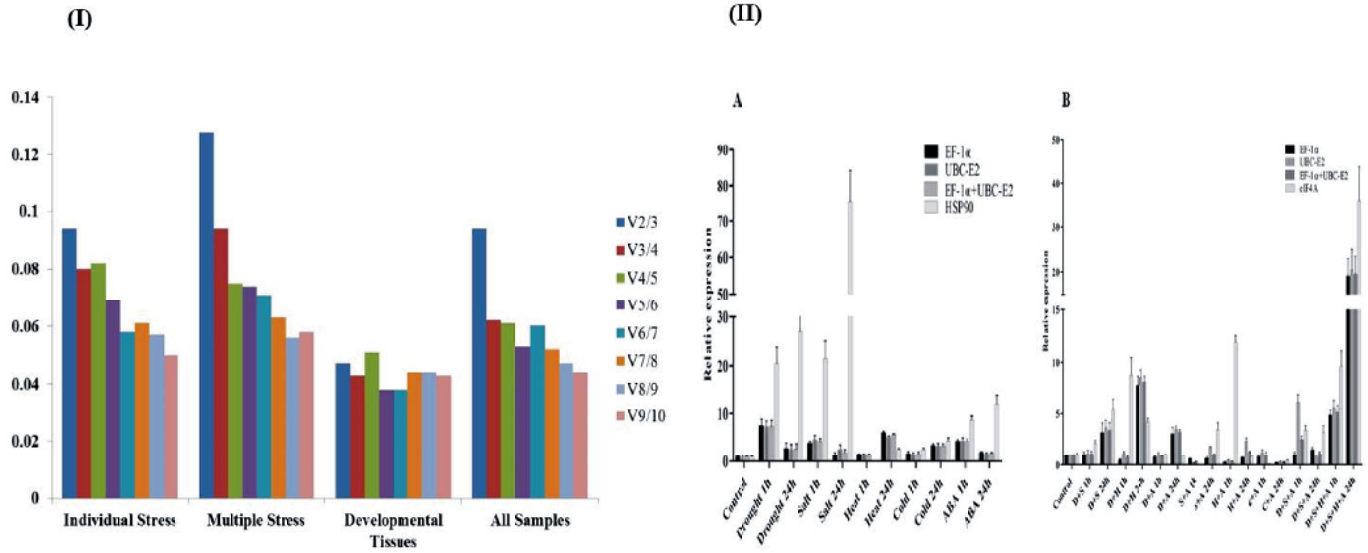


Fig. 5. Pairwise variation (V) to determine the optimal number of control genes for accurate transcript normalization in all the four experimental sets (I). geNorm calculates pairwise variation (Vn/Vn+1) for the normalization factors NFn and NFn+1 to determine (V<0.15) the optimal number of reference genes. Relative expression of *PgAP2 like-ERF* using selected reference genes including the most and the least stable reference genes for transcript normalization (II) following (A) individual and (B) multiple stress treatments after 0, 1 and 24 h. Bars indicate the standard error (±SE) evaluated from the three independent experiments.

In-House Projects

Plant growth promoting rhizobacteria mediated stress management for increasing crop productivity

Biological control of Fusarium sp. pathogenic to cultivated betelvine by *Bacillus* sp NBRI-W9

Betelvine is prone to several fungal diseases including leaf spots, foot and root rot caused by *Fusarium* spp. due to humid conditions prevailing in fields. A potent antagonistic bacterial endophyte and a virulent fungal pathogen were selected after rigours screening of isolates from different betelvine varieties to provide an efficient biocontrol strategy in cultivation of betelvine. Wild varieties of crops are a rich source of untapped endophytes. Of the four betelvine varieties used for isolations and screening, the wild variety was most rich in endophytic population. Using 16S rRNA sequencing the selected antagonist was identified as *Bacillus* sp. (NBRI-W9). Pathogen, virulent against cultivated varieties was identified as *Fusarium* sp. (NBRI-PMSF12) using ITS 1 and 4 region sequencing. Under *in vitro* and field conditions NBRI-W9 was able to induce early rooting, provide plant growth promotion, increase leaf size and yield (leaf number) and provide biocontrol against the *Fusarium* sp. infection. NBRI-W9 treatments showed bacterial colonization on leaf surface preferably in the vicinity of pearl glands and the collenchyma region in scanning electron microscope studies. NBRI-W9 was observed to directly enter the leaf by degrading cell walls and colonize the sub cellular layers. SEM analysis showed direct confrontation of NBRI-W9 with *Fusarium* on leaf surface and in collenchyma region as one of the probable mode of biocontrol (Fig. 6).

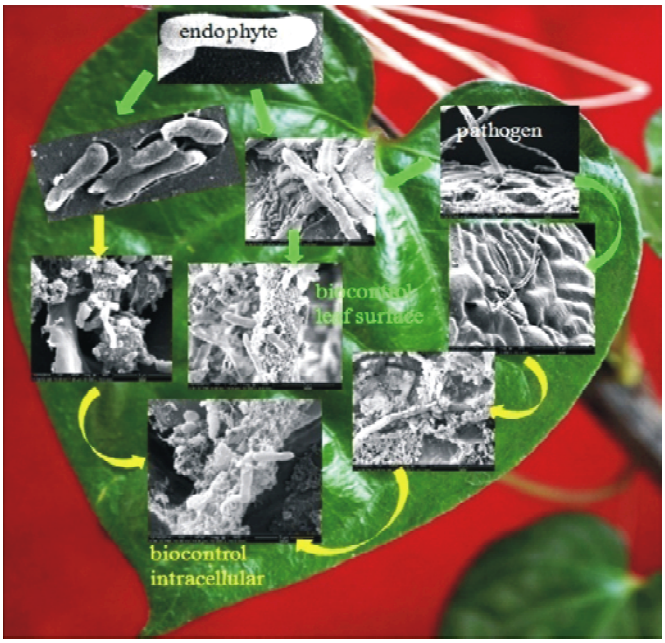


Fig. 6. Biological control of fungal pathogen on betelvine using endophytes. Green arrows show surface interactions; yellow arrows show intracellular interactions.

PHARMACOGNOSY

Grant-in-Aid Projects

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

In total 80 samples of *Gloriosa superba* and 65 of *Coleus forskholii* had been collected from varied phytogeography of India. A herbarium database and passport datasheet of collected samples of targeted species were documented for complete mapping of their natural occurrence. In addition, botanical (macro-microscopic) and physicochemical descriptors has also been established for quality regulation. A new method for quantification of colchicine through OPLC had been developed. HPTLC method developed for quantification of major marker colchicine and forskolin in *Gloriosa superba* and *Coleus forskholii* respectively was also validated and the content was analysed in samples.

Forty live germplasms of *G. superba* and 19 germplasms of *C. forskohlii* had been maintained under natural conditions for multi location trials. A set of maintained germplasms of Coleus and Gloriosa were harvested in selected seasons and re-analysed for quantification of forskolin and colchicine respectively to document the cause of chemotaxonomic variation i.e. genetic or due to geography. Effect of soil profile on variation of forskolin content in natural population was also documented. The study was further extended to collect the germplasms from remaining phytogeography of India and to establish the morpho-chemotypic correlation with eco-geographical factors.

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

The germplasm of the targeted species i.e., *Ageratum conyzoides* were collected from 23 locations covering five states namely, Madhya Pradesh, Uttarakhand, Maharashtra, Sikkim and Jammu and Kashmir. A passport data sheet of each collection was prepared depicting information about the altitude, latitude, longitude, phyto-geographical zones etc. Physicochemical parameters viz., water soluble extractive, alcohol soluble extractive, total ash and acid insoluble ash were evaluated.

The plant material was dried in shade, powdered and methanolic extract was prepared for HPTLC profiling to quantify the bioactive marker compounds Precocene I and Precocene II. The solvent system used for simultaneous estimation of both markers was Toluene: Ethyl Acetate (9.8 : 0.2). Quantification data suggests that there are variations

in the concentration of marker compound in germplasms of different geographical conditions. On an average Precocene II was found to be present in higher concentrations in comparison to Precocene I. However, the maximum amount of Precocene I (0.083%) was found in NAC-82 (Bhowali, Uttarakhand) while for Precocene II, maximum content (0.277%) was found in NAC-85 (Mahichak, J&K). Further, each collected sample was subjected to bulk 95% ethanolic extraction repeatedly up to complete extraction. The filtrate obtained was pooled, concentrated, lyophilized and sent to Indian Veterinary Research Institute, Bareilly for *in vitro* and *in vivo* activity tests.

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

Physico-chemical, phytochemical, antioxidant activity (DPPH Assay, Reducing Power Assay, Beta-Carotene linoleic acid Assay) was evaluated for *Bauhinia purpurea, B. variegata, B. acuminata, Oxalis corniculata,* and *Luffa cylindrica*. Elemental analysis was also performed by using ICP-MS for all the above plant parts. Anticancer activity was evaluated by Cell Migration Assay, Scratch Assay and Measurement of Reactive Oxygen Species by the 2,7-dichlorodihydrofluorescein diacetate (DCF-DA) assay. HPTLC analysis was also performed on all the plant parts for the identification and quantification of Phenolic compounds.

The methanolic extract of *B. purpurea* floral buds (BPBM) showed comparatively better antioxidant activity in terms of total phenolic content (104.24 µg GAE/mg), flavonoid content (28.52 µg QE/mg), DPPH scavenging activities (0.13 mg/mL), beta-carotene assay (82.38 µg / ml) and significant reducing power activity in a concentration dependent manner by ferrous reducing power assay among different extracts. The methanolic extract of *B. purpurea* L. floral buds (BPBM) showed the highest antiproliferative activity on PC3 cells (IC50 = 104.0 ± 2.4 µg/mL) by MTT assay, prevented PC3 cell migration by scratch assay and measurement of ROS by DCF-DA assay suggesting its potential in cancer prevention and inhibition of metastasis. *B. purpurea* buds can be a good candidate for fighting micronutrient malnutrition as it contains good amount of iron (512.16±6.2 ppb) and zinc (43.51±1.6 ppb). Kaempferol was quantified by HPTLC analysis in methanolic extract of both varieties which can be the reason of its antioxidant and anticancer properties. The plants show potential in preventing oxidative stress-related diseases and would be useful as food supplements in micronutrient malnutrition and cancer.

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

Selaginella bryopteris (Sanjeevani) is among the most mysterious and most sought-after herbs in Indian mythology. While the miracle associated with this herb is due to its alleged potentiality for 'resurrecting' life, despite its evasiveness, the herb has been a subject of serious discussions for over centuries. Of late, there is a renewed interest in searching for its identity owing to the emerging realization that biological resources are the untapped capital of any country. Stress tolerance is a phenomenon that manifests itself in our bodies in many different ways. Some of the more common symptoms of stress include, sleeping disturbance, depression, anxiety, irritability, fatigue and lethargy. Perhaps the single most important property of an adoptogenic plan is the proven ability to combat stress in all forms. Herbal drugs has gained importance in recent years because of their efficacy and cost effectiveness. Drugs from Ayurvedic literature have been used as remedies for various alignments in the folk and indigenous system of medicines. However adaptogens are pharmacological agents that induce a state of non-specific increase of resistance of the organism (SNIR) to aversive stimuli which threatens to perturb internal homeostasis. Stress induced by diverse stressors is indistinguishable; therefore, a host of experimental stress situations were investigated to study the biological and pharmaceutical applications of the identified phytochemicals of sanjeevani.

Standardization and validation of Lichen species: *Usnea longissima* and *Cladonia furcata* used in peptic ulcer

Lichens are composite organisms formed by the symbiotic association of fungi and algae. This unique mutualistic symbiotic relationship endows lichens with novel biological characteristics that are different from those of regular fungi and algae. Lichens contain large amounts of usnic acid, lichesterinic acid, and other substances that possess potent antiseptic and antibacterial activities. *Usnea longissima* refers to species in the genus *Usnea*, the family *Parmeliaceae*. *Usnea longissima* is a conspicuous circumboreal "beard lichen" draping tree canopies in moist coastal and mountainous forests. Among the medicinal lichens, *Usnea longissima* lichen is edible and is utilised in the preparation of traditional foods and medicines in both Eastern and Western countries. *Usnea longissima* is a conspicuous circumboreal "beard lichen" draping tree canopies in moist coastal and mountainous forests. It is extirpated in many European and North-American localities, presumably due to industrial forestry and air pollution, but still has a stronghold in parts of

Scandinavia and U.S. and Canadian Pacific Northwest. *Cladonia furcata* used in this study had a stronger antibacterial than antifungal activity. This observation is in accordance with other studies focused on the antimicrobial activity which have demonstrated that bacteria are more sensitive to the antimicrobial activity than the fungi due to differences in the composition and permeability of the cell wall. However, the different fractions of the *Usnea longissima* lichen contains rhizonyl alcohol, pulmonarianin, vesuvianic acid, ergosterol-5α,8α-peroxide, usnic acid etc. The potency of the antiulcer activity against mucosal defensive factors needs detailed investigation.

In-House Projects

Quality Evaluation and Scientific Validation of Indigenous Indian Medicinal Plants Having Industrial Application (Pharmaceutical, Nutraceutical, Cosmaceutical) and Development of Herbal Product(s) Based on Traditional Knowledge

Authentication of Commercial samples of 'Shankhpushpi' using HPTLC

'Shankhpushpi' has the Conch or 'Shankha' shaped flowers. It is a well known Ayurvedic drug of Medhya Rasayana and has several medicinal properties such as rejuvenator to nervous tissue, beneficial for the voice, aphrodisiac; bestows memory, complexion, energy and appetite. *Convolvulus pluricaulis* Choisy (Fam., Convolvulaceae) is official drug as per API but *Evolvulus alsinoides* L. (Fam., Convolvulaceae), *Clitoria ternatea* L. and *Tephrosia perpurea* (L.) Pers. (Fam., Fabaceae) are reported and being sold as Shankhpushpi in different regions of India.

The commercial samples procured from Lucknow, Delhi, Varanasi, Hisar, Jalandhar, Dehradun, Mumbai and Jaipur markets of India were authenticated up to the species level using HPTLC fingerprinting (Fig. 7). Caffiec acid, ferulic acid, lupeol and β-sitosterol were also identified as chemical markers for the quality evaluation of Shankhpushpi and authentication of aforesaid commercial samples. The results indicated that Delhi, Jaipur and Hisar market samples consisted of *Convolvulus pluricaulis* only. However, Lucknow and Varanasi samples were the mixture of *C. pluricaulis* and *Evolvulus alsinoides*. Sample procured from Jalandhar seems to be the mixture of *Convolvulus pluricaulis* and *Tephrosia purpurea* while Dehradun sample resembled to *Evolvulus alsinoides* and *Tephrosia purpurea* in mixed form.

Comparative chemoprofiling of *Betula utilis* D.Don and *B. alnoides* Buch.-Ham. ex D.Don

Betula utilis (Fam. Betulaceae), commonly known as Bhurjah or Bhojpatra in tradition systems of medicine and found throughout the main Himalayan range ascending to an altitude of 4200 m. Another species *B. alnoides* found in India is also known as Bhojpatra. The bark of *Betula* is widely used in Ayurveda and Unani system of medicine,

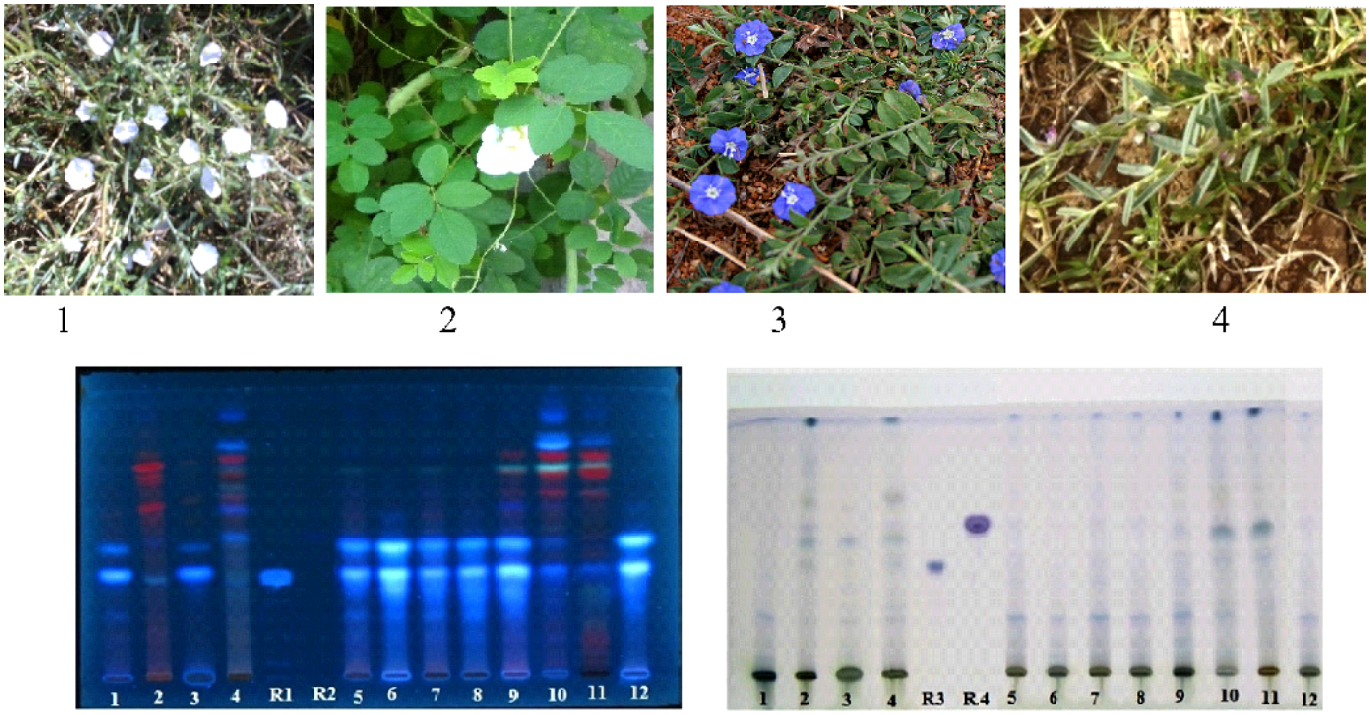


Fig. 7. Collected samples: *Convolvulus pluricaulis* (1), *Cltoria ternatea* (2), *Evolvulus alsinoides* (3), *Tephrosia purpurea* (4); Standard markers: ferulic acid (R1), caffeic acid (R2), β-sitosterol (R3), lupeol (R4); Commercial samples: Lucknow (5), Delhi (6), Varanasi (7), Hisar (8), Jalandhar (9), Dehradun (10), Mumbai (11) and Jaipur (12).

in the treatment of various ailments and diseases such as wound healing, skin disinfectant, bronchitis, convulsions, leprosy and diseases of the blood and the ear. HPTLC protocols were developed for simultaneous estimation of betulin, β-sitosterol, lupeol and oleanolic acid in the stem bark of *B.utilis* and *B. alnoides* (Fig. 8).

along with their antioxidant activity. Significant seasonal alterations in their composition and content were observed. The DPPH radical scavenging activities and the total antioxidant capacity were strongly correlated with total phenolic content of these extracts. The most abundant flavonoid glycoside was quercetin-3-O-rhamnoglucoside

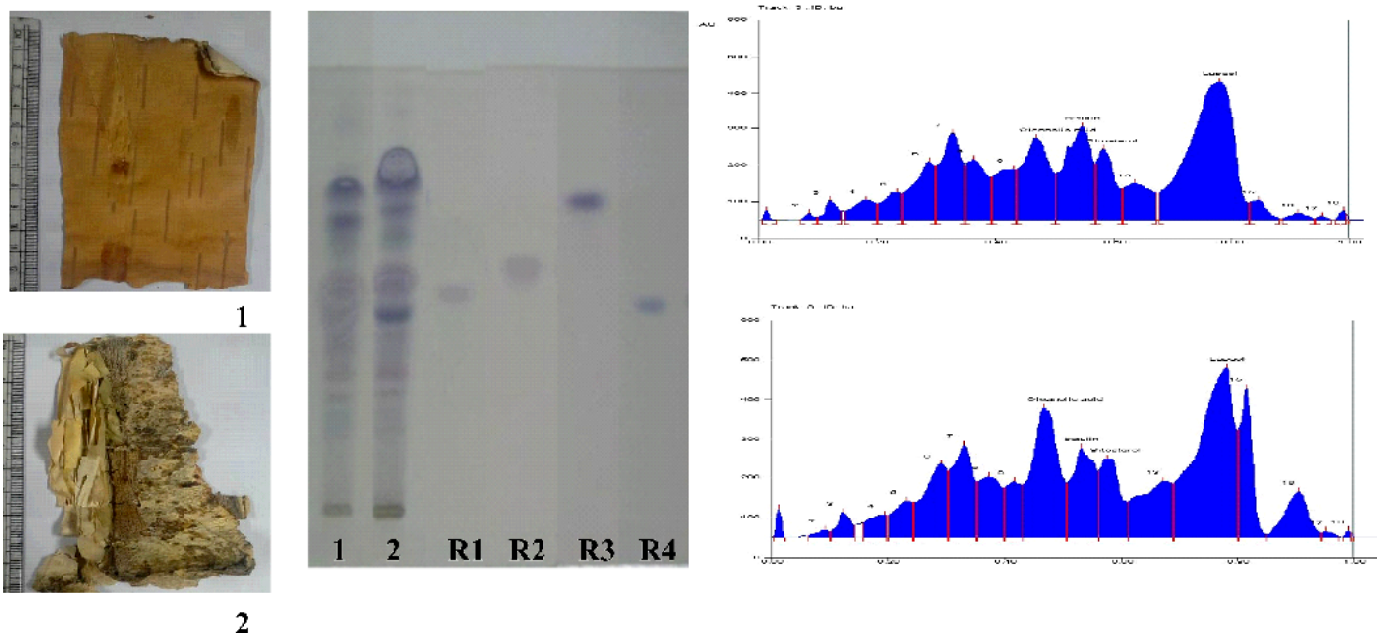


Fig. 8. Comparative analysis of *Betula utilis* and *B. alnoides* stem bark. 1, *B. utilis;* 2, *B. alnoides;* R1, Betulin; R2, β-sitosterol; R3, Lupeol; R4, Oleanolic acid

HPTLC analysis of Leucas species

Leucas species are well known as '*Dronpushpi*', in *Ayurveda*, used in treatment of various ailments. HPTLC method was developed for the comparison and estimation of caffeic, ferulic and gallic acids in nine *Leucas* species viz. *L. aspera* (Willd.) Link; *L. biflora* (Vahl) R.Br.; *L. cephalotes* (Koen. ex Roth) Spreng.; *L. clarkei* Hook.f.; *L. decemdentata* (Willd.) R. Br. ex Sm.; *L. lanata* Wall. ex Benth.; *L. lavandulaefolia* Sm.; *L. stricta* Wall. ex Benth; *L. urticifolia* (Vahl) Sm.) (Fig. 9). Caffeic, ferulic and gallic acids were estimated in all aforesaid nine Leucas species but quantity varied from species to species.

Seasonal studies on *Tephrosia purpurea* (Sarapunkha) to identify best time for harvesting

Tephrosia purpurea is widely used in traditional medicine to treat liver disorders, febrile attacks, enlargement and obstruction of liver, spleen, and kidney. HPLC analysis confirmed the presence of quercetin-3-O-rutinoside, biochanin A-7-O-rhamnoglucoside and kaempferol-3-O-rutinoside in its extracts. Plant was collected in three different seasons: summer (April, 40 ^{0}C), rainy (August; 36 ^{0}C) and winter (December; 20 ^{0}C). Seasonal impact on the content of these flavonoid glycosides was determined using HPLC/PDA analysis in all the seasons (Fig. 10A). The content of all flavonoids was the highest in the 95% ethanolic extract of the August sample (TP-3), which also happened to be the flowering season. The 50% hydro alcoholic extract of the December sample (TP-6) showed the lowest amount of flavonoids and antioxidant activity (Fig. 10B).

PHYTOCHEMISTRY

Grant-in-Aid Projects

Extraction and microencapsulation of nutraceuticals for effective delivery into different food matrices

Mechanical studies such as true density, tapped density, angle of repose, carr's index was done on five characterized nutraceutically rich gum encapsulants (NBRE-13, 15, 16, 22, 23,) and compared with commercial semi-synthetic encapsulants. Functional group identifications of stable matrix formed from encapsulants NBRE-13 and NBRE-15 was carried out. Microcapsules were formulated with different core materials viz. curcumin, bixin (colouring pigments), β-carotene, essential oil and fatty oils (ω6/ω-3 fatty acids) with five encapsulants in different concentrations using five different methods (solvent evaporation- emulsification, lyophilization, pancoating method, ionotropicgelation method,

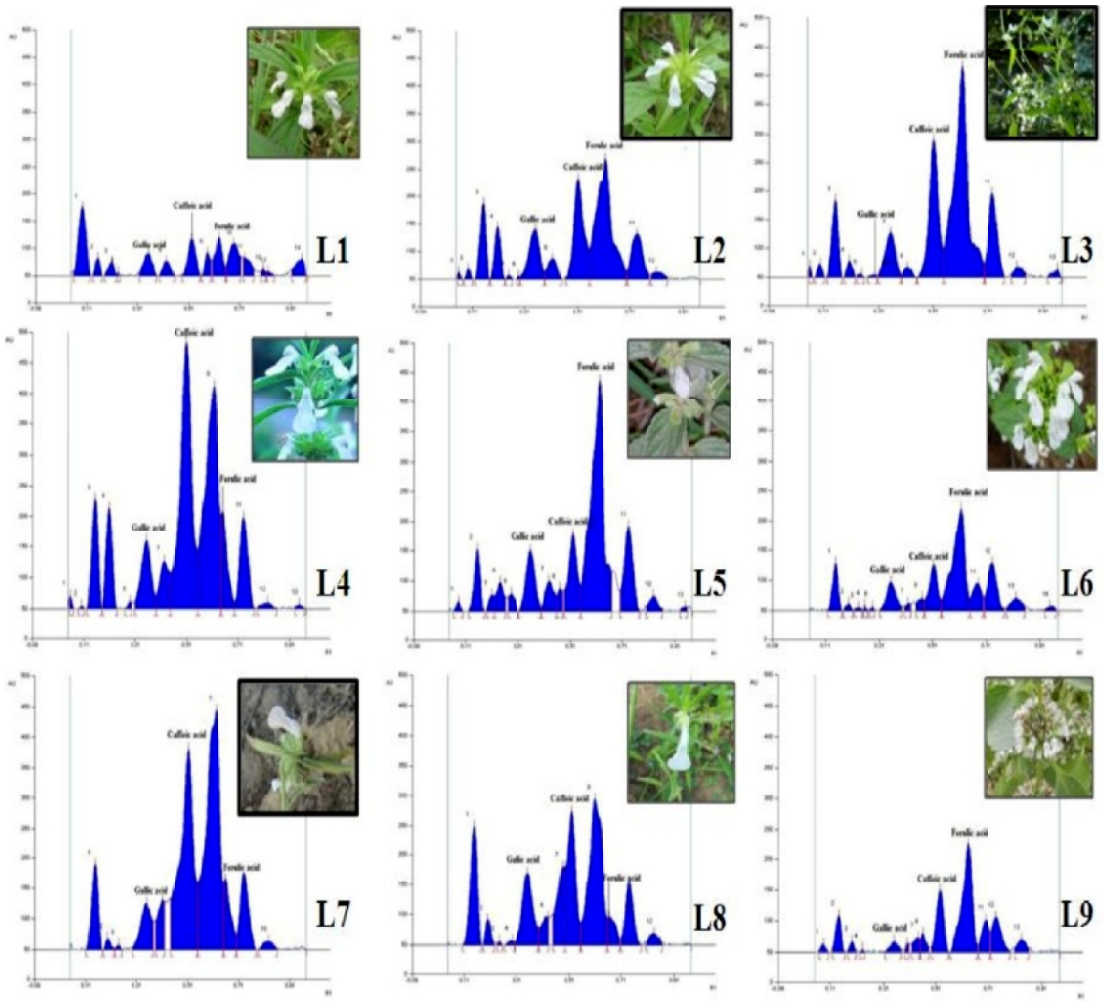


Fig. 9. TLC densitometer scan profiles of nine *Leucas* species at 300 nm. (Abbreviations: CA- caffeic acid; FA- ferulic acid; GA- gallic acid; L1- *L. aspera*; L2- *L. cephalotes*; L3- *L. biflora*; L4- *L. lavandulaefolia*; L5- *L. lanata*; L6- *L. decemdentata*; L7- *L. clarkei*; L8- *L. stricata*; L9- *L. urticifolia*).

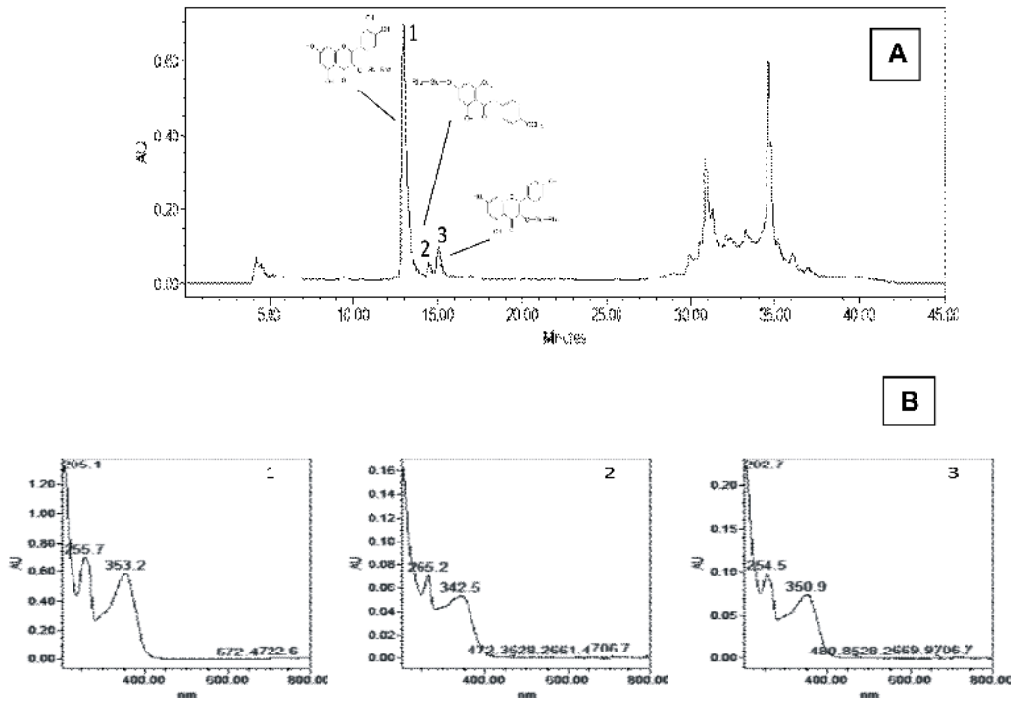


Fig. 10. HPLC profile (A) and UV absorption spectra (B) of flavonoid glycosides in *T. purpurea*. 1. Quercetin-3-O-rhamnoglucoside (rutin); 2. Biochanin A-7-O-rhamnoglucoside; 3. Kaempferol-3-O-rhamnoglucoside

concervation phase separation (non- solvent addition) and compared with standards. An encapsulation method (sodium alginate-calcium chloride complexation) was modified for improving encapsulation process. Multi core encapsulation was carried out using edible oils and coloring principle/ pigments as core material and NBRE-15, 12, and16 as gum encapsulants for its utilization in formation of stable matrices for effective deliveries of foods (Fig. 11).

Development of low cost technology for extraction/ isolation of some lesser know natural gums and value addition thereof

Phytochemical investigation of *Acacia mangium*, *Mangifera indica*, *Buchanania, Butea monosperma*, Chironji and Mahua from identified villages of tribal areas in Sonbhadra district of Uttar Pradesh was carried out for isolation and preparation of formulations. Survey of some villages and tribal areas of Lucknow, Sultanpur, Varanasi, Mirzapur was done for training/ awareness programmes and identifying groups of beneficiaries specifically women's/tribals for value addition and income generation prospects using gums/gum technologies. Pilot scaling of lab scale scientific leads as for gums as colour stabilizer, binders for food and other common needs, careers of foods and phytochemicals as biodegradable products in villages and tribals is initiated to dissipate local need based technology for rural people for income generation and societal upliftment.

Utilization of natural gums as low cost material for development of sanitary napkins and awareness on health and menstrual hygiene issues in rural area

Gums were selected on the basis of literature reviewed and market survey of materials used for sanitation purposes. Five abundant and easily available, gums were collected/ procured and studied for as suitable biomaterial along with commercial samples. Gums are neutral heterogeneous vegetable polysaccharides which show the unique property of holding and retaining water molecules. Their ability to dehydrate, swell and solubilize are under study to explore for development of novel cost effective alternate sanitary products of health and hygiene.

Prospects of Gum rich plant for technological intervention and societal benefits

A survey was carried out in Sonebhadra and Mirzapur region (UP) with some adjoining villages of Tribes where Indian gum rich plants are locally identified. Collection, authentication and separation of gums was carried out to prepare gum binder food and disease resistant gums. A base line data of targeted area is also collected from tribal communities about different gums and their usage which are traditionally used. Two such gums

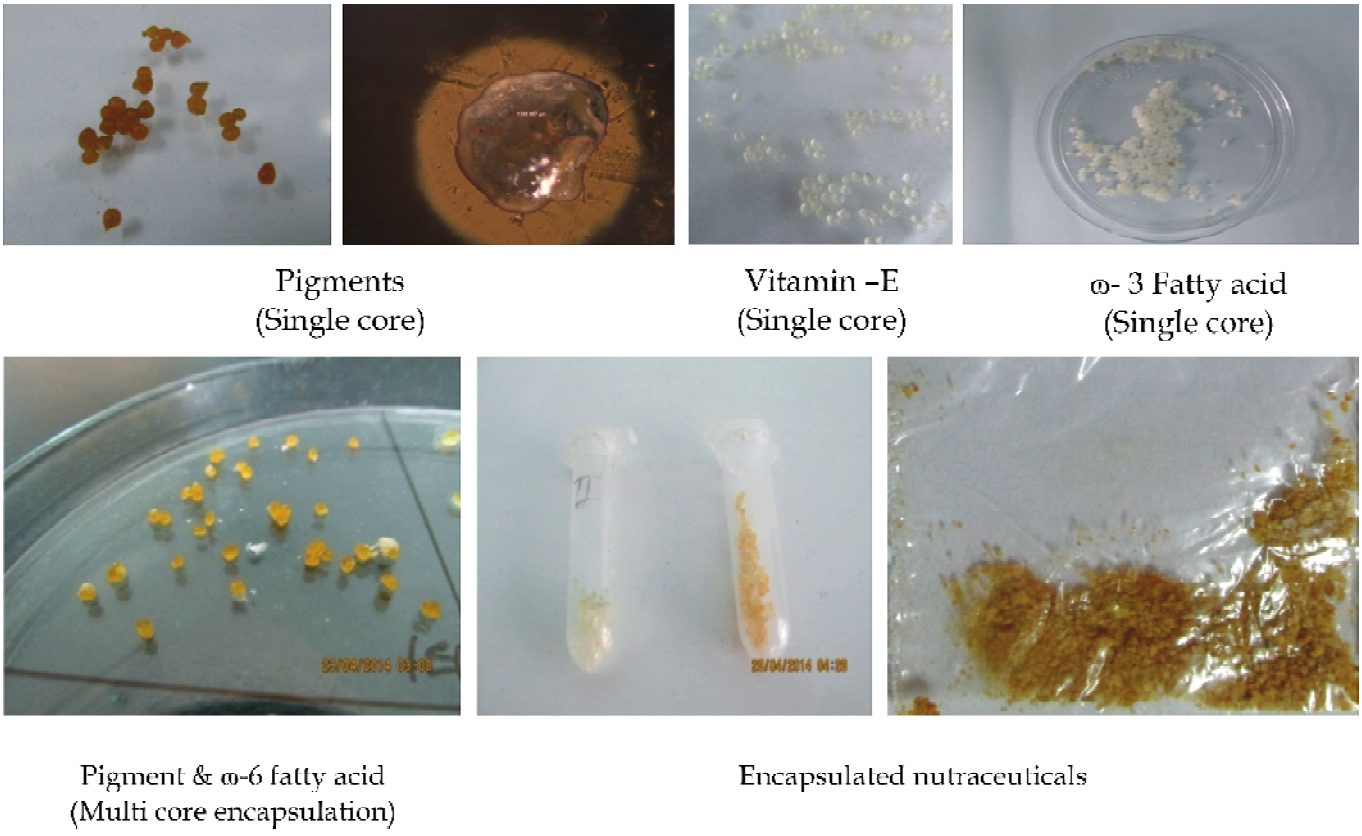


Fig. 11. Multi core encapsulation of nutraceuticals

are under identification for their binding and medicinal behaviour for nutritional and health indicators of tribal. Motivational trainings and awareness for using gum and its product for exploration of technological intervention is initiated for their income generation source and future prospects.

Promoting gugulsterone production in *Commiphora wightii*: Metabolite profiling of contrasting chemotypes and identifying precursors of guggulsterones

Leaf, stem, and latex of *Commiphora wightii* were collected from arid (Barmer and Jaisalmer, Rajasthan), semi-arid (Kayalana, Jodhpur) and subtropical climate (Lucknow) during summer and analyzed for their aqueous and non-aqueous metabolites using HPLC and GC-MS.

Non-targeted metabolite profiling of various different accessions of *Commiphora wightii* namely NBRI-101, NBRI-102, NBRI-103, NBRI-104, NBRI-105, NBRI-106, NBRI-107, NBRI-108 and NBRI-109 collected during extreme summer season from arid and semi-arid regions was carried out using HPLC and GC-MS and identified 59 chemically diverse metabolites including amino acids, organic acids, sugars, sugar alcohol, fatty acids, phenolics, steroids, sterols and terpenoids representing primary and secondary metabolic pathways. A significant qualitative as well as quantitative variation was observed in both the aqueous and non-aqueous metabolites among different accessions of *C. wightii*. Guggulsterone E and Z analysed using HPLC showed significant quantitative variations among different accessions (Fig. 12).

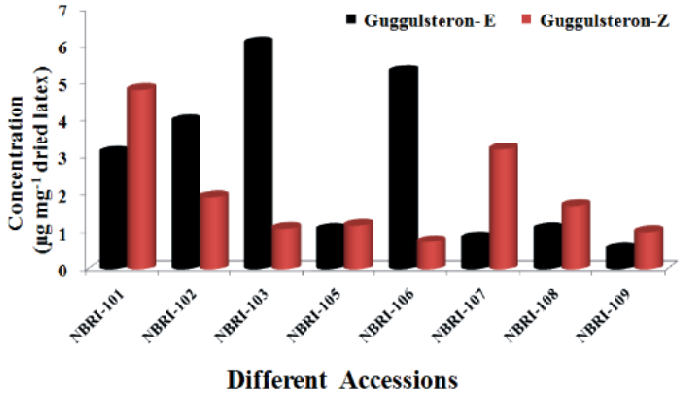


Fig. 12. Shows variations in guggulsterone E and Z among different accessions of *C. wightii* collected during extreme summer from arid and semi-arid regions.

In-House Projects

Phytochemical studies of medicinal and Aromatic plant

Antitermite Activity

Four plant extracts NBHS, NBCI, NBEG and NBEH along with Chlorpyriphos 20% EC were tested against *Odontotermes obesus (Rambur)* termites in the field trial. Results showed that NBEG, NBEH, NBHS and NBCI having 5%, 3%, 2% and 1% infestation, which were at par of chlorpyriphos 20%, EC (2%). Untreated wood were completely destructed (100%) (Fig. 13).

Fig. 13. Antitermite Activity against *Odontotermes obesus (Rambur)* termites

Identification of fatty acid in roots and leaves of *Launaea procumbens*

The major fatty acids in roots and leaves were palmitic (30.80 and 43.78%), myristic (5.52% and 6.47%), margaric (1.52 and 3.22%), oleic acid (12.68 and 8.33%), linoleic acid (14.84 and 11.12%), linolenic (2.47 and 4. 26%) behenic (6.38 and 1.41%), cerotic (1.20 and 1.31%), montanic (3.69% and 2.14%) respectively (Fig. 12). The minor fatty acids were caprylic, pelargonic, capric, lauric, pentadecanoic, palmitoleic, arachidic, henicosanoic, tricosanoic, and pentacosanoic acid. The proportions of saturated fatty acid (55.76% – 63.84%) were higher than unsaturated fatty acid (32.82%-24.82%) in roots and leaves, respectively.

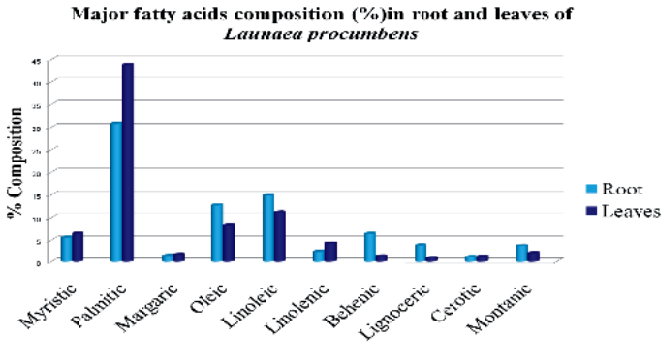


Fig. 14. Major fatty acids composition (%) in root and leaves of *Launaea procumbens*.

Isolation and Identification of compounds along with the Cytotoxicity of the extracts in *Launaea procumbens*

Fifteen compounds have been isolated and identified from the *Launaea procumbens* as 1-H- pyrazole, 1-H -

Imidazole, Inositol, Stigmasterol, β-amyrin, α-amyrin, Lup-20(29)-en-3-ol, Xylitol, Ribitol, D-glucose, proline, arabitol, mannitol, fractose, trehalose, galactinol, 3-α-mannobiose. The cytotoxicity study was carried out for different fractions LPH (n-Hexane), LPE (Ethyl acetate), LPW (Water) and LPB (n-Butanol). These extracts were tested against human cancer cell lines as leukemia (K 562), cervix (HeLa), pancreatic (MIA-Pa-Ca-2) and breast (MCF-7) at different concentrations to determine the IC_{50} value by SRB assay. Ethyl acetate fraction was found active against cervix (HeLa), leukemia (K562) and breast (MCF-7) cancer cell lines with IC_{50} value of 42, 56.70 and 64 µg/ ml respectively (Fig. 15).

Extraction, isolation purification and phytochemical studies of some medicinal and aromatic plants viz. *Ficus*, *Cassia. fistula*, *Moringa*, *Sterculia*, *Sesbania and Mucona species*., were carried out for development of economically useful phytochemicals, natural additives, formulations and products. Chemical profiling of more than 20 seperated plant gums was accomplished for identification of functional groups, properties and development of chemomarkers which was compared with commercial standards, D-Glactose, D- mannose, arabinose and galactomannan. Utilization of two identified potential plant gum binders for food and health was carried out. Preparation of formulations was done in solid and semisolid forms using NBRBf-26, NBRBf-27, NBRBf-8) as binders in concentration ranges of 0.25-2% for value addition and development of nutritional foods.

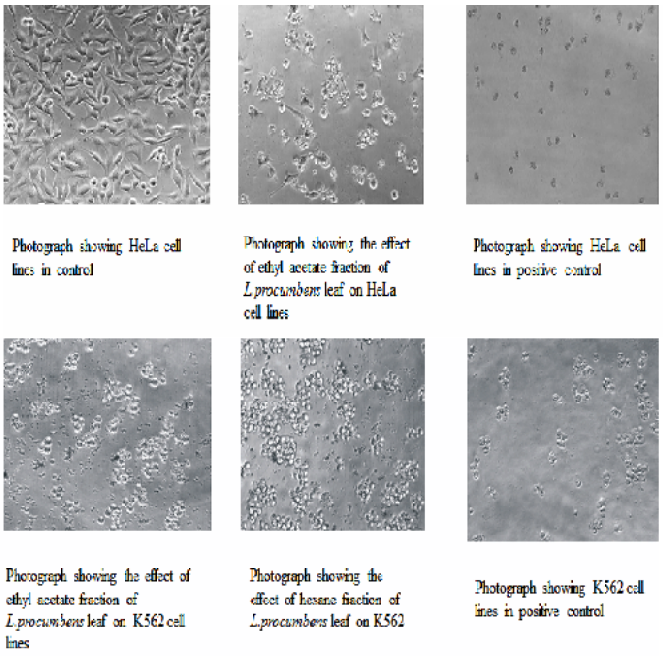


Fig. 15. Compounds along with the Cytotoxicity of the extracts in *Launaea procumbens*

Modification of more than 10 gums/ gum films was undertaken for improved functional properties and to develop biodegradable polythenic / plastic films. Value added biodegradable films (NBRg-11, NBRg-13, NBRg-15, NBRg-17 and NBRg-21) were prepared, standardized and investigated. Three interacted components NBRg-13+ SLS, NBRg-13 + sap and NBRg-13 + Ac.co. at 1 and 2% concentrations were analyzed for functional properties. NBRg-13 + sap showed best properties as compared to commercially available synthetic material (SLS). Exploitation of potential combatants is in process for preparation of plant based detergents and cleansing agent.

Phytochemical investigation of different flowers from CSIR-NBRI garden was carried out for extraction of colour from them. Five plant gums were exploited for extracted colour stabilization and its development. Standardization and optimisation of protocol/process for preparation of stable plant colours, (dark red and yellow colors) using seed/exudate gums in powder and other acceptable forms (extracts; film /strip; tablet; capsule etc.) are in process for sustainable utilization.

S & T SUPPORT

S & T SUPPORT SERVICES

INFORMATION, PUBLICATION & LIBRARY (IPL)

IPL functions as one of the core S&T support systems of the Institute. It primarily caters to the information needs of scientists, researchers, students, industrialists, planners, administrators, and people from other walks of life on various aspects of plant sciences and related research disciplines. With its three constituent functional units, IPL serves as a gateway for science dissemination and as a knowledge resource centre for the benefit of a wide user groups. The main functions of IPL include collection, collation, publication and effective dissemination of the S&T information resources generated by the Institute through different communication tools, including print and electronic media.

It serves as the principal communication link between the Institute and its stakeholder groups. It organizes scientific events, press meets, celebration of national and international days of scientific, technological and strategic importance to the Institute and our nation, besides showcasing the Institute's publication and other R&D outputs to the science community and the public through different media and means.

Its primary function is publication of the research and development outcomes and outputs of the Institute in the form of *NBRI News Letter* (a quarterly in-house publication), *Annual Report*, and other science and popular books, bulletins and calendars on different themes of topical interests on plants, environment, biotechnology, agro-technology, ornamental horticulture, etc.

Publications : It is one of the major activities of the division. Following publications were brought out during 2015-2016 :

i) *CSIR-NBRI Newsletter*, 2015, Vol. **42**, Nos. 2-4 and 2016, Vol. **43,** No. 1.

ii) Educational Material (Calendar) for the year 2016 was designed and produced, depicting coloured photographs.

iii) CSIR-NBRI Annual Report **:** Annual Report 2014-2015 was compiled and brought out. It was released on the occasion of Annual Day of the Institute on October 25, 2015 by Prof. JP Khurana, Delhi University, South Campus, New Delhi and Dr. VP Kamboj, former Director, CSIR-CDRI, Lucknow.

iv) CSIR Annual Report **:** Progress report on important R&D projects was compiled with respect to CSIR-NBRI, which covered significant contributions of CSIR-NBRI in the areas of Science & Technology, HRD activities, Awards and Distinctions, Patents Filed & Granted and sent to CSIR HQ for inclusion in the CSIR Annual Report 2014-2015.

Sale of Publications : **₹ 15,510/-**

Parliament Questions : Thirty one parliament questions received from CSIR HQ were answered.

KNOWLEDGE RESOURCE CENTRE (KRC)

The library is the designated Knowledge Resource Centre of the Institute and provides services and facilities to meet the S&T knowledge requirement of the R& D Groups of the Institute and other user groups as well. The KRC operates with the following objectives :

- To support the learning process of the students through provision of knowledge/ Information.
- To meet knowledge/information needs of the scientists and research students to support their research activities.
- To respond effectively, where possible, to the knowledge/information needs of the Institute's clientele.

The KRC repository at NBRI includes: Books (29351); Periodicals – Bound Volumes (31529), Currently subscribed periodicals (Indian + Foreign) - including print only (87), Print + online (16), Online only subscribed through NBRI (KRC) (20), Online periodicals subscribed through CSIR-Consortium (475), Complimentary periodicals (22); Online/CD- ROM Databases; OPAC (Online Public Access Catalogue); Biological Abstracts on CD-ROM from 1995 to 2005; ASTM standards on CD-ROM; ISI WEB OF KNOWLDEGE (Web of Science); QPAT patent database.

At present KRC (Library) is using LIBSYS Software and all operations of KRC are fully automated. OPAC (Online Public Access Catalogue) is available to the users on their desks.

LIBRARY HOLDINGS (As on 31.3.2016)

Books & Journals	
1. Number of books and journals added during 2015-2016	
(i) Books Purchased	118
(ii) Books received on gratis/ exchange	09
(iii) FAO's Books received	38
(iv) Bound Journals	NIL
Total number of books added during 2015-16	**165**
2. Number of books and bound journals as on 31.3.2016	60880
Current Periodicals	
(i) Print only	87
(ii) Print + Online	16
(iii) Online only	20
(iv) Online received through CSIR consortium (NKRC) on share basis	475
(v) Complimentary/Exchange	22
Total number of Periodicals (titles) received during 2015-2016	**620**
Document Delivery Services	05
Reprography Service	7800
Total number of photocopies of documents and scientific publications provided to the scientists of the Institute during 2015-2016	

PLANNING, MONITORING AND EVALUATION

The Planning, Monitoring and Evaluation Division of the Institute assist Director and acts as a liaison between Director and various R&D groups : CSIR HQ and other organizations. The Division strives to spearhead the programmes and projects of various divisions of the institute from the stage of planning to outputs of value to diverse stakeholders. The activities of the division include scrutiny, coordination and evaluation of new research proposals, monitoring the progress of research projects and maintenance of repository of R&D projects in both physical documents as well as electronic databases.

During 2015-16, 18 Grant-in-Aid/Consultancy projects were populated in the R&D module as a part of ERP solutions for quick online accessibility and usability of complete accurate information. Newly joined employees were mapped for the new projects commenced during the period under report. The necessary project receipts of the FY 2015-16 of ongoing projects were processed in the Centralized Valuable Receipt (CVR).

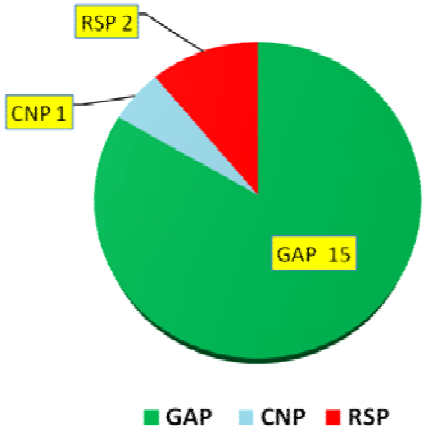
The major activities carried out during the year were:

- Preparation of CSIR-NBRI Policy and Road Map Document
- Mapping new Contract R&D Projects in R&D Project Module
- Technical manpower planning and human resource development
- Coordination between various agencies with respect to R&D activities
- Project evaluations of new research proposals (through Project Evaluation Committee)
- The necessary project receipts of the FY 2015-16 of ongoing projects were processed in the CVR
- Database maintenance for R&D projects (in-house, sponsored, collaborative, Grant-in-aid, Consultancy, NMITLI, Plan Projects & Network Projects)
- Organization of 44th and Special Research Council (RC) meetings held during September 19, 2015 and January 2, 2016, respectively.
- Interface with auditors : the division interacted and provided supporting information for submission of internal and external audit parties of CSIR in the auditing of R&D projects
- Examination, evaluation and processing of indents
- Facilitating distribution of money realized from license fee/royalty/consultancy
- Processing foreign deputation cases of researchers for various R&D purposes

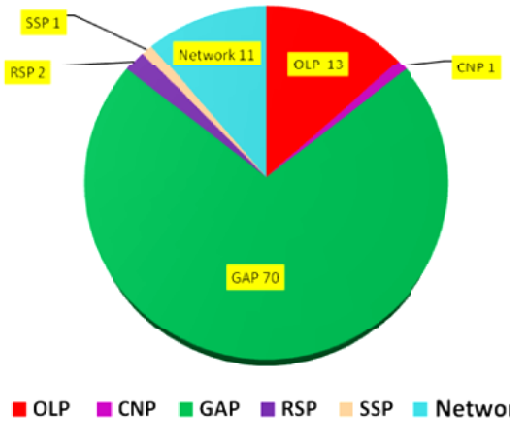
Projects Initiated during 2015-16

S. No.	Project	Project title	Funding Agency	Project Co-ordinator/ Investigator	Duration
1.	RSP 4025	CSIR-NBRI initiatives for rural development through "Green Technologies" under CSIR 800 Rural Development Programme	CSIR	Dr. SK Tewari	12 months w.e.f. April 1, 2015
2.	RSP 4001	Field demonstration of region specific medicinal & aromatic plants genotypes of CSIR for socio-economic upliftment of masses in J&K regions (J&K Aroma Arogya Gram-JAAG)	CSIR	Dr. S Kumar	21 months w.e.f. June 12, 2015
3.	GAP 3355	Establishment of small nursery for fast multiplication of elite clones and new varieties of medicinal and aromatic plants	Directorate of Horticulture and Food Processing UP	Dr. RC Nainwal	12 months w.e.f. April 22, 2015
4.	GAP 3356	Water quality monitoring of Ganga river from Gomukh to Hooghly, under National Mission for Clean Ganga (NMCG)	NEERI, Nagpur through Ministry of Water Resources, Govt. of India, New Delhi	Dr. DK Upreti	14 months w.e.f. May 13, 2015
5.	GAP 3357	Metabolite profiling of Amaranth for high squalene yielding chemotypes in control of hypertension	ICMR, New Delhi	Dr. OP Sidhu	12 months w.e.f. June 23, 2015
6.	GAP 3358	Phytochemical and pharmacological studies of the isolated polyphenols from the resurrection plant *Selaginella bryopteris* (Sanjeevani)	ICMR, New Delhi	Dr. ChV Rao	12 months w.e.f. June 23, 2015
7.	GAP 3359	Deciphering the beneficial microbes mediated signaling cross-talk for enhanced crop productivity under stressed conditions (JC Bose Fellowship)	SERB, New Delhi	Dr. CS Nautiyal	60 months w.e.f. June 22, 2015
8.	GAP 3360	Mapping of floristic diversity and conservation studies on plant resources of Kishanpur Wild Life Sanctuary	UPCST, Lucknow	Dr. P Agnihotri	36 months w.e.f. June 16, 2015
9.	GAP 3361	To decipher protein interaction network of TAF4b (TBP associated factor 4b) involved in plant defense	DBT, New Delhi	Dr. SV Sawant	36 months w.e.f. July 15, 2015
10.	GAP 3362	Phylogentic grouping South Asian Lichen of the *Teloschestaceae* (Ascomycota) for biotechnological purposes	DST, New Delhi	Dr. DK Upreti	36 months w.e.f. August 27, 2015
11.	GAP 3363	Assessment of bryophyte diversity, species richness and composition in Darjeeling Hills with special reference to climate change and its conservation strategies	SERB, New Delhi	Dr. AK Asthana/ Dr. R Gupta	36 months w.e.f. January 4, 2016
12.	GAP 3364	Studies on genome wide epigentic variations in natural populations of west Himalayan *Arabidopsis thaliana* along altitudinal gradient	DBT, New Delhi	Dr. S Roy	36 months w.e.f. 1 December 4, 2015

S. No.	Project	Project title	Funding Agency	Project Co-ordinator/ Investigator	Duration
13.	GAP 3365	Investigation of arsenic toxicity and tolerance mechanism by studying proteomic and gene expression response during dimethylarsenic acid and silicon interaction in rice (*Oryza sativa* L.)	SERB, New Delhi	Dr. RD Tripathi & Dr. S Dwivedi/ Dr. P Tripathi	36 months w.e.f. January 15, 2016
14.	GAP 3366	Development of bio-augmentation based safe cultivation practice for remediating arsenic contamination to paddy crop	DBT, New Delhi	Dr. P Srivastava	36 months w.e.f. December 31, 2015
15.	GAP 3367	Agrotechnological development of *Aloe* species for popularization and training among farmers for cultivation on sodic degraded lands of U.P.	UPCST, Lucknow	Shri TS Rahi	24 months w.e.f. February 01, 2016
16.	GAP 3368	Molecular genetics of guar (*Cyamopsis tetragonoloba*) using SNP markers	DBT, New Delhi	Dr. H Yadav	36 months w.e.f. February 8, 2016
17.	GAP 3369	Molecular systematics of the *Didymocarpus-Henckelia* generic complex (Gesneriaceae) in India	SERB, New Delhi	Dr. KN Nair	36 months w.e.f. February 25, 2016
18.	CNP 3041	Consultancy for advanced molecular biology at JISL	Jain Irrigation Systems Limited, Jalgaon	Dr. AP Sane	36 months w.e.f. June 1, 2015



New projects initiated during 2015-16



Projects in operation during 2015-16

DEPUTATION OF NBRI SCIENTISTS/FELLOWS ABROAD

S. No.	Name of Scientist	Country of Visit	Visit Duration	Purpose of visit
1.	Dr. PK Trivedi	Singapore	July 13-15, 2015	To attend Plant and Animal Genome (PAG) ASIA conference as speaker and deliver a talk at Plant Genomics Workshop on "Comparative transcriptome analysis of different chemotypes of *Withania somnifera* to elucidate biosynthetic pathway for specific withanolides"
2.	Dr. S Roy	University of Guelph, Canada	August 17-22, 2015	To attend the Sixth International Barcode of Life Conference and present the paper entitled 'Plant DNA barcoding of a wildlife sanctuary across a wide climatic zone in Uttarakhand, India'

S. No.	Name of Scientist	Country of Visit	Visit Duration	Purpose of visit
3.	Dr. OP Sidhu	University Darul Ta'zim, Malyasia	September 27 to October 13, 2015	To participate in the Natural Products Chemistry Training and Development Programme
4.	Dr. VA Sane	Darwin, Australia	September 28, 2015 to October 2, 2015	To attend the XIth International Mango Symposium for oral presentation of paper entitled 'Spatio-temporal regulation of ripening related genes in two differently ripening varieties of mango'
5.	Dr. S Kumar	NPFC, Nantong, P.R. China	October 26-30, 2015	To participate in the workshop on "Production and Application of Bio-botanical Pesticide Formulations" and to attend Tripartite Review/Project Management Committee (TPR/PMC) Meeting
6.	Dr. AKS Rawat	Dhaka, Bangladesh	November 6-9, 2015	To deliver an invited lecture under theme Herbal Medicine for Health care in 21th Century, at 20th IUPAC Conference on "Chemical Research Applied to World Needs (CHEMRAWN XX)"
7.	Dr. PK Trivedi	University of Cologne, Germany	November 23, 2015 to December 01, 2015	To discuss progress and further planning on the project entitled "Light dependent flavonol biosynthesis by MYB transcriptions factors : identification of interaction factors" under CSIR-BMBF Cooperative Science Programme (2015-2017)
8.	Drs. PS Chauhan and D Chakraborty	International Rice Research Institute (IRRI), Philippines	February 08-14, 2016	To discuss potential collaboration on drought response in rice and to become familiar with the ongoing research and available genetic resources at IRRI

TECHNOLOGY TRANSFER AND BUSINESS DEVELOPMENT, PATENT, RTI AND TRAINING CELL

Technology Transfer & Business Development (TTBD) division continued its efforts to increase the business development opportunities for the Institute. The major activities of the division are:

- To interact with industries, agencies for increasing business possibilities for the Institute.
- To make agreements (MoU, MoA, Secrecy Agreement, Technology Transfer Agreement) for smooth business activities of the Institute.
- Negotiations with various stakeholders in the R&D activities of the Institute for exploring business opportunities.
- Information dissemination about the technologies of the Institute for publicity and attracting potential clients.
- Participation in displaying technologies/knowhow of the Institute through exhibitions.
- Training Cell : Short term (3-6 months) training / project work of PG students of various Universities from all over the country, so as to develop trained manpower in research activities leading to capacity building.
- Patent Cell : IP protection by identification of patentable invention, patent application filing and prosecution of application of the Institute, patent analysis, prior art search and co-ordinates with IPU division, CSIR HQ, New Delhi, for patent related matters.

MoUs/MoAs/MTAs SIGNED

Sl. No.	Details	Client	Date
1.	Secrecy Agreement for Natural Colours	Roha Dyechem Pvt. Ltd., Mumbai	15.04.2015
2.	MoU for Consultancy Services	Jain Irrigation Systems Ltd., Jalgaon	01.06.2015
3.	Secrecy Agreement for Herbal Lip Balm	Wipro Enterprises Ltd., Bangalore	06.06.2015
4.	MTA for germplasm of *Lepidium* species and *Vitex* species	ICAR-National Bureau of Plant Genetic Resources, New Delhi	24.06.2015
5.	MoU to work together for discovery of new gene linked to cotton	Nuziveedu Seeds Limited, Ranga Reddy District, Telangana	27.07.2015

Sl. No.	Details	Client	Date
6.	MTA for germplasm of *Oryza sativa*	ICAR-National Bureau of Plant Genetic Resources, New Delhi	14.01.2016
7.	Agreement for project titled "Development of Bioaugmentation based Safe Cultivation Practice for Remediating Arsenic Contamination to Paddy Crop"	DBT, New Delhi	01.02.2016
8.	Agreement for project "Tomato Ripening Network"	DBT, New Delhi	03.02.2016
9.	Agreement for "Consultancy Project"	Rail Coach Factory (RCF), Raebareli, UP	03.02.2016
10.	Agreement for "Collaborative, Academic and R&D Programs of Mutual Benefit in the Area of Plant Molecular Biology and Germplasm/Mutual Population Trials of Cotton"	Mahtma Gandhi Mission, Aurungabad	08.02.2016

EXPOSITION

The maintenance and developmental works of the exposition were regularly undertaken. More than 1000 dignitaries from various scientific and non-scientific organizations including common public, school children, college and university students, teachers, scientists, researchers and other academicians of the country and abroad have visited the institute's exposition. On the 'Open Days' of the institute the exposition was also kept open for the public and common people. The visitors got acquainted with the research activities and other programmes carried out by the the institute through displays at the exposition. To inspire and influence the visitors, day-to-day thoughts and inspiring phrases were regularly displayed by the group.

CENTRAL INSTRUMENTATION FACILITY (CIF)

Technical Services Provided and Achievement

Central Instrumentation Facility of the institute, maintaining all the equipments (GCMS-IRMS, TD-NMRHPLC, HPTLC, LC/MS, GLC, AAS, Flash Chromatography, Microwave Digestion system, Stereo Microscope, Refractometer, Tintometer, and SCFE etc.) has provided analytical services to various industries/ organization/entrepreneurs/individuals (External samples) and various scientists/staff of the institute (Internal samples). The details of external and internal samples analyzed are given below :

Analytical testing services provided (1st April 2015 to 31st March 2016)

No. of external samples analyzed	:	**63**
Total revenue generated	:	**Rs. 245, 107.00**
No. of internal samples analyzed	:	**10,195**
Participation in International and National PT/ILC programme	:	**4**
Entrepreneurs/ individuals benefited	:	**27**

NABL-Accreditation

CSIR-NBRI has been NABL accredited since February 2008. Desktop audit has been conducted in July 2015 and after audit, recommended for continuation of NABL-accreditation up to September 2016.

PUBLICATIONS

Research Papers

1. Agarwal P., Pathak S., Lakhwani D., Gupta P., Asif M. H. and Trivedi P. K. (2016). Comparative analysis of transcription factor gene families from *Papaver somniferum*: identification of regulatory factors involved in benzylisoquinoline alkaloid biosynthesis. *Protoplasma*, **253**(3): 857-871.
2. Agnihotri P., Husain D. and Husain T. (2015). An assessment of diversity, endemism and distribution of the genus *Aconitum* L. (Ranunculaceae) from India. *Pleione*, **9**(1): 95-102.
3. Agnihotri P., Husain D. and Husain T. (2015). Lectotypification of the name *Aconitum naviculare* (Ranunculaceae). *Phytotaxa*, **218**(2): 195-196.
4. Agnihotri P., Husain D., Singh H. and Husain T. (2016). Revisiting the *Delphinium viscosum Hook.* f. & Thoms.(Ranunculaceae) complex in the Himalaya. *Taiwania*, **61**(1): 16-20.
5. Alam A., Rawat K. K., Verma P. K., Sharma V. and Gupta D. S. (2015). Moss flora of Central India. *Plant Science Today*, **2**(4): 159-171.
6. Anjali A. B., Mohabe S., Reddy M. A. and Nayaka S. (2015). Efficacy of a potential lichen *Parmotrema andinum* (Müll. Arg.) Hale against pathogenic microorganisms. *Journal on New Biological Reports*, **4**(2): 149-156.
7. Anjali A. B., Mohabe S., Reddy A. M. and Nayaka S. (2015). Antimicrobial activities of 2-Propanol crude extract from lichen *Parmotrema tinctorum* (Despr. ex. Nyl.) Hale, collected from Eastern Ghats, India. *Current Research in Environmental & Applied Mycology*, **5**(3): 160-168.
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11. Asthana A. K. and Sahu V. 2015. Two new records of *Plagiothecium* from India. *Acta Botanica Hungarica*, **57**(1-2): 1-6.
12. Asthana A. K. and Srivastava A. (2015). A study on genus *Fissidens Hedw.* in Meghalaya (North-Eastern Hills), India. *Taiwania*, **60**(3): 137-142.
13. Asthana A. K. and Srivastava A. (2015). New national and regional bryophyte records: *Fissidens griffithii* Gangulee & *Fissidens robinsonii* Broth. *Journal of Bryology*, **37**(2): 133-134.
14. Asthana A. K. and V Sahu. (2015). Occurrence of *Tetralophozia filiformis* (Steph.) Urmi in Uttarakhand, India. *Geophytology*, **45**(1): 81-85.
15. Asthana A. K., Omar I. and Srivastava P. (2015). *Lejeunea minutiloba* A. Evans, new to bryoflora of South India with a note on its interesting morphoform. *Indian Journal of Forestry*, **38**(3):245-248.
16. Asthana A. K., Sahu V. and Srivastava A. (2015). *In-vitro* propagation of three species of *Bryum* Hedw.: A comparative study. *Geophytology*, **45**(2): 215-220.
17. Azeez A. and Sane A. P. (2015). Photoperiodic growth control in perennial trees. *Plant Signaling & Behavior*, **10**(12), p.e1087631.
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Exiguobacterium oxidotolerans, Glomus fasciculatum, and vermicompost improves growth, yield and quality of *Mentha arvensis* in salt-stressed soils. *Industrial Crops and Products*, **83**:717-728.

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29. Chandra P., Kannaujia R., Pandey R., Shukla S., Bahadur L., Pal M. and Kumar B. (2016). Rapid quantitative analysis of multi-components in *Andrographis paniculata* using UPLC-QqQLIT-MS/MS: Application to soil sodicity and organic farming. *Industrial Crops and Products*, **83**:423-430.
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Bauhinia acuminata L. *Journal of Planar Chromatography-Modern TLC*, **28**(6): 452-457.

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13. वर्मा एस. एवं कुमार आर. - बोन्साई : 29-32.

14. वर्मा एस. एवं कुमार आर. - रॉक गार्डन (चट्टानों पर उद्यान) : 37-39.

15. वर्मा एस., चौधरी आर. के. एवं रॉय आर. के. - वर्टीकल उद्यान : गृह सज्जा की नई तकनीकी : 33-36.

16. शर्मा जी., दयाशंकर. एवं रॉय आर. के. - लॉन बनाने की वैज्ञानिक तकनीकी : 26-28.

17. सिंह एस., कुमार एस. एवं रॉय आर.के. - राष्ट्रीय वनस्पति अनुसन्धान संस्थान की वृक्ष सम्पदा : 46-49.

18. सिंह एस., सिंह पी. एवं रॉय आर. के. - कैक्टस: 40-42.

19. सिंह डी., नैनवाल आर. सी., कुमार ए. एवं तिवारी एस. के. - उद्यान में आवश्यक पोषक तत्वों का प्रबंधन : 71-76.

20. सिंह पी. के., सिंह डी., नैनवाल आर. सी., कुमार ए. एवं तिवारी एस. के. - प्रसन्नता और सम्पन्नता के लिए पुष्प उगायें : 77- 82.

PATENTS GRANTED / FILED

PATENTS GRANTED

Sl. No	Title	Inventors	Complete Filing date	Country & Grant date	Patent No.
1.	Synergistic composition useful as microbiological growth medium for rapid screening of phosphate accumulating microorganisms	Nautiyal CS and Chaudhry V	20/07/2011	US/16/06/2015	9057091
2.	A novel recombinant strain of *Trichoderma* useful for enhancing nutritional value and growth of plants	Mishra A and Nautiyal CS	05/09/2013 30/07/2013 12/08/2015 12/08/2015 12/08/2015	US/30/06/2015 EP/12/08/2015 GB/12/08/2015 DE/12/08/2015 FR/12/08/2015	9068189 2658961 2658961 2658961 2658961
3.	A process for preparation of a Novel insecticidal chitinase toxic against whiteflies, it's encoding nucleotides and application thereof	Singh PK, Singh R, Krishnappa C, Rai P, Saurabh S, Upadhyay SK, Singh H, Mishra M, Singh AP, Verma PC, Nair KN and Tuli R	24/06/2014	ZA/30/09/2015	2014/04656

PATENTS FILED

Sl. No.	Title	Inventors	Country	Filing Date/NF No.
1.	Novel reversible expression system for transgene expression in plants	Sawant SV and Singh SP	India	16/04/2015/0174NF2014
2.	A wound inducible expression construct and a method of its preparation	Sane AP, Pandey SP and Singh AP	WO	29/04/2015/0061NF2014
3.	Herbal composition for the management of diabetes	Nautiyal CS, Rao ChV, Ojha SK, Rawat AKS, Mani D, Pal A and Kumar D	WO	11/06/2015/0097NF2014
4.	A novel insecticidal protein toxic to whiteflies and lepidopteran caterpillars, toxin encoding gene and its application thereof	Singh PK, Singh R, Krishnappa C, Rai P, Saurabh S, Upadhyay SK, Singh H, Mishra M, Singh AP, Verma PC, Nair KN, Tuli R	WO	12/11/2015/ PCT/IN2015/050165
5.	A novel formulation for polyherbal masticatory product useful for tobacco de-addiction and health rejuvenation	Nautiyal CS, Kumar D, Rawat AKS, Agarwal S, Mani D, Ojha SK, Pal A, Rao CV, Darokar MP and Kalra A	LK (SRI LANKA)	22/12/2015/18546
			MY (MALASIYA)	30/12/2015/PI2015704828
6.	A novel formulation for improving the yield and quality of fiber in cotton plants	Sawant SV, Singh SK, Singh B and Bhattacharya P	WO	28/01/2016/ PCT/IN2016/050027

HUMAN RESOURCE DEVELOPMENT

TRAININGS/WORKSHOPS/EXHIBITIONS ATTENDED

Sl. No.	Name of person (s)	Subject	Place/Organizers	Date/Peroid
1.	Dr. TS Rahi	i) Workshop on Ethics and Values in Public Governance ii) Climate Change vulnerabilities and adaptation strategies	HRDC Ghaziabad, U.P. ICFRE, Dehradun, Uttarakhand	May 20-22, 2015 February, 08-12, 2016
2.	Dr. Lal Bahadur	Advances in Medicinal and Aromatic Plants Research	Directorate of Medicinal and Aromatic Plants Research, Anand, Gujrat	July 14 to August 3, 2015
3.	Dr. S Rastogi	Work-Life Balance for Women Scientists and Officers	HRDC Ghaziabad, U.P.	August 19-21, 2015
4.	Dr. M Srivastava	The Art of Public Speaking and Technical Writing	CSIR-HRDC, Ghaziabad	November 18- 20, 2015
5.	Drs. KK Rawat and V Sahu	Capacity Building Programme for Technical Officers	CSIR-HRDC, Ghaziabad	January 5-9, 2016
6.	Dr. Charu Lata	Induction Training Programme	HRDC Ghaziabad, U.P.	February 01-10, 2016
7.	Dr. D Singh	Revitalizing Soil and Crop Productivity for Secured Agriculture	Dept. of Agromomy, GBPUAT, Pantnagar, Uttarakhand	February 03-23, 2016
8.	Mr. V Srivastava	Good Governance and Transparency New Models of Partnership and Technology Transfer	HRDC, Ghaziabad	February 18-20, 2016 March 09-11, 2016

TRAINING IMPARTED

a) Group Trainings/Workshops

Sl. No.	Name of the organization	Subject of training Course	No. of the participants	Date/Period
1.	Farmers of Piprauli, Gorakhpur		280 260	April 13, 2015 April 14, 2015
	Farmers of Raibareli	Popularization of Biofertilizer use	350	July 25, 2015
	Farmers of Basti		380	January 16, 2016
	CSIR-CIMAP Kisan Mela		600	January 31, 2016
	Farmers of Dafedar ka Purwa, Barabanki		300	February 23, 2016
2.	Ashiyana Jan Kalyan Samiti, Ashiyana, Lucknow	Kitchen Gardening	25	May 06, 2015
3.	Soil Testing Laboratory, Uttar Pradesh.	Soil Testing and Atomic Absorption Spectroscopy	40	October 26 -28, 2015 and December 15-19, 2015
4.	Gardeners of CMS, Lucknow	Garden Management	20	December 14-19, 2015
5.	Gardeners of the High Court, Lucknow Bench	Garden Management	10	January 01-15, 2016 and February 01-13, 2016
6.	Farmers form Gorakhpur and Army Personals of AMC, Lucknow	Vermicompost Preparation	06	March 09 and 16, 2016

b) Individual Trainings

1. Mr. Yogesh Mahajan, Technical Assistant, CSIR-NCL, Pune, was imparted ten days training on "Garden Management" during June 8-10, 2015.
2. Sixty six post-graduate students of different universities/institutes were imparted training on various topics of their interest, during April 2015 to March 2016. A sum of ₹ 10,44,000.00 was realized from them as training fee.

HONOURS/AWARDS/DISTINCTIONS

Honours/Awards/Recognitions

CSIR-Technology Award-2015 conferred jointly to CSRI-NBRI, CSIR-CIMAP, CSIR-CDRI and CSIR-IICB for **"Development of improved varieties and promotion of cultivation of medicinally important Ashwagandha for improving the economy of small and marginal farmers in Semi Arid-Tropical (SAT) Regions in Deccan Plateau".**

Dr DK Upreti, Chief Scientist : 'E.K. Janaki Ammal National Award for Plant Taxonomy 2015'

Dr DK Upreti, has been conferred the prestigious 'EK Janaki Ammal National Award for Plant Taxonomy 2015' by the Ministry of Environment, Forest and Climate Change, New Delhi, for his contributions in the field of Lichen taxonomy. Instituted in the name of Late Prof. Dr EK Janaki Ammal, an eminent scientist and botanist of international repute, this award is given to encourage work of excellence in plant, animal and microbial taxonomy.

Dr. DK Upreti's consistent and remarkable work during the last three decades has led to the discovery of more than 100 new species and more than 200 species as new records to the lichen flora of India. He pioneered lichenometric studies in Indian Himalayan region to record the glacial retreat caused as the result of global warming. The bio-monitoring and bio-prospection studies conducted by him on Indian lichens and his work on the Antarctica lichens and their response to environmental pollutants are widely recognized.

The award was given by Shri Prakash Javadekar, Honorable Minister, Environment, Forest and Climate Change, Government of India, on 5th June, 2015, the World Environment Day. The award carries a cash prize of Rupees One Lakh, medallion and a citation.

Sl. No.	Scientist(s)	Award(s)
1.	Singh D	**Outstanding Performance Award** in Agronomy, Swadeshi Vigyan Sansthanam U.P. Chapter-III of Vijnana Bharti
2.	Agnihotri P	**Prof. Hira Lal Chakravarty Memorial Award for the year 2015-2016** for significant research contributions in the field of plant sciences by the Indian Science Congress Association
3.	Sahu V	**Dr. S. K. Jain Best Paper Award** by Association of Plant Taxonomy, Dehradun under the category of lower group of plants
4.	Singh BN	**Young Scientist Award** by Sai Shiksha Samiti, Allahabad for outstanding research work on Bioprospecting medicinal plants for biomedical application

Member/Editor, Referee, Expert, Reviewer, Judge, etc. (selected, recognized, enrolled, empanelled, nominated)

1.	Asthana AK	Reviewer of *Natl Acad. Sci. Lettr, Taiwania, J. Threatened Taxa* and *Pl. Sci. Today*
2.	Chakraborty D	Editor of *J. Envir. Biol., PLOS One* and *Scient. Rep.*
3.	Husain T	Life member of Indian Science Congress Association
4.	Khatoon S	Editor of *Asian J. Pl. Sci., Int. J. Bot., Res. J. Med. Pl., J. bot. Sci., Pharmacog. J.* and *J. Develop. Biol. Tissue Engin.*
5.	Khuraijam JS	Member of the IUCN/SSC Cycad Specialist Group, Switzerland
6.	Ojha SK	i) Fellow of the Society of Ethnobotanist (FES) by the Society of Ethnobotanists. ii) Nominated as External Expert Member of the Committee for Performance Review of Centre for National Facility for Tribal and Herbal Medicine (NFTHM), BHU, Varanasi.
7.	Pal M	Ph.D. Guide of Mangalayatan University, Aligarh; Jawahar Lal Nehru University, New Delhi and Amity University, Noida, UP
8.	Rahi TS	Life member of Indian Society of Soil Science
9.	Rao ChV	Member, Research Council, Amity University, Lucknow and Jawaharlal Nehru Tropical Botanic Garden & Research Institute, Palode, Thiruvanathapuram; Ph.D. Guide of Revenshaw University, Cuttack
10.	Rawat KK	Life member of the Indian Botanical Society, India
11.	Roy RK	Fellow of the Indian Society of Ornamental Horticulture (ISOH), IARI, New Delhi
12.	Sahai K	Fellow of the Association for Plant Taxonomy (FAPT), Dehradun, India
13.	Sawant SV	Fellow of The National Academy of Sciences (NASI), India, 2015
14.	Singh AP	Member of The Indian Lichenological Society, 2015
15.	Srivastava M	Reviewer of the *Am. Chem. Sci. J.* and *J. Adv. Fd Sci. & Technol.*
16.	Srivastava S	Member of The Royal Society of Chemistry, UK (MRSC)
17.	Trivedi PK	Fellow of National Academy of Agriculture Sciences, India (FNAAS)-2016 and Member, Editorial Board of *PLoS One, Sci. Rep. Physiol. Mol. Biol. Pl.* and *Int. J. Pl. Envir.*

Ph.D. Awarded

1. Mr. Anil Bhatia

Metabolomics of medicinally important plants using GC-MS, HPLC and NMR spectroscopy

Guides : **Dr. OP Sidhu**, Principal Scientist, CSIR-NBRI, Lucknow and **Prof. A Mishra**, Gautam Budha University (GBTU), Greater Noida

University : GBTU, Greater Noida

2. Ms. Aparna Misra

Identification and characterization of wound inducible promoters in crops

Guides : Dr. VA Sane, Principal Scientist, CSIR-NBRI, Lucknow

University : UPTU, Lucknow

3. Mr. Arvind Kumar

Induction of somatic mutation in *Chrysanthemum morifolium* through induced mutagenesis and characterization of mutants

Guides : **Dr. S Shukla**, Senior Principal Scientist, CSIR-NBRI, Lucknow and **Prof. M Singh**, Lucknow University, Lucknow

University : Lucknow University, Lucknow

4. Mr. Brij Kishore Mishra

Genetic diversity and combining ability in relation to heterosis in Opium Poppy (*Papaver somniferum* L.)

Guides: Dr. S Shukla, Senior Principal Scientist, CSIR-NBRI, Lucknow and **Prof. NC Sharma,** Barkatullah University, Bhopal

University: Barkatullah University, Bhopal

5. Ms. Deepika Sharma

Functional characterization of *miR*858 in *Arabidopsis thaliana*

Guide : **Dr. PK Trivedi**, Principal Scientist, CSIR-NBRI, Lucknow

University : Academy of Scientific and Innovative Research (AcSIR), New Delhi

6. Ms. Preeti Shukla

Revisionary studies on lichen genus *Usnea* Dill. ex Adans. from India with special reference to Uttarakhand.

Guides : Dr. DK Upreti, Chief Scientist, CSIR-NBRI, Lucknow and **Prof. LM Tewari,** Kumaun University, Nainital

University : Kumaun University, Nainital

7. Ms. Priya Gupta

Genetic diversity analysis of *Jatropha curcas* L. using Single Nucleotide Polymorphism (SNP)

Guides : **Dr. CS Mohanty**, Senior Scientist and **Dr. SV Sawant**, Principal Scientist, CSIR-NBRI, Lucknow

University : Academy of Scientific and Innovative Research (AcSIR), New Delhi

8. Ms. Priya Srivastava

Screening of antimicrobial properties of some Indian Lichens against human pathogens

Guide : Dr. DK Upreti, Chief Scientist, CSIR-NBRI, Lucknow

University : Dr. R.M.L. Avadh University, Faizabad

9. Ms. Rajluxmi

Role of SIN3, a global transcriptional regulator, in plant growth and development

Guide : **Dr. AP Sane**, Principal Scientist, CSIR-NBRI, Lucknow

University : Academy of Scientific and Innovative Research (AcSIR), New Delhi

10. Ms. Rani Singh

Characterization of Scaffold Attachment Regions (SARs) from chickpea (*Cicer arietinum* L.) genome for enhancement of transgene expression

Guide : **Dr. I Sanyal**, Principal Scientist, CSIR-NBRI, Lucknow

University : Academy of Scientific and Innovative Research (AcSIR), Delhi

11. Ms. Reesa Gupta

Assessment of bryodiversity of Pachmarhi Biosphere Reserve

Guides: Dr. V Nath, Chief Scientist (Retd.), CSIR-NBRI, Lucknow and **Prof. N Pande**, Kumaun University, Nainital.

University: Kumaun University, Nainital

12. Ms. Ruchi Singh

An integrative approach for analyzing drought tolerance in Cotton (*Gossypium* sp.)

Guides : Dr. PA Shirke Senior Principal Scientist, CSIR-NBRI, Lucknow and **Dr. J Naskar**, Sam Higginbottom Institute of Agriculture, Technology & Sciences (SHIATS), Allahabad

University: SHIATS, Allahabad

13. Ms. Samatha Gunapati

Isolation and characterization of drought related NAC transcription factor from cotton roots (*Gossypium herbaceum)*

Guides : Dr. VA Sane, Principal Scientist, CSIR-NBRI, Lucknow and **Dr. Rekha Gadre**, Devi Ahilya Vishwavidyalaya, Indore

University : Devi Ahilya Vishwavidyalaya, Indore

14. Mr. Saurabh Prakash Pandey

Identification and characterization of wound inducible promoters in crops

Guide : **Dr. AP Sane**, Principal Scientist, CSIR-NBRI, Lucknow

University : Academy of Scientific and Innovative Research (AcSIR), New Delhi

15. Ms. Veena Dixit

Screening and evaluation of antimicrobial potential of the genus *Leucas* R. Br. (Lamiaceae)

Guides : Dr. T Husain, Senior Principal Scientist, CSIR-NBRI, Lucknow and **Dr. AK Paliwal**, Kumaun University, Nainital

University : Kumaun University, Nainital

Ph.D. Theses Submitted

1. Ms. Ila Trivedi

Study of the role of chromatin and chromatin modifying machinery in the genome regulation of cotton plant during water stress condition

Guides: Dr. SV Sawant, Principal Scientist, CSIR-NBRI, Lucknow and **Dr. YK Sharma**, Lucknow University, Lucknow

University: Lucknow University, Lucknow

2. Ms. Mala Singh

Role of histone acetyl transferases in epigenetic regulation of *PR-1* gene expression in *Arabidopsis thaliana*

Guides : Dr. SV Sawant, Principal Scientist, CSIR-NBRI, Lucknow and **Dr. YK Sharma,** Lucknow University, Lucknow

University : Lucknow University, Lucknow

3. Ms. Mrinalini Srivastava

Enhancement of secondary metabolites with the use of biotic and abiotic elicitors in hairy root cultures of *Rauwolfia serpentina* L., *Glycyrrhiza glabra* L., and *Solanum khasianum* C. B. Clark.

Guides : **Dr. P Misra**, Principal Scientist, CSIR-NBRI, Lucknow and **Dr. Swati Sharma**, Integral University, Lucknow

University : Integral University, Lucknow

4. Ms. Neha Karakoti

Ecophysiological attributes of selected lichen species of Garhwal Himalayas along altitudinal gradient

Guides : Dr. DK Upreti, Chief Scientist, CSIR-NBRI, Lucknow and **Prof. (Mrs.) Kiran Bargali**, Kumaun University, Nainital

University : Kumaun University, Nainital.

5. Mrs. Nidhi Verma

Genetic characterization of indigenous germplasm lines of opium poppy (*Papaver somniferum* L.) through morphological, biochemical and molecular approaches

Guides : **Dr. S Shukla**, Senior Principal Scientist, CSIR-NBRI, Lucknow and **Dr. K Yadav**, Lucknow University, Lucknow

University : Lucknow University, Lucknow

6. Ms. Nishi Srivastava

Variation in secondary metabolites of *Bergenia ciliata* (Haw.) collected from different altitudes of Himalaya and exploration of biosynthetic/ biogenesis pathways of secondary metabolites of *Andrographis paniculata, Artemisia annua* and *Bergenia ciliata*

Guides : **Dr. AKS Rawat**, Senior Principal Scientist, CSIR-NBRI, Lucknow and **Prof. AR Khan**, Integral University, Lucknow

University : Integral University, Lucknow

7. Ms. Rinkey Tiwari

Diversity assessment and taxonomic revision of the genus *Ficus* L. (Moraceae) of the Gangetic Plain in India

Guides : Dr. LB Chaudhary, Principal Scientist, CSIR-NBRI, Lucknow and **Dr. A Durgapal,** Kumaun University, Nainital

University : Kumaun University, Nainital

8. Ms. Saba Irshad

Botanical, Chemical and Molecular Characterization of a Controversial Drug 'Shankhpushpi' and evaluation of its antioxidant potential

Guides: Dr. Sayyada Khatoon, Principal Scientist, CSIR-NBRI, Lucknow and **Prof. PK Mishra**, Lucknow University, Lucknow

University: Lucknow University, Lucknow

9. Ms. Shweta Singh

Selection and gamma induced mutation for development of high yielding superior quality genotypes of *Curcuma longa* L.

Guides : **Dr. SK Tewari**, Sr. Principal Scientist, CSIR-NBRI, Lucknow and **Dr. Manjul Dhiman**, KLDAV College, Roorkee

University : HNB Garhwal University, Srinagar, Garhwal

10. Mr. Sunil Kumar Singh

The role of histone modifier in cotton fiber development and their target

Guides: Dr. SV Sawant, Principal Scientist, CSIR-NBRI, Lucknow and **Prof. Kumkum Mishra**, Lucknow University, Lucknow

University: Lucknow University, Lucknow

11. Ms. Syed Saema

Functional characterization of sterol glycosyltransferase (SGT) L1 gene of *Withania somnifera*

Guides : **Dr. P Misra**, Principal Scientist, CSIR-NBRI, Lucknow and **Dr. Iffat Zareen Ahmad**, Integral University, Lucknow

University : Integral University, Lucknow

DATELINE

Sl. No.	Date	Salient Feature
1.	April 21-23, 2015	A training programme on "Bonsai Technique" was organized at CSIR-NBRI Botanic Garden during April 21-23, 2015 for the garden lovers, hobbyists, housewives and unemployed persons. Altogether 20 trainees took part in the programme.
2.	April 24, 2015	CSIR-NBRI and Meghalaya Basin Development Authority (MBDA), Meghalaya are working in collaboration through Bio-resources Development Centre (BRDC) to ensure inclusive and sustainable growth of NE Region in general and Meghalaya, in particular. Dehydrated floral crafts (DFC) of CSIR-NBRI is identified for promoting income generating activity and women empowerment tool. On April 24, 2015, a programme was organized under the Integrated Basin Development & Livelihood Promotion Programme at Shillong for providing green energy solution to rural women entrepreneurs engaged in enterprise, adopting green technology. On this occasion, women entrepreneurs of 36 DFC clusters were present along with officials of Meghalaya government, BRDC and CSIR-NBRI. An exhibition of DFC products, made by these groups was arranged on this occasion. Solar dryers were gifted to all the 36 DFC clusters.
3.	May 11, 2015	**The National Technology Day** was celebrated on May 11, 2015. Padma Shri & Padma Bhushan (Prof.) G. Padmanaban, INSA Senior Scientist/ Hon. Professor, Indian Institute of Science, Bangalore & Senior Science and Innovation Advisor, BIRAC, DBT, New Delhi, was the Chief Guest of the function. Prof. Padmanaban delivered the National Technology Day lecture on "***Relevance of Biotechnology to Indian Agriculture***". Dr. P.V. Sane, Former Director of CSIR-National Botanical Research Institute was the Guest of Honour.
4.	May 19, 2015	A one day Workshop on "Bonsai Techniques" was organized on May 19, 2015 at Army Public School, Lucknow for teachers and students.
5.	May 30, 2015	A one day Workshop on "Urban Gardening & Vermicomposting" was organized in the Botanic Garden on May 30, 2015 jointly with Times of India & CSIR-NBRI under the theme, "Live Green Campaign" launched by Times of India. The main purpose was to make people aware about the different Urban Gardening techniques suitable for multi-storeyed buildings. Altogether 50 selected Lucknowites participated in this programme.
6.	June 29, 2015	A workshop was organized on June 29, 2015 for entrepreneurship development in Dehydrated Floral Crafts at CSIR-NBRI. The programme was attended by members of SRCP India, a MSME organization, promoting DFC in manufacturing section and Shashwat Jigyasa, an NGO, engaged in making DFC products through physically challenged children.
7.	July 01-31, 2015	CSIR-NBRI organized a one month Certificate Course on "Garden Management" during July 01-31, 2015 for the benefit of unemployed persons and garden enthusiasts. Altogether 25 candidates attended the course.
8.	August 15, 2015	**INDEPENDENCE DAY**
9.	August 21, 2015	CSIR-NBRI organized a workshop on dehydrated floral crafts on August 21, 2015 at Mahila Vidyalaya P.G. College, Lucknow. About 42 selected B.Sc. students participated in the workshop. All the students were given training in preparation of greeting cards using dehydrates flower and plant parts.
10.	August 31, 2015	A Biodiversity Awareness Workshop was organized at Shri Shakti Degree College, Ghatampur, Kanpur Nagar on August 31, 2015. A total of 58 students participated in the workshop. The programme was sponsored by the Uttar Pradesh State Biodiversity Board, Lucknow.
11.	सितंबर 1–14, 2015	सीएसआईआर–राष्ट्रीय वनस्पति अनुसंधान संस्थान, लखनऊ में दिनांक 1–14 सितंबर 2015 को हिन्दी पखवाड़ा का आयोजन किया गया। जिसके अंतर्गत संस्थान में कार्य करने वाले अधिकारियों कर्मचारियों को प्रेरणा–प्रोत्साहन, उत्साह व हिन्दी के प्रयोग को बढ़ावा देने के उद्देश्य से लिए विभिन्न कार्यक्रम आयोजित किए गए। इनमें मुख्यतः हिन्दी टिप्पण आलेखन प्रतियोगिता, हिन्दी ज्ञान पहेली, हिन्दी वर्ग पहेली प्रतियोगिता, हिन्दी निबंध प्रतियोगिता कर्मचारियों के बच्चों के लिए, कवि सम्मेलन (कर्मचारियों द्वारा), हिन्दी व्याख्यानः श्री हरेन्द्र पाल द्वारा कार्य कुशलता हेतु प्रबंधन विषय पर, हिन्दी पुस्तकों की प्रदर्शनी (पुस्तकालय में), हिन्दी दिवस समारोह का आयोजन सम्मिलित है।
12.	September 21, 2015	A training programme on betelvine cultivation was organized on September 21, 2015 at Distant Research Centres, Banthra, Lucknow for 40 farmers of Lucknow, Unnao, Raibareilly and Sitapur districts.

Sl. No.	Date	Salient Feature
13.	September 26, 2015	The CSIR-National Botanical Research Institute, Lucknow, observed "Open Day" on September 26, 2015 to commemorate the 73rd Foundation Day of Council of Scientific & Industrial Research, New Delhi. Dr. P.K. Seth, CEO, Biotech Park, Lucknow, was the Chief Guest of the function. Dr. Seth, while addressing the audience appreciated the research carried out at CSIR-NBRI. He further said that CSIR-NBRI is reaching to the common man of the city as well as the state. "The research in the area of soil nutrients by CSIR-NBRI is commendable. The Institute should do more work toward societal benefit", he added. Dr. P.K. Seth, distributed certificates and mementoes to 14 employees who have completed 25 years of CSIR service and to 27 employees who retired during 2014-15. Dr. CS Nautiyal, Director, distributed prizes and certificates to those children of staff, who participated and won in the Science Essay competition organized on this occasion.
14.	September 28-29, 2015	A two day 'National Conference on Cryptogam Research in India: Progress and Prospects' was organized jointly by the Indian Lichenological Association, Lucknow and CSIR-NBRI during 28 – 29th September 2015 at NBRI Lucknow. A total of 270 delegates and guests from all over India participated in the conference. The conference was inaugurated by the Chief Guest, Dr. Paramjit Singh, Director, Botanical Survey of India, Kolkata. Dr. S.K. Jain, INSA Honorary Scientist, Lucknow was the Guest of Honour. At the inaugural function 12 retired eminent scientists and professors were felicitated for their outstanding contributions to cryptogam research.
15.	October 15, 2015	A one day training cum motivation programme on on Medicinal plants and their usage organized at CSIR-NBRI, Lucknow on October 15, 2015. Students and teachers from the City Montessori School, Asharfabad campus Lucknow, participated in the programme. Medicinal plant saplings were also distributed to the participants.
16.	October 25, 2015	CSIR-NBRI, Lucknow celebrated its **62nd Annual Day** on October 25, 2015. Prof. JP Khurana, Delhi University South Campus, New Delhi was the Chief Guest. Dr. VP Kamboj, Former Director, CSIR- Central Drug Research Institute, Lucknow, was the Guest of Honour. Dr. CS Nautiyal, Director, CSIR-NBRI welcomed the guest and presented the annual report of the Institute for the period 2014-15 and informed about the various activities and achievements of the Institute during the year. On this occasion Annual Report 2014-15, Annual Hindi Magazine (Vigyanvani) and a book on Bougainvillea were also released by the Dignitaries. A new variety of Bouaginvillea, named "APJ Abdul Kalam", developed by CSIR-NBRI, was released. The occasion was also marked by the launching of a herbal product 'BGR-34' for diabetes management, developed jointly by CSIR-NBRI and CSIR-CIMAP, for commercial manufacturing and marketing by M/s Aimil Pharamaceuticals Pvt Ltd, New Delhi. Scientists and students of the Institute, who had published their research work in journals with high impact factors, were felicitated on this occasion.
17.	October 29 to November 4, 2015	CSIR-NBRI organized a seven day training course on "Classical and Modern Methods in Plant Taxonomy and Biosystematics" from October 29 to November 4, 2015. Dr. Rakesh Shah, Additional Principal Chief Conservator of Forests and Chairman, Uttarakhand Biodiversity Board was the Chief Guest of the Inaugural Function on October 29, 2015. The Director of CSIR-NBRI, Dr. C. S. Nautiyal encouraged the participants to utilize the opportunity of the training course to sharpen their skills in plant taxonomy. About 40 participants from various institutions, colleges, universities, and other departments participated in the training course.
18.	November 18-20, 2015	A National Conference on "Indian Botanic Gardens (NCIBG 2015)" was organized at CSIR-NBRI from 18 to 20 November 2015. Shri Hem Pande, Spl. Secy. MoEF & CC, Govt. of India and Dr. Paramjit Singh, Director, Botanical Survey of India (BSI) were the Chief Guest and the Guest of Honour respectively. Dr. P. Pushpangadan, former CSIR-NBRI Director, and presently DG & Sr. Vice President of Ritnand Balved Education Foundation (RBEF) gave the presidential address.
19.	November 27-28, 2015	A two day training cum motivation programme was organized at CSIR-NBRI during November 27-28, 2015, in which 21 science teachers/lecturers from 12 schools and colleges participated. Dr. PK Srivastava, internationally renowned Scientoonist and former Chief Scientist, CSIR-CDRI, Lucknow, was the Chief Guest.. Dr. Srivastava delivered a lecture on "Biodiversity & climate change: Challenges ahead". Dr. CS Nautiyal, Director highlighted the importance of such programmes, especially for scientific updates to the faculties who are the important chain towards knowledge dissemination. Dr. SK Tewari briefed about the genesis and curriculum of the programme. The training programme covered thematic lectures on various subjects/aspects of botany and allied areas by NBRI Scientists. Participants also visited laboratories/ botanic gardens/exposition and herbarium, Distance Research Centre, Banthra. Dr. CS Nautiyal Lucknow distributed certificates to the participants.

Sl. No.	Date	Salient Feature
20.	December 02, 2015	A one day training cum motivation programme on 'erbs for Health organized at SN Sen Balika PG College, Kanpur on 2nd December, 2015. A total of 120 participants including students and teachers of various colleges participated in the programme. All the participants were trained to study medicinal plant specimens.
21.	December 12-13, 2015	A two-day Chrysanthemum & Coleus – 2015 show was organized during December 12-13, 2015, at the Central Lawn of CSIR-National Botanical Research Institute, Lucknow. The main idea to organize the flower show is to promote floriculture industry and to develop awareness about the floriculture. This show provides an opportunity for the public to enjoy and gather knowledge on Chrysanthemum and Coleus. This is a rare occasion where people can see the entire diversity of flower colors, types, shapes and also their cultivation practices. The prize distribution function was organized at the open-air theater of the Institute, on 13th December, 2015. Shri Amit Mohan Prasad, IAS, Principal Secretary (Agriculture), Govt. of UP was the Chief Guest and Dr. Mukesh Gautam, Director, Rajya Krishi Prabandh Sansthan, U.P. was the Guest of Honour. Mrs. Manju Nautiyal, Principal, CMS, Lucknow, also graced the occasion.
22.	जनवरी 13, 2016	एक दिवसीय हिंदी कार्यशाला का आयोजन दिनांक जनवरी 13, 2016 को संस्थान के के एन कॉल ब्लाक के सभागार में किया गया। कार्यशाला की अध्यक्षता, डॉ. डी के उप्रेती, मुख्य वैज्ञानिक ने की। इस अवसर पर डॉ. के के रावत, तक. अधि. ने 'हिंदी लेखन' पर व्याख्यान दिया। अपने व्याख्यान में डॉ. रावत ने लोगो में दिन प्रतिदिन कम होती हिंदी लेखन क्षमता का उल्लेख करते हुए इसके कारणों की समीक्षा की। मंच का संचालन सचिव, रा. का. स. डॉ. संजीव ओझा ने करते हुए निदेशक महोदय का आभार व्यक्त किया। डॉ. ए के एस रावत, उपाध्यक्ष, रा. का. स. ने धन्यवाद प्रस्ताव दिया। इस कार्यशाला में संस्थान के लगभग 90 से अधिक अधिकारियों एवं कर्मचारियों ने भाग लिया।
23.	January 26, 2016	**REPUBLIC DAY**
24.	February 6-7, 2016	The Rose & Gladiolus Flower Show was organized on February 6-7, 2016 in the central lawn of the Botanic Garden. The show attracted a total of 601 entries belonging to 56 exhibitors from Lucknow and outstation. This year, A total number of 26 running cups/shields/trophies along with 252 prizes (First - 87, Second – 73 and Commendation – 92) were given to the winners. Shri Ram Naik, Hon'ble Governor, U.P was the Chief Guest at the prize distribution ceremony.
25.	February 25-27, 2016	A three day National Symposium on 'Plant Biotechnology for Crop Improvement' & 37th Annual Meeting of Plant Tissue Culture Association, India was organized at CSIR-NBRI during February 25-27, 2016. Over 350 delegates from different universities and Institutes participated in the symposium. Prof. HY Mohan Ram, INSA Fellow, India and Chief Guest of the event, inaugurated the symposium. Prof. Mohan Ram in his brief inaugural address, discussed the latest information on various fields of science and emphasized the need to extend scientific information to common people for the development of the country. Prof. Akhilesh Tyagi, Director, NIPGR, New Delhi was the Keynote Speaker and delivered the lecture on the low yield of rice under water deficit stress conditions.
26.	February 29, 2016.	**The National Science Day** was celebrated by the CSIR-National Botanical Research Institute on February 29, 2016. The day was observed as 'Open Day' when its various laboratories, *viz.*, Exposition, Herbarium, Library, Botanic Garden, various R&D Laboratories were visited by large number of students drawn from various local schools and colleges. On this occasion, Dr. VP Kamboj, Former Director, CSIR-CDRI, Lucknow, was the Chief Guest and Dr. BN Dhawan, Former Director, CSIR-CDRI, Lucknow, was the Guest of Honour.
27.	March 4, 2016	**The National Safety Day**
28.	मार्च 15, 2016	रा. का. स. द्वारा 'राजभाषा नीति अधिनियम तथा तनाव प्रबंधन विषयक' पर हिंदी कार्यशाला का आयोजन दिनांक मार्च 15, 2016 को किया गया। कार्यक्रम की अध्यक्षता डॉ. डी के उप्रेती, मुख्य वैज्ञानिक ने की। कार्यशाला में सी एस आई आर – सी डी आर आई, लखनऊ के डॉ. विजय नारायण तिवारी, वरिष्ठ हिंदी अधिकारी ने अपना व्याख्यान प्रस्तुत किया। अपने व्याख्यान में, डॉ. तिवारी ने दैनिक जीवन में तनाव प्रबंधन का महत्व बताते हुए इसकी आवश्यकता एवं अनुपालन की चर्चा की। मंच का संचालन डॉ. संजीव ओझा, सचिव, रा. का. स. ने करते हुए निदेशक महोदय का आभार व्यक्त किया तथा अंत में धन्यवाद ज्ञापन प्रस्तुत किया। इस कार्यशाला में संस्थान के लगभग 120 से अधिक अधिकारियों एवं कर्मचारियों ने भाग लिया।
29.	March 15, 2016	CSIR-NBRI, Lucknow organized one day training programme on 'Betelvine Farming and Protected Cultivation of Vegetables', on 15 March, 2016 at Distant Research Centre, in which 26 farmers participated. The participants were explained about the traditional and modern techniques of Betelvine cultivation and the protected cultivation of vegetables. The participants also visited the paan model bareja at Banthra and vegetable poly house at Gehru Farm. Planting materials were also distributed to the farmers.

Glimpses of CSIR-NBRI Events

CSIR-NBRI'S dehydrated floral crafts technology in Meghalaya

Workshop on Vertical Gardening and Vermicomposting

Glimpses of CSIR-NBRI Events

Discussions at workshop on entrepreneurship development in Dehydrated Floral Crafts

National Technology Day

Workshop on Dehydrated Floral Craft held at Mahila Vidyalaya PG College Lucknow

Glimpses of CSIR-NBRI Events

Training programme on Betelvine cultivation in Progress

हिन्दी दिवस समारोह की झलकियाँ

CSIR Foundation Day

Glimpses of CSIR-NBRI Events

National Conference on Cryptogam Research in India

Faculty training, motivation & adoption of school and colleges programme

National Conference on Indian Botanic Gardens

Glimpses of CSIR-NBRI Events

CSIR-NBRI Annual Day Celebration

Annaul Chrysanthemum and Coleus Show

Glimpses of CSIR-NBRI Events

Annual Rose & Gladiolus Show

National Science Day

Glimpses of CSIR-NBRI Events

National Symposium on 'Plant Biotechnology for Crop Improvement' & 37th Annual Meeting Of Plant Tissue Culture Association

हिन्दी कार्यशाला का आयोजन

ACADEMY OF SCIENTIFIC AND INNOVATIVE RESEARCH (ACSIR)

The **Academy of Scientific and Innovative Research** or **AcSIR** is an Indian institute of national importance, currently head quartered in CSIR Campus, Taramani, Chennai. The Academy was established for the purpose of granting doctoral and post-doctoral degrees, through a centralized institution to manage research and development in CSIR laboratories. It was established in 2010 (Government of India resolution of June 17, 2010 and the Academy of Scientific and Innovative Research Act, 2011 notified on April 3, 2012), as an 'Institution of National Importance', with an aim of furtherance of advancement of learning and research in the field of Science & Technology and their interfaces in association with Council of Scientific and Industrial Research (CSIR), India.

Mission

The mission of the Academy is to create highest quality personnel with cross- disciplinary knowledge, aiming to provide leaders in the field of science and technology. The Academy shall primarily focus on research and imparting instructions in such a manner that the methodology is novel and off the beaten track. Further, the Academy aims to :

- Nurture a research-propelled, technology-enabled, industry-linked, socially conscious higher education platform.
- Achieve a seamless integration of intellectual strengths with current market needs with a people centric focus.
- Develop niche capability required to bolster research efforts in futuristic science. Provide the opportunity to work on the frontier and contemporaneously challenging areas for nurturing innovation.

It is one of its kind meta-University in India with study centers in 37 laboratories and 6 units of CSIR, spread across 23 cities of India.

At present the Academy has about 2200 full-time faculty members from CSIR Laboratories, over 2000 students enrolled in various programmes and 7 non-academic staff members

National Research Professor Prof. RA Mashelkar took charge as the first Chairperson of AcSIR, from Prof. SK Brahmachari (former Acting Chairperson of interim AcSIR) and Director General, CSIR. The Academy has received recognition from Department of Scientific and Industrial Research (DSIR), Ministry of Science & Technology, as a Scientific and Industrial Research Organization (SIRO).

ACSIR Course work option for CSIR-NBRI students

S. No.	Course Name	Course Number
1	Biostatistics (Compulsory)	1-001
2	Computation/bioinformatics(Compulsory)	1-002
3	Basic Chemistry (Compulsory)	1-003
4	Research Methodology, Communication/ethics/safety (Compulsory)	1-004
5	Biotechniques and Instrumentation (Compulsory)	2-001
6	Biology of Inheritance	2-003
7	Genomics: Information flow in Biological System	2-005
8	Plant Microbe Interaction	2-009
9	Plant Environemnt Interaction	2-010
10	Cell Signalling	2-012
11	Developmental Biology-Plants	2-016
12	Epigenetics and Chromatin Organization	2-017
13	Homeostasis and feedback in biological systems	2-018
14	Molecular Breeding of Plants	2-021
15	Biodiversity	2-025
16	Plant morphogenesis and regeneration	2-486
17	Seminar Course (Compulsory)	3-001
18	Cell and Tissue Engineering	3-003

S. No.	Course Name	Course Number
19	Climate change and Plants	3-486
20	Bioremediation	3-487
21	Environmental Biochem and Biotech	3-488
22	Taxonomy and speciation	3-489
23	Plant conservation and reproductive biology	3-490
24	Economic Plants and Pharmacology	3-491
25	Floriculture and Agronomy	3-492
26	PHYLOGENOMICS – An interdisciplinary course	3-493
27	Biofuels – An interdisciplinary course	3-494
28	Knowledgebase Research Management and it's utilization	3-495

राजभाषा यूनिट

संस्थान में राजभाषा कार्यान्वयन समिति के तत्वाधान में हिन्दी के प्रगामी प्रयोग से संबंधित निम्नांकित गतिविधियाँ 2015-2016 में की गयी।

1. संस्थान में राजभाषा विभाग, गृहमंत्रालय, भारत सरकार द्वारा जारी दिशानिर्देशों के अनुसार समय में तिमाही बैठकों का आयोजन किया गया।
2. संस्थान कें अधिकारियों तथा कर्मचारियों के लिए हिन्दी के प्रगामी प्रयोग में और भी अधिक वृद्धि लाने हेतु संस्थान के निदेशक महोदय द्वारा व्यक्तिशः आदेश जारी किये गये।
3. समय-समय पर कार्यालय ज्ञापन व सूचनायें जारी की गयी जिससे संस्थान के अधिकारियों वं कर्मचारियों द्वारा कार्यालयी कार्य हिन्दी में करने में वृद्धि हुई।
4. संस्थान के हिन्दी के प्रगामी प्रयोग सम्बन्धी त्रैमासिक व छमाही रिपोर्ट तैयार कर सीएसआईआर मुख्यालय, नई दिल्ली तथा सचिव, नराकास, एचएएल, लखनऊ को समय से प्रेषित की गयी जिन्हें मुख्यालय व नराकास द्वारा प्रशंसनीय कहा गया।
5. संस्थान में हिन्दी के प्रयोग में और भी अधिक वृद्धि लाने हेतु संस्थान से राजभाषा पत्रिका 'विज्ञानवाणी' का प्रकाशन किया गया जिसे पिछले कई वर्षो से लखनऊ में स्थित 169 केंद्रीय सरकार के कार्यालय में प्रकाशित पत्रिकाओं में से प्रथम स्थान प्राप्त होता रहा है जो संस्थान के लिए बहुत बड़ी उपलब्धि रही है। इस वर्ष 'विज्ञानवाणी' के 22वें अंक का प्रकाशन किया गया है जिसमें संस्थान की उपलब्धियों को दर्शाने वाले लेखों का समावेश है जो शीघ्र ही प्रकाशित हो जाएगा।
6. संस्थान में हिन्दी के प्रयोग करने हेतु राजभाषा विभाग, गृह मंत्रालय द्वारा जारी दिशा-निर्देशों के अनुसार संस्थान के अधिकारियों व कर्मचारियों के लिए वर्ष में चार हिन्दी कार्यशालाओं का आयोजन किया गया।

हिन्दी पखवाड़ें का आयोजन

इसके अतिरिक्त 1-14 सिम्बर 2015 के बीच हिन्दी पखवाड़ा का आयोजन किया गया जिसमें विभिन्न प्रतियोगिताओं द्वारा हिन्दी में दक्षता बढ़ानें का प्रयास किया गया। इसके अतिरिक्त हिन्दी में कार्य करने वाले कर्मचारियों को प्रोत्साहन हेतु पुरस्कृत भी किया गया।

RESEARCH COUNCIL

Prof. SK Sopory Former Vice Chancellor, Jawaharlal Nehru University, **584, Sector 14,** **FARIDABAD -121007**	Chairman	**Dr. Ehrlich Desa** CSIR Distinguished Scientist, CSIR-4 PI, NAL Belur Campus **BENGALURU-560 037**	DG Nominee
Prof. R. Uma Shankar Professor & Head, Dept. of Crop Physiology and School of Ecology & Conservation, University of Agricultural Sciences, GKVK, **BENGALURU-560 065**	Member	**Dr. AK Tripathi** Director CSIR- CIMAP, P.O. CIMAP, Near Kukrail Picnic Spot **LUCKNOW – 226 015**	Director, Sister Laboratory
Prof. PK Gupta Hon. Emeritus Professor & NASI Senior Scientist Department of Genetics & Plant Breeding, Ch. Charan Singh University, **MEERUT – 250 004**	Member	**Dr. RA Vishwakarma** Director CSIR- Indian Institute of Integrated Medicine, Canal Road, **JAMMU - 180 001**	Cluster Director
Prof. JS Singh Professor Emeritus, Department of Botany, Banaras Hindu University, **VARANASI-221 005**	Member	**Dr. CS Nautiyal** Director CSIR-National Botanical Research Institute, Rana Pratap Marg, **LUCKNOW – 226 001**	Member
Prof. JP Khurana Coordinator (UGC-SAP) Department of Plant Molecular Biology, University of Delhi, South Campus, Benito Juraj Marg, **NEW DELHI-110021**	Member	**Dr. Sudeep Kumar** Head or his Nominee Planning & Performance Division, CSIR, Anusandhan Bhawan, 2, Rafi Marg, **NEW DELHI – 110001**	Permanent Invitee
Prof. Sunil Kumar Mukherjee NASI-Sr. Scientist, Platinum Jubilee Fellow, Genetics Department, University of Delhi, South Campus, Benito Juraj Marg, **NEW DELHI-110021**	Member	**Prof. V Verma** Dean Faculty of Engineering, Director, School of Biotechnology, Shri Mata Vaishno Devi University, **JAMMU – 182 320**	Member
Dr. Paramjit Singh Director Botanical Survey of India, CGO Complex, Salt Lake City, **KOLKATA – 700 064**	Agency	**Dr. SK Tewari** Senior Principal Scientist CSIR-National Botanical Research Institute, Rana Pratap Marg, **LUCKNOW – 226 001**	Member-Secretary

MANAGEMENT COUNCIL

Dr. CS Nautiyal Director CSIR-National Botanical Research Institute **LUCKNOW - 226 001**	Chairman
Dr. Ram Rajsekharan Director CSIR-Central Food Technological Research Institute **mysore**	Member
Dr. DK Upreti Chief Scientist CSIR-National Botanical Research Institute **Lucknow - 226 001**	Member
Dr. AK Gauniyal Senior Principal Scientist CSIR-National Botanical Research Institute **Lucknow - 226 001**	Member
Dr. ChV Rao Principal Scientist CSIR-National Botanical Research Institute **Lucknow - 226 001**	Member
Mr. Vivek Srivastava Senior Scientist CSIR-National Botanical Research Institute **Lucknow - 226 001**	Member
Dr. P Agnihotri Scientist CSIR-National Botanical Research Institute **Lucknow - 226 001**	Member
Shri AA Malick Senior S E CSIR-National Botanical Research Institute **LUCKNOW - 226 001**	Member
Mr. Sanjeev Shekhar Finanace & Accounts Officer CSIR-National Botanical Research Institute **LUCKNOW - 226 001**	Member
Mr. BJ Deuri Administrative Officer CSIR-National Botanical Research Institute **LUCKNOW - 226 001**	Member Secretary

EXPENDITURES AND EARNINGS 2015-16

I.	EXPENDITURE	Figure in Lakhs of Rupees
A.	**Revenue**	
	1. Salary & Sal. Linked Allowances	2712.074
	2. Other Allowances	
	a. Re-imburs. of Med.Exp./CGHS/Med.charges	65.014
	b. Overtime Allowance	2.000
	c. Honorarium	1.000
	d. Leave Travel Concession	16.709
	e. T.A. (India)	9.886
	f. T.A. (Foreign)	
	g. Professional Update Allowance	11.600
	h. Total Other Allowances (a to g)	106.209
3.	**Total Salaries (1+2h)**	**2818.283**
4.	P-04 Contingencies	345.012
5.	P-05 H.R.D.	
6.	P-06 Lab. Maintenance	226.562
7.	P-701 Staff Qrs. Maintenance	73.349
8.	P07 Chemical/Consum.& Other Res.Exp.	575.346
9.	**Total Revenue (3 to 8)**	**4038.552**
B.	**Capital**	
a)	P-50 Land Cost	
a)	P-50 Land Cost	
b)	(i) P-50 Works & Services/Elec. Installations (Lumpsum)	129.461
b)	(ii) P-50 Works & Services/Elec. Installations (Other)	
c)	P-50 App. & Equip./Computer Equipments	769.948
d)	P-50 Workshop Machinery	
e)	P-50 Office Equipments	3.500
f)	P-50 Furniture & Fittings	6.346
g)	P-50 Library (Books/ Journals/ e-Journal)	74.999
h)	P-50 Model & Exhibits	
i)	P-50 Vehicles	4.227
j)	P-50 Tools & Plants	
k)	P-50 Software development/procurement/LAN/WAN	
l)	P-26 -ICT	
m)	(i) P-702 Staff Qrs.(Construction) (Lumpsum)	121.456
m)	(ii) P-702 Staff Qrs.(Construction) (Other)	
Total Capital (a to m)		**1109.937**
Total A+B		**5148.489**
C.	**Special Proj. SIP/NWP/FAC/IAP/RSP/HCP/12th Plan Proj.**	
1.	Revenue	
	(i) T. A. (India)	20.897
	(ii) T.A. (Foreign)	6.255
	(iii) Contingencies	240.786

(iv) Maintenance	68.650
(v) Chemical, Consum.& Other Res.Exp.	1712.889
Total Rev.(C1)	**2049.477**
2. Capital	
(i) Work's & Services	44.974
(ii) Appartus & Equipment	141.000
(iii) Other Capitals	
Total Capital(C2)	**185.974**
C. Total allocation SIP/NWP/FAC/IAP/RSP/HCP/12th Plan (C1+C2)	**2235.451**
Total National Labs. (A+B+C)	**7383.940**
D. Central Administration	
P-804 Pension & Other retirement benefits	1776.852
P-801 and P-62 ISTADS	
P-803 PPD/TNBD	
P-805 HRD	
P-80508 RAB	
P-807 Publicity & Exhibition	
P80804 Grant to other Sci. Organisations	
P80805 CSIR Guest House (Science Centre)	
P80806 Celebrations	
P906- Advance	
(i) Conveyance/Computer Advance	3.000
(ii) House Building Advance	
(iii) Others	
Total Central Admin.	**1779.852**
II. EARNINGS	
RECEIPTS	
R04 DONATION	
R05 CONTRIBUTION	63.813
R06 MISC RECEIPTS	
R906 RECOV. OF ADV.	10.018
TOTAL R06+R906	**73.831**
R071 LAB RESERVE	
a) Royality Premia	
b) Testing & Analytical Charges	1.119
c) Other Technical Service	
d) Job Work	16.347
e) Rest of R 071 heads	50.339
Total Lab Reserve(R-071)	**67.805**
R909 EXTERNAL CASH FLOW	
a) Govt deptt./PSU's	523.658
b) Private agencies	4.391
c) Foreign govt/agencies	
TOTAL ECF (a+b+c)	**528.049**
Royalty & Premia for distribution (R907)	**1.485**

PERSONNEL (AS ON 31.03.16)

Director
C S Nautiyal

Chief Scientists
D K Upreti
S A Ranade
RS Katiyar

Sr. Principal Scientists
Kanak Sahai
S Kumar
Tariq Husain
A K S Rawat
R K Roy
P A Shirke
S K Tewari
T S Rana
A K Gauniyal
K N Nair
Sudhir Shukla

Principal Scientists
Anand Prakash
Talewar Singh
Nandita Singh
P K Trivedi
L B Chaudhary
Vivek Pandey
Samir V Sawant
A P Sane
Pratibha Misra
V A Sane
Alok Lehri
Ch. V Rao
Sayyada Khatoon
Mahesh Pal
Sharad Srivastava
Sanjeeva Nayaka
Ashish K Asthana
S K Ojha
O P Sidhu
Indraneel Sanyal

Senior Scientists
P K Singh
Arvind Jain
Vivek Srivastava
Shubha Rastogi
C S Mohanty
H K Yadav
MH Asif
Debasis Chakrabarty
Shekhar Mallick
Pankaj K Srivastava
Soumit K Behera
Suchi Srivastava
P C Verma
S N Jena
A P Singh
Manjoosha Srivastava
S K Bagh
Sribash Roy
Aradhana Mishra
Baleshwar
P S Chauhan

Scientists
Poonam C Singh
Lal Bahadur
Devendra Singh
Priyanka Agnihotri
RC Nainwal
Brahmanand Singh
Manoj Kumar
V V Wagh
Charu Lata

Pr. Technical Officers
A A Malick
S S Tripathi
Yogendra Nath
M L Kain
Bhaskar Dutt
Yogendra Misra
V D Tripathi

Sr. Tech. Officers (3)
A C Little
R K Tripathi
D K Purshottam
Alok Kumar
Shankar Verma

Sr. Tech. Officers (2)
Lalit K Srivastava
Anil Kumar
Daya Shanker
Bhagwan Das
Atul Batra
Sanjay Dwivedi
Abhishek Niranjan

Sr. Tech. Officers (1)
R N Gupta
Sushma Verma
Rajeev Kumar
G Sharma
Harendra Pal
Sandeep K Behera
Vinay Sahu
Anil Kumar
MK Shukla
Kiran Toppo
MM Pandey

Technical Officers
Surjit Kumar
Swati Sharma
Sara Jamil
Leena Wahi
SK Sharma
KN Maurya
Babita Kumari
GG Sinam
Sumit Yadav
KK Rawat
DD Toppo
Somanath Swain

Technical Assistants
Satish Kumar
Prashant Srivastava
Jai Chand
Shweta Singh
Rameshwar Prasad
Rekha Kannaujia
Shashank K Mishra
Komal K Ingle
Bharat Lal Meena
Vivek Kumar Gupta
RR Rastogi
Devranjan
Vandana Tiwari
MG Prasad

Administration
BJ Deuri, AO
Rajhans Gautam, CoF&A
Sanjeev Shekhar, F&AO
Kaushal Kishore, SPO
Dinesh Kumar, SPO
KK Singh, SPO
Prasoon Misra, SO
Shiva Kant Mishra, SO
Sachin Mehrotra, SO
RK Verma, SO
SK Singh, SO
Ishwar Nath Jha, SO
Prabha Tirkey, SO
BP Pande, PS
Bijendra Singh, Hindi Officer
SK Pandey, Security Officer

CSIR-National Botanical Research Institute

(Council of Scientific & Industrial Research, New Delhi)
Rana Pratap Marg, Lucknow - 226 001, U.P., India

Phones : 0522-2205848, 0522-2297802 Fax : 0522-2205839
E-mail : director@nbri.res.in Website: http://www.nbri.res.in

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