सीएसआईआर - भारतीय समवेत औषध संस्थान
CSIR-Indian Institute of Integrative Medicine
(Council of Scientific and Industrial Research)

वार्षिक प्रतिवेदन
Annual Report
2019-20

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सीएसआईआर - भारतीय समवेत औषध संस्थान,

जम्मू - 180001 (भारत)

CSIR-Indian Institute of Integrative Medicine

(Council of Scientific and Industrial Research)

JAMMU-180001 (INDIA)

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IIIM

OVERVIEW OF CSIR-IIIM

The Laboratory was established in 1941 as a research and production centre, known as Drug Research Laboratory of J&K State and was later taken over by Council of Scientific & Industrial Research (CSIR) of Govt. of India in December 1957 as Regional Research Laboratory, Jammu. In view of its core strength in natural products based drug discovery, the mandate of Institute was redefined in 2005 and its name changed to Indian Institute of Integrative Medicine (IIIM). The current mandate of IIIM is to discover new drugs and therapeutic approaches from Natural Products, both of plant and microbial origin, enabled by biotechnology, to develop technologies, drugs and products of high value for the national and international markets.

Mission

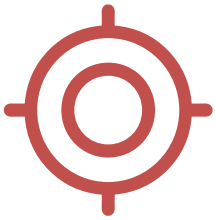
To become a Centre of Excellence in Natural Products chemistry and biotechnology driven drug discovery, integrating modern biology with chemistry

Vision

The vision of the Institute is to position IIIM as a International center of excellence for natural products chemistry, chemical biology, pharmacology and biotechnology to discover new chemical entities (NCEs) as drugs for unmet medical needs and provide scientific rationale and validity to various Indian systems of medicine. The institute aspires to achieve leadership position as a research Institute for creating a broad knowledge base, a work force of dedicated and trained scientists and a technology development center through scientific exploration of secondary metabolites from plants and microbial biodiversity, at the same time generating awareness for their conservation and protection.

Mandate

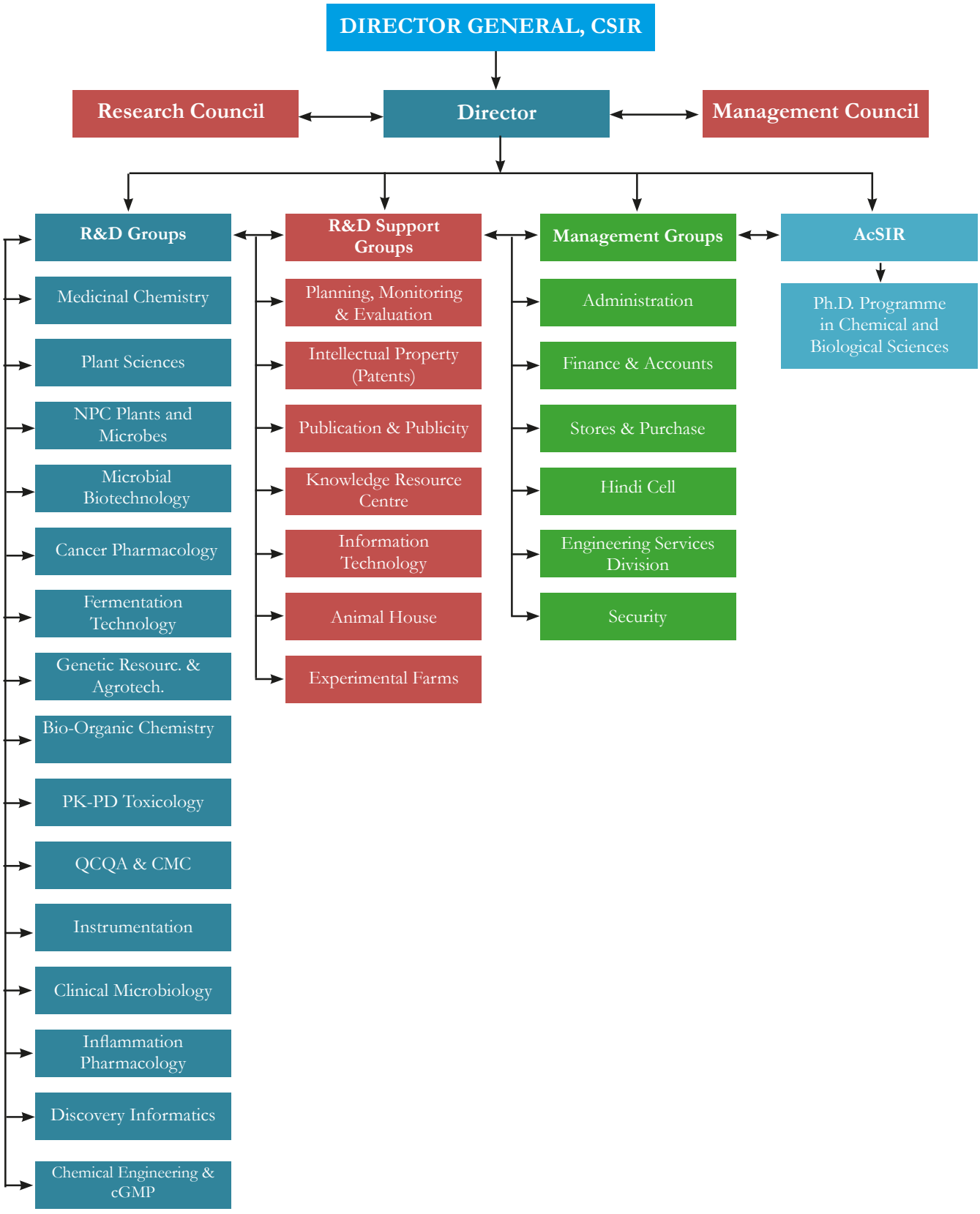
The mandate of IIIM is to be an internationally competitive centre of excellence in all facets of natural products research and technology, including (a) discovery of novel pharmacologically active natural products from plants and microbial species and translating them into drug leads and candidates by medicinal chemistry, preclinical pharmacology and clinical development. This approach is pursued both in NCE as well as botanical herbal mode; (b) Preclinical and clinical validation and establishment of mechanism of action of drugs used in various Indian systems of Medicines (Ayurveda, Unani, Siddha and other Indigenous systems of medicine); (c) develop agro-technologies and commercial cultivation of high value medicinal and aromatic plants from Western Himalayas including Kashmir Valley and Laddkh for national and international markets; and (d) to work with Indian and global pharmaceutical industry to out-license new products and technologies.



Current Focus Areas:

- Medicinal Chemistry (Hit to pharmacokinetics, formulation and Preclinical development)
- Biotechnology of plants and microbial secondary metabolites
- Fermentation based technologies of Industrial products
- Phytopharmaceutical drug discovery (GAP,GLP,GMP,GCP)
- NABL accredited QC/QA of drugs, foods, essential oils etc.
- Pharmacology of Cancer, Inflammation, Infection (Clinical microbiology) and Neurodegenerative disorders
- Societal outreach programme in cultivation of Medicinal and Aromatic crops for better income and lively hood to rural poor and employment generation.

ORGANISATIONAL SETUP



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11.	DG CSIR or his nominee	Member	

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Sh. Pankaj Bahadur **COA / AO** CSIR-Indian Institute of Integrative Medicine, Jammu	**Member Secretary**

FROM THE DIRECTOR'S DESK

It gives me immense pleasure to present the annual report of CSIR-IIIM for the year 2019-20. This report summarizes the achievements in all facets of natural products research and technology including discovery of novel pharmacologically active natural products from plants and microbial species and translating them into drug leads, preclinical pharmacology and clinical development in both NCE as well as botanical herbal mode. We have filed 10 patent applications both in India and in foreign and 12 patents were granted to CSIR-IIIM. In the calender Year 2019, IIIM published a total of 147 scientific publications with an average impact factor of 3.186 Several important events took place during this year. Firstly, IIIM-TBI, Jammu was formally inaugurated by Dr Shekhar C. Mande, Director General, CSIR on 30th Nov'19. Secondly, CSIR-IIIM filed an IND application of Cdk inhibitor IIIM-290 to the Drug Controller General of India (in January 2020). Thirdly, CSIR-IIIM and INSDUSSCAN, a Canada based company signed a major scientific agreement on Cannabis Research on 22nd February, 2020. Director, IIIM in his welcome address in presence of the Hob'le Union Minister Dr Jitendra Singh, Shri R.R. Bhatnagar, Advisor to LG (J&K) and Dr. Shekhar C. Mande, DG CSIR & Secretary to Govt., DSIR, Dr. Sanjay Kumar, Director, CSIR-IHBT, Palampur and scientific and technical staff said that recent scientific discoveries have confirmed that most of the psychoactive properties come from Δ 9-tetrahydrocannabinol (THC). Further he said that an another major compound was discovered named cannabidiol (CBD) which is totally devoid of psycho-active properties and possesses remarkable therapeutic activities. In last decade, four drugs namely Sativex (nabiximols), Marinol (Dronabinol), Nabilone (Cesamet), Epidelox have been approved by US FDA/EU regulatory and many others in different clinical trials namely Ajulemic acid (Resunab, Phase-II), Dexanabinol (HU-211 or ETS2101, Phase-I). Fourthly, CSIR-IIIM and M/s Racemix Molecules Pvt Ltd, Jammu has entered into an umbrella agreement to do collaborative research & development and industrial production of Active Pharmaceutical Ingredients (APIs) of life saving drugs. Fourthly, CSIR-IIIM, Jammu has signed 10 MoUs with various parties.

CSIR-IIIM organized Public Outreach Programme as a part of the India International Science Festival (IISF-2019), which was jointly organised by Ministries of Science and Technology and Earth Sciences and Vijnana Bharati (VIBHA). As a part of CSIR Integrated Skill Initiative, CSIR-IIIM, Jammu has started offering several skill development courses for diploma holders, graduates, people from industries in various disciplines of Biological and Chemical sciences based on the mandate of the institute. I wish to thank the Research and Management Council of CSIR-IIIM, for their constant support and cooperation. Lastly, I acknowledge the role of stakeholders, the scientists, staffs and the students of CSIR-IIIM who made possible this outstanding output for inclusion in this annual report.

(Ram A. Vishwakarma)

1 PLANT SCIENCES

1.1 Molecular Cloning and Characterisation of AaMYC2-LIKE, a bHLH transcription factor from *Artemisia annua*

Ishfaq Majid, Nazia Abbas

Malaria, the world's most severe disease caused by *Plasmodium falciparum* infection, has caused more than a million deaths annually (Greenwood and Mutabingwa, 2002). Although many efforts have been tried to control malaria, no apparent result has been obtained except the artemisinin combination therapies recommended by the world health organization (WHO) (Graham *et al.*, 2010). Engineering metabolic pathways of *A. annua* plants holds a great potential for increasing artemisinin production (Ro *et al.*, 2006). In comparison with the great progress made in cloning enzymes of the artemisinin pathway and engineering the pathways in microorganisms (Bouwmeester*et al.*, 1999; Ro *et al.*, 2006; Teoh*et al.*, 2006; Zhang *et al.*, 2008; Teoh*et al.*, 2009), relatively little information is available about the regulatory mechanisms of artemisinin biosynthesis in plants. The MYC family proteins constitute the second largest family of DNA binding bHLH transcription factors having important regulatory roles in plants. MYCs are involved in various processes e.g., regulation of anthocyanin, flavonoid, tryptophan biosynthesis, floral initiation, seed germination, certain roles in the signaling pathways of jasmonate, ABA, and gibberellin and mediating tolerances to biotic and abiotic stresses (Zhao *et al.,* 2011, Fursova*et al.,* 2009). In present study the role of a bHLH transcription factor in regulation of artemisinin biosynthetic pathway in *Artemisia annua* is being investigated.

Isolation of Full length *AaMYC2-LIKE* cDNA from *Artemisia annua*

AaMYC2-Like is a MYC type bHLH transcription factor and has a close homology with the MYC type bHLH transcription factors of other plant species. The full length CDS of a bHLH transcription factor in *Artemisia annua* was cloned by RACE-PCR and was named as *AaMYC2-Like*. Based on the sequence, a pair of primers Aa*MYC2-LIKE*-F and Aa*MYC2-LIKE*-R were synthesized, and used to amplify Aa*MYC2-LIKE* transcription factor from *A. annua*. The 1272bp sequence of the Aa*MYC2* was amplified and cloned in pTZ57R/T vector. The CDS of Aa*MYC2-LIKE* is 1272 bp long and codes for 424 amino acids with a molecular weight of 46.6 KD. The 424 amino acid sequence was analysed by SWISS PROSITE software and the bHLH structural motif was depicted as shown in Figure 1.1.1.

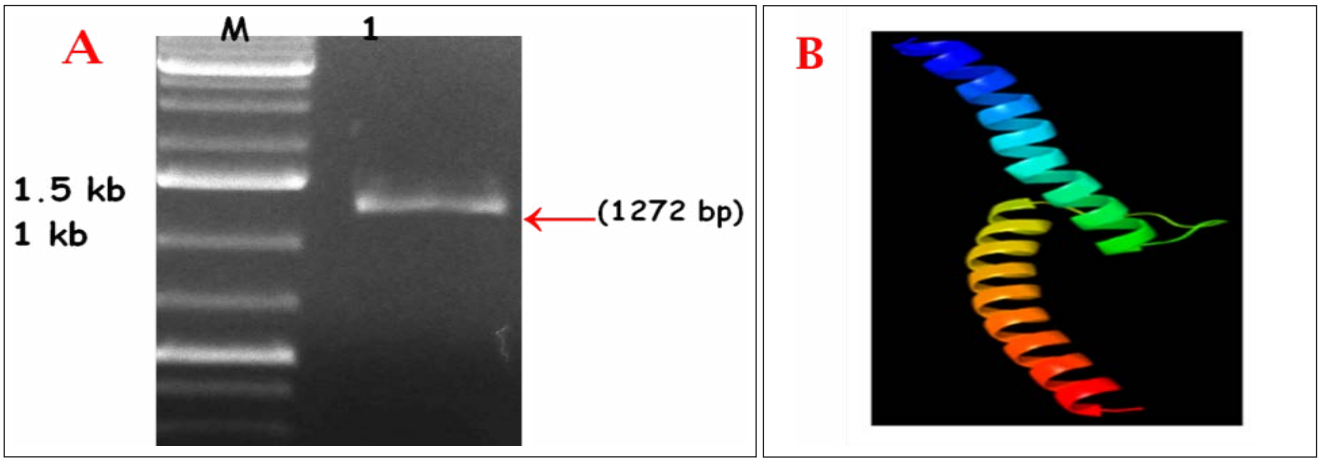


Figure 1.1.1. Cloning of full length CDS of *AaMYC2-LIKE. A,* Lane M shows 1kb ladder, lane 1 shows 1272 bp full length of *AaMYC2-LIKE*.B, Structural analysis of *AaMYC2-LIKE* as depicted by SWISS-PROSITE.

Multiple Sequence alignment and Phylogenetic analysis of AaMYC2-LIKE:

The amino acid sequences of AaMYC-LIKE and their orthologs from other plants were retrieved from GenBank database at National Center for Biotechnology Information (NCBI). The BLAST-Protein (BLASTP) online (http:// www.ncbi.nlm.gov/blast) performed retrieved the most similar sequences of MYC type bHLH proteins from the other species like *Cynara cardunculus, Helianthus annuus, Juglans regia, Vitis vinifera, Herrani cumbratica and Theobroma cacao*. On the basis of similarity the highly homologous sequences were aligned by CLUSTAL OMEGA software (Figure 1.1.2A) which showed that AaMYC2-LIKE was having highly conserved bHLH domain which was homologous with the MYC type bHLH proteins from other plant species. The phylogenetic tree was developed using the Neighbor-Joining method of MEGA 6 software (Tamura et al., 2013). The percentage of replicate trees in which the associated taxa clustered together in the bootstrap test (1000 replicates) is shown next to the branches (Figure 1.1.2B). The tree was drawn to scale, with branch lengths in the same units as those of the evolutionary distances used to infer the phylogenetic tree.

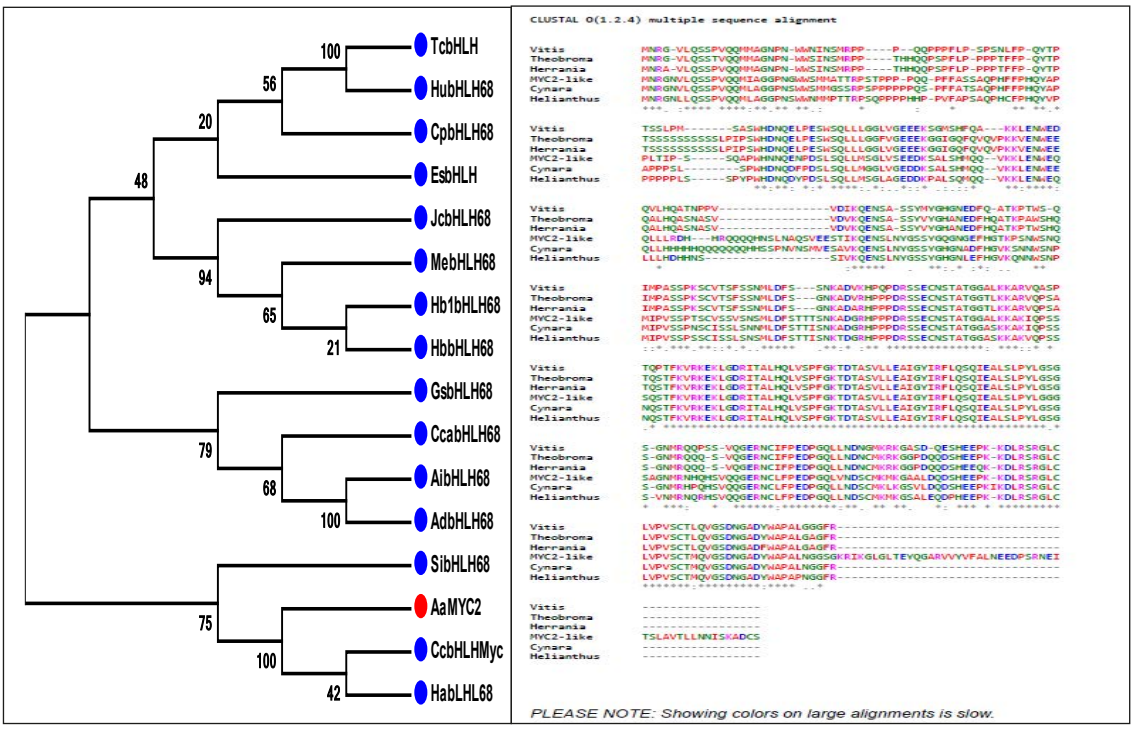


Figure 1.1.2 (A) Multiple sequence alignment of AaMYC-LIKE bHLH transcription factors from different plant species by CLUSTAL Omega. (B) Phylogenetic analysis of AaMYC2-LIKE by MEGA 6 Software confirms the MYC type bHLH transcription factor.

Expression Analysis of *AaMYC2-LIKE* in response to different phytohormones and Abiotic stresses

It is well known that the phytohormones e.g., jasmonate (JA), salicylic acid (SA), and abscisic acid (ABA) help plants in survival from the biotic and abiotic stresses by triggering a de novo synthesis of protective metabolites and proteins (Yuan and Lin, 2008; Browse, 2009). Recent reports showed that JA treatment of *A. annua* plants resulted in enhanced artemisinin production (Baldi and Dixit, 2008; Wang et al., 2010), possibly by stimulating both the glandular trichome formation and the sesquiterpene accumulation in glandular trichome (Maes et al., 2011). However, transcription factors involved in JA regulation of artemisinin biosynthesis have not

been reported. The expression of *AaMYC2-LIKE* under the influence of different phytohormones like Methyl jasmonate, 2-4D, Abscisic acid, Gibberellic acid, Salicylic acid and abiotic stresses like Methyl viologen, NaCl, UV, Cold, Heat was investigated using Real time PCR as shown in Figure 1.1.3. For this study 8 week old plants of *Artemisia annua* were treated with different concentrations of phytohormones for 2, 12 and 24 hours. The total RNA was isolated and the expression of *AaMYC2-LIKE* was studied. The expression of *AaMYC2-LIKE* was induced in presence of various phytohormones like auxin (2, 4-D), methyl jasmonate, abscisic acid and was also elevated in presence of various abiotic stresses. The stage specific expression of *AaMYC2-LIKE* was also performed at the different developmental stages of *Artemisia annua* like root, stem leaf and flower. From the Figure 1.1.3(F) the highest expression of *AaMYC2-LIKE* was seen in leaves followed by flowers and least in roots. Also expression of *AaMYC2-LIKE* was elevated in presence of methyl jasmonate confirming its predominant role in jasmonic acid signalling pathway.

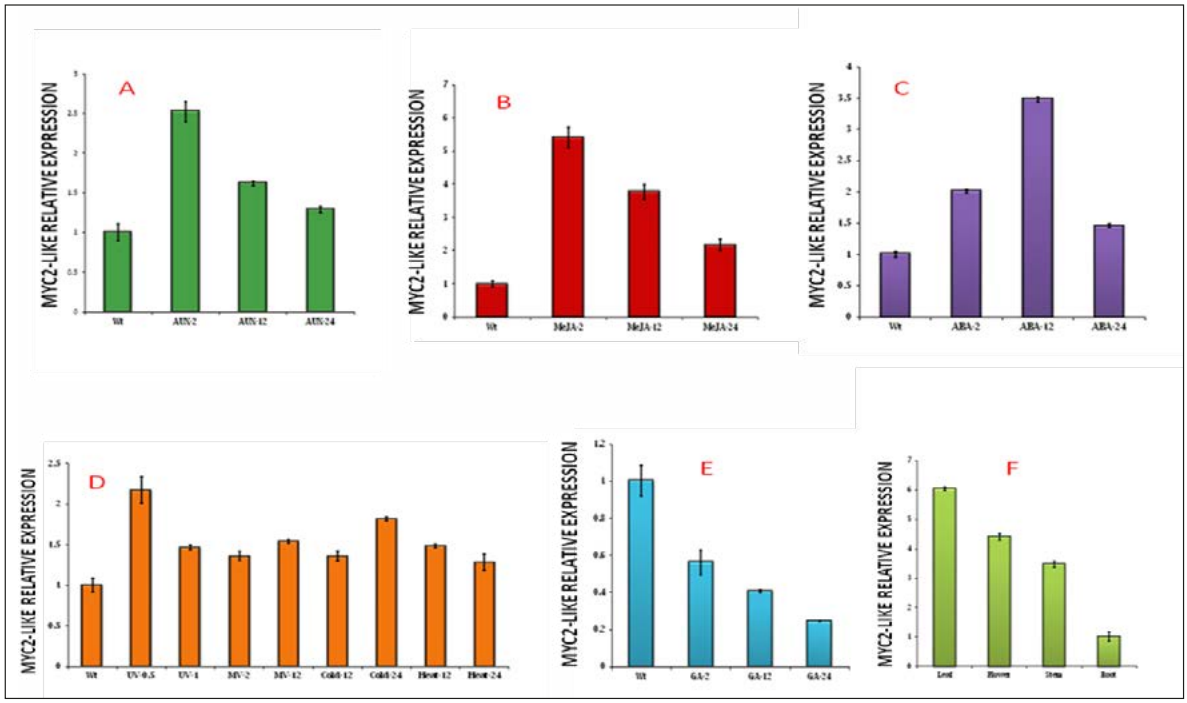


Figure 1.1.3 Relative expression of *AaMYC2-LIKE* in response to various phytohormones, abiotic stress and at different stages of plantA: 2,4-D auxin, B: Methyl Jasmonate, C: Abscisic Acid, D: UV, Methyl Viologen, Cold and Heat Shock, E: Gibberlic Acid. F: Stages (Leaf, Stem, Root, Flower).

Nuclear localisation of AaMYC2-LIKE in Onion epidermal cells by *Agrobacterium* mediated transformation.

In order to determine the subcellular localization of AaMYC2-LIKE within plant cells, an *in vivo Agrobacterium* ediated targeting experiment was performed in onion epidermal cells. A highly efficient and rapid technique of Agrobacterium mediated transient transformation in living cells of planta was used (Kedong et.al 2014). In order to study the nuclear localisation the coding sequence of AaMYC2-LIKE was fused in-frame with the GUS reporter gene of plant expression vector, pBI121. The *AaMYC2-LIKE* fusion gene was driven by the 35S promoter and was delivered into onion epidermal cells by microinjecting *Agrobacterium tumefaciens* infiltration medium. In the case of AaMYC2-LIKE *GUS* fusion, strong GUS staining was observed in the nucleus of onion cells, whereas in Vector only GUS staining was found to be localized in both the nucleus and the cytosol (Figure 1.1.4). The results of the *in vivo* targeting experiment suggested that AaMYC2-LIKE is localized in the nucleus.

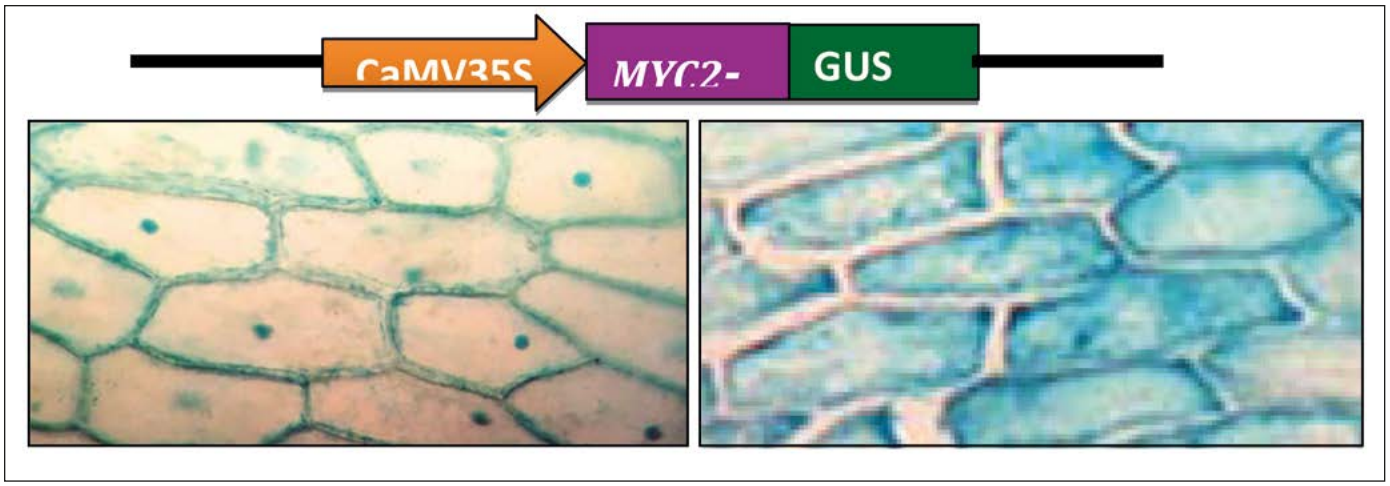


Figure 1.1.4 Nuclear Localisation of *AaMYC2-LIKE* **in Onion epidermal:** A, shows the localisation of *AaMYC2-LIKE* in the nucleus of onion cells; B, shows the localisation of vector control (pBI121) in the onion cells

Transactivation of AaMYC2-Like

To investigate the ability of AaMYC2-like to activate transcription, a transient expression assay was performed using a GAL4-responsive reporter system in yeast cells. For this, the full-length coding region of *AaMYC2-like* was fused to the GAL4 DNA-binding domain (BD) to generate pGBKT7-*AaMYC2 –like - BD* construct which was then Co-transformed into yeast strain Y187 along with AD vector. The pGBKT7-P53-BD and AD (positive control), AD and BD (Vector control) and pGBKT7-LAM-BD and AD (negative control) were used as positive and negative controls respectively. The transformants were assayed for their ability to activate transcription from the GAL4 upstream activation sequence. All the Co-transformed cells grew well in the SD medium lacking tryptophan and leucine. While as the transformed yeast cells harboring pGBKT7-AaMYC2-like *–BD + AD* was able to grow on triple auxotrophic mutant media lacking tryptophan, leucine and histidine alongwith Positive control. Further the quantification of transactivation assay by β-galactosidase activity confirmed the transcriptional activity of AaMYC2-like within yeast strain Y187, (Figure 1.1.5).

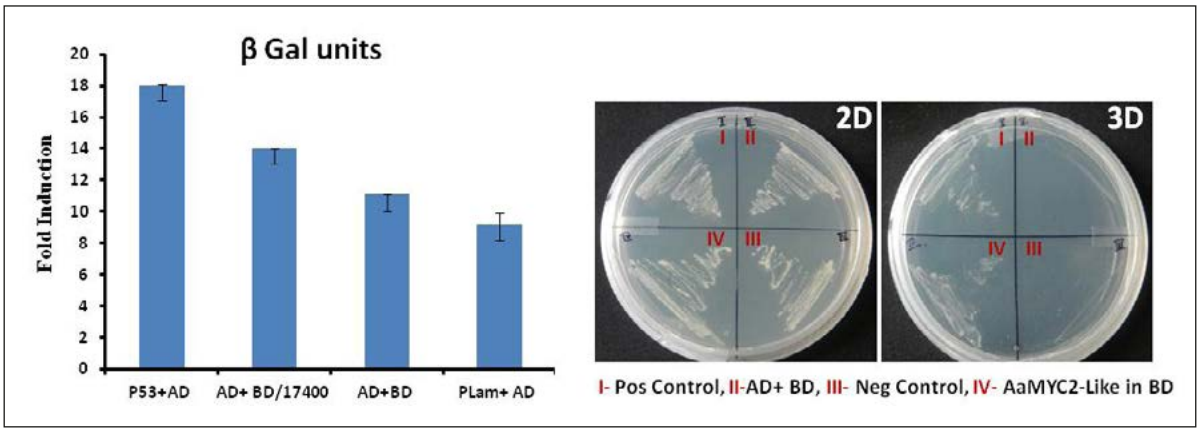


Figure 1.1.5: Transactivation analysis of *AaMYC2-like* **by β-galactosidase assay:** A, β-galactosidase activity of *AaMYC2-like* within yeast cells using ONPG as substrate.B, Growth of various combination of pGBKT7 and pGADT7 in double and triple dropout media. I- Positive control (P53BD + AD); II-Vector control (AD+BD); III-Vector control (AD+pLAMBD); IV-BD+AaMYC2-like+AD

AaMYC2-Like positively regulates Artemisinin biosynthetic genes *(CYP71AV1, ALDH1and DBR2)* within *Artemisia annua.*

In order to confirm the regulatory role of Aa*MYC2*-like in artemisinin biosynthetic pathway, the gene was transiently expressed in *Artemisia annua* leaves under the control of CaMV-35S promoter. The presence of transgene in transiently transformed leaves was confirmed by the GUS staining. Further, we checked expression of few of the Artemisinin biosynthetic genes and observed that *Cytochrome P-450 dependent hydroxylase* (*AaCYP71AV1), Aldehyde dehydrogenase (AaALDH1)* and *Double bond reductase (AaDBR2)* genes were showing upregulation in Aa*MYC2*-like overexpressing leaves as compared to vector control and wild type (Figure 1.1.6A). The transcript levels of *CYP71AV1, DBR2* was increased by around 5 times as compared to *ALDH1* which was drastically increased to about 12 times in the transiently over expressing transgenic plants as compared to *WT* and Vector control plants Figure 1.1.6 (D).The drastic increase of *ALDH1* transcript in the *AaMYC2-Like* over expression plants suggest the major regulatory role of *AaMYC2-Like* on *ALDH1*. At the preliminary level promoter analysis for the presence of typical *MYC* binding sites within Artemisinin biosynthetic genes was performed by New PLACE software. The promoter analysis of *ALDH1, DBR2* and *CYP71AV1* by New PLACE software confirmed the putative *MYC* consensus or E-boxes which are the probable binding sites of MYC transcription factors within the sequence. Thus the analysis suggests that *AaMYC2-Like* may directly bind to the *ALDH1* promoter and regulate its expression pattern which needs to be further studied.

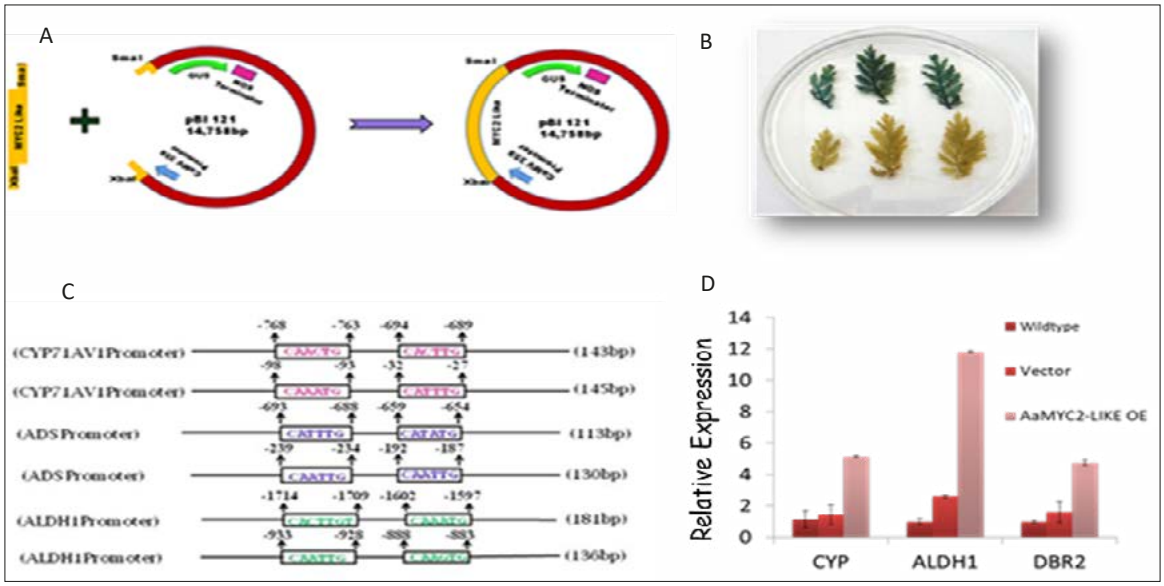


Figure 1.1.6: Aa*MYC2*-Likepositively regulates Artemisinin biosynthetic geneA, Cloning of Aa*MYC2*-like in pBI121 vector. **B,** Transient over-expression of Aa*MYC2*-like in Artemisia annua leaves by agrobacterium mediated transformation and confirmation of transgene by GUS staining. **C,** Promoter sequences of Artemisininbiosynthetic genes.**D,** Relative expression of *AaCYP71AV1, AaALDH1* and *AaDBR2* in the overexpression Aa*MYC2*-like transgenic leaves.

Relative Quantification of *AaMYC2*-LIKE in overexpressed Artemisia annua plants by HPLC depicts increased Artemisinin content.

The quantification of artemisinin content within the transient over expression Aa*MYC2*-Like was performed by the HPLC analysis using artemisinin from sigma as standard. As expected the artemisinin content was significantly higher in over expressing Aa*MYC2*-Like transgenic plants as compared to vector control. The artemisinin content was increased approximately 4 times in Aa*MYC2*-Like over expression plants as compared to vector control plants.

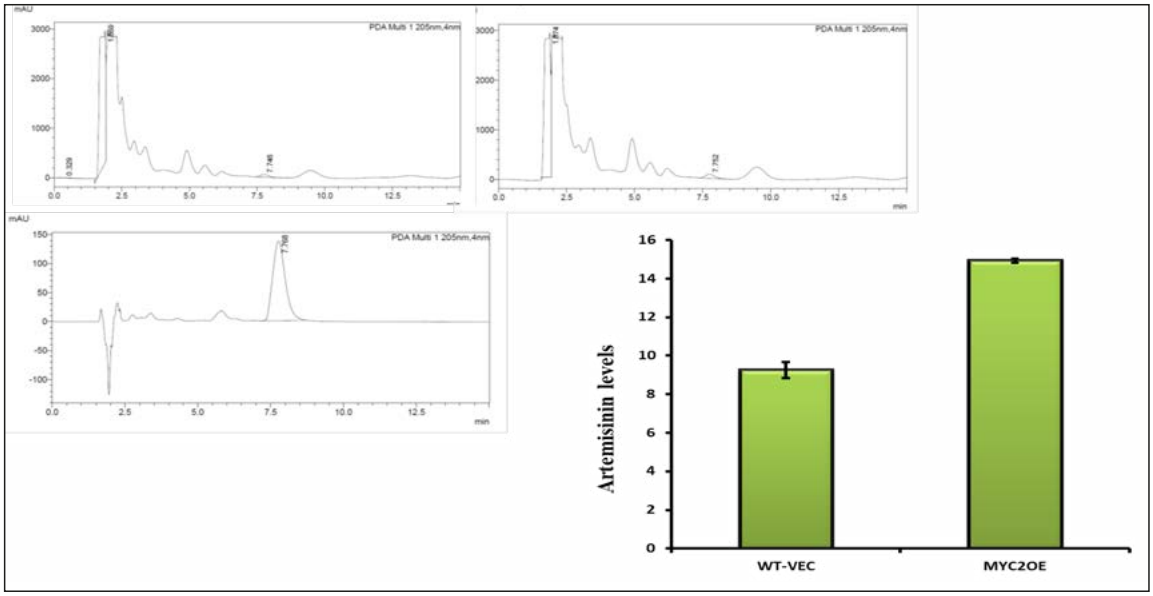


Figure 1.1.7: Relative Quantification of Artemisinin content between the WT and Aa*MYC2*-LIKE overexpressed Artemisia annua plants by HPLC depicts a 4 fold increase in Artemisinin content.

AaMYC2-Like binds to ALDH1 Promoter

As discussed earlier the expression of biosynthetic genes *CYP, ALDH1* and *DBR2* was elevated in *AaMYC2-Like* over expression plants among which *ALDH1* showed highest expression level suggesting the major regulatory role of *AaMYC2-Like* with respect to *ALDH1*. The promoter analysis of *ALDH1* with the help of NEW PLACE software confirmed the presence of Two E-boxes. In order to confirm the direct binding of *AaMYC2-Like* with *ALDH1* promoter Yeast –One Hybrid assay was performed as per Matchmaker® Gold Yeast One-Hybrid Kit. The growth of Yeast cells on the auxotrophic deficient plates as per the Matchmaker® Gold Yeast One-Hybrid Kit by using the proper positive and negative controls confirmed the binding of Aa*MYC2*-Like on ALDH1 promoter. The Figure 1.1.8 clearly depicts Aa*MYC2*-LIKE directly binds to ALDH1 promoter as the growth of Yeast cells was seen in only pABAi-ALDH1+ pGADT7-AaMYC2-LIKE and Kit positive control but not in negative control.

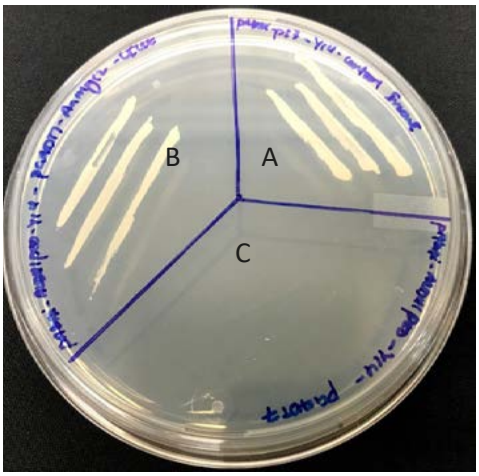


Figure 1.1.8: AaMYC2-Like binds to ALDH1 Promoter A: shows interactions of Positive controls of kit. B: shows interaction of pABAi-ALDH1-promoter region and pGADT7-AaMYC2-LIKE C: shows no interaction of pABAi-ALDH1-promoter region and pGADT7 as negative control.

Protein -Protein interaction of AaMYC2-Like with *AaMYC2* within yeast cells by yeast Two-hybrid assay

We performed a protein-protein interaction using *AaMYC2* as it is a well-known transcription factor in the jasmonate pathway among the bHLH protein family. It would be interesting to verify the interaction affinity between *AaMYC2* and *AaMYC2-like*. In order to confirm the interaction, yeast two hybrid assay was performed as per Matchmaker® Gold Yeast Two -Hybrid Kit,the protein of interest (Aa*MYC2*-Like) is expressed as a fusion protein to the DNA Binding Domain (DBD- Aa*MYC2*-Like; also known as the "bait" protein) and the activation domain is fused to the second protein of interest (Aa*MYC2*), (AD-*MYC2*; also known as the "prey" protein).The growth of Yeast cells on the auxotrophic deficient plates as per the Matchmaker® Gold Yeast Two-Hybrid Kit by using the proper positive and negative controls confirmed the interaction of Aa*MYC2*-Like and Aa*MYC2*.

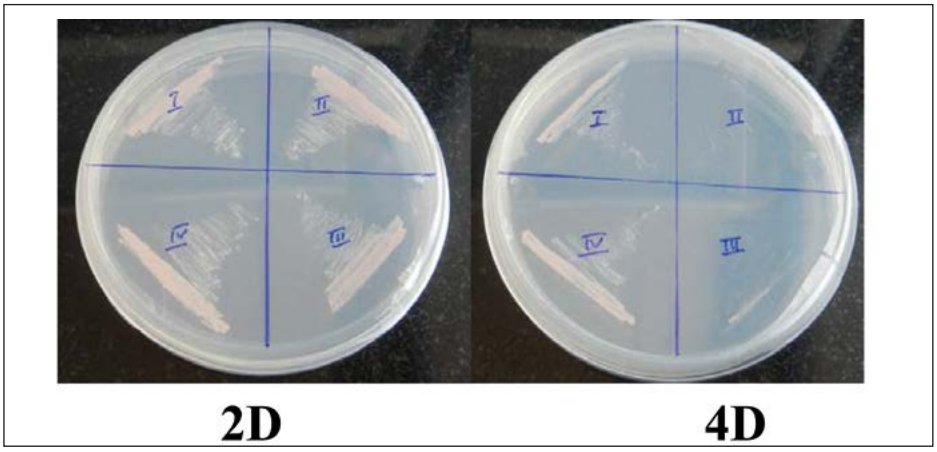


Figure 1.1.9: Aa*MYC2*-Like Interacts with Aa*MYC2*
Yeast colonies were able to grow on **2D media** (Double Drop Out specific to DNA Binding Domain and Activation Domain vectors only) while as only positive control, *AaMYC2* and *AaMYC2-like* were able to grown on **4D media** (Quadruple Drop Out Media specific to proein – protein interaction). I – pGADT7-T + pGBKT7-53 (Positive control), II – pGADT7 + pGBKT7 (Negative control), III – pGADT7 + pGBKT7-Lam (Negative control), IV –pGADT7-Aa*MYC2* + pGBKT7- Aa*MYC2*-Like

1.2 Identification of putative transcription factors involved in the regulation of trichome aspects in *Nicotiana tabacum*

Abhishek Kumar Nautiyal, Umar Gani, Priyanka Sharma, Maridul Kundan, Mohd. Fayaz, Prashant Misra

The transcriptomes of different tissues of *N. tabacum* (Mature leaf, young leaf, stem, root, mature flower, trichomes and trichome-free leaf) were analyzed for the identification of transcription factor genes. The analysis revealed a set of 1750 transcription factor genes, which express at a cutoff of FPKM≥1 in trichomes. The k-mean clustering identified of one interesting cluster (cluster 6) with 147 transcription factor genes (Figure 1.2.1 and Figure 1.2.2a). Most of the transcription factor genes within this cluster displayed highest expression values in trichomes.

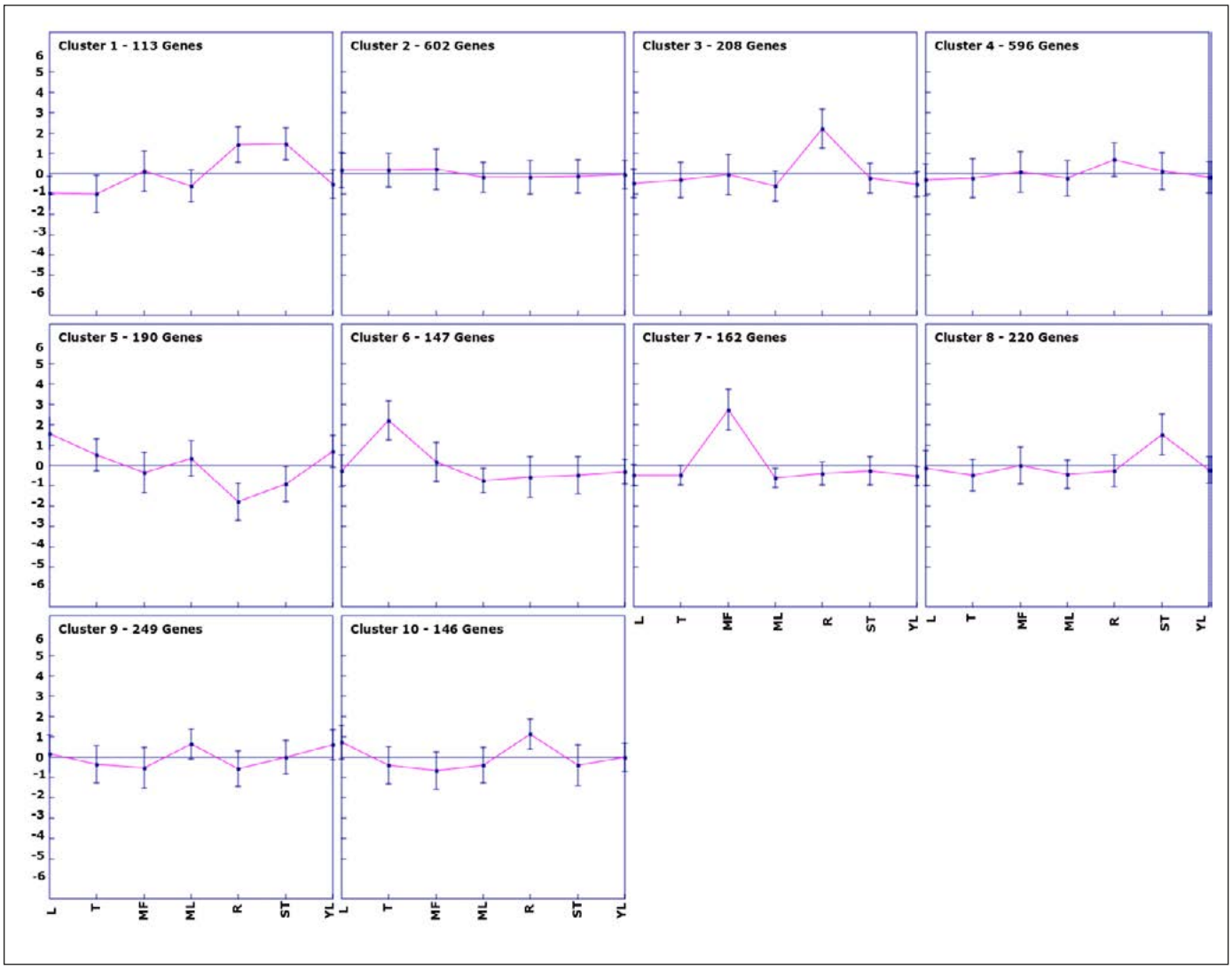


Figure 1.2.1: k-means clustering of transcription factor genes. The transcription factor genes were identified using the transcriptome resource and assigned to different families. The transcription factor genes were clustered in 10 groups based on the expression pattern in young leaf (YL), mature leaf (ML), stem (ST), mature flower (MF) and trichome-free leaf (L). The Y axis of the graph depicts mean cantered $\log_2$ FPKM+1 values. [Plant Mol Biol. (2020) 102:625-644].

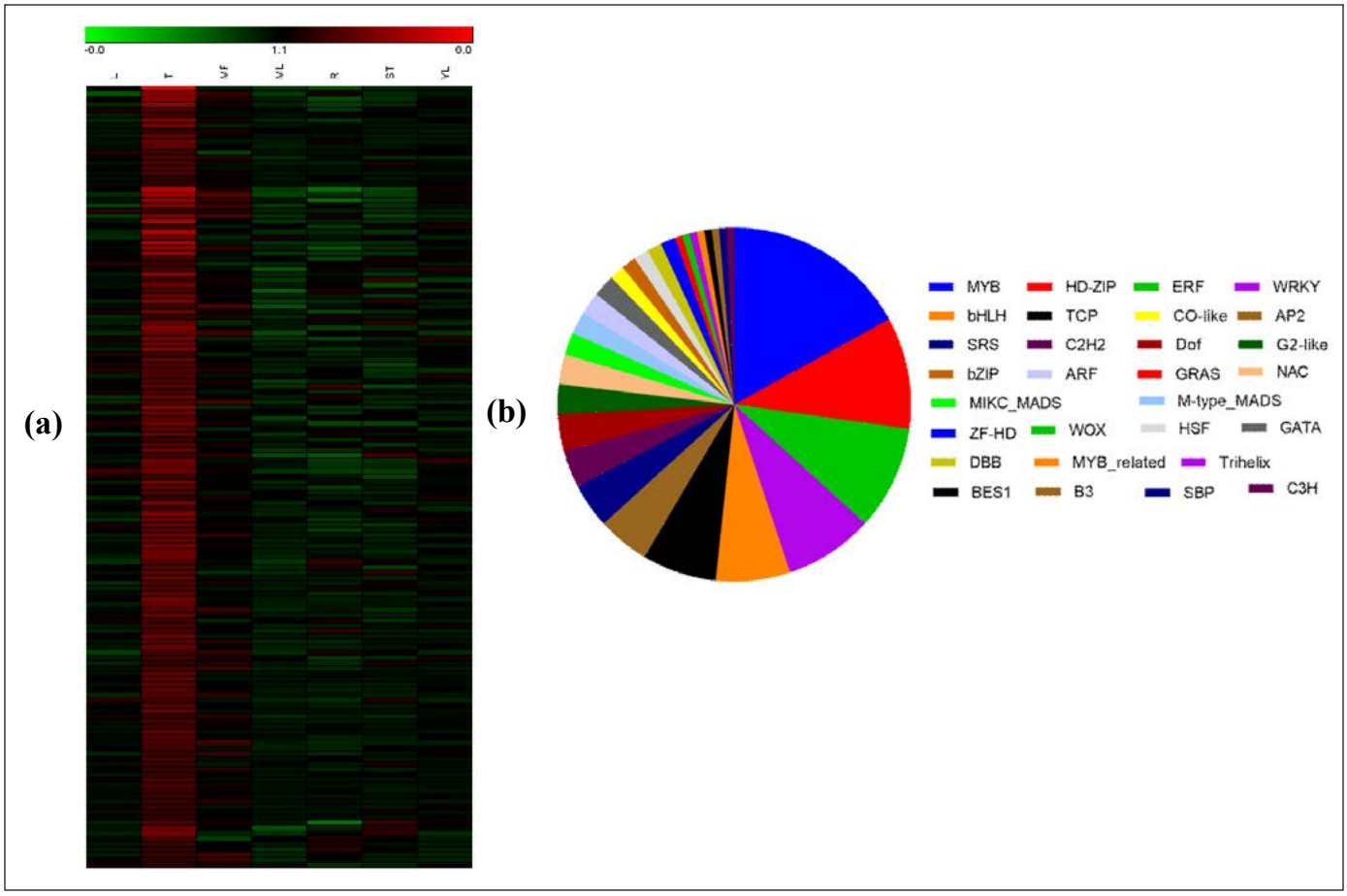


Figure 1.2.2: Expression pattern of transcription factor genes displaying preferential expression in trichomes. (a) Heat map depicting expression of transcription factor genes within the cluster 6. The expression values (FPKM+1) of the transcription factor genes were $\log_2$ transformed, mean centered and represented in the form of Heatmap. The red and green colors represent the extent of expression levels. **(b)** Classification of transcription factor genes within the cluster 6. The transcription factor were classified in different transcription factor families and represented in the form of a pie chart. [Plant Mol Biol. (2020) 102:625-644].

The classification of transcription factors belonging to the cluster 6 suggested that MYB (25 members), HD-ZIP (15 members), ERF (14 members), WRKY (12 members) and bHLH (10 members) were top five transcription factor families based on the numbers (Figure 1.2.2b). The expression pattern of some of these transcription factors was studied using real time PCR, which validated their preferential expression in the trichomes (Figure 1.2.3). To identify gene regulatory networks and to reveal candidate transcription factors potentially involved in the regulation of genes displaying preferential expression in trichomes, a coexpression analysis was carried out. In total, we identified 6687 pair wise co-expressing interactions of total 387 genes. Based on the betweenness centrality, top 30 transcription factor genes were identified (Figure 1.2.4). These transcription factors, for obvious reasons, are likely to be involved in the transcriptional regulation of genes displaying trichome specific expression.

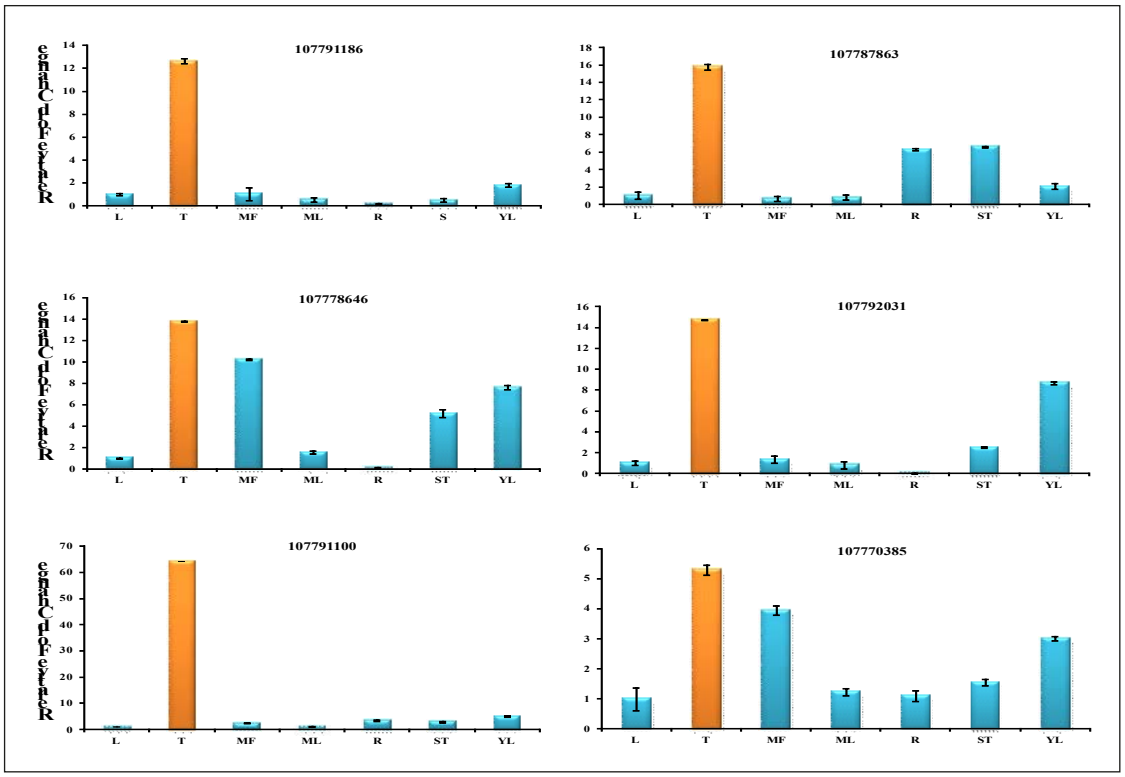


Figure 1.2.3: Real time PCR based expression profiling of some transcription factor genes. Some transcription factor genes belonging to the cluster 6 were randomly selected and their expression profiling was carried out in trichome (T), young leaf (YL), mature leaf (ML), stem (ST), mature flower (MF) and trichome-free leaf (L). Each graph represents relative fold change in the expression of a selected transcription factor gene in different tissue with respect to L. The results are the mean of three replicates. [Plant Mol Biol. (2020) 102:625-644].

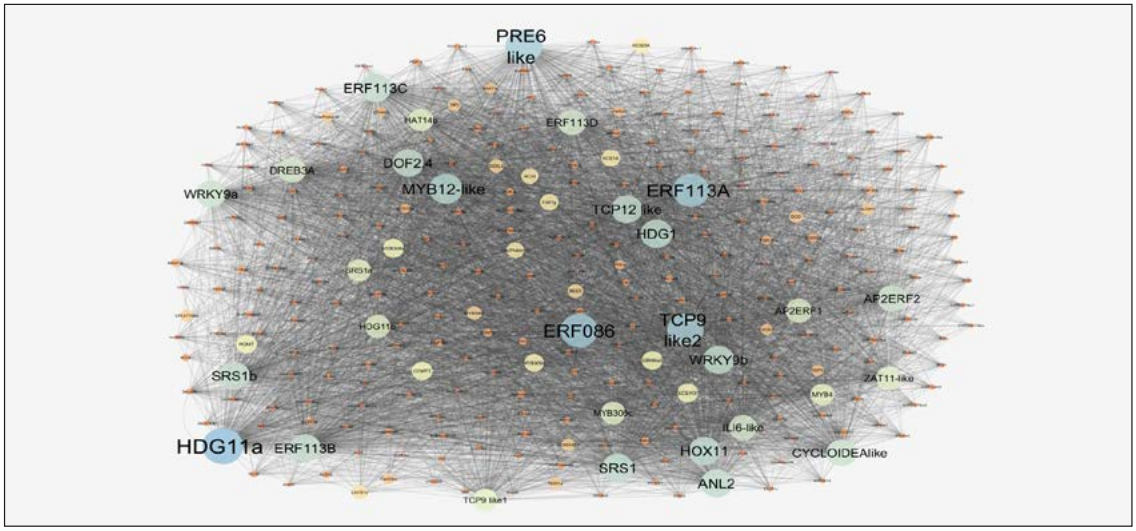


Figure 1.2.4: Co-expression network of genes displaying preferential expression in trichomes including transcription factors. The pair-wise co-expressions between genes and transcription factor genes were calculated in terms of Pearson correlation coefficient having a threshold filter of 0.99. The interactions were presented in the form of a network of genes using Cytoscape tool. The sizes and fonts of the nodes were mapped with the betweenness centrality measure. Thus, the higher the size more is the betweenness centrality. [Plant Mol Biol. (2020) 102:625-644].

1.3 Transcriptome sequencing of Monarda citriodora develops background for the elucidation of the molecular basis of essential oil biosynthesis

Priyanka Sharma, Mir Abdul Wajid, Abhishek Kumar Nautiyal, Umar Gani, Maridul Kundan, Sabha Jeet, Ravi Shanker, Sumeet Gairola, Prashant Misra

Monarda citriodora, belonging to the family lamiaceae produces essential oil, which is rich in thymol content. Besides, the essential oil from *M. citriodora* contains other phenolic monoterpenes. A selection from the previous breeding efforts of IIIM Jammu, popularized as Jammu *Monarda* has been in use for cultivation purposes under the CSIR Aroma Mission project. Despite its economic value, there is currently no information available on the molecular aspects of the biosynthesis of essential oil in this plant species. Therefore, we have carried out transcriptome sequencing of leaves of *M. citriodora*. The RNA isolated from different developmental stages of the leaves from young *M. citriodora* plants were used for the preparation of paired-end cDNA libraries, which were sequenced using Illumina HiSeq platform. Following sequencing and pre-processing involving cleaning of low quality data and rRNA reads, approximately 42 GB clean data was obtained. The clean data was assembled using Trinity assembler, which led to the establishment of 261,636 transcripts (Table 1.3.1). The CD-HIT program was used to establish 177451 unigenes (Table 1.3.2). The annotation of organism based on the BlastX hits of the top 25 organisms suggested that most of the hits belonged to *Erythranthe guttata*, which is a plant belonging to the order lamiales. The annotation of the assembled transcriptome was performed by using Uniprot Plant Database. Our preliminary analysis of the assembled transcriptome revealed several genes involved in the isoprenogenesis (i.e belonging to the MVA and MEP pathways). In addition, we identified several putative genes putatively encoding Terpene synthases and CYP450s. To sum up, a rich transcriptome resource of the *M. citriodora* has been developed, and currently detailed studies for gene expression and functional characterization of genes involved in the essential oil biosynthesis are underway.

Table 1.3.1: Features of the assembled transcripts

GC content	43%
Length N50	1448
Length max	14488
Length mean	972
Length median	701
Length min	201
Number of sequences	261636

Table 1.3.2: Features of the unigenes

GC content	42.7
Length N50	1353
Length max	14488
Length mean	896
Length median	617
Length min	201
Number of sequences	177451

1.4 Morpho-taxonomic, and genetic characterization of wild Cannabis germplasm from Western Himalaya, India

Sumeet Gairola, Javaid Fayaz Lone, Kanwaljeet Singh, Pankaj Kumar, Prashant Misra, and Dhiraj Vyas
[Project No. MLP-1007]

Cannabis, a genus of flowering plants in family Cannabaceae, is one of the oldest crops used by humanity since time immemorial. The number of species within the genus is disputed and may be recognized as C. *sativa*, *C. indica,* and *C. ruderalis*. It is worth mentioning that this plant has been mostly absent from scientific research, especially in our country, due to restrictions from the narcotics department. This plant is widely adapted and found growing at a variety of habitat and altitudes and is inarguably the world's most distinct, notorious and controversial plant. The *Cannabis* plant harbors a plethora of chemical constituents, and over 500 compounds have been isolated from *Cannabis*, with approximately 105 being cannabinoids. Out of those 105 compounds, Δ9-tetra- hydro cannabinol has been determined as the primary constituent, which is also responsible for the psycho activity associated with *Cannabis*. The combination of Δ9-THC and other compounds from Cannabis, such as cannabidiol (CBD), have exhibited specific pharmacological effects. During the past century, and especially in the past two decades, researchers have investigated Δ9-Tetrahydrocannabinol (THC), the primary active constituent in marijuana, and its derivatives, for medical uses. These uses include wasting-syndrome in AIDS patients, anti-anxiety, epilepsy, antiemetic (in patients receiving cancer chemotherapy), analgesic (especially in cancer pain), anti-inflammatory, and neuroprotective effects, among others. The development of treatment strategies for these disorders remains a high priority. Several pharmaceutical drugs have been developed which either contain or have similar chemicals like those found in different drug type strains of *Cannabis*. Therefore, developing a wider variety of *Cannabis* strains using wild populations may be preferable to new formulations of the active ingredients, and these strains may be developed through breeding or mass selection. The Western Himalayan region of India possesses great altitudinal variation, diverse geological formation, and different climatic zones *viz*., subtropical to temperate to alpine, resulting in the immense diversity of its flora. The range of climatic conditions in this region is extremely variable because of considerable variation in altitudes. Marked variations are noticeable both in the quality and quantity of flora with respect to the different latitudinal, altitudinal, and habitat conditions. This variation in Western Himalaya makes its environment extremely suitable for the growth of *Cannabis*. Wider genetic adaptability, coupled with the wide range of environmental variation, has given rise to the large numbers of populations of *Cannabis* adapted to the particular microclimate in the Western Himalayan region. Due to this, an immense variation in the wild populations of *Cannabis* growing in the region is observed. CSIR-Indian Institute of Integrative Medicine (CSIR-IIIM), Jammu is a National Institute of the Council of Scientific & Industrial Research (CSIR), Ministry of Science & Technology, Government of India. For the first time in India, approval for legal captive cultivation of *Cannabis* was accorded to the CSIR-IIIM, Jammu by the Government of Jammu and Kashmir. After getting approval for *Cannabis* cultivation for research purposes, the present study was initiated to assess morphotaxonomic, and genetic variation in wild *Cannabis* germplasm from Western Himalaya, India. This is the first study of its kind from India on this extremely important plant.

Figure 1.4.1: Morpho-taxonomic and genetic characterization of wild *Cannabis* germplasm from Western Himalaya, India

For the present study, different geographically separated locations along an altitudinal gradient between 300 and 4000 m asl were visited in Western Himalayan region viz., Union Territory of Jammu & Kashmir, Uttarakhand, and Himachal Pradesh. During the field visits, seeds of different wild *Cannabis* accessions along with morphological, ecological, and locational data were collected. During the course of the study the seeds of more than 100 ***Cannabis*** accessions were collected. The seed viability of the collected seeds was tested in the laboratory at CSIR-IIIM Jammu. These seeds were grown in the controlled conditions as per terms of the license received from the J&K Government (Figure 1.4.1). Grown plants were assessed for their morphological, phenological, genetic, and chemical characters. More than 300 herbarium specimens of *Cannabis* accessions collected from different locations of Western Himalaya were prepared and submitted to the internationally recognized Janaki Ammal Herbarium (RRLH) at IIIM, Jammu. Studies on morpho-taxonomic, genetic and chemical variation in the grown accession are undergoing.

1.5 Development of transcriptome resource of aromatic grasses: Towards an understanding of the molecular basis of chemotype diversity in *Cymbopogon* spp.

Sheetal Bhat, SR Meena, Prashant Misra and Sumeet Gairola [Project No. HCP-0007]

Different species and varieties of *Cymbopogon* display variations in the qualitative and quantitative profiles of essential oils. Thus, these genotypes of *Cymbopogon* provide a useful resource for the elucidation of the molecular basis of essential oil biosynthesis. Therefore, it is desirable to carry out detailed transcriptome sequencing of different genotypes of aromatic grasses. To this end, we have carried out transcriptome sequencing of leaves of four different genotypes of *Cymbopogon* using the Illumina HiSeq platform (Table 1.5.1). A summary of the raw reads developed following the transcriptome sequencing is given in table 1.5.2. The raw reads, thus developed, were further pre-processed for removal of adaptor sequences, filtering out reads whose average quality score less than 20 in any of the paired-end and removal of rRNAs (Table 1.5.3). The pre-processed reads were assembled using Trinity assembler, leading to the identification of transcripts and unigenes from the four genotypes (Table 1.5.4). The unigenes obtained from de *novo* transcriptome assemblies were annotated using the NCBI plant NR & Uniprot database. Based on the annotation using the NR plant database, the top hits of most of the annotated unigenes corresponded to *Sorghum bicolor* followed by other monocots (Figure 1.5.1). Further, the assembled annotated transcriptome was studied for the putative genes involved in the biosynthesis of aroma compounds. Several unigenes putatively encoding terpene synthases, enzymes involved in MEP and MVA pathways, PPase, ADH, AKR, CCD, AAT, and ALDH were identified. To sum up, comprehensive transcriptome resources of four different genotypes of *Cymbopogon* have been developed. Further studies pertaining to the comparative analysis of these transcriptomes and identification of genes determining specific chemo-type are underway.

Table 1.5.1: Genotypes of the aromatic grasses used for the transcriptome sequencing

Genotype of aromatic grass	Variety name	Given code name
Cymbopogon winterianus	Java bio13	Z1
Cymbopogon khasianus×Cymbopogon pendulus	CKP25	Z2
Cymbopogon nardus	CN5	Z3
Cymbopogon pendulus	RRl16	Z4

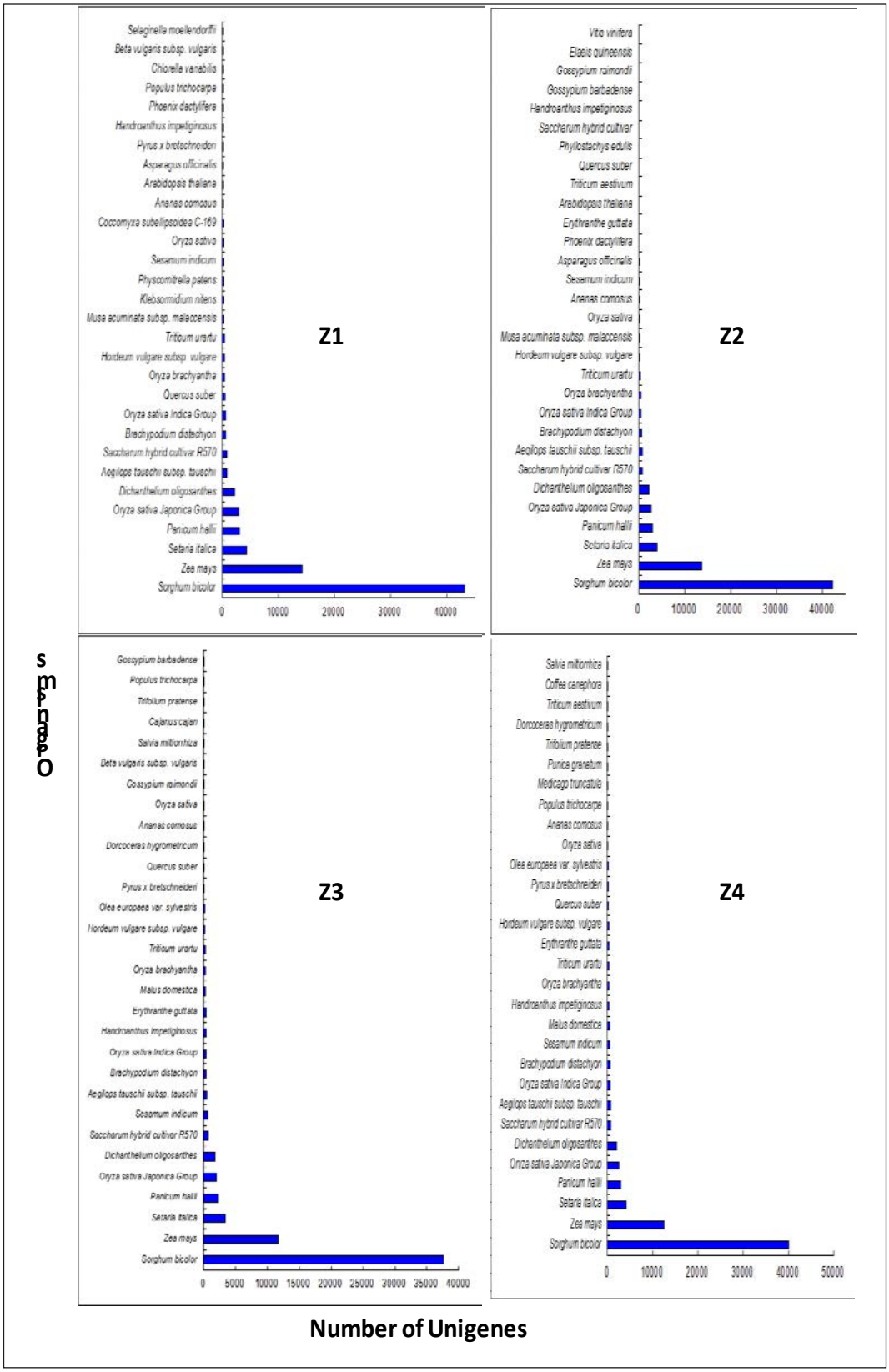


Figure 1.5.1: Top 30 organisms based on the annotation of unigenes corresponding to Z1, Z2, Z3, and Z4 assemblies through the NR plant database.

Table 1.5.2: Summary of raw Illumina reads obtained through transcriptome sequencing

Sample name	No_of_RAW_reads (R1+R2)	Number of_ bases(Mb)	GC percent	Q 30	Read length
Z1	148,835,352	14883.54	53.375	95.84	100 X 2
Z2	145,375,222	14537.52	52.935	95.29	100 X 2
Z3	222,128,868	22212.88	52.36	95.765	100 X 2
Z4	155,972,074	15597.2	53.835	95.655	100 X 2

Table 1.5.3: Summary of the clean data following the pre-processing step

Sample name (R1+R2)	Raw reads (R1+R2)	%	Processed reads (Adapter trimmed and Quality Trimmed)	% of reads left	Reads after rRNA removal (R1+R2)	% of reads left
Z1	148,835,352	100	148,815,236	99.986	147,523,620	99.132
Z2	145,375,222	100	145,347,286	99.981	144,318,524	99.292
Z3	222,128,868	100	222,063,730	99.971	220,270,620	99.193
Z4	155,972,074	100	155,873,331	99.937	154,324,320	99.006

Table 1.5.4: Summary of assembled transcriptomes

Sample name	Total Trinity unigenes	Total Trinity transcript (isoforms)	Percent of GC content
Z1	155,225	228,961	48.91
Z2	137,723	202,859	49.23
Z3	115,071	162,374	48.78
Z4	135,292	205,687	50.01

1.6 Morpho-taxonomic, palynological and nutritional evaluation of wild *Rosa L.* germplasm of Western Himalaya, India

Kanwaljeet Singh, Javaid Fayaz Lone, Deepika Singh, Yash Pal Sharma, PR Sharma and Sumeet Gairola [Project No. GAP-2132]

The genus *Rosa* L. (Roses; Rosoideae; Rosaceae) comprises about 150-200 species widely distributed throughout the temperate and sub-tropical habitats of the northern hemisphere, except one tropical African species. For more than five thousand years, roses have delighted humans as ornamental plants and have been used as a medicine, food, perfumes, cosmetics, and pharmaceuticals. Moreover, numerous traits (small nuclear genome, extensive cross-species fertility and advanced industrial horticultural and micropropagation techniques), as well as their close affinity with several important woody Rosaceae crop species (e.g., raspberries, apples, almonds, cherries, and peaches), suggest that roses could provide an ideal model for exploring woody plant genomes. Despite its high economic importance, little is known about *Rosa* genetics, genome structure, and the function of rose genes. Reasons for this lack of information are polyploidy in most cultivars, simple breeding strategies, and high turnover rates for cultivars. The genus *Rosa* is one of the taxonomically most complicated groups of vascular plants. The complex taxonomy and homogeneity in morphology associated with hybridization make species identification difficult in this genus. Wild roses are important sources of valuable germplasm for creating variability and improvement of roses as per the enormous future needs. This wealth of indigenous germplasm is a valuable source of many important commercially valued traits, such as perpetual flowering, winter hardiness, fragrance, color, thornlessness, among others. Traditionally, the roots, leaves, flower, and fruits of rose species such as *R. moschata* and *R. webbiana, R. canina, R. Corymbifera, R. multiflora*, *R. Centifolia*, *R. damascena* have been employed for treating a broad spectrum of diseases

like cold, cough, asthma, influenza, diarrhea, inflammations, cancer, diabetes, pain, and ophthalmic, liver, cardiac and gastro-intestinal issues in various countries including India. In India, a total of 27 species in the genus *Rosa* have been reported to grow in the wild, and most of them are found growing wild in the Western Himalayan region of India. The rose species grow wild in Indian Himalayan ranges between an altitude of 500 and 4700 m asl, which are well adapted to the climatic conditions of the region and may have some distinct and potential strains which can play a significant role in the development of future roses. It is need of the hour to evaluate, conserve, and utilize this valuable and rare germplasm existing in nature. Keeping in view the facts described above, the present study was conducted to study Morpho-taxonomic, palynological and nutritional evaluation of wild *Rosa* L. germplasm of Western Himalaya, India. Field visits were carried out in various parts of the Western Himalaya in different seasons between 2016 and 2019 for the collection of wild *Rosa* species. A total of fifty-nine *Rosa* accessions were collected from Himachal Pradesh and the Union Territories of Jammu and Kashmir (UT) and Ladakh (UT). Various regional floras, eFloras, and regional Herbaria were consulted for the identification of specimens. In total, fifty-three morphological characters (37 qualitative and 16 quantitative traits) were scrutinized in their natural state and the laboratory. Rose descriptors developed by NBPGR, Regional Station, Phagli, Shimla, HP, India were followed with modification for assigning descriptor codes for the documentation of morphological traits (Figure 1.6.1). Phenotypic variability among the studied accessions was evaluated using descriptive statistics, principal component analysis (PCA), and cluster analysis. Pollen morphological variability was studied using light (LM) and scanning electron microscopy (SEM) on 31 accessions representing nine *Rosa* species from Western Himalaya.

Morpho-taxonomic and palynological variation among wild Rosa germplasm from Western Himalaya

In the present study wild roses were found to be distributed from the subtropical areas of Kathua, J&K (792 m a.s.l.) to the higher arid regions of Nyoma, Leh, Ladakh (4504 m a.s.l.), indicating the robustness and adaptability of these species to this wide range of climatic conditions.

Morphological characters portrayed a plethora of phenotypic variability in the qualitative and quantitative characters. A significant difference was observed in the mean values of all the quantitative morphological and pollen grain characters after ANOVA analysis. Among the quantitative characters analyzed, the coefficient of variation (CV) was highest for the number of rose hips per inflorescence and lowest for petal length; for the qualitative characters, the CV was highest for rosehip shape and lowest for sepal prickles. Results of the PCA indicated that the first six components accounted for 65.44% of the total variation. Leaflet length displayed a significant positive correlation with leaflet width, petiole length, and pedicel length. Petal length, petal breadth, and flower diameter were positively correlated with each other. Hip length showed a positive correlation with hip-width and a negative correlation with pedicel length and hip color. Hip number per inflorescence showed a positive correlation with leaflet length, leaflet breadth, petiole length, pedicel length, and a strong negative correlation with prickle length. The key traits among the species identified to have a high discriminating value were leaflet length, leaflet breadth, prickle shape and size, stipule margin, style nature, sepal margin, flower color, and size and shape of hips. These results indicate that there is a high potential for obtaining desirable trait combinations. As pollen grains have peculiar biological attributes and portray strong genetic conservancy; thus, they can be put to use for species identification, we conducted one more morphological study with regard to the pollen grains. Pollen grains of all the studied species were tricolporate, andprolate and subprolate were found to be the dominant pollen shape types. Largest sized pollen grains were found in *R. canina*. In contrast, the smallest ones were observed in *R. moschata* variation and positively associated with the polar axis, equatorial axis, length of colpi, and the number of striae was found to be the most variable characters. *R. webbiana* and *R. macrophylla* showed intraspecific pollen variation as well. Exine ornamentation in our study almost distinguished all the species of *Rosa* in the present study.

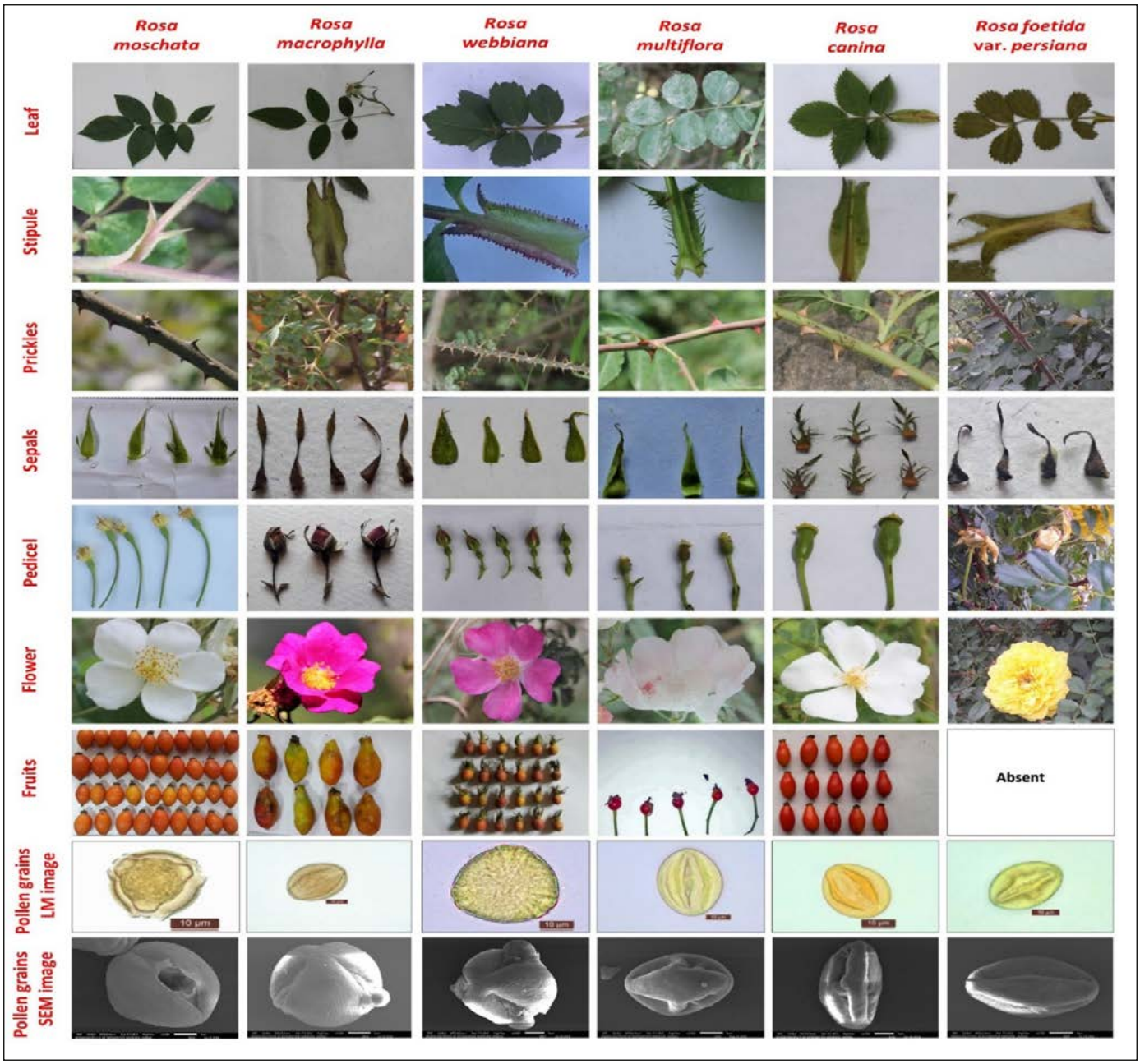


Figure 1.6.1: The morphological and palynological variation observed in some wild Roses from India.

Nutritional profiling *of Rosehips of three important wild Rosa species from Western Himalaya*

To find out the nutraceutical potential of rose hips of selected wild *Rosa* species growing in this region, we quantified the important biochemical parameters in 10 accessions of the widely distributed three wild *Rosa* species, i.e., *R. moschata*, *R. webbiana,* and *R. canina*. Biochemical analysis of the rose hips revealed the highest percentage of moisture content in *R. moschata,* followed by *R. canina* and *R. webbiana*. The carbohydrate content was maximum in *R. moschata,* followed by *R. webbiana* and *R. canina*. A similar trend was observed for protein content in the case of *R. canina*, *R. moschata,* and *R. webbiana*. The highest average percentage of crude fat content was

obtained for *R. webbiana,* followed by *R. moschata* and *R. canina*. The highest ascorbic acid content was found in *R. canina,* followed by *R. webbiana* and *R. moschata*. Moreover, ascorbic acid content was found to be increasing altitudinally in *R. webbiana* and *R. moschata*. The total phenolics content was maximum in *R. canina,* followed by *R. webbiana* and *R. moschata*. The crude fibre was found decreasing in the order: *R. webbiana* >*R. moschata*> *R. canina*. Among studied 18 minerals in the Rosehips, Ca and Mg were present in the highest quantity in all the studied accessions. Furthermore, the toxic mineral elements such as Ni, and Cr were found in trace amounts, which make Rose hips of the studied accession useful for the development of nutraceutical products.

1.7 Botanical standardization of medicinally important Rare Endangered and Threatened (RET) Astavarga plants

Bushan Kumar, Pankaj Kumar, Javaid Fayaz Lone and Sumeet Gairola [Project No. HCP-0010]

Astavarga is a group of eight important medicinal plants in Ayurveda with medicinal and health-promoting properties. These plants are A). Kshirakakoli [*Lilium polyphyllum* D. Don], B). Meda [*Polygonatum verticillatum* (L.) All.], C). Vriddhi [*Habenaria edgeworthii* D. Don], D). Rishbhak [*Malaxis muscifera* (Lindl.) Kuntze], E). Jeevak [*Crepidium acuminatum* (D. Don) Szlach.], F). Riddhi [*Habenaria intermedia* D. Don], G). Kakoli [*Fritillaria roylei* Hook.], and H). Maha meda [*Polygonatum cirrhifolium* (Wall.) Royle]. Mostly, their underground part (rhizomes, tuber, bulb) are medicinally used in a variety of Ayurvedic formulations. Astavarga plants are considered as a very good Rasayana with rejuvenating and health promoting properties and are claimed to strengthe the immune system and have immense cell regeneration capacity. These are used in various *Ayurvedic* formulations, including Chyavanprasha, a health-promotive and disease-preventive tonic. These plants are found in small pockets between an altitudinal range of 800 to 3900 m asl in Western Himalaya viz., Jammu & Kashmir, Uttarakhand, and Himachal Pradesh. Commercial demand for these plants has increased many folds. These plants are already rare in the wild due to habitat specificity and a narrow range of distribution. Besides, this coupled with overexploitation and anthropogenic disturbances, these plants are getting threatened in the wild. The natural regeneration of these plants in the wild is very slow. Thus, there is an urgent need to take every possible measure to conserve the gradually declining natural population of these valuable plants and to botanically standardize them. Due to high demand and less availability (collection from wild), there are reports of adulteration and substitution of these Astavarga herbal drug species with each other and with other species. Adulteration in Astavarga herbal drug is generally reported due to similar common names, confusing synonyms and similar appearance, or other botanical features. Proper identification and authentication of a genuine herbal drug sample are necessary to ensure the quality of Astavarga herbal drugs. In the current study, botanical identification methods were employed for proper identification and characterisation of herbal drug specimens of Astavarga used for medicinal purposes. Study methods involved detailed characterisation of morphological, macroscopic, anatomical, and powder samples of underground drug samples of Astavarga species. Surface characters such as surface colour, nodes, internodes, surface hairs, size, shape, etc. were studied. The anatomical study includes an examination of transverse sections for internal tissue characters such as parenchyma, sclerenchyma, vascular bundles, pith, etc. for presence, distribution, arrangement, size, and shape of cells and tissues. Powder's study included the presence and abundance of various cell types and ergastic contents (such as starch grains and calcium oxalate crystals) in microscopic observation. Macroscopic and microscopic characters of the Astavarga plants have been studied in detail, and botanical monographs of each of these species have been developed.

Figure 1.7.1: A) *L. polyphyllum*; B) *P. verticillatum*; C) *H. edgeworthii*; D) *M. muscifera*; E) *C. acuminatum*; F) *H. intermedia*; G) *F. roylei*; H) *P. Cirrhifolium*

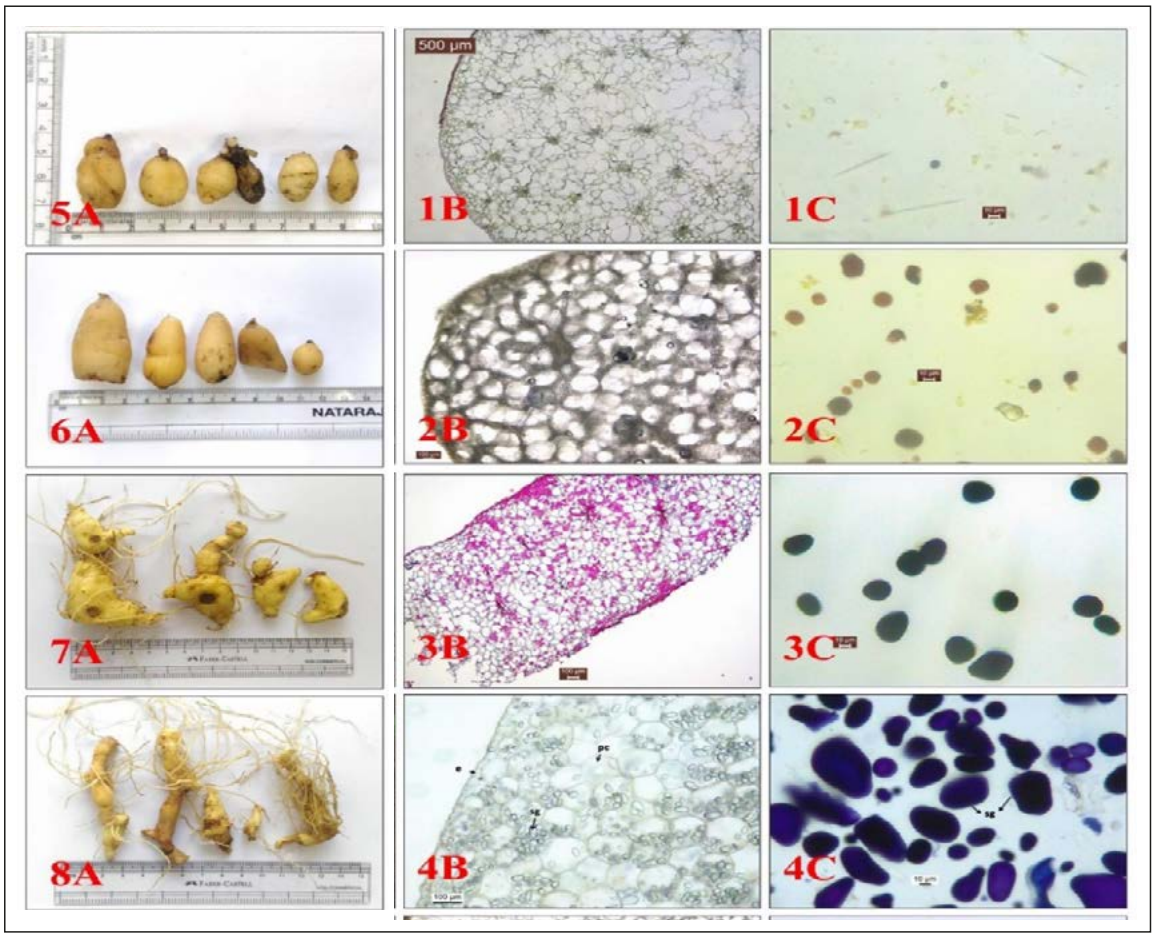


Figure 1.7.2: 1) *C. acuminatum* 1A) Bulb, 1B) Bulb T.S., 1C) Bulb powder; 2) *M. muscifera* 2A) Bulb, 2B) Bulb T.S., 2C) Bulb powder (starch grains); 3) *F. cirrhosa* 3A) Bulb, 3B) Bulb T.S., 3C) Bulb powder (starch grains); 4) *L. polyphyllum* 4A) Bulb, 4B) Bulb T.S., 4C) Bulb powder (starch grains); 5) *H. edgeworthii* 5A) Tuber, 5B) Tuber T.S., 5C) Tuber powder (starch grains); 6) *H. intermedia*; 6A) Tuber, 6B) Tuber T.S., 6C) Tuber powder (starch grains); 7) *P. cirrhifolium* 7A)) Rhizome, 7B) Rhizome T.S., 7C) Rhizome powder (prismatic crystals); 8) *P. verticillatum* 8A) Rhizome, 8B) Rhizome T.S., 8C) Rhizome powder (prismatic crystals).

The botanical study of Astavarga plants revealed similarity in several characters among plants of the same family. Vernacular names also create confusion in identification. For example, *Polygonatum* species are also known with confusing common names; both *Habenaria* species also have nearly similar common names. Such similarity in common names results in the identification difficulty and mixing of drug samples with different species. The Astavarga species belonging to the same family also observed similarly in some morphological features, similar in some anatomical and powder features. Such similarity in several aspects creates an identification problem during the collection of species and many difficulties in the identification of herbal samples in dried form, which lack specific distinguishing characters. Several species appeared nearly indistinguishable based on superficial examination. The two *Polygonatum* species appeared similar in anatomical features; however, they can be distinguished by morphological features of rhizomes and also some powder characters. Similarly, both *Habenaria* species being much similar in morpho-anatomical features can be distinguished by detailed characterisation of surface, anatomical, and powder features. Pseudobulb of *C. acuminatum* and *M. muscifera* were characterised as distinct in morphological appearance and anatomical features in the current study. Based on detailed morphological, anatomical, and powder studied, the various Astavarga species were characterised with several distinct characters useful in the distinction of crude drug samples in fresh and dry form (Figure 1.7.2).

1.8 Palynological studies on important Rare Endangered and Threatened (RET) medicinal plants of Western Himalaya, India

Bushan Kumar, Kanwaljeet Singh, Pankaj Kumar, Kamlesh Singh and Sumeet Gairola [Project No. MLP-1007]

Medicinal plants play a crucial role in facilitating primary health care services to rural populations in many developing countries. The use of traditional medicines by the indigenous people for their primary healthcare is still widespread in developing countries. The palynological analysis is an important field of research since the morphological characteristics of pollen such as the shape, apertural pattern, and exine configuration are very conservative features for the taxonomic evaluation of the plants. Pollen characters help determines the inter-relationships between different taxa and in assessing their classification status, especially for families, sub-families, groups, genera, species, and sub-species. Palynological studies on highly important Rare Endangered and Threatened (RET) medicinal plant species are still lacking that might be helpful in reproductive biology and conservation.The micro-morphological pollen characters are taxonomically useful in species identification within the genus, therefore, promised to be valuable to complement future phylogenetic studies in India. Reproductive biologists can correlate the possible relationship between pollinators and pollen features. Realizing an important role of palynology in plant systematics and conservation, a large scale study has been initiated to document and illustrate palynology of important **(**RET) medicinal plants of Western Himalaya, India. In this study, a comparison of the pollen micro-morphological characters, shape, size, exine ornamentation, aperture peculiarities, and exine thickness are being used as a taxonomic tool in the systematics of these medicinal plants. The data recorded in the present investigation will lay the foundation for future scientific studies to be conducted on the species as well as shed some light on their systematics.

Field tours were conducted in different seasons in temperate, sub-alpine, and alpine regions of the Western Himalayan region of India. Plant specimens (along with flowers or inflorescences) were collected from UT of Jammu and Kashmir, UT of Ladakh, Himachal Pradesh, and Uttarakhand. Proper botanical identification of the collected specimens was made by consulting regional floras, and voucher specimens were submitted to the internationally recognized Janaki Ammal Herbarium (RRLH) at CSIR-IIIM, Jammu. All pollen samples were acetolysed according to Erdtman's method (1952) with some modifications. Pollen material was mounted on a glass slide with glycerine for Light microscopic observations. The observations and measurements were carried out on acetolysed pollen grains with a compound light microscope, LEICA DM 750, Camera associated-LEICA ICC50 E. For Scanning Electron

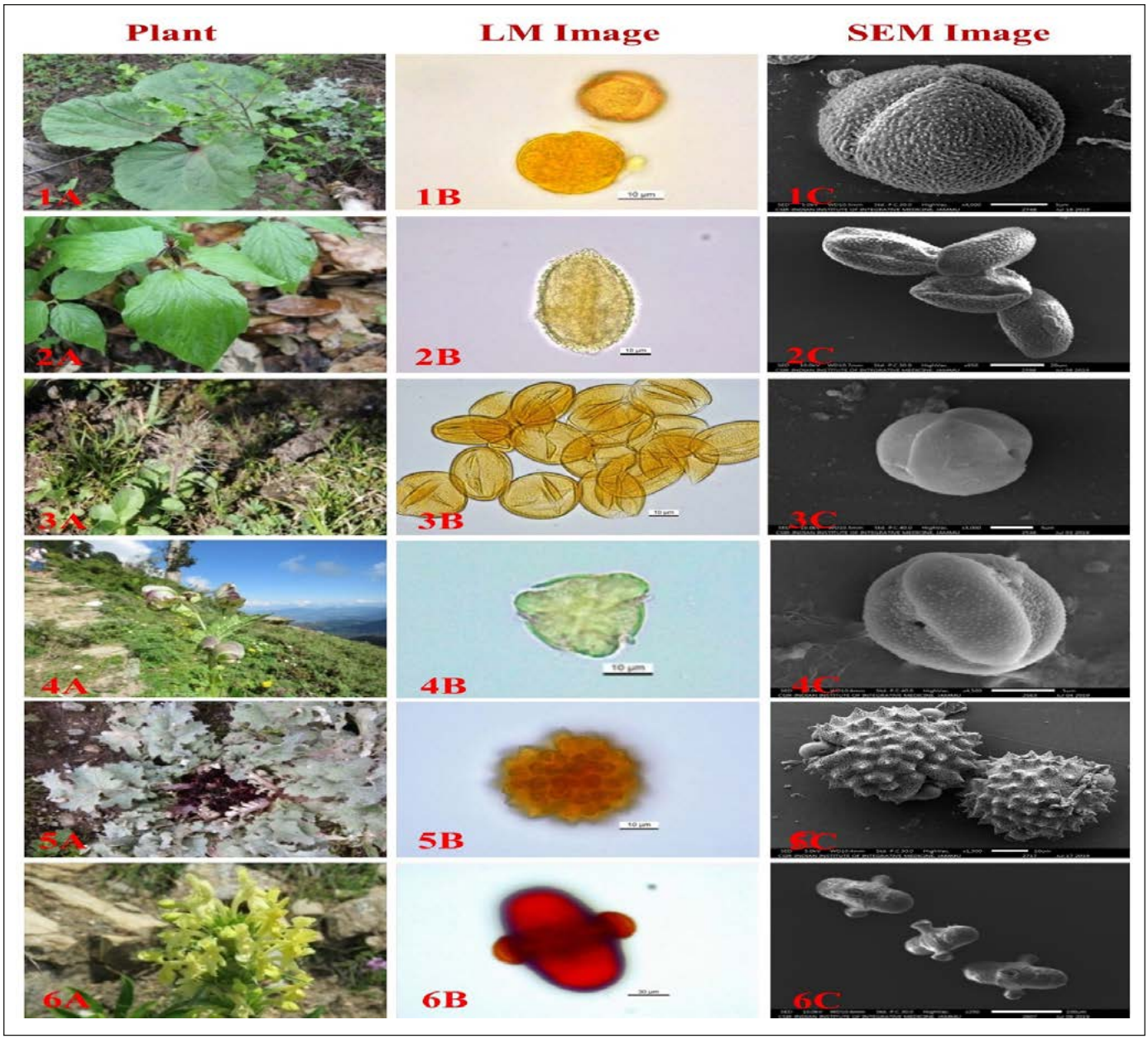


Figure 1.8.1: 1A-1C) *Rheum australe* D.Don; 2A-2C) *Trillium govanianum* Wall. ex D.Don; 3A-3C) Pi*crorhiza kurroa* Royle ex Benth; 4A-4C) *Aconitum heterophyllum* Wall. ex Royle; 5A-5C) *Jurinea dolomiaea* Boiss.; 6A-6C) *Morina longifolia* Wall. ex Dc

Microscopy (SEM), acetolysed pollen grains were mounted on 12.5 mm diameter stubs then coated in sputter coater with approximately 25 nm gold-palladium and observed under SEM model JEOL JSM-IT300. All the quantitative and qualitative parameters such as polar axis (P) and equatorial axis (E), P/E ratio, exine (Ex) thickness were studied. The micrographs (both LM and SEM) of a few selected studied representative RET plants are shown in Figure 1.8.1. Various studied parameters of these taxa showed a wide range of variations in micro-morphological characters of pollen grains that become the taxonomic character for the identification and delineation of taxa. Exine sculpturing that has significant taxonomic value in the authentication of the studied RET medicinal plants. The size of the studied pollen grains ranges from small to large, and circular to elliptical monad outlines were observed. Some aberrations were also observed; for example, in the case of *Morina longifolia,* no suitable term was found in the literature to describe the outline of pollen grains. Tricolporate, tricolpate, triporate, and monocolpate apertures were found, and ornamented aperture membranes were observed in *Aconitum*

heterophyllum and *Picrorhiza kurroa*. The pollen grains of *Aconitum heterophyllum* and *Picrorhiza kurroa* were subprolate in shape while prolate-spheroidal pollens were found in *Jurinea dolomiaea* and *Rheum australe*. In *Trillium govanianum* and *Morina longifolia* prolate pollens were observed. Microechinate, echinate, perforate, verrucate, perforate, psilate, perforate, microgamete, and gemmate type of exine ornamentation were observed in the studied species (Figure 1.8.1). It was observed in the present study that the species of the same family showed much variation in size and exine ornamentation, which may be helpful in the species delimitation. These may also be helpful in various plant studies in the future like cytology, reproductive biology, paleontology, anatomy, chemistry, seed characteristics, and other biosystematic characters for better understanding of the intra- and inter-relationship and phylogeny of the studied taxa. These are also helpful in the identification of adulterants mixed with the main plants in the raw drug samples. All the included species were studied for the first time in India; thus, our study has contributed to the knowledge of these RET plants and its diversity in the region.

1.9 Cross-cultural ethnobotanical studies on the flora used by the indigenous communities of UT of Ladakh, India.

Zohra Batool and Sumeet Gairola [Project No. MLP-1007]

The Union Territory of Ladakh is popularly known as "The land of high-rising passes" or 'Little Tibet.' Ladakh is often referred to as a 'cold desert,' presenting a combination of extremely cold conditions (winter temperatures down to 30°C to 40°C) and marked water scarcity (very low precipitation,' i.e., <100 mm year^{-1}). Owing to its topography, this region harbors some of the unique ecosystems and biodiversity, which are not present in any other part of the world. It has a fragile ecosystem that sustains some rare fauna and flora, which are specially adapted to its peculiar environment. Ladakh has great geostrategic importance since ancient times and is inhabited by very hardworking and talented indigenous communities like Amchie, Bakarwal, Balti, Dard, Changpa, Ladhaki, and Zanskari. Administratively Ladakh consists of two districts that are, Leh and Kargil. It is situated in the north of the greater Himalaya, straddling the Trans-Himalaya. It lies between 31° 44' 57" to 32° 59' 57"N latitude and 76° 46' 29" to 78° 41' 34" E longitude covering more than 65,000 square kilometers area. Due to its high-altitude and continentality, the climate of Ladakh is quite cold. Winters are harsh and frigid, while summers are cool. Precipitation is low and mostly in the form of snow. The majority of the population is Buddhist, followed by Muslims, Christians, and Hindus. The majority of the Muslim population inhabits Kargil and Drass region, while the people of Leh are predominantly Buddhist. The language spoken by the Muslim community of Kargil and Drass regions is in the form of a dialect called Dard, whereas Buddhists speak in Tibetan dialect. The region gets cut off from the rest of the country for almost six months during winters, due to its harsh climatic condition; the lives of the local population are tough and dependent on local resources. These local resources are used for food, medicine for humans and animals, fodder, and other purposes. Although vegetation is scarce, Ladakh is immensely rich in biological diversity and has an enormous number of medicinal plants at various locations spread throughout the entire region. The flora consists of the alpine, high alpine zone, few stunted shrubs, and bushes. The economy of Ladakh is mainly based on subsistence agriculture. Plants do play a vital role in the life of the people of this region for various purposes, particularly in the primary health care of tribal communities, which do not have much access to the generic medicines due to remote locations of the region. The local healers (Amchis and Akhones) are highly-skilled people. They play an important role in the traditional health care system despite the least recognition in the outside community of medical fraternity. The traditional health care system of Ladakh is known as the Tibetan system of medicine (Sowa-rigpa/Amchi system). The present study was conducted to understand cross-cultural consensus and variation in knowledge of plants used by the indigenous communities of UT of Ladakh, India. Ethnobotanical surveys were conducted in four different regions of Ladakh (UT) in different seasons of the years 2018-2019. The surveys were conducted in Suru valley, Wakha-Mulbekh, Zanskar, and Aryan valley, which are situated between an altitudinal range of 2000 to 5500 m asl (Figure 1.9.1A & 1.9.1B). During the study, interviews with the local people, including senior citizens, women, traditional healers such as Akhone and Amchi, were conducted using semi-structured questionnaires. The informants consist of different ethnic groups of Purigpa, Buddhist

Dard, Bodh Boto between an age group of 30 to 90 years. The interviews and discussions were conducted in local languages, and at some places help of the translator was taken. Information regarding indigenous uses of the plants, including the local names of the plants, part used, mode of administration, and the dosage, were obtained. During field surveys, plant specimens, along with photos and other necessary information, were collected. The local people confirmed plant specimens on the spot by their local names. Plant specimens were brought to CSIR-IIIM Jammu, and herbarium specimens were prepared identified and submitted to the Janki Ammal Herbarium (RRLH). A total of 95 plant species were reported during the present study. Around 64 species were used to treat various diseases such as gastrointestinal ailments, musculoskeletal diseases, common cold, arthritis, diabetes, etc. Some of the important medicinal plants used were *Aconitum heterophyllum, Nepeta longibracteata, Sinopodophyllum hexandrum*, *Corydalis* spp.; some plants were used as food such as *Rhodiola heterodonta*, *Thymus* spp., *Rumex* spp., and some as fodder like *Medicago falcata*, *Medicago sativa*, and *Cicer microphyllum* (Figure 1.9.1C to 1.9.1F). Some of the medicinal plants, such as *Cicer microphyllum, Stachys tibetica*, etc. were also used as veterinary medicine. The plant parts used were leaves, shoot, seeds, flower, tuber, rhizomes, bulb, and whole plant. The common modes of formulation were decoction, paste, powder, and poultice. In addition to the plants, some minerals, animal parts, and common salt were also used in the formulation of medicines for the treatment of various ailments.

Figure 1.9.1. A-B) Villages of Suru Valley in Ladakh, C) *Cicer microphyllum* Benth.,D) *Thymus linearis* Benth., E) *Acantholimon lycopodioides* (Girard) Boiss., F) *Sinopodophyllum* hexandrum (Royle) T.S.Ying., G) Sun-drying of leafy vegetables,H). Crushed form of maize/barley used for fodder, I) Storage of vegetables by digging pit, J) Cow eating fodder, K), Thrashing of crops by local people, L). Traditional floor Mill, locally known as Ranthak.

Due to lack of connectivity during winter, the food grains and vegetables are stored by the locals for use during harsh winters. Most of the leafy vegetables were sun-dried during summer and stored for use during prolonged winter (Figure 1.9.1G). Some of the vegetables like turnip, carrot, potato were stored in underground pits locally known as Sabong/ Labdong (Figure 1.9.1I). The livestock populations also relied on stored fodder during winter, known locally as "fokma," which is a crushed form of wheat, maize, and barley (Figure 1.9.1H & 1.9.1J). A cross-cultural study on the usage of the plants at these four locations showed the importance and effectiveness of reported plants in the traditional systems of medicine in the region. Through the present study, we hope to gather and analyze useful information on the traditional system of medicine in the region. Besides, gathered information on the food resources used during the harsh winter seasons would help in identifying nutritional plants for the further socio-economic upliftment of the people of this region.

1.10 Botanical and molecular standardisation of High-Value Raw Plant Drugs used in Indian Systems of Medicine

Pankaj Kumar and Sumeet Gairola [Project No. MLP-1007]

Many important medicinal plants are used in Indian Systems of Medicine (ISM) such as Ayurveda, Unani, Siddha, and Homeopathy for the treatment of a variety of health problems. Different plant parts are known to contain specific organic compounds that are responsible for specific pharmacological activities. In ISM, plant material is mostly used in crude dried form. Specific plant parts such as roots, stem, bark, seeds, fruits flowers, rhizome, gum/resin, leaves, etc., are used as medicine. Crude herbal drugs in traditional medicine systems are known by traditional common names and are identified by traditional herbalists. The similarity in common names, botanical characters, and lack of proper botanical knowledge often leads to the identification problem of herbal crude drug samples. The identification of such samples is more difficult in the absence of authentic reference identification standards. Due to incorrect identification of herbal drug samples, dried herbal drugs face a huge problem of adulteration and substitution, resulting in issues related to safety, quality, and efficacy of herbal drugs. The safe use of herbal drugs for medicinal purposes requires accurate identification and authentication of crude herbal medicines. For the identification of such samples, detailed characterisation of dried herbal drug samples is required to develop authentic reference standards. Botanical standardisation of specific plant parts of some high-value drug specimens used in ISM was done to develop authentic reference standards for easier identification (Table 1.10.1). The selected plant specimens were of highly traded medicinal plants well known in ISMs. They are used in a number of Ayurvedic formulations and known to possess therapeutic properties for the treatment of several diseases, as mentioned in different volumes of Ayurvedic Pharmacopoeia. Different herbal drug samples such as bulb, flowers, fruits, gum/resin, leaves, rhizomes, root, seed, stem, stem bark were studied. The current study involved a detailed botanical study including morphological characterisation, macroscopic, anatomical, and powder study of some of the highly traded herbal drug samples, with well known traditional medicine value. Also, the comparative study was done performed in some species belonging to the same family reported with similarity in several botanical features and more prone to adulteration. Due to similarity in several morpho-anatomical characters in species belonging to the same family, identification and distinction of genuine herbal drug samples may become difficult. In addition to botanical standardisation, molecular identification by DNA barcoding was also made for some plant species. DNA barcode-based identification is known for quicker identification of herbal drug samples with illegal trade problems across national and international borders. In the current study, DNA barcode sequences were developed for some species belonging to the same family with similar morpho-anatomical botanical characters. DNA barcode sequences were developed using nuclear (ITS) and cytoplasmic (matK, rbcL, and psbA-trnH) DNA barcode markers.

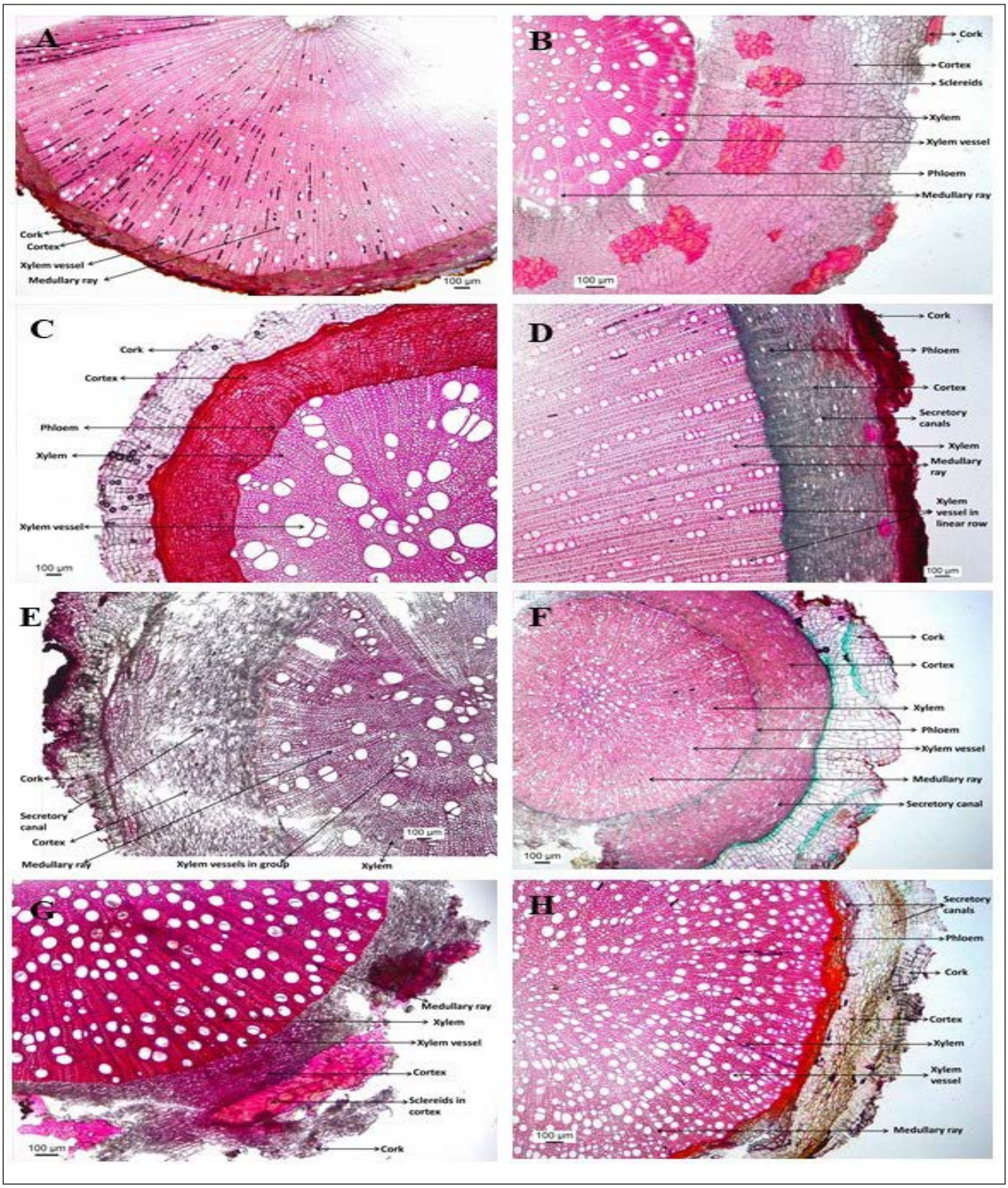


Figure 1.10.1: Transverse sections of roots of some representative raw drugs studied A) *Asclepias curassavica*; B) *Marsdenia tenacissima*; C) *Calotropis gigantea*; D) *Nerium oleander*; E) *Calotropis procera*; F) *Rauvolfia serpentina*; G) *Carissa spinarum*; H) *Tabernaemontana divaricata*

Table 1.10.1: Some of high-value Raw Plant Drug specimens studied for botanical standardisation.

S. No	Plant part standardized/ Plant name [Family]	S. No	Plant part standardized/ Plant name [Family]	S. No	Plant part standardized/ Plant name [Family]
	Flower	25	*Acorus calamus* L. [Acoraceae]		**Seeds**
1	*Bombax ceiba* L. [Malvaceae]	26	*Cheilocostus speciosus* (J.Koenig) C.D.Specht [Costaceae]	53	*Cullen corylifolium* (L.) Medik. [Leguminosae]
2	*Butea monosperma* (Lam.) Taub. [Leguminosae]	27	*Hedychium spicatum* Sm. [Zingiberaceae]	54	*Butea monosperma* (Lam.) Taub. [Leguminosae]
3	*Calotropis procera* (Aiton) Dryand. [Apocynaceae]	28	*Nardostachys jatamansi* (D.Don) DC. [Caprifoliaceae]	55	*Senna tora* (L.) Roxb. [Leguminosae]
4	*Mallotus philippensis* (Lam.) Müll.Arg. [Euphorbiaceae]	29	*Trillium govanianum* Wall. ex D.Don [Melanthiaceae]	56	*Mucuna pruriens* (L.) DC. [Leguminosae]
	Fruit		**Root**	57	*Abrus precatorius* L. [Leguminosae]
5	*Melia azedarach* L. [Meliaceae]	30	*Nerium oleander* L. [Apocynaceae]		**Stem**
6	*Sapindus mukorossi* Gaertn. [Sapindaceae]	31	*Achyranthes aspera* L. [Amaranthaceae]	58	*Achyranthes aspera* L. [Amaranthaceae]
7	*Terminalia bellirica* (Gaertn.) Roxb. [Combretaceae]	32	*Asparagus adscendens* Roxb. [Asparagaceae]	59	*Boerhavia diffusa* L. [Nyctaginaceae]
8	*Vitex negundo* L. [Lamiaceae]	33	*Asparagus racemosus* Willd. [Asparagaceae]	60	*Cissampelos pareira* L. [Menispermaceae]
9	*Zanthoxylum armatum* DC. [Rutaceae]	34	*Berberis lycium* Royle [Berberidaceae]	61	*Eclipta prostrata* (L.) L. [Compositae]
	Gum/Resin	35	*Boerhavia diffusa* L. [Nyctaginaceae]	62	*Ephedra gerardiana* Wall. ex Stapf [Ephedraceae]
10	*Ficus religiosa* L. [Moraceae]	36	*Calotropis procera* (Aiton) Dryand. [Apocynaceae]	63	*Euphorbia hirta* L. [Euphorbiaceae]
11	*Pinus roxburghii* Sarg. [Pinaceae]	37	*Catharanthus roseus* (L.) G.Don [Apocynaceae]	64	*Ocimum tenuiflorum* L. (Syn.- *Ocimum sanctum* L.) [Lamiaceae]
	Leaves	38	*Cissampelos pareira* L. [Menispermaceae]	65	*Ocimum americanum* L. [Lamiaceae]
12	*Justicia adhatoda* L. [Acanthaceae]	39	*Coleus forskohlii* (Willd.) Briq. [Lamiaceae]	66	*Ocimum basilicum* L. [Lamiaceae]
13	*Aegle marmelos* (L.) Corrêa [Rutaceae]	40	*Cryptolepis dubia* (Burm.f.) M.R.Almeida [Apocynaceae]	67	*Rhododendron campanulatum* D. Don [Ericaceae]
14	*Boerhavia diffusa* L. [Nyctaginaceae]	41	*Cullen corylifolium* (L.) Medik. [Leguminosae]	68	*Sida rhombifolia* L. [Malvaceae]
15	*Senna occidentalis* (L.) Link [Leguminosae]	42	*Abrus precatorius* L. [Leguminosae]	69	*Withania somnifera* (L.) Dunal [Solanaceae]
16	*Vitex negundo* L. [Lamiaceae]	43	*Plumbago zeylanica* L. [Plumbaginaceae]		Stem bark
17	*Cissampelos pareira* L. [Menispermaceae]	44	*Plumbago zeylanica* L. [Apocynaceae]	70	*Acacia catechu* (L.f.) Willd. [Leguminosae]
18	*Datura metel* L. [Solanaceae]	45	*Rubia cordifolia* L. [Rubiaceae]	71	*Cassia fistula* L. [Leguminosae]
19	*Murraya koenigii* (L.) Spreng. [Rutaceae]	46	*Saussurea costus* (Falc.) Lipsch. [Compositae]	72	*Alstonia scholaris* (L.) R. Br. [Apocynaceae]
20	*Rhododendron anthopogon* D. Don [Ericaceae]	47	*Senna tora* (L.) Roxb. [Leguminosae]	73	*Butea monosperma* (Lam.) Taub. [Leguminosace]
21	*Rhododendron campanulatum* D. Don [Ericaceae]	48	*Solanum americanum* Mill. [Solanaceae]	74	*Aegle marmelos* (L.) Corrêa [Rutaceae]
22	*Rhododendron campanulatum* D.Don [Ericaceae]	49	*Solanum virginianum* L. [Solanaceae]	75	*Terminalia arjuna* (Roxb. ex DC.) Wight & Arn. [Combretaceae]
23	*Catharanthus roseus* (L.) G.Don [Apocynaceae]	50	*Tabernaemontana divaricata* (L.) R.Br. ex Roem. & Schult. [Apocynaceae]	76	*Oroxylum indicum* (L.) Kurz [Bignoniaceae]
24	*Withania somnifera* (L.) Dunal [Solanaceae]	51	*Withania somnifera* (L.) Dunal [Solanaceae]	77	*Syzygium cumini* (L.) Skeels [Myrtaceae]
	Rhizome	52	*Vitex negundo* L. [Lamiaceae]	78	*Ficus religiosa* L. [Moraceae]

1.11 Management and enrichment of Janaki Ammal Herbarium (RRLH) and bioprospection of Western Himalaya flora [Project no. MLP-1007]

Sumeet Gairola, Madan Lal, Pankaj Kumar, Kanwaljeet Singh, Javaid Fayaz Lone, Bushan Kumar, Zohra Batool

India, the seventh-largest country of the world, ranks sixth among the 12 mega biodiversity centers of the world. It has a rich diversity of plant species recorded mainly from its ten biogeographic zones, viz. Trans-Himalayan, Himalayan, Desert, Semiarid, Western Ghats, Deccan plateau, Indo-Gangetic plain, Northeast India, Indian Islands, and coastal areas. The Himalayan region harbors large numbers of important medicinal plants. Many studies in the Western Himalayan region have reported the use of plants in traditional health care systems to treat various health-related problems. Plant identification is considered important for many activities, such as studying the biodiversity of a region, endangered species, climate change, and species distribution, weed control actions, etc. Proper knowledge of plant identification and the geographic distribution of plants are essential for biodiversity conservation. The Janaki Ammal Herbarium at CSIR-IIIM, Jammu, is an internationally recognized national referral facility. The acronym RRLH has been assigned to it, which is registered in Index herbariorum at New York, U.S.A. Various maintenance and management activities were undertaken in the RRLH during 2019-20 viz., taxonomic up-gradation as per latest classification, fumigation, change of genus and family covers, etc. For an exploration of biodiversity field trips were undertaken in different ecological niches of the Western Himalayan region (Figure 1.11.1). Many medicinally important plants used for the treatment of various diseases were collected, and their Herbarium specimens were prepared. Duly identified and mounted voucher specimens were submitted to internationally recognized Janaki Ammal Herbarium (RRLH), CSIR-IIIM, Jammu. Associated ecological information viz., altitude, longitude, latitude, slope angle, slope aspect, etc. was also recorded for each of the collected specimens. In addition to that, efforts were made to bring some of the rare and endangered (RET) plants under captive cultivation at various IIIM farms and greenhouses. Services of identification of herbarium specimens were provided to the industry, academia, and other Government departments. Overall,> 300 Herbarium specimens were accessioned to RRLH during 2019-20. More than 500 herbarium specimens were collected from different ecological niches and localities of J&K, Ladakh, Uttarakhand, and Himachal Pradesh. All the collected plant specimens were processed as per the standard procedure. In addition to that, more than 1000 digital photographs of plants were taken for preparing digital database.

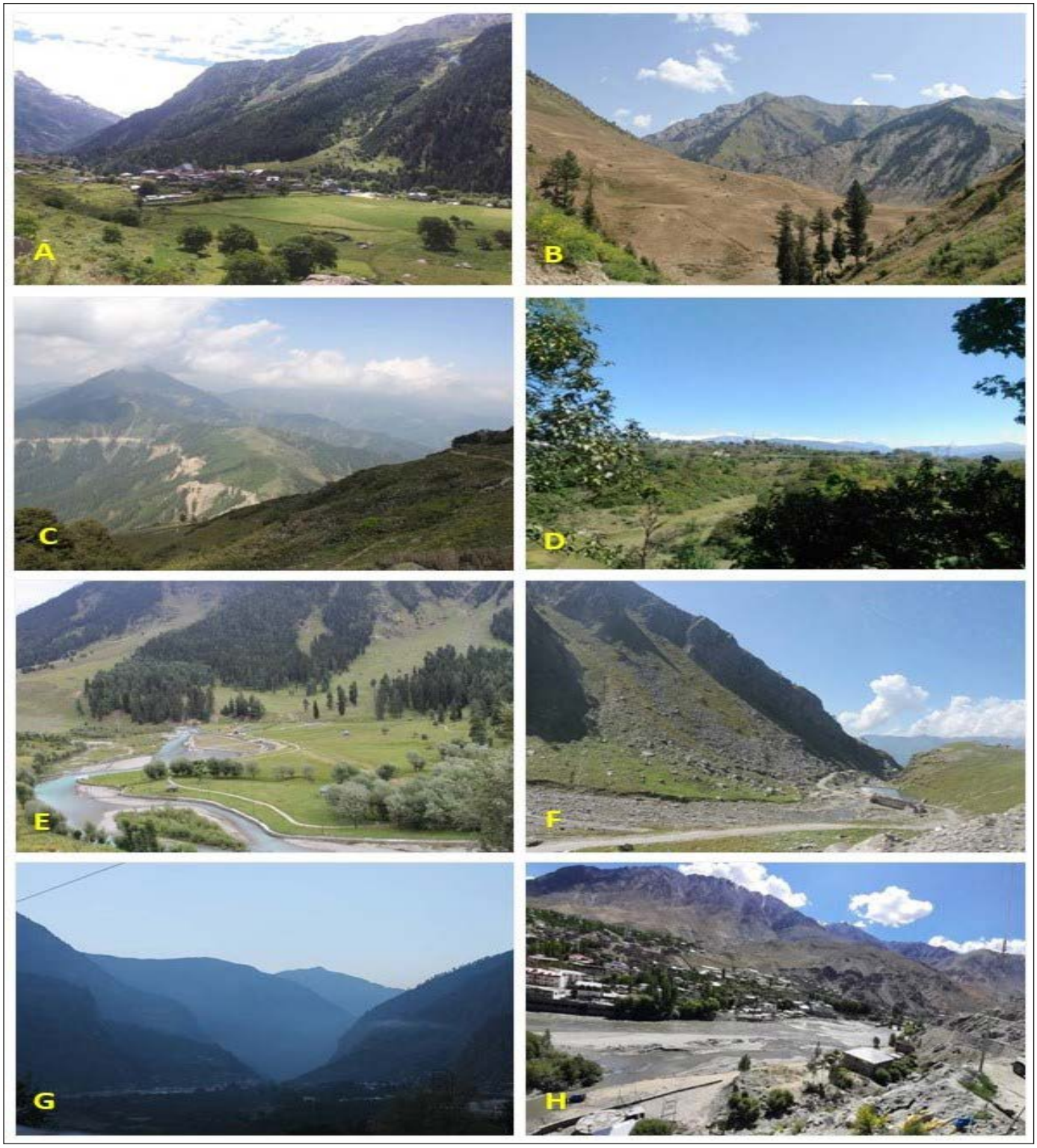


Figure 1.11.1. Pictures of some study areas visited for collection of wild Roses, A) Machail , Paddar, Kishtwar, J&K; B) Gurez, Kashmir, J&K; C) Chattergala, Kathua, J&K; D) Billawar, Kathua, J&K; E) Betab Valley, Kashmir, J&K; F) Rohtang, H.P.; G) Sangla, H.P.; H) Kargil, Ladakh

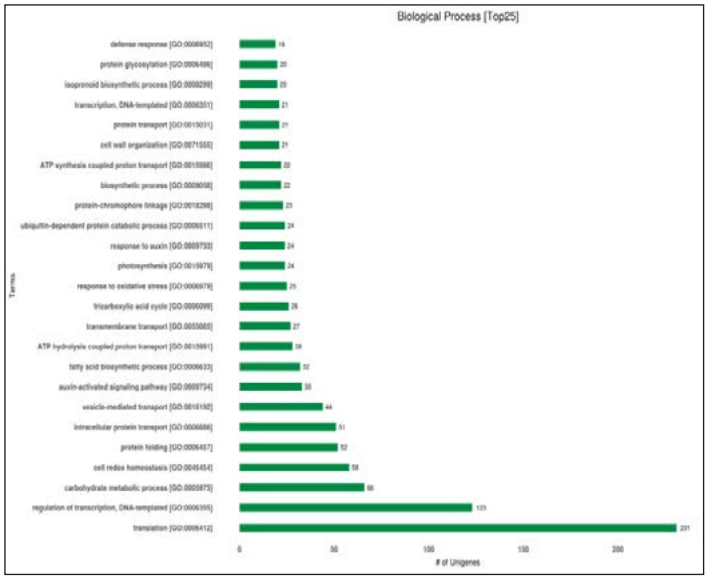
1.12 Generation of transcriptome map of *Ocimum gratissimum*

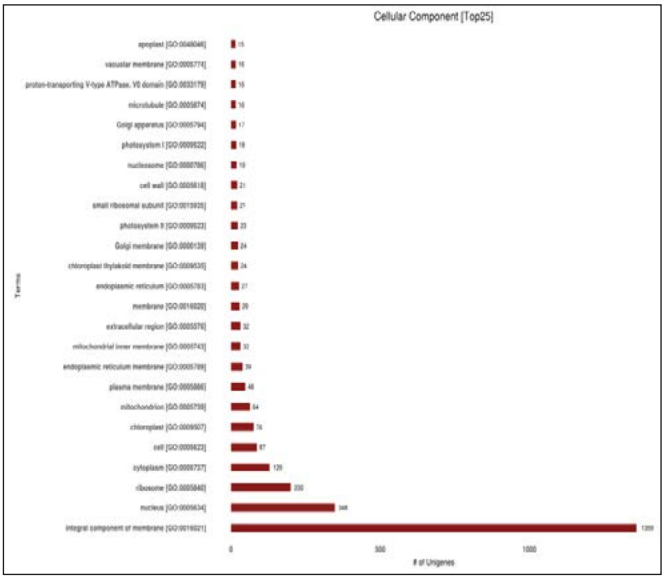
Mamta Gochar, Pooja Goyal & Suphla Gupta

Transcriptome mapping of selected lines of *O. gratissimum* was performed following paired-end denovo trancriptome assembly using IlluminaHiSeq platform. The assembled sequences were subjected to quality parameters checking like base quality score distributions, average base content/read and GC distribution in the reads which are present in the table below.

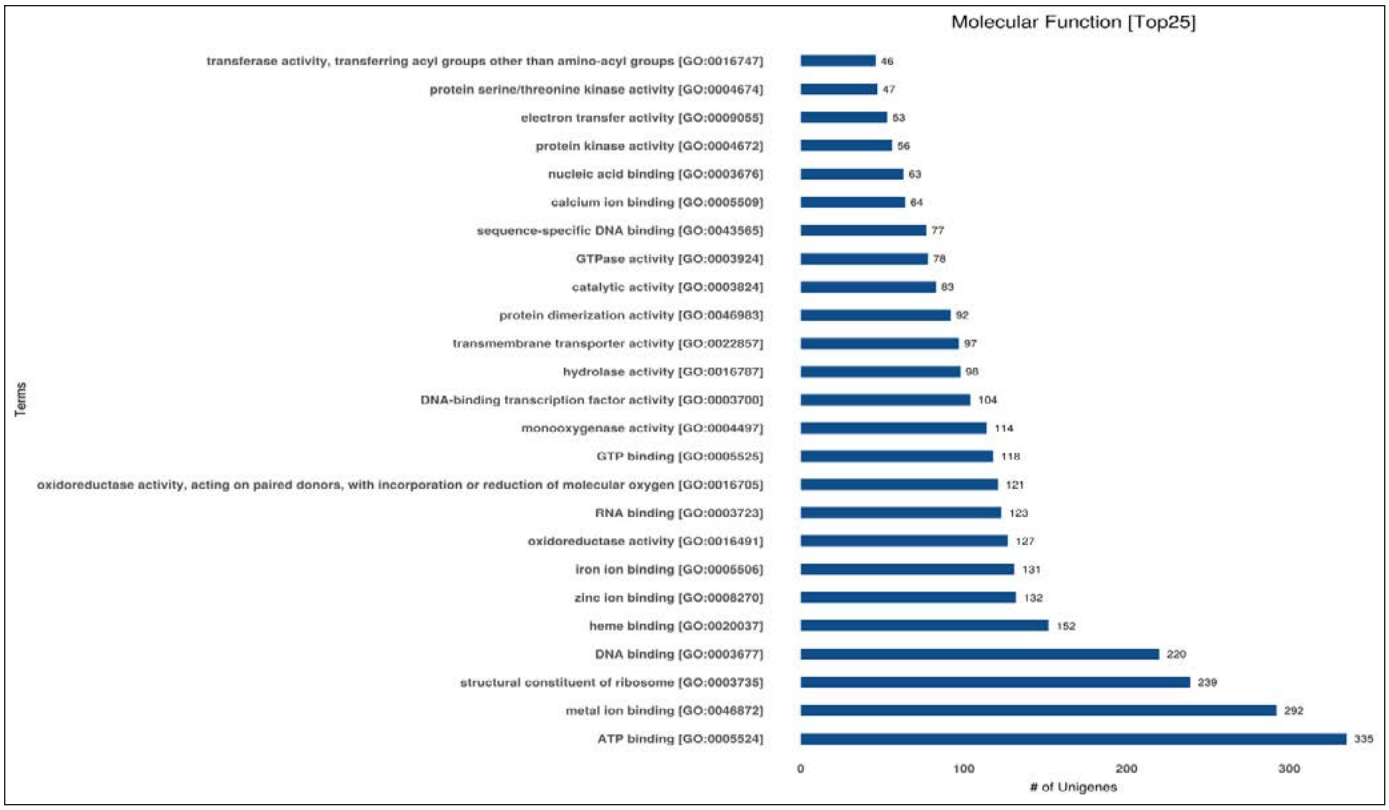
Sample Name	No of Reads	No of bases (MB)	GC %	Q30	Read Length
1	90904224	9090.42	48.28	94.17	100X2
3	86867514	8686.76	49.86	91.34	100X2

The raw fastq files were preprocessed. The adapter's sequences were trimmed, followed by quality trimming [Q20] using Adapter Removal. The removal of rRNAs was performed using bowtie2 based on SILVA database. The high quality reads were then assembled using Trinity with default options. The trimmed reads were aligned to the assembled unigenes (length >= 200bp) using Bowtie2 program. Of all filtered reads about ~ 98.22 % of reads from each sample were properly aligned back to the assembled unigenes. The assembled unigenes were annotated using NCBI Plant NR Database.

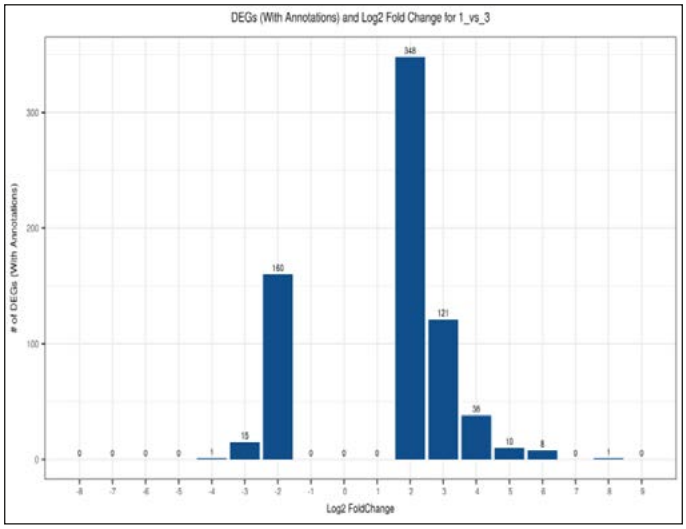


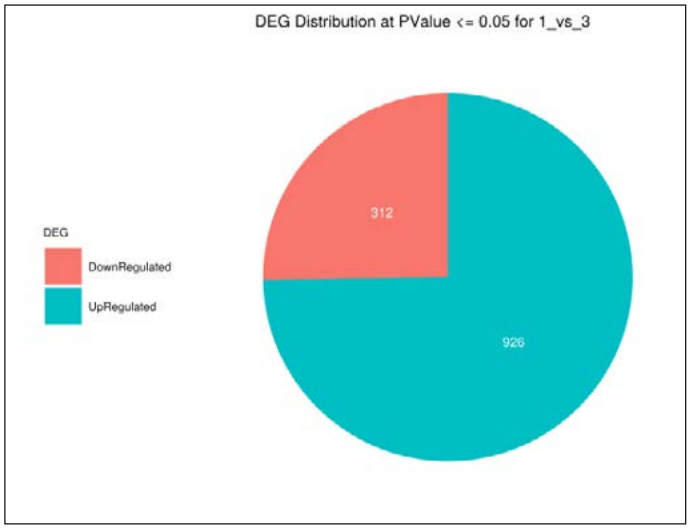


The assembled unigenes were compared with NCBI Plant NR Database using BLASTX program. Matches with E-value cutoff of 10-5 and identity of 40 were retained for further annotation. Overall, we found 22,848 assembled unigenes have at least one significant hit in NCBI Plant NR Database. The predicted proteins from BLASTX were annotated against UniProt, Pathway and other databases. Among the total significant BLASTX hit unigenes, 22,848 unigenes were annotated using UniProt Plant Database. The Gene Ontology (GO) terms for unigenes were extracted wherever possible.



The total numbers GO different terms identified in Biological Process, Cellular Component and Molecular Function category. SSR prediction was performed using MISA. A total of 31849 SSRs were predicted from the total unigenes belonging to 8 classes of microsatellites. Differential Gene Expression Analysis was performed using edgeR program. The numbers of unigenes considered for differential gene expression analysis were 123,903.





1.13 Mass selection approach to identify high Eugenol containing Superior lines of *Ocimum gratissimum*

Mamta Gochar, Rajender Gochar, Ajai P Gupta, Suresh Chandra & Suphla Gupta

Ocimum genus is rich in aromatic compounds of commercial importance having medicinal and aromatic significance. CSIR IIIM has six species of different chemotypes of *Ocimum*, which have aromatic compound of commercial value like methyl-chavicol, elemicin, methyl-cinnamate, thymol, eugenol, linalool, carvacrol and citral etc. The present proposal further improve *Ocimum* species namely, *Ocimum gratissimum* and *O. basilicum* on oil quality, content of the oil composition and subsequently to develop improved lines and varieties through mass selection. The developed variety will be better in terms of oil content, herbage yield and oil yield. To achieve the target, identification & development of superior lines having higher estragol and eugenol contents, respectively and herbage yield was performed. Nursery was raised using the bulk seed collected in different years during the cultivation at Chatha Farm, under different conditions like Polyhouse, Shed net house, Glass house, and Screen house and in the open field. The germination was periodically monitored and data was recorded in the plant nursery in the months of February to March from 2017-2019 (Figure 1.13.1). Subsequently land preparation and layout for *Ocimum* plantation was done at Chatha farm following RBD method. Before undertaking the experimentation, the species were identified using barcode loci as shown in gel picture in Figure 1.13.1.

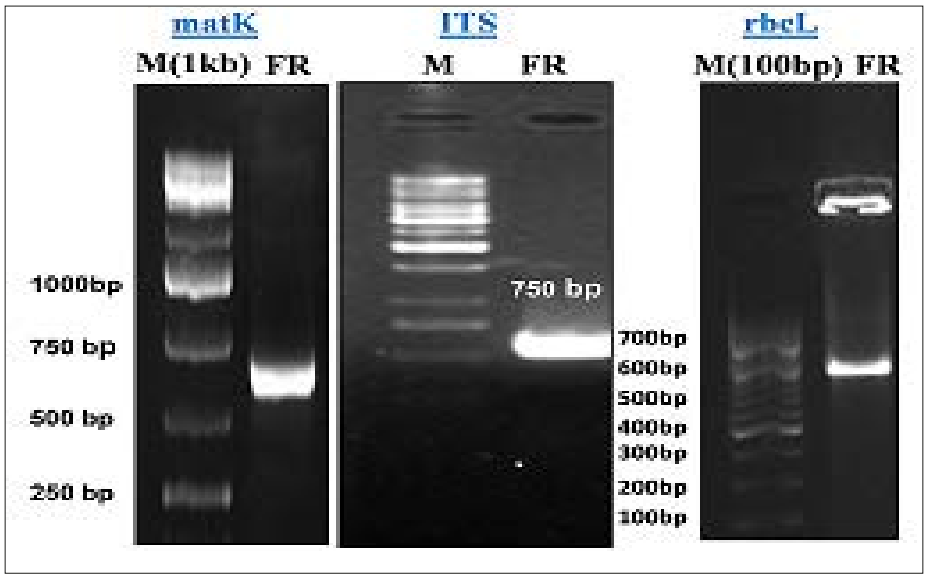


Figure 1.13.1

Figure 1.13.2

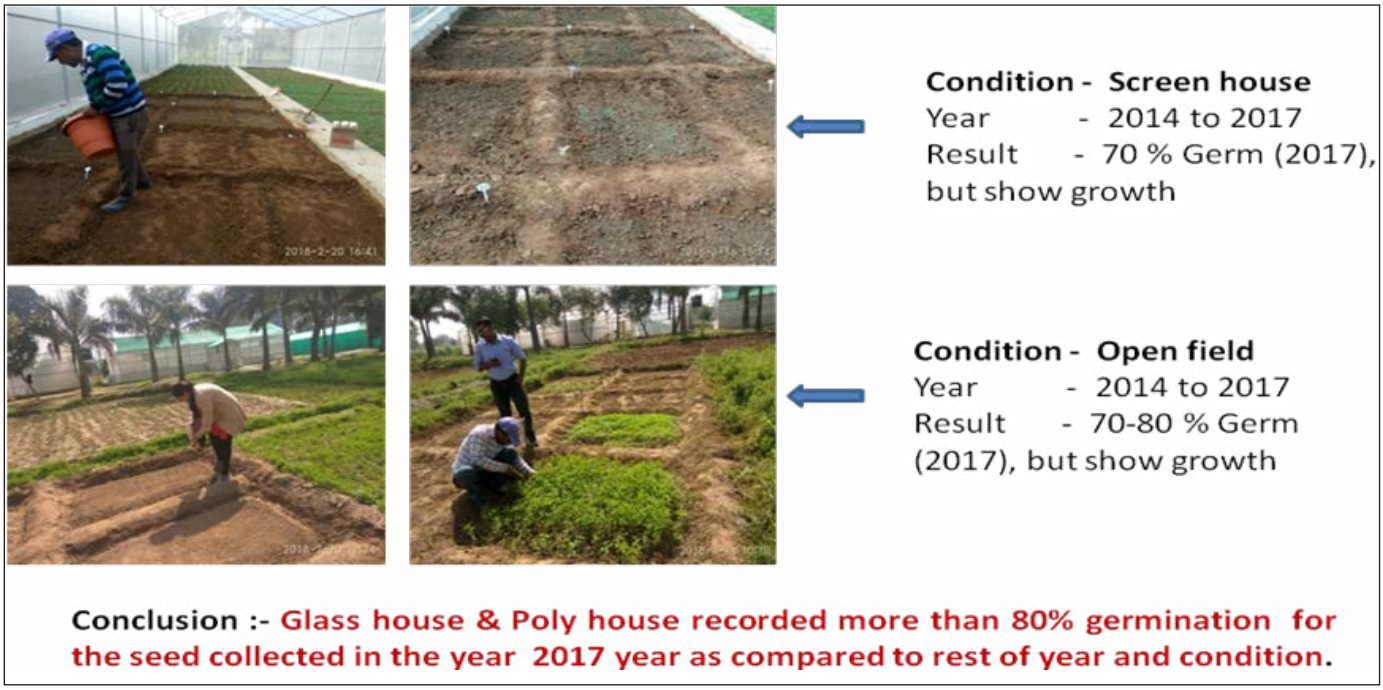


Figure 1.13.3

The germination results are given in Table1.13.1. The germination was observed to decline with increase in seed storage time.

Table 1.13.1 Ocimum species (*O.basilicum & O. sanctum*) germination (%) in different years of study

Condition/year	2014	2015	2016	2017	2018	2019
Ocimum basilicum-15						
Polyhouse	10-15 plants	10-15 plants	70 %	80-90 %	80-90 %	80-90 %
Glass house	No Gem.	No Gem.	70 %	80-90 %	80-90 %	80-90 %
Green house	No Gem.	No Gem.	50 %	70-80 %	70-80 %	70-80 %
Screen house	No Gem.	No Gem.	50-60 %	70-80 %	70-80 %	70-80 %
Open field	No Germ.	No Germ.	50 %	60-70%	60-70%	60-70%
Ocimum gratissimum-14						
Polyhouse	No Germ.	No Germ.	30 %	60 % Very slow	60 % Very slow	60 % Very slow
Glass house	No Germ.	No Germ.	No	80-90 %	80-90 %	80-90 %
Green house	No Germ.	No Germ.	50 %	70 %	70 %	70 %
Screen house	No Germ.	No Germ.	No	50 %	50 %	50 %
Open field	No Germ.	No Germ.	very low	70%	70%	70%

The *Ocimum* plants transferred to the field were selected on the basis of morphology. The morphological parameters recorded were plant height, density, leaf size, color and inflorescence color, size and number. The selected tagged plants were also subjected to GC-MS based chemical analysis. The essential oil was extracted by hydro-distillation using *Ocimum* herbage (500g). Representative chromatograms are shown below (Figure 1.13.4).

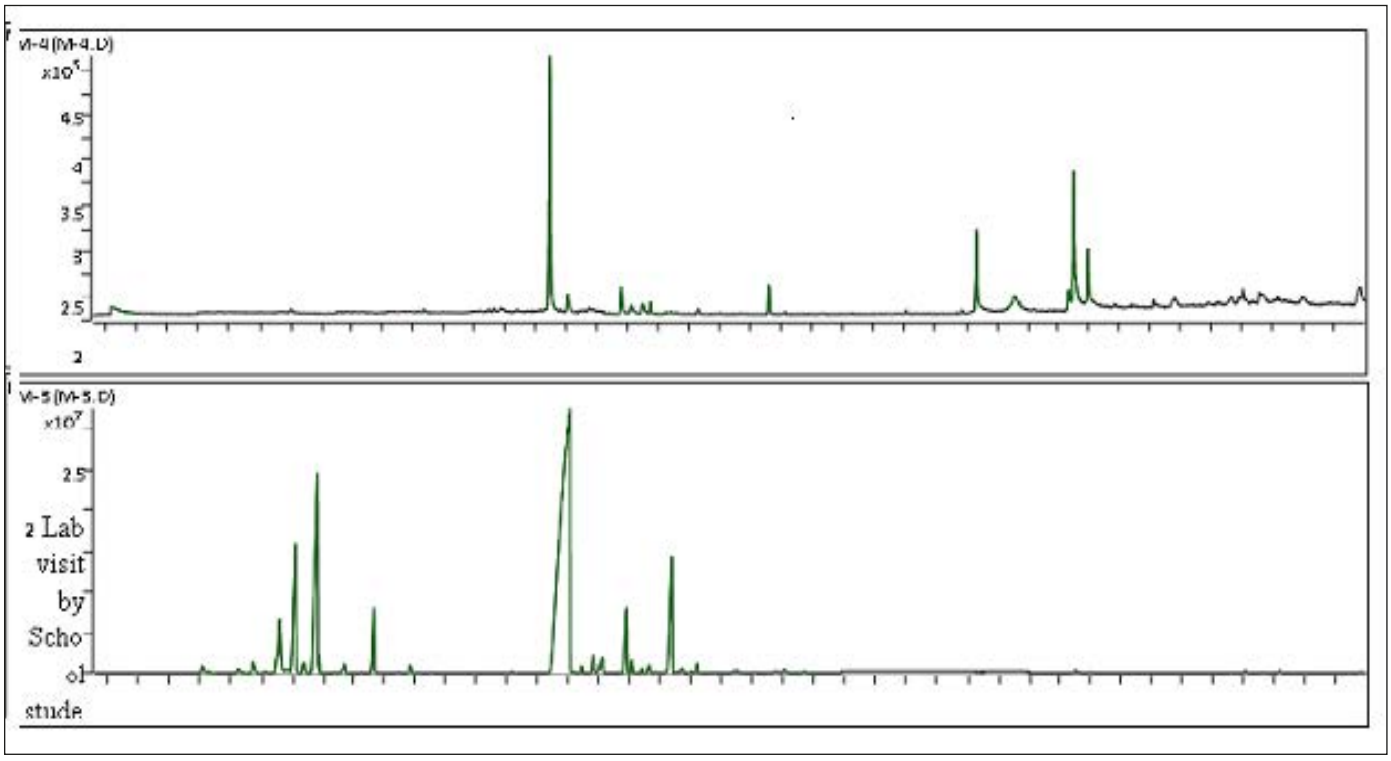


Figure 1.13.4

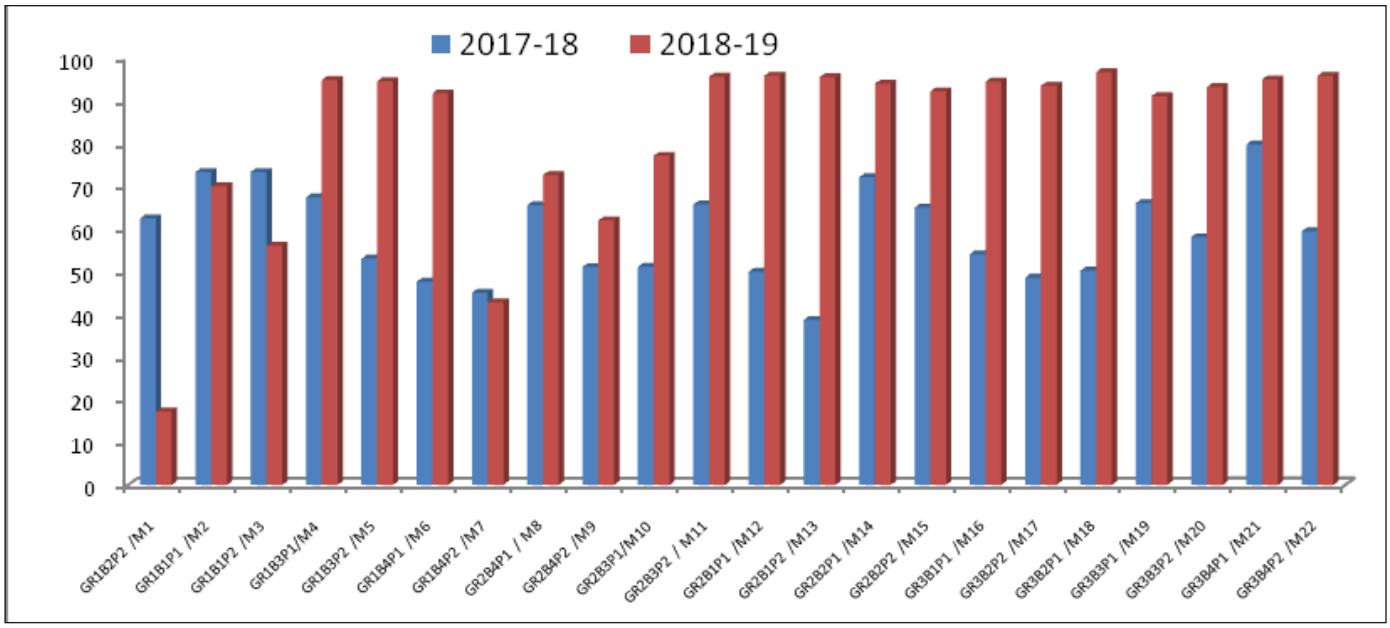


Figure 1.13.5

The plants were selfed and seeds were collected for evaluating the performance in the following year. The oil was analyzed from the selected lines for two subsequent years (2017-18 & 2018-19). The compiled data is shown in Figure 1.13.5.

1.14 Bioactive secondary metabolites from *Rumex abyssinicus* Jacq.

Ntemafack Augustin, Vijay K. Nuthakki, Mohd. Abdullaha, Arem Qayum, Shashank K. Singh, Sandip B. Bharate, Qazi Parvaiz Hassan and Sumit G. Gandhi

Rumex abyssinicus Jacq. (synonyms *Rumex schimperi* Meisn and *Acetosa abyssinica* (Jacq.) A.Löve&B.M.Kapoor) is a medicinal plant widely spread in the highlands of tropical Africa where it grows in many countries. The plant is commonly known as Spinach rhubarb and can be found in the drier areas, mainly in Nigeria, Ethiopia, Angola, Zambia, Cameroon and Mozambique. *R. abyssinicus* is used in traditional medicine to manage many ailments including hypertension, stomach-ache, neckache, microbial infections, jaundice, rheumatism, wounds and liver diseases. Different classes of secondary metabolites have been reported from the plant including anthraquinones, flavonoids, terpenes, acids, alcohols, steroids and ketones. Its pharmacological potential includes antimicrobial, antioxidant and anticancer activity. The plant sample was collected from West region, Cameroon and secondary metabolites were isolated from ethyl acetate extract using column chromatography and preparative TLC techniques. The extract, selected fractions and pure compounds were assayed for antimicrobial and anticancer activity using micro-dilution and Sulforhodomine B assay, respectively. In the search for novel drugs against Alzheimer 'disease, the extract and pure compounds were screened for inhibitory effect against acethylcholinesterase (AChE) and butyrylcholinesterase (BChE) using spectrophotometric method. Five pure compounds were isolated from the extract and identified as emodin, chrysophanol, physcion, helminthosporin and syringic acid. Helminthosporin and syringic acid are isolated here for the first time from *Rumex* species. Further, the extract and the pure compound helminthosporin are also reported here for the first time as dual inhibitors of AChE and BChE. The extract inhibited AChE and BChE with IC_{50} values of 2.7 and 11.4 µg/mL, respectively. Helminthosporin inhibited both enzymes with IC_{50} equal to 2.63 µM and 2.99 µM, respectively. The compounds exhibited antimicrobial effect against bacteria and fungi, with minimum inhibitory concentration (MIC) ranging from 1.95 to 250 µg/mL. Helminthosporin

was the most potent compound with MIC ranging from 1.95 to 3.90 µg/mL against *Bacillus cereus*, *Bacillus subtilis* and *Streptococcus pyogenes*. The extract and compounds also showed cytotoxic effect on different human cancer cell lines. The extract was most toxic to prostate cancer cell line PC-3, IC_{50} = 13.33µg/mL. Helminthosporin was also the most cytotoxic compound against breast and colon cancer cell line, with IC_{50} values of 9.71 and 9.16 µM, respectively. Fraction R7C3 showed potent cytotoxic effect against all cancer cell lines, with 100% inhibition and IC_{50} ranging from <1 to 4.35 ng/mL. From our investigations it is evident that ethyl acetate extract of *Rumex abyssinicus* and its secondary metabolites are inhibitors of cholinesterase, the key enzyme in the development of Alzheimer's disease. The secondary metabolites also exhibit antimicrobial and cytotoxic effect and can be used in development of anti-Alzheimer, antimicrobial and anticancer drugs.

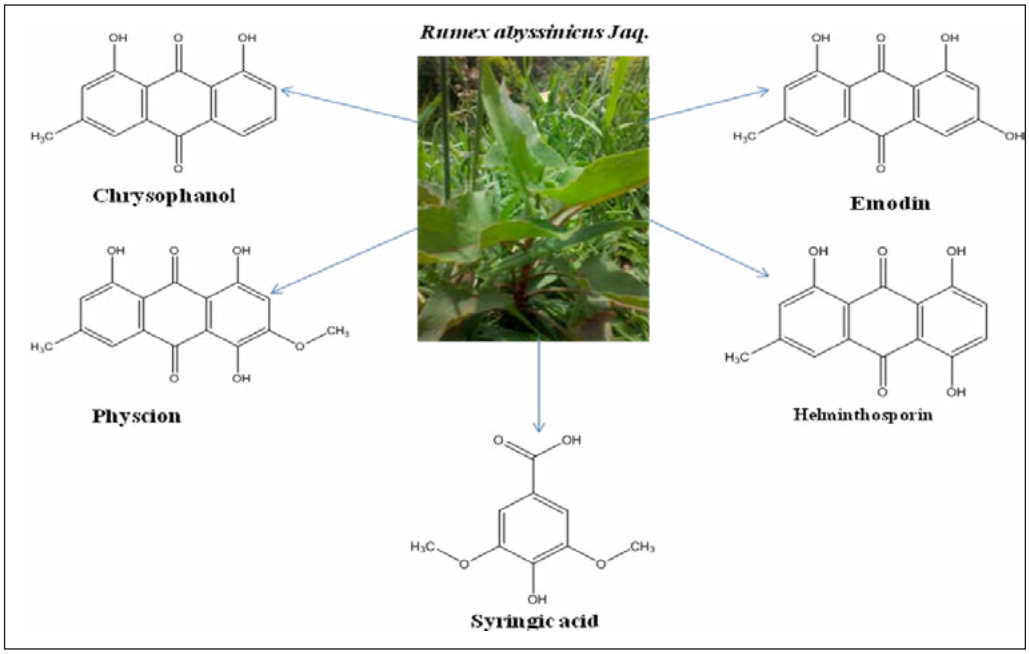


Figure 1.14.1. Chemical structure of isolated secondary metabolites of *Rumex abyssinicus*

1.15 Endophytes from Rumex dentatus

Ntemafack Augustin, Arem Qayum, Ravi Singh Manhas, Tahirah Khaliq, Sajad Ahmed, Sheikh Gulfam, Shashank K. Singh, Asha Chaubey, Qazi Parvaiz Hassan and Sumit G. Gandhi

Rumex dentatus is commonly known as toothed dock, Indian dock or Aegean dock. The plant is an annual herb, rarely biennial which grows up to 30-70 cm tall. It is native to Eurasia and North Africa, and is found in other parts of the world as introduced species. In China, the *R. dentatus* is used in traditional medicine system to cure many kinds of diseases including bacterial and fungal infections, dysentery, enteritis and ascariasis. Traditional preparations of *R. dentatus* are also used to manage eczema and diarrhea. In Pakistan, the roots and leaves of the plant are used by local communities in the treatment of foot and mouth infection, asthma, cough, jaundice, fever, weakness and scabies. *R. dentatus* has also been reported to contain different classes of pharmacological bioactive secondary metabolites with anti-microbial, anti-diabetes, anti-cancer, anti-inflammatory, anti-Alzheimer's and insecticidal activity. These include anthraquinones, flavonoids, terpenes, acids, naphtalenes and aldehydes. Plants are known to be host of endophytes and endophytic actinomycetes have been isolated previously from *R. dentatus* in China. The term "endophyte" is used to qualify microorganisms that live within plants tissues for at least a part of their life cycle without causing any visible manifestation of disease under normal circumstances. Endophytes may form symbiotic or mutualistic association with the host plant from which they usually get nutrition and protection. In return, they protect the plant against predators like insects, pathogens, herbivores and environmental stress conditions by producing a wide range of secondary metabolites. Endophytic secondary metabolites have been reported to exhibit different pharmacological potential including anti-diabetes, anti-obesity, anticancer, anti-fungal, anti-bacterial, antioxidant and antiviral activity. The fresh samples of *Rumex dentatus* were collected from Jammu and Kashmir, India. Endophytes were isolated and identified from different surface sterilized tissues. Endophytic extracts were prepared

from the fermented cultures and screened for antimicrobial and anticancer activity using microdilution and sulforhodomine B dye method, respectively. Endophytic fungi were screened in dual culture against plant pathogens *Verticillium dahliae*, *Fusarium oxysporum* and *Colletotrichum capsici*. From different tissues of *Rumex dentatus*, a total of 82 endophytes were isolated. Isolates were classified into three different groups viz fungi, actinomycetes and bacteria, based on colony morphology and microscopic identification. Endophytic fungi were identified and assigned to three genera including A*spergillus, Colletotricum* and *Fusarium*. Most identified bacterial endophytes belong to the genus *Bacillus*. Antimicrobial activity showed that endophytic actinomycetes were the most active isolates, with MIC values ranging from 0.062 to 512 µg/mL. Isolates JR9 and KS3 were the most active and were identified as *Streptomyces* species based on scanning electron microscopy and in comparison with literature. Endophytic fungus *A. niger* JS6 was the potent inhibitor of plant pathogens with 100% inhibition against all filamentous fungi tested in co-culture. Ethyl acetate extract of *A. niger* showed good cytotoxic effect on colon cell line PC-3 and breast cancer cell line MF-7 with IC_{50} values of 16.43 and 14.40 µg/mL, respectively. From our investigations it is evident that *R. dentatus* harbors different species of endophytes with potent antimicrobial and anticancer activity, therefore can be used in the development of antimicrobial and anticancer drugs. Endophytic isolates belonging to *Streptomyces sp.* were potent sources of antimicrobial agents whereas *Aspergillus niger* was found to be a potent source of anticancer agents. *Aspergillus niger* is also a potent plant pathogen inhibitor and can be used in biotechnology as biocontrol agent.

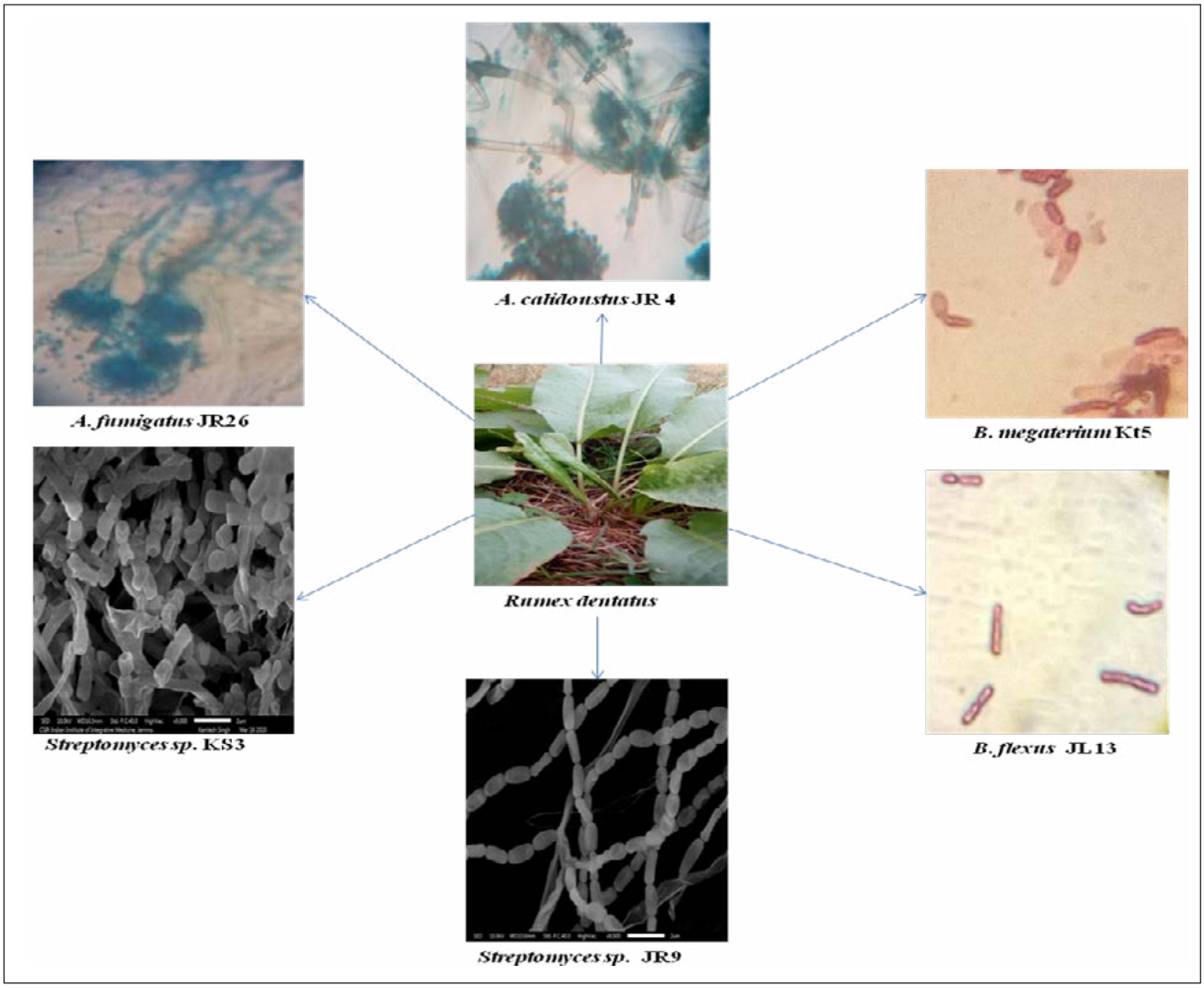


Figure 1.15.1. Microscopic morphology of some endophytes of *Rumex dentatus*

1.16 Induction, transgenesis, maintenance and metabolite analysis of hairy roots from Coleus forskohlii

Vijay Lakshmi Jamwal, Irshad Ahmad Rather, Nitika Kapoor and Sumit G. Gandhi

Coleus forskohlii (Willd.) Briq is a medicinal herb that belongs to Lamiaceae family (mint family) and cultivated in the warm, subtropical, temperate areas in India, Myanmar and Thailand. It is known for the production of a labdane diterpene: forskolin, which is responsible for its anti-hypertensive and anti-obesity properties. Forskolin is a potent and reversible activator of adenylate cyclase. 1, 9 dideoxy forskolin (anti-cancer) and genkwanin (anti-inflammatory) are other important bioactive metabolites produced by *C. forskohlii*. Most of the bioactive labdane diterpenes including forskolin which are synthesized by *C. forskohlii* are accumulated in its roots. Extraction of these bioactive metabolites requires uprooting the plant. Further, the growth of the plant and production of these metabolites is severely impacted by changes in weather, soil condition, rainfall pattern, availability of water as well as biotic factors such as nematode infections of root, which significantly reduces the biomass and quantity of metabolites. *Agrobacterium rhizogenes* is a gram negative soil bacterium which induces hairy root disease in dicotyledonous plants. *A. rhizogenes* transmits the T-DNA from their Ri plasmid which then integrates into the chromosomal DNA of the plant cell. T-DNA carries the *rol* genes, which are responsible for the induction and phenotype of hairy roots. Hairy roots provide an economically viable and eco-friendly alternative for the production of high value secondary metabolites. Apart from this, hairy roots have been used for a variety of other applications including metabolic engineering, recombinant protein production, etc. Hairy roots grow in hormone-free medium and much faster than plant cell cultures. They often possess a high biosynthetic capacity for the production of secondary metabolites. Generation of transgenic hairy roots is a quick assay as compared to generation of transgenic plant, to assess the expression of gene and metabolites content related to that genes. Thus, induction of hairy root cultures was done by using *A. rhizogenes* (LBA9402) from the leaves of *C. forskohlii* (Figure 1.16.1). Production of forskolin in hairy roots was ascertained by microscopy, thin layer chromatography and mass spectrometry. Microscopic detection of forskolin and related diterpenes was done using 10% vanillin and perchloric acid by staining the transverse sections of hairy root and normal root (Figure 1.16.2). Forskolin and related diterpenes were also detected in the methanol-chloroform extracts of hairy roots and normal roots on TLC and also through mass-spectroscopy (Figure 1.16.3). In order to generate transgentic hairy root culture, a foreign or heterologous gene was introduced in *C. forskohlii* by using *A. rhizogenes* mediated transformation. We had earlier cloned and functionally characterized Osmotin gene from *Ocimum basilicum*. A PR-5 (Pathogenesis-related) protein, showing a high degree of homology with osmotin-like protein was isolated from sweet basil (Ocimum basilicum L.). Pathogenesis-related (PR) proteins are involved in biotic and abiotic stress responses of plants and are grouped into 17 families (PR-1 to PR-17). PR-5 family includes proteins related to thaumatin and osmotin, with several members possessing antimicrobial properties. A complete open reading frame consisting of 675 nucleotides, coding for a precursor protein, was obtained by PCR amplification. We have subcloned the Osmotin gene into a plant expression vector (pBI121) which was used for *A. rhizogenes* mediated generation of transgenic hairy roots in *C. forskohlii*, expressing the Osmotin gene. Presence of Osmotin gene was confirmed in transformed hairy root lines, through PCR using Osmotin gene specific primers and total DNA of hairy roots as template. Hairy roots induced with wild type *A. rhizogenes* (not transformed with pBI121-Osmotin) and *A. rhizogenes* transformed with pBI121 vector alone (without the Osmotin gene insert) were used as negative controls (Figure 1.16.4a). Expression of Osmotin transgene was assessed using semi-quantitative RT-PCR analysis, using gene specific primers. *Actin* gene was used as housekeeping control for normalization (Figure 1.16.4b).

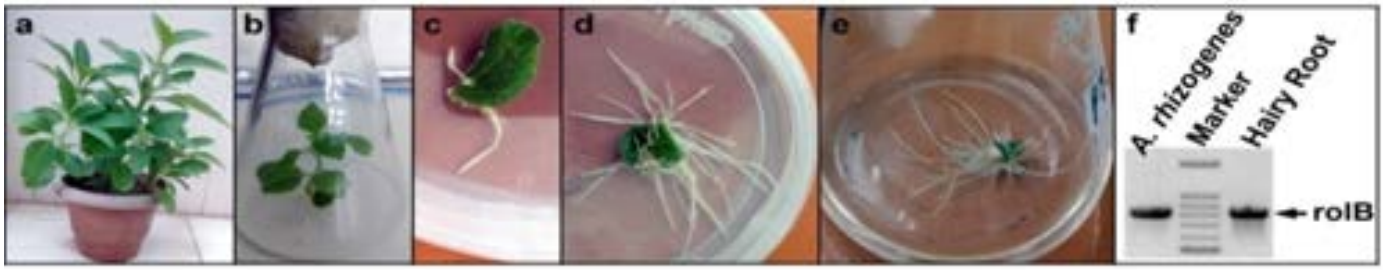


Figure 1.16.1. Hairy root culture of *Coleus forskohlii*

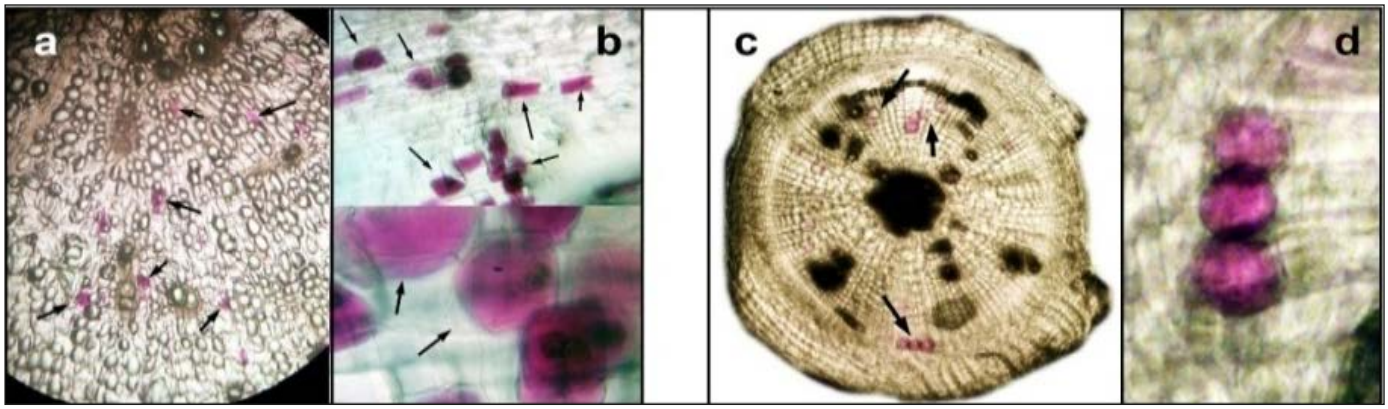


Figure 1.16.2. Localisation of forskolin and related terpenes in roots and hairy roots of *C. forskohlii*

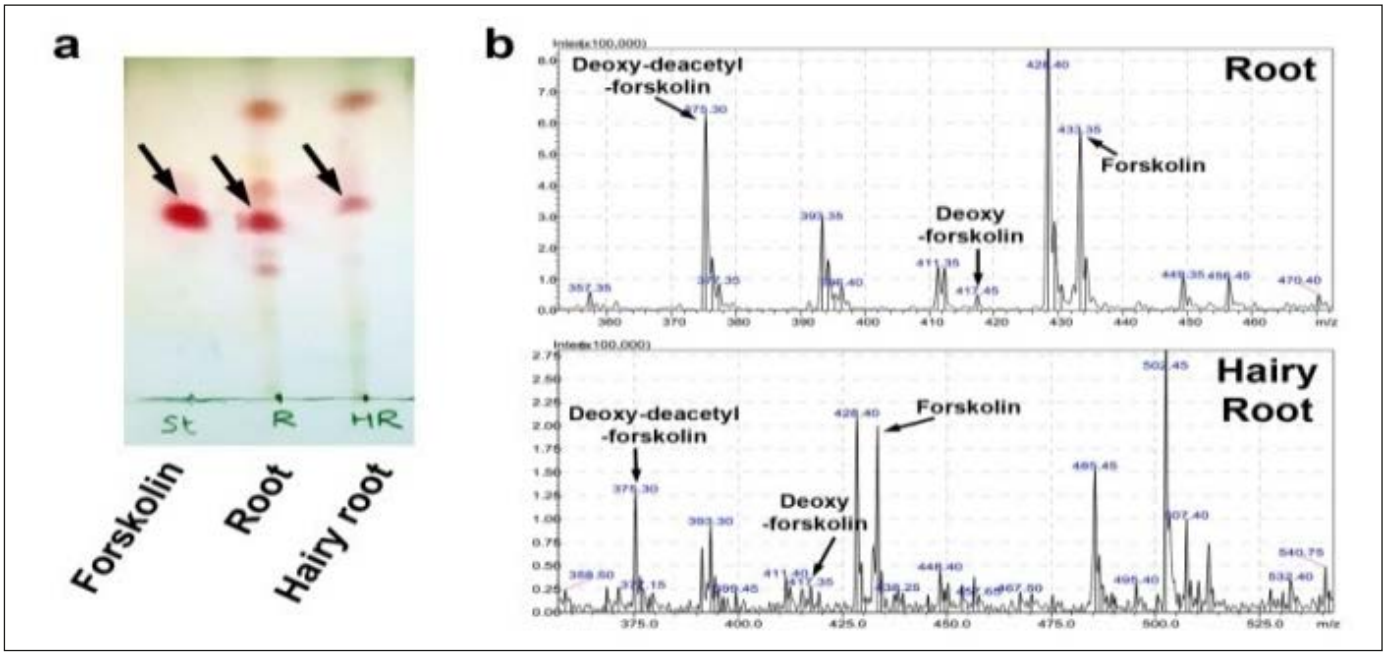


Figure 1.16.3. Detection of key metabolites in roots and hairy roots of *C. forskohlii*

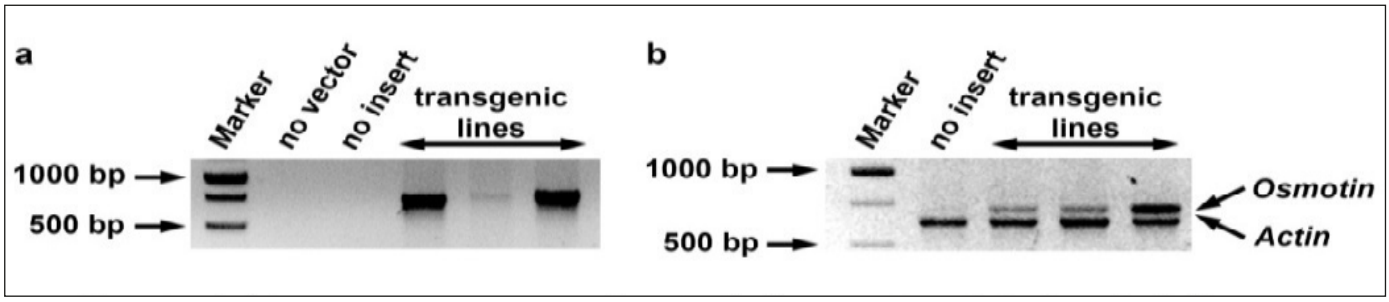


Figure 1.16.4. Transgene expression in hairy roots of *C. forskohlii*

1.17 Captive cultivation of *Dysoxylum gotadhora*

Vijay Lakshmi Jamwal, Natish Kumar, Rajendra Gochar, SR Meena, Sabha Jeet and Sumit G. Gandhi

Rohitukine is a chromone alkaloid isolated from medicinal plant *Dysoxylum gotadhora* (*Dysoxylum binectariferum*), has inspired the discovery of flavopiridol and riviciclib, both of which are approved anti-cancer drugs, bioavailable via the intravenous route. *D. gotadhora* is a tree belongs to Meliaceae family and grows predominantly in evergreen forests found in West Bengal, Assam, Western Ghats, Annamalai and North Kanara regions. IIIM-290 is a synthetic chromone alkaloid that is discovered by semisynthetic modification of a natural product rohitukine, possessing potent Cdk inhibitory activity. It is a potent inhibitor of Cdk-1/A, Cdk-2/A, Cdk4/D3 Cdk5/p25, Cdk-6/D1 and Cdk-9/T1 showing IC_{50} values < 100 nM. It possess cytotoxicity in different types of cancer tissues, with most potent cytotoxicity in leukemia and pancreatic cancer cells (IC_{50} < 1μM). It possesses excellent physicochemical properties (solubility, Log P, pKa, permeability) and oral pharmacokinetics in BALB/c mice and SD rats with >60% oral bioavailability, better than a clinical candidate flavopiridol. Under the phytopharma mission, an enriched fraction of *D. gotadhora* extract was prepared for treatment of arthrites. In order to fulfil the present and future requirement of the extract and bioactive molecules from *D. gotadhora*, its captive cultivation was undertaken. Fruits of *D. gotadhora* were collected from Forest Research Institute, Dehradun. Seeds were separated from the fruits and sowed in already prepared poly-bags. Approximately, 3300 seeds were sowed in poly-bags (8 X 12 inches). The sowed seeds were watered daily and antifungal spray was done initially every 3rd day for first 3 weeks and later on as per requirement. It took approximately 7-8 weeks for seedlings to emerge from sowed seeds. Out of 3300 sowed seed, 2200 healthy *D. gotadhora* seedlings emerged. After 4-8 months of healthy growth in poly-bags, young plants were transferred for captive cultivation at Chattha field station of CSIR-IIIM. 900 plants of *D. gotadhora* were planted along the boundaries of Chattha farms at the distance of 3-4 foot between the plants.

1.18 Expression analysis of major biosynthetic genes of cannabinoids and ABC Transporters in *Cannabis sativa*

Rekha Chouhan, Sajad Ahmed, Yadunandan Sen and Sumit G. Gandhi*

Cannabis sativa L. (Cannabaceae) is a herbaceous flowering plant extensively used throughout recorded history as a source of industrial fibre, oil, food, recreation, and medicine. The plant is known to be rich in secondary metabolites like terpenes, alkaloids, flavonoids, phenolics, etc. Cannabinoids is a peculiar class of compounds unique to *Cannabis* genus. At least 144 cannabinoids are reported in *Cannabis*, most of them being produced only in trace amounts. Cannabinoids are terpenophenolic substances, differing in the structure of their terpenic moiety and/or the length of the prenyl side chain attached to the phenolic portion. The main psycho-active cannabinoid constituent of *Cannabis* is tetrahydro-cannabinol (THC). Besides THC, another cannabinoid produced in high concentrations is cannabidiol (CBD), which is not psychoactive. The interest in *Cannabis* is today mainly focused on the necessity to limit THC content and also on cannabinoids' therapeutic activity and potential employment for pharmaceutical purposes. In the present study we have done expression analysis of major ABC transporters to correlate them with the accumulation patterns of cannabinoids in *Cannabis* plant. ATP-binding cassette (ABC) transporter is one of the largest expressed gene subfamilies involved in the transportation and accumulation of secondary metabolites in plants. Identification of ABC transporters involved in the transport of therapeutically important CBD component of *Cannabis* will be very helpful in designing transformation strategies for raising CBD rich plants. Transcriptomes of *Cannabis sativa* were downloaded from NCBI. The contigs were assembled using CLC genomics software (Figure 1.18.1). Further BLAST analysis was done to obtain ABC transporters sequences. Gene specific primers were designed. RNA was isolated from leaves and root tissues of the female *Cannabis* plant, and cDNA was prepared. qPCR was done using gene specific primers in both the tissues (Figure 1.18.2). The Cq value was used for analyzing the expression of various ABC genes in the two tissues (Figure 1.18.3). We also optimized the medium combination for callus induction in *Cannabis sativa* from leaf explants. Best results were obtained with MS medium supplemented with TDZ and NAA (Figure 1.18.4). Further, we have done expression analysis of cannabinoid synthesis genes (Figure 1.18.5) in leaves of male and female plants, and in the callus obtained from the same (Figure 1.18.6).

Contig measurements	Length
N75	572
N50	951
N25	1799
Minimum	200
Maximum	11,493
Average	759
Count	140,354
Total	106,553,677

Figure 1.18.1. Statistics of assembly of downloaded transcriptomic data (173 no. – 146.5 GB data)

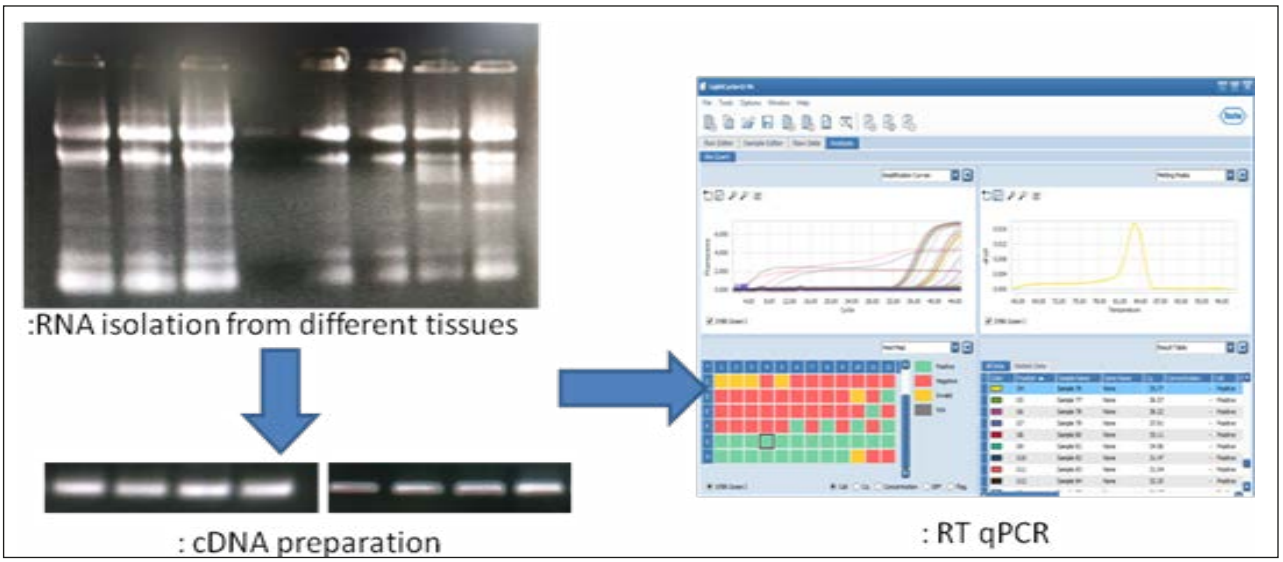


Figure 1.18.2. RNA isolation from leaves and root tissues of *Cannabis sativa*, cDNA preparation and RT qPCR using ABC transporter primers.

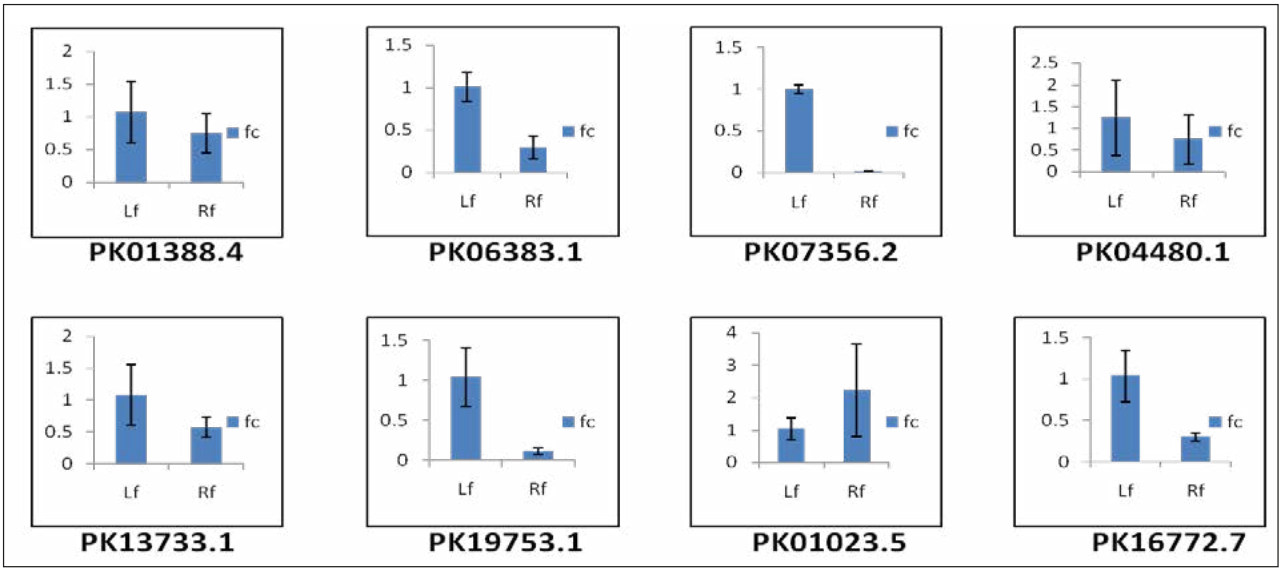


Figure 1.18.3. Graphs representing the expression of various ABC transporters in leaves and roots of female *Cannabis* plants.

Figure 1.18.4. Callus induction in leaf explants of *Cannabis sativa*

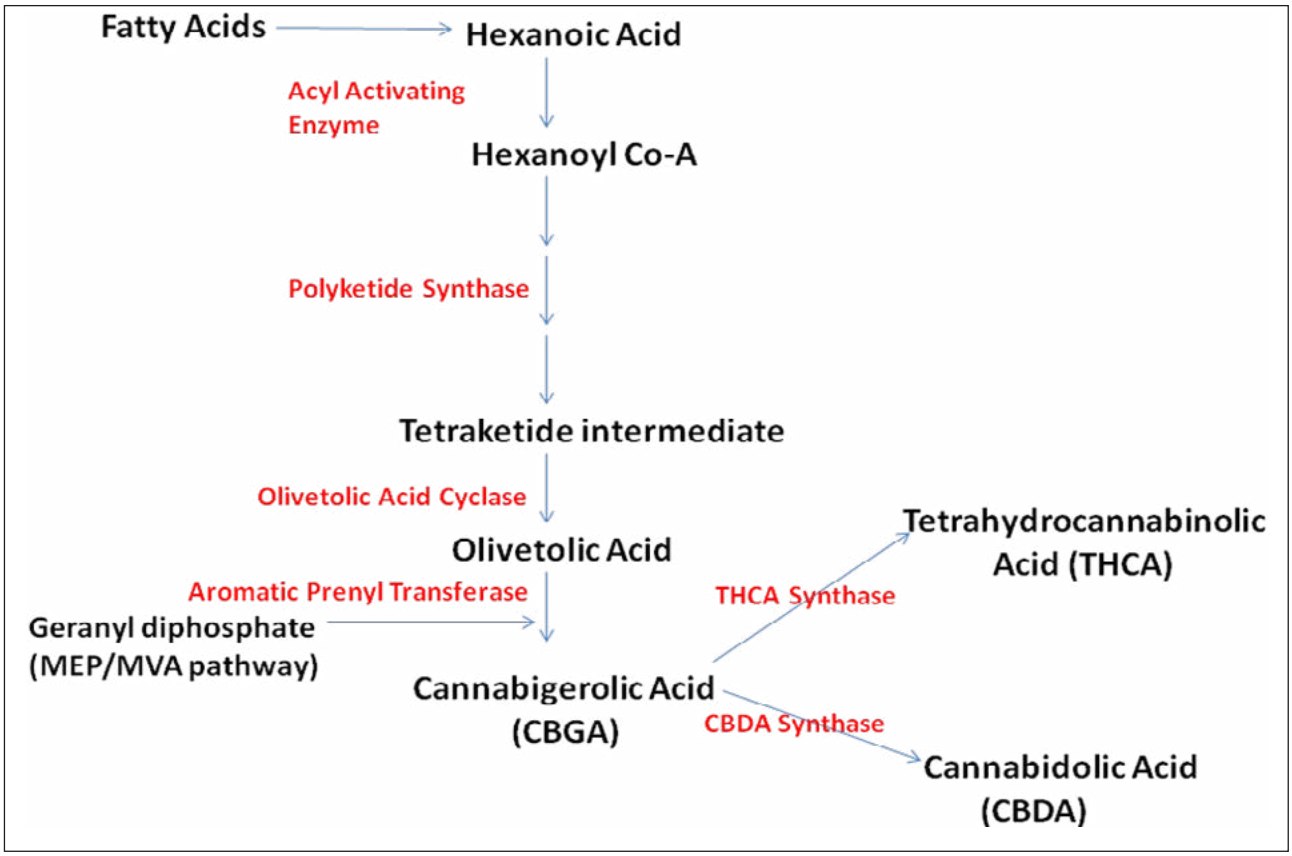


Figure 1.18.5. Schematic diagram showing major steps in cannabinoid synthesis in *Cannabis sativa.*

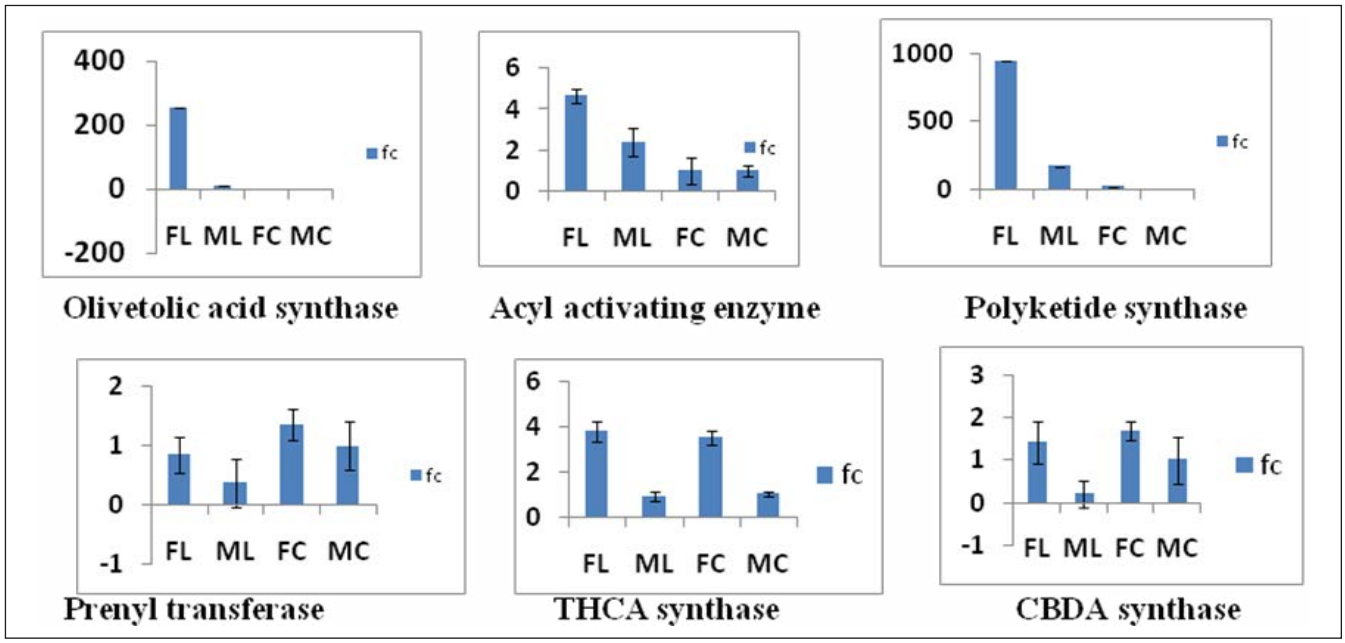


Figure 1.18.6. Expression analysis of major cannabinoid synthesis genes of *Cannabis sativa* (FL- female leaf; ML- male leaf; FC- callus from female leaf; MC- callus from male leaf)

1.19 Establishment of hairy roots of endangered Himalayan plant *Swertia chirata*: a sustainable alternative to extraction from nature

Rekha Chouhan, Natish Kumar, Amit Kumar, Sajad Ahmed, Yadunandan Sen and Sumit G. Gandhi

Swertia chirata (Gentianaceae) is a herb of immense ethno-medicinal value, native to temperate Himalayas. Widespread use of the plant as traditional medicine has been well documented in British and United States pharmacopoeias, Ayurvedic pharmacology and Unani medicine. The herbal extract is a bitter tonic. It has been conventionally used in the treatment of several ailments like skin diseases, ulcers, gastrointestinal infections, diabetes, liver disorders, scorpion bites and malaria. The plant is known to possess anti-pyretic, anti-fatigue, anti-inflammatory, anti-aging, anti-microbial, anti-cancerous, analgesic, hepato-protective and hypoglycemic properties, and thus, is a part of various known herbal formulations. The herbal properties of the plant are attributed to the presence of different bioactive compounds including, amarogentin, swerchirin, chiratol, swertiamarin, mangiferin, sweroside, gentianine, amaroswerin, oleanolic acid, swertanone and ursolic acid. While the whole plant is medicinally important, roots are considered to be the most potent. The diverse pharmacological properties of the plant have led to overharvesting of the plant from its natural habitat. The present IUCN status of the plant is described to be critically endangered, and thus, demands for elucidating new techniques enhancing the production of active plant constituents and establishing sustainable harvesting methods without causing much of harm to the plant in the nature. Hairy root culture is a plant tissue culture technique that offers a sustainable alternative for the production of various valuable metabolites from plants in a culture system. Hairy roots are the manifestation of infection caused by a gram negative soil bacterium *Agrobacterium rhizogenes* in plants. These neoplastic root culture systems are easy to maintain for indefinite period of time without growth factors and, are also genetically stable. They are not impacted by any biotic or abiotic factors. The system can potentially be used for enhanced production of native as well as novel metabolite. The increasing usage of *Swertia chirata* for medicinal usage, leading to its illegal overharvesting, has resulted in a drastic reduction of its populations. In this regard, such culture system provides holistic conservation strategy by providing alternative to metabolite production from the plant. So, we have optimized protocols for induction and maintenance of hairy root culture of *Swertia chirata* (Figure 1.19.1.) and confirmed it with a PCR using *rolb* primers (Figure 1.19.2.). Also, LC-MS/MS based identification (Figure 1.19.3.) and HPLC based quantification (Figure 1.19.4.) of major markers: amarogentin and mangiferin was done in the hairy root cultures.

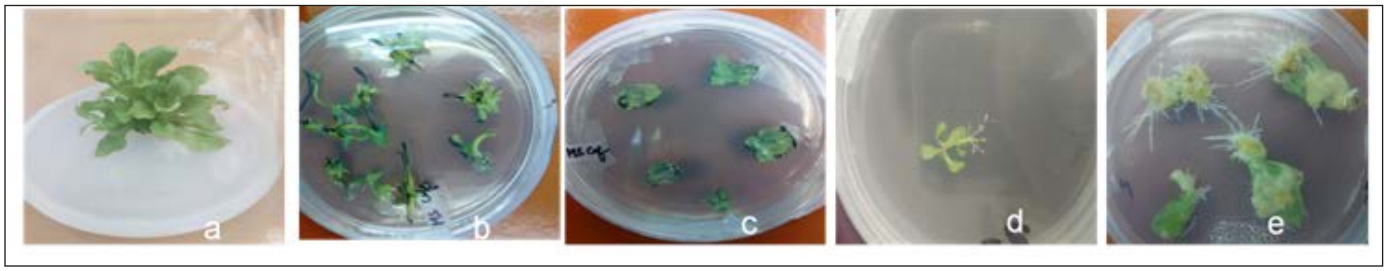


Figure 1.19.1. a.) Tissue culture raised plants of *Swertia chirata;* b.),c.) Nodal and leaves explant treated with *Agrobacterium rhizogenes* strain *LBA9402;* d),e) Induction and maintenance of hairy root cultures on MS basal medium.

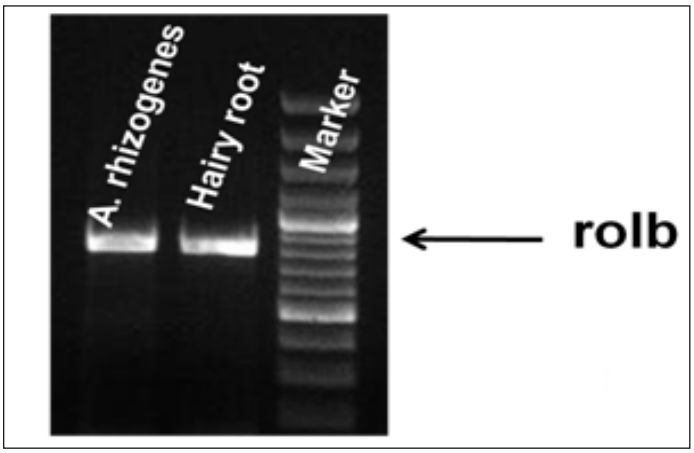


Figure 1.19.2. PCR confirmation of hairy roots of *Swertia chirata using rolb primers*

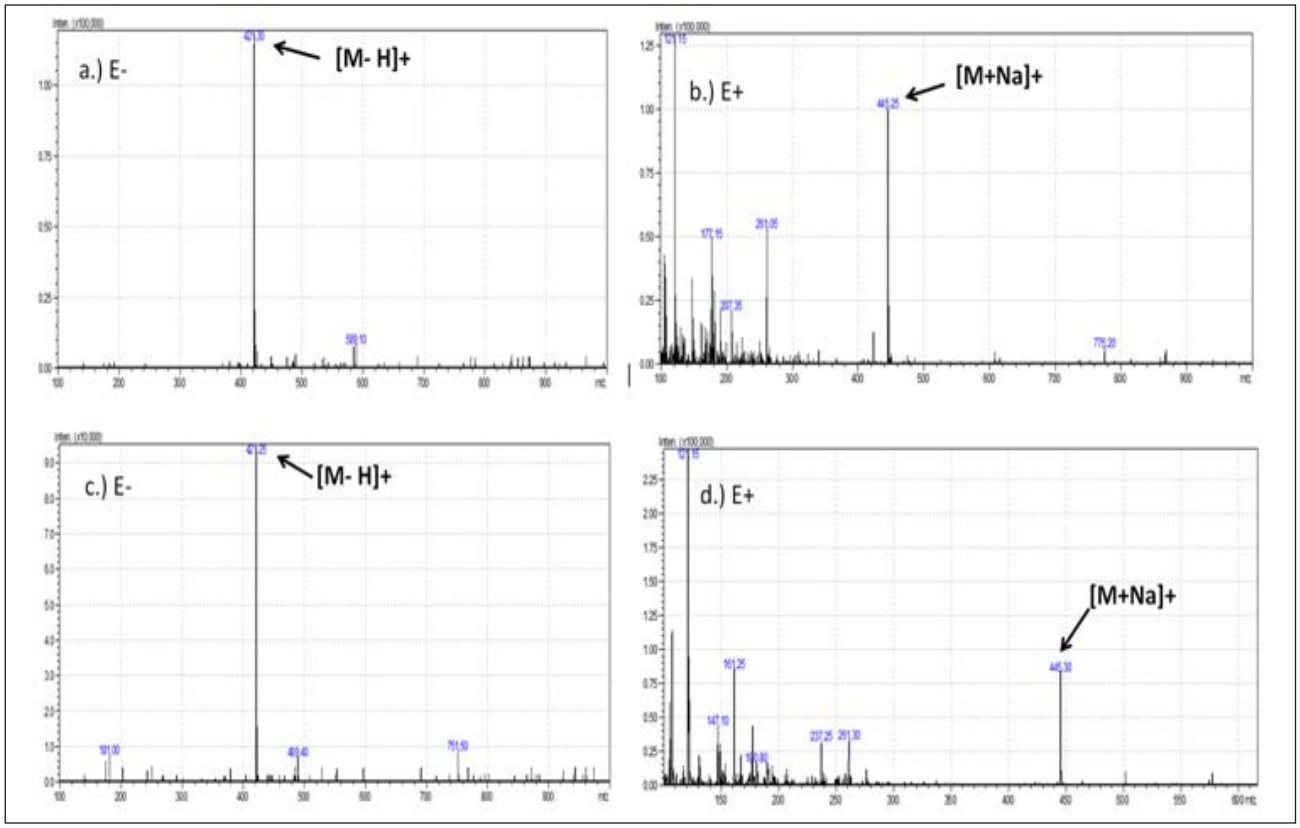


Figure 1.19.3. a.), b.) LCMS of methanolic extract of hairy roots of *Swertia chirata; c.),d.)* LCMS of methanolic extract of normal roots of *Swertia chirata*- showing the presence of Mangiferin (MW- 422.33g/mol).

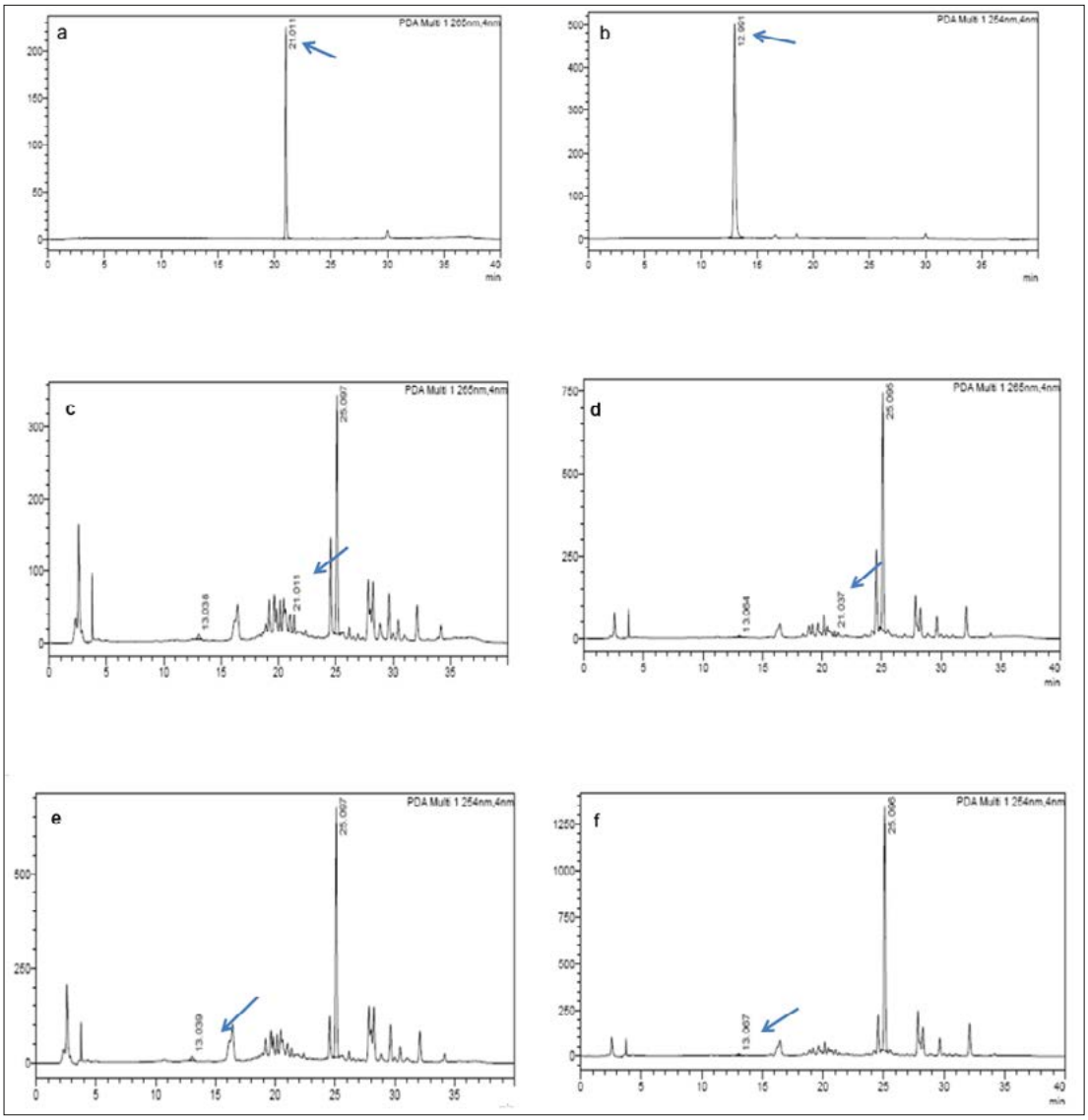


Figure 1.19.4. HPLC Analysis of hairy roots and normal roots of *Swertia chirata; a.)* Amarogentin standard; b.) Mangiferin standard; c.),d.) Amarogentin peaks in hairy root and normal root extracts of *Swertia chirata*, respectively; e.),f.) Mangiferin peaks in hairy root and normal root extracts of *Swertia chirata,* respectively.

1.20 *CstMyb1* and *CstMyb1R2* modulate Crocus apocarotenoid metabolism by regulating carotenogenic genes

Zahid yaqoob Bhat, Tabasum Mohiudin, Nasheeman Ashraf

Apocarotenoids like crocin, picrocrocin and safranal are restricted to genus *Crocus* and are synthesized by oxidative cleavage of zeaxanthin followed by glycosylation reactions. In *Crocus sativus*, the major source of these apocarotenoids, they are synthesized in stigma part of the flower in developmentally regulated manner. Most of the genes of apocarotenoid pathway are known, however, the mechanism that regulates its tissue and stage specific biosynthesis remains elusive. Myb family was identified as the largest transcription factor family from *Crocus* transciptome which indicated its possible role in apocarotenoid regulation besides regulating other metabolic pathways. Towards this, we started with identification of 65 full length *Myb* genes from *Crocus* transcriptome. The phylogenetic analysis of *Crocus Myb* genes divided them into 8 clusters. Domain analysis resulted in identification of four groups of Mybs depending upon the number of R repeats present. Expression profiling indicated that 12 Mybs are upregulated in stigma out of which expression of four genes CstMyb1, 14, 16 and CstMyb1R2 correlated with crocin accumulation in stigma. The study was further carried out with two Myb genes (CstMyb1 and CstMyb1R2) which were nuclear localized and transcriptionally active (Figure 1.20.1). Transient overexpression of these two genes (CstMyb1 and CstMyb1R2) in *Crocus* confirmed their role in regulating carotenoid metabolism (Figure 1.20.2). Yeast one hybrid confirmed that CstMyb1 binds to carotenoid cleavage dioxygenase 2 (CCD2) promoters while CstMyb1R2 binds to phytoene synthase (PSY) and CCD2 promoters. Overall, our study established that CstMyb1 and CstMyb1R2 regulate apocarotenoid biosynthesis by directly binding to promoters of pathway genes.

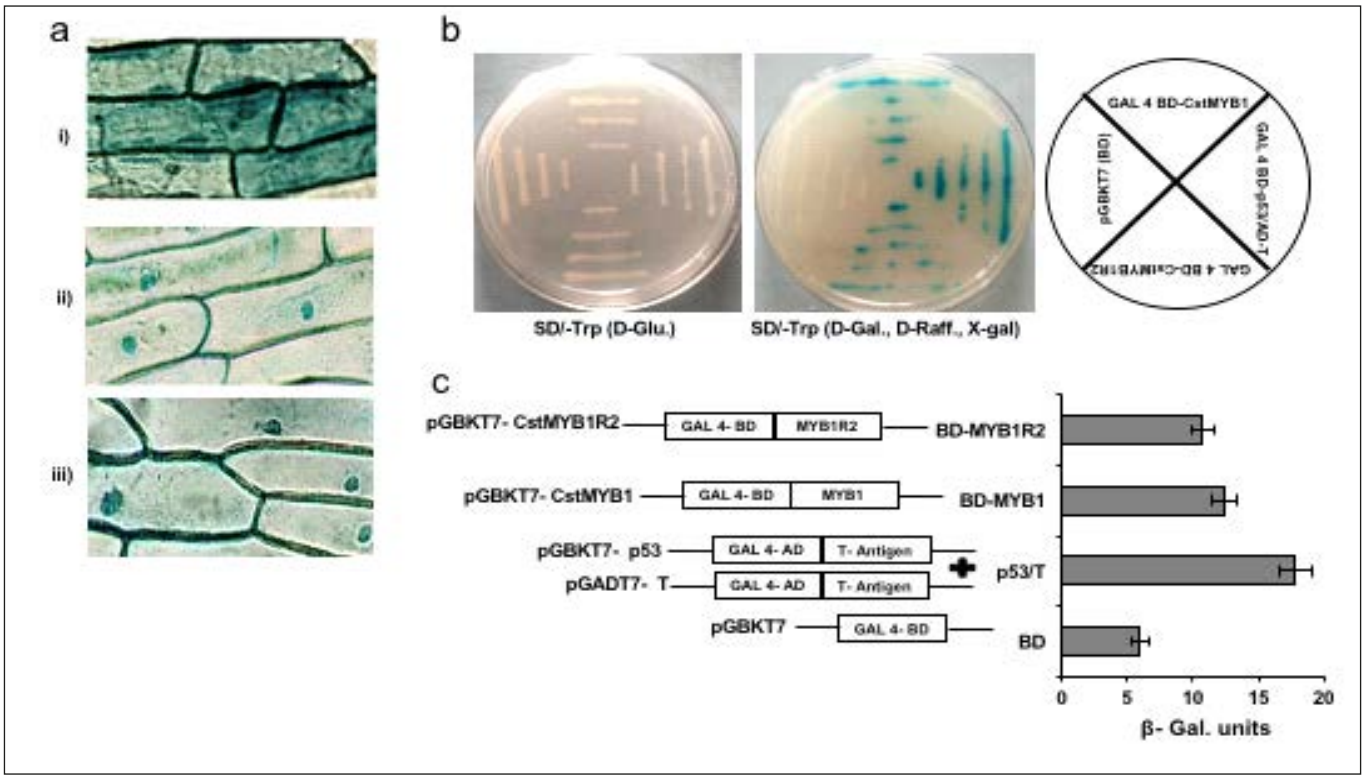


Figure 1.20.1. Sub-cellular localization and transactivation of *Cst*MYB1 and *Cst*MYB1R2 genes (A) Nuclear localization of *Myb* genes: (i) control vector: pBI121-GUS (ii) CsMYB1-GUS fusion protein (iii) CsMYB1R2-GUS fusion protein (B) transactivation assay with the cells harbouring BD-CstMyb1 and BD-CstMyb1R2 and positive control (Y187 cells co-transformed with pGBKT7-p53 and pGADT7-T plasmids) developed the blue colour due to activation of β-galactosidase reporter gene (C) quantification of transactivation using β-galactosidase assay.

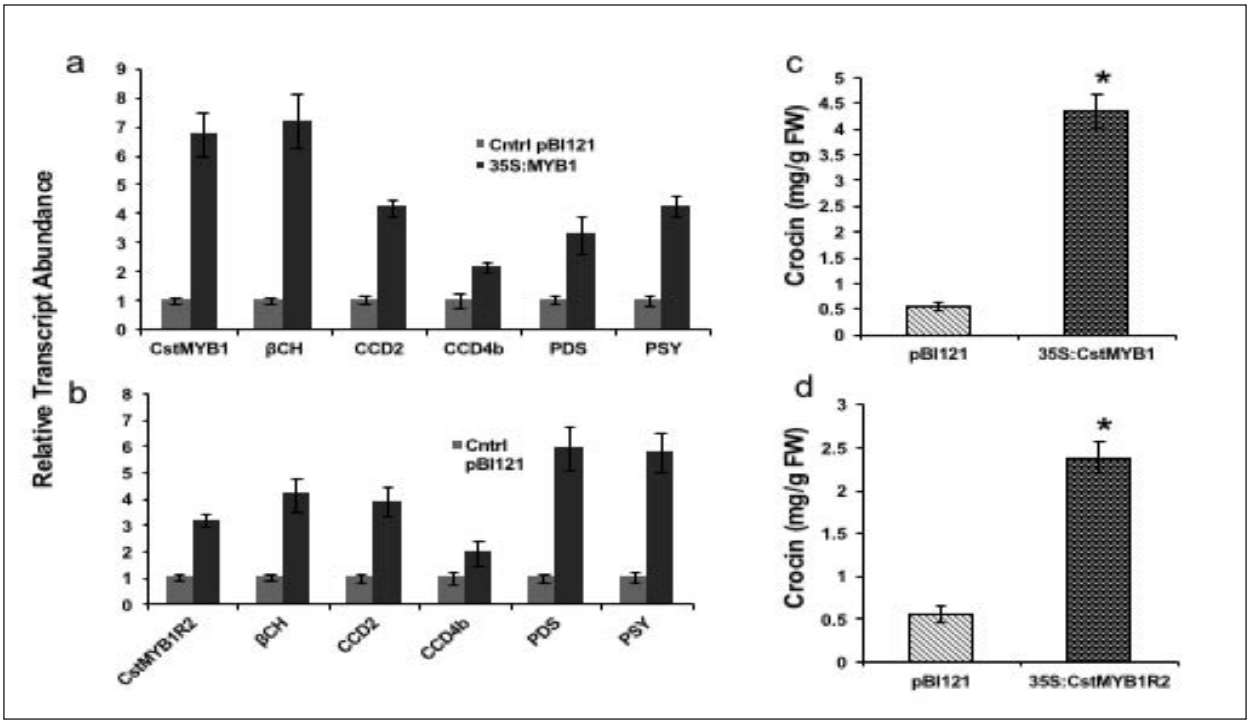


Figure 1.20.2. Effect of overexpression of *Cst*MYB1 and *Cst*MYB1R2 on pathway genes of apocarotenoid metabolism and crocin content in *Crocus sativus*. The expression levels of pathway genes in (A) *Cst*MYB1 and (B) *Cst*MYB1R2 overexpressing plants and those overexpressing empty vector were quantified by qPCR. All the values represent means of three independent biological replicates ± S.D.18-S gene was used as endogenous control. The crocin content was quantified by HPLC in *Cst*MYB1 (C) and *Cst*MYB1R2 (D) overexpressing plants.

1.21 Survey, Collection and Identification of Plant Vouchers in Herbarium of Indian Institute of Integrative Medicine, Jammu: Floristic and Ecological Aspects

Bikarma Singh, Opendra Surmal, Sumit Singh, Mudasir Nazir Bhat and Mohammed Asif Chowdhary

The Janaki Ammal Herbarium of Indian Institute of Integrative Medicine, Jammu (Formerly RRL, Jammu), is a national referral facility for identification and certification of higher plant samples. This herbarium harbour more than 25000 plant vouchers, and confirmation of identity of plants at Janaki Ammal Herbarium were carried out by following standard international SOP. During 2019-2020, many surveys and field tours were undertaken for collection of plant materials and plant vouchers for studying mapping of plant diversity, ecology, genetic variability, DNA bar-coding, tissue culture, and for characterization of different markers and natural products from different bio-geographic regions of Himalaya. The important field tours undertaken during the reporting period are given below:

- Bhallesa Mountain in Doda, J&K State: Three field tours to Bhallesa and adjoining areas of Doda were undertaken for survey and collection of plant samples for R&D. The first tour conducted w.e.f. 30-3-2019 to 8-04 2019, and the places visited were Gandoh and Ghill forests range. During the field trip, 45 field numbers were collected and 120 photopgraps. Some of the major plant species were *Pinus wallichiana, Cedrus deodara, Aesculus indica, Rubus elipticus*. The second field tour was conducted w.e.f. 01-5-2019 to 10-05-2019, and the places visited were Chilly Bhallesa forest range. During the field trip 50 field numbers were collected and 130 photographs. Some of the specimens collected were *Viburnum grandiflorim*, *Berginia ciliata* and *Valeriana jatamansi*. The third field tour conducted w.e.f. 02-07-2019 to 12-07-2019, and the places visited were Khanthi dhar, Ghilldhar and Kunan of the study area. During the field tour 60 field numbers were collected and 100 photographs taken and some of the species collected were *Isodon rugosus*, *Berberis lycium* and *Fagopyrum esculantum*.
- Sarthal Mountain and Bani Valley: Two survey and collection field tours were undertaken to inventorize Sarthal mountains

and Bani valley. It was conducted in the month of May 2019, *w.e.f.* 1 to 10 for ten days. The places visited were Bani, Lowang and Sarthal. Total 155 plant species were collected along with 250 digital photographs. Some of the major species includes *Salix alba, Alnus nitida, Celtis australis, Ficus palmata, Juglans regia, Aesculus indica, Sinopodophyllum hexandrum* and *Iris hookeriana*. Another field tour was conducted w.e.f 28th July to 5th August 2019 for ten days. The places visited were Lowang, Sarthal and Chattargala. Total 115 plant species were collected along with 225 digital photographs. Some of the major species includes *Aster falconeri, Morina longifolia, Betula uitilis, Anemone falconeri, Pedicularis* species etc.

Figure 1.21.1. Achillea millefolium

Figure 1.21.2. *Potentilla nepalensis*

Figure 1.21.3. Anemone falconeri

Figure 1.21.4. *Geranium wallichianum*

Figure 1.21.4. Aster falconeri

Figure 1.21.5. Erigeron multiradiatus

Figure 1.21. 6. *Stachys sericea*

Figure 1.21.7: *Senecio chrysanthemoides*

Figure 1.21.8. *Sinopodophyllum hexandrum*

Figure 1.21.9. *Iris hookeriana*

1.22 Loss of Biodiversity by Anthropogenic Burden and Climate Change: A Spatio-Temporal Analysis of District Rajouri (J&K) by using RS and GIS approach

(Abstract published in National Conference: Climate change: Agriculture, Biodiversity and Human Health" from 22-23 February 2020, held at CSIR-National Botanical Research Institute, Lucknow)

Mohammed Asif Chowdhary and Bikarma Singh

Numeral issues are intimidating our planet's biodiversity, from climate change to invasive species. Anthropogenic activities through changing the pattern of land use and land cover, pollution, overexploitation, habitat and forest destruction, invasions of exotic species and possibly climate change associated with global warming are the primary drivers of biodiversity loss. An attempt was presented in this study to detect the change detection in land use and land cover in the Rajouri district of J&k throughout 8 years of gap (2008 to 2016). The LULC change was investigated through a remote sensing approach using two different time satellite images. Supervised classification in ArcGIS software has been adopted. To identify LULC changes post-classification comparison techniques are used. The finding of LULC showed that the study has experienced a decrease in forests by 5.74% with an increase in agricultural land, open fields, and settlement areas during the study period. These amendments in the LULC of the study area revealed that this change is due to the rising anthropogenic burden on forests and the high level of deforestation is responsible. The change in climate by anthropogenic activities has a contagion effect on ecosystems, some species may not able to survive with environmental changes and die-off, and the entire ecosystems they sustain collapse as well. Coordinated efforts are mandatory for adaptation and improvement as the whole world is likely to face a greater risk of climate change impacts. The implementation of proper land use planning is mandatory for ideal and systematic development.

1.23 High Value Ethnomedicinal Plants Growing in Temperate Region of Bhallesa Mountain in North-Western Himalaya

(Abstract published: International Symposium on Plant Taxonomy and Ethnobotany, 13-14 February, 2020, held at Botanical Survey of India, Kolkata)

Opender Surmal and Bikarma Singh

Interiors of North-Western Himalaya are a repository of active constituents of wild medicinal plants growing in unique climatic conditions. Most of the documented and scientifically explored plants have wide applications in traditional system of medicine such as ayurveda, unani, siddha or amchi since ancient time. Current drug and medicine discovery findings have reported that most of the herbal medicines available in today's market were earlier reported as traditional medicine in health care of local people residing in the interior regions of Himalaya and elsewhere in the globe. Considering the importance of traditional knowledge of wild plants, a study was planned to document high value ethnomedicinal plants growing in temperate region of Bhallesa mountain in north-western Himalaya used as herbal medicine by local *Gaddis, Gujjars* and *Bakerwal* tribes. The study area is unexplored from floristic points of views and situated in district Doda (32°17'N, 72°31'E, elevation ranges from 1000 to 4000 m ASL). Results indicated 113 species belonging to 104 genera and 55 families used as ethnomedicine in the study area. Analysis reports indicated the most dominant families are Asteraceae, Lamiaceae, Ranunculaceae, Polygonaceae, Solanaceae, Apiaceae, Fabaceae, Berberidaceae and Urticaceae. In terms of growth forms, 69.6% species are herbs, 15.4% are trees, 12.4% are shrubs and 4% are climbers. The most commonly used plants having wide application in multiple diseases include *Sinopodophyllum hexandrum, Trillium govanianum, Viola canesens*, *Berberis lycium, Berginia ciliata, Cirsium arvense, Equisetum arvense, Pinus wallichiana, Valeriana jatamansii, Potentilla nepalensis, Urtica dioica* and several others. The local populace lack proper health care facilities so they mostly depends on local plants as a source of medicine to cure seasonal diseases, therefore, to conserve this precious knowledge associated with plants, there is need of proper documentation and ecological research to conserve these valuable species before they get extinct forever.

Berberis lycium

isodon rugosus

Valeriana jatamansi

Viburnum grandiflorum

1.24 Plant and fungi diversity of Devi Pindiyan Valley in Trikuta Hills of northwestern Himalaya, India

(Published in Journal of Threatened Taxa, 11(14), 14827-14844. https://doi.org/10. 11609/ jott. 4792. 11.14.14827-14844)

Sajan Thakur, Harish Chander Dutt, Bikarma Singh (Corresponding)*, Yash Pal Sharma, NawangTashi, Rajender Singh Charak, Geeta Sharma, Om Prakash Vidyarthi, Tasir Iqbal & Kewal Kumar

Devi Pindiyan Valley of Trikuta Hill is situated 36km from Jammu Town and 13km from Katra city (Reasi District) in Panthal forest area. It lies between latitudes of 32.982° –33.010° and longitudes of 74.986°– 74.995° and the elevation range of 860–1,360m above sea level. It covers approximately an area of 17.3km^2. The study area is part of district Reasi of Jammu &Kashmir. This mountainous belt falls in the Palaearctic Realm and the forest terrains are rugged and the hills are characterized by moderate to steep slopes. The vegetation components are characterized by typical subtropical and temperate forests. The forest components as a whole are regarded as a sacred grove and named Devi Pindiyan Shakti Pith. The upper ridges of Trikuta Hill experiences winter snowfall which is responsible for the moderate temperature in summer and cool weather in winter. December–January are the coldest months of the year when minimum temperatures reach minus 4°C. The mean temperature in January is about 8°C, and in May, the temperature rises between 35°C and 40°C. The annual rainfall ranges between 3,200mm and 3,472mm, distributed over 60–90 rain days. A number of seasonal streams that provide water to the local community for domestic purposes originate from the forest reserve. River Jhajjar is one of the important sacred perennial water system originating from Trikuta Hill which runs through the valley. There are only four villages where an indigenous community of Duggar and Dogri reside. Due to the remote location, typical physiography and climate, the local people derive much of their livelihood from agriculture, horticulture and floriculture. They mostly depend on forest resources for food, shelter and medicine. Since the region is known as a sacred place, some of them cultivate marigolds for sale in the market which adds to their earnings. This study presents information on the plant diversity of Devi Pindiyan Valley of Trikuta Hills. Several line-transect (100m N-S and E-W) surveys were conducted in which nested quadrats of 10 × 10m were laid for trees, within which interspersed two 5m × 5m sub-quadrats for shrubs and five 1m × 1m sub-quadrants for herbs at different places for determination of floristic composition. In the diverse habitats of this valley, we recorded a total of 213 plant species belonging to 165 genera and 71 vascular families were collected from the Devi Pindiyan and associated hills of Trikuta Mountain. Out of a total of 213 plant species, 204 were angiosperms (166 dicots and 38 monocots), one was gymnosperm and the remaining eight were pteridophytes. The highly represented families were Poaceae (19 species), Lamiaceae (14 species), Fabaceae (13 species), Asteraceae & Moraceae (12 species each), Solanaceae (9 species), Euphorbiaceae (8 species), Rosaceae (7 species), Ranunculaceae (6 species),

and Malvaceae, Pinaceae & Pteridaceae (5 species each). Highly represented genera in the valley were *Ficus* (10 species), *Euphorbia* & *Solanum* (5 species each), *Rubus* (4 species), and *Acacia* & *Datura* (3 species each). A total of 100 plant species were herbaceous in habit, 46 were shrubby bushes, 53 were trees and 12 were climbers.

Figure 1.24.1. Vegetation survey, data collection and identification of plants of Devi Pindiyan Valley

Figure 1.24.2. Plant diversity found in Devi Pindiyan Valley and adjoining areas: A—*Engelhardtia spicata* Lechen ex Blume var. *integra* (Kurz) Manning ex Steenis | B—*Woodwardia radicans* (L.) Sm. | C—*Euphorbia royleana* Boiss. | D—*Thysanolaena latifolia* (Roxb. ex Hornem.) Honda | E—*Adiantum recurvatum* (D.Don) Fraser-Jenk. | F—*Pteris vittata* L. | G—*Toona sinensis* (A.Juss.) M.Roem. | H—*Vitex altissima* L.f. | I—*Rubus ellipticus* Sm. | J—*Senna occidentalis* (L.) Link | K—*Bauhinia variegata* L. | L—*Dendrocalamus strictus* (Roxb.) Nees

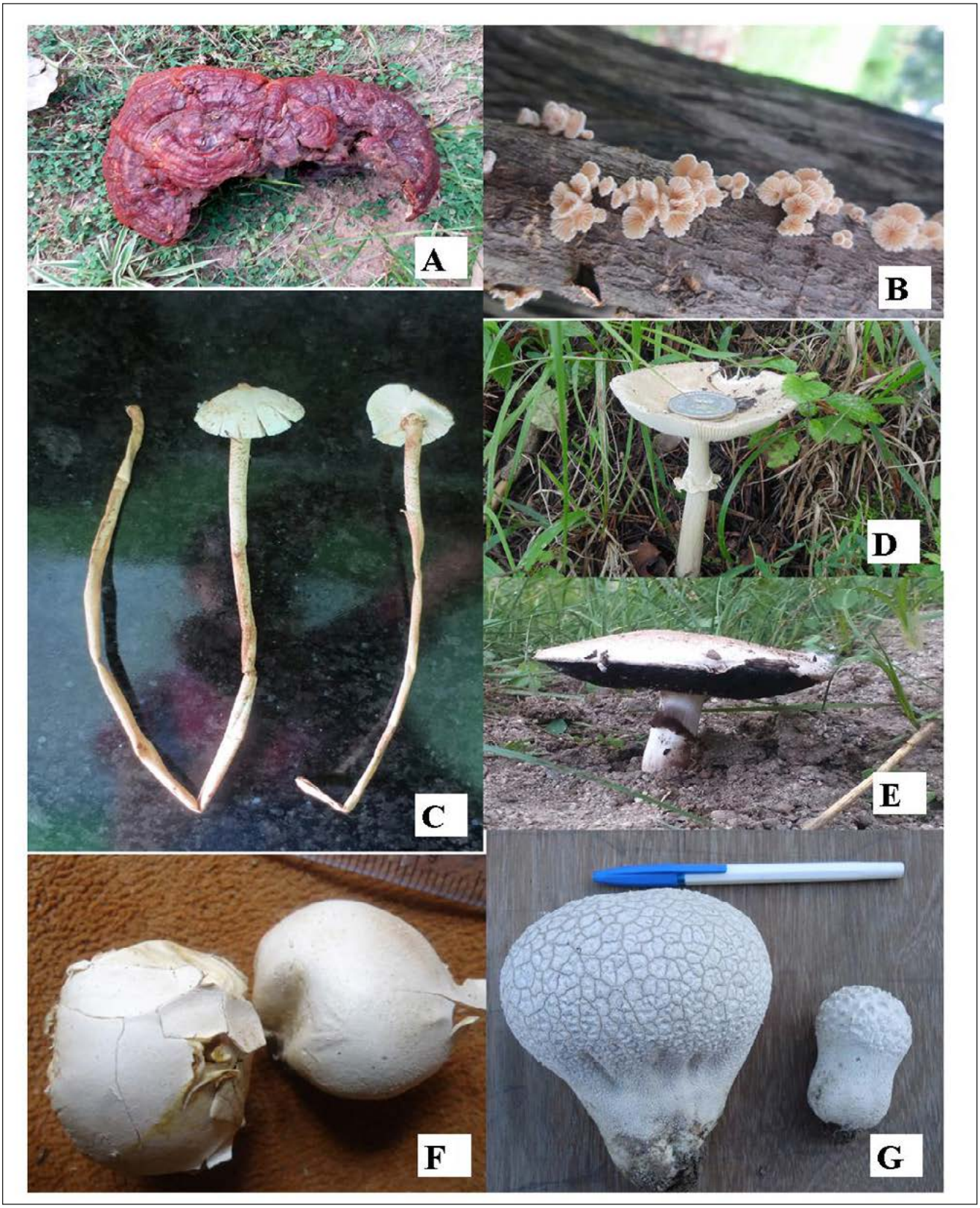


Figure 1.24.3. Macro-fungi diversity found in Devi Pindiyan Valley and adjoining areas: A—*Ganoderma lucidum* (Curtis) P.Karst. | B—*Schizophyllum commune* Fr. | C—*Termitomyces heimii* Natrajan | D—*Macrolepiota procera* Scop. | E—*Agaricus arvensis* Schaeff. | F—*Calvatia gigantea* (Batsch) Lloyd | G—*Bovista minor* Morgan.

Human disturbance coupled with habitat fragmentation have been identified as a major cause of biodiversity loss in many hotspots. Destruction of forests has resulted in the degradation of the environment and habitat of native species of the state. The rich genetic diversity has been depleted and many plant species are facing the threat of extinction in their natural habitats. Expansion of developmental activities (road/dam/city construction), logging, mining and similar associated activities are major threats to plants and animals species. The conservation status of all collected and authenticated species were worked out following IUCN Red List website (www.iucnredlist.org) and out of a total of 213 species, 34 species have been categorized under one or other threat concern. 1 species each was categorized under Vulnerable and Data deficient, 32 species were listed as Least Concern species and remaining 178 species were not assessed as per IUCN classification (Figure 1.24.4.). The study area also represented rich diversity in terms of macro-fungi where seven species of macro-fungi of seven genera belonging to four families were recorded. Out of the documented species, 35 species have been categorized threatened based on the latest IUCN Red list criteria, while 178 species are included in the catalogue of world life. The species diversity indicates the high conservation value of this area and documenting such an ecologically rich ecosystem becomes a prerequisite for developing and formulating conservation-cum-management strategies. Therefore, we recommend there is need for ecological research in terms of biodiversity conservation on Devi Pindiyan Valley and similar ecosystems.

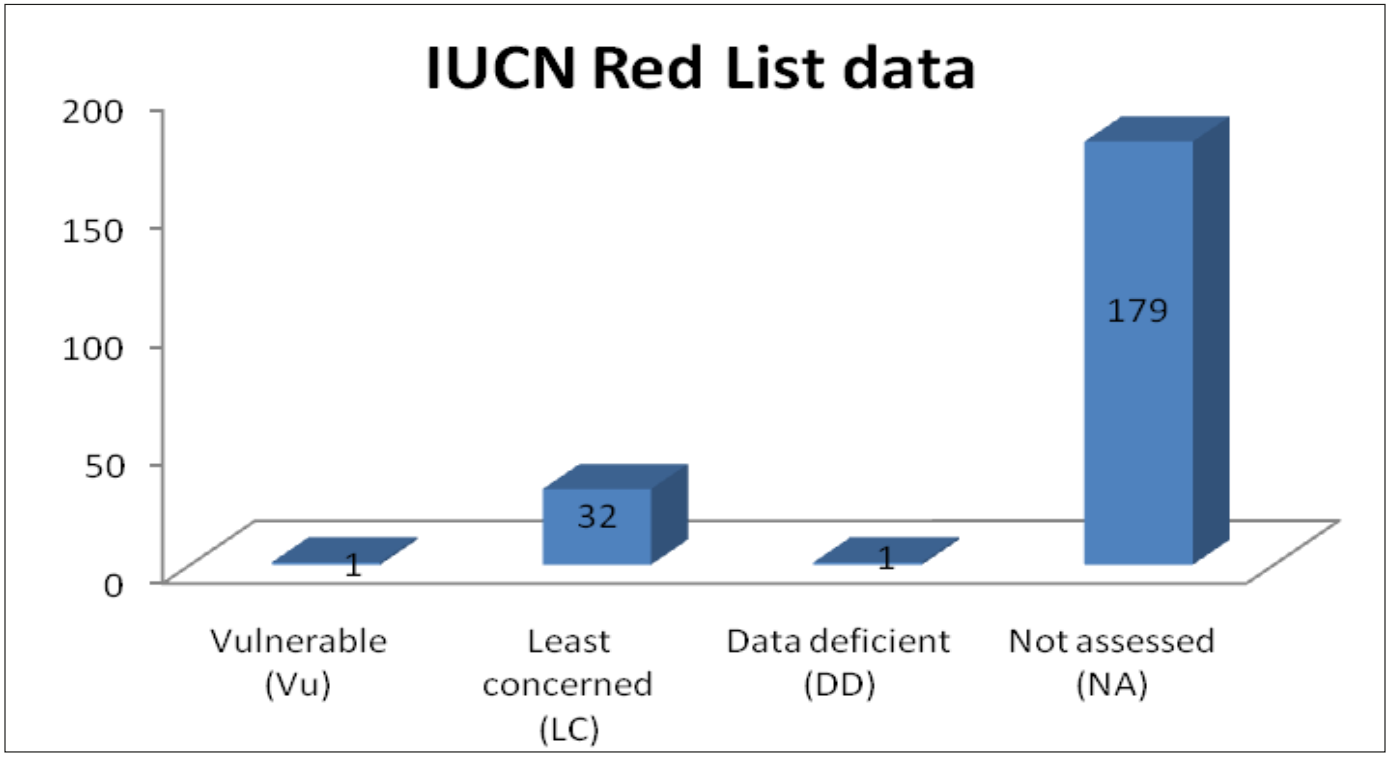


Figure 1.24.4. Graphical representation of species of Devi Pindiyan Valley as per IUCN

1.25 New Record for Kashmir Himalaya: *Artemisia verlotiorum* Lamotte (Compositae) (Published in the JETB)

Bikarma Singh, Sumit Singh, Sneha, Mudasir Nazir Bhat, Opender Surmal, Abhishek Dutta and Rajendra Bhanwaria

While studying the floristic diversity of lesser known and unexplored areas of Jammu and Kashmir State from 2013 to 2017, several angiosperm species were collected and described. One species of the genus *Artemisia* L. of family Compositae was collected on the way to Banol from Kashmir (GPS point: 34°37.790N, 74°52.538E, elevation 2461m ASL, Figure 1.25.1.). Critical studies were carried out by matching, comparing and evaluating the collected vouchers with that of the similar and allied herbarium specimens of the genus *Artemisia* deposited in Janaki Ammal Herbarium (RRLH), Jammu, Herbarium of Botanical Survey of India at Shillong (ASSAM), samples housed at National Botanical Research Institute (NBRI) Lucknow and Central National Herbarium (CNH) Kolkata. After complete scrutiny, the identity of the species was confirmed as *Artemisia verlotiorum* Lamotte. The plant is a perennial herb which grows 20–120 cm high. The stem of the plant is 30–120 cm tall, 0.4–0.6 cm in diameter, usually grooved, pubescent when young, glabrescent when mature; inner parts creamy white when dry. The leaves are pinnatifid or 4–5 partite, and the leaf segments are small, broadly ovate or linear-lanceolate, 4.7–8.2 cm long, 2–3.8 cm broad, white gland-dotted adaxially, densely gray tomentose abaxially. The petioles of the plants are 0.3–0.5 cm long; basal leaflets shortly petiolated; the basal segments are ovate, 1–or 2-pinnatisect; middle leaflets sessile, leaf segments broadly ovate, 5–8 cm long, and 3–3.8 cm broad, usually 1-pinnatisect; the upper leaflets are 3- or 5-lobed, and the leaf segments are 3 or 4 pairs, linear-lanceolate, 3–5 cm long, and 0.4–0.5 cm broad. The inflorescences are sessile, leafy and slightly pink to brownish, ellipsoid or oblong-ellipsoid, and 0.2–0.3 cm in diameter. The involucral bracts are usually oblong and obtuse with scarious margins. The receptacles are naked. The outer female florets are fertile, whereas the disc florets are hermaphrodite. The fruiting body called 'achenes' are obovoid and only ca 1 mm long, smooth and grey in colour.

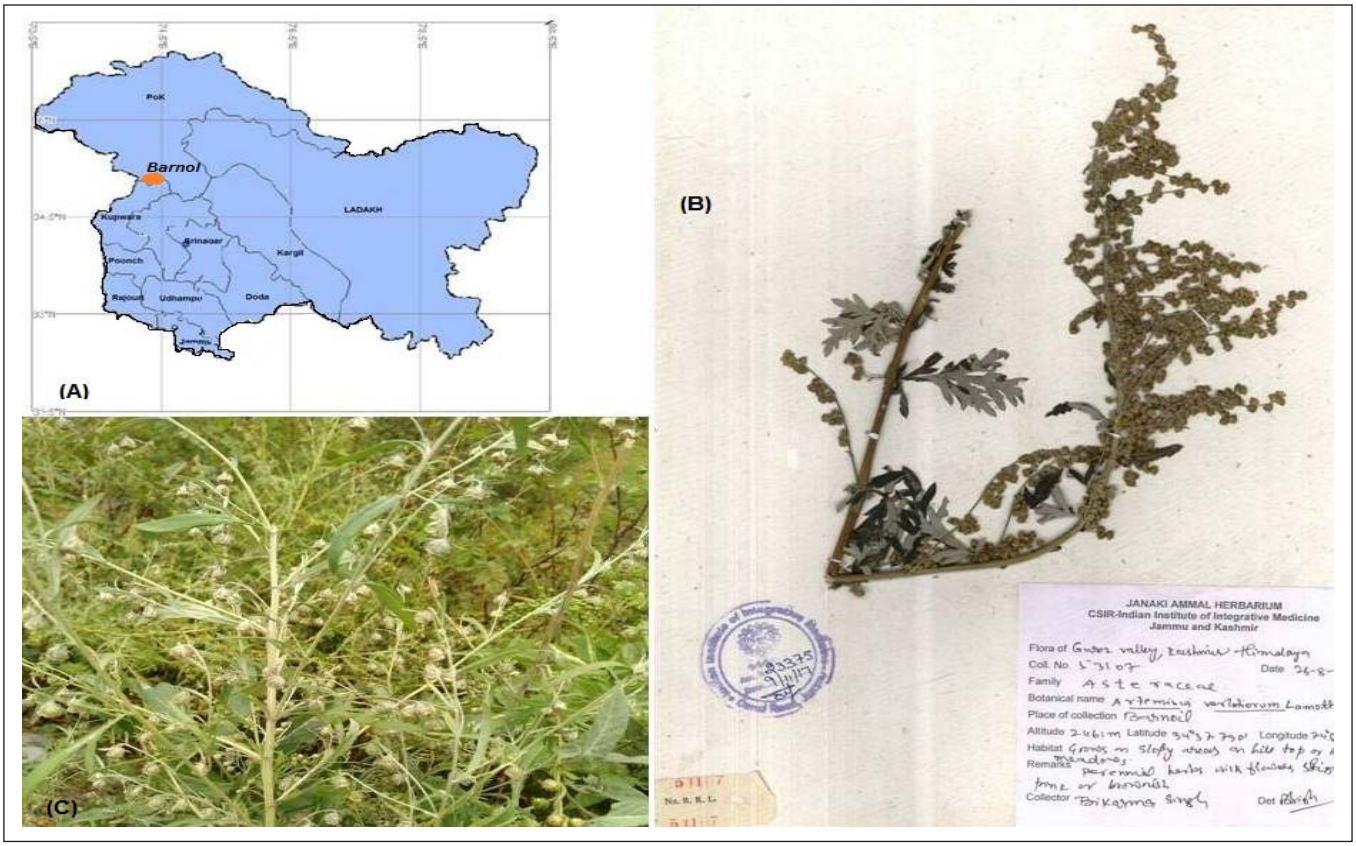


Figure 1.25.1. Location of *Artemisia verlotiorum* in Kashmir Himalaya, (A) Study site, (B) Herbarium specimen, (C) Wild habit of *A. verlotiorum*.

1.26 RRL (J) ML-4 Variety of Mint as a Rich Source of Carvone and Limonene for Value Addition and Product Development

(Abstract Published in National Conference on Mints: Prospects, Challenges and Threats, held between 24-26 February 2019 at CSIR-CIMAP Lucknow, India)

Bikarma Singh and Rajendra Bhanwaria

It has been observed from the past that the medicinal, aromatic and nutraceutical plants are a matter of special concern to human due to their therapeutic use. It has been proven that essential oils are highly effective medicine for human over hundreds of years as they can easily overcome stressful day. Natural essential oils derived from plants are used as cosmetics, perfumes and flavours in confectionary foods and beverages. Aromatherapy is frequently used to uplift mood and relieve stress, especially when combined with massage by a professional. Herbal business offers unlimited opportunity to add value for new era for development of nutraceuticals and medicines, and several value-added products are used in animal and human health care. Value addition of plants can be done directly through minor processing or indirectly through maintaining quality standard of different formulations prepared from plants. Resourgence of public interest in herbal products has created a huge market for plant based products which not only satisfies human needs, but also provides quality and safety insurance. Carvone and limonene are two natural occurring terpenoids usually found in aroma bearing plants. *Mentha spicata* L. (spear-mint), *Mentha longifolia* L. (horse-mint), *Carum carvi* L. (caraway), *Anethum graveolens* L. (dill) are major source of carvones, while limonene reported from the aroma of citrus fruit peels and *M. longifolia* var. *incana* (Willd) Dinson. These two compounds have wide applications in food, flavour, fragrance, aromatherapy and pharmaceutical industries. In the present communication, we examined RRL (J) ML-4 variety of Mint (*M. longifolia*) as a rich source for both carvone and limonene content, and have high potential for product development. Gas chromatography mass spectrometry analysis (GC-MS) has shown that the main compounds within essential oil of RRL(J)ML-4 are carvone (41.63%), limonene (38.09%), eucalyptol (4.76%), beta-caryophyllene (2.44%), laevo-beta-pinene (2.43%), beta-pinene (1.77%), alpha-pinene (1.66%), dihydrocarveol (1.38%), beta-elemene (1.21%), sabinene (1.06%) and several other useful compounds found in minor quantities. The crop was propagation through rooted suckers. The first harvesting of aerial parts can be done between 100 to 110 days of planting where crop exhibits 50% blooming. Harvesting interval of approximately 60 to 70 days is recommended between first, second and third harvest of crop. Irrigation is not recommended before 7 to 10 days of harvesting. Besides in rainy days, crop harvesting is not recommended as it results in poor quality and low oil yields. The essential oil extraction through steam distillation method for 3 to 4 hours is ideal for oil distillation. The essential oil recovery of RRL (J) ML-4 varies from 0.5-0.7%. Finally, it is very important to explore, manage and conserve available natural resources such as mint and other aromatic crops at national and international levels in a sustainable way and this will guarantee the safety and healthy life for the new generation to come.

1.27 Volatiles profiling and agronomic practice of *Cymbopogon khasianus* [IIIM (J) CK-10 Himrosa] for commercial cultivation and value addition

(Published in Edited Book: Plants for Human Survival and Medicine, Joint publication of CRC Press Taylor & Francis, UK and NIPA, India)

Rajendra Bhanwaria, Bikarma Singh and Rajendra Gochar

Aromatic grass *Cymbopogon* Spreng is one of the most important aroma bearing genus of the family Poaceae (or Gramineae) widely adapted to various agroclimatic zones, and few of them grows as wild natural vegetation. Currently 52 species recommended as accepted names under the genus *Cymbopogon* (http://www.theplantlist.org/), reported to have wide distribution in tropical to temperate regions of the world (https://www.tropicos.org/home). Several species under this genus have been reported used in traditional herbal medicine, while those known to be rich in volatile constituents have usefulness in the cosmetics, pharmaceuticals,

and perfumery industries. The volatile essential of these grasses shows various biological functions such as antimcrobial, immuno-modulatory and anti-oxidant properties. Cymbopogon plants are perennial grasses, with narrow and long leaves that are mostly characterized by the presence of silica thorns aligned on the leaf edges. Leaves bear glandular hairs, usually each with a basal cell that is wider than the distal cell. *Cymbopogon khasianus* (Hack.) Stapf. ex Bor. variety [IIIM (J) CK-10 Himrosa] is a commercial important aromatic grass belong to the family Poacae and contains high valued volatile constituents which has high demand in pharmaceutical, flavour, fragrance and cosmatic industries. This plant variety is one of the rich sources of two monoterpenoids, geraniol and ocimene. Geranoil is an alcohol frequently used as terpenoid fragrance material, and ocimene is a group of isomeric hydrocarbons. The present communication deals with the herb yields, volatile constituents and agrotechnology of CK-10 Himrosa. The volatile constituents vary from season to season and from geographic locations of cultivation.

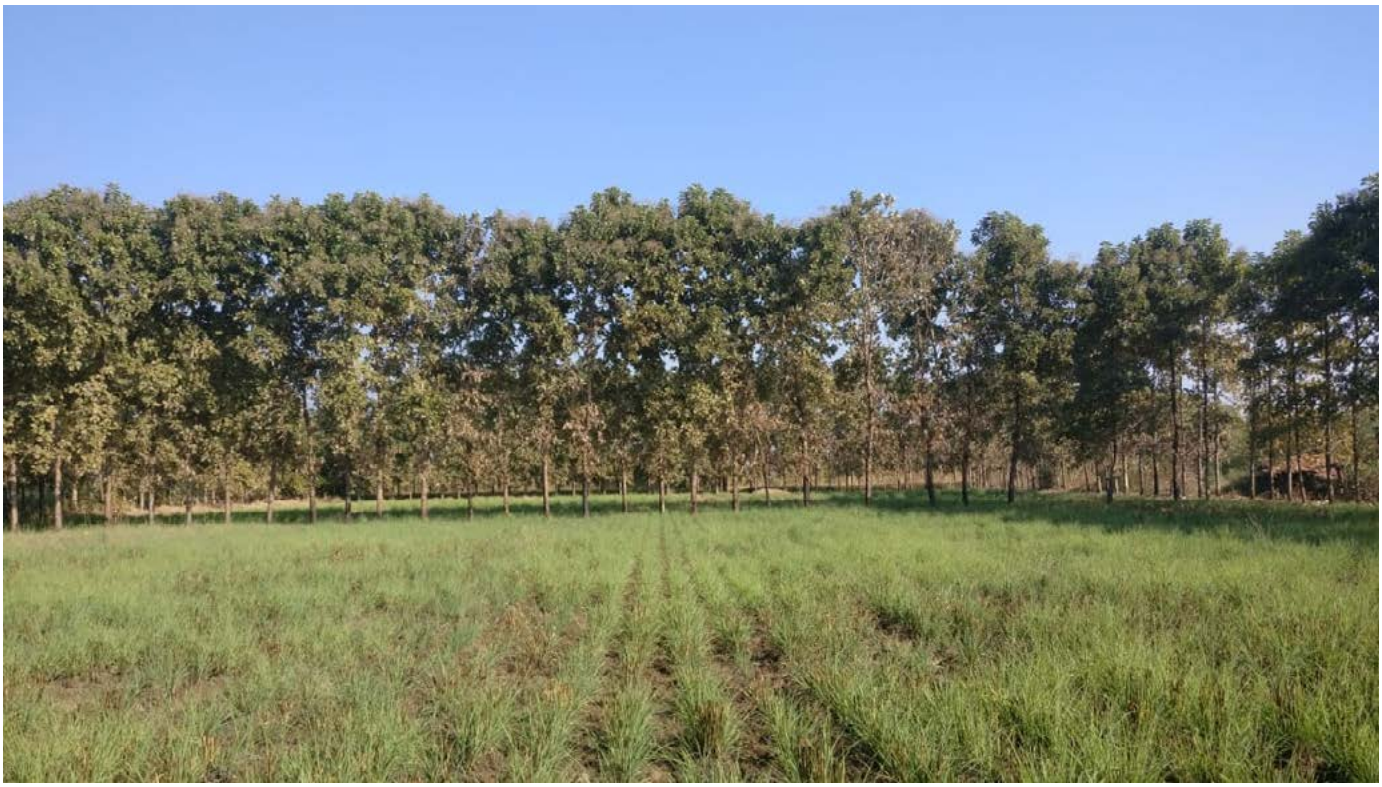


Figure 1.27.1. *Cymbopogon khasianus* as potential crop for rainfed areas

Data presented were collected from field trials and experiment works conducted on farmer field at Balesar area of district Jodhpur (Rajasthan). It has been observed that [IIIM (J) CK-10] is rich in geraniol whose percentage varies from 70-80%, cis-ocimene (10-11%), trans-cimene (5-6%), geranyl acetate (2-3%), and various others constituents present in minor quantities. For analysis of volatile constituents, Gas Chromatography–Flame Ionization Detector (GC-FID) and GC-Mass Spectrometry (GC–MS) methods developed were developed. Agronomic data indicate substantial variations in the essential oil compositions, which vary due to season of harvest and place of cultivation. This crop is hardy in nature and from future perspective; extension of these aromatic crops in rainfed and saline areas could brought un-utilized barrenlands and wastelands under cultivation. Biomass and essential oil obtained from this crop would be helpful in development of new value added products. This may serves as economics for marginal farmers and helpful in gaining international recognition after development of products in the form of perfumes, soaps, cosmetics and other products for human use.

Table 1.27.1. Volatile constituents of *Cymbopogon khasianus* [IIIM (J) CK-10 Himrosa] of Jodhpur Rajasthan

Name of compound	Retention time	(%)
p-Cymene	6.44	1.11
a- Phellandrene	7.27	1.01
cis-Ocimene	7.97	10.87
trans- Ocimene	8.24	5.36
Linalool	9.70	2.09
p-Menth-2-en-l-ol	10.42	2.16
L-Terpineol	10.91	1.22
Geraniol	14.13	73.01
Geraniol acetate	17.20	2.09
Caryophyllene	18.36	1.07

The presence of geraniol, ocimene and geranyl acetate is the main characteristic of the essential oil of CK-10 Himrosa. This plant variety cultivated is superior in terms of geraniol content as compared to other grass variety cultivated in India. Figure 3.2.2 provides the structure of major chemical constituents of IIIM (J) CK-10 Himrosa.

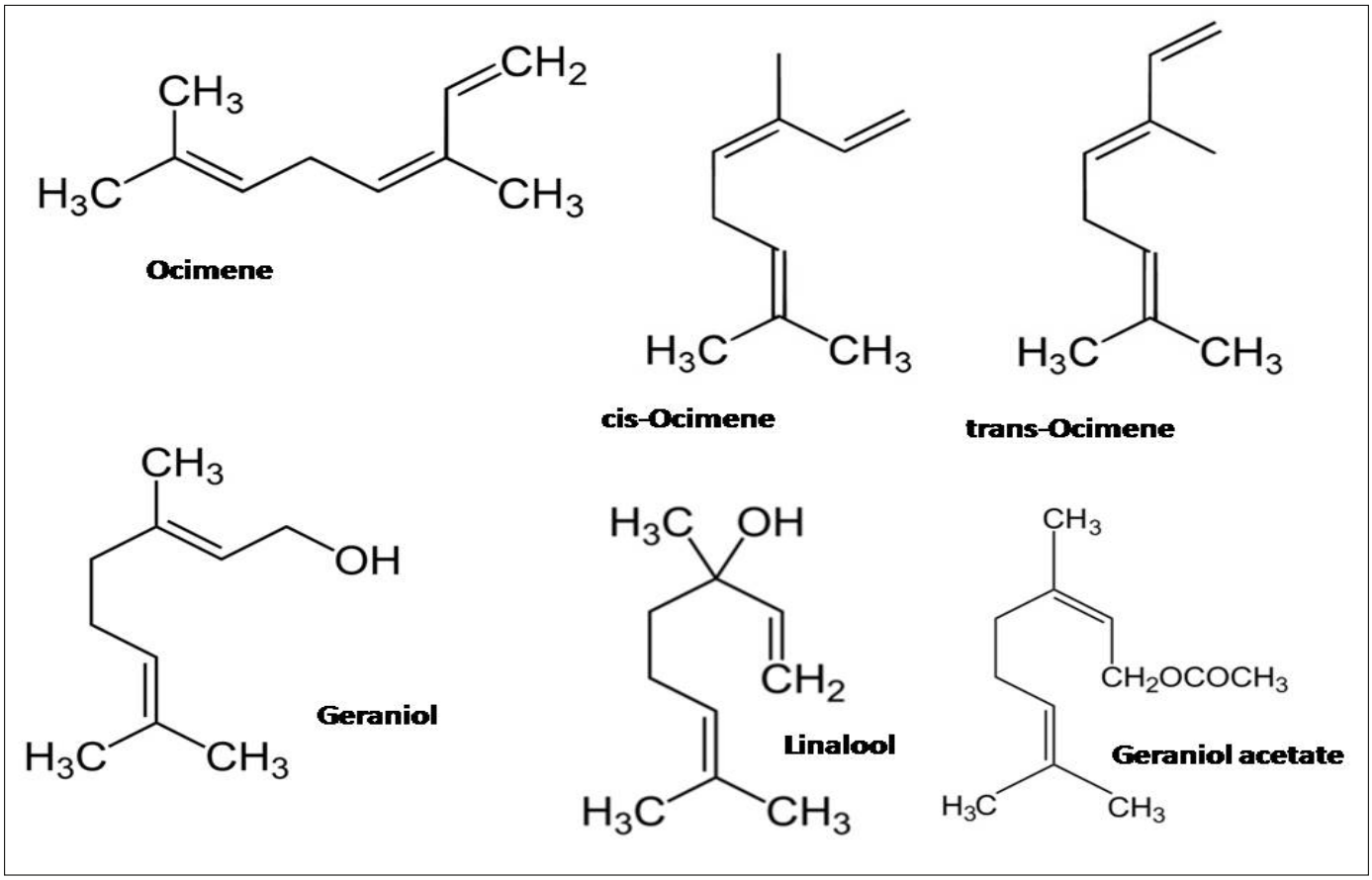


Figure 1.27.2 Structure of major essential oil constituents of CK-10 Himrosa

Geranoil rich essential oil has high demand in the International market and its price is increasing every year. The prevailing price of the essential oil of this crop in the Indian market is Rs. 1,500-2000 per kg. Under well management condition and using of all package and practices, crop will be give approximately net profit of Rs. 1 to 1.25 lakh per annum in first year and subsequently in the next year onwards.

1.28 Sale and business development through Aroma bearing crops from IIIM Jammu to boost Indian economy

Bikarma Singh, Rajneesh Anand, Abdul Rahim, Vikrant Awasthi, S R Meena and Kiran Koul

Essential oils (EOs) bearing plants have added lots of value to the growth of flavor and fragrance industries as well as boasted Indian economic and agriculture sector. The EOs is backbone in the process of globalization, which started about a decade before, and is now growing rapidly. Industrial data indicated the essential oils of tulsi, citronella, lemongrass, lavender, palmarosa, patchouli, sandalwood, tagetes, geranium and various varieties of mints are finding increasing use in formulations of aroma-based value added products, and also act as a roadway therapeutically in aromatherapy. It is believed that the herbal aromatherapy can give good effect to body without causing side effects to human's life. Besides, the usage of aromatic plants in various sector have supported the economy of the country. Perfumes, essential oils and aroma are some of the products which indicate religious values, living standards, personality development for personal use and adornment from years back. Currently, CSIR-Indian Institute of Integrative Medicine Jammu has developed agrotechnology of high yielding varieties of aroma bearing crops, and involved in captive cultivation and extension of these crops in J&K state and elsewhere in India. Important commercial valuable crops of high yielding aroma are, (1) Anant carvomint [*Mentha longifolia* (L) Hudson var. *incana* (Willd) Dinson RRL (J) ML-4]: This species of mint is hyper productive strain developed though clonel multiplication, wider adaptability (Kashmir to Kanya Kumari). It is rich in ℓ-carvone 67±5 %). It has essential oil content (0.5 to 0.9%w/w FWB) depending on season to season. It has wider acceptability shown by perfume, flavour and pharmaceutical industries. (2). Jammu Monarda (*Monarda citriodora* Cerv. ex Lag. [IIIM (J) MC-02]: This species is a rich source of thymol (about 60-75%) and better economic returns (100-125 kg/ha). This volatile oil is active against cancerous cell line (HL60), acceptability by flavour and pharmaceutical industries. It is also used as an antiseptic, expectorant and cough medication, to treat nail fungus infection. (3) Himrosa [*Cymbopogon khasianus* Bor IIIM (J) CK-10]: This species is known for acclimatized to high drought and salt tolerance ability, and is a rich source of geraniol (75-85 %). The oil is extensively used as perfumery raw material in soaps, "oral rose-like perfumes, cosmetics preparations, and in the manufacture of mosquito repellent products. The essential oil has a scent similar to that of rose oil, and named Himrosa. (4) Lemon grass (*Cymbopogon khasianus* x *C. pendulus*) [CKP-25]: Lemongrass variety developed by IIIM is an interspecific hybrid and the oil contents are 0.5%. Its main constituents are citral (80-85%). It is very useful in perfumery, flavoring & pharmaceutical industry. (5) Lavender (*Lavandula officinales*) [RRL 12]: Lavender is high altitude high value crop and is an incredible and much sought aromatic plant having significant position in trade all over the world due to its essential oil which has multifarious uses and market outlets. Main constituents are Linalool, Linalyl acetate, 1, 8 cineole, borneol, caryophyllene, terpineol, ocimenes, Lavandulyl acetate. It is useful in perfumery, flavor and cosmetic industry. (6) Rose Mary (*Rosmarinus officinalis* L.): This plant species locally called as Rose Mary is yet another high value industrial crops. The main volatile constituents are p-cymene (40-44.02%), linalool (18-20.5%), gamma-terpinene (14-16.62%), thymol (1-1.81%), beta-pinene (2-3.61%), alpha-pinene (1-2.83%) and eucalyptol (1-2.64%), which is useful in perfumery, flavor and cosmetic industry. During the reporting period, lots new partners join the business on aroma bearing crops in IIIM Jammu. Some of the main buyers are M/S Hati, Jammu, M/S Biogene Biotics, New Delhi, M/S Sankhububa International, Mumbai, M/S KLJ Resources Ltd, Mumbai, M/S Local people, Rajni, M/S Herbal Strategi, Bangalore, M/S Sankhububa International, Mumbai, M/S Exim Sugandhim, Mumbai, M/S Global Herbitek, Jammu, M/S CIMAP, Lucknow, M/S Sumit Enterprices, Mumbai, M/S Green Essence Enterprices PVT Ltd, M/S Global Herbitek Jammu, M/S Agarwal Consultant, Mumbai, M/S Ultra International Ltd, Gaziabad, M/S Sankhububa International, Mumbai, M/S Global Herbitek Jammu and M/S Ashok Jallan, Delhi.

2. GENETIC RESOURCES AND AGRO-TECHNOLOGY

2.1 Rural prosperity through promotion of aromatic crops

Rajendra Bhanwaria, Rajendra Gochar, S.R. Meena, Sumeet Gairola, Sumit G. Gandhi and Ram Vishwakarma

CSIR-IIIM is working on societal upliftment under rural prosperity through extension project of aromatic crops. Several skill development programmes were organized under aroma mission project in various states such as Tamil Nadu, Karnataka and Maharashtra in southern India. These programmes were focused on themes such as rural employment through cultivation, processing, marketing and product development of aromatics crop. Major objectives of skill development programmes were to motivate for cultivation of aromatic crops, generating employment, prevent to migration, rural upliftment and doubling the framer income, More than 1500 farmers and students of Puddukottai and Keernaure in Tamil Nadu and Doddamaragowdanahalli in Mysore of Karnataka were benefitted. Similarly, a training programme was jointly organized with KVK Kharpudi in Jalna of Maharashtra state and several farmers and business man were benefited.

2.2 Demonstration and Transplanting of aromatic crops in south India

Rajendra Bhanwaria, Rajendra Gochar, S.R. Meena, Sumeet Gairola, Sumit G. Gandhi and Ram Vishwakarma

Under this activity CSIR- IIIM, Jammu has undertaken more than 100 acres of wasteland of various regions under cultivation of different aromatic crops. The variety RRL (J) CK-10 (*Cymbopogon khasianus*) was developed by IIIM, known as 'Himrosa' belong to the family Poaceae. This variety is a hardy in nature, high drought tolerance capacity and easily cultivated in tropical and sub tropical environment. This crop having various valuable chemical compounds such as geraniol (80-85%) and geranyl acetate (10-15%), which has high demand in flavor and fragrance industries for development of aroma based products. This cultivar responds well under rainfed climatic condition and less fertile soil condition. The state Tamil Nadu, Karnataka and Maharashtra falls in these regions and having lots of rainfed areas and farmers are only depends on rain for irrigation; they cultivate their crop only in rainy session. Further demonstration, and distributed of planting material to needy farmers were undertaken. This variety is performing well and providing more income to farmers than traditional crop cultivated in these regions by them.

2.3 Installation of field distillation units at various locations in Maharashtra, Karnataka and Tamil Nadu

Rajendra Bhanwaria, Rajendra Gochar, S.R. Meena Sumeet Gairola, Sumit G. Gandhi and Ram Vishwakarma

Under CSIR's National Aroma Mission, there was a provision of installation of field distillation units at easily accessible locations near the farmer fields where extension of aromatic crops was undertaken. Previously, we have carried out extension of *Cymbopogon nardus* (CN-5) and *Cymbopogon khasianus* (CK-10), *Ocimum gratissimum* (RRL-Og-14) and *Monarda citriodora* in approximately 100 acres of land, benefiting more than 100 farmers. In order to enable them to utilize their aromatic crops, distillation units were installed and they were provided training for extraction of oil. Further, an attempt was made to establish linkages of these farmer groups with industries that buy essential oils. We also helped farmers through free-of-cost analysis of their essential oils.

2.4 Opportunity of higher income generation to growers through extension of CSIR Agro-technology in Bundelkhand region, India

Sabha Jeet, Dhiraj P. Singh Gurjar, TundupNamgial,C. P. Singh, V.P Rahul, Rajendra Bhawanria, Sumit Gandhi, Ram ji and Ravindra Verma

CSIR-IIIM, Jammu provide good opportunity to farmers of Bundelkhand region of M.P. and U.P. through the extension of CSIR-Agro-technology by cultivation, processing and marketing of Medicinal and Aromatic crops in rainfed, dryland and waste land. Bundelkhand region is comprised 14 districts consisting in U.P. and M.P. where the more than 65-70% area comes under the rainfed and proper irrigation facility is not existing. The soil of this area is heavy clay, loamy to sandy, deep red to grey and marginal/ problem soil mixed with stone and gravel. Farmers of this region facing livelihood challenges due to continuous drought. Therefore, all agricultural crops difficult to grown due to moisture stress causes low productivity and poor economic condition in this region. To enhance the economic status of farmers living in these regions, Department of Biotechnology, Govt. of India, Ministry of Science and Technology, sponsored project in this region on "Demonstration of cultivation, processing and value addition of selected aromatic crops in Bundelkhand region". Promotion and growing of following aromatic plants of CSIR agrotechnology viz., Lemongrass (CKP 25), Rosagrass {IIIM (J) CK-10 and RRL (J) CN 5}, Jammu Monarda {IIIM (J) MC 02} and Ocimum species (Og 14 & Ob 15) to utilize and development of wasteland/ alternate land use system in the area.These aromatic plants were demonstrated/ cultivated at >350 farmers field in > 300 acres area up to March, 2020.

Performance of Lemongrass, *vari.*CKP 25, *Cymbopogon khasianus x Cymbopogon pendulus*

CKP-25 is *Citrol rich* novel variety developed by CSIR-IIIM, Jammu. This variety was mostly recommended in areas where irrigation facility is available since, this variety is lowmoisture stress tolerance. In Bundelkhand region this variety was cultivated in rainfed and dryland condition (where at least one life saving irrigation facility available) in the soil Mar (Heavy clay), Kabar (Coarse grained mixed with parent rock, stone and gravel) and Parwa (loamy to sandy in texture brownish and deep red to reddish grey) and transplanted in District, Jalaun (U.P.), Jhansi (U.P.), Datia (M.P.) and Lalitpur (U.P.) in > 50 Acre field in month of December, July, February and March in which > 54 farmers benefited. This variety transplanted in December performed well during that time plant receive rainfall of North-east monsoon. The mortality percentage was found 10-15% in December, 30-40% in February, 45-50% in March and 20-25% planted in June- July. The plant height was 0.80 to 1.20 metre (average 95 cm) and the highest tillers 147 number was recorded. On an average 50-60 tillers were recorded in different location of the district. The average green herbage yield 70-90 quintal was recorded in first year in rainfed area and 110- 125 quintal herbage in irrigated area. Supply of moisture is significant factor for the production of Lemongrass (CKP 25). However, moisture stress is considered to be one of the environmental factors responsible for accumulation of secondary metabolites in plant. Moisture stress could not affect the quality of essential oil. The essential oil recovery was found to be higher varies from 0.6% to 1.2% in different district of this region. Based on the recovery percentage 70- 80 kg oil obtained in one acre of land in first year. The sale value of essential oil was Rs. 1000-1500/- kg. The grass return was obtained by farmers Rs. 70,000-80,000/ acre in first year.

Figure 2.4.1. Glimpses of Lemongrass (CKP 25) cultivated in Bundelkhand region

Performance of Rosagrass, *vari.* IIIM (J) CK 10 (*Cymbopogon khasianus*)-Himrosa and RRL (J) CN 5 (*Cymbopogon nardus*)

*Cymbopogon khasianus (*Himrosa) and *Cymbopogon nardus* variety is Gereniyal rich and tolerate high moisture stress. This varieties introduced at farmers field of district Jalaun (U.P.), Jhansi (Jhansi), Lalitpur (U.P.), Mahoba (U.P.), Sagar (M.P.), Datia (M.P.), Tikamgarh (M.P.) and Niwari (U.P.) in Bundelkhand region.The soil of this region is locally called Mar (Heavy clay), Kabar (Coarse grained mixed with parent rock, stone and gravel) Parwa (loamy to sandy in texture brownish and deep red to reddish grey) having the soil pH 80- 8.5. These two varieties were planted in > 175 acres of rainfed land in which 230 farmers were benefitted. Both the varieties were performed well even under the extreme moisture stress condition and recorded highest 1.4-1.5-meter plant height (average 1.00 meter) and highest 106-134 number of tillers (average nos. 55-65). On average 90-100 quintal green herbage were obtained in one acre in first year. The secondary metabolites were found highest in moisture stress condition. The essential oil recovery percentage was found higher 0.5-0.8% and 60- 65 kg/ acre essential oil produced in first year. The value of essential oil is Rs. 1500- 2000/- kg and farmers obtained Rs. 80,000- 90,000/- gross income per acre in first year.

Figure 2.4.2. Glimpses of Rosa grass IIIM (J)CK 10 (Himrosa) and RRL (J)CN 5 cultivated in Bundelkhand region

Performance of Jammu Monarda (*Monarda citriodora*) *vari.*IIIM (J) MC 02

Jammu monarda is an annual aromatic plant and introduced by CSIR-IIIM, Jammu. Monarda is known for its essential oil and the major chemical constituent present called Thymol. Monarda can easily cultivated in well drained sandy loam soil where assured irrigation facility exists. In Bundelkhand region Jammu monarda introduced and demonstrated in 05 acres of area in the district Jalaun (U.P.) and Jhansi (U.P.) in irrigated land. The soil of this region was heavy clay locally called Mar having soil pH 7.5-8.0. Seed sown in Nursery was raised in November and December and transplanted 45 days old seedlings in December and January, keeping with the plant and row distance was 30x30 cm. The plant was taller, a height of 80 cm with the 2-3 primary branches. The mortality rate of plant was very high (30-40%) in heavy clay soil, therefore, plant population was not found satisfactory. Harvesting was done in May, only 15-20 quintal green herbage was obtained in one acre of land area. However, secondary metabolites were found higher. The essential oil recovery was higher and varies from 0.8 to 1.0%. On an average 08-12 kg essential oil produced by farmers in one acre of land. The value of essential oil is varying up to Rs. 2000/ kg and farmers obtained only Rs.15,000- 25,000/- in per acre of area.

Figure 2.4.3. Glimpses of Jammu Monarda {IIIM (J) MC 02} cultivated in Bundelkhand region

Processing of Aromatic plants

Processing is one of the most important processes for extraction of essential oil from the green/ dry herbage of aromatic plants to obtained essential oil after the harvest. CSIR-IIIM, provide 04 numbers of distillation units to farmers in free of cost and installed at the Government Institute/ panchayat land of village cluster formed by the farmers in Bundelkhand region in first year. The MS distillation unit having capacity of 500 kg and installed in district Jhansi (02 nos), Jalaun (01 nos.) and Lalitpur (01 nos.).

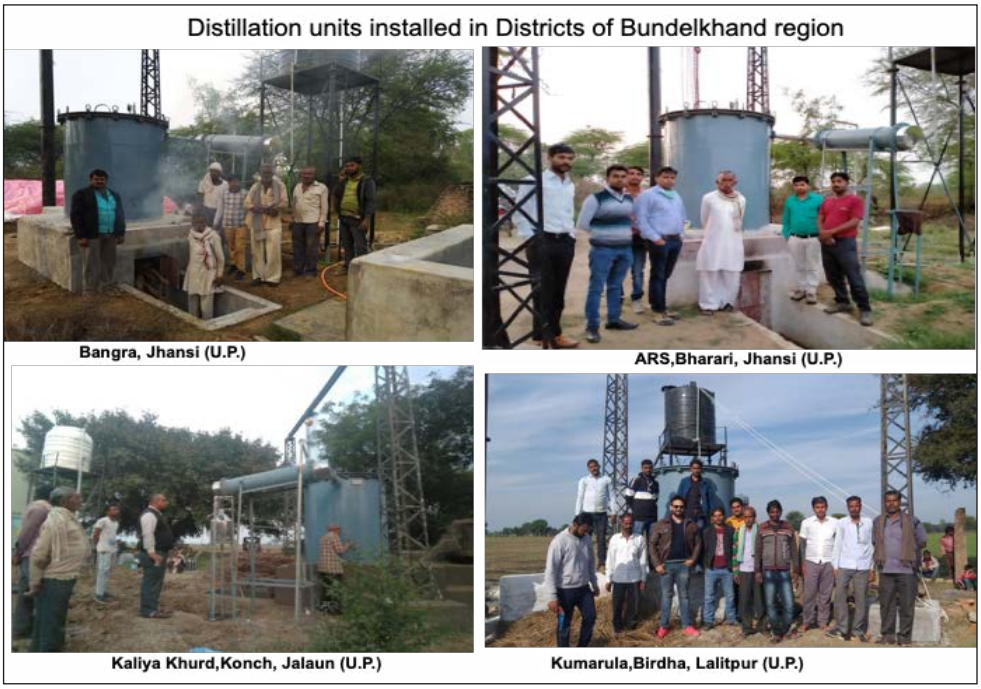


Figure 2.4.4. Glimpses of distillation unit installed in different districts of Bundelkhand region

2.5 Expansion of CSIR Agro-technology through awareness cum training programmes in Bundelkhand region, India

Sabha Jeet, Amit Kumar, Chandra Pal Singh, Indrapal Verma, Jaganath Pal, Kaushal Kumar, Rishikesh Meena, Shyam P. Singh, Shweta Pandey, Amit Kumar Singh, S.R. Meena, Rajendra Gochar, Nupun Kumar Pandey

CSIR- Indian Institute of Integrative Medicine (IIIM) Jammu organized >25 Awareness- cum-Training programmes on cultivation, processing and marketing of medicinal and aromatic plants suitable for Bundelkhand region under Department of Biotechnology, sponsored Bundelkhand project and CSIR- Aroma mission. This awareness cum training programme organized under the guidance of Dr. Ram A. Vishwakarma, Director, IIIM, and Jammu in different district *viz.,* Jhansi (U.P.), Lalitpur (U.P.), Jalaun (U.P.), Mahoba (U.P.), Sagar (M.P.), Datia (U.P.), Tikamgarh (M.P.) and Niwari (U.P.). The training programme organized with the active co-operation of Bundelkhand University, Jhansi, Krishi Vigyan Kendra, Lalitpur, Krishi Vigyan Kendra, Sagar, Krishi Vigyan Kendra, Mahoba and Regional Agricultural Research Station, Jhansi and Aravalli Biotechnology, Sagar. The overall objectives of the different programmes to explore the CSIR Agro-technology of targeted commercial Medicinal and aromatic plants and their package and practices, suitable for rainfed and kandi areas among the farmers/ growers of Bundelkhand region. CSIR developed varieties such as Lemongrass (CKP-25 & CPK-F2-38), Rosagrass (RRL (J) CN5 & IIIM (J) CK-10), *Ocimum* species (Og 14 & Ob 15) and Jammu monarda (IIIM (J) MC 02) varieties were key crops discussed at the event. More than >3000 farmers/ growers from these different districts were participated and share their experiences of growing medicinal and aromatic crops of CSIR developed technologies. Farmers took keen interest in adopting the cultivation of medicinal and aromatic plants, as suggested in the training programme.

Figure 2.5.1. Glimpses of training cum awareness programmes in Bundelkhand region.

2.6 Entrepreneurship Development Programme on Medicinal and Aromatic Plants Jointly Organized by CSIR-IIIM Jammu and J&K-ITCO Limited, Jammu

VP Rahul, Bikarma Singh, Sumeet Gairola, SabhaJeet, Rajendra Bhanwaria, SR Meena, Firdoous Ahmad Mir, Rajendra Gocahr, Chandrapal Singh, Anil Kumar Katare, Amit Kumar and Meenu Katoch.

One month (*w.e.f.* 17thDecember 2019 to 16th January 2020) Entrepreneurship Development Programme (EDP) for farmers, students, NGOs and Industrial participants were jointly organized by CSIR-IIIM, Jammu and J&K-ITCO Ltd., on medicinal and aromatic plants (MAPs). It was a joint venture company of the central and state government financial and industrial infrastructure enterprises, for promotion of the commercially valuable MAPs growing in J&K regions. This programme was designed especially keeping in view the needs of small and marginal farmers, whereby, through this, it may boost farmers' economy through cultivation MAPs and by using recent scientific interventions particularly targeting for rain-fed and degraded waste-lands. This programme and certificate course focused on practical intensive hands on experiences, enough theoretical basis to better understand the subject involves and power-point lectures undertaken by renowned scientists and staff of this institute. The main idea behind this programme was to contribute by building the desired capacity and ability of advancement in farmers and their interest in the cultivation of medicinal and aromatic plants, adding the skill of processing and marketing technologies for value addition, and hence, it may thereby enhancing the ability of farmers to respond to industries and fulfils the desired needs of society and individuals doubling of income. During the event organized, 25 numbers of participants from different districts of Jammu and Kashmir, Punjab and Uttar Pradesh were called for and enrolled in the programme EDP. The programme was successfully completed under the guidance of worthy Director, Dr. Ram Vishwakarma, CSIR-IIIM Jammu. This programme has been jointly sponsored by CSIR-IIIM Jammu and National Research Development Corporation (An enterprise of DISR, Ministry of Science & Technology), Govt. of India. On the first day, Er. Rajneesh Anand, Chief Scientist, of this institute inaugurated the function and cheered session among the participants of one month EDP, by highlighting the importance of the programme and educated the members about significance outcomes in near future to come. Dr. Dhiraj Vyas, Head of the Division, Genetic Resources and Agro technology Division chaired the inaugural session of the program and held formal interaction with all the participants of EDP at the Farmer's Training Centre located at IIIM Chatha Farm, and spoke about importance of medicinal plants. Dr. VP Rahul, Scientist of Genetic Resources and Agrotech. Division, was the main Coordinator deputed for the function and exhibited the blueprint of the whole course and pointed from the beginning about the importance of MAPs in current scenario, and how this institute will play role in this programme, citing an example of ongoing CSIR-Aroma Mission programme and completed JAAG programme. He also focused on criticalness of significant worth planting material, crop money related issues and the activity of CSIR agro-advancement in subtleties of grassroots game plan in farms. Mr. Sanjeev Dogra, CEO, JK-ITCO representing JK-ITCO Ltd. was of equal attraction and welcomed the Chief Guest and all 25 participants enrolled in EDP. At the concluding remarks, Dr. Sabha Jeet, Scientist and Farm In-charge, Chatha delivered a vote of thanks and discussed the importance of farming in the current aspects and how Farm-like Chatha has been contributing the emerging economic society of India.

The detail of key activities of the programme is provided in Table below.

LECTURE TOPIC	SPEAKER	TYPE OF PROGRAMME	HELD AT
Introduction of ongoing project on CSIR-AROMA MISSION	Dr. Sumeet Gairola, Senior Scientist	Theory	Chatha Farm
Survey, collection and identifications of medicinal and aromatic plants	Dr. Bikarma Singh, Senior Scientist	Theory and Practical	Chatha Farm & Main Campus

LECTURE TOPIC	SPEAKER	TYPE OF PROGRAMME	HELD AT
Agro technology of high value lemongrass, Rsemarry, and Salvia species and their promotion for social upliftment.	Dr. VP Rahul, Scientist	Theory and Practical	Chatha Farm
Importance of soil and climatic condition for aromatic crops	Dr. Rajendra Bhanwaria, Scientist	Theory and Practical	Chatha Farma & Main Campus
Jammu Monarda and Rosagrass cultivation and its processing in Fixed Distillation Unit.	Dr. SR Meena, Sr. Technical Officer(1)	Theory and Practical	Chatha Farm
Nursery management and lavender plantation in Kashmir.	Dr. Firdoous Ahmad Mir, Scientist	Theory and Practical	Chatha Farm
Package practices of *Ocimum* spp cultivation, processing and marketing.	Dr. SabhaJeet, Scientist	Theory and Practical	Chatha Farm
Clevenger type distillation method (in Laboratory conditions) and pilot scale by fixed and mobile distillation unit.	Rajendra Gocahr, Technical Assistant	Theory and Practical	Chatha Farm
Intercropping of medicinal and aromatic plants	Chandrapal Singh, Technical Assistant	Theory and Practical	Chatha Farm
Post harvest management of MAPs; Distillation and extraction for quality products in lab scale and industry.	Er. Anil Kumar Katare, Senior Scientist	Theory and Practical	Main Campus
Identification of essential oil and essential oil storage	Mr. Amit Kumar, Technical Assistant	Theory and Practical	Main Campus
Essential oil and its value additions	Dr. Meenu Katoch, Senior Scientist	Theory	Main Campus
Characteristics of entrepreneurs and why require entrepreneurship in medicinal/aromatic Plants Cultivation and distillation-	Mr. Binoy Kumar (J&KITCO)	Theory	Chatha farm
Idea of Formulation of techno economic project report on cultivation of medicinal/Aromatic Plants processing and distillation.	Mr. Binoy Kumar (J&KITICO)	Theory	Chatha Farm
How to conduct Market Survey on essential oil.	Mr. Binoy Kumar (J&KITICO)	Practical	Local Market

During the whole activities under EDP, an evaluation and monitoring committee lead by Mr. Aditya Sharma, Technology Transfer Analyst, NRDC, New Delhi visited and graded excellent task undertaken by IIIM and J&K-ITICO. At the end of the function, certificates to all participants were issued by this institute and J&K-ITICO. Feed-backs from all the participants were recorded and all graded the programme was excellent and motivating thanking this institute.

2.7 Allelopathy as a tool to influence essential oil profile of *Mentha piperita L.*

Sougata Sarkar, Pooja Saraswat, Amit Kumar, Indrapal Verma, Chandra Pal Singh, Amit Kumar and VP Rahul

Allelopathy is an interesting phenomena/mechanism of plant interference mediated by the release of plant produced secondary metabolites or decomposition products of microbes to the aerial or soil environment in natural as well as cultivated ecosystems. Allelochemicals are released into the soil rhizosphere by many ways like volatilization, decomposition of residues and root exudation. A number of plant organs may be instrumental in exhibiting allelopathic interaction like foliage, flowers, roots, bark and mulch. Although defoliation is considered to be the most common form of this activity as leaves fall to the ground, decompose and release allelochemicals to the soil. The allelochemicals present in them spread along the soil to affect nearby plants. Trees too exhibit allelopathy to protect their space by pulling more water from the soil, so that other competing plants cannot thrive nearby. Other allelopathic plants channel their allelochemicals to impede growth and development of nearby competing plants. The potential impacts of using the benefits of allelopathy on agricultural perspective have been studied and exploited in detail. Putnam and Duke (1974) first explored the possibility of using crops having allopathic effect to suppress weeds in agricultural systems which later paved way to developing weed-suppressive crops and later described rotational crops, intercrops or cover crops for effective weed suppression. Classical breeding methods have however not been employed to produce effective allelopathic crops with end benefits may be because of multigenic nature of allelochemical biosynthesis. The earlier allelopathic research was mainly focused on the detrimental effects of allelopathic plants or their residues on cultivable crops growth and yields. In other words the paradigm was majorly concentrated on the negative effects or non-beneficial attributes of allelopathy. But now the negative concept of allelopathy is observing a paradigm shift and allelopathy is being thought to be a contributor in enhancement of secondary metabolite profile of economically important aromatic crops. Most recently, the number of publications in the field of allelopathy has increased exponentially as physiologists, soil scientists, weed scientists and natural products chemists continue to study this challenging area. The present investigation was carried out to determine whether *Rauvolfia tetraphylla* L can exhibit allelopathic effect on *Mentha piperita* L in a co-cultivation condition (Figure 2.7.1). Thereby exploring the possibility of exploiting the phenomena of allelopathy in relation to the alteration of secondary metabolite profile in essential oil of *Mentha piperita* L.

Figure 2.7.1. (a) *Mentha piperita* (check) growing alone (b) *Mentha piperita* and *Rauvolfia tetraphylla* (experiment) growing in co-cultivation state.

Rauvolfia tetraphylla L is a member of Apocynaceae, is a bush or small tree. It has been cultivated widely both as an ornamental plant and for use in traditional medicine. It contains indole alkaloids like serpentine, reserpine, serpentinine etc. *Mentha piperita* L is a member of Lamiaceae commonly called as peppermint. It is a herbaceous, rhizomatous, perennial plant that grows to a height of 30–90 cm and has smooth stems. The rhizomes bear fibrous roots. The leaves are 4–5 cm long and 1.5–3 cm broad. They are dark green with reddish veins, have an acute apex and coarsely toothed margins. This plant is a source of menthyl acetate, menthofuran, menthone, iso-menthone, pulegone, menthol (Figure 2.7.2) etc. It is among the oldest herbs used for both culinary and medicinal products. Both the plants were available at the Research Station, Chatha, CSIR-Indian Institute of Integrative Medicine (IIIM), Jammu (India) (Figure 2.7.3).

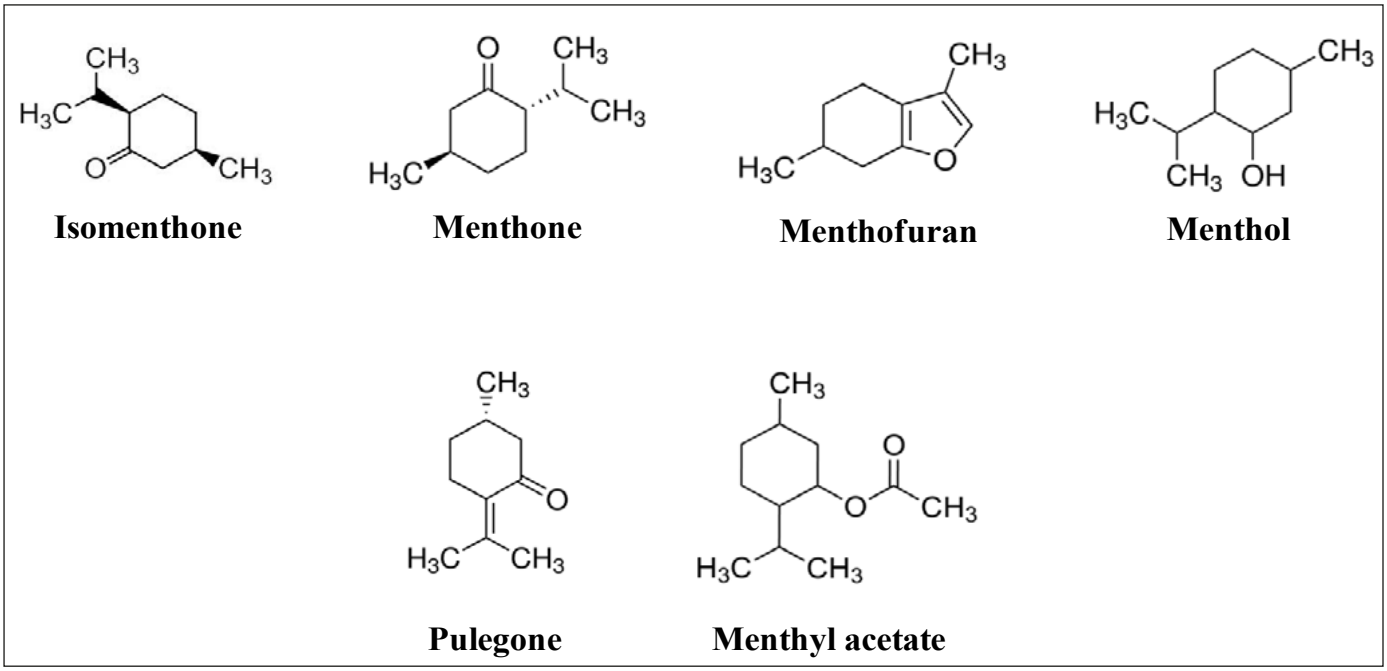


Figure 2.7.2. Structures of chemical compounds identified in GCMS

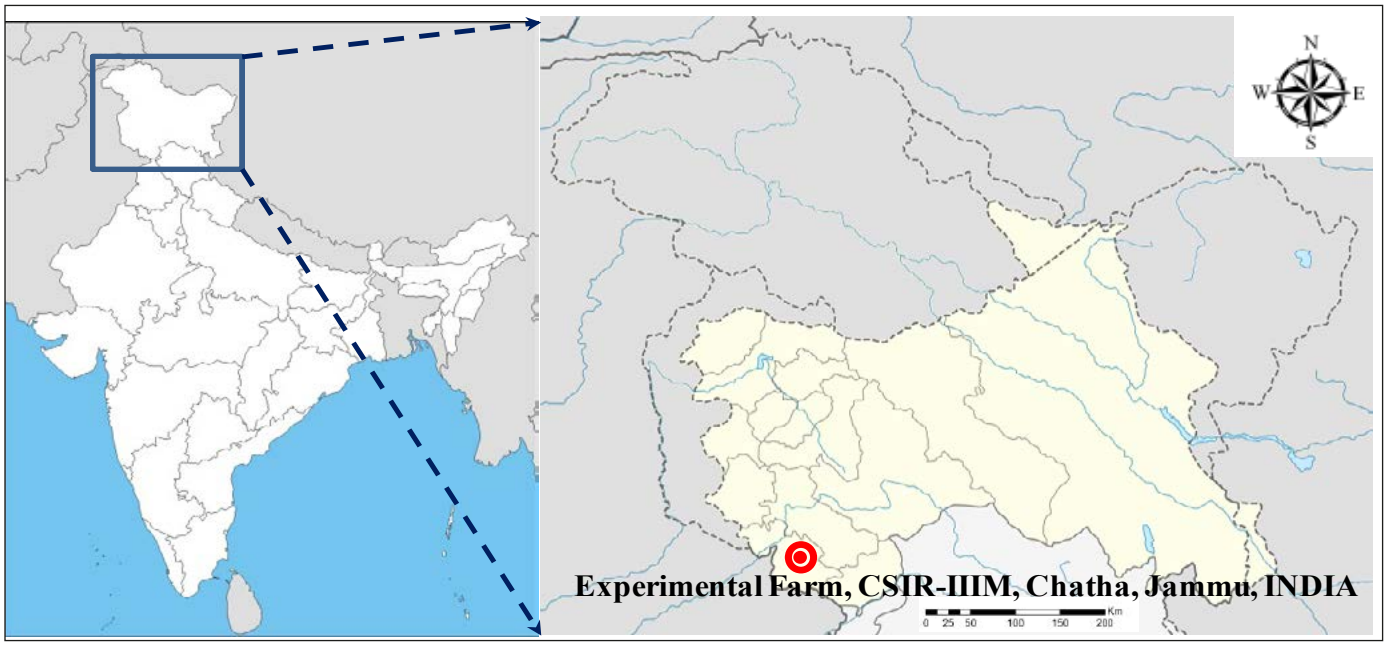


Figure 2.7.3. Site of experimental farm.

Morphometric observations were recorded for statistical analysis from ten randomly chosen plants from each treatment with respect to six important characters as following: plant height (the length of the erect plants from the ground surface to the shoot apex was measured in centimeters), number of branches (total number of branches present in a plant), leaf length (length from the apex to the base of lamina measured in centimeters), leaf breadth (measurement of the widest part of the lamina in centimeters), fresh weight (weight of the freshly harvested biomass in grams) and oil yield (after hydro-distillation, the amount of oil in milliliters obtained from a gram of freshly harvested biomass). The data for all the above traits were collected in two time intervals – after 95 days and after 125 days of plantation. The mean data was subjected to statistical analysis available in our Department. The GC-MS analysis of each sample was carried out on Agilent (S-80) series GC-MS equipped with a Combi Pal auto-sampler. The columns used were Agilent J&W DB-5 GC capillary column (30 m × 0.25 mm i.d., 0.25 μm) DB-5. Helium was used as the carrier gas. The column temperature was initially programmed at 60°C held for 5 min and increased to 280°C at 10°C/min for 27 minutes through splitless mode. Injector and detector temperatures were 250°C. The ionization energy was 70eV and a mass range of 45–500 AMU. The management of the GC-MS system, parameter settings for GC and mass spectrometry, data receipt and processing were performed using Agilent Chemstation. The compounds were identified by using NIST library. ANOVA represents highly significant ($p<0.01$) differences for the traits plant height (cm), leaf breadth (cm) and fresh weight (g) while significant ($p<0.05$) differences appear in number of branches, leaf length (cm) and oil yield (ml/g) as evident from the table 2.7.1. GC-MS results after ninety five days of growth indicated the presence of 1.87% menthyl acetate in check whereas 10.26% menthyl acetate in experiments and 22.36% menthofuran in check whereas 26.02% menthofuran in experiments (Table 2.7.2, Figure 2.7.4). Again, 23.98% menthone in check whereas 8.34% menthone in experiments, 4.07% iso-menthone in check whereas 1.40% iso-menthone in experiments and 12.13% pulegone in check whereas 11.26% pulegone in experiments (Table 2.7.2, Figure 2.7.4). Menthol was neither detected in check nor in experiments as evident from the table (2.7.2).

Table 2.7.1. ANOVA for six traits of *Mentha piperita.*

Sl No	Traits	Replications (MS) df=9	Treatments (MS) df=1	Error (MS) df=9
1	Plant Height (cm)	7.12	245.00**	2.69
2	Branches	0.69	0.80*	0.13
3	Leaf length(cm)	0.005	0.06*	0.01
4	Leaf breadth(cm)	0.02	0.20**	0.01
5	Fresh weight(g)	4.61	143.11**	2.89
6	Oil yield(ml/g)	0.002	0.013*	0.002

Where, * = $p < 0.05$; ** = $p < 0.01$, respectively.

Table 2.7.2. Variation in essential oil concentration as per GCMS analysis

Sl no	Compounds with a difference in concentration	Observation after 95 days		Observation after 125 days	
		Check (%)	Experiment (%)	Check (%)	Experiment (%)
1	Menthone	23.98	8.34	15.13	Not detected
2	Isomenthone	4.07	1.40	10.11	9.13
3	Menthyl acetate	1.87	10.26	2.58	9.75
4	Menthofuran	22.36	26.02	15.44	20.65
5	Pulegone	12.13	11.26	12.17	9.504
6	Menthol	Not detected	Not detected	15.47	14.81

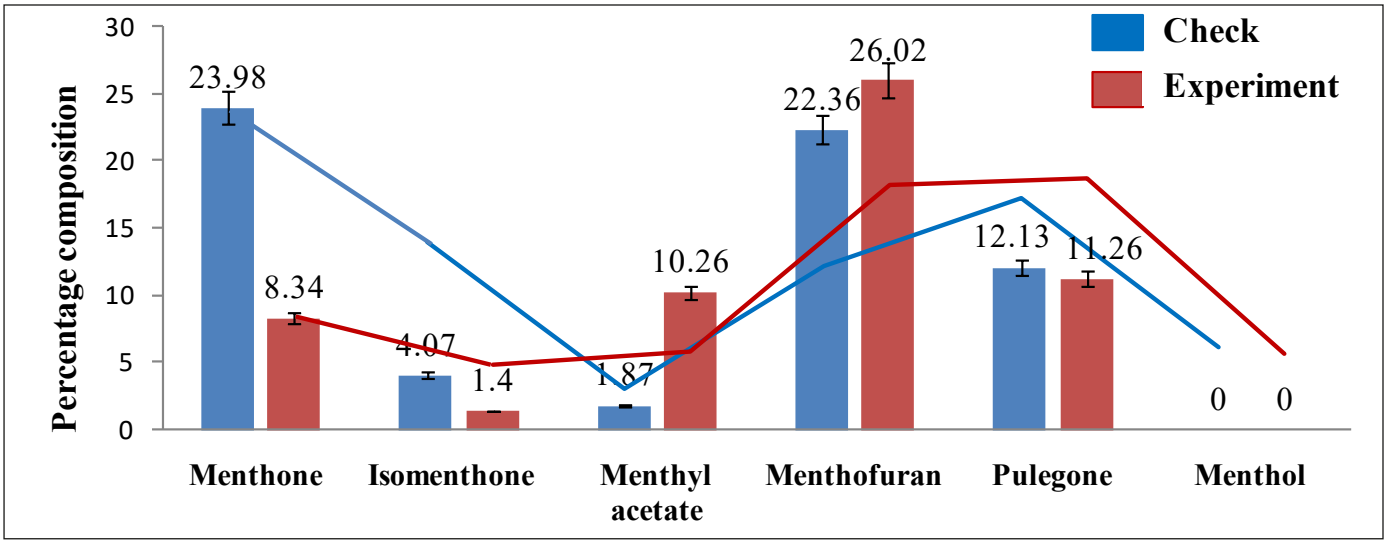


Figure 2.7.4. Components of essential oil of *Mentha piperita* after 95 days of planting

GC-MS results after one hundred twenty five days of growth indicated the presence of 2.58% menthyl acetate in check whereas 9.75% menthyl acetate in experiments and 15.44% menthofuran in check whereas 20.65% menthofuran in experiments (Table 2.7.2, Figure 2.7.5; 2.7.6 and 2.7.7). Again, 15.13% menthone in check while menthone was undetected in experiments and 10.11% iso-menthone in check whereas 9.13% iso-menthone in experiments (Table 2.7.2, Figure 2.7.5). Again, 12.17% pulegone in check whereas 9.50% pulegone in experiments and 15.47% menthol in check whereas 14.81% menthol in experiments (Table 2.7.2, Figure 2.7.5).

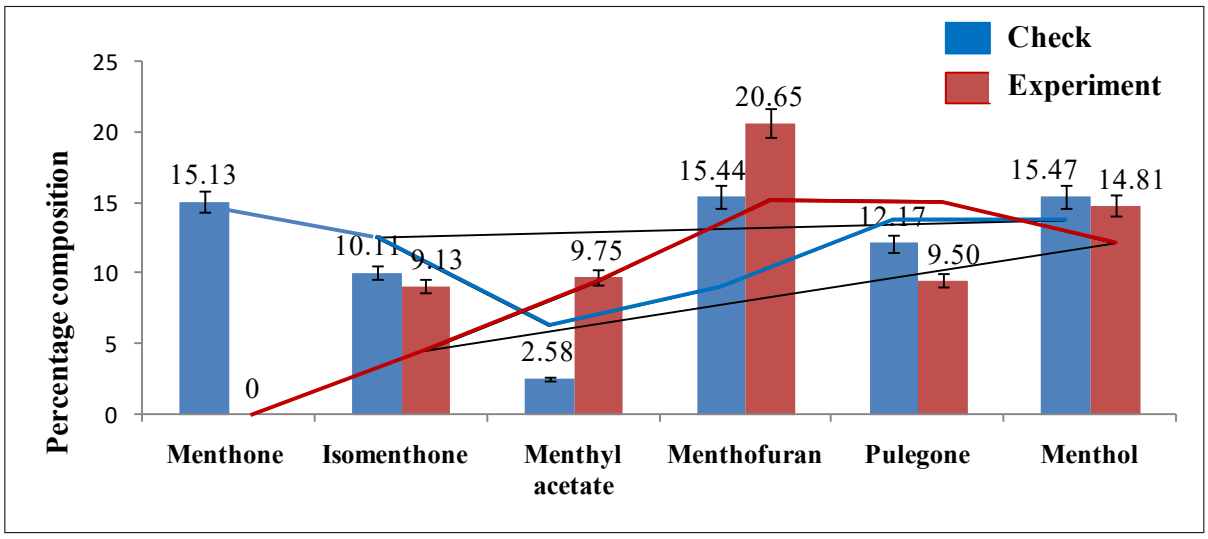


Figure 2.7.5. Components of essential oil of *Mentha piperita* after 125 days of planting

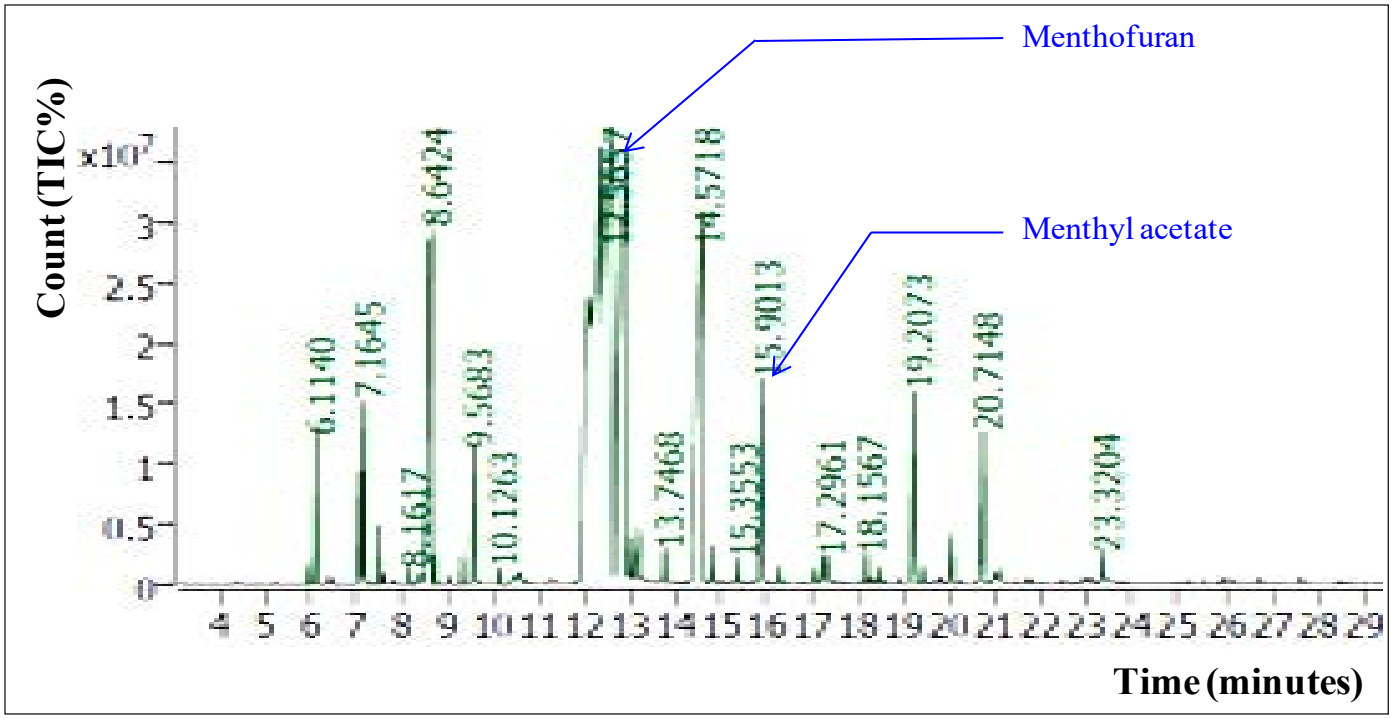


Figure 2.7.6. GCMS chromatogram of menthyl acetate and menthofuran components of *Mentha piperita* (check) after 125 days of planting.

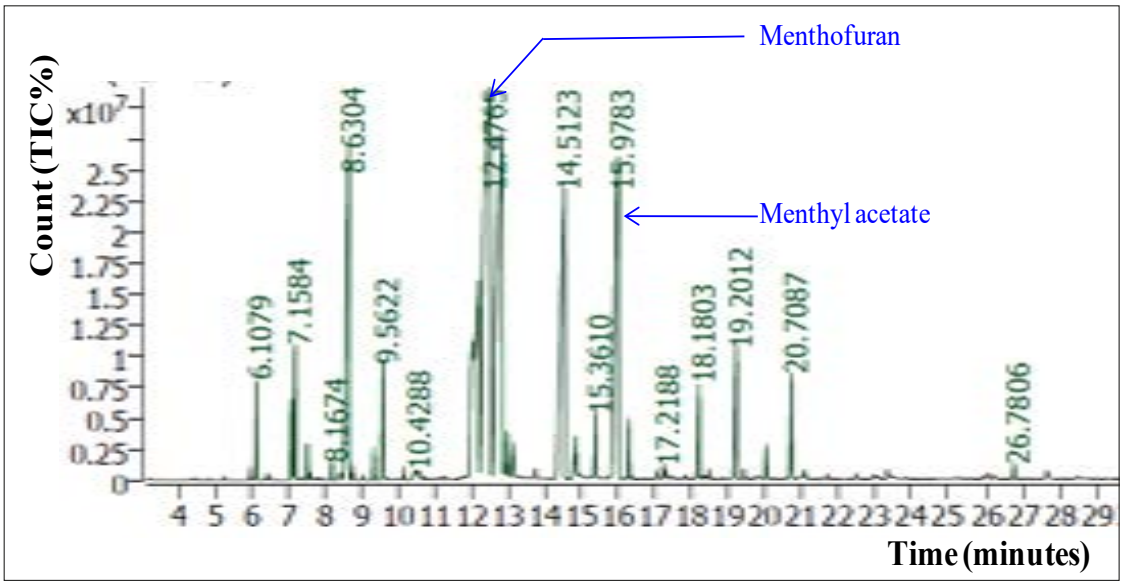


Figure 2.7.7. GCMS chromatogram of menthyl acetate and menthofuran components of *Mentha piperita* (experiment) after 125 days of planting.

Menthyl acetate and menthofuran component of essential oil in *Mentha piperita* L exhibited increasing trend in check as well as in experiments in both time intervals of ninety five and one hundred twenty five days. After a span of ninety five days, the difference in concentration of menthyl acetate and menthofuran in check and experiment was recorded as 8.39% and 3.66% respectively. Whereas after a span of one hundred twenty five days, the difference in concentration of menthyl acetate and menthofuran in check and experiment was recorded as 7.17% and 5.21% respectively. This reflects that production of menthyl acetate is diminished by 1.22% whereas the production of menthofuran is enhanced by 1.55% during the span of thirty days. Menthone and pulegone component exhibited decreasing trend in check as well as in experiments in both time intervals of ninety five and one hundred twenty five days. Iso-menthone during one hundred twenty five days and menthol during both time intervals of ninety five and one hundred twenty five days remained almost unaffected. After a span of one hundred twenty five days, the difference in concentration of iso-menthone in check (10.11%) and experiment (9.13%) was recorded to be less than 1% (≈0.98%) whereas after the same span of time, concentration of menthol in check (15.47%) and experiment (14.81%) was also recorded to be less than 1% (≈0.0.66%). Menthol component could not be detected till the initial ninety five days of growth period both in check and experiment whereas; menthone component in experiment could not be detected after one hundred twenty five days of initial growth period. From the GC-MS results it may be ascertained that the biochemical process of formation of menthol took more than ninety five days to activate itself in *Mentha piperita* L. While, it is interesting to deduce that menthone component may have uniformly given way to convert into its associate downstream components/ products in check and experiments soon after ninety five days of growth period which exhibits harmonious reduction in yield of this component after one hundred twenty five days. *Mentha piperita* L being an export oriented crop of India has a considerable indigenous and foreign market. The valuation of menthyl acetate component depends on its physical form (natural solid form, liquid form and 100% pure form) in the indigenous market. Import of menthyl acetate was to the tune of 3380kg/year from Germany and Spain amounting to $56,979.00 whereas export was to the tune of 153,707kg/year to USA ($1,983,876.00), China ($466180.00) and Germany ($156,790.00) amounting to a total of $3,007,535.00 in the year 2016. The study revealed that menthyl acetate and menthofuran component exhibited increasing trend while menthone, iso-menthone and pulegone component exhibited decreasing trend in the essential oil profile of *Mentha piperita* L when it is cocultivated with *R. tetraphylla* L. It was interesting to note that a little more than fivefold increase (i.e. from 1.87% to 10.26%) was observed in the concentration of menthyl acetate after applying the phenomenon of allelopathy which had contributed positively in the enhancement of menthyl acetate component in the essential oil of *Mentha piperita* L. The period between ninety five days to one hundred twenty five days after plantation proved to be the best time for harvest in order to get maximum menthyl acetate from essential oil of *Mentha piperita* L when it is grown along with R. *tetraphylla* L. In the context of plants exhibiting allelopathic interactions, *R. tetraphylla* L is not a prominent and popular name. Despite this fact, the plant had influenced the secondary metabolite profile of *M. piperita* L. This proves that using a more competent plant in this regard (like *Ocimum basilicum*, *O. sanctum* family Lamiaceae etc.) will certainly bring more promising results in the context of using allelopathy as a tool to improve essential oil composition.

2.8 Plantation in Bonera field station

Firdoous Ahmad Mir

Bonera field station is the largest farm of IIIM Jammu which were used for cultivation and research purpose of different medicinal plants. Rose, Lavender, Geranium, Salvia and Rosemary were cultivated at large scale and are the main crops of the farm. Along the daily routine work of farm the following work is also under taken in different mode mission under the instruction of our prime minister and direction by our worthy director

I. **Distributed** 12 lac *Lavender plantlets* to different districts of Jammu Kashmir from field station Bonera under aroma mission during 2019-20.

II. **Raise** 15 lac nursery plantlets during 2019-20 at Bonera field station under aroma mission.

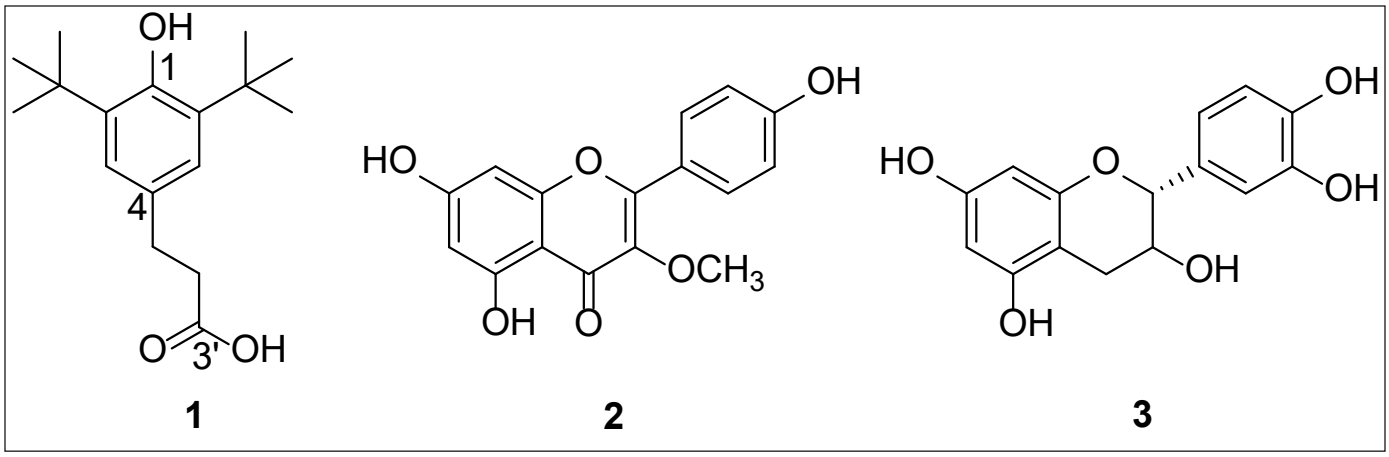
III. **Plant propagules** of *Cerepedium acumination, Polygonatum cirrhifolium, Polygonatum verticilatum, Nardostachys jatamansi,* and *Roscoea purpurea* of 15000 in numbers were planted at Bonera under phytopharma mission.

3. NATURAL PRODUCT CHEMISTRY

3.1 Identification of Anticancer Compounds from Ayurvedic Crude Drug: *Roscoea purpurea*

Venugopal Singamaneni, Gurpreet Singh, Shashank Singh, Sumeet Gairola, Prasoon Gupta

In our continuing research program to discover bioactive natural products from natural resource especially from high altitude Himalayan endangered medicinal plants with profound biological activities, our attention was focused on the rhizomes of *Roscoea purpurea* commonly known as "kakoli". *Roscoea purpurea* Sm. (Zingiberaceae) is an essential ingredient of an important Ayurvedic preparation known as *Astavarga*, which is a group of eight medicinal plants claimed to be useful in promoting body fat, healing fractures, seminal weakness, fever, abnormal thirst, diabetic conditions and as a cure for vata, pitta, rakta doshas. *Astavarga* plants are considered as very good *Rasayana* with rejuvenating and health-promoting properties, and are known to strengthen the immune system and have immense cell regeneration capacity. *Astavarga* plants are also reported to restore health immediately and work as antioxidants in the body. Amongst eight Astavarga plants *Roscoea purpurea* is one of the essential ingredients of several herbal formulations like tonic and Chyawanprash. Traditionally it is used for the treatment of diabetic, hypertension, diarrhea, fever, inflammation etc. In Nepal, the tubers are boiled for edible purpose and also used in traditional veterinary medicine. We were mainly interested in the traditional use of the rhizomes of *Roscoea purpurea* as immuno-potentiating agent. In the view of its importance in traditional medicinal system, no substantial phytochemical and pharmacological works have been carried out. Previous phytochemical investigations on *R. purpurea* have described the isolation of two principal groups of compounds, steroids and phenolic derivatives. To date, only few compounds have been identified and quantified through HPLC analysis from tubers of this plant by Singh and co workers, and they are presumed to be associated with its potent antioxidant activity. Ethanolic extract of the plant have shown *in-vitro* anti cancer, anti-oxidant and immunomodulatory activities. In this study, a fraction of the crude extract, guided by the anti-oxidant bioactivity, led to the isolation of a potent antioxidant compound which was identified as 3-(3,5-di-*tert*-butyl-4-hydroxyphenyl) propanoic acid (**1**) commonly known as Fenozan acid (FZA) together with several known compounds **2-9**. The structures of isolated compounds were elucidated on the basis of extensive spectroscopic 1D/2D analysis. Compounds **1-3** showed potent anticancer activity against Mia-Pa-Ca and MCF-7 cancer cell lines in a range of 2-6 μM (IC_{50}) concentration.



1 **2** **3**

Figure 3.1.1

3.2 Novel Cytotoxic Polyhydroxylated Sterols from the Sponge *Dysidea herbacea*

Venugopal Singamaneni, Mridula Singh Thakur, Satyanarayan Sethi, Prasoon Gupta

Marine sponges retain their importance for isolating novel and biologically active molecules despite several new classes of organisms like bacteria, tunicates, microalgae, bryozoans, etc. offering increased promise in recent years. In our ongoing research program of screening pre-fractionated and semi-purified extracts of marine sponges in an effort to discover anticancer using a 96-well plate system, activity was discovered for the extract of the marine sponge *Dysidea herbacea*, collected from the coast of Chennai, at a depth of 10-15 m. It is a large genus widely distributed in tropical and subtropical waters around the world. *D. herbacea*, is a soft-bodied, bright blue sponge striking in the low light zone of the reef system. It is previously investigated chemically and found to contain structurally diverse secondary metabolites including sesquiterpenes, sesterterpenes, alkaloids, and highly oxygenated sterols having novel side chain alkylation patterns and some differing in the degree of acetylation. These natural products also showed a wide range of biological activities such as antihelmintic, protein phosphate inhibitor, plant growth regulator and cytotoxicity. The methanol extract of sponge was fractionated using HP-20 resin column; HP-20 poly (styrene-divinylbenzene) resin is a macroporous, cross-linked polymer that lacks any polar sites. Thus it has good utility for the separation of medium-polar biologically active compounds from water soluble salt, carbohydrates, fats and steroids. The HP-20 column was eluted with 400 mL fractions of (1) 40% Me_2CO/H_2O (2) 75% Me_2CO/H_2O and finally with (3) Me_2CO. All the three extracts were concentrated separately on freeze dryer and submitted for cytotoxic and antimicrobial screening. Medium polar fraction of *D. herbacea* was taken for further purified by PRP-1 HPLC with a mobile phase flow rate of 1.4 ml/min. The mobile phase consisted of (A) MeCN (B) Water containing 0.1% HCOOH. A linear gradient elution was applied, as follows: 0-20.0 min linear gradient of 100 to 50% B, followed by 20.0-30.0 min linear gradient to 20% B, then 30.0-32.0 min linear gradient to 100% A, then 32.0-43.0 min linear gradient to 100% B resulted in isolation of compound **1** (3.2 mg, R_t 18.05 min) and compound **2** (3.0 mg, R_t 22.96 min). A large-scale extraction and purification yielded two new compounds (**1-2**) along with three known compounds (**3-5**). All the isolated compounds (**1–5**) were tested *in vitro* for cytotoxicity against a panel of human cancer cell lines, MIAPaCa-2 (Pancreatic cancer), MCF-7 (breast cancer) and PC-3 (prostate cancer) using the standard MTT (3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide) method. Compounds **1** and **3** displayed significant growth inhibition of MIAPaCa-2 with an IC_{50} of 9 and 14 μM respectively

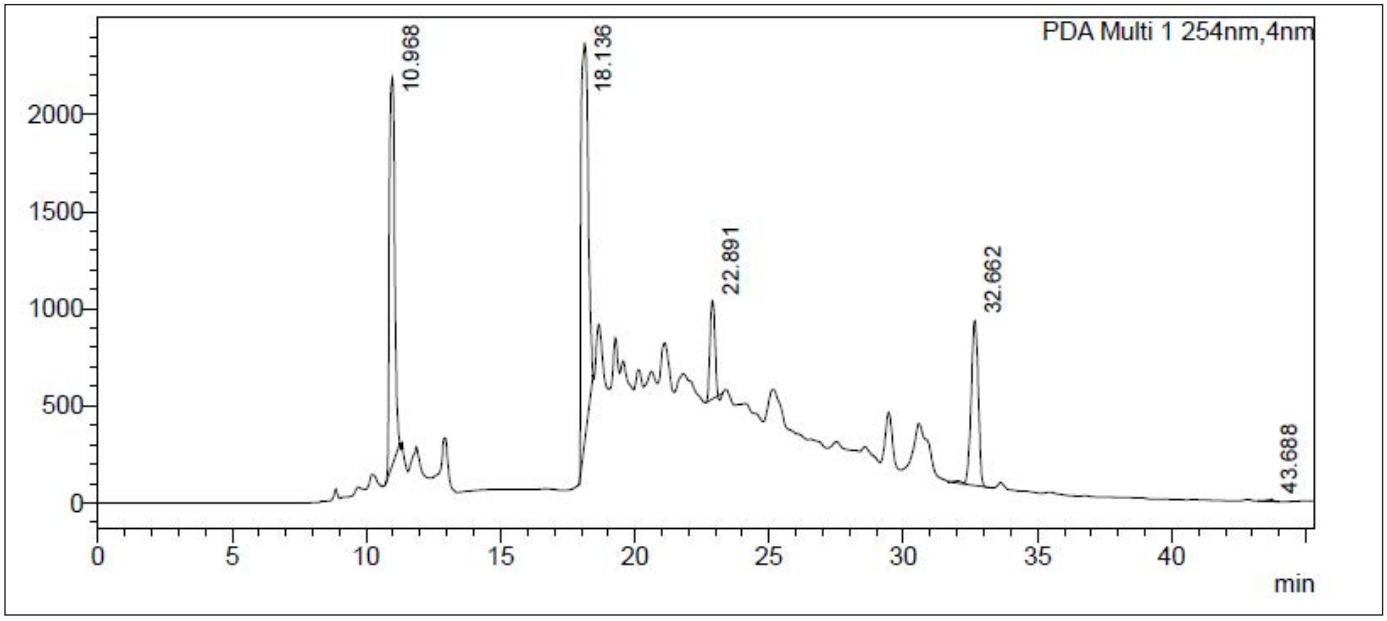


Figure 3.2.1: HPLC chromatogram of medium polar fraction D. herbacea

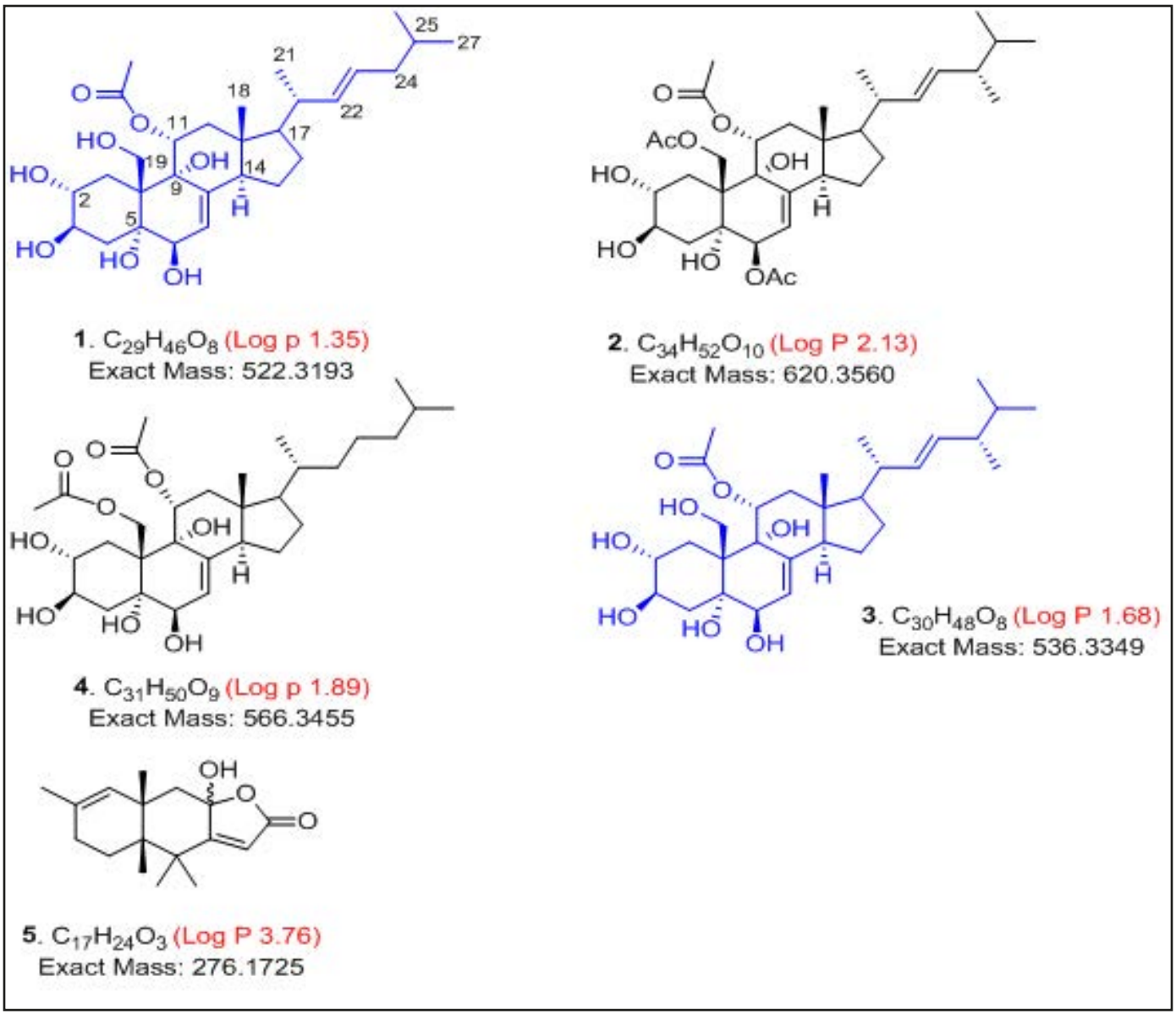


Table 3.2.1: Cytotoxic data of compounds 1-5

Compound	MIA-PA-CA-2	MCF-7	PC-3
	IC_{50} (µM)	IC_{50} (µM)	IC_{50} (µM)
1	**9** ± 0.17	45 ± 1.02	14 ± 0.12
2	34 ± 1.32	>50	32 ± 0.83
3	14 ± 0.92	>50	12 ± 0.83
4	32 ± 1.76	39 ± 1.82	28 ± 1.52
5	>50	>50	>50
Paclitaxel (nM)	6 ± 0.05	5 ± 0.07	7 ± 0.06

3.3 Carissic acid from fruits of *Carissa carandas* induced apoptotic cell death in A-549 cells

Navneet Kour, Arem Qayum, Venugopal Singamaneni, Shashank K Singh, Vikas Sharma and Prasoon Gupta

Cancer, a leading cause of death worldwide affecting millions of people per year, is characterized by deregulation of signaling pathways with initial loss of controlled cell growth, cell invasion and finally results in metastasis. Cancer is considered as main cause of mortality / morbidity and all over the world the increase in number of cancer cases are estimated to be 21 million by 2030. To combat the cancer / develop novel anticancer drugs, intense search is going on various biological sources. Therefore, 30 plant-derived compounds have been isolated, used for clinical trials and are found to be active on various cancer cells. As per World Health Organization data, about 14.1 million new cancer cases and 8.2 million deaths are reported in the year 2012. Moreover 70% of new cancer cases have been estimated in next twenty years. Almost 80% of world population is dependent on traditional medicine and more than 60% of clinically approved anticancer drugs are derived from these medicinal plants. *Carissa carandas* Linn commonly known as karonda 'Christ's thorn' is an exotic, minor fruit which grows wild in bushes. Previous studies have reported numerous biological activities such as anti-diabetic, anti-microbial, anti-tumour, anti-convulsant, hepatoprotective, cardiac depressant, anti-inflammatory and anti-viral. This research aimed to determine the *in vitro* cytotoxic potential of fruit extract of *C. carandas* against human cancer cell lines and isolate its bioactive constituents that possess remarkable anticancer efficacy. Karonda fruit extract (100 µg/mL) suppressed the proliferation of three human cancer cell lines namely Breast (MCF-7), Colon (HT-29) and Lung (A-549) with growth inhibition of 70%, 72% and 75% respectively. On the other hand, *C. carandas* extract seems to be inactive against five human cancer cell lines, as it suppressed growth of PC-3 by 43%, MDAMB-231 by 52%, SW-620 by 54%, HCT-116 by 65% and MIA PaCa-2 by 69%. Based on the cytotoxic effect of karonda extract, it was then fractionated with n-hexane, chloroform and butanol to further evaluate its *in vitro* cytotoxic effect against the same human cancer cell lines against which the extract showed activity. The results revealed that chloroform fraction of *C. carandas* showed remarkable results against all the three human cancer cell lines with 100% growth inhibition of A-549, HT-29 and MCF-7 at the concentration of 100 µg/mL. Surprisingly, the growth inhibition was seen 100% *i.e.,* more than methanolic extract at the same conc. (100 µg/mL).

Table 3.3.1: Growth inhibitory effect of *Carissa carandas* (extract & fractions) against different human cancer cell lines along with positive controls

Extract & Fractions	Conc. (µg/mL)	Human cancer cell lines from five different tissues							
		Breast	Breast	Colon	Colon	Colon	Lung	Pancreatic	Prostate
		MCF-7	MDAMB-231	HCT-116	HT-29	SW-620	A-549	MIA PaCa-2	PC-3
		Growth Inhibition (%)							
Extract (Methanolic)	**100**	**70**	52	65	**72**	54	**75**	69	43
Fractions (n-hexane)	**100**	**87**	*	*	68	*	**74**	**74**	*
Butanol	**100**	24	*	*	0	*	61	**89**	*
Chloroform	**100**	**100**	*	*	**100**	*	**100**	**100**	*
	50	**98**			**100**		**100**		
	30	**89**			**99**		**100**		
	10	**77**			**94**		**99**		
	1	0			37		24		

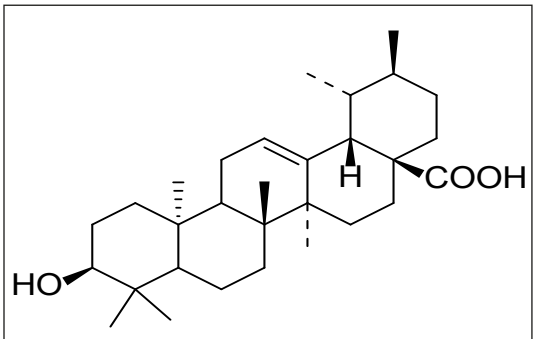
Extract & Fractions	Conc. (µg/mL)	Human cancer cell lines from five different tissues							
		Breast	Breast	Colon	Colon	Colon	Lung	Pancreatic	Prostate
		MCF-7	MDAMB-231	HCT-116	HT-29	SW-620	A-549	MIA PaCa-2	PC-3
		Growth Inhibition (%)							
IC_{50} (µg/mL)		3.98±0.24			1.28±0.02		1.48±0.002		
Positive controls (standard drugs)	Conc. (µM)								
Doxorubicin	1	65	65	-	-	-	-	-	-
5-Fluorouracil	20	-	-	52	52	65	-	-	-
Mitomycin-C	1	-	-	-	-	-	-	-	-
Paclitaxel	1	-	-	-	-	-	78	-	66
Paclitaxel	50	-	-	-	-	-	-	87	-

Growth inhibition of 70% or more has been indicated in bold numbers

Mark (-) indicates that particular human cancer cell line was not treated with that particular positive control

Symbol (*) means not further evaluated

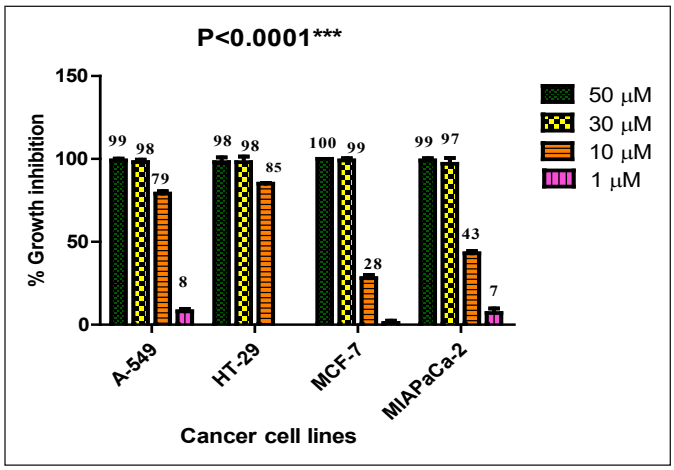
Further, at lower concentrations (50, 30 µg/mL), it again showed 100% growth inhibition, with 99% GI at 10 µg/mL but at 1 µg/mL it was not seemed to be active in A-549 cell line. In case of HT-29 cell line, 100% growth inhibition at 100 µg/mL, 100% growth inhibition at 50 µg/mL, 99% growth inhibition at 30 µg/mL, 94% growth inhibition at 10 µg/mL and 37% growth inhibition (inactive) at 1 µg/mL was observed. In MCF-7 cell line, 100% growth inhibition at 100 µg/mL, 98% growth inhibition at 50 µg/mL, 89% growth inhibition at 30 µg/mL, 77% growth inhibition at 10 µg/mL and 0% growth inhibition (inactive) at 1 µg/mL was observed. These fractions were further taken up for determining the IC_{50} values which were calculated as 3.98±0.24 µg/mL (MCF-7), 1.48±0.002 µg/mL (A-549) and 1.28±0.02µg/mL (HT-29) (Table 3.3.1). The n-hexane fraction was found to suppress the proliferation of three human cancer cell lines with 74% GI each in A-549 and MIA PaCa-2, 87% GI in MCF-7 at 100µg/mL. Whereas, the *n*-butanol fraction exhibited cytotoxic effect against pancreatic (MIA PaCa-2) cancer cell line with 89% GI. The results demonstrated that chloroform fraction of karonda was found to be most cytotoxic against three human cancer cell lines (A-549, HT-29, MCF-7) with IC_{50} values <10 µg/mL.



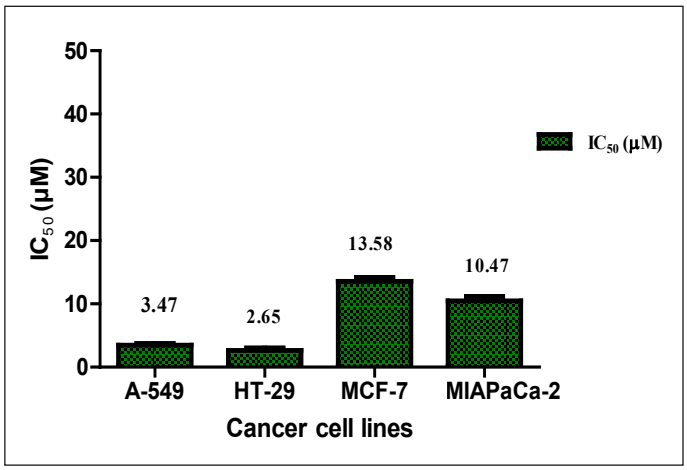
Chemical Formula: $C_{30}H_{48}O_3$
Molecular Weight: 456.7003

Carissic acid (CA), White powder; ^{1}H NMR (CD_3OD & $CDCl_3$, 400 MHz); δ_H 5.24 (1H, d, *J*=3.6 Hz, H-12), 3.19 (1H, m, H-3), 2.20 (1H, m, H-18), 1.91(1H, m, Ha-22), 1.66 (1H, dd, m, Hb-22), 1.26 (3H, s, Me-23), 1.10 (3H,s, Me-24), 0.98 (3H, s, Me-25), 0.96 (3H, s, Me-26), 0.93 (3H, s, Me-27), 0.82 (3H, d, *J*=6.5 Hz, Me-29),0.78 (3H, d, *J*=5.9 Hz, Me-30); ^{13}CNMR (CD_3OD& $CDCl_3$,100 MHz); δ_C 180.4, 138.1, 125.5, 78.5, 55.3, 52.9, 48.9, 48.9, 41.9, 39.4, 39.0, 38.9, 38.7, 38.5, 36.8, 36.7, 32.9, 30.5, 27.9, 27.7, 26.5, 24.0, 23.1, 23.1, 20.6, 20.6, 18.2, 16.6, 15.3, 15.0; HR-ESIMS m/z 455.3533 [M-H]$^-$ (cal for $C_{30}H_{48}O_3$, m/z 456.35)

This compound was isolated from chloroform fraction prepared from the fruit part of *C. carandas*. The component namely Carissic acid produced significant results from medicinal point of view as remarkable *in vitro* cytotoxic effect against four human cancer cell lines *viz* A-549, HT-29, MCF-7 and MIA PaCa-2 was observed in this case. Starting from the concentration of 50µM, the compound suppressed the overall proliferation of A-549 cells by 99%, HT-29 by 98%, MCF-7 by 100% and MIA PaCa-2 by 99%. Further, at 30 µM, the compound again showed excellent results as the growth inhibition of 98%, 99% and 97% was observed against A-549 & HT-29, MCF-7 and MIA PaCa-2 respectively. At 10µM, the compound showed activity against A-549 (79%) and HT-29 (85%) whereas 28% and 43% growth inhibition was observed in case of MCF-7 and MIA PaCa-2 cells respectively. At the lowest concentration (1µM), it did not exhibit any cytotoxic effect as the percent growth inhibition lies between 0-8 (Figure 3.3.1A). The IC_{50} values were calculated as 3.47±0.26 µM for A-549, 2.65±0.35 µM for HT-29, 10.47±0.69 µM for MIA PaCa-2 and 13.58±0.59 µM for MCF-7 cells (Figure 3.3.1B). Therefore, the compound displayed the potent *in vitro* cytotoxic effect against all the four human cancer cell lines with maximum growth inhibition and less IC_{50} values.



A



B

Figure 3.3.1: (A) *In vitro* cytotoxic potential of Carissic acid isolated from *C. carandas* against human cancer cell lines and (B) IC_{50} values of Carissic acid. Data is presented as Mean±S.D. and P value <0.0001***

4. MICROBIAL BIOTECHNOLOGY

4.1 Role of the endohyphal partner in the growth and secondary metabolism of *Aspergillus aculeatus* (MLP1008)

Sadaqat Farooq, Syed Riyaz-Ul-Hassan

A strain of *Aspergillus aculeatus,* an endophyte of rose plant, was found to harbour an endohyphal bacterium, *Koccuria palustris*. We developed an endohyphal-free fungal culture to study the role of the bacterium in modulating the secondary metabolism of the host fungus. The endohyphal bacterium promoted growth and sporulation in its host under normal and stress conditions, like osmotic stress. GC/MS analysis identified two common compounds, Cetene and pentadecanoic acid in the cultures, whereas they differed in the production of several other compounds. The *Aspergillus aculeatus* culture harbouring the endohyphal bacteria was found to produce a novel derivative of secalonic acid. The compound was potent against the cancer cell line MDA-MB 231 with an IC_{50} value of 6.86 ± 0.09 µM.

4.2 Pot and field experiments for influence of endophytes on growth of saffron (MLP1002)

Tanveer Ahmad, Syed Riyaz-Ul-Hassan

On the basis of plant growth promoting and biocontrol activities of endophytes of saffron, we selected ten endophytes for pot experiments. These endophytes promoted the growth parameters, like number of adventitious roots, buds, leaves and total biomass etc., efficiently. The treatments also increased total flavonoid and phenolic content in the plants. In the field experiments, two endophytes were found to increase the yield of saffron significantly.

4.3 T*richoderma lixii* (IIIM-B4), an endophyte of *Bacopa monnieri* L. producing peptaibols

Meenu Katoch, Deepika Singh, Kamal K Kapoor, RA Vishwakarma

For bioactive natural products, a strain of *Trichoderma lixii* (IIIM-B4) was isolated from *Bacopa monnieri* L. The ITS based rDNA gene sequence of strain IIIM-B4 displayed 99% sequence similarity with different *Trichoderma harzianum* species complex. The highest score was displayed for *Hypocrea lixii* strain FJ462763 followed by *H. nigricans* strain NBRC31285, *Trichoderma lixii* strain CBS 110080, *T. afroharzianum* strain CBS124620 and *Trichoderma guizhouense* BPI: GJS 08135 respectively. Position of *T. lixii* (IIIM-B4) in phylogenetic tree suggested separate identity of the strain. Microbial dynamics of *T. lixii* (IIIM-B4) was investigated for small peptides. Medium to long chain length peptaibols of 11 residues (Group A), 14 residues (Group B) and 17 residues (Group C) were identified using Matrix Assisted Laser Desorption/Ionization-Time of Flight (MALDI-TOF) mass spectrometer. Optimization is undeniably a desideratum for maximized production of desirable metabolites from microbial strain. Here optimization studies were carried out on *T. lixii* (IIIM-B4) using different growth media through Intact Cell Mass Spectrometry (ICMS). A multifold increase was obtained in production of 11 residue peptaibols using rose Bengal medium. Out of these, one of them named as Tribacopin AV was isolated and sequenced through mass studied. It was found novel as having unique sequence Ac-Gly- Leu- Leu-Leu-Ala- Leu-Pro-Leu-Aib-Val-Gln-OH. It was found to have antifungal activity against *Candida albicans* (25 µg /mL MIC). In this study, we isolated a strain of *T. lixii* (IIIM-B4) producing medium and long chain peptaibols. One of them named as Tribacopin AV was found novel as having unique sequence Ac-Gly-Leu-Leu-Leu-Ala-Leu-Pro-Leu- Aib-Val-Gln-OH, which had antifungal properties. Endophytic fungi IIIM-B4 was

isolated from healthy and symptomless leaves of *B. monnieri* to isolate the bioactive molecule. Endophyte was identified by its characteristic colony morphology and microscopic features (Figure 4.3.1). *T. lixii* (IIIM-B4) grew slowly on PDA medium with white cottony hyphae. Mycelium appeared first smooth, watery white in color, sparse, until floccose aerial mycelium produced. Fifteen-twenty days post incubation; greenish conidia were appeared on the culture plate. In microscopic view, pyramidal conidiophores and effuse conidiation were observed. Ampulliform to flask-shaped phialides were found to have globose or subglobose conidia. In old cultures, terminal or intercalary chlamydospore were also visualized. Further their molecular identification was carried out by ITS based rDNA sequence analysis. Details of the closest sequence homologs of fungal endophyte, their isolation source and their GenBank accession numbers are given in Table 4.3.1. Furthermore, ITS sequence data showed that the endophyte is a strain of the *Trichoderma lixii* (Figure 4.3.2). The ITS1 5.8S ITS2 region of ribosomal gene of IIIM-B4 showed a maximum homology of 99% with different *Trichoderma harzianum* species complex. The highest score was displayed for *Hypocrea lixii* strain FJ462763 followed by *H. nigricans* strain NBRC31285, *T. lixii* strain CBS 110080, *T. afroharzianum* strain CBS124620 and *T. guizhouense* BPI: GJS 08135 respectively.

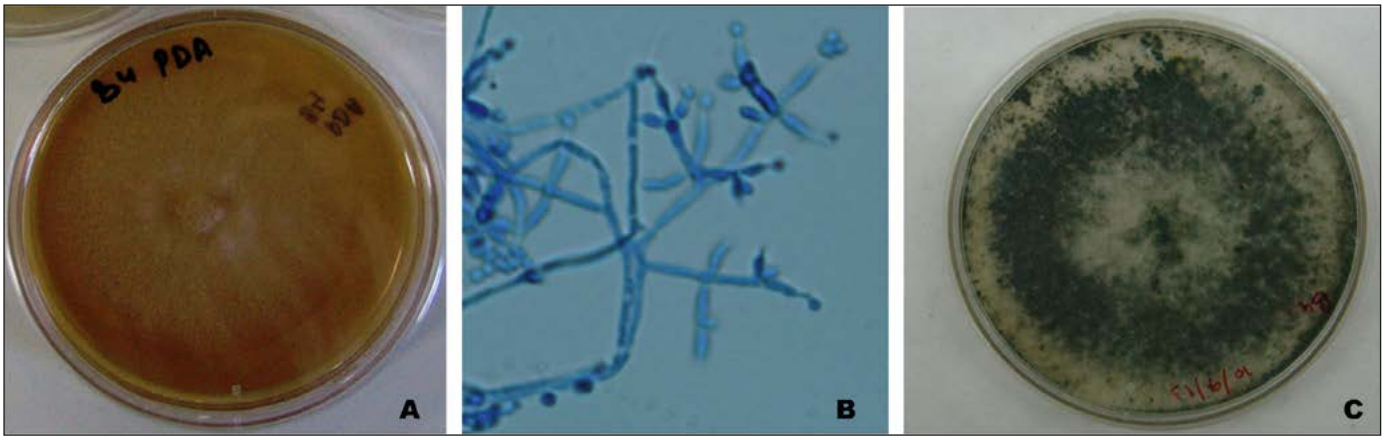


Figure 4.3.1 Morphological and microscopical view of *Trichoderma lixii* (IIIM-B4) endophytic fungi *associated with B. monnieri at 400X magnification A) Growth of* IIIM-B4 on PDA for 15 days B) microscopically view of IIIM-B4 stained with lacto phenol cotton blue C) *Growth of* IIIM-B4 on Rose Bengal medium for 15 days

Table 4.3.1 Comparison of the 16s rRNA gene sequence of IIIM-B4 among isolates of *Streptomyces*

Species	Strain	Similarity (%)	Total score	GenBank accession number
Hypocrea lixii	*FJ462763*	*99*	*1109*	*FJ462763*
Hypocrea nigricans	*NBRC31285*	*99*	*1096*	*JN943368*
Trichoderma lixii	*CBS 110080*	*99*	*1090*	*NR_131264*
T. afroharzianum	*CBS124620*	*99*	*1066*	*NR137304*
T. guizhouense	BPI:GJS 08135	99	1040	KP115286
T. harzianum	ATCC58674	99	959	AF057584
T. virens	ATCC9645	97	998	KU729029
T. atroviride	ATCC20476	90	739	JQ745258
T. erinaceus	ATCCMYA4844	90	728	KC171340
T. asperellum	CBS433.97	89	645	NR130668
T. viride	ATCC28038	88	625	AY380909

To characterize *T. lixii* (IIIM-B4), a phylogenetic tree was constructed which contained two clusters (Figure 4.3.2). *T. lixii* (IIIM-B4) was laid down in Cluster I with *Hypocrea lixii, H. nigricans, T. lixii*, *T. afroharzianum*, *T. guizhouense, T. harzianum*, while cluster II contained *T. virens, T. atroviride, T. erinaceus, T. asperellum* and *T. viride.*

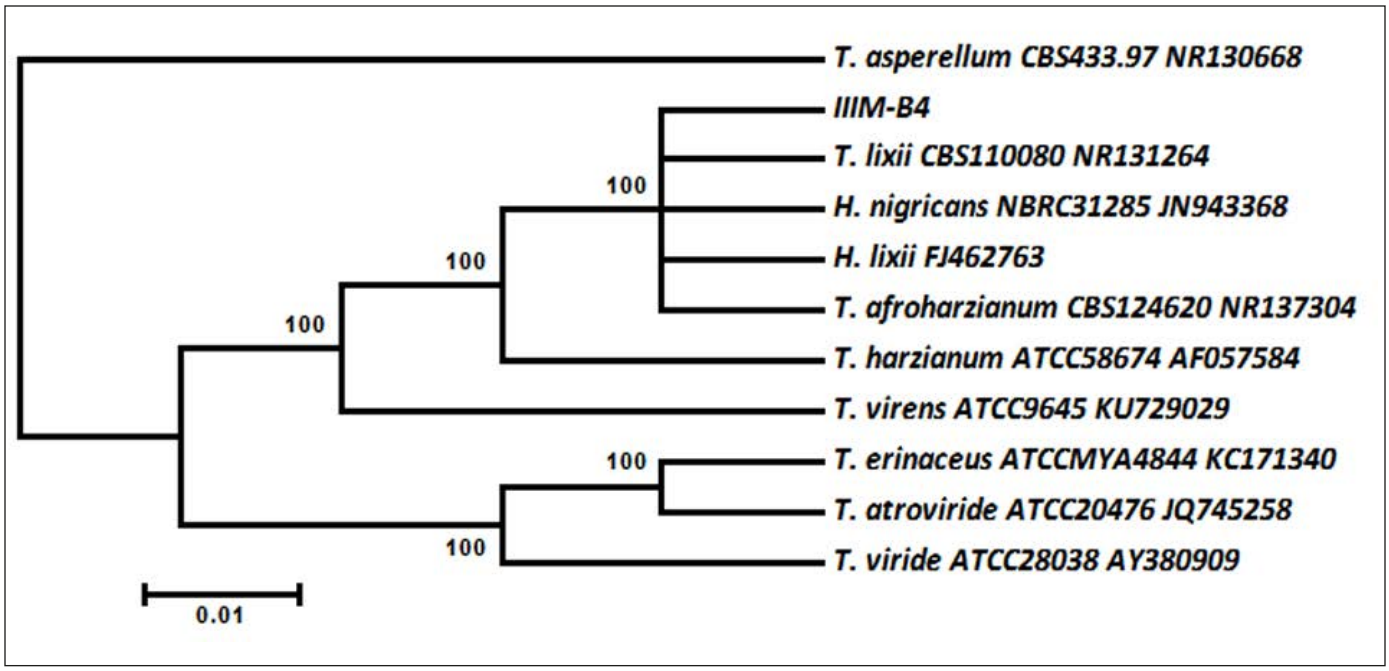


Figure 4.3.2. *Phylogenetic Tree based on ITS-5.8S rDNA sequence of Trichoderma lixii* (IIIM-B4) *endophytic fungi associated with B. monnieri showing the relative position of* its close relatives.

Identification of peptaibols production from *T. lixii* (IIIM-B4)

T. lixii (IIIM-B4) extract was analyzed through ICMS and was found to be the producer of peptaibols. Illustrious peptaibols spectra of B4 showed characteristic metabolite fingerprints of 11 residue peptaibols (Group A) having mass of m/z 1169, 1184, 1198, 1199, 1213, 1215, 1357, 14 residue peptaibols (Group B) having masses as 1466, 1467, 1482, 1484, 1496 and 17 residue peptaibols (Group C) showing masses as 1699, 1756, 1768, 1770 indicating three groups of peptaibols falling in respective medium, medium and long chain length of peptaibols (Figure 4.3.3).

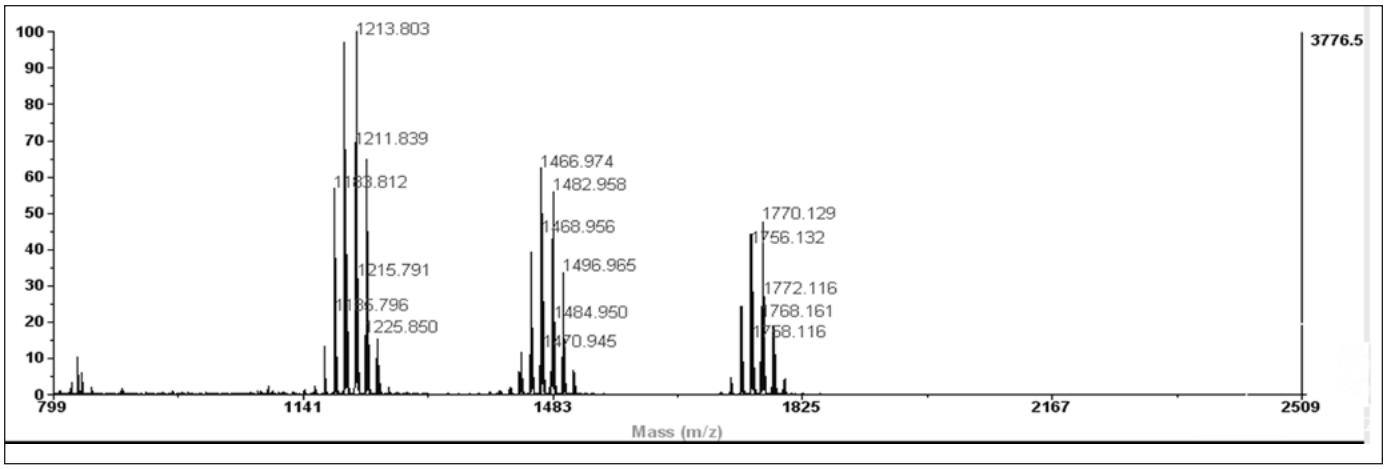


Figure 4.3.3. Mass spectral profile of *Trichoderma lixii* (IIIM-B4) obtained through Intact Cell Mass Spectrometry by MALDI TOF mass analyzer indicating three groups of peptaibiotics medium and long chain length.

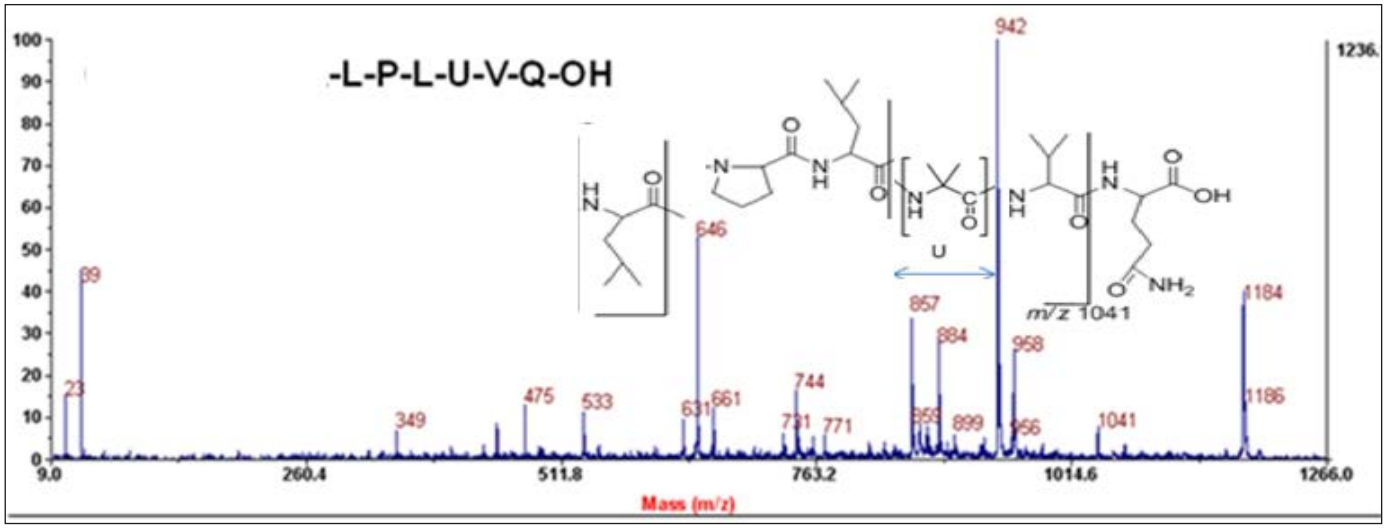


Figure 4.3.4. MS/MS spectra showing fragmentation of m/z 1184 production by *Trichoderma lixii* (IIIM-B4) for confirming peptaibols

MS/MS studies using collision ion dissociation through MALDI-TOF/TOF mass spectrometer were used to characterize these peptides. According to MS/MS spectra, presence of non standard amino acids like *a*-aminoisobutyrate, Aib (U), clearly confirms the identity of peptaibols (Figure 4.3.4).

Medium chain peptides having masses *m/z* 1169, 1184, 1198, 1199, 1213, 1215, 1357 and 1466, 1467, 1482, 1484, 1496 belonged to subfamily SF4, where as long chain peptides having mass *m/z* 1699, 1756, 1768, 1770 belonged to subfamily SF1, under physiological pH 7.0.

Effect of different solid medium on peptaibols production

Peptaibols production was studied through media optimization using ICMS technique. Summation of media optimization studies was shown in figure 4.3.5, which indicated best quantitative formation of Group short chain peptaibiotics, named as Tribacopins I-VII in solid media particularly in rose Bengal medium upto five fold.

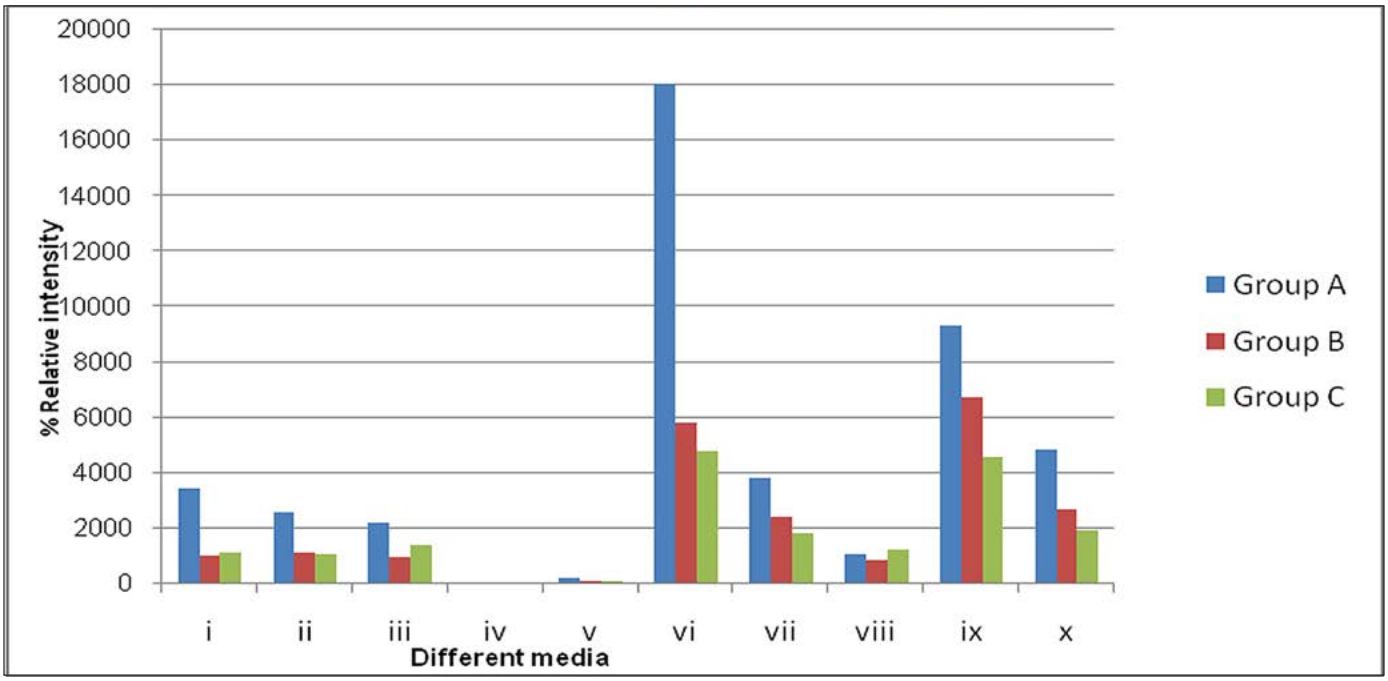


Figure 4.3.5. Effect of different media [(i) Potato Dextrose Agar (PDA) (ii) malt extract agar (iii) yeast extract malt extract agar (iv) Sabrauds dextrose agar (v) Oat meat agar (vi) Rose Bengal agar (vii) Potato carrot agar (viii) Corn meal agar (ix) Synthetic medium 1(x) synthetic medium 2] on different group of peptaibiotics production through ICMS (Group A: 11 residue medium chain peptaibiotics in blue; Group B: 14 residue medium chain peptaibiotics in red; Group C: 18 residue long chain peptaibiotics in green).

Isolation and characterization of a peptaibol.

Using the mentioned HPLC program, separation of 11 residue medium chain peptaibols (Fraction A named as Tribacopin AI - AVII) having mass as 1169, 1183, 1184, 1197, 1198, 1199, 1213 was achieved from long chain peptaibols (Fraction C named as Tribacopin CI-CIII) having mass as 1727, 1729 and 1742. Fraction A was further purified and Tribacopin AV having mass as m/z 1184 was isolated. Further, it was sequenced through mass studies. It was found to have a novel sequence (Ac-Gly-Leu-Leu-Leu-Ala-Leu-Pro-Leu-Aib-Val-Gln-OH) as shown in Figure 4.3.6.

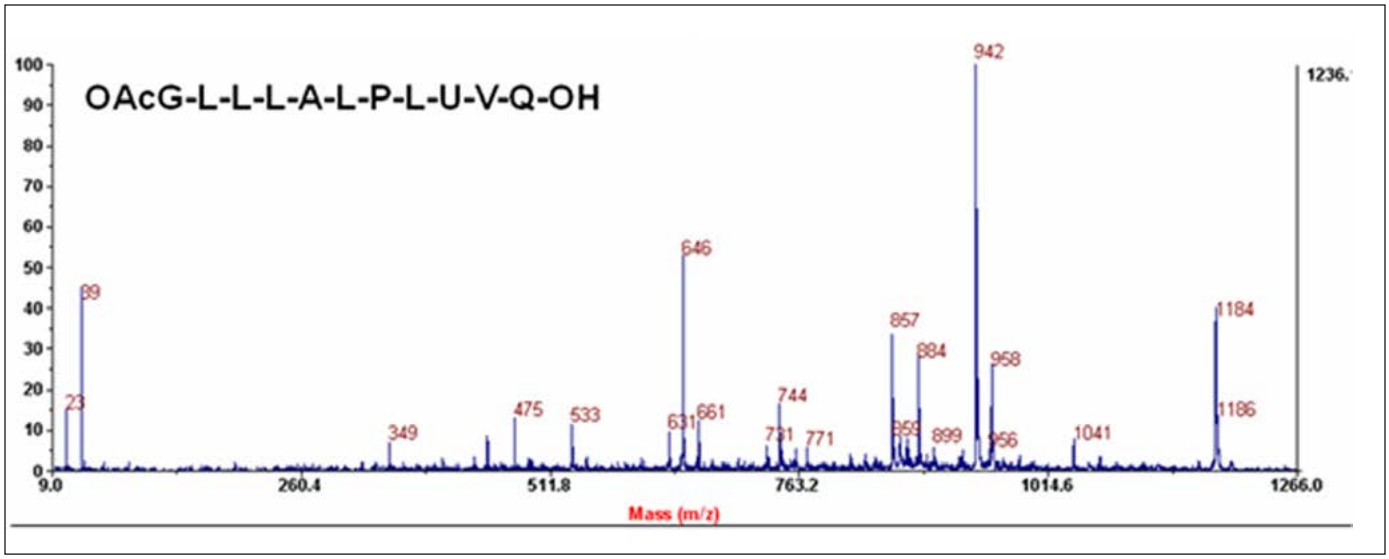


Figure 4.3.6 MS/MS spectra showing Sequence of Tribacopin AV

Antimicrobial activity of Tribacopin AV

Tribacopin AV was tested for antimicrobial activity and was found to have antifungal activity against *C. albicans* (25 µg/mL MIC) but not active against bacterial pathogens. Thus, present study describes a strain of *Trichoderma lixii* (IIIM-B4) which was isolated as an endophyte from *Bacopa monnieri* L. and showed the production of antifungal peptaibol. IIIM-B4, the only reported *Trichoderma,* as an endophyte of *Bacopa monnieri* has not yet been explored for neurological disorders, but recently a study suggested that a new cyclopentenone isolated from *Trichoderma* sp. with free radical scavenging properties, might be effective in Alzheimer's disease (AD) models (Harrison 2012). Hence it can also be explored for neurological disorders.

5. DISCOVERY INFORMATICS

5.1 Study of the binding mode of identified E. *coli* MurA inhibitor "3772-9534" with molecular dynamics simulation.

With the help of *in silico* screening earlier we identified "3772-9534" as a potential hit targeting *E.coli* MurA. In continuation to our earlier studies, we studied the mode of action of the hit identified with the help of molecular dynamics simulation using Desmond software. In order to study the binding mode, 100 ns molecular dynamic simulations was performed in Desmond. The trajectory was recorded at 1 ps. various systems used for MD simulation is given in Table 5.1.1. From the RMSD plot of the protein Cα and ligand, it was inferred that the Protein and ligand remained stable and show less RMSD from initial frame in case of MurA-PEP-UNAG and MurA-Fosfomycin-UNAG complex. All the ligands remain stable in their respective binding pockets (Figure 5.1.1). While in case of MurA-3772-9534-UNAG complex RMSD changes suddenly around 20 ns. It was observed by manual visualization that the compound 3772-9534 left fosfomycin binding pocket and occupied another pocket as illustrated in Figure 5.1.2.

Table 5.1.1: System Used in MD studies

1	MurA complex with natural substrates PEP and UNAG	MurA-PEP-UNAG
2	MurA complex with natural substrate UNAG and approved drug fosfomycin	MurA-Fosfomycin-UNAG
3	MurA complex with natural substrate UNAG and inhibitor identified after *in silico* screening	MurA-3772-9534-UNAG

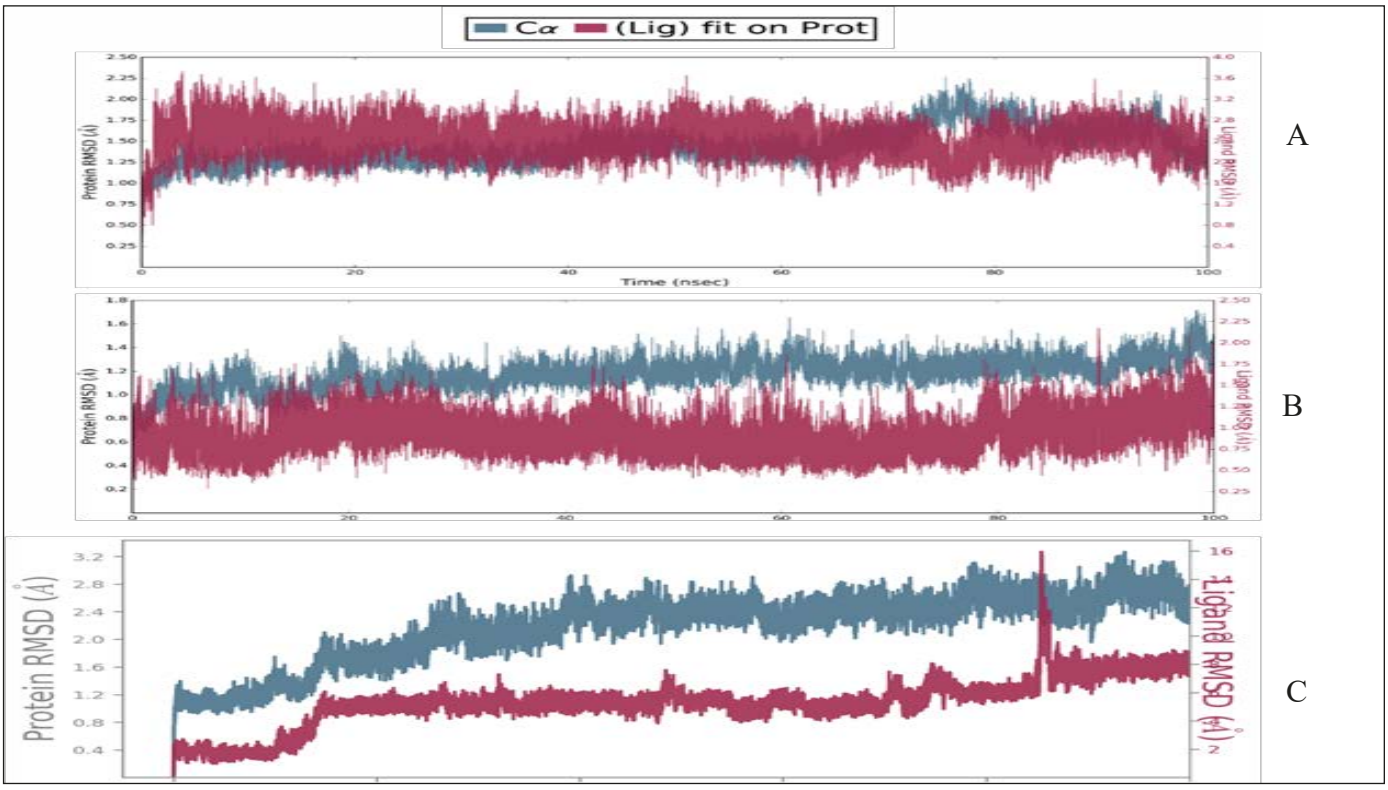


Figure 5.1.1. Comparison of Protein and ligand heavy atom during 100 ns of simulation. (A) MurA-PEP-UNAG, (B) MurA-Fosfomycin-UNAG, (C) MurA-3772-9534-UNAG complex.

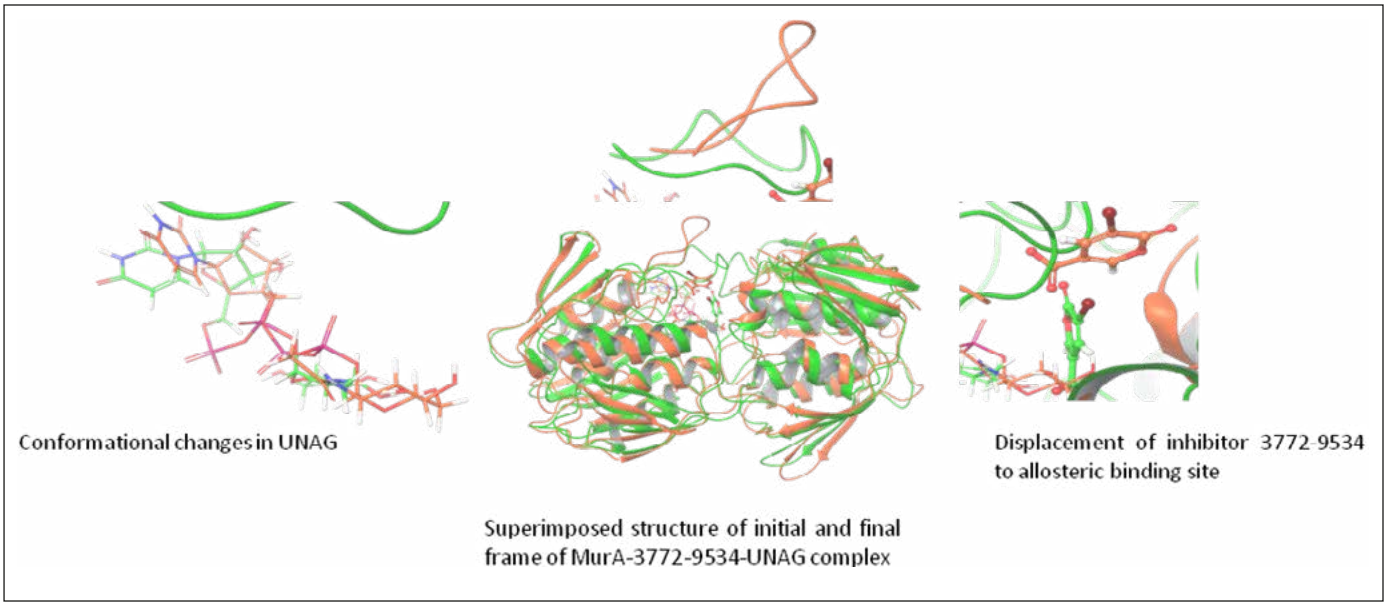


Figure 5.1.2. Conformational changes in MurA-3772-9534-UNAG complex after 100ns Molecular dynamics simulation. Initial frame is presented in green and final frame is presented in orange colour.

5.2 Identification of plant-based acetylcholine esterase inhibitors

The aim of the present work was to find some natural plant-based cholinesterase inhibitors using the fingerprints of currently approved drugs (huperzine A, galantamine, and donepezil) that target AChE.

(i) Development of multiple linear regression QSAR models of reported phytomolecules/ derivatives related to Alzheimer's and Parkinson's diseases.

(ii) Prediction of potential anti-alzheimer and anti-parkinson activities of untested compounds using the generated QSAR models.

(iii) Molecular docking and MD simulations study of the lead molecules to elucidate their mechanism of action and lead optimisation.

(iv) Semi-synthesis of screened out compound (s).

(v) *In vivo* validation of the lead candidate(s) using transgenic *C. elegans* or mouse models.

We validated few top hits based on the pharmacophore fitness score (docking score > -7 kcal/mol) from each hypothesis using the AChE of electric eel (eAChE). The pharmacophore model for each of the drugs is shown in figure 5.2.1. Ellman's method was used to examine the *in vitro* activity of acetylcholinesterase enzyme. The percentage inhibition of the enzyme was evaluated using donepezil (10μM) as a standard and its inhibition was considered as 100 % inhibition of the enzyme AChE. All molecular dynamics (MD) simulations were performed using the Desmond software. In vivo assays viz. a) Aldicarb assay, b) Levamisole assay and c) β-Amyloid (Aβ) aggregation assay were used for in vivo validation of the results.

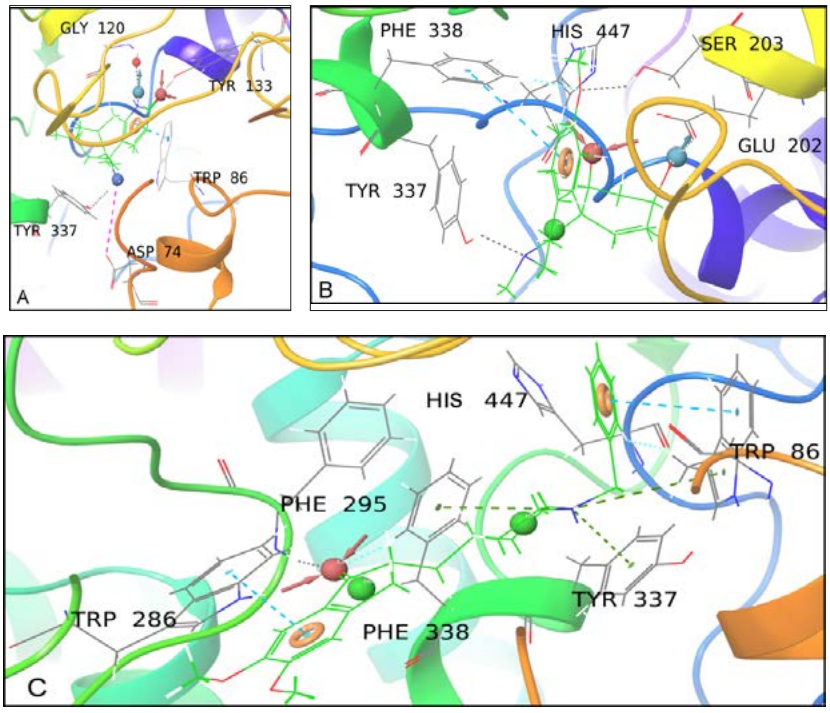


Figure 5.2.1. Pharmacophore models (A: huperzine-A, B: galantamine, and C: donepezil) used for the virtual screening of drug-like compounds. The positive (P) and hydrophobic (H) features are rendered as blue and green spheres, acceptor (A) is shown as light red sphere (centered on the atom with the lone pair), donor (D) is indicated by light blue sphere (centered on the H atom, with an arrow pointing in the direction), whereas the aromatic ring (R) is depicted as orange torus in the plane of the ring. Water is represented in red sphere. The feature interactions with the key amino acid residues of rhAChE are also shown.

The outcome of the study was that we reported a new donepezil-like natural compound derivative (D1) as a convincing AChE inhibitor. The *in silico* studies suggested that D1 exhibits a dual-binding mode of action and interacts with both the catalytic anionic site and PAS of human AChE (Figure 5.2.2). The biological studies revealed that D1 not only enhances the acetylcholine levels but also reduces the accumulation of Aβ plaques in *C. elegans*. In fact, 5µM of D1 was seen more potent in elevating the acetylcholine expression than 25µM of donepezil. While most of the noncholinergic functions of donepezil associated with the PAS of AChE were gradually lost at higher concentrations, D1 was more functional at similar doses. Promisingly, D1 also exerted agonistic effect on the α7 nicotinic acetylcholine receptor.

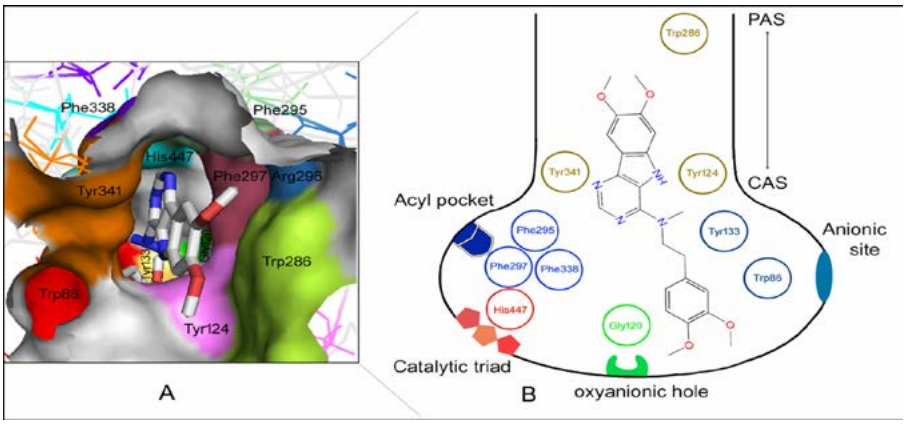


Figure 5.2.2. Graphical representation of D1 entrance into the active site gorge of rhAChE. (A) Three dimensional view of the binding of D1 within the active site of rhAChE. (B) 2D diagram showing the positioning of D1 in the gorge of rhAChE. The interacting residues are color coded according to their location in the active site

5.3 Phytopharmaceutical compound repository and the portal update

The Phytopharmaceutical portal is being regularly updated. The Compound repository section of the portal has grown to a total of 73 compounds. Similarly, extract details for three plants viz., *Boswellia serrata*, *Withania somnifera* and *Glycyrrhiza glabra* were added in the GMP extract section of the portal. The snapshot of the phytopharmaceutical compound repository within the portal is shown in figure 5.3.1. The portal is now having a secured access with a username and password. All the documents within the portal are also password protected. The portal is also accessible from the Institute's website.

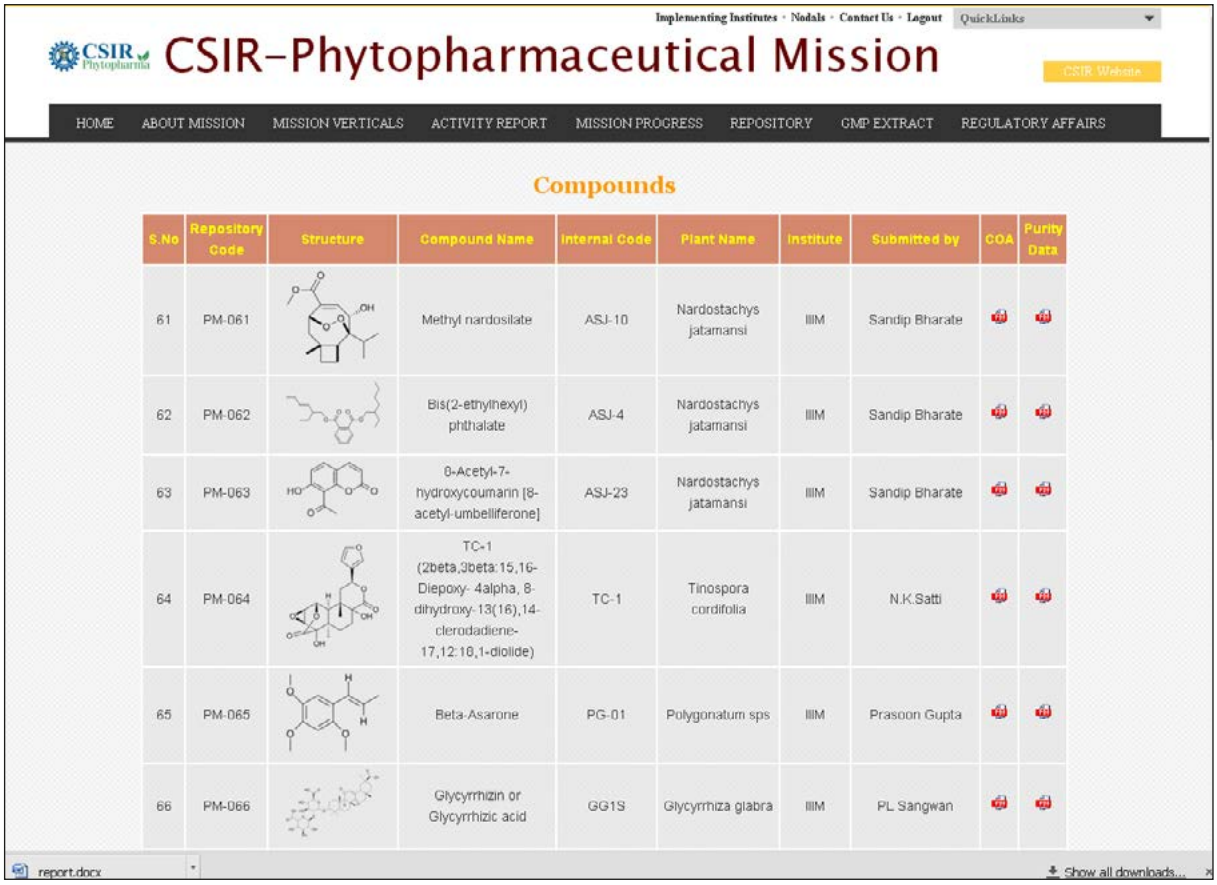


Figure 5.3.1. Snapshot of the phytopharmaceutical compound repository within the mission phytopharmaceutical portal

5.4 Development of IIIM publication database

A repository of publication from IIIM (year 2004 onwards) was created. A total of about 1500 publications were collected from Scifinder and Pubmed, as well as the data obtained from CSIR-NISCAIR. Each publication was searched for the PMID and DOI from the NCBI database.

The main tabs of the portal are (figure 5.4.1):

(i) Home,

(ii) Search/Advanced Search,

(iii) Publications (yearly) and

(iv) Help

The user must register and then login to access the portal. For each publication, the database contains the following fields (figure 5.4.2):

i) Year, ii) PMID, iii) DOI, iv) Title, v) Author, vi) Journal, vii) Volume, viii) Page numbers. The entire database is searchable via author, title, and year or journal name. All these publications are also segregated year-wise

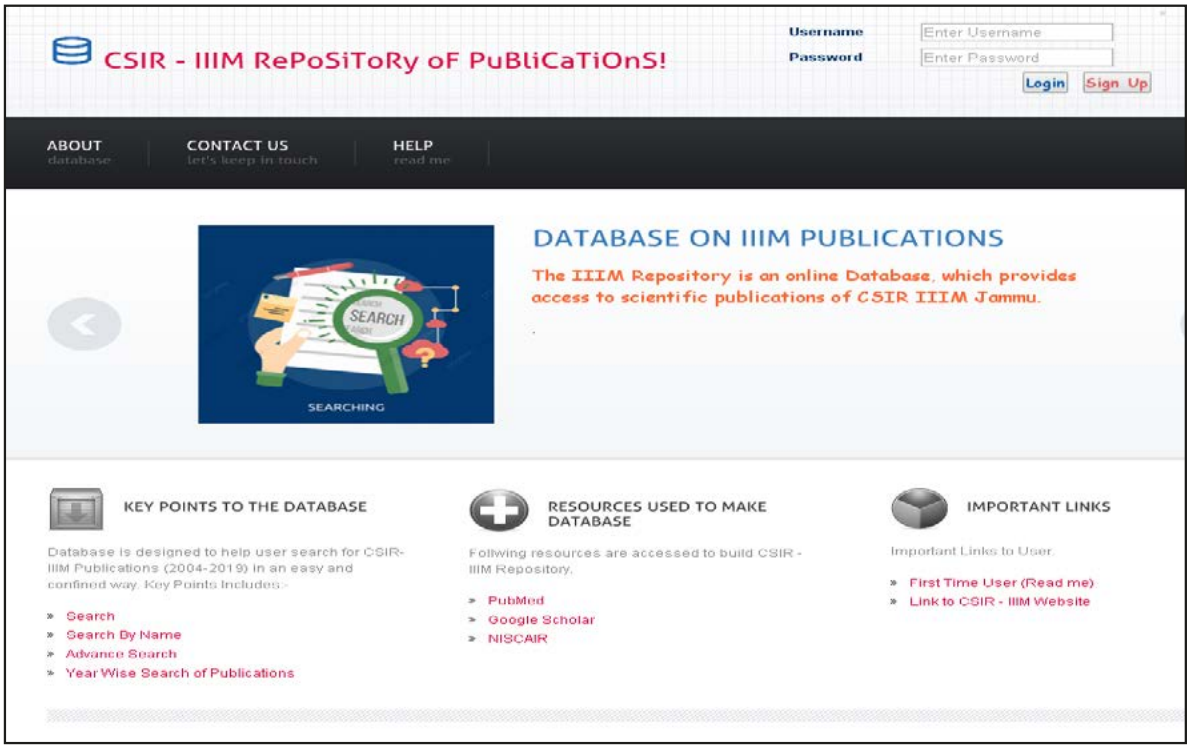
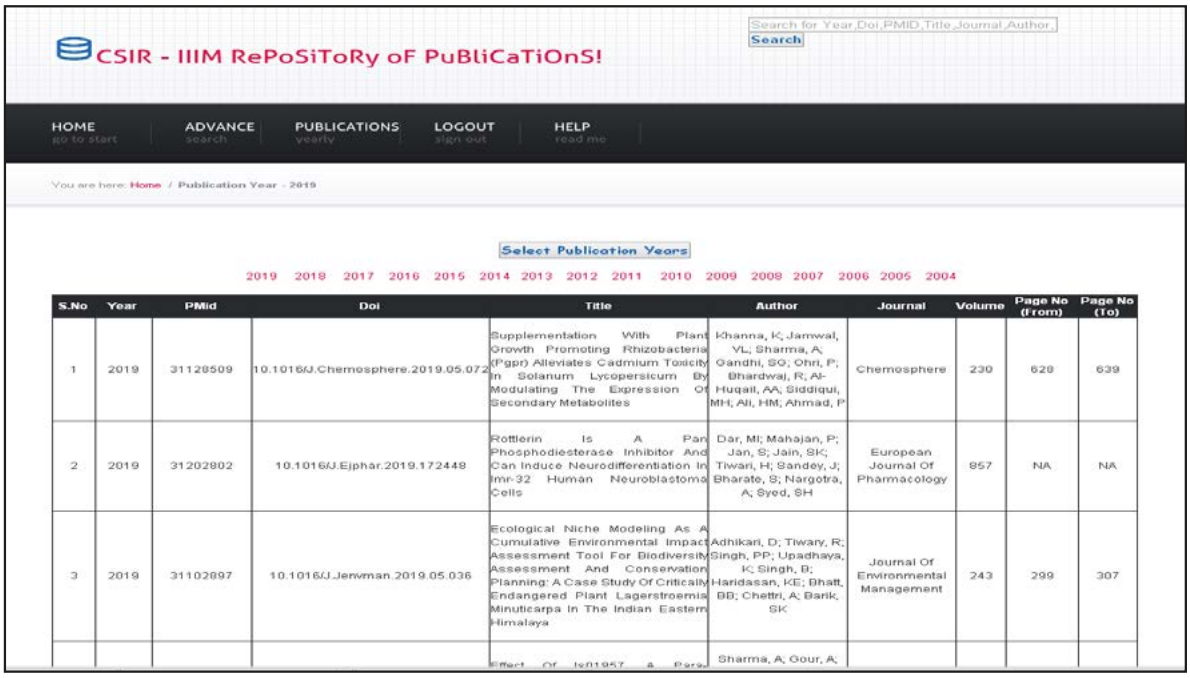


Figure 5.4.1. Snapshot of the main page of the IIIM publication repository



S.No	Year	PMid	Doi	Title	Author	Journal	Volume	Page No (From)	Page No (To)
1	2019	31126509	10.1016/J.Chemosphere.2019.05.072	Supplementation With Plant Growth Promoting Rhizobacteria (Pgpr) Alleviates Cadmium Toxicity In Solanum Lycopersicum By Modulating The Expression Of Secondary Metabolites	Khanna, K; Jamwal, VL; Sharma, A; Gandhi, SG; Ohri, P; Bhardwaj, R; Al-Huqail, AA; Siddiqui, MH; Ali, HM; Ahmad, P	Chemosphere	230	628	639
2	2019	31202802	10.1016/J.Ejphar.2019.172449	Rottlerin Is A Pan Phosphodiesterase Inhibitor And Can Induce Neurodifferentiation In Imr-32 Human Neuroblastoma Cells	Dar, MI; Mahajan, P; Jan, S; Jain, SK; Tiwari, H; Sandey, J; Bharate, S; Nargotra, A; Syed, SH	European Journal Of Pharmacology	857	NA	NA
3	2019	31102897	10.1016/J.Jenvman.2019.05.036	Ecological Niche Modeling As A Cumulative Environmental Impact Assessment Tool For Biodiversity Assessment And Conservation Planning: A Case Study Of Critically Endangered Plant Lagerstroemia Minuticarpa In The Indian Eastern Himalaya	Adhikari, D; Tiwary, R; Singh, PP; Upadhaya, K; Singh, B; Haridasan, KE; Bhatt, BB; Chettri, A; Barik, SK	Journal Of Environmental Management	243	299	307
				Effect Of Is01957 A Para-	Sharma, A; Gour, A;				

Figure 5.4.2. Year-wise publications and illustration of the fields

5.5 Updation and outcome of IIIM compound repository

Continuing the earlier efforts of establishing the Institutional compound library, following activities were carried out:

- 187 new in-house compounds (natural products and medchem programs) were added to the repository during the reporting period.
- About 1400 compounds were issued from the repository for several biological evaluation studies during the reporting period

The outcome of this Institutional resource so far is illustrated in figure 5.5.1.

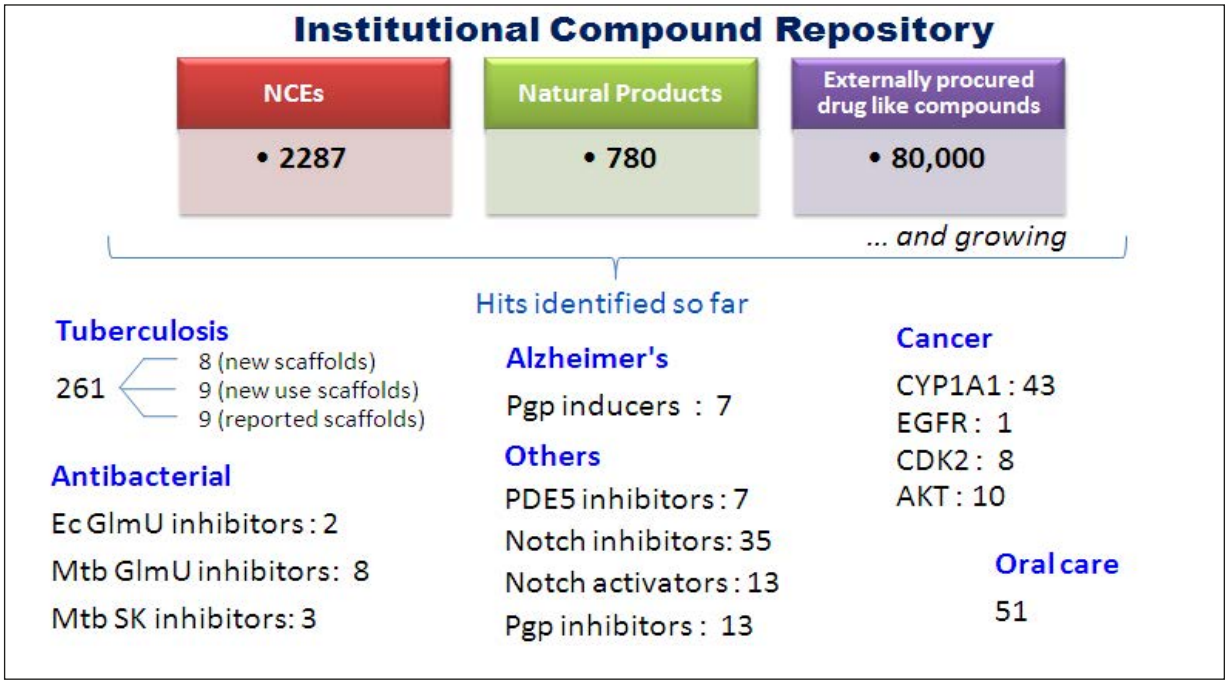
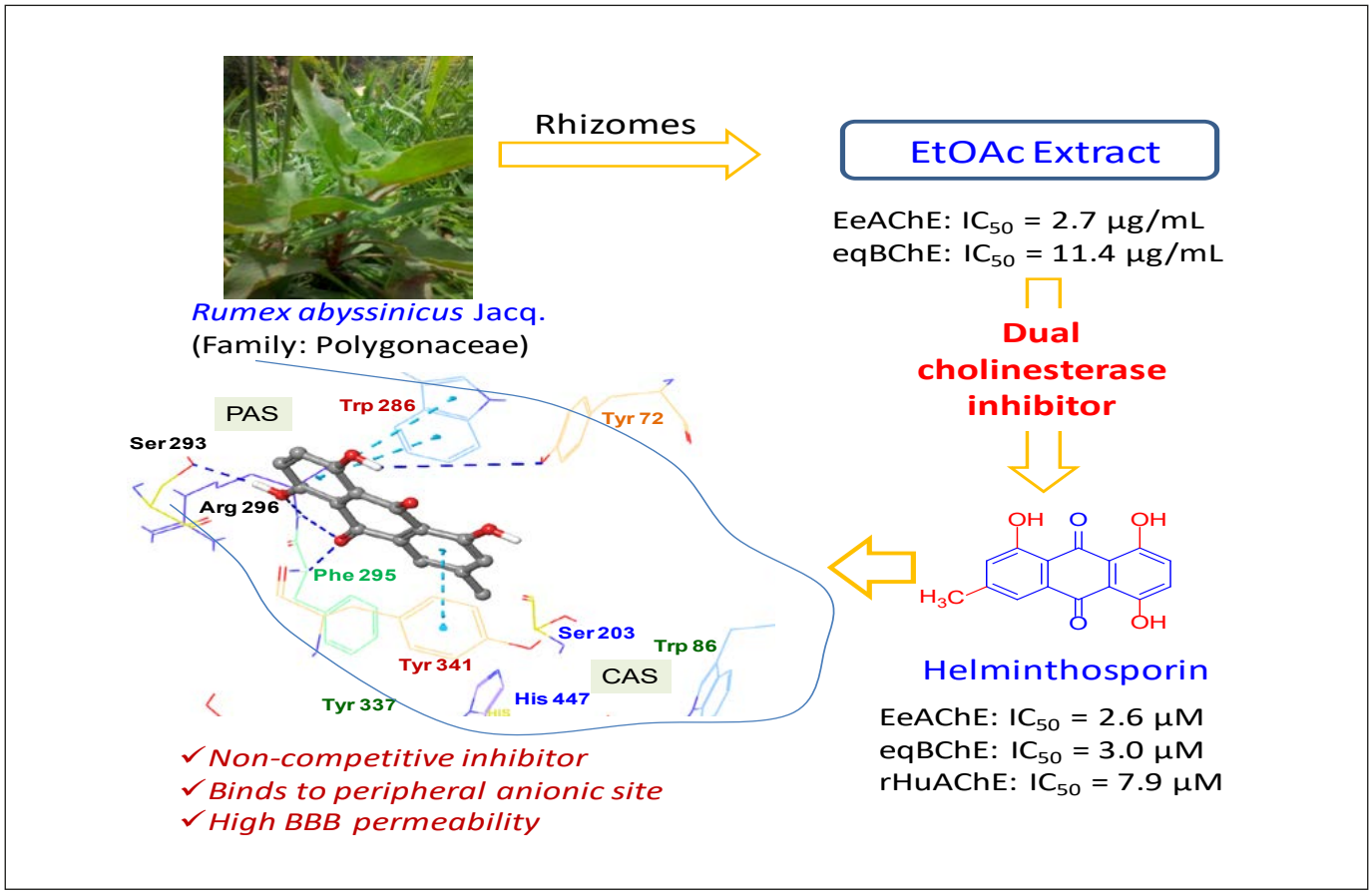


Figure 5.5.1. Ilustration of the outcome so far of the Institutional compound library

6. MEDICINAL CHEMISTRY

6.1 Discovery of Helminthosporin, an Anthraquinone Isolated from *Rumex abyssinicus* Jacq as a Dual Cholinesterase Inhibitor (ACS Omega, 2020, 5, 1616-1624)

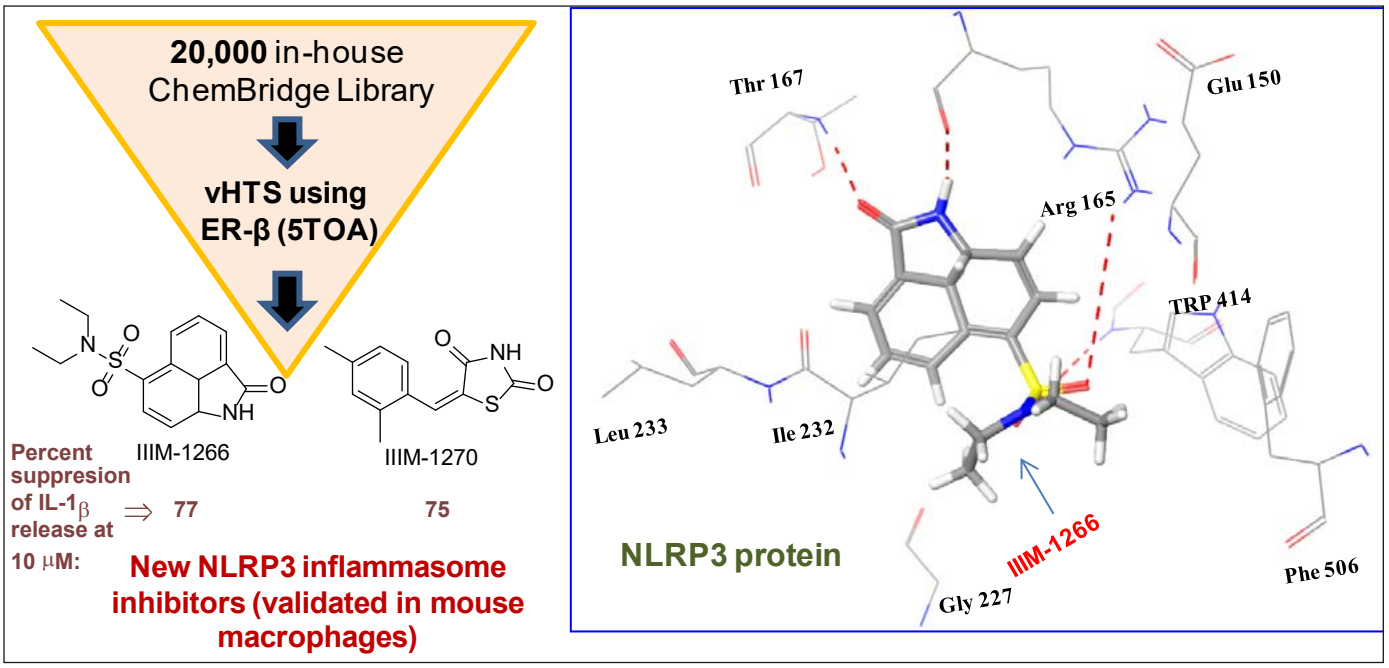
Ntemafack Augustin, Vijay K. Nuthakki, Mohd. Abdullaha, Qazi Parvaiz Hassan, Sumit G. Gandhi, and Sandip B. Bharate



Natural products have extensively contributed towards the discovery of new leads for Alzheimer disease. During our search for new inhibitors of cholinesterase enzymes from natural source, the ethyl acetate (EtOAc) extract of *Rumex abyssinicus* Jacq was identified as a dual cholinesterase inhibitor with IC_{50} values of 2.7 and 11.4 µg/mL against acetylcholinesterase (AChE) and butyrylcholinesterase (BChE), respectively. The phytochemical investigation of EtOAc extract has resulted in isolation of four anthraquinones namely helminthosporin, emodin, chrysophanol and physcion. Helminthosporin has been isolated for the first time from *Rumex sp.* All isolated secondary metabolites have displayed significant inhibition of EeAChE with IC_{50} values of 2, 63, 15.21, 33.7 and 12.16 µM, respectively. In addition, the helminthosporin was also found to inhibit BChE with IC_{50} value of 2.99 µM. The enzyme kinetic study has indicated that helminthosporin inhibits AChE and BChE in a non-competitive-manner with k_i values of 10.3 and 12.3 µM, respectively. The results of molecular modeling and propidium iodide displace- ment assay have revealed that helminthosporin occupies the peripheral anionic site of the active site gorge of AChE. In the BBB permeability assay, helminthosporin was found to possess high BBB permeability (P_e = 6.16 x 10^{-6} cm/s). In nutshell, helminthosporin has been identified as a brain permeable dual cholinesterase inhibitor, and thus its further synthetic exploration is warranted foroptimization of its potency.

6.2 Discovery of Benzo [cd] indol-2-one and Benzylidene-thiazolidine-2,4-dione as New Classes of NLRP3 Inflammasome Inhibitors via ER-β Structure Based Virtual Screening (Bioorg. Chem, 2020, 95, 103500)

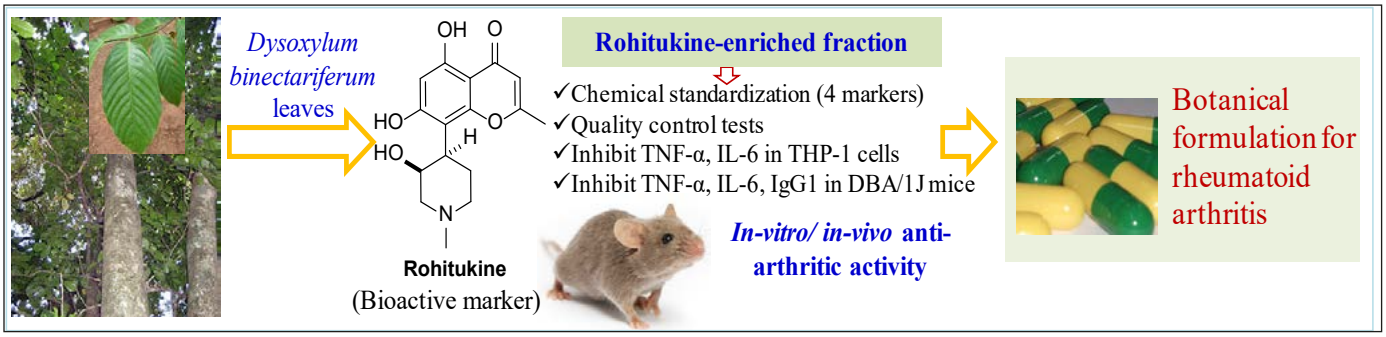
Mohd Abdullaha, Mehboob Ali, Dilpreet Kour, Ajay Kumar, and Sandip B. Bharate



The structure-guided virtual screening (VS) has proved to be successful strategy in identification of new scaffolds for biological targets. The overactivity of NLRP3 inflammasome has been implicated in variety of inflammatory diseases including Alzheimer's disease. The up-regulation of estrogen-receptor β (ER-β) activity has been directly linked with inhibition of NLRP3 inflammasome activity. In the present study, we report discovery of new NLRP3 inflammasome inhibitors via ER-β crystal structure (PDB: 5TOA) guided virtual screening of 20,000 compound library. For experimental validation, top 10 ligands were selected based on structure novelty, docking score, prime MMGB/SA binding affinity and interaction pattern analysis. Amongst the tested compounds, three thiazolidin-4-ones IIIM-1268, IIIM-1269 and IIIM-1270 and benzo[cd]indol-2-one IIIM-1266 have shown 73, 69 and 75% suppression of IL-1β release in mouse macrophages (J774A.1 cells) at 10 μM. Benzylidene-thiazolidine-2,4-diones IIIM-1268 and IIIM-1270 inhibited IL-1β release with IC_{50} of 2.3 and 3.5 μM and also significantly decreased the protein expression level of mature form of IL-1β in western-blot analysis. IIIM-1266 and IIIM-1270 displayed bidentate H-bonding with Arg 346 and Glu 305 residues in the active site of ER-β; and they also strongly occupied the ADP-binding site of NLRP3 protein. The results presented herein, indicate that ER-β guided VS can be successfully used to identify new NLRP3 inflammasome inhibitors, which may have potential in the development of novel anti-Alzheimer agents.

6.3 Evaluation of rohitukine-enriched fraction of *Dysoxylum binectariferum* Hook.f. (Leaves) as Anti-arthritic Phytopharmaceutical Candidate: Chemical Standardization, In-vivo validation, Formulation Development and Oral Pharmacokinetics (J. Ethnopharmacol., 2020, 254, 112758)

Vikas Kumar, Sonali S. Bharate, Deendyal Bhurta, Mehak Gupta, Sumit G. Gandhi, Deepika Singh, Sundeep Jaglan, Ajay Kumar, Ram A. Vishwakarma, and Sandip B. Bharate

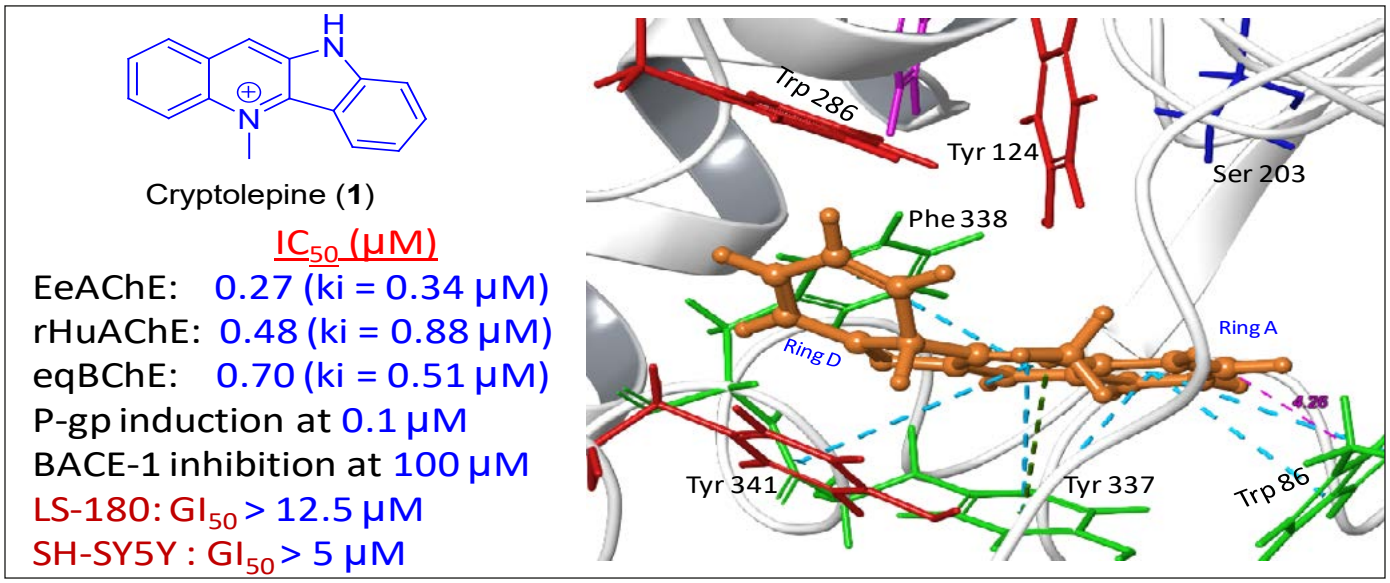


Rheumatoid arthritis is a chronic inflammatory disease of joints. *Dysoxylum binectariferum* Hook.f (Family: Meliaceae) is a Indian medicinal plant which is traditionally being used to heal inflammation of joints. This work was aimed to carry out chemical standardization, *in-vitro*/ *in-vivo* validation, oral pharmacokinetics and formulation development of anti-arthritic botanical lead, the rohitukine-enriched fraction of *D. binectariferum*. Rohitukine and schumaniofioside A were found to be major chemical constituents of the botanical lead. The rohitukine-enriched fraction of *D. binectariferum* significantly reduced the production of both pro-inflammatory cytokines TNF-α and IL-6 (>50% inhibition at 3.12 μg/mL) in THP-1 cells. In LPS-treated wild-type mice model, the rohitukine-enriched fraction at 200 mg/kg (PO, QD) completely reduced serum TNF-α level. In transgenic mice model (collagen-induced arthritis in DBA/1J mice), rohitukine-enriched fraction at 100 mg/kg (PO, QD) dose has resulted in >75% reduction of TNF-α/ IL-6 serum levels, 68% reduction in anti-mouse type II collagen IgG1 antibody levels, decreased joint proteoglycan loss and reduced paw edema in DBA/1J mice. The sustained release capsule formulation of rohitukine-enriched fraction showed sustained-release of rohitukine over the period of 24 h, and resulted in an improved plasma-exposure of rohitukine in SD rats. The data presented herein demonstrated anti-arthritic potential of rohitukine-enriched fraction of *D. binectariferum* and this study will serve as the benchmark for further research on this botanical lead and developed sustained release capsule formulation.

6.4 Synthesis and Biological Evaluation of Indoloquinoline Alkaloid Cryptolepine and its Bromo-derivative as Dual Cholinesterase Inhibitors (Bioorg. Chem., 2019, 90, 103062)

Vijay K. Nuthakki, Ramesh Mudududdla, Ankita Sharma, Ajay Kumar and Sandip B. Bharate

Alkaloids have always been a great source of cholinesterase inhibitors. Numerous studies have shown that inhibiting acetylcholinesterase as well as butyrylcholinetserase is advantageous, and have better chances of success in preclinical/ clinical settings. With the objective to discover dual cholinesterase inhibitors, herein we report synthesis and biological evaluation of indoloquinoline alkaloid cryptolepine (1) and its bromo-derivative 2. Our study has shown that cryptolepine (1) and its 2-bromo-derivative 2 are dual inhibitors of acetylcholinesterase and butyrylcholinesterase, the enzymes which are involved in blocking the process of neurotransmission. Cryptolepine inhibits Electrophorus electricus acetylcholinesterase, recombi- nant human acetylcholine- sterase and equine serum butyrylcholinesterase with IC_{50} values of 267, 485 and 699 nM, respectively. The 2-bromo-derivative of cryptolepine also showed inhibition of these enzymes, with IC_{50} values of 415, 868 and 770 nM, respectively. The kinetic studies revealed that cryptolepine inhibits human acetylcholinesterase in a non-competitive manner, with ki value of 0.88 µM. Additionally, these alkaloids were also tested against two other important pathologies of Alzheimer's disease viz. stopping the formation of toxic amyloid-β oligomers (via inhibition of BACE-1), and increasing the amyloid-β clearance (via P-gp induction). Cryptolepine displayed potent P-gp induction activity at 100 nM, in P-gp overexpressing adenocarcinoma LS-180 cells and excellent toxicity window in LS-180 as well as in human neuroblastoma SH-SY5Y cell line. The molecular modeling studies with AChE and BChE have shown that both alkaloids were tightly packed inside the active site gorge (site 1) via multiple p-p and cation-p interactions. Both inhibitors interact with allosteric "peripheral anionic site", inside the active-site gorge via hydrophobic interactions. The ADME properties including the BBB permeability were computed for these alkaloids, and were found within the acceptable range.



7. CANCER PHARMACOLOGY

7.1 Understanding the role of Protein Kinase-B isoforms in Breast Cancer Stemness and metastasis.

Bhumika Wadhwa and Fayaz Malik

Hyper-activation of Protein Kinase B (AKT) remains one of the driving signals of the most aggressive subtype of breast cancer called Triple Negative breast cancer (TNBC). Keeping in view of the non-redundant role of three AKT isoforms, we tried to evaluate the role of its individual isoforms in TN breast cancer's aggressive nature. A large number of evidences have shown that only fraction of cancer stem cells (CSCs) in tumor have the capability of micro-metastasis or tumor cells attain stemness feature by undergoing through the programme of epithelial to mesenchymal transition (EMT), pre-requisite to attain invasive and migratory properties. Our studies examined the role of AKT isoform in different breast cancer cell lines, syngeneic mice models and clinical samples. It was found that AKT isoforms play differential role in the proliferation, stemness and metastasis of TNBCs.

7.2 AKT2 not AKT1/3 over-expression is allied with stemness and metastatic properties in TN breast cancers

Bhumika Wadhwa and Fayaz Malik

Since TN breast cancers are highly invasive and metastatic, we tried to investigate the functional role of each isoform in the onset of metastasis; we evaluated the invasive and migratory properties of AKT isoforms in BT-549 and MCF-10A cells. In both MCF-10A and BT-549, knockdown (sh) of AKT2 reduced, while knocking down of AKT1 enhanced the Invasive and migratory proper-ties of these cells, however no significant change was observed in shAKT3 cells. To further, unravel whether these properties requires the presence of two isoforms or only individual isoform, we further performed the dual isoform silencing in both BT-549 and MCF-10A cells to delineate the potential of individual isoform. Dual silencing of AKT1/2, AKT2/3 and AKT1/3 (shAKT1/2, shAKT2 /3, shAKT1/3) showed that

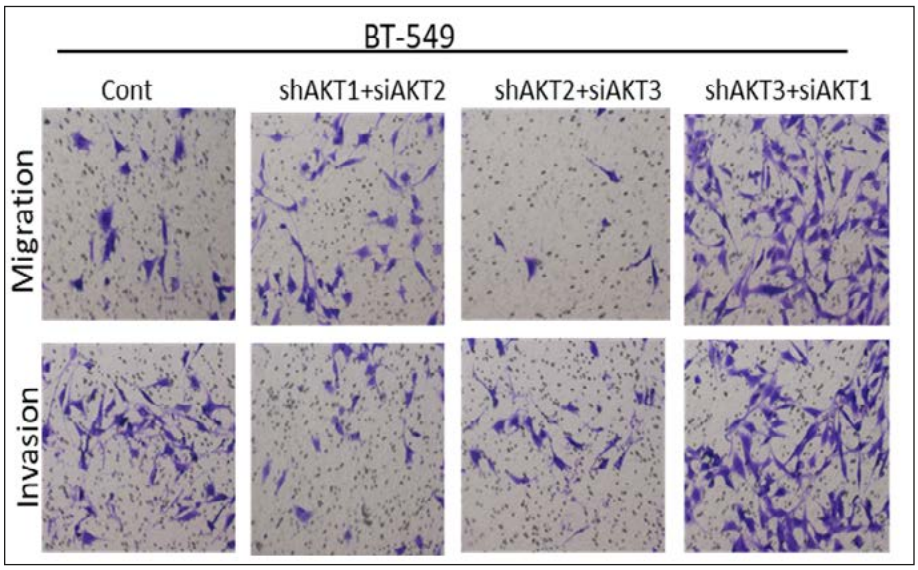


Figure 7.2.1. Invasive and Migratory Potential of AKT Isoforms

the expression of AKT2 isoform in shAKT1/3 cells is accountable for conferring invasive and migratory properties to cells (Figure 7.2.1), thus indicating the strong role of AKT2 in process of the initiation of metastasis. These results were in accordance with that of IHC staining of FFPE clinical specimen of TNBCs, showing that among the three isoforms, AKT2 has

possibly major role in metastasis. In order to delineate the role of three isoforms in the stemness of cancer cells, we performed FACS analysis of stem cell markers. A double knockdown of isoforms revealed that presence of AKT2 is associated with increased CSCs population as can be seen in shAKT1/3 dual silenced MCF-10A and BT-549 cells. Dual silencing of AKT isoforms revealed that shAKT1/3 cell have shown significant expansion of CSCs of the order of ~8 fold increase (9.07%) in MCF-10A compared to its base value 1.33% (Figure 6.2.2). Similarly, in BT-549 cells, double knockdown of AKT1/3 led to 3 fold (12.5%) increase of CSCs compared to control cells with 3.8% (Figure 7.2.2). These results further substantiated that presence of AKT2 led to expansion of CSCs, while as silencing of AKT2 brings down the population of CSCs. Another important property of metastasis initiating cells is the self-renewal and survival under matrix detachment conditions. Collectively, our results showed the involvement of AKT2, but not AKT1 and AKT3 in cancer cell migration and invasion and stemness properties.

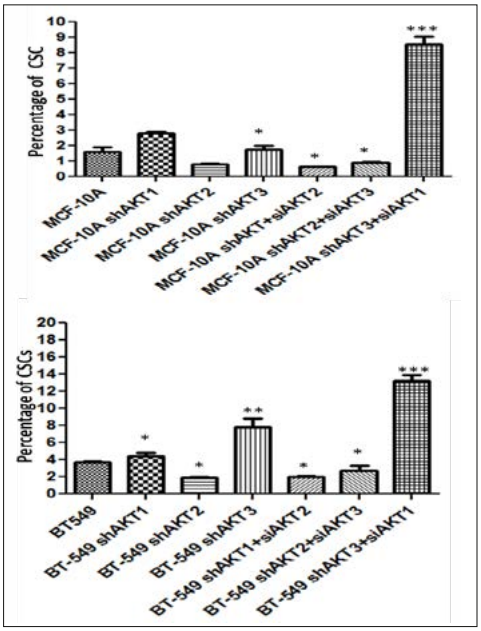


Figure 7.2.2. Role of AKT isoforms on CSCs

7.3 Vimentin activation in early apoptotic cancer cells errands survival pathways during DNA damage inducer CPT treatment in colon carcinoma model

Souneek Chakraborty, Aviral Kumar, Mir Mohd Faheem, Archana Katoch, Anmol Kumar, Vijay Lakshmi Jamwal, Debasis Nayak, Aparna Golani, Reyaz Ur Rasool, Syed Mudabir Ahmad, Jedy Jose, Rakesh Kumar, Sumit G Gandhi, Lekha Dinesh Kumar, Anindya Goswami

Epithelial to mesenchymal transitions (EMT) is a preparatory process for cancer cells to attain motility and further metastasis to distant sites. Majority of DNA damaging drugs have shown to develop EMT as one of the major mechanisms to attain drug resistance. Here we sought to understand the resistance/ survival instincts of cancer cells during initial phase of drug treatment. We provide a tangible evidence of stimulation of EMT factors in colorectal and lung adenocarcinoma cells (HCT-116 & A549) and *Apc* knockout colorectal carcinoma model (Figure 7.3.1). Our results implied that CPT-treated*Apc* knockout cohorts depicted increased pro-invasive and pro-survival factors (Vimentin & NFκB) (Figure-7.3.1C & 7.3.1D). Notably, induction of Vimentin mediated signaling (by CPT) delayed apoptosis progression in cells conferring survival responses by modulating the promoter activity of NFκB (Figure 7.3.2A-D). Furthermore, our results unveiled a novel link between Vimentin and ATM signaling, orchestrated via binding interaction between Vimentin and ATM kinase. Finally, we observed a significant alteration of crypt-villus morphology upon combination of DIM (EMT inhibitor) with CPTnullified the background EMT signals thus improving the efficacy of the DNA damaging agent (Figure 7.3.2E-G). Thus, our findings revealed a resistance strategy of cancer cells within a very initial period of drug treatment by activating EMT program, which hinders the cancer cells to achieve later phases of apoptosis thus increasing the chances of early migration.

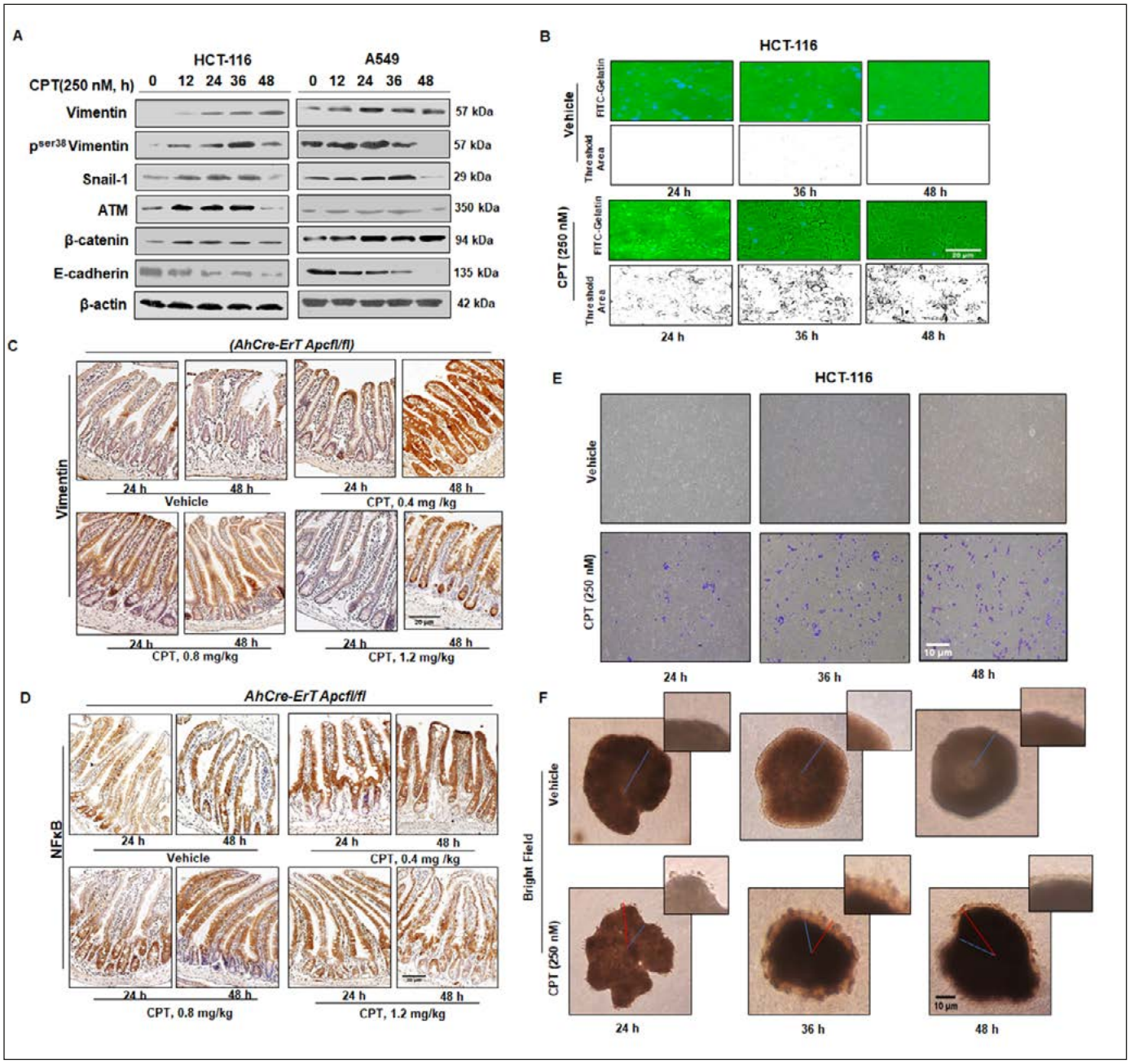


Figure 7.3.1: Activation of EMT and apoptosis in Camptothecin-mediated DNA damage response. (A) HCT-116 and A549 cells were treated with 250 nM of CPT for 0, 12, 24, 36, and 48 h and checked for the expression of Vimentin, p^{ser38}Vimentin, Snail-1, ATM, β-catenin, and E-cadherin through western blot analysis. β-actin was used as loading control. (B) Cells were treated with CPT (250 nM) for 24, 36 & 48 h along with vehicle and tested for their ability to degrade gelatin matrix and invadopodia formation through FITC-gelatin degradation assay. Blue stains indicate nuclear staining through DAPI mounting media. Images were taken at 20X magnification. Bar graph showing the threshold area of degradation quantified through Image j analysis (n = 3, error bars ± s.d.). (C,D) Induced $Cre^{+}Apc^{fl/fl}$ mice were treated with CPT (0.4, 0.8 & 12.2 mg/kg) for 24 and 48 h and the dissected colon tissues were sectioned and subjected to immunohistochemistry, to analyze the expression of Vimentin and NFκB. Images were taken at 20X magnification. (E) HCT-116 was treated with CPT (250 nM) for 24, 36, and 48 h along with their respective vehicle controls; cells were analyzed for their invasion capability through Boyden chamber assay system. Images were taken under an inverted microscope (Nikon Eclipse 200) at 10X magnification. Bar graphs represent the average number of migrated cells per field (n = 3, error bars ± s.d.); *** $p<0.001$, ** $p<0.0011$, $p=0.9125$ & $p=0.2657$. (F) Spheroids were prepared with HCT-116 cells embedded in ECM matrix by hanging drop method and treated with indicated concentration of CPT for given time points. Migration of cells from the core of the spheroids was observed under inverted microscope at 20X magnification.

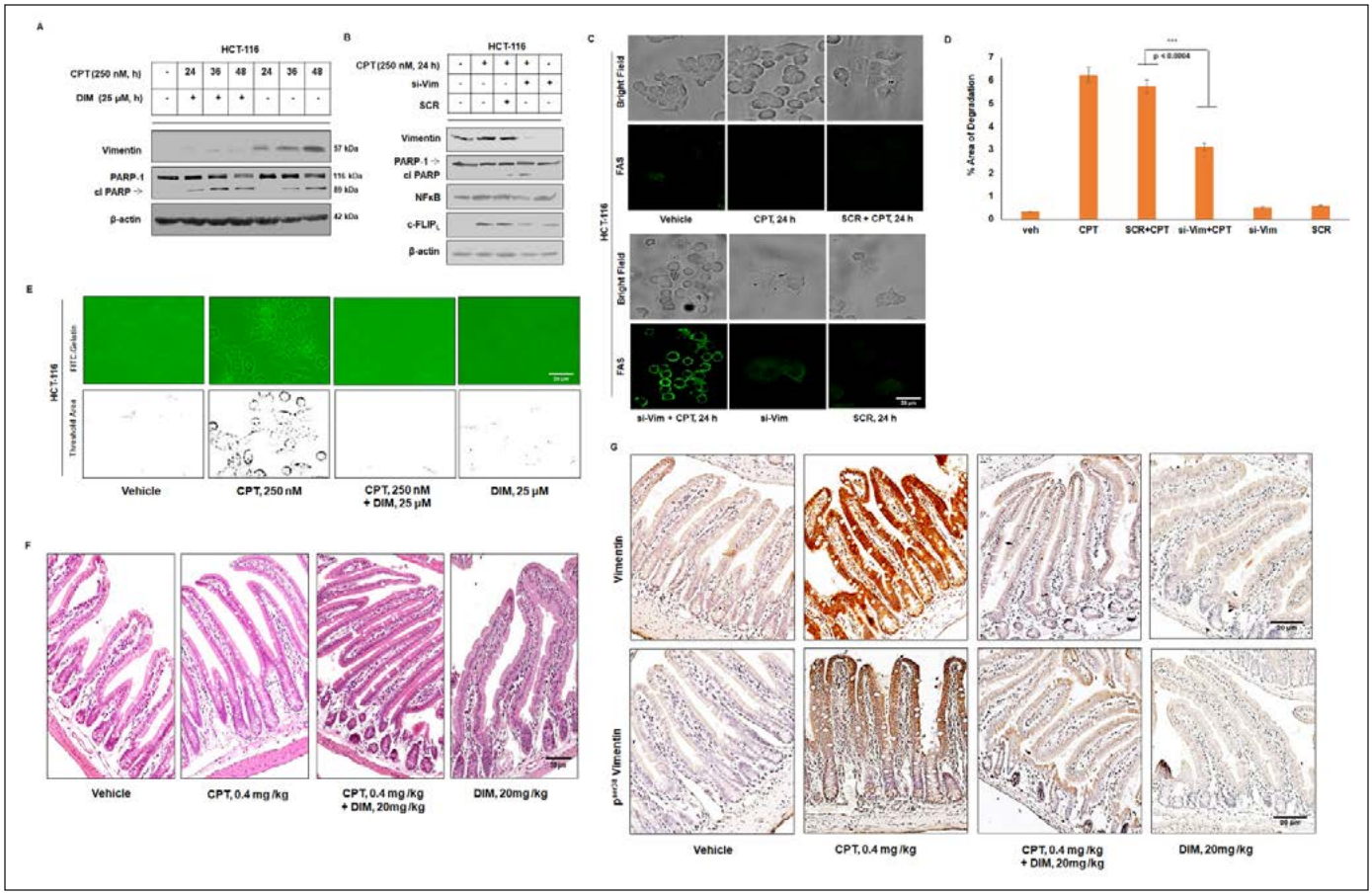


Figure 7.3.2: Induction of Vimentin hinders the progression through apoptosis.(A)HCT-116 cells were either treated with vehicle, CPT (250 nM) and CPT (250 nM) + DIM (25 µM) for indicated time points; whole cell lysates were prepared and subjected to western blot analysis of Vimentin and PARP-1 protein. (B) Cells were either transfected with vehicle, CPT (250 nM), SCR + CPT (250 nM), si-Vimentin plus CPT (250 nM) & si-Vimentin for 24 h; whole cell lysates were employed for western blot analysis of Vimentin, PARP-1, NFκB and cFLIP. (C) Immunocytochemistry was performed for the indicated treatment conditions to examine the expression and trafficking of FAS ligand in HCT-116 cells. Images were taken by using Floid Cell Imaging Station; magnification 20X. (D) HCT-116 cells were either transfected with vector, NFκB-luc alone and/or treated with NFκB-luc + CPT (250 nM), NFκB-luc + CPT (250 nM) + SCR, NFκB-luc + si-Vimentin + CPT (250 nM), NFκB-luc + si-Vimentin & NFκB-luc + SCR in 96 well plates for 24 h; luciferase activity was measured using Dual-Glo Luciferase Assay system (Promega). Normalization was done with luciferase activity of vector (n= 3, error bars ± SD). *** $p<0.001$. (E) HCT-116 cells seeded ontoFITC-gelatin coated coverslips were treated with Vehicle, 250 nM CPT, 250 nM CPT +25 µM DIM and 25 µM DIM for 36 h and the slides were observed in fluorescence microscope at 20X magnification (F) Hematoxylin & Eosin staining of colon tissue obtained from induced $Cre^{+}Apc^{fl/fl}$ treated with Vehicle, 0.4 mg/kg CPT, 0.4 mg/kg + 20 mg/kg DIM and 20 mg/kg DIM for 48 h. Images were taken at 20X magnification. (G) Immunohistochemistry analysis of Vimentin & p^{ser38} Vimentin was performed in colon tissues obtained from Apc floxed mice treated with Vehicle, 0.4 mg/kg CPT, 0.4 mg/kg + 20 mg/kg DIM and 20 mg/kg DIM for 48 h. Images were acquired in 20X magnification.

7.4 Indolylkojyl methane analogue IKM5 potentially inhibits invasion of breast cancer cells via attenuation of GRP78

Debasis Nayak, Archana Katoch, Deepak Sharma, Mir Mohd. Faheem, Souneek Chakraborty, Promod Kumar Sahu, Naveed Anjum Chikan, Hina Amin, Ajai Prakash Gupta, Sumit G. Gandhi, Debaraj Mukherjee, Anindya Goswami

More than 90% of the breast cancer deaths occur due to the metastasis of the cancer cells to secondary organ sites. Increased Glucose-regulated protein 78 (GRP78) expression is critical for epithelial–mesenchymal transition (EMT) and invasion in breast cancer resulting in poor patient survival outcomes. Therefore, there is an urgent need of potential inhibitors of GRP78 for the abrogation of invasion and metastasis in breast cancer. We investigated the effect of IKM5 (2-(1-(1H-indol-3-yl)octyl)-3-hydroxy-6-(hydroxymethyl)-4H-pyran-4-one) (a

novel Indolylkojyl methane analogue) on invasion abilities of human breast cancer cells employing invadopodia formation, Matrigel invasion assays, and mouse models for metastasis. Treatment with IKM5 at its sub-toxic concentration (200 nM) suppressed invasion and invadopodia formation, and growth factor-induced cell scattering of aggressive human breast cancer MDA-MB-231, MDA-MB-468, and MCF7 cells. IKM5 spontaneously binds to GRP78 (Ki=1.35 μM) and downregulates its expression along with the EMT markers MMP2, Twist1, and Vimentin. Furthermore, IKM5 amplifed the expression and nuclear translocation of tumor suppressor Par-4 to control NF-kB-mediated pro-EMT activities. Interestingly, IKM5 disrupts the interaction between GRP78 and TIMP-1 by inhibiting GRP78 in a Par-4-dependent manner. Moreover, IKM5 inhibited tumor growth and lung metastasis at a safe dose of 30 mg/kg/body weight.Our study warrants IKM5, a potential anticancer agent that can abrogate invasion and metastasis, suggesting its clinical development for the treatment of patients with advanced breast cancer.

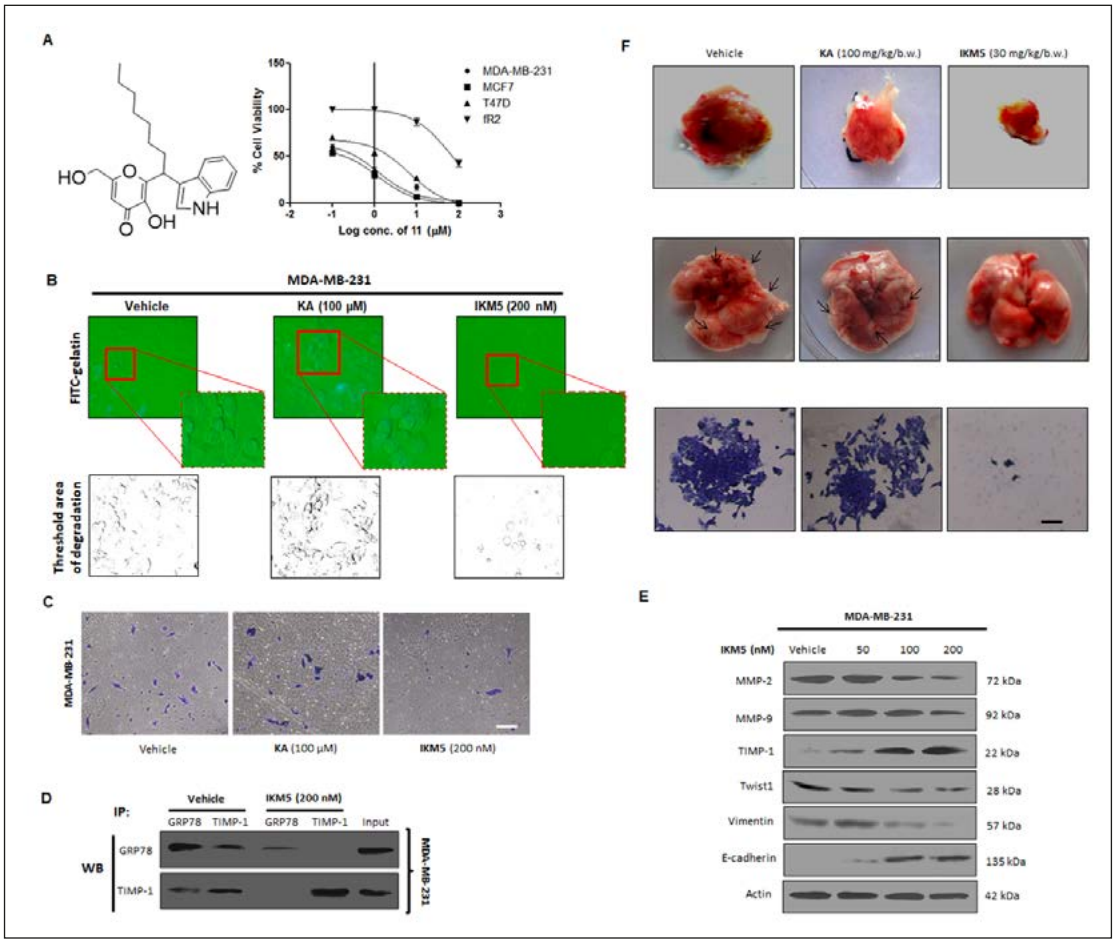


Figure 7.4.1: IKM5 abrogates proliferation, invasion, and migration abilities in breast cancer cells. (A) Structure of Indolylkojyl methane analogue (IKM5).Graph showing the % cell viability in MDA-MB-231, MCF7, MDA-MB-468, T47D, and fR2 cells treated with logarithmic concentrations of IKM5 for 48 h. (B) MDAMB-231 cells were treated with indicated concentrations of KA and IKM5 for 48 h and checked for their ability to degrade the gelatin matrix/invadopodia formation over the FITC-gelatin coated coverslips. Blue parts indicate nuclear staining through DAPI mounting media. Images were captured under Floid CellImaging Station at ×20 magnifcation. The threshold area of degradation was determined with the help of Image J software analysis. (C) MDA-MB-231 cells were checked for their ability to invade through the Matrigel barrier in Boyden chamber invasion assay system in the presence or absence of indicated concentrations of KA and IKM5. (D) Co-immunoprecipitation analysis results depicting that IKM5 disrupts GRP78-TIMP-1 interaction in invasive breast cancer cells. MDA-MB-231 cells were treated with vehicle or IKM5 for 48 h, whole-cell lysates were prepared and subjected to immunoprecipitation with GRP78 and TIMP-1 antibody. The immunoprecipitates and inputs were employed for western blotting analysis to check the expression of GRP78 and TIMP-1. (E) MDAMB-231 cells were exposed to increasing concentrations of IKM5 for 48 h; whole-cell lysates were prepared and subjected to western blotting analysis for checking the expression of MMP-2, MMP9, TIMP-1, Twist1, Vimentin, and E-cadherin. The expression of β-actin was checked as a loading control. (F) Effect of vehicle (normal saline), KA (100 mg/kg, b.w.), and/or IKM5 (30 mg/kg, b.w.) on tumor growth was studied in 4T1 mouse mammary carcinoma model.

7.5 Par-4 mediated Smad4 induction in PDAC cells restores canonical TGF- β/ Smad4 axis driving the cell towards lethal EMT

Mir Mohd Faheem, Reyazur Rasool, Syed Mudabir Ahmad, Vijay Lakshmi Jamwal, Souneek Chakraborty, Archana Katoch, Sumit G. Gandhi, Madhulika Bhagat, Anindya Goswami

Deregulation of TGF-β signaling is intricately engrossed in the pathophysiology of pancreatic adenocarcinomas (PDACs). The role of TGF-β all through pancreatic cancer initiation and progression is multifarious and somewhat paradoxical. TGF-β plays a tumor suppressive role in early-stage pancreatic cancer by promoting apoptosis and inhibiting epithelial cell cycle progression, but incites tumor promotion in late-stage by modulating genomic instability, neo-angiogenesis, immune evasion, cell motility, and metastasis. Here, we provide evidences that Par-4 acts as one of the vital mediators to regulate TGF-β/Smad4 pathway, wherein, Par-4 over-expression strongly provoked Smad4 induction in PDAC cells (Panc1 and Miapaca 2). The Smad4 induction by Par-4 was assessed by transfecting Panc-1 and Miapaca-2 cells with GFP/ GFP-Par-4. Post transfection, the cells were treated with TGF-β (5 ng/ml) for 48 h followed with western blotting to check the respective expression of Par-4 and Smad4 (Figure 7.5.1A). Corresponding bar graph shows the quantification of relative change in Smad4 protein expression (Figure 7.5.1B). In a similar sort of experimental conditions, restoration of TGF-β/Smad4 axis by Par-4 resulted in aggressive EMT phenotype as determined by immunocytochemistry analysis (Figure 7.5.1C) for Snail1 (40x magnification) and E-cadherin (40x magnification), which was later culminated into apoptosis in presence of TGF-β via positive regulation of Smad4. Further, our FACS results unveiled that Par-4 dragged the PDAC cells to G_1 arrest in presence of TGF-β triggering lethal EMT (Figure 7.5.1D). The mechanistic relevance of Par-4 mediated Smad4 activation was additionally validated by co-immunoprecipitation (Figure 7.5.1E) wherein disruption of NM23H1-STRAP interaction by Par-4 rescues TGF-β/Smad4 pathway in PDAC and mediates the tumor suppressive role of TGF-β, therefore serving as a vital cog to restore the apoptotic functions of TGF-β pathway.

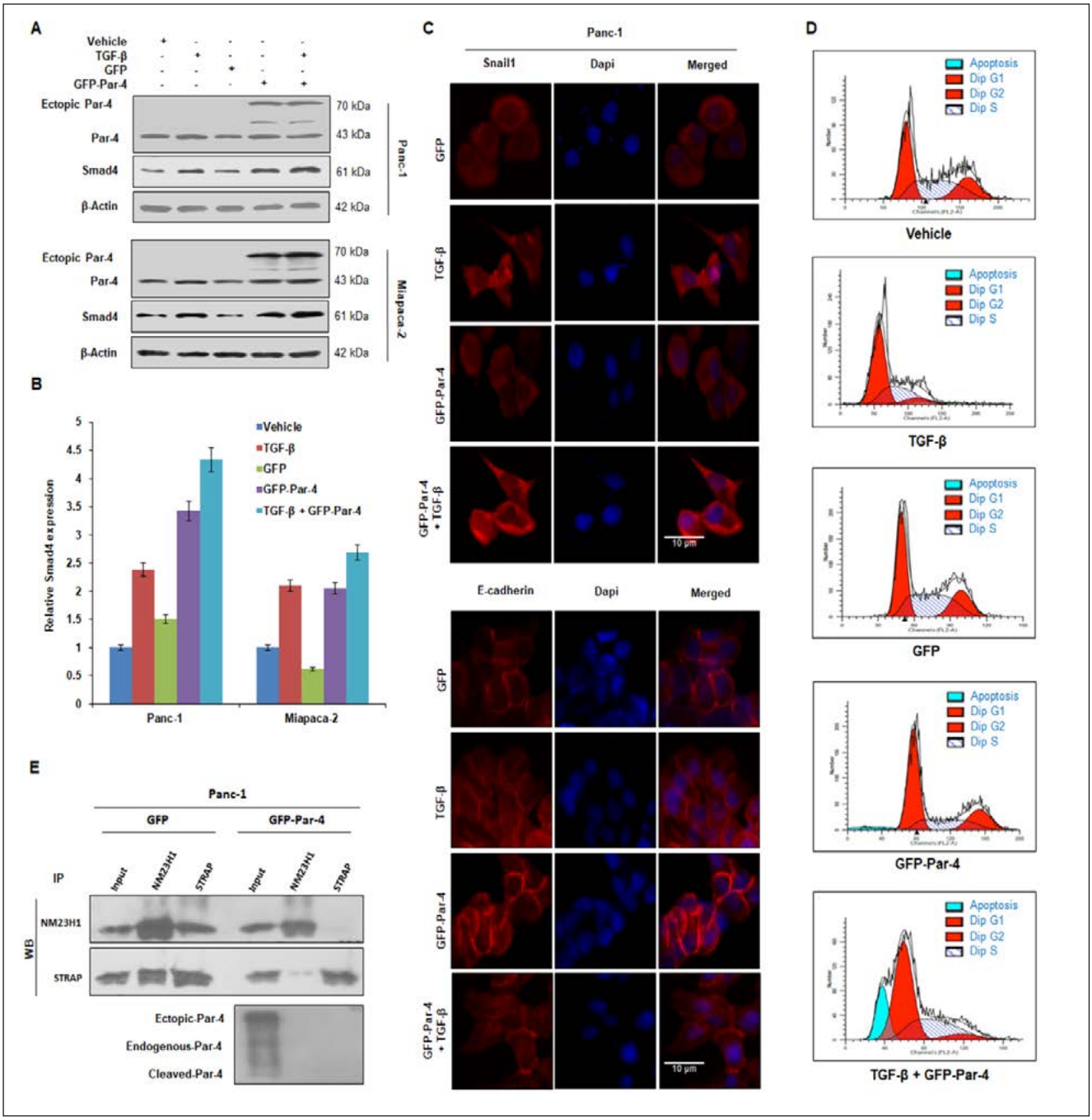
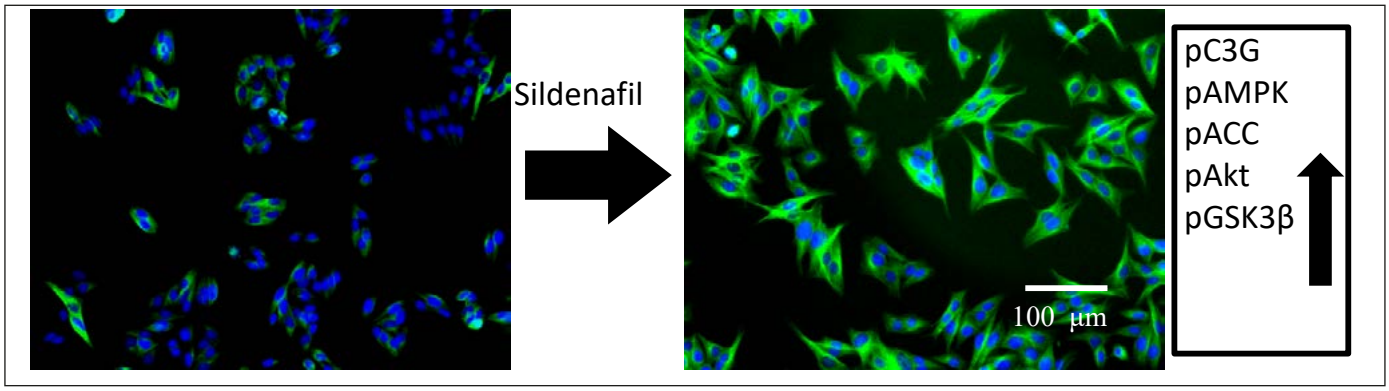


Figure 7.5.1: Par-4 induces Smad4 in PDAC cells. (A) The Smad4 induction by Par-4 was assessed by transfecting Panc-1 and Miapaca-2 cells with GFP/ GFP-Par-4. Post transfection, the cells were treated with TGF-β (5 ng/ml) for 48 h followed with western blotting to check the respective expression of Par-4 and Smad4. β-Actin was used as a loading control. (B) The graph shows the fold increase in the expression level of Smad4 mRNA upon GFP/GFP-Par-4-overexpression along with TGF-β treatment in Panc-1 cells. Error bars: mean ± s.d of three independent experiments (N = 3) performed. *$p \leq 0.05$. (C) Immunocytochemistry analysis of TGF-β treated (5 ng/ml), GFP or GFP-Par-4 transfected Panc-1 cells for Smad4 (red, original magnification is 20x), nuclear DAPI (blue). Scale bar (10 μm). (D)Cell cycle analysis by flow cytometry was performed in Panc-1 cells transfected with GFP/ GFP-Par-4, subsequently treated with TGF-β (5 ng/mL, 48 h). (B) Bar graph corresponds to percentage of cells in various phases of cell cycle (G1, S, G2M), besides showing the apoptotic population as determined by Propidium Iodide analysis. All experiments were performed in triplicates. Statistical significance was calculated by one-way analysis of variance (ANOVA) followed by Tukey's multiple comparison test, bar graphs are mean ± s.d.(N = 3). *$p \leq 0.05$; **$p \leq 0.01$. (E) Co-immunoprecipitation (co-IP) assay showing disruption of NM23H1 and STRAP interaction by exogenous Par-4 in TGF-β treated Panc-1 cells.

7.6 Discovery of novel PDE5 inhibitors and their pharmacological activities

Dar M. I., Reddy G. L., Mahajan P., M. J. Srinivas, Jan S., Jain S. K., Tiwari H., Sandey J., Wani R., U. Wazir, Syed M., Gupta G., Sahu P. K., Bharate S. S., Singh S., Sharma S. C., Tikoo M., Hudwekar A. D. Nandi P., Singh G., Bharate S, Dar M.J., Nargotra A, Vishwakarma R. A, Sawant S. D and Syed, S. H

Phosphodiesterases are a group of druggable enzymes implicated in the onset or progression of many clinical manifestations. We have been working on the discovery of specific as well as novel chemical scaffold which could be developed as lead molecule/s. Our focussed efforts have been to discover inhibitors of PDE5 isoform. This isoform is a proven drug target against erectile dysfunction and COPD and several of its inhibitors, including Sildenafil, are already FDA approved drugs. Sildenafil is a very potent inhibitor of PDE5 having sub-nanomolar IC_{50}. However, the major drawback of this compound is non-specificity especially against another isoform namely PDE6. The inhibition of PDE6 is known to cause blurred vision, a major side effect associated with Sildenafil consumption. Based on the *in silico* docking data of PDE5-Sildenafil, we decided to chemically modify the sildenafil and synthesized several analogs in hope to discover specific PDE5 inhibitors. Some of the analogs resembled the structure of sildenafil metabolites generated through its liver metabolism. Bioassay validation of these analogs leads us to the discovery of many PDE5 active molecules with compounds Compound-5 and compound IS00384 being more active and specific than the parent molecule. Compound 5 was found to be 20 folds selective to PDE5 than PDE6 having in vivo efficacy, pharmacokinetic properties and other physicochemical parameters comparable to sildenafil. We have already patented the Compound-5 (*1*) and published the work in Bioorganic Chemistry journal (*2*). Compound IS00384 was found to be more active than Sildenafil, however there was not much advantage on the specificity front against PDE6 (*3*). Recently there have been many reports emphasizing the role of Phosphodiesterases in neuronal health and brain development. We decided to check if Sildenafil and Compound IS00384 could be projected as probe molecules to study the neuronal differentiation. Our microscopy data showed that these compounds could induce the differentiation of neuroblastoma cell line IMR-32. The data was confirmed through immunochemistry and western blotting by using different neuronal marker antibodies. Both these compounds were found to elevate and activate the Guanine nucleotide exchange factor C3G, which is a regulator of differentiation in IMR-32 cells. They were also found to elevate the levels of cGMP and activate the AMPK-ACC and PI3K-Akt signalling pathways. The work was recently published in Cellular Signalling journal(*4*). In a parallel effort to discover PDE inhibitors from different chemical scaffolds, we screened (*in silico*) the CSIR-IIIM institutional natural product chemical library against PDE5 enzyme activity. The 37 identified molecules were further validated by *in vitro* assays and only one molecule namely Rottlerin was found to inhibit the PDE. Isoform selectivity data showed that this compound is actually a pan PDE inhibitor inhibiting all the PDE isoforms (PDE1-PDE11). Rottlerin was found to induce the differentiation of IMR-32 cells but not comparable to the sildenafil or IS00384. It was shown to activate the AMPK pathway and cause autophagy, apoptosis and G2/S cell cycle arrest in IMR-32 cells at higher concentrations. This work was also recently published in European Journal of Pharmacology (*5*).



References:

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4. Dar, M. I., Jan, S., Reddy, G. L., Wani, R., Syed, M., Dar, M. J., Sawant, S. D., Vishwakarma, R. A., and Syed, S. H. (2020) Differentiation of human neuroblastoma cell line IMR-32 by sildenafil and its newly discovered analogue IS00384, *Cell Signal 65*, 109425.

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8. INFLAMMATION PHARMACOLOGY

8.1 Anti-diabetic activity in rat models

I. 18 h fasted rat model

Wistar rats fasted overnight (18 h) were treated with vehicle or drug or test extract. The blood sample was collected 3 h after dosing via retro-orbital plexus puncture and serum glucose concentration was determined by GOD-POD method. Those compounds/drugs/extracts/ agents that can cause insulin release (insulin secretogogues) bring about changes in blood glucose levels rapidly. Anti-diabetic drugs belonging to the class of sulfonylurea exert their action in this manner which can cause hypoglycemia as a major, acute side effect. Drugs belonging to biguanides class are not effective in this model. Some of the plant extracts were tested for their blood glucose lowering activity in this model.

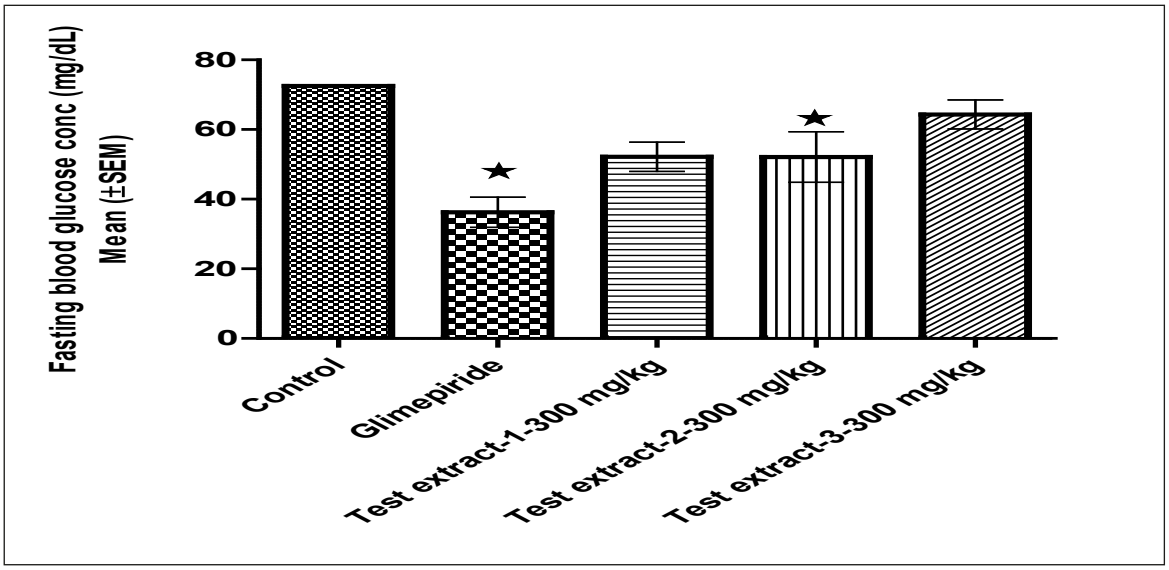


Figure 8.1.1. Effect of test extracts on fasting blood glucose levels of normal rats. * $p < 0.05$ compared to control

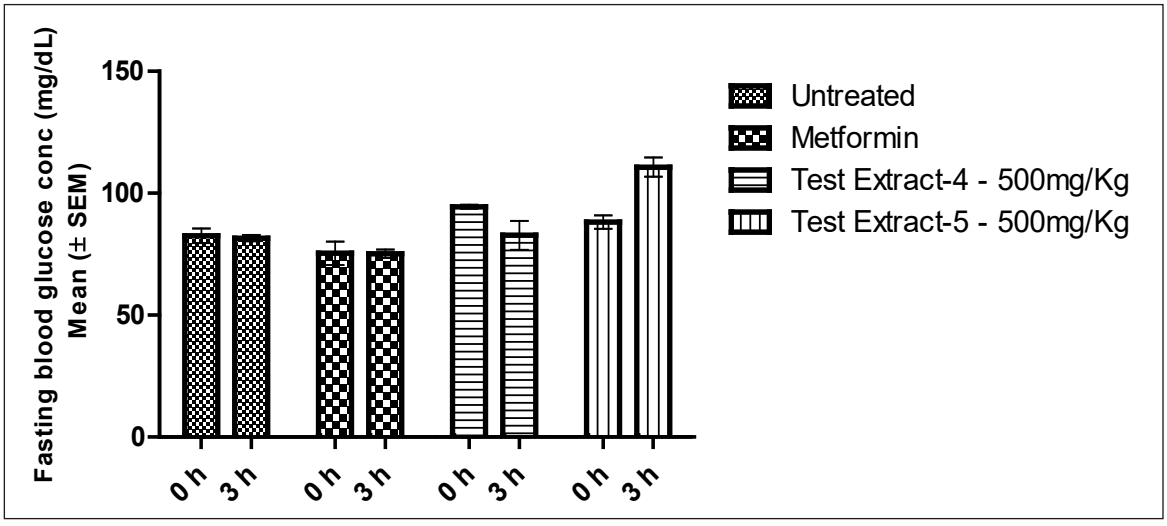


Figure 8.1.2. Effect of test extracts on fasting blood glucose levels of untreated/control rats.

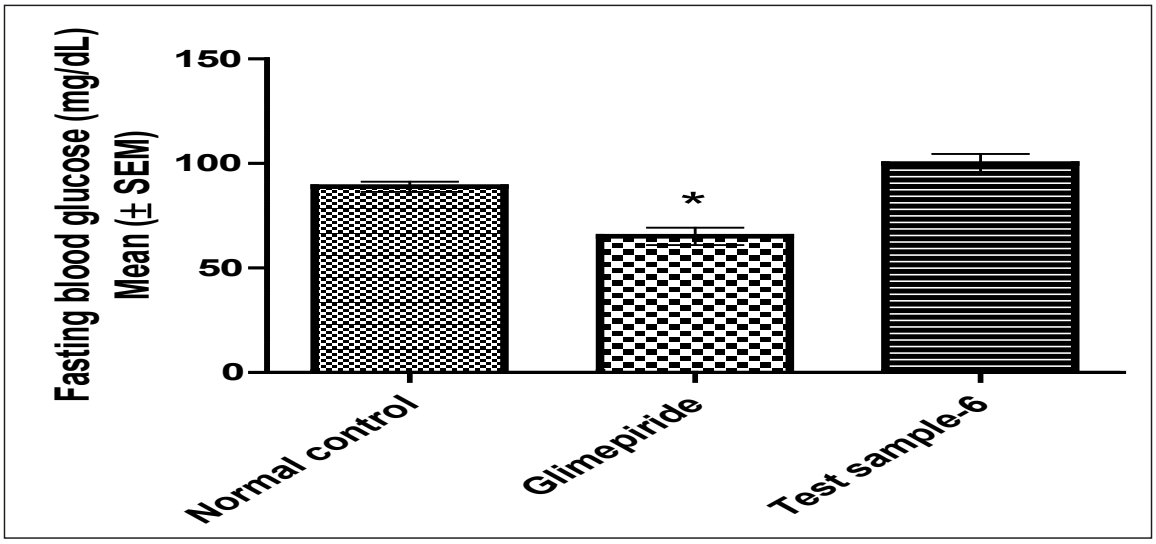


Figure 8.1.3 Effect of test extracts on fasting blood glucose levels of normal rats. *p < 0.05 compared to normal control

II. Streptozotocin (STZ) induced diabetes rat model

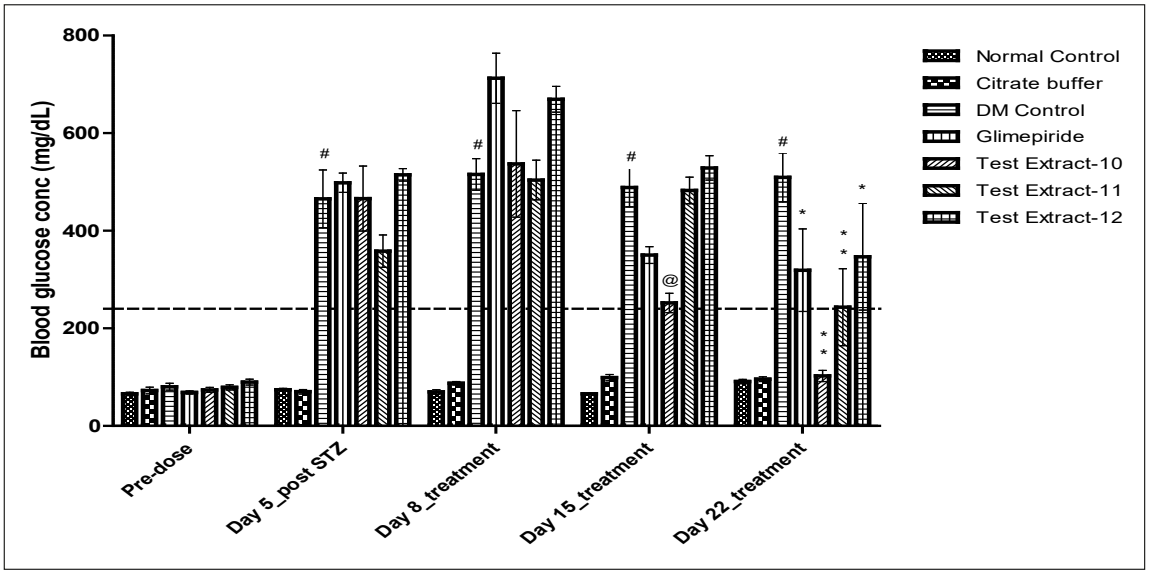


Figure 8.1.4. Blood glucose levels of diabetic rats treated with drug or test extract or vehicle. # P < 0.001 compared to normal control, @P < 0.01, * P < 0.05, ** P < 0.001 compared to DM control

Intraperitoneal administration of STZ at 45 mg/Kg in freshly prepared citrate buffer pH 4.5, to overnight fasted Wistar rats resulted in elevation of blood glucose levels (on 5th day) rendering the rats diabetic. Some of the plant extracts/fractions were tested for their blood glucose lowering activity in this model. The drug/ plant extract / fraction / vehicle were administered once daily orally, as a suspension in 0.1 % CMC for the indicated time period. Blood samples were collected by retro-orbital plexus puncture 24 h after dosing and serum glucose concentration was determined by GOD-POD method. In addition, the body weight was monitored over a period of 28 days following the streptozotocin administration which indicated that the diabetic rats lost body weight continuously. As shown in Figure 8.1.5, the body weight observed for untreated (normal) or citrate buffer treated rats was significantly higher when compared to streptozotocin treated rats indicating development of one of the prominent feature of diabetes (i.e. loss of body weight). Following treatment with

pioglitazone (Figure 8.1.6) there was significant gain in the body weight compared to diabetic rats (indicates one of the prominent features of this drug to cause weight gain as a side effect in clinical use). The feed consumption was monitored for one week (during third week of the experiment) indicated that diabetic rats consumed more food compared to normal rats. Within diabetic rats, vehicle treated and pioglitazone treated rats consumed higher feed content than metformin treated rats (Figure 8.1.7). The key difference was that the vehicle treated diabetic rats lost weight whereas pioglitazone treated diabetic rats gained weight. Although, their feed consumption was lower, the body weight of metformin group was comparable to that of vehicle treated diabetic rats (Figure 8.1.6). These results indicate that the streptozotocin administration successfully induced diabetes in rats and the behavior of the diabetic rats manifests actual disease conditions in many respects. Further, we would like to explore the utility of such models to investigate on complications of diabetes.

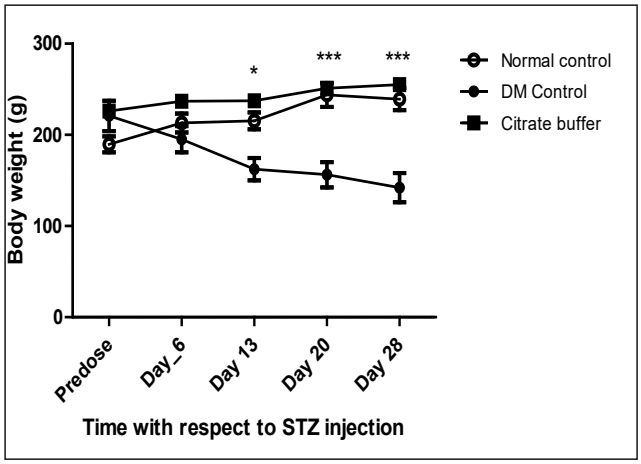


Figure 8.1.5. Body weight of rats treated with streptozotocin to induce diabetes. * P < 0.05 compared to DM control, *** P < 0.001 compared to DM control

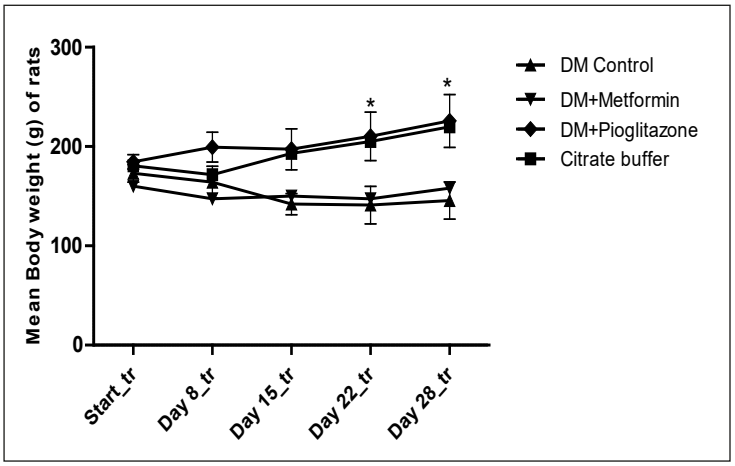


Figure 8.1.6. Body weight of diabetic rats treated with drugs. * P < 0.05 compared to DM control

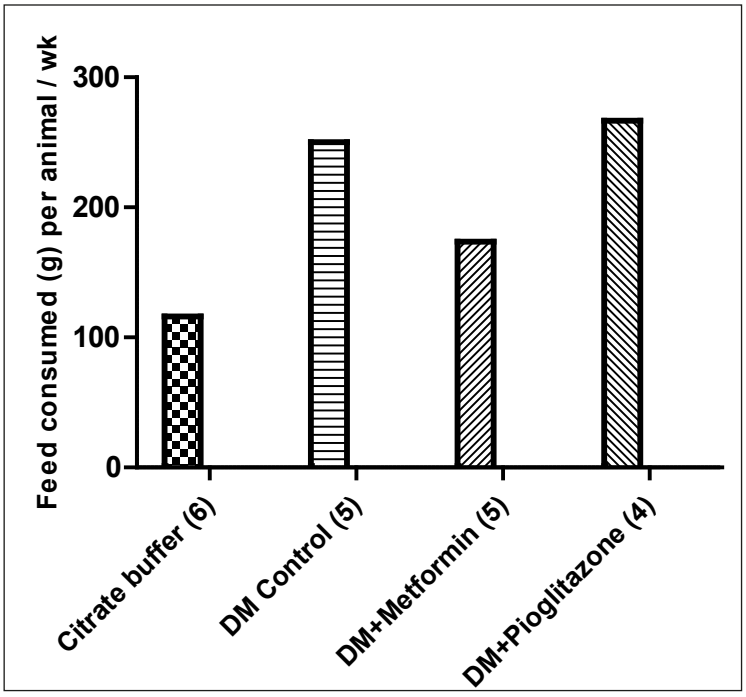


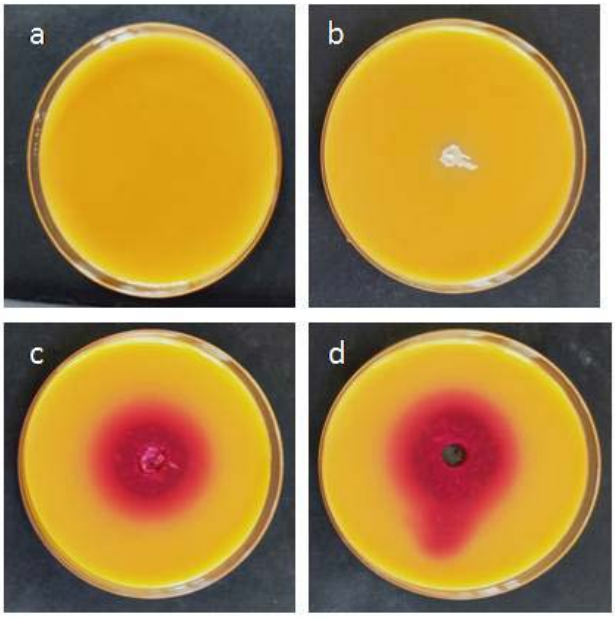
Figure 8.1.7. Feed consumption of diabetic rats treated with drugs.

9. FERMENTATION TECHNOLOGY

9.1 Screening of bacterial cellulose producing microorganism for the Development of antibiotic impregnated transdermal patches

Manoj Kumar, Nipunta Tajon, Saurabh Saran

Bacterial cellulose (BC) is a highly pure biopolymer devoid of hemicelluloses and lignin is produced by certain bacteria in the form of a membrane. They mainly are belonging to the *Acetobacter (Gluconacetobacter)* genera. It is one of the important biopolymer of the current times because of its immense applications in different industrial sectors particularly in health care area. In literature certain bacteria are reported to produce bacterial cellulose those mainly belongs to genera *Acetobacter* and a few other genera like *Pseudomonas, Alcaligenes, Rhizobium, Agrobacterium* and *Aerobacter*. However, this bacterium produces small fibrils or amorphous cellulose. Thus, there is an utmost requirement for the screening of potent cellulose producing bacteria, mainly from the genera *Acetobacter* (acetic acid bacteria) as these have been reported for the highest cellulose production ability. The microorganisms employed in this study were bacteria isolated from the vinegar and rotten apples and were maintained on nutrient agar (NA). Hestrin-Schramm (HS) medium was used as detection medium. Experimentally, after autoclaving, half of the medium (250 ml) was supplemented with filter sterilized Methyl red dye before pouring of the plates and half of the medium was poured as it is, without adding the dye, plates were then allowed to harden. The present study clearly reveals that plate containing methyl red dye is of better use in comparison to without dye plates for the qualitative screening of microorganisms producing acid. In the control experiments where no dye was used a zone of solubilisation is formed near the bacterial growth (MS-18 of *Gluconobacter* sp) on HS agar plate, the zone formed around the plate is due to solubilization of $CaCO_3$ by acetic acid produced from the oxidation of ethanol during fermentation. It showed oxidation of ethanol which is a characteristic property of genera *Acetobacter*.



Detection of acid producers on plates supplemented with MR dye along with $CaCO_3$ and ethanol: (a) uninoculated plates; (b) non-acid producer *Bacillus* sp; (c) plate inoculated with *Gluconobacter* sp. (acid producer); (d) plate inoculated with culture filtrate of *Gluconobacter* sp.

9.2 Consistent production and synthesis of pharmacologically important derivatives of kojic acid from *Aspergillus sojae* SSC-3 isolated from rice husk

Shifali Chib, Ashish Dogra, Utpal Nandi, Saurabh Saran

Kojic acid (5-Hydroxy-2-(hydroxymethyl)-4H-pyran-4-one) is a natural organic acid with the molecular formula $C_6H_6O_4$. It is widely used in cosmetic and health care industries. Kojic acid primarily functions as the basic material for the production of skin whitening creams, skin protective lotions, whitening soaps and tooth care products. It has the ability to act as the ultraviolet protector, whereby, it suppresses hyper-pigmentation in human skins by restraining the formation of melanin through the inhibition of tyrosinase formation, the enzyme that is responsible for skin pigmentation. It works by inhibiting formation of pigment by suppressing specific amino acids. The components of kojic acid will compete or block natural enzymes that allow creation of these pigments so that the colors do not form. In the present study, a consistent kojic acid producing fungal strain has been isolated from rice husk using glucose-peptone medium. The isolate was identified as *Aspergillus sojae* SSC-3 on 18S rDNA analysis. *A. sojae* was capable of producing substantially good amount of kojic acid; however the production was varying from batch to batch. In order to obtain consistent, repeated and high levels of kojic acid, monospore isolation procedures was adopted. The highest production of kojic acid obtained was 12 ± 2 gL^{-1} in 120 h with sucrose (10%) and yeast extract (0.5%) as carbon and nitrogen source respectively. The process was scale up to 7L fermenter size which repeatedly resulted in the production of 18 ±2 gL^{-1} of kojic acid in 96 h. Kojic acid was recovered (>82%) from the fermentation broth with >99% purity. Two kojic acid derivatives have been synthesised from the purified kojic acid which are known to possess diverse range of pharmacological activities that might advantageously be used in pharmacology and also for the preparation of newer biologically active compounds. Best to our knowledge this is the first report were kojic acid production is reported from *Aspergillus sojae* strain.

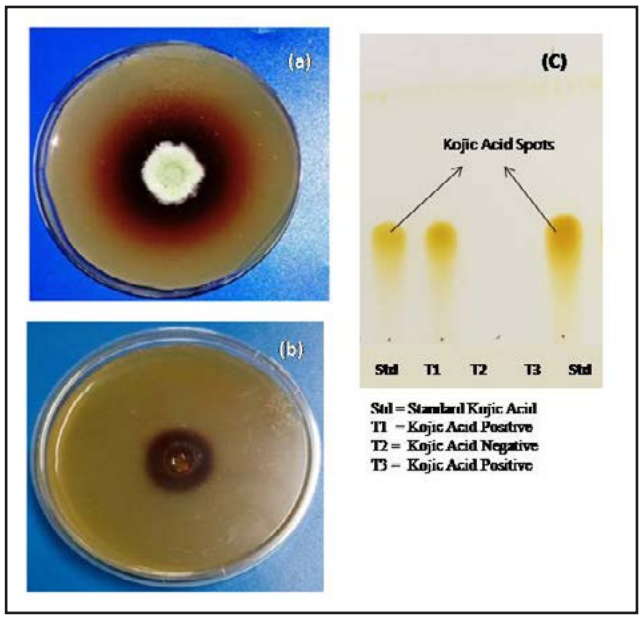


Figure 9.2.2

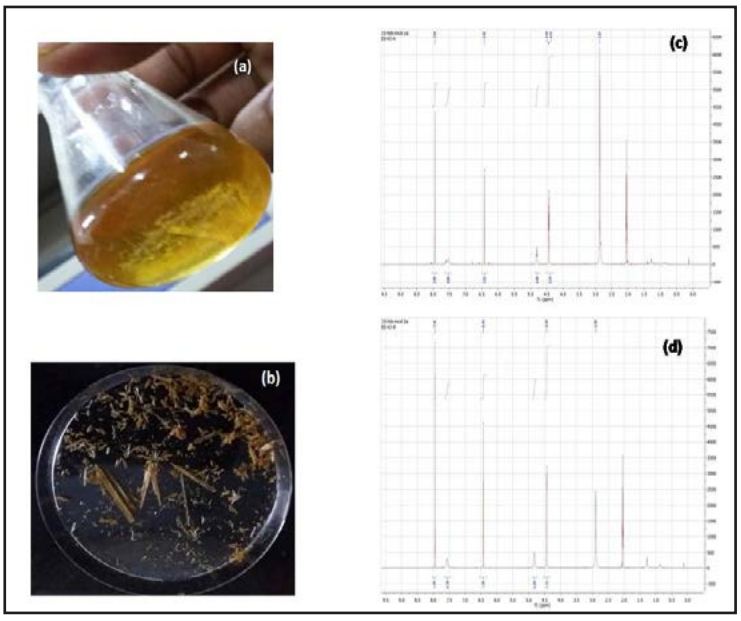


Figure 9.2.3

9.3 Exploration of mulberry phyllosphere for serratiopeptidase production

Diksha Koul, Devtulya Chander, Ravi S. Manhas and Asha Chaubey

Serratiopeptidase is a proteolytic enzyme known to be produced from the non-pathogenic enterobacteria *Serratia* sp. E-15. Although, *Serratia marcescens* has a wide range of distribution in nature, inhabiting soil, animals as well as plants, its presence in silk worm bears ecological importance. *Serratia marcescens* was first isolated from silk worm *Bombyx mori* L. The serratiopeptidase secreted by these bacteria help in dissolving the cocoon leading to the emergence of moth. Thus isolates of *Serratia marcescens* from silk worm gut would have higher potential for production of protease enzyme. The Serratiopeptidase produced by *Serratia marcescens*, as well as some other bacteria of genus *Serratia*, is used as an anti-inflamatory drug. In the present study, a total of 19 isolates were obtained, in which 14 were isolated from the rhizospheric soil and 5 endophytes each were isolated from stem and leaves respectively as shown in Figure 9.3.1. Among these, 14 cultures showed a clear zone around the colony on skim milk agar plates and therefore were positive for protease activity. The isolates showing positive results for protease activity were further evaluated for their quantitative protease activity. It was observed that one endophyte (MES-4) and one isolate from rhizospheric soil (MRS-11) had significantly higher activities as compared to the other isolates. Both the isolates were found to have maximum similarity with *Serratia marcescens,* a known serratiopeptidase producer. Therefore, both the isolates are now being exploited for serrationpeptidase production.

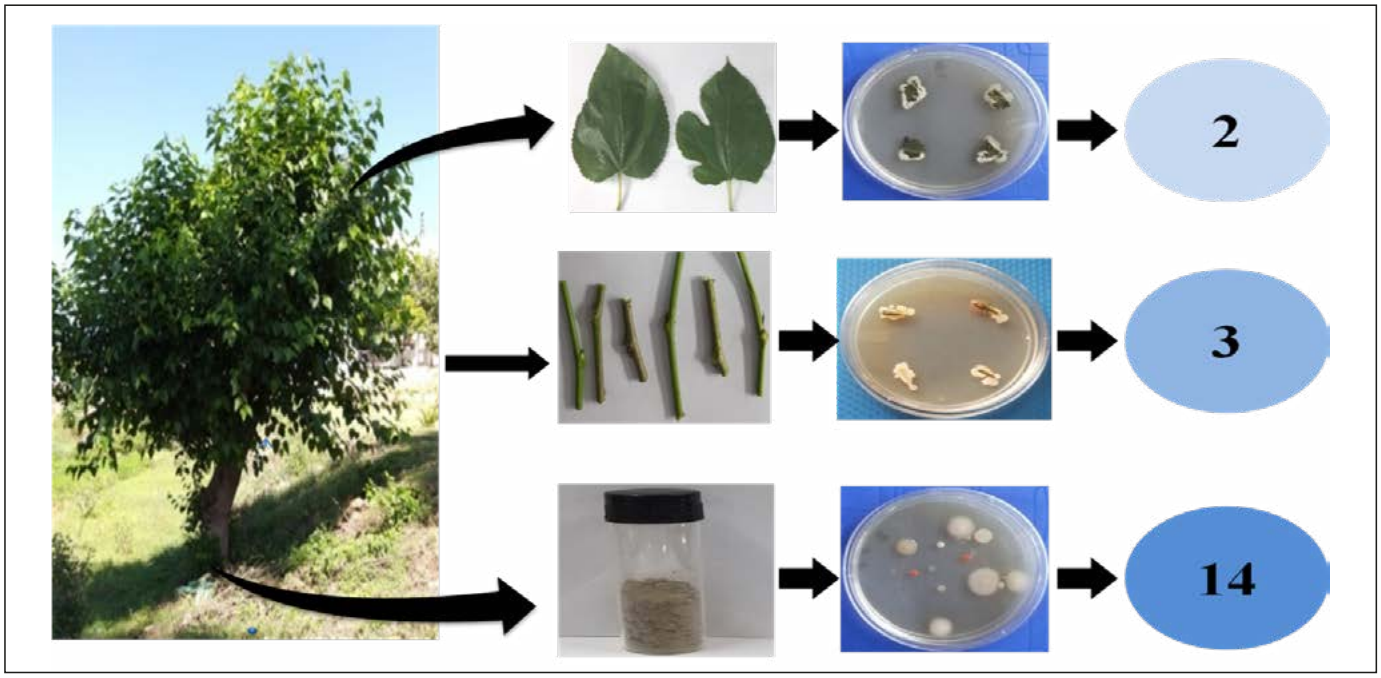


Figure 9.3.1. Isolation procedure of microorganisms from mulberry plant

Figure 9.3.2. Screening of pure isolates for protease activity

9.4 Biotransformation of (-)-verbenone to (-)-10-hydroxyverbenone

Ravi S. Manhas, Diksha Koul and Asha Chaubey

Verbenone is a natural monoterpene present as an essential component in rosemary oil from *Rosmarinus officinalis, Verbena triphylla* and *Eucalyptus globule*. Biotransformation is an economically and ecologically viable technology which has been used extensively to modify the structures of many classes of biologically active products. Biotransformation of Verbenone was carried out using a fungus isolated from soil and identified as *Talaromyces purpurogenus*. Biotransformation of Verbenone was carried out in fermentation broth during exponential phase to (-)-10-Hydroxyverbenone. The biotranformation product was extracted in ethyl acetate and observed on TLC. The product was further identified on the basis of Gas chromatography-mass spectrometry (GC/MS).

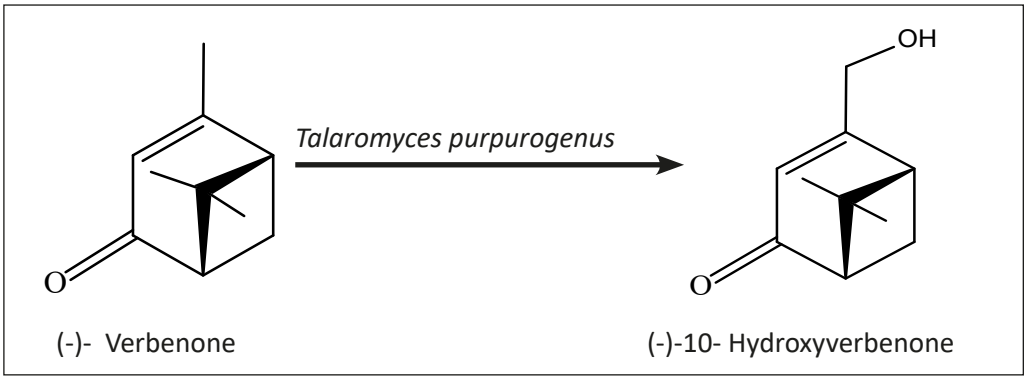


Figure 9.4.1. Microbial bioconversion of (-)-verbenone to (-)-Hydroxyverbenone

9.5 Biotransformation study of limonene

Rahul Vikram Singh, Haseena Shafeeq, Ananta Ganjoo & Vikash Babu

(R)-(+)-limonene is the most abundant monoterpene in nature. It is used as a substrate for the synthesis of terpene derivatives that have a significant importance in the production of food, as well as in the pharmaceutical and perfumery industry. Limonene can be biotransformed into oxygenated monoterpenes such as α-terpineol, which is a monoterpenoid that has a significantly higher added value than limonene, and a market of 13,000 tons per year. Moreover, α-terpineol is considered to be a safe additive (GRAS 3045), because it has a characteristic aroma of lavender, which is commonly used as fragrance in the industry of perfumes, fragrances, cosmetics and toiletries. In the present research work, one endophyte isolated from aromatic crop was used for the biotransformation of limonene and thereafter fungal endophyte was cultured in 5L fermenter for the biotransformation of limonene (Figure 9.5.1). Biotransformation reaction was analyzed by TLC (Figure 9.5.2a) and one compound (Carveol) was purified by column chromatography and characterized by GC-MS (Figure 9.5.2b).

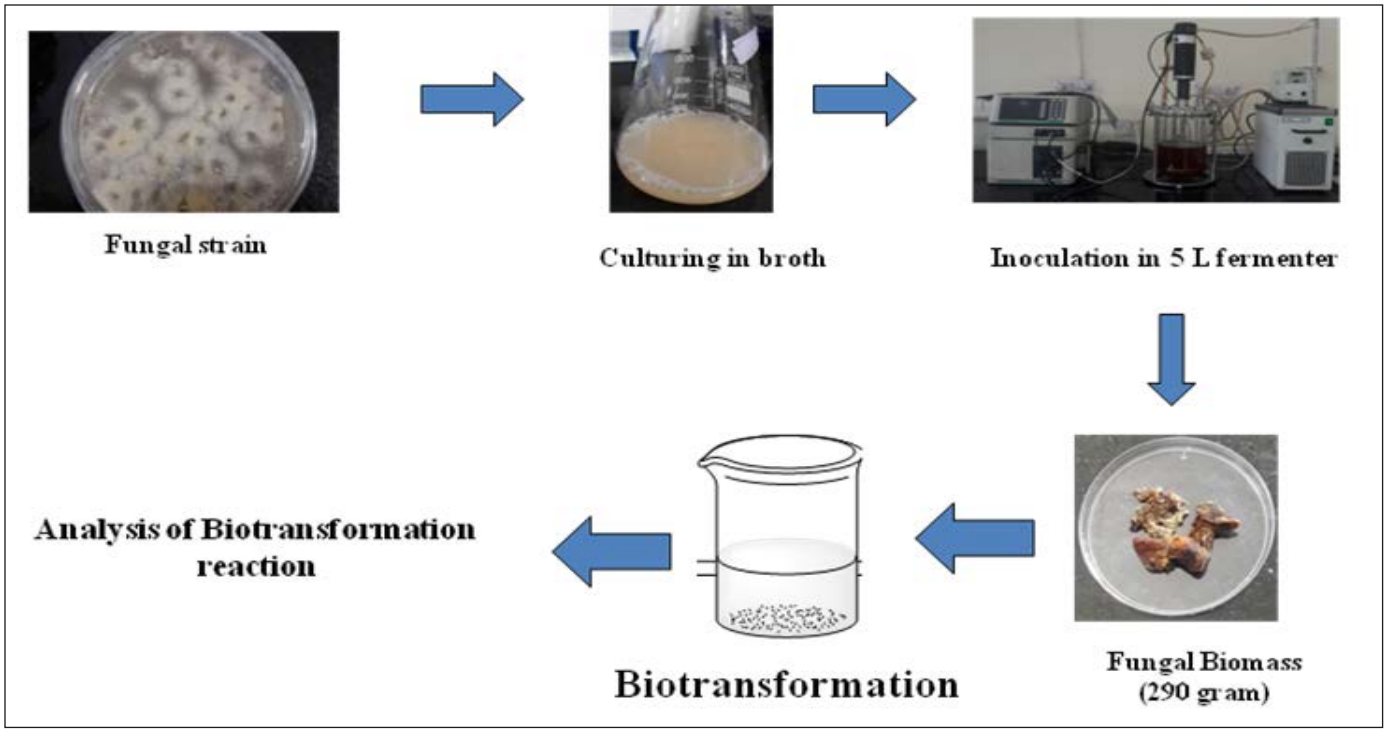
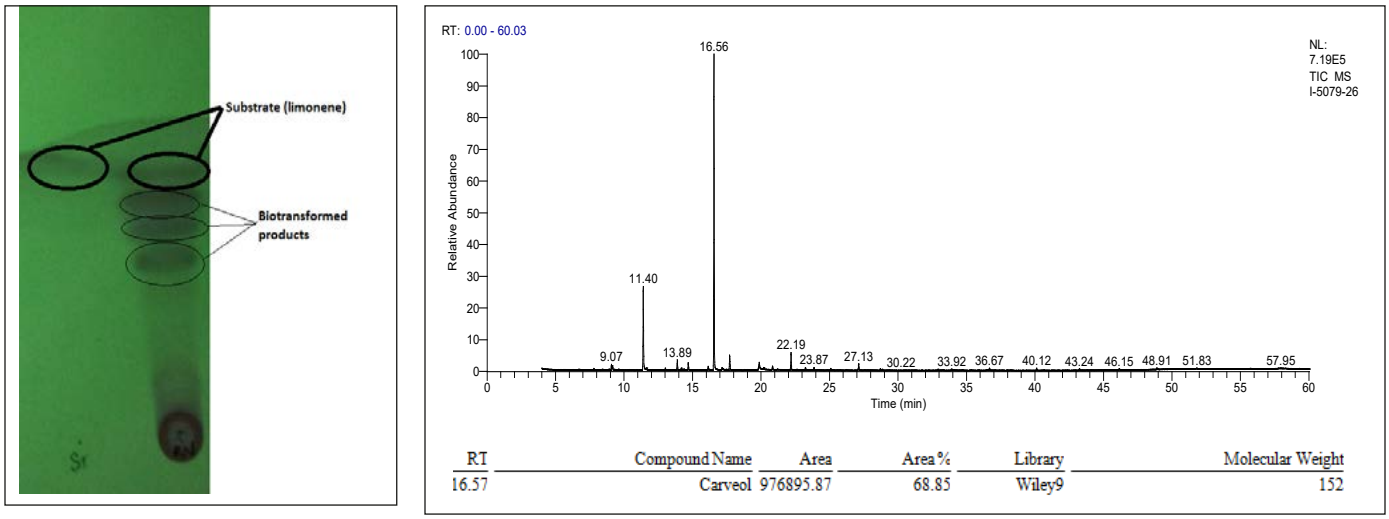


Figure 9.5.1. Fungal Biomass Production and biotransformation reaction



(a) (b)

Figure 9.5.2. (a) TLC analysis . (b) GC-MS analysis of bio-transformation reaction

9.6 Isolation and screening of microorganism for the biotransformation of Geraniol

Haseena Shafeeq, Ananta Ganjoo & Vikash Babu

Geraniol (2-trans-3,7-di- methylocta-2,6-dien-1-ol, $C_{10}H_{18}O$) is one of the most important acyclic monoterpene alcohols. It is the chief constituent of the oil of palmarosa and rose oil. Geraniol is used as a fragrance in household products and as a component of artificial 'essential oils'. The microbial transformation of geraniol has attracted many researchers and, depending on the type of micro-organism employed, different compounds are produced. Most studies dealing with microbial conversion of geraniol have resulted in a mixture of products however; there is a considerable interest in obtaining a microbial conversion that yields a single bioconversion product. Geraniol was transformed into a single bioconversion product, namely methylheptanone, by the fungus *Penicillium digitatum* in such a pursuit. Geranic acid has a role as a pheromone, an EC 1.14.18.1 (tyrosinase) inhibitor, a plant metabolite, an antifungal agent and a melanin synthesis inhibitor. In the ongoing research work, biotransformation of geraniol into geranic acid which is a polyunsaturated fatty acid i.e., octa-2, 6-dienoic acid bearing two methyl substituents at positions 3 and 7 (the 2E-isomer), was carried out. For the biotransformation of geraniol to geranic acid, microbes were isolated from rhizosphere and different parts (endophytes) of aromatic plants. Only culture (LG) was able to biotransformed Geraniol into product (Table 9.6.1). Geranic acid was initially analyzed by TLC (Figure 9.6.1a) and further confirmed by GC-MS analysis ((Figure 9.6.1b).

Table 9.6.1. Screening of biotransformation reaction with Geraniol as substrate

Code	Substrate	Reaction time	Result
LG(Fungus)	Geraniol	48 hrs.	+
Rsh (Fungus)	Geraniol	48 hrs.	ND
LDR (Fungus)	Geraniol	48 hrs.	ND
RL-28(Fungus)	Geraniol	48 hrs.	ND
MTA (Fungus)	Geraniol	48 hrs.	ND

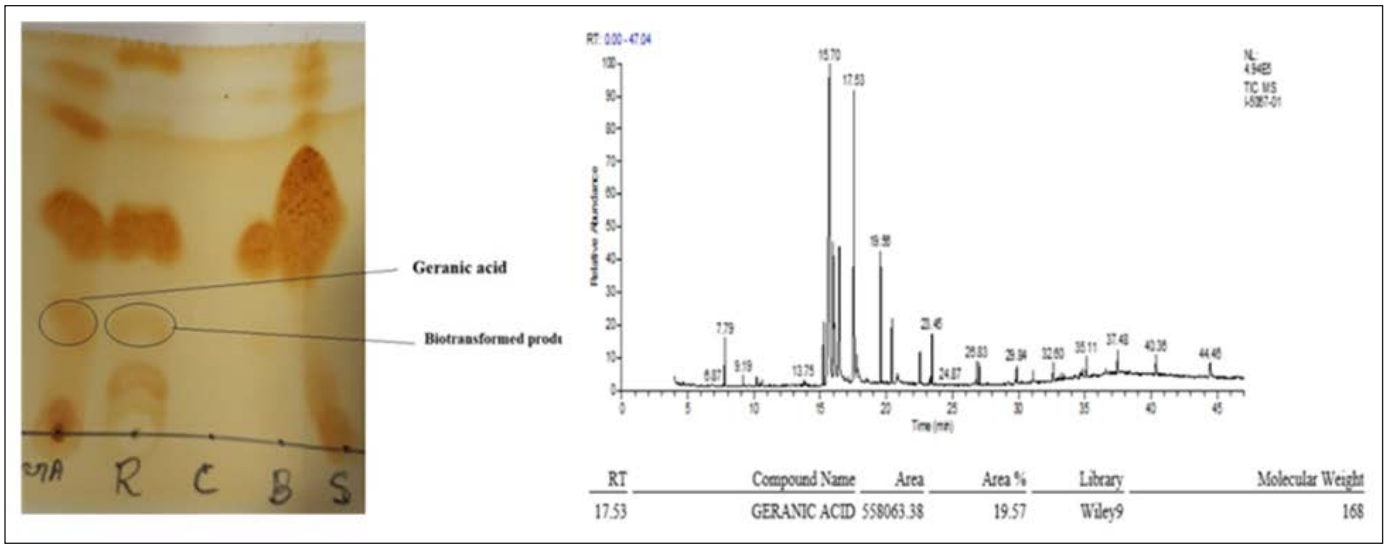


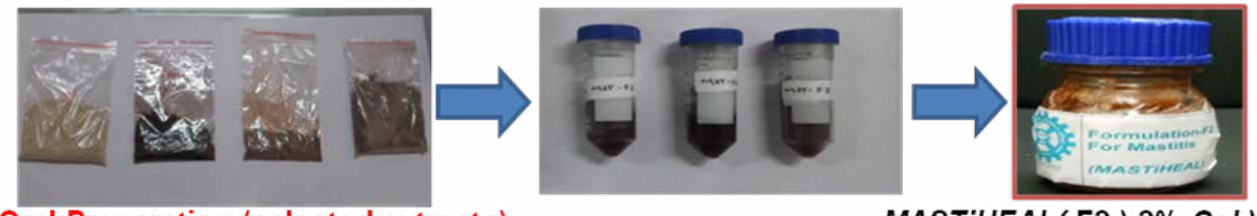
Figure 9.6.1. Geraniol biotransformation reaction analysis by (a) TLC (b) GC-MS

10. ANIMAL HOUSE

10.1 Development of Phytopharmaceutical product for Bovine mastitis

Yadav Govind, Sangwan PL, Gupta PN, Khan IA Katare, Anil, Singh Deepika, Kumar Amit, Chouhan Narender, Gupta Rahul, Diksha Raina, Dang Ajay K, Rahal Anu

Development of Phyto-pharmaceutical product for Bovine mastitis



Oral Preparation (selected extracts)
Boswellia serrata, Berginia ciliate, Terminalia bellerica, Piper betle,)

MASTiHEAL(F2) 2% Gel)
Topical formulation

	Studies conducted for the development of Phytopharmaceutical product	
1.	Antibacterial Activity *Effective against S.aureus, Streptococcus agalactiae,St. disgalactiae* etc	√
2,	Invitro Anti inflammatory Activity (inhibition of pro-inflammatory cytokines IL1β,IL2,IL6,TNFα)	√
3	CMC (Marker compounds indentified)	√
3	Effective in Invivo carragenan induced paw edema mouse model	√
4.	Effective in Invivo LPS induced Mouse model of Mastitis	√
5.	Found safe in Dermal irritation study (OECD), Mutagenicity(AMES OECD)	√
6	Evaluated and found effective in Target animals of Mastitis (Cows &Goats)	√
7.	Found most effective in subclinical Mastitis(70% of losses due to Mastitis)	
	Can be recommended as co therapy to shorten treatment period with antibiotic in Dairy animals	

10.2 Antibacterial efficacy of natural product (*Boswellia serrata* extract) against *staphylococcus aureus* clinical isolate from mastitis.

Govind Yadav, Rakesh Kumar Nagar, Amit Kumar, Narendra Chouhan, PL Sangwan, Anil Kumar Taku

Among the bacterial pathogens causing mastitis, *staphylococcus* aureus is most common cause of infection of the mammary gland that affects a high proportion of dairy cows throughout the world. *S. aureus* bacteria produce toxins that destroy cell membranes and can directly damage milk-producing tissue. White blood cells (leukocytes) are attracted to the area of inflammation, where they attempt to fight the infection. Initially, the bacteria damage the tissues lining the teats and gland cisterns within the quarter, which eventually leads to formation of scar tissue. The bacteria then move up into the duct system and establish deep-seated pockets of infection

in the milk secreting cells (alveoli). This is followed by the formation of abscesses that wall-off the bacteria to prevent spread but allow the bacteria to avoid detection by the immune system. The abscesses prevent antibiotics from reaching the bacteria and are the primary reason why the response to treatment is poor (as described in VCE Publications / 404 / 404-229 by *C. S.* Petersson-Wolfe). Use of synthetic antibiotics irrationally, causing antibiotic resistance and drug residue problems. Keeping in view above facts present study was planned to see *invitro* antibacterial efficacy of natural product against *staphylococcus aureus* from clinical sample. In Present study *Boswellia serrata* hydro alcoholic extract was tested for MIC determination (broth dilution method) against clinical isolate of *Staphylococcus* aureus which was previously isolated (*S. aureus* clinical isolate was gifted by Dr. Anil kumar Taku, Prof. Deptt. of Microbilogy, FVSC&AH, SKUAST, Jammu) from milk of the mastitis cow. Bacterial isolate from milk of mastitis cow was previously biochemically characterized and further confirmed to be *S. aureus* by 23SrRNA PCR amplification. Inhibitory potential of proinflammatrory cytokine was also determined in LPS induced RAW 264.7 (Murine macrophage cell lines). Result shows that *Boswellia serrata* effective against clinical isolate of *staphylococcus aureus* and minimum inhibitory concentration was 64µg/ml (MIC) whereas ciprofloxacin kept as control showing 0.25 µg/ml (MIC), in another study *Boswellia serrata* showing 44.62% inhibitory activity against TNFα (Proinflamatory cytokine) in LPS induced RAW 264.7 (Murine macrophage cell lines). Conclusion of the present study that natural product having antibacterial potential, it is suggestive to be used as co-therapy to reduce the dose of antibiotics.

1. Projects in Animal House:

Project No.	*Funding*	*Title*	*Type of project*	*Rs.*
GAP2141	DBT	Development of phyto-pharmaceutical product for bovine mastitis	R&D	889800
MLP-6012	CSIR	IND-Enabling studies (Mutagenecity)	R&D	
HCP-0008	CSIR	Sickle Cell Anemia Mission	R&D	
STS-0005	CSIR	Science and Technology Services	S&T Services	

2. Revenue generated:

	Revenue generated in FY 2019-20	Total (Rs.)
1	Animal(Rodents) sale	351200
	Order Booked (CRI,Kasouli,HP)	250000
2	Animal contributed in IIIM R&D : Equillent cost	944640
3	Training	90000
	Total (Rs.) (Annual sale and contribution reduced in last 2 months(COVID- 19 period))	1635840

3. Training program (1, April 2019 – 31, March 2020):

Six trainees were trained in handling, designing Animal studies and care of experimental animals, cell culture, microbial culture and PCR

Name of candidate	Institution	Area	Period	Amount (Rs.)
Miss Ramandeep kaur	Guru Nanak Dev University, Amritsar	Learning Animal house techniques for preclinical studies.	3 months	15000
Ms. Reezwan M	Leh & Ladakh	Cell culture & Microbial culture techniques, Animal handling, techniques for preclinical studies.	3 months	15000

Name of candidate	Institution	Area	Period	Amount (Rs.)
Ms. Deachen angmo	Leh & Ladakh	Cell culture & Animal handling, techniques for preclinical studies.	3 months	15000
Ms. Jasbir kour	University of Kashmir	Mutagenicity and Animal handling, techniques for preclinical studies.	6 months	30000
Mr Vinay Kumar	Deptt. of Biotechnology, IIT Roorkee	Wound healing and animal handling.	3 months	15000

4. Clients: 16 clients added from Scientific Institutions

S.No	Name & Address	Institution	Date	Rs.
1	Dr. Manzoor ur Rehman mir, Prof. & Head Deptt. of Biochemistry	SKUAST-K FVSC & AH, Srinagar (J&K)	08.04.2019	9600
2	Dr. Jyoti prakash Assistant Prof. School of Basic Science, CUP(PB)	Central University Punjab, School of Basic and Applied Sciences, Bhatinda (PB)	15.04.2019	24000
3	Ms Sheeba Department of Pharmaceutical Science	University of Kashmir,Srinagar, J&K	03.05.2019	32000
4	Dr. AK Tyagi, principal scientist and Head , ICAR-NDRI, Karnal	ICAR-NDRI, Karnal (HR)	06.05.2019	21000
5	Dr. Yogendra Padwad , CSIR-IHBT, Palampur	CSIR-IHBT, Palampur, Himachal	14.05.2019	24900
6	Dr. Sadhna Sharma , Prof and Head Department of Biotechnology	PGI Chandigarh	16.05.2019	51000
7	Prof and Head Dept. of Anatomy Govt. Medical College (GMC) Srinagar,	GMC, Srinagar, Kashmir	20.05.2019	47600
8	Dr. ZA Bhat , Department of Pharmaceutical Sciences ,	University of Kashmir	21.05.2019	5000
9	Dr. Sabeeha Safi Associate Prof. Department Of Pharmaceutical Sciences	University of Kashmir	22.07.2019	8000
10	Dr. Suman Tapryal, Assistant Professor, Department Of Biotechnology,	Central University of Rajasthan, Ajmer, (Raj)	20.08.2019	16500
11	Dr.Yogendra Padwad , CSIR-IHBT, Palampur	CSIR-IHBT, Palampur, Himachal	17.09.2019	24900
12	Dr. Seema Akbar Asst. Director I/C Rrium Srinagar (J&K))	RRIUM Srinagar (J&K)	18.10.2019	28000
13	Dr .Muhee , Prof. Division of Veterinary Medicine,	FVSC&AH, SKUAST-K Srinagar	07.11.2019	17600
14	Prof. Saroj Arora Department of Biochemistry GNDU, Amritsar Panjab	GNDU, Amritsar Panjab	11.12.2019	18000
15	Manpreet Kaur Department of Chemistry, GNDU Amritsar	GNDU, Amritsar Panjab	15.01.2020	21600
16	Pria Department of Chemistry, GNDU Amritsar	GNDU, Amritsar Panjab	15.01.2020	8400

5. Over all Distribution of client in five years

Distribution of Clients in States of India

1. Jammu and Kashmir
2. Haryana
3. Punjab
4. Himachal Pradesh(HP)
5. Rajasthan
6. Delhi
7. Madhya Pradesh(MP)

11. CHEMICAL ENGINEERING AND cGMP PILOT PLANT

Product development of Standardized plant *Trillium govanianum* extract and capsule.

Trillium govanianum Wall. ex. D. Don [Syn. *Trillidium govanianum* (D. Don) Kunth)] belongs to the genus *Trillium* (family: Melanthi aceae *alt*. Trilliaceae) commonly known as 'nag chhatri' or 'teen patra'. This species is distributed between 2,500 to 4,000 m across the Himalayan region.

*Trillium govanianum (*Rhizomes)

Trillium govanianum Plant

In folk medicine, the rhizomes of *T. govanianum*are used to treat boils, dysentery, and inflammation, menstrual and sexual disorders, as an antiseptic and in wound healing. The plant has analgesic, anti-inflammatory, anticancer and antifungal properties. We are in the process of developing a standardized dietary supplement / Nutraceutical product in the form of capsules from its rhizomes, which is backed by scientific data including complete CMC (Chemistry, Manufacture and Control) of raw material and finished product, toxicity / safety pharmacology). This dietary supplement will be helpful for menstrual, reproductive and sexual disorders. CSIR-IIIM has procured 100 kg of authentic Botanical Raw Material i.e. dried rhizomes of *T. govanianum* for product development as specialty food from the J & K Forest Department. It is further authenticated and accessioned in the crude drug Repository of CSIR-IIIM.

भारतीय समवेत औषध संस्थान
(वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद्)
केनाल रोड, जम्मू – 180001
Indian Institute of Integrative Medicine
(Council of Scientific & Industrial Research)
Canal Road, Jammu - Tawi - 180 001 (INDIA)

IIIM/RRLH/2019/03 **Dated**: 15-01-2019

Subject: Identification of the foreign matter in the plant material.

Kindly refer to the internal samples analysis request submitted to Janaki Ammal Herbarium (RRLH) and Crude Drug Repository section for authentication on 26/12/2019 by Mr Sumit Roy from cGMP, CSIR-IIIM, Jammu. After critical taxonomic evaluation followed by consultation with scientific literature, provided raw drug specimen (specimen no. Trillium/B-01/Pl.Mat.) was identified as dried roots/rhizome of *Trillium govanianum* Wall. ex D.Don belonging to the family Melanthiaceae. Provided sample was compared with the authentic samples of *Trillium govanianum* Wall. ex D.Don stored at CSIR-IIIM crude drug repository (Sample no. 4051). Duly identified dry herb material of the received herb specimen has been submitted to the Crude Drug Repository of CSIR-IIIM with accession number CDR-4081.Provided sample was evaluated for the presence of foreign matter. Provided herb sample was found to have 1.64 % foreign matter in the form of aerial parts of the same plant, soil and some unidentified plant material.

15/01/19
(Sumeet Gairola)
Scientist and Assistant Professor (AcSIR)
Plant Sciences Division, CSIR-IIIM, Jammu

Note:
- This report is only for private use. It is not deemed to be a report of analysis of drugs manufactured under licence issued under Drugs and Cosmetic Act. 1940 and the rules there under.
- The report refers ONLY to the particular sample submitted for test by customer.
- This report may not be published or reproduced in full or part for commercial purposes without the prior permission, in writing of the Director, Indian Institute of Integrative Medicine, Jammu Tawi.

Phones : EPABX (0191) 2569000-06; (Director) 2569111, 2569222, 2569333 (Fax) : PME 2569019 (P/F) (CoA) 2569016-17 (F), PUR 2569025 (P/F), ACCTS 2569026, Website : (www.rrljammu.org)

The CMC study on crude plant material done and report of various parameters received.

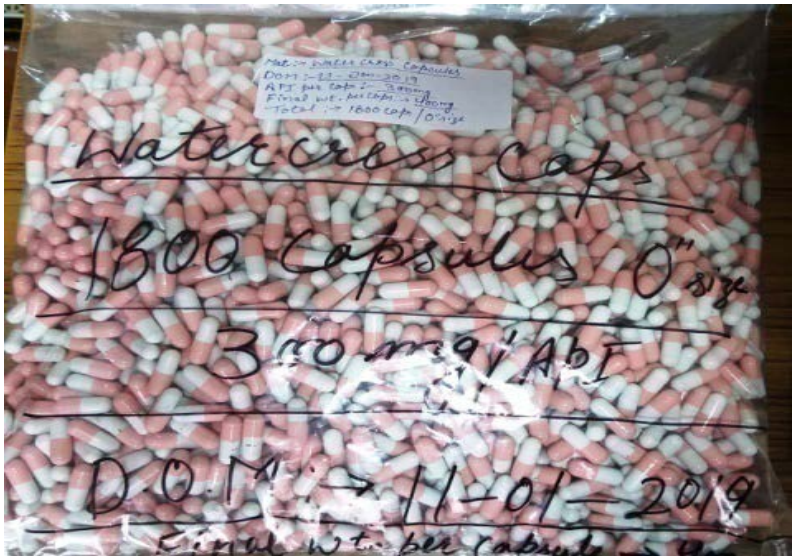
- The Rhizomes of *T. govanianum* processed at normal temperature and pressure with 1:6 solute solvent (>90% Purity) ratio (Plant material: alcohol), extract filtered, concentrated and recovery of solvent done with distillation vessel. The concentrated extract dried in vacuum tray dryer/ Lyophilizer and dried extract stored at low temperature. One no. of batch prepared for in-house as well as external funded project. Extract of *T. govanianum* submitted for CMC studies and report received. Formulation of capsules for further studies i.e. CMC, safety, toxic etc, done. More than 1500 nos. of capsule prepared. The dose of capsule is 400 mg (API) as decided by competent authority and overall weight of capsule is approximately 546 mg. The sample (400 Nos.) for CMC study already been submitted to QCQA department.

Capsule formulation (*Trillium govanianum*)

Product development for M/s. Glowbil Pvt. Ltd. Lasipura Pulwama (J&K)

CSIR-IIIM Jammu is mainly focus on Natural product chemistry, New Phyto pharmaceutical, new drug discovery, Plant biotechnology etc., This institute is focussed on safe & quality innovative product (Herbal) make available to the public through Govt. of India.

- **Watercress** or yellowcress is an aquatic plant species with the botanical name *Nasturtium officinale* watercress is a rapidly growing, aquatic or semi-aquatic, perennial plant native to Europe and Asia, and one of the oldest known leaf vegetables consumed by humans. It is a member of the family Brassicaceae; watercress and its relatives garden cress, mustard, radish, and wasabi are all noteworthy for their piquant flavors. The hollow stems of watercress will float; the leaf structure is pinnately compound. Small, white and green flowers are produced in clusters and are frequently visited by insects, especially hoverflies such as Eristalis flies. Plant is a Nutraceutical enriched and this invention envisages the potential of an extract obtained from the leaves of the plant to act as an effective therapy against Muti-vitamins deficiency. The plant contains Vitamin A, B_1, B_2, B_6, B_9, B_{12}, C, E and K. The total quantity of capsules from watercress plant material prepared are more then 1800 with dosage form of 300 mg (API), total weight of the capsule is around 400 mg.



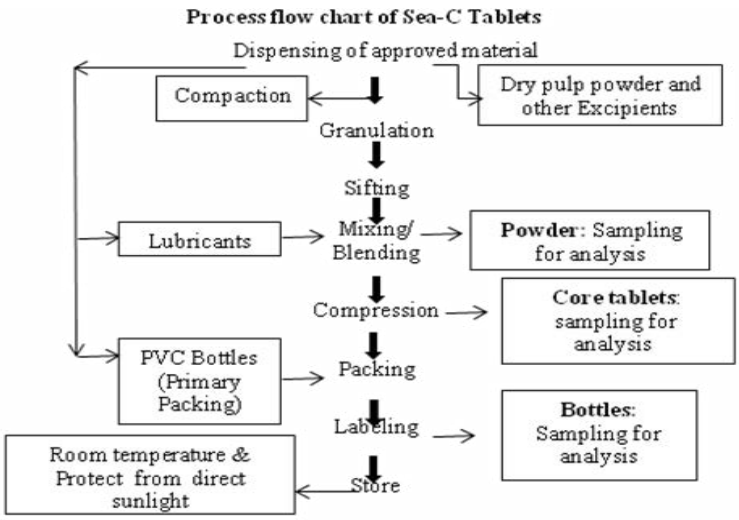
Nutraceutical formulation (**Watercress**)

Hippophae rhamnoides (Sea Buckthorn):

CSIR-IIIM Jammu is mainly focus on Natural product chemistry, New Phyto-pharmaceutical (GSR 702 E), new drug discovery, Plant biotechnology etc., *Hippophae rhamnoides* (Sea Buckthorn) is a Nutraceutical products This institute is focus safe & quality innovative product (Herbal) make available to the public through Govt. of India. The present invention comprising an effective amount of a Pulp / lyophilized Pulp along with one or more pharmaceutical acceptable additives/ carriers. This invention envisages the potential of an extract obtained from the fruit of the plant to act as an effective therapy against anti-oxidative suppressor property as well as Muti-vitamins source. Contains Vitamin A, B_1, B_2, B_6, B_9, B_{12}, C, E, K and malic acid. The overall dose of the tablets is 750 mg. with API **225 mg**. The CMC study on formulation also been completed.

Tablet Formulation

Proposed Brand Name: Sea-C



Specifications of the Vitamin-C enriched "Chewable Tablets"

Parameters	Sample report (mg/100g)	Parameters	Sample report (mg/100g)
Vitamin C	25.80	Vitamin E	78.11
Vitamin A	0.02	Vitamin B_2	0.11
Vitamin B_1	0.05	Vitamin B_9	0.01

- Nos. of batches of extraction done in cGMP/CED Division for in-house research as well as national mission project.

Standardized extract development of *Boswellia serrata* (cold extraction)

Resigns of *Boswellia serrata* processed at normal temperature and pressure with 1:10 solute solvent ratio (Plant material: alcohol), extract filtered, concentrated and recovery of solvent done with distillation vessel. The concentrated extract dried in vacuum tray dryer/Lyophilizer and dried extract stored at low temperature. Three nos. of batches prepared for in-house as well as external funded project.

Standardized extract development of *Cannabis sativa* (Alcoholic Cold Extraction)

Leaves of *Cannabis sativa* processed at normal temperature and pressure with 1:8 solute solvent ratio (Plant material: Alcohol), extract filtered, and concentrated with the help of distillation. The concentrated extract dried in vacuum tray dryer and semi solid extract stored at low temperature. Three nos. of batches prepared for in-house as well as external funded project.

Standardized extract development of *Glycyrrhiza glabra* (Hydro-alcoholic/Aqueous Hot Extraction).

Roots of *Glycyrrhiza glabra* processed at higher temperature and pressure with 1:8 solute solvent ratio (Plant material: Water, Alcohol), extract filtered, and concentrated with the help of distillation and wiped film evaporator. The concentrated extract dried in vacuum tray dryer/spray dryer/ Lyodryer and dry extract stored at low temperature. Four nos. of batches prepared for in-house as well as external funded project.

Standardized extract development of *Withania somnifera* (Hydro-alcoholic Extraction).

Roots of *Withania somnifera* processed at higher temperature and pressure with 1:8 solute solvent ratio (Plant material: Water, Alcohol), extract filtered, and concentrated with the help of distillation and wiped film evaporator. The concentrated extract dried in vacuum tray dryer/spray dryer/ Lyodryer and dry extract stored at low temperature. One no. of batch prepared for in-house as well as external funded project.

Development extract of *Trillium govanianum* (Naag Chhatri) (Alcoholic Extraction)

Rhizome of *Trillium govanianum* processed at normal temperature and pressure with 1:10 solute solvent ratio (Plant material: alcohol), extract filtered, concentrated and recovery of solvent done with distillation vessel. The concentrated extract dried in vacuum tray dryer/Lyophilizer and dried extract stored at low temperature. One no. of batch prepared for external funded project.

Spry Drying of *Glycyrrhiza glabra and Bergenia Ciliata* extract:

Extract developed at GMP pilot plant dried on spry dryer facility and around 40 Kg of each extract in the form of dry powder prepared by maintaining 25-30% TSS content, with the help of said equipment.

12. IIIM - TECHNOLOGY BUSINESS INCUBATOR

IIIM-TBI is to create an environment to inspire Start ups and entrepreneurial minds of the J&K state to pursue innovation and entrepreneurship. IIIM-TBI supports entrepreneurs, new start ups, researchers, students, institutes / universities, scientists, small or medium companies who plan to incubate their ideas or budding technologies into commercially successful ventures. The main objective of the IIIM-TBI is to produce successful business ventures that create jobs and wealth in the J&K region, along with encouraging an attitude of innovation in the country as a whole.

IIIM-TBI has took 05 projects for the development and formulation of pharmaceutical and nutraceutical products

- Project 1: Calcium supplement
- Project 2: Wormicide
- Project 3: Development of Trillium capsule
- Project 4: To manufacture capsules of Vijaya (Cannabis) annually at cGMP-Facility for Herbal drugs.
- Project 5: *Cannabis* oil impregnated Bacterial Cellulose based trans dermal patches

13. QUALITY CONTROL & QUALITY ASSURANCE (QCQA)

QCQA is a National Accreditation Board for Testing and Calibration Laboratories (NABL) accredited division in field of chemical testing. It is dedicated to render analytical services of highest quality meeting the requirement of the standard ISO/ IEC 17025:2017 and other criteria's of NABL. It is the first notified Food Testing Laboratory in J & K approved by GOI, Ministry of Health and Family Welfare under Section 43 (1) of FSS Act, 2006 for food commodities such as Nuts, Honey and Nutraceuticals.

Mission & Vision

To render analytical services of highest quality associated with degree of professional satisfaction & confidence to customer as

Scope of Accreditation

Food & Agricultural products
- Nuts
- Honey
- Alcoholic Drinks & Beverages
- Spices & Condiments

AYUSH Products
- Ayurvedic Drugs
- Unani drugs
- Herbal Formulations

Cosmetic & Essential Oils
- Qualitative analysis

Animal Food & feeds

Nutraceuticals

Certificate No : T-6948

Competencies
- Chromatographic Fingerprinting by HPLC /HPTLC
- Assay of active constituents by HPLC / LCMS/MS
- Pesticides residue analysis
- Heavy metals
- Micronutrients
- Adventitious Toxins; Aflatoxins
- Physico chemical analysis
- Energy value
- Microbial load
- Quality analysis of Water
- Vitamins

CMC studies were conducted and data was generated for following Botanical Raw Plant Materials, Extracts and Formulations.

1. *Woodfordia fruticosa*
2. *Boswellia serrata*
3. *Withania somnifera*
4. *Bergenia ciliata*
5. *Colebrookea oppositifolia*
6. *Dysoxylum binecteriferum*
7. *Tinospora cordifolia*
8. *Trillium govandinum*
9. *Glycyrrhiza glabra*
10. *Cocculus hirsutus*
11. *Piper bitle*
12. *Ficus semicordata*

Stability Studies: 3 months, 6 months, 12 months stability data was generated for the following

Formulations

Bergenia ciliata Hard gelatin capsules	**Stability Conditions 40 °C, 75 % RH**		
	DEXTD 0015-150	3rd Month	I-5060 (01)
	DEXTD 0016-150	3rd Month	I-5060 (02)
	DEXTD 0021-150	3rd Month	I-5060 (03)
	Stability Conditions 25 °C, 60 % RH		
	DEXTD 0015-150	3rd Month	I-5060 (04)
	DEXTD 0016-150	3rd Month	I-5060 (05)
	DEXTD 0021-150	3rd Month	I-5060 (06)
	Stability Conditions 40 °C, 75 % RH		
	DEXTD 0015-150	6th Month	I-6024 (01)
	DEXTD 0016-150	6th Month	I-6024 (02)
	DEXTD 0021-150	6th Month	I-6024 (03)
	Stability Conditions 25 °C, 60 % RH		
	DEXTD 0015-150	6th Month	I-6024 (04)
	DEXTD 0016-150	6th Month	I-6024 (05)
	DEXTD 0021-150	6th Month	I-6024 (06)

Extract

Bergenia ciliata Extract Powder	**Stability Conditions 40 °C, 75 % RH**		
	DEXTD 0015-150	3rd Month	I-5061 (01)
	DEXTD 0016-150	3rd Month	I-5061 (02)
	DEXTD 0021-150	3rd Month	I-5061 (03)
	Stability Conditions 25 °C, 60 % RH		
	DEXTD 0015-150	3rd Month	I-5060 (04)
	DEXTD 0016-150	3rd Month	I-5060 (05)
	DEXTD 0021-150	3rd Month	I-5060 (06)
	Stability Conditions 25 °C, 60 % RH		
	DEXTD 0015-150	6th Month	I-6024 (04)
	DEXTD 0016-150	6th Month	I-6024 (05)
	DEXTD 0021-150	6th Month	I-6024 (06)

Extract of *Withania somnifera*

Extract Powder	**Stability Conditions 25 °C, 60 % RH**		
	EEXTD 0013	3rd Month	I-6074 (01)
	EEXTD 0015		I-6074 (02)

Advanced Phase of Dengue Herbal Project (CNP 1313):

In advanced phase of CNP 1313 project, CCRAS (Central Council for Research in Ayurvedic Sciences), General guidelines for drug development of Ayurvedic formulations, Ministry of AYUSH, Government of India were followed. Method development of pesticides, aflatoxins, heavy metals and physicochemical parameters were established as per these guidelines. Complete CMC study of *Cocculus hirsutus* plant material and drug substance was carried out. Estimation of Mass balance analysis and nutritional value was also established. Certificate of Analysis were generated for following plant material and drug substance.

Details of Complete CMC study carried out in *Cocculus hirsutus* BRM and BDS

S.No	Sample Code	Sample Batch Details	Registration Number	Analysis Conducted	Release date
1	Stability Studies *Cocculus hirsutus* aqueous extract	Batch No: FCH 1901002, 3 mon 40° C, 75 % RH	I-5068	Aflatoxin analysis	10-07-2019
2	Formulation AQCH tablet Strength: 100 mg/tablet	Batch No: ZACHT 002 1119	I-6085	Complete CMC	14-12-2019
3	Formulation AQCH tablet Strength: 25 mg/tablet	Batch No: ZACHT 001 1119	I-6086 (01)	Complete CMC	03-02-2020
4	Formulation AQCH tablet Strength: 300 mg/tablet	Batch No: ZACHT 003 1119	I-6086 (02)	Complete CMC	03-02-2020
5	Formulation AQCH tablet Strength: 500 mg/tablet	Batch No: ZACHT 004 1119	I-6086 (03)	Complete CMC	03-02-2020
6	Stability Studies *Cocculus hirsutus* aqueous extract 12 months	Batch No: FCH 1901002 12 mon 30° C, 60 % RH	I-7021	Aflatoxin analysis	11-03-2020

Due to unprecedented condition of SARS-CoV-2 pandemic, AQCH extract of *Cocculus hirsutus* was repurposed. It is the first Phytopharmaceutical drug approved in the country as a potential treatment for COVID-19 patients. Drug has shown anti-SARS-CoV-2 effects in-vitro studies. Phase-II Clinical trials in AQCH extract is in progress.

The division is moving ahead in the direction for being designated as Drug Testing Laboratory (DTL Ayurveda). As the testing of AYUSH drugs is now covered under the provision of Drug and Cosmetic Act 1940, this requires application to be submitted to licensing authority as well as AYUSH department, New Delhi. Application is under process for approval on Form 48 as private AYUSH drug testing laboratory under Rule 160 A -J to the Drugs & Cosmetic Rules. Following samples were received from Directorate of Indian System of Medicine (J & K) and analyzed as per regulatory guidelines.

i) Samples Received from: Inspector Ayurveda

Reference Number	Sample Description	Registration Number
Drugs /10-13 Dated 11 May 2019 Government of J & K	Coldache tab.; Multani Pharmaceuticals Ltd: B. No 1173/K, Mfg 09/2018; Exp: 08/2021	C-2080 (01)
	Diacure Syp.; Himalaya Research Laboratory, B. No 0T1816, Mfg 10/2018; Exp: 09/2021	C-2080 (02)
	Krimihar Syp.; Shree Dhanwantri Herbals, B. No KRS-165, Mfg 09/2018; Exp: 08/2021	C-2080 (03)
	Swas Kuthar Ras; Kashmir Herbal Remedies, B. No 7139, Mfg 08/2018; Exp: 07/2023	C-2080 (04)
	Gluconil Powder, Himalaya Research Laboratory; B. No OT1817, Mfg 10/2019; Exp: 09/2021	C-2080 (05)
	Sarras ata Rishta, Multani Pharmaceutical Ltd.; B. No. 1371-K, Mfg 10/2018; Exp: 09/2023	C-2080 (06)

(ii) Samples received from: Inspector Unani, Office of Assistant District Medical Officer (ADMO) (ISM & H) Anantnag /Kulgam

Reference Number	Sample Description	Registration Number
Ref No: Drugs /U/ 04-09 Dated 03/09/2019 Office of ADMO (ISM & H)	Sharbat-e-Banafsha; B. No 487/2, Mfg 10/2018; Exp: 09/2021	C-3017 (01)
	Sikanabeen Lemuni; B. No 519/2 Mfg 10/2018; Exp: 09/2021	C-3017 (02)
	Sharbat-e-Nilofar; B. No 163-KU Mfg 10/2018; Exp: 09/2021	C-3017 (03)
	Itrifal-e-Shahatra; B. No 158/KU Mfg 10/2018; Exp: 09/2021	C-3017 (04)
	Habb-e-Suranjaan; B. No 65/1 Mfg 03/2019; Exp: 02/2022	C-3017 (05)
Ref No: Drugs/U/ 10-15 Dated 23/10/2019	Sharbat-e-Bazoori Motadil: B. No 485/6 Mfg 10/2018; Exp: 09/2021	C-3032 (01)
	Sharbat-e-Unnab: B. No 501/5 Mfg 10/2018; Exp: 09/2021	C-3032 (02)
	Habb-e-Musafi Khoon: B. No. 028 Mfg 09/2018; Exp: 08/2021	C-3032 (03)
	Khamira Gowzaban Sada: B. No 060 Mfg 02/2018; Exp: 01/2021	C-3032 (04)
	Itrifal Mulayan; B. No 017 Mfg 09/2018; Exp: 08/2021	C-3032 (05)
	Majoonn Ushba: B. No 272-JU Mfg 03/2018; Exp: 02/2021	C-3032 (06)
	Itrifal Shahtara: B. No 207-JU Mfg 01/2018; Exp: 12/2020	C-3032 (07)
	Habb-e-Kabid Naushadari; B. No 155-KU Mfg 10/2018; Exp: 09/2021	C-3032 (08)
	Jawarish-e-Jalinoos; B. No 169-KU Mfg 10/2018; Exp: 09/2022	C-3032 (09)
Drugs /U/ 25-30 Dated 19/12/2019	Sharbat-e-Banafsha; B. No 018 Mfg 08/2019; Exp: 07/2022	C-3050 (01)
	Qurs Jiryan; B. No OKS0033 Mfg 05/2019; Exp: 04/2022	C-3050 (02)
	Khamira Sandal Sada; B. No OK00016 Mfg 10/2018; Exp: 09/2021	C-3050 (03)
	Majun Jograg Gugal; B. No OK00017 Mfg 05/2019; Exp: 04/2022	C-3050 (04)
	Majun Supari Pak; B. No MEO35A Mfg 10/2019; Exp: 09/2022	C-3050 (05)

14. KNOWLEDGE RESOURCE CENTER (LIBRARY)

Knowledge Resource Centre (KRC) is a supporting division of the Institute with an objective to further the interests of 'Scientists and other Researchers' by providing them library services to enable them to keep a track of significant development in their fields of interest. It supports its users with current and even evolving knowledge in their respective spheres of R&D activities. Besides catering to the Institutional information requirements, it also extends its services to the visiting research scholars and faculty members from other academic and research Institutions located in the area. Over the decades, CSIR-IIIM has developed its rich Library resources and it has grown as one of the most valuable research library in the country. It has more than 100 year old rare research documents in its collection including books, periodicals, databases and other intellectual reference material both in print and electronic formats. Broadly covering subject areas like-Biotechnology, Botany, Medicinal Chemistry, Natural Products Chemistry (NPC), Pharmacology, Quality Control and Agrotechnology & Cultivation of Medicinal and Aromatic plants.

The print holding status as on 31.03.2020 is as under:

- No. of purchased documents: 27838
- No. of Periodicals Bound Volumes: 17187

It has computerized all its in-house activities using 'KOHA' open source software. These services are being maintained and updated on a regular basis. IIIM-KRC is an important member of 'National Knowledge Resource Consortium (NKRC)'. Through this consortium, KRC provides access to thousands of journals published by various publication groups - like American Chemical Society, Emerald, IEEE, JCCC, Nature Publishing Group, Oxford University Press, Royal Society of Chemistry, Taylor and Francis, Wiley, etc. It also subscribes other e-resources which are not available through NKRC consortium. The total budget allocation during the financial year 2019-20 was Rs.1.83 crore.

Presently, following services are being provided to the users:

- Online access to e-Journals and Databases.
- Electronic Document Delivery Service (EDDS).
- Information search and retrieval facility.
- Plagiarism Detection Service.
- Reprographic & Print facilities.

IIIM-KRC URL: http://onlinelibrary.iiim.res.in/. Besides other useful information and links, links to all the subscribed e-resources; NKRC resources, etc. are available through this website.

15. AcSIR ACTIVITIES AT CSIR- IIIM, JAMMU

CSIR-IIIM, Jammu is an important unit of AcSIR System. The Institute offers PhD programme to eligible candidates in the following research areas:

a) Biological Sciences;

b) Chemical Sciences.

The admission takes place twice in a year i.e., for the January & July/August sessions. In July/August, 2019 session a total of thirty four (34) PhD Students were registered at IIIM, Jammu. Similarly, in January, 2020 session forty three (43) students were selected for admission to PhD programme. The Academic Cell at IIIM is taking necessary initiatives to ensure smooth functioning of all AcSIR Academic activities, viz. student's Admission Processes, Course Work, DAC formation and arranging of meetings, Pre and post thesis submission formalities, etc. It acts as a liaison between AcSIR Headquarter Office, AcSIR Lab Coordinator, Ph.D Supervisors, Students, DAC Members & other External Experts.

During this period, a total of twenty six (26) AcSIR students successfully defended their viva voice (OEB) examination. This includes:

- Biological Sciences – 15 candidates
- Chemical Sciences – 11 candidates

Mr Atul Kumar, AcSIR, PhD student at CSIR-IIIM, successfully defending his Ph.D. thesis on 29th of November 2019 at CSIR-IIIM, Jammu.

The list of successful candidates is as under:

S. No.	Name & Enrollment No. of Scholar	Supervisor/ Co-Supervisor	Date
1	Mr. Love Sharma (10BB13J37009)	Dr. Sheikh Tasdaq Abdulla	22.4.2019
2	Ms. Tabasum Mohi Ud Din (10BB13J37004)	Dr. Nasheeman Ashraf	25.4.2019
3	Mr. Saidulu Dara (10CC11J37021)	Dr Ram Vishwakarma / Dr. P.P. Singh	22.05.2019
4	Mr. Veeranjaneyulu Gannedi (10CC11J37024)	Dr. Ram Vishwakarma	22.05.2019
5	Ms. Rohini Bhat (10BB13A37004)	Dr. Dhiraj Vyas	24.05.2019
6	Mrs. Palak Arora (10BB14J37004)	Dr. Syed Reyaz-Ul-Hassan	11.06.2019
7	Mr. Abhubakar Wani (10BB15J37015)	Dr. Sandip B. Bharate	17.7.2019
8	Mrs. Gayatri Jamwal (10BB11A37005)	Dr. Mohd Jamal Dar	02.8.2019
9	Mr. Vishal Sharma (10BB13J37013)	Dr. Sundeep Jaglan	09.8.2019
10	Ms. Shaista Sultan (10CC15J37026)	Dr. Bhawal Ali Shah	09.8.2019
11	Mr. Abhinandan D. Hudwekar (10CC12A37030)	Dr. S. D. Sawant	25.09.2019
12	Mr. Jasvinder Singh (10BB15J37001)	Dr. Shashank K Singh	11th Oct., 2019
13	Mr. Amarinder Singh (10BB15J37007)	Dr. G. D. Singh	30th Oct., 2019
14	Mr. Nazar Hussain (10CC15J37021)	Dr. Debaraj Mukherjee	5th Nov., 2019
15	Ms. Shilpa Gupta (10BB14A37015)	Dr. Zabeer Ahmad	5th Nov., 2019
16	Mr. Showkat Rashid (10CC16J37010)	Dr. Bilal Ahmad Bhat	11th Nov., 2019
17	Ms. Anjana Sharma (10BB14A37012)	Dr. G. D. Singh	22nd Nov., 2019
18	Ms. Sudha Shankar (10CC14A37016)	Dr. Raj Kishore Rai	28th Nov., 2019
19	Mr. Atul Kumar (10CC15J37024)	Dr. Naveed Qazi	29th Nov., 2019
20	Mrs. Sadhana Sharma (10BB13J37011)	D. Zabeer Ahmad	10th Dec., 2019
21	Mr. Gurjinder Singh (10BB12A37020)	Dr. Mohd Jamal Dar	27th January, 2020
22	Mr. Vikas Kumar (10BB14A37004)	Dr. Ram Vishwakarma	13th Feb., 2020
23	Mr. Faheem Rasool (10CC14J37010)	Dr. Debaraj Mukherjee	25th Feb., 2020
24	Ms. Divya Dheer (10BC14A37001)	Dr. Ravi Shankar	26th Feb., 2020
25	Mrs. Mehak Gupta (10BB14A37014)	Dr. G. D. Singh/Dr. Ajay Kumar	29th Feb., 2020
26	Ms. Arem Qayum (10BB14A37014)	Dr. Shashank Singh	29th Feb., 2020

It is taking utmost care in proper record-keeping; to ensure that rules & guidelines are followed in a timely manner at local level; handling of Students Fee issues; providing hospitality services to the invited External Experts; timely processing of their TA/DA payment claims and other related matters.

LIST OF PUBLICATIONS

CALENDER YEAR 2019

S. No.	Title	Author	Impact Factor
1	Catalytic advances in direct functionalizations using arylated hydrazines as the building blocks. *Catalysis Reviews: Science and Engineering* **(2019)**, Ahead of Print. DOI:10.1080/01614940.2019.1702191	Balgotra, Shilpi; Verma, Praveen Kumar; Vishwakarma, Ram A.; Sawant, Sanghapal D	9
2	Approaches for the genetic improvement of Lavender: a short review. *Journal of Pharmacognosy and Phytochemistry* **(2019)**, 8(2), 736-740.	Ashraf, Asif; Sultan, Phalisteen; Qazi, Pervez; Rasool, Shahid	---
3	A Modified, Efficient and Sensitive pH Indicator Dye Method for the Screening of Acid-Producing Acetobacter Strains Having Potential Application in Bio-Cellulose Production. *Applied Biochemistry and Biotechnology* **(2019)**, Ahead of Print. , DOI:10.1007/s12010-019-03211-x	Kumar, Manoj; Tanoj, Nipunta; Saran, Saurabh	2.14
4	Trigonelline, a naturally occurring alkaloidal agent protects ultraviolet-B (UV-B) irradiation induced apoptotic cell death in human skin fibroblasts via attenuation of oxidative stress, restoration of cellular calcium homeostasis and prevention of endoplasmic reticulum (ER) stress. *Journal of Photochemistry and Photobiology, B: Biology* **(2019),** DOI:10.1016/j.jphotobiol.2019.111720	Lone A., Nazir; Malik A., Tanveer; Naikoo H., Shahid; Raghu R., Sharma; Tasduq, Sheikh A.	4.067
5	Functionalization of Alkynes and Alkenes Using a Cascade Reaction Approach: Synthesis of β-Keto Sulfones under Metal-free Conditions. *Journal of Organic Chemistry* **(2019)**, DOI:10.1021/acs.joc.9b02779	Kumar, Mukesh; Ahmed, Riyaz; Singh, Maninder; Sharma, Shweta; Thatikonda, Thanusha; Singh, Parvinder Pal	4.745
6	Chromatography: An important tool for drug discovery. *Journal of Separation Science* **(2019),** 43 (1), 105-119. DOI:10.1002/jssc.201900656	Ahmad Dar, Alamgir; Sangwan, P. L.; Kumar, Anil	2.516
7	Solvent free stereoselective iodoacetoxylation of alkenes and glycals using N-iodosuccinimide and acetic anhydride. *Chemical Methodologies* **(2019)**, 3(5), 663-669. DOI:10.33945/sami/chemm.2019.5.9	Reddy, Aleti R.; Farooq, Saleem; Dar, Bashir Ahmad	---
8	LC-MS/MS profile of an active pharmaceutical ingredient and its impurities in commercial preparation. *Journal of Liquid Chromatography & Related Technologies* **(2019),** Ahead of Print. , DOI:10.1080/10826076.2019.1680561	Kushwaha, Manoj; Goel, Bharat; Jaglan, Sundeep; Jain, Shreyans K.	0.987
9	A Marine-based Meriolin (3-Pyrimidinylazaindole) Derivative (4ab) Targets PI3K/AKT /mTOR Pathway Inducing Cell Cycle Arrest and Apoptosis in Molt-4 Cells. *Clinical Cancer Drugs* **(2019)**, 6(1), 33-40. DOI:10.2174/2212697x06666190509094514	Chashoo, Gousia; Singh, Umed; Singh, Parvinder P.; Mondhe, Dilip M.; Vishwakarma, Ram A.	---
10	Hyaluronic Acid-Tacrolimus Bioconjugate: Synthesis, Characterization, and Pharmacokinetic Investigation of an Acid-Responsive Macromolecular Prodrug. *ACS Applied Bio Materials* **(2019)**, 2(11), 4728-4736. DOI:10.1021/acsabm.9b00423	Dheer, Divya; Gupta, Rahul; Singh, Davinder; Magotra, Asmita; Singh, Gurdarshan; Gupta, Prem N.; Shankar, Ravi	----
11	Metal-free, room temperature, acid-K2S2O8 mediated method for the nitration of olefins: an easy approach for the synthesis of nitroolefins. *RSC Advances* **(2019)**, 9(52), 30428-30431. Language: English, Database: CAPLUS, DOI:10.1039/c9ra06414a	Ambala, Srinivas; Singh, Rohit; Singh, Maninder; Cham, Pankaj Singh; Gupta, Ria; Munagala, Gurunadham; Yempalla, Kushalava Reddy; Vishwakarma, Ram A.; Singh, Parvinder Pal	3.049
12	Corrigendum to "Design, synthesis and biological evaluation of pyrazolopyrimidinone based potent and selective PDE5 inhibitors for treatment of erectile dysfunction" [Bioorg. Chem. 89 (2019) 103022]. *Bioorganic Chemistry* **(2019)**, 92, 103257. DOI:10.1016/j.bioorg.2019.103257	Reddy, G. Lakshma; Dar, Mohd. Ishaq; Hudwekar, Abhinandan D.; Mahajan, Priya; Nargotra, Amit; Baba, Adil Manzoor; Nandi, Utpal; Wazir, Priya; Singh, Gurdarshan; Bharate, Sonali S.; et al	3.926

S. No.	Title	Author	Impact Factor
13	Binary and ternary solid dispersions of an anticancer preclinical lead, IIIM-290: In vitro and in vivo studies. *International Journal of Pharmaceutics* (Amsterdam, Netherlands) **(2019),** 570, 118683. DOI:10.1016/j.ijpharm.2019.118683	Kumar, Vikas; Mintoo, Mubashir J.; Mondhe, Dilip M.; Bharate, Sandip B.; Vishwakarma, Ram A.; Bharate, Sonali	4.213
14	Recent Advances in Solid Dispersion Technology for Efficient Delivery of Poorly Water-Soluble Drugs. *Current Pharmaceutical Design* **(2019)**, 25(13), 1524-1535. DOI:10.2174/1381612825666190618121553	Paudwal, Gourav; Rawat, Neha; Gupta, Rahul; Baldi, Ashish; Singh, Gurdarshan; Gupta, Prem N.	2.412
15	Chorismate synthase from malaria parasites is bifunctional enzyme. *Molecular & Biochemical Parasitology* **(2019**), 233, 111202. DOI:10.1016/j.molbiopara.2019.111202	Khera, Harvinder Kour; Singh, Susheel Kumar; Singh, Subhash	2.158
16	Method validation and simultaneous quantification of five triterpenoids from Codonopsis ovata by high-performance thin-layer chromatography. *Journal of Planar Chromatography--Modern TLC* **(2019)**, 32(3), 251-256. DOI:10.1556/1006.2019.32.3.11	Dar, Alamgir A.; Sangwan, Payare L.; Singh, Nasseb; Kumar, Anil	----
17	Consistent production of kojic acid from Aspergillus sojae SSC-3 isolated from rice husk. *Molecular Biology Reports* **(2019),** 46(6), 5995-6002., DOI:10.1007/s11033-019-05035-8	Chib, Shifali; Dogra, Ashish; Nandi, Utpal; Saran, Saurabh	2.107
18	Synthesis and Investigation of the Role of Benzopyran Dihydropyrimidinone Hybrids in Cell Proliferation, Migration and Tumor Growth. *Anti-Cancer Agents in Medicinal Chemistry* (2019), 19(2), 276-288. DOI:10.2174/1871520618666180903101422	Dash, Ashutosh K.; Nayak, Debasis; Hussain, Nazar; Mintoo, Mubashir J.; Bano, Sumera; Katoch, Archana; Mondhe, Dilip M.; Goswami, Anindya; Mukherjee, Debaraj	2.18
19	Vimentin activation in early apoptotic cancer cells errands survival pathways during DNA damage inducer CPT treatment in colon carcinoma model. *Cell Death & Disease* **(2019)**, 10(6), 1-16. , DOI:10.1038/s41419-019-1690-2	Chakraborty, Souneek; Kumar, Aviral; Faheem, Mir Mohd; Katoch, Archana; Kumar, Anmol; Jamwal, Vijay Lakshmi; Nayak, Debasis; Golani, Aparna; Rasool, Reyaz Ur; Ahmad, Syed Mudabir; et al	5.959
20	Effect of IS01957, a para-coumaric acid derivative on pharmacokinetic modulation of diclofenac through oral route for augmented efficacy. *Drug Development Research* **(2019)**, 80(7), 948-957. DOI:10.1002/ddr.21574	Sharma, Anjna; Gour, Abhishek; Bhatt, Shipra; Rath, Santosh K.; Malik, Tanveer A.; Dogra, Ashish; Sangwan, Payare L.; Koul, Surrinder; Abdullah, Sheikh Tasduq; Singh, Gurdarshan; et al	1.742
21	Metabolic and transcriptional analyses in response to potent inhibitors establish MEP pathway as major route for camptothecin biosynthesis in Nothapodytes nimmoniana (Graham) Mabb. *BMC Plant Biology* **(2019)**, 19(1), 1-15. DOI:10.1186/s12870-019-1912-x	Rather, Gulzar A.; Sharma, Arti; Jeelani, Syed Mudassir; Misra, Prashant; Kaul, Veenu; Lattoo, Surrinder K.	3.67
22	Isolation, Synthesis And Structure Determination Of Cannabidiol Derivatives And Their Cytotoxic Activities. *Natural Product Research* **(2019)**, July 8, 1-10 DOI:10.1080/14786419.2019.1638381	Nalli, Yedukondalu; Jan, Suraya; Lauro, Gianluigi; Ur Rasool, Javeed; Lone, Waseem I.; Sarkar, Aminur R.; Banday, Junaid; Bifulco, Giuseppe; Laatsch, Hartmut; Syed, Sajad H.; et al	1.999
23	Preclinical development of gastro-protective botanical candidate from Woodfordia fruticosa (Linn.) Kurz: Chemical standardization, efficacy, pharmacokinetics and safety pharmacology. *Journal of Ethnopharmacology* **(2019),** 241, 112023pp.. , DOI:10.1016/j.jep.2019.112023	Khan, Inshad A.; Singh, Amarinder; Mindala, Durga P.; Meena, Samdarshi; Vij, Bhavana; Yadav, Arvind K.; Roy, Sumit; Nandi, Utpal; Katare, Anil K.; Jaglan, Sundeep; et al	3.414
24	Synthesis and biological evaluation of indoloquinoline alkaloid cryptolepine and its bromo-derivative as dual cholinesterase inhibitors. *Bioorganic Chemistry* **(2019)**, 90, 103062. DOI:10.1016/j.bioorg.2019.103062	Nuthakki, Vijay K.; Mudududdla, Ramesh; Sharma, Ankita; Kumar, Ajay; Bharate, Sandip B.	3.926

S. No.	Title	Author	Impact Factor
25	Visible Light-Mediated [2 + 2] Cycloaddition Reactions of 1,4-Quinones and Terminal Alkynes. *Journal of Organic Chemistry* **(2019)**, 84(14), 8948-8958. , DOI:10.1021/acs.joc.9b00855	Sultan, Shaista; Bhat, Muneer-ul-Shafi; Rizvi, Masood Ahmad; Shah, Bhahwal Ali	4.745
26	Regeneration of Gardenia gummifera Linn.f by using cyanobacteria - a novel approach to tissue culture. *Annals of Plant Sciences* **(2019)**, 8(1), 3489-3494. , DOI:10.21746/aps.2019.8.1.2	Mir, Firdoous; Khanday, Zakir Hussain; Yadav, A. S.; Singh, Sumer	----
27	Indolylkojyl methane analogue IKM5 potentially inhibits invasion of breast cancer cells via attenuation of GRP78. *Breast Cancer Research and Treatment* **(2019)**, 177(2), 307-323. , DOI:10.1007/s10549-019-05301-0	Nayak, Debasis; Katoch, Archana; Sharma, Deepak; Faheem, Mir Mohd.; Chakraborty, Souneek; Sahu, Promod Kumar; Chikan, Naveed Anjum; Amin, Hina; Gupta, Ajai Prakash; Gandhi, Sumit G.; et al	3.471
28	Trichoderma lixii (IIIM-B4), an endophyte of Bacopa monnieri L. producing peptaibols. *BMC Microbiology* **(2019)**, 19(1), 1-10. Language: English, Database: CAPLUS, DOI:10.1186/s12866-019-1477-8	Katoch, Meenu; Singh, Deepika; Kapoor, Kamal K.; Vishwakarma, R. A.	3.287
29	Bioprospection of marine actinomycetes: recent advances, challenges and future perspectives. *Acta Oceanologica Sinica* **(2019),** 38(6), 1-17. DOI:10.1007/s13131-018-1340-z	Sharma, Swati; Fulke, Abhay B.; Chaubey, Asha	0.699
30	Photoredox-Mediated Generation of gem-Difunctionalized Ketones: Synthesis of α,α-Aminothioketones. *Organic Letters* **(2019)**, 21(12), 4793-4797. DOI:10.1021/acs.orglett.9b01677	Chalotra, Neha; Rizvi, Masood Ahmad; Shah, Bhahwal Ali	6.555
31	C-H Arylation of N-Heteroarenes under Metal-Free Conditions and its Application towards the Synthesis of Pentabromo- and Pentachloropseudilins. *European Journal of Organic Chemistry* **(2019)**, 2019(22), 3591-3598. DOI:10.1002/ejoc.201900353	Kumar, Mukesh; Sharma, Shweta; Sil, Parijat; Kushwaha, Manoj; Mayor, Satyajit; Vishwakarma, Ram A.; Singh, Parvinder Pal	3.029
32	Reaction Medium as the Installing Reservoir for Key Functionalities in the Molecules. *Asian Journal of Organic Chemistry* **(2019),** 8(6), 777-801. DOI:10.1002/ajoc.201900223	Kumar Verma, Praveen; Vishwakarma, Ram A.; Sawant, Sanghapal D.	2.496
33	Transformation of Santonin to a Naproxen Analogue with Anti-Inflammatory Activity. *Journal of Natural Products* **(2019)**, 82(6), 1710-1713. DOI:10.1021/acs.jnatprod.8b00318	Singh, Rohit; Mandrah, Kapil; Asati, Ankita; Patel, Devendra K.; Goel, Bharat; Vishwakarma, Ram A.; Roy, Somendu K.; Jain, Shreyans K.	4.257
34	Jasmonate responsive transcription factor WsMYC2 regulates the biosynthesis of triterpenoid withanolides and phytosterol via key pathway genes in Withania somnifera (L.) Dunal. *Plant Molecular Biology* **(2019)**, 100(4-5), 543-560. DOI:10.1007/s11103-019-00880-4	Sharma, Arti; Rather, Gulzar A.; Misra, Prashant; Dhar, Manoj K.; Lattoo, Surrinder K.	3.928
35	Isolation of depsipeptides and optimization for enhanced production of valinomycin from the North-Western Himalayan cold desert strain Streptomyces lavendulae. *Journal of Antibiotics* **(2019)**, 72(8), 617-624. DOI:10.1038/s41429-019-0183-y	Singh, Varun P.; Sharma, Richa; Sharma, Vandana; Raina, Chand; Kapoor, Kamal K.; Kumar, Anil; Chaubey, Asha; Singh, Deepika; Vishwakarma, Ram A.	2.446
36	Functional characterization of flavonoid 3'-hydroxylase, CsF3'H, from Crocus sativus L: Insights into substrate specificity and role in abiotic stress. *Archives of Biochemistry and Biophysics* **(2019)**, 667, 70-78. DOI:10.1016/j.abb.2019.04.012	Baba, Shoib Ahmad; Ashraf, Nasheeman	3.559
37	Identification of embelin, a 3-undecyl-1,4-benzoquinone from Embelia ribes as a multitargeted anti-Alzheimer agent. *Drug Development Research* **(2019),** 80(5), 655-665. DOI:10.1002/ddr.21544	Nuthakki, Vijay K.; Sharma, Ankita; Kumar, Ajay; Bharate, Sandip B.	1.742
38	Design, synthesis and biological evaluation of alantolactone derivatives as potential anti-inflammatory agents. *Medicinal Chemistry Research* **(2019),** 28(6), 849-856. DOI:10.1007/s00044-019-02337-1	Kumar, Chetan; Kumar, Anil; Nalli, Yedukondalu; Lone, Waseem I.; Satti, Naresh K.; Verma, M. K.; Ahmed, Zabeer; Ali, Asif	1.72

S. No.	Title	Author	Impact Factor
39	Cyclodextrin-based delivery systems for dietary pharmaceuticals. *Environmental Chemistry Letters* **(2019)**, 17(3), 1263-1270. DOI:10.1007/s10311-019-00878-w	Arora, Divya; Saneja, Ankit; Jaglan, Sundeep	4.617
40	Construction of Fused Oxabicyclic Scaffolds from Glycals and Styrenes via One-Pot Domino Transformations. *Organic Letters* **(2019)**, 21(9), 3038-3042. DOI:10.1021/acs.orglett.9b00234	Bhardwaj, Monika; Rasool, Faheem; Tatina, Madhu Babu; Mukherjee, Debaraj	6.555
41	Synthesis of Sugar-Based Enones and Their Transformation into 3,5-Disubstituted Furans and 2-Acyl-Substituted 1,2,3-Trideoxy Sugars in the Presence of Lewis Acids. *Organic Letters* **(2019)**, 21(9), 3034-3037. DOI:10.1021/acs.orglett.9b00680	Hussain, Nazar; Bhardwaj, Monika; Ahmed, Ajaz; Mukherjee, Debaraj	6.555
42	Combining ligand- and structure-based in silico methods for the identification of natural product-based inhibitors of Akt1. *Molecular Diversity* **(2019)**, DOI:10.1007/s11030-019-09924-9	Mahajan, Priya; Wadhwa, Bhumika; Barik, Manas Ranjan; Malik, Fayaz; Nargotra, Amit	2.032
43	Myrosinase: insights on structural, catalytic, regulatory, and environmental interactions. *Critical Reviews in Biotechnology* **(2019)**, 39(4), 508-523. DOI:10.1080/07388551.2019.1576024	Bhat, Rohini; Vyas, Dhiraj	7.054
44	Alborixin clears amyloid-β by inducing autophagy through PTEN-mediated inhibition of the AKT pathway. *Autophagy* **(2019)**, 15(10), 1810-1828. , DOI:10.1080/15548627.2019.1596476	Wani, Abubakar; Gupta, Mehak; Ahmad, Masroor; Shah, Aabid M.; Ahsan, Aitizaz Ul; Qazi, Parvaiz H.; Malik, Fayaz; Singh, Gurdarshan; Sharma, Parduman R.; Kaddoumi, Amal; et al	11.1
45	Isolation, structural modification of macrophin from endophytic fungus Phoma macrostoma and their cytotoxic potential. *Medicinal Chemistry Research* **(2019)**, 28(3), 260-266. DOI:10.1007/s00044-018-2281-y	Nalli, Yedukondalu; Arora, Palak; Khan, Sameer; Malik, Fayaz; Riyaz-Ul-Hassan, Syed; Gupta, Vivek; Ali, Asif	1.72
46	A vicarious, one-pot synthesis of benzo- and naphthofurans: Applications to the syntheses of stereumene B and paeoveitols. *Tetrahedron Letters* **(2019),** 60(16), 1122-1125. DOI:10.1016/j.tetlet.2019.03.037	Rashid, Showkat; Bhat, Bilal A.; Mehta, Goverdhan	2.259
47	Discovery of Quinazolin-4(3H)-ones as NLRP3 Inflammasome Inhibitors: Computational Design, Metal-Free Synthesis, and in Vitro Biological Evaluation. *Journal of Organic Chemistry* **(2019),** 84(9), 5129-5140. DOI:10.1021/acs.joc.9b00138	Abdullaha, Mohd; Mohammed, Shabber; Ali, Mehboob; Kumar, Ajay; Vishwakarma, Ram A.; Bharate, Sandip B.	4.745
48	Introducing Oxo-Phenylacetyl (OPAc) as a Protecting Group for Carbohydrates. *Journal of Organic Chemistry* **(2019),** 84(7), 4131-4148. DOI:10.1021/acs.joc.9b00126	Kumar, Atul; Gannedi, Veeranjaneyulu; Rather, Suhail A.; Vishwakarma, Ram A.; Ahmed, Qazi Naveed	4.745
49	Analyzing the role of cannabinoids as modulators of Wnt/β-catenin signaling pathway for their use in the management of neuropathic pain. *Bioorganic & Medicinal Chemistry Letters* **(2019)**, 29(9), 1043-1046. DOI:10.1016/j.bmcl.2019.03.013	Nalli, Yedukondalu; Dar, Mohd Saleem; Bano, Nasima; Rasool, Javeed Ur; Sarkar, Aminur R.; Banday, Junaid; Bhat, Aadil Qadir; Rafia, Basit; Vishwakarma, Ram A.; Dar, Mohd Jamal; et al	2.448
50	Iodine-DMSO-promoted divergent reactivities of arylacetylenes. *Chemical Communications* (Cambridge, United Kingdom) **(2019)**, 55(31), 4511-4514. DOI:10.1039/c9cc00346k	Rather, Suhail A.; Kumar, Atul; Ahmed, Qazi Naveed	6.164
51	Assessment of preclinical drug interactions of bedaquiline by a highly sensitive LC-ESI-MS/MS based bioanalytical method. *Journal of Chromatography B: Analytical Technologies in the Biomedical and Life Sciences* **(2019)**, 1112, 48-55. DOI:10.1016/j.jchromb.2019.02.022	Kotwal, Pankul; Magotra, Asmita; Dogra, Ashish; Sharma, Sumit; Gour, Abhishek; Bhatt, Shipra; Wazir, Priya; Singh, Parvinder Pal; Singh, Gurdarshan; Nandi, Utpal	2.813

S. No.	Title	Author	Impact Factor
52	BCl3-Mediated C-N, C-S, and C-O Bond Formation of Imidazo[1,2-a]pyridine Benzylic Ethers. *ACS Omega* **(2019)**, 4(3), 4530-4539. DOI:10.1021/acsomega.9b00035	Singh, Davinder; Kumar, Gulshan; Dheer, Divya; Jyoti; Kushwaha, Manoj; Ahmed, Qazi Naveed; Shankar, Ravi	2.584
53	Synthesis and Biological Evaluation of Novel Osthol Derivatives as Potent Cytotoxic Agents. *Medicinal Chemistry* (Sharjah, United Arab Emirates) **(2019),** 15(2), 138-149. DOI:10.2174/1573406414666180911161047	Farooq, Saleem; Banday, Javid A.; Hussain, Aashiq; Nazir, Momina; Qurishi, Mushtaq A.; Hamid, Abid; Koul, Surrinder	2.53
54	Pharmacokinetic evaluation of medicinally important synthetic N,N' diindolylmethane glucoside: Improved synthesis and metabolic stability. *Bioorganic & Medicinal Chemistry Letters* **(2019)**, 29(8), 1007-1011.DOI:10.1016/j.bmcl.2019.02.010	Magotra, Asmita; Gour, Abhishek; Sharma, Deepak K.; Dash, Ashutosh K.; Singh, Gurdarshan; Mukherjee, Debaraj; Nandi, Utpal	2.448
55	Acteoside ameliorates inflammatory responses through NFkB pathway in alcohol induced hepatic damage. *International Immunopharmacology* **(2019),** 69, 109-117. DOI:10.1016/j.intimp.2019.01.020	Khullar, Mowkshi; Sharma, Ankita; Wani, Abubakar; Sharma, Neha; Sharma, Neelam; Chandan, B. K.; Kumar, Ajay; Ahmed, Zabeer	3.361
56	Liquid Chromatography Based Methods for Analysis of Disease-Modifying Antirheumatic Drugs (DMARDs) in Biological Matrices. *Critical Reviews in Analytical Chemistry* **(2019),** 49(3), 224-242. DOI:10.1080/10408347.2018.1503943	Dogra, Ashish; Sharma, Anjna; Kumar Mandal, Uttam; Kotwal, Pankul; Bhatt, Shipra; Nandi, Utpal	4.325
57	Murrayanine Attenuates Lipopolysaccharide-induced Inflammation and Protects Mice from Sepsis-associated Organ Failure. *Basic & Clinical Pharmacology & Toxicology* **(2019)**, 124(4), 351-359. DOI:10.1111/bcpt.13032	Gupta, Shilpa; Khajuria, Vidushi; Wani, Abubakar; Nalli, Yedukondalu; Bhagat, Asha; Ali, Asif; Ahmed, Zabeer	2.452
58	Programmed synthesis of triarylnitroimidazoles via sequential cross-coupling reactions. *Organic & Biomolecular Chemistry* **(2019),** 17(8), 2134-2147. , DOI:10.1039/c9ob00144a	Raina, Gaurav; Kannaboina, Prakash; Mupparapu, Nagaraju; Raina, Sushil; Ahmed, Qazi Naveed; Das, Parthasarathi	3.49
59	Gemcitabine and betulinic acid co-encapsulated PLGA-PEG polymer nanoparticles for improved efficacy of cancer chemotherapy. *Materials Science & Engineering, C: Materials for Biological Applications* **(2019)**, 98, 764-771. DOI:10.1016/j.msec.2019.01.026	Saneja, Ankit; Kumar, Robin; Mintoo, Mubashir J.; Dubey, Ravindra Dhar; Sangwan, Payare Lal; Mondhe, Dilip M.; Panda, Amulya K.; Gupta, Prem N.	4.959
60	Thioacetamide potentiates high cholesterol and high fat diet induced steato-hepatitic changes in livers of C57BL/6J mice: A novel eight weeks model of fibrosing NASH. *Toxicology Letters* **(2019),** 304, 21-29. DOI:10.1016/j.toxlet.2019.01.001	Sharma, Love; Gupta, Divya; Abdullah, Sheikh Tasduq	3.499
61	Engineering solid dispersions of anticancer preclinical lead, IIIM-985: Physicochemical characterization and in vivo pharmacokinetics. *Journal of Drug Delivery Science and Technology* **(2019),** 49, 594-602., DOI:10.1016/j.jddst.2018.12.028	Kumar, Vikas; Vishwakarma, Ram A.; Bharate, Sonali S.	2.606
62	Transition Metal-Free Oxidative Coupling of Primary Amines in Polyethylene Glycol at Room Temperature: Synthesis of Imines, Azobenzenes, Benzothiazoles, and Disulfides. *European Journal of Organic Chemistry* **(2019)**, 2019(6), 1242-1250. CAPLUS, DOI:10.1002/ejoc.201801610	Hudwekar, Abhinandan D.; Verma, Praveen K.; Kour, Jaspreet; Balgotra, Shilpi; Sawant, Sanghapal D.	3.029
63	Impurity profiling of anticancer preclinical candidate, IIIM-290. *Journal of Pharmaceutical and Biomedical Analysis* **(2019)**, 166, 1-5. DOI:10.1016/j.jpba.2018.12.027	Kumar, Vikas; Bhurta, Deendyal; Sharma, Ankita; Kumar, Puneet; Bharate, Sandip B.; Vishwakarma, Ram A.; Bharate, Sonali S.	2.983

S. No.	Title	Author	Impact Factor
64	Recent Advances in Formulation Strategies for Efficient Delivery of Vitamin D. *AAPS PharmSciTech* **(2019),** 20(1), 1-12. , DOI:10.1208/s12249-018-1231-9	Gupta, Rahul; Behera, Chittaranjan; Paudwal, Gourav; Rawat, Neha; Baldi, Ashish; Gupta, Prem N.	2.608
65	In vitro evaluation of dinactin, a potent microbial metabolite against Mycobacterium tuberculosis. *International Journal of Antimicrobial Agents* **(2019)**, 53(1), 49-53. DOI:10.1016/j.ijantimicag.2018.09.019	Hussain, Aehtesham; Rather, Muzafar Ahmad; Bhat, Zubair Shanib; Majeed, Aasif; Maqbool, Mubashir; Shah, Aabid Manzoor; Aga, Mushtaq A.; Shah, Aiyatullah; Mushtaq, Saleem; Sangwan, Payare L.; et al	4.615
66	Synthesis of amides from (E)-3-(1-chloro-3,4-dihydronaphthalen-2-yl) acrylic acid and substituted amino acid esters as NorA efflux pump inhibitors of Staphylococcus aureus. *Bioorganic & Medicinal Chemistry* **(2019)**, 27(2), 343-353. , DOI:10.1016/j.bmc.2018.12.008	ath, Santosh K.; Singh, Samsher; Kumar, Sunil; Wani, Naiem A.; Rai, Rajkishor; Koul, Surrinder; Khan, Inshad A.; Sangwan, Payare L.	2.802
67	A basic helix loop helix transcription factor, AaMYC2-Like positively regulates artemisinin biosynthesis in Artemisia annua L.. *Industrial Crops and Products* **(2019)**, 128, 115-125. DOI:10.1016/j.indcrop.2018.10.083	Majid, Ishfaq; Kumar, Amit; Abbas, Nazia	4.191
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145	Recent Developments in Azole Compounds as Antitubercular Agent. *Mini-Reviews In Organic Chemistry* **(2019),** 16 (3), 290-306	Das, R; Asthana, GS; Suri, KA; Mehta, D; Asthana, A	1.824
146	Nutritional, physicochemical, and functional quality of beetroot (Beta vulgaris L.) incorporated Asian noodles, *Cereal Chemistry* **(2019),** 96 (1), 154-161	Chhikara, N; Kushwaha, K; Jaglan, S; Sharma, P; Panghal, A	1.807
147	Palladium catalysed carbonylation of 2-iodoglycals for the synthesis of C-2 carboxylic acids and aldehydes taking formic acid as a carbonyl source. *RSC Advances* **(2019),** 9 (39), 22227 - 22231	Ahmed, A; Hussain, N; Bhardwaj, M; Chhalodia, AK; Kumar, A; Mukherjee, D	3.119

LIST OF PATENTS

FINANCIAL YEAR 2019-2020

(A) FILED IN INDIA

SNO	NFNO	TITLE	INVENTORS	PROV. FILING DATE	COMP. FILING DATE	APPLICATION NO.
1	0029NF2019/IN	Process For The Preparation Of Derivatives Of 1,1-Dialkylethane-1,2-Diols As Useful Intermediates	Sharma Sumit, Ahmed Riyaz, Raina Sushil, Ram Asrey Vishwakarma, Singh Parvinder Pal	01-Apr-19	---	201911013022
2	0166NF2018/IN	Pharmaceutical Compositions to Enhance the Bioavailability/ Bioefficacy of Drugs	Kumar Ajay, Khan Inshad Ali, Koul Surrinder, Sangwan Payare Lal, Mondhe Dilip Manikrao, Nandi Utpal, Singh Gurdarshan, Tikoo Manoj Kumar, Wani Abubakar, Rath Santhosh Kumar, Singh Samsher, Mintoo Mubashir Javeed, Vishwakarma Ram Asrey, Sharma Sadhana	---	20-Nov-19	201911047260
3	0093NF2017/IN	Enzymatic Process For The Preparation Of Vorinostat	Vikash Babu, Rahul Vikram Singh, Hitesh Sharma, Amit Kumar, Shaista Sultan, Varun Pratap Singh, Bhahwal Ali Shah, Parvinder Pal Singh	---	20-Nov-19	201911047261
4	0162NF2019/IN	Process For The Synthesis Of Cannabidiol And Intermediates Thereof	Radhika Anand, Sumit Sharma, Pankaj Singh Cham, Veeranjaneyulu Gannedi, Mukesh Kumar, Varun Pratap Singh, Vishav Prakash Rahul, Vishwakarma Ram Ashrey, Singh Parvinder Pal	12/Mar/2020	---	202011010503

(B) FILED IN FOREIGN COUNTRIES

SNO	NFNO	COUNTRY	TITLE	INVENTORS	COMP. FILING DATE	APPLICATION NO.
1	0179NF2017/WO	WO	Sustained Release Formulations Of Dysoxylum Binectariferum	Bharate Sonali Sandip, Kumar Vikas, Gupta Mehak, Gandhi Sumit, Kumar Ajay, Bharate Sandip Bibishan, Vishwakarma Ram	18-Apr-19	PCT/IN2019/050313

SNO	NFNO	COUNTRY	TITLE	INVENTORS	COMP. FILING DATE	APPLICATION NO.
2	0039NF2018/ WO	WO	Solid Dispersion Comprising An Anticancer Compound With Improved Solubility And Efficacy	Bharate Sonali Sandip, Kumar Vikas, Mintoo Mubashir Javed, Mondhe Dilip Manikrao, Bharate Sandip Bibishan, Vishwakarma Ram	14-Jun-19	PCT/ IN2019/050454
3	0180NF2016/ GB	GB	Indolylkojyl Methane Analogues, Process Of Preparation Thereof And Use As Inhibitor Of Cancer Cell Invasion And Metastasis	Debaraj Mukherjee, Anindya Goswami, Deepak Sharma, Debasis Nayak, Shreyans Kumar Jain	04-Dec-19	1917718.7
4	0180NF2016/ US	US	Indolylkojyl Methane Analogues, Process Of Preparation Thereof And Use As Inhibitor Of Cancer Cell Invasion And Metastasis	Debaraj Mukherjee, Anindya Goswami, Deepak Sharma, Debasis Nayak, Shreyans Kumar Jain	23-Dec-19	16/626274
5	0092NF2017/ CA	CA	Sustained Release Formulations Of Crocus Sativus	Bharate Sonali Sandip, Kumar Vikas, Singh Rohit, Rani Sarita, Gupta Mehak, Kumar Ajay, Bharate Sandip Bibishan, Vishwakarma Ram	27-03-2020	3077335
6	0120NF2017/ CA	CA	Gastroretentive Sustained Release Formulations Of Bergenia Ciliata	Bharate Sonali Sandip, Singh Rohit, Gupta Mehak, Singh Bikarma, Katare Anil Kumar, Kumar Ajay, Bharate Sandip Bibishan, Vishwakarma Ram	27-03-2020	3077342
7	0029NF2019/ WO	WO	Process For The Preparation Of Derivatives Of 1,1-Dialkylethane-1,2-Diols As Useful Intermediates	Sharma Sumit, Ahmed Riyaz, Raina Sushil, Ram Asrey Vishwakarma, Singh Parvinder Pal	31-03-2020	PCT/ IN2020/050309

(C) GRANTED IN INDIA

S NO	NFNO	TITLE	INVENTORS	PROV. FILING DATE	COMP. FILING DATE	APPLICATION NO.	GRANT DATE	PATENT NO.
1	0063NF2012/IN	Tetrahydro-2h-Pyrano [3,2-C] Isochromene-6-Ones And Analogs For The Treatment Of Inflammatory Disorders	Jain Shreyans Kumar, Sidiq Tabasum, Meena Samdarshi, Khajuria Anamika, Vishwakarma Ram Asrey, Bharate Sandip Bibishan	---	24-May-13	1565DEL2013	31-May-19	313578
2	0057NF2009/IN	Inducible Catalase R Promoter Useful For Expressing Foreign Genes In Fungus	Katoch Meenu, Sharma Ruchika, Qazi Ghulam Nabi	---	27-Apr-10	1006DEL2010	13-Aug-19	318156
3	0219NF2012/IN	Cyclin-Dependent Kinase Inhibition By 5,7-Dihydroxy-8-(3-Hydroxy-1-Methylpiperidin-4-Yl)-2-Methyl-4h-Chromen-4-One Analogs	Vishwakarma Ram Asrey, Bharate Sandip Bibishan, Bhushan Shashi, Mondhe Dilip Manikrao, Jain Shreyans Kumar, Meena Samdarshi, Guru Santosh Kumar, Pathania Anup Singh, Kumar Suresh, Behl Akanksha, Mintoo Mubashir Javed, Bharate Sonali Sandip, Joshi Prashant	17-Apr-13	16-Apr-14	1142DEL2013	04-Oct-19	322330
4	0178NF2006/IN	Biotransformation Process For The Preparation Of Diosgenin From Dioscin	Somal Priti, Koul Surrinder, Taneja Subhash Chandra, Rizvi Syed Mustafa, Arjuna, Anania, Singh Jasbir, Naik Surabhi, Singh Brajeshwar, Riyaz-Ul-Hassan Syed, Verma Vijeshwar, Khajuria Ravi Kant, Qazi Ghulam Nabi	11-Mar-08	09-Mar-09	0609DEL2008	20-Nov-19	325414

S NO	NFNO	TITLE	INVENTORS	PROV. FILING DATE	COMP. FILING DATE	APPLICATION NO.	GRANT DATE	PATENT NO.
5	0202NF2006/IN	A Synergistic Non-Toxic Herbal Formulation Extracted From Withania Somnifera Useful For Anti-Cancer And Th1-Dominant Immune Up-Regulating Activites	Qazi Ghulam Nabi, Singh Jaswant, Malik Fayaz, Saxena Ajit Kumar, Khajuria Anamika, Suri Krishan Avtar, Satti Naresh Kumar, Kumar Arun, Kumar Ajay, Bhushan Shashi, Khan Inshad, Mondhe Dilip Manikrao, Muthiah Shanmu Gavel, Chandra Harish, Gupta Amit, Kumar Manoj, Sharma Sandeep, Singh Surjeet	---	19-Jun-07	1321DEL2007	31-Dec-19	328622
6	0042NF2011/IN	Novel Diamides As Potentiators Of The Bioefficacy Of Drugs	Surrinder Koul, Mallepally Venkat Reddy, Payare Lal Sangwan, Buddh Singh, Ch Parveen Kumar, Inshad Ali Khan, Nitin Pal Kalia, Amit Nargotra, Ram Vishwakarma	29-Mar-11	27-Mar-12	0864DEL2011	13-Jan-20	329295
7	0106NF2013/IN	Novel Pyrazolopyrimidinones For The Treatment Of Impotence And Process For The Preparation Thereof	Sawant Sanghapal Damodhar, Ginnereddy Lakshma Reddy, Mahesuni Srinivas, Syed Sajad Hussain, Dar Mohd Ishaq, Nargotra Amit, Mahajan Priya, Vishwakarma Ram Asrey	---	30-Jan-14	0281DEL2014	13-Jan-20	329337

(D)GRANTED IN FOREIGN COUNTRIES

S No	NFNO	Country	Title	Inventors	Comp. Filing Date	Application No.	Grant Date	Patent No.
1	0302NF2013/ GB	GB	N-Substituted Beta-Carbolinium Compounds As Potent P-Glycoprotein Inducers	Bharate Sandip, Kumar Ajay, Manda Sudhakar, Joshi Prashant, Bharate Sonali, Vishwakarma Ram	30-Mar-17	15807703.2	15-May-19	3227291
2	0302NF2013/ EP	EP	N-Substituted Beta-Carbolinium Compounds As Potent P-Glycoprotein Inducers	Bharate Sandip, Kumar Ajay, Manda Sudhakar, Joshi Prashant, Bharate Sonali, Vishwakarma Ram	30-Mar-17	15807703.2	15-May-19	3227291
3	0225NF2012/ JP	JP	6-Notro-2,3-Dihydroimidazo [2,1-B] Oxazoles And A Process For The Preparation Thereof	Parvinder Pal Singh, Gurunadham Munagala, Kushalava Reddy Yempalla, Inshad Ali Khan, Nitin Pal Kalia, Vikrant Singh Rajput, Amit Nargotra, Sanghapal Damodhar Sawant, Ram Asrey Vishwakarma	01-Apr-16	2016-520053	31-May-19	6532457
4	0127NF2014/ EP	EP	Novel 1,3,5 -Triazine Based Pi3k Inhibitors As Anticancer Agents And A Process For The Preparation Thereof	Thatikonda Thanusha, Kumar Suresh, Singh Umed, Mahajan Priya, Mahajan Girish, Nargotra Amit, Malik Fayaz, Mondhe Dilip Manikrao, Vishwakarma Ram Asrey, Singh Parvinder Pal	19-May-17	15820891.8	24-Jul-19	3221307
5	0058NF2014/ US	US	Alkylidene Phosphonate Esters As P-Glycoprotein Inducers	Bharate Sandip, Kumar Ajay, Manda Sudhakar, Joshi Prashant, Bharate Sonali, Wani Abubakar, Sharma Sadhana, Vishwakarma Ram	13-Mar-17	15/510952	13-Aug-19	10377781

S No	NFNO	Country	Title	Inventors	Comp. Filing Date	Application No.	Grant Date	Patent No.
6	0176NF2014/ CN	CN	Substituted 1,2,3-Triazol-1-Yl-Methyl-2,3-Dihydro-2-Methyl-6-Nitroimidazo [2,1-B]Oxazoles As Anti-Mycobacterial Agents And A Process For The Preparation Thereof	Yempalla Kushalava Reddy, Munagala Gurunadham, Singh Samsher, Sharma Sumit, Khan Inshad Ali, Vishwakarma Ram Asrey, Singh Parvinder Pal	16-Jun-17	2015800691411	18-Oct-19	ZL201580069141.1

BOOKS & BOOK CHAPTERS

Books

- *Majid,I., Kumar, A and* ***Abbas, N.*** "Characterisation and Ectopic expression of AaMYC2-Like, A bHLH transcription factor from *Artemisia annua*, enhances Artemisinin content within *Artemisia annua* L." Industrial Crops and Products. Elsevier, 2019.

- ***Singh Bikarma****, Barik SK, Anand R, Gupta P, Khan IA, Katare AK, Singh G, Kumar B, Sharma YP, Yadav G, Bhanwaria R, Gupta PN, Jain SK, Upadhya K, Baishya R, Mylliemngap W, Mondal AK, Verma MK, Chettri A, Gandhi SG, Dutt HC, Rahim A, Bedi YS, Das T, Singamanenia V, Sharm U, Mindala DP, Satti NK, Chandan BK, Khullar M, Sharma N, Kumar S, Gochar R, Gochar M, Nongbri LB, Kharwanlang L, Bajpai V, Mir AH, Jeri L, Butt NA, Bora R, Choudhary H, Kumar Y, Bhatia H, Manhas RK, Sharma S, Basumatary M, Nagar RK, Saikia R, Das AK, Laling N, Arya OP, Sundriya RC, Paudwal G, Naskar AK, Ray S, Singh S, Koul K, Kitchlu S, Singh B, Goyal P, Sharma A, Lone JF, Sneha, Sachdev R, Ali S and Hassan QP.* Plants for Human Survival and Medicine (Edited Book). 1st Ed.CRC Press Taylor & Francis, UK and NIPA, India, pp. 524, 2019. [ISBN: 9780367818944 - CAT# K455460].

- *Saurabh Saran, Vikash Babu and* ***Asha Chaubey*** (Editors). High Value Fermentation Products, Published in Human Health, Vol.1, Scrivener Publishing & John Wiley & Sons, Inc, Wiley 2019. [**ISBN** 978-1-119-46001-5]

- *Saurabh Saran, Vikash Babu and* ***Asha Chaubey*** (Editors). High Value Fermentation Products, Published in Human Welfare, Vol. 2, Scrivener Publishing & John Wiley & Sons, Inc, Wiley 2019. [**ISBN** 978-1-119-55483-7]

- *Majid,I., Kumar, A and* ***Abbas, Nazia***. Characterisation and Ectopic expression of AaMYC2-Like, A bHLH transcription factor from *Artemisia annua*, enhances Artemisinin content within *Artemisia annua* L., Industrial Crops and Products, Elsevier, 2019.

- *Divya Arora, Chetan Sharma,* ***Sundeep Jaglan*** *and Eric Lichtfouse* (Editors). *"*Pharmaceuticals from Microbes: The Bioengineering Perspective*"* Published in Environmental Chemistry for a Sustainable World (Book Series), 2019, Springer Nature.

- *Divya Arora, Chetan Sharma,* ***Sundeep Jaglan*** *and Eric Lichtfouse* (Editors). "Pharmaceuticals from Microbes: Impact on Drug Discovery". Published in Environmental Chemistry for a Sustainable World (Book Series). 2019, Springer Nature.

Book Chapters

- *Malik Muzafar Manzoor, Pooja Goyal, Ajai P. Gupta, and* ***Suphla Gupta.*** **"**Heavy Metal Soil Contamination and Bioremediation". Published in ***Bioremediation and Biotechnology,*** Vol. 2, pp 1-13, Springer, 2020. DOI 978-3-030-40333

- Arora .M, Ahmad T, Farooq S, Riyaz**-Ul-Hassan S.** "Endophytes: A Hidden Treasure of Novel Antimicrobial Metabolites". Published in ***Antibacterial Drug Discovery to Combat MDR,*** pp 165-192. Springer, 2019, Singapore.

- *Pankaj Pandotra, Parshant Bakshi, Anil Kumar Singh, and* ***Suphla Gupta.*** **"**Exploring Genetic Resources for Identification of Potential Novel Genes for Crop Improvement". Published in ***Rediscovery of Genetic and Genomic Resources for Future Food Security,*** edited by Salgotra, Romesh Kumar, Zargar, Sajad Majeed, pp 225-237, Springer, USA, 2020.

- ***Singh Bikarma.*** **"**Himalaya is a repository of wild food and medicine: a close look on plants for human survival". Published in ***Plants for Human Survival and Medicine,*** 1st. Ed., Routledge, Taylor & Francis, CRC Press UK and NIPA, India, pp 1-26, 2019. [**ISBN**: 9780367818944]

- *Thakur S &* ***Singh Bikram. "****Zanthoxylum armatum* DC. Perspectives of biology and chemistry in medicine discovery". Published in ***Plants for Human Survival and Medicine,*** 1st Ed., Routledge, Taylor & Francis, CRC Press UK and NIPA, India, pp 119-137, 2019. [**ISBN**: 9780367818944]

- ***Singh Bikarma,*** *Sneha & Anand R.* 'Himalayan *Saussurea costus* (Falc.) Lipsch.: traditional uses, therapeutic potential and conservation perspective of critically endangered medicinal plant". Published in ***Plants for Human Survival and Medicine,*** 1st Ed., Routledge, Taylor & Francis, CRC Press UK and NIPA, India, pp 429-446, 2019. [**ISBN**: 9780367818944]

- *Lone JF &* ***Singh Bikrama.*** "Revisiting Himalayan high altitude plants for skin care and disease". Published in ***Plants for Human Survival and Medicine,*** 1st Ed., Routledge, Taylor & Francis, CRC Press UK and NIPA, India, pp 397-406, 2019. [**ISBN**: 9780367818944]

- *Lone JF &* ***Singh Bikram.*** "Revisiting Himalayan high altitude plants for skin care and disease". Published in ***Plants for Human Survival and Medicine,*** 1st Ed., Routledge, Taylor & Francis, CRC Press UK and NIPA, India, pp 397-406, 2019. [**ISBN**: 9780367818944]

- *Koul K,* ***Singh Bikarma****, Verma MK, Singh S, Goyal P, Yadav G, Singh B, Kitchlu S & Anand R.* "Crop-weather interactions, phytochemistry, pharmacology and evaluation of the phenological models for *Echinacea purpurea* (L.) Moench under temperate and subtropical environments". Published in ***Plants for Human Survival and Medicine,*** 1st Ed., Routledge, Taylor & Francis, CRC Press UK and NIPA, India, pp 365-382, 2019. [**ISBN**: 9780367818944]

- *Bhanwaria R,* ***Singh Bikarma*** *& Gochar R.* "Volatiles profiling and agronomic practice of *Cymbopogon khasianus* [IIIM (J) CK-10 Himrosa] for commercial cultivation and value addition". Published in ***Plants for Human Survival and Medicine,*** 1st Ed., Routledge, Taylor & Francis, CRC Press UK and NIPA, India, 2019. [**ISBN**: 9780367818944]

- *Nagar RK, Yadav G &* ***Singh Bikrama. "****Boswellia serrata* Roxb. ex Colebr., a multiferous medicinal plant used as anticancerous and anti-inflammatory in drug discovery: review". Published in ***Plants for Human Survival and Medicine,*** 1st Ed., Routledge, Taylor & Francis, CRC Press UK and NIPA, India, 2019. [**ISBN**: 9780367818944]

- *Bajpai V, Singh P,* ***Singh Bikarma*** *& Kumar B.* "Validated LC-MS method for quantitation of osteogenic phytochemicals in *Butea monosperma* (Lam.) Taub." Published in ***Plants for Human Survival and Medicine,*** 1st Ed., Routledge, Taylor & Francis, CRC Press UK and NIPA, India, pp 173-194, 2019. [**ISBN**: 9780367818944]

- *Gochar R,* ***Singh Bikarma,*** *Gochar M, Bhanwaria R & Katare AK.* "*Grewia asiatica* L., an important plant of Shivalik Hills: agrotechnology and product development". Published in ***Plants for Human Survival and Medicine,*** 1st Ed., Routledge, Taylor & Francis, CRC Press UK and NIPA, India, 2019. [**ISBN**: 9780367818944]

- *Katare AK, Khan IA, Mindala DP, Satti NK, Chandan BK,* ***Singh Bikarma****, Singh G, Khullar M & Sharma N.* "*Colebrookea oppositifolia* Sm., an important hepato-protective phytopharma plant in drug discovery". Published in ***Plants for Human Survival and Medicine,*** 1st Ed., Routledge, Taylor & Francis, CRC Press UK and NIPA, India, 2019. [**ISBN**: 9780367818944]

- *Bashir Akhlaq Akhoon, Harshita Tiwari and* ***Amit Nargotra.*** "In Silico Drug Design Methods for Drug Repurposing" (Chapter 3). Published in In ***Silico Drug Design: Repurposing Techniques and Methodologies,*** Academic Press (Elsevier), pg 47-84, 2019.

- *Durga Prasad Mindala,* ***Inshad Ali Khan.*** "Regulations for Health Care Biotechnology Products in Major Markets of the World". Published in Saxena A. (eds) ***Biotechnology Business - Concept to Delivery,*** Eco Production (Environmental Issues in Logistics and Manufacturing), Springer, Cham, Pp: 131-143, 2019. DOI**:** https://doi.org/10.1007/978-3-030-36130-3_7, **[ISBN:** 978-3-030-36129-7]

- *Vidushi Abrol, Manoj Kushwaha, Nisha Sharma,* ***Sundeep Jaglan,*** *Sharada Mallubhotla.* "Good Practices of Hazardous Waste Management". Published in: **Zero Waste: Management Practices for Environmental Sustainability,** 2020, CRC Press, Taylor & Francis Group, USA.

- *Anil Panghal,* ***Sundeep Jaglan,*** *Neelesh Sindhu, V. Anshid, Manga Veera Sai Charan, Vinod Surendran, Navnidhi Chhikara.* "Microencapsulation for Delivery of Probiotic Bacteria". Published in **Nanobiotechnology in Bioformulations**, 2019, Springer Nature Switzerland AG.

- *Nisha Sharma, Vishal Sharma, Vidushi Abrol, Anil Panghal,* ***Sundeep Jaglan.*** "An Update on Bioactive Natural Products from Endophytic Fungi of Medicinal Plants". Published in **Pharmaceuticals from Microbes Impact on Drug Discovery,** 2019, Springer Nature Switzerland AG.

INVITED TALKS / SEMINARS / CONFERENCES / WORKSHOPS / SYMPOSIUM / POST PRESENTATIONS / EXTERNAL REVIEWERS

- *Shukla P,* ***Singh Bikarma.*** **"**Medicinal plant diversity and folklore knowledge of local people residing in the Atraulia of Burhanpur tehsil, district Azamgarh, Uttar Pradesh" Published Abstract in Global Conference on Our Biodiversity, Our Food and Our Health, Vol 1, pp. 44 on 21-22nd May 2019 at Blue Planet Society (BPS); Global Environment & Social Association (GESA) & BSI

- *Dutta A,* ***Singh B,*** *Sharma YP.* "Ethnoveterinary Phytoremedies Prevalent Among Tribals of District Poonch". Published Abstract in International Conference on Applied Biology and First Annual Convention of the Society of Biologist, pp. 172 on 4-6th Nov. 2019 at SMVDU, Jammu & Kashmir

- *Dutta A,* ***Singh Bikarma,*** *Sharma YP.* "Allopathy to traditional medicine: a shift towards plant based healthcare practices for curing some human and livestock ailments". Published Abstract in 89th Annual Session of NASI, pp. 61-62 on 21-23rd Dec. 2019 at The National Academy of Sciences, India

- *Singh B, Kishor A,* ***Singh Bikarma.*** **"**Herbal ethnomedicinal practices in Himalaya preserves the age-old traditional knowledge: a case study around Jasrota Wildlife Sanctuary in District Kathua J&K**".** Published Abstract in National Seminar on Diversity and Reproduction in Plants and Microbes: Present scenario, pp. 13 on 7-8th Feb. 2020 at Department of Botany, University of Jammu, J&K

- *Dutta A,* ***Singh Bikarma,*** *Sharma YP.* "Wild medicinal plant resources in revitalizing the traditional herbal remedies". Published Abstract in National Seminar on Diversity and Reproduction in Plants and Microbes: Present scenario , pp. 01 on 7-8th Feb. 2020 at Department of Botany, University of Jammu, J&K

- *Bhat MN,* ***Singh Bikarma.*** **"**Floristic composition and mapping of Lolab Valley (Jammu & Kashmir) based in altitudinal gradients". Published Abstract in International Symposium on Plant Taxonomy and Ethnobotany, pp. 60 on 13-14th Feb. 2020 at Botanical Survey of India, Kolkata.

- Invited Lecture on "Emerging Trends in Plant Biology Research" at Lovely Professional University, Punjab on 15 -16th of November 2019 at the department of Molecular Biology and Genetic Engineering School of Bio-engineering and Biosciences. *[Delivered by Dr. Suphla Gupta]*

- Radio talk on "जैव ववविधिता के संकट" on 06.12.2019 *[Delivered by Dr. Suphla Gupta]*

- Invited Talk on Microbial natural products in service of mankind presented under the theme 'Women in Science' held on 28 February 2020 in University of Jammu, Jammu. *[Delivered by Dr. Asha Chaubey]*

- Invited Talk on "Microbial cell factories: Promising source of new antibiotics", presented in International ***Conference*** on Applied ***Biology*** (ICAB), held from 4 to 6 November 2019 in SMVDU, Katra. *[Delivered by Dr. Asha Chaubey]*

- Invited talk on "Bioprospection of Microbes for the Development of high value molecules" in National Conference on Microbial Bioprospecting: Present & Future Scope" Lovely University, Phagwara, 6th-7th March 2020. *[Delivered by Dr. Vikas Babu]*
- Invited lecture on "Composting of fruit and vegetable waste to organic fertilizers" in "ICAR" sponsored ten days training programme on "Recent advances in biofertilizers and biopesticides" from 13-22nd September 2019 conducted by Sher-e-Kasmir University of agricultural sciences and technology, Jammu is going to conduct. *[Delivered by Dr. Vikash Babu]*
- Invited talk on "Scope, Importance and Value Addition of Essential Oils" in ASEAN-India Training workshop on "Emerging Technologies for Young Biotech. Professionals from ASEAN MS" from 20-28thSeptember, 2019 held at CSIR-IGIB, New Delhi. *[Delivered by Dr. Vikash Babu]*
- *Er. Anil Katare*, Participated in Exhibition for National seminar on "Ayurveda and Integrative Medicine and its contemporary relevance" held at Hotel Ramada Jammu on 11th and 12th January 2020.
- *Er. Anil Katare* Participated in Exhibition on Technologies in Food Processing-Developed by CSIR on 13th November, 2019, Constitution Club of India, New Delhi.
- *Er. Anil Katare*, Participated in Exhibition entitled "Sanrachna 2019" organized by Parichit foundation at Kathua (J&K) December 2019

AWARDS / RECOGNITIONS / THESIS

1. *Dr. Nazia Abbas* (Scientist) awarded a grant of Rs. 18 Lakhs with SERB-Women Excellence Award by SERB-DST in 2019.

2. *CSIR-IIIM, Jammu* and Team Awarded II Runner Up at Sanrachna-2019 exhibition held at Kathua in December 2019 in the category of best exhibitor to create awareness among local population.
3. *Dr. Sandip B. Bharate* (Principal Scientist) has been selected for MEDI Young Investigator Award 2020 by ACS Division of Medicinal Chemistry [January 2020].
4. *Dr. Sandip B. Bharate* (Principal Scientist) has been awarded with OPPI Young Scientist Award (2019) in pharmaceutical sciences by "The Organization of Pharmaceutical Producers of India (OPPI)" [Awarded on 21 Aug 2019].
5. *Dr. Saurabh Saran* (Senior Scientist) IIIM-Technology Business Incubator Jammu awarded with Best in Category of 'Agriculture and Biotech' at Organic and Biotech India World Expo 2019 in August 2019 held at Mumbai.

- *Er. Anil Kumar Katare* (Senior Scientist) has been appointed for judging in Industrial Development segment for Kendriya Vidyalaya CRPF Bantalab; Jammu organized Regional Level "47th Jawahar Lal Nehru National Science, Mathematics & Environment Exhibition (JNNSMEE)" for Children-2019-20 on 1st October 2019.
- *Er. Anil Kumar Katare* (Senior Scientist) recognized as honorary speaker for "One month skill development programme on cultivation and processing of medicinal and aromatic plants with the collaboration of JKITCO @ CSIR-IIIM Farm Chatha". The programme scheduled from 17th December 2019-16th January 2020.
- *Er. Anil Kumar Katare* (Senior Scientist) recognized as projects reviewer for the Inspire Award winners of 2018-19 at KV2 Jammu Cantt Jammu.

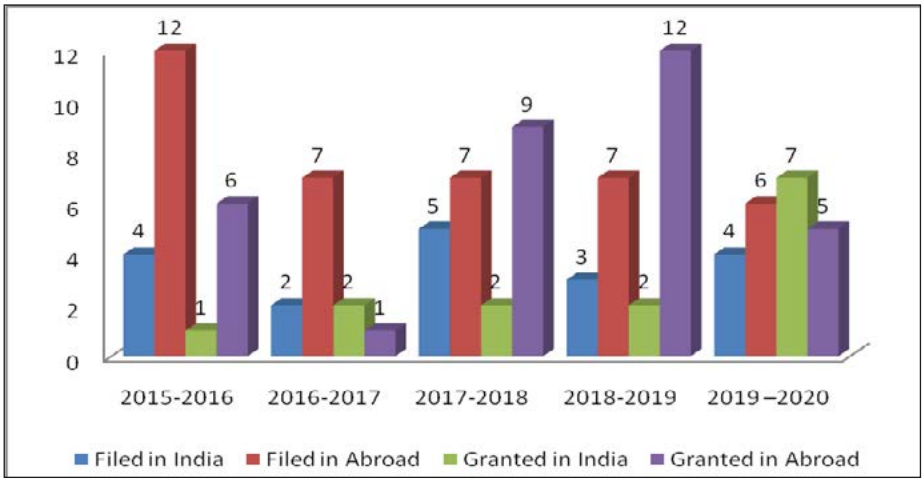
- *Dr. Debaraj Mukherjee* (Principal Scientist) recognised with prestigious D.K.Banerjee Memorial Lecture award from the Chemical Science department of IISc Bangalore on 19th Feb 2020.
- *Dr. Deepika Singh* (Senior Scientist) notified as "Government Analyst" for whole state of J & K for the purpose of Chapter IV-A by the State Government for Sub Section (1) and Sub-Section (2) of Section 33-F of the Drugs and Cosmetics Act, 1940 (Central Act), Notification no SRO 453 dated 17 July 2019.

RESEARCH GRANTS RECEIVED

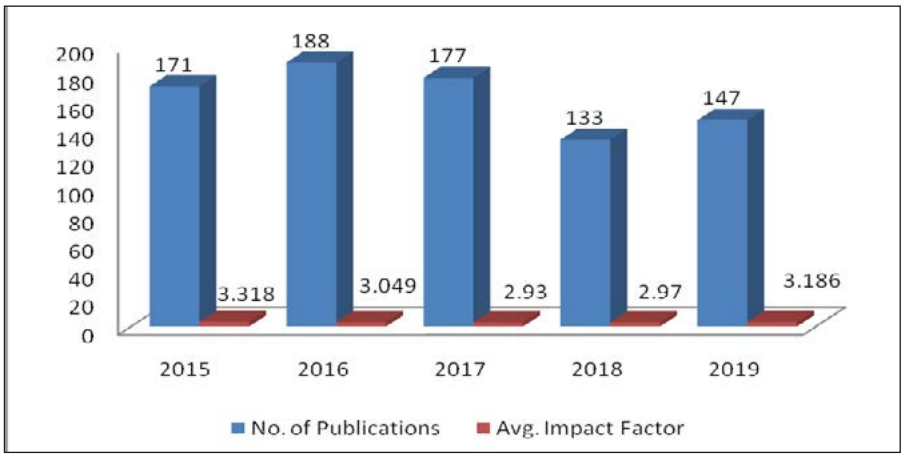
1. *Dr. Nazia Abbas* (Scientist) awarded a grant of Rs. 18 Lakhs with SERB-Women Excellence Award by SERB-DST in 2019.
2. "Deciphering role of astrocytes in pathogenesis of central nervous system tuberculosis (CNS-TB) and exploiting its related pathways as potential therapeutic targets for CNS-TB". Funding Agency: Indian Council of Medical Research (Govt. of India) Budget: Rs-8500000:00)-2019. Role: Principal Investigator *Dr. Zahoor Ahmad Parry*.
3. "Investigating Multidrug Resistant Tuberculosis in Kashmir". Funding Agency: Department of Science and Technology (Govt. of India) under Teachers Associateship For Research Excellence scheme (Just approved November 2018) (Budget: Rs-2000000:00) Role: Principal Investigator *Dr. Zahoor Ahmad Parry*.
4. *Dr. Zabeer Ahmad,* Senior Principal Scientist funded by DBT-NER-BPMC for the title "Investigation on the antiobesity activity of *Argyreia nervosa, Garcinia* species":
5. *Dr. Vikash Babu*, Senior Scientist funded by ICMR for the title "Fermentation based process development for the production of tacrolimus drug". Total cost-45.886 Lakhs (10th August 2019- ongoing).

PERFORMANCE PARAMETERS

Patents



Publications



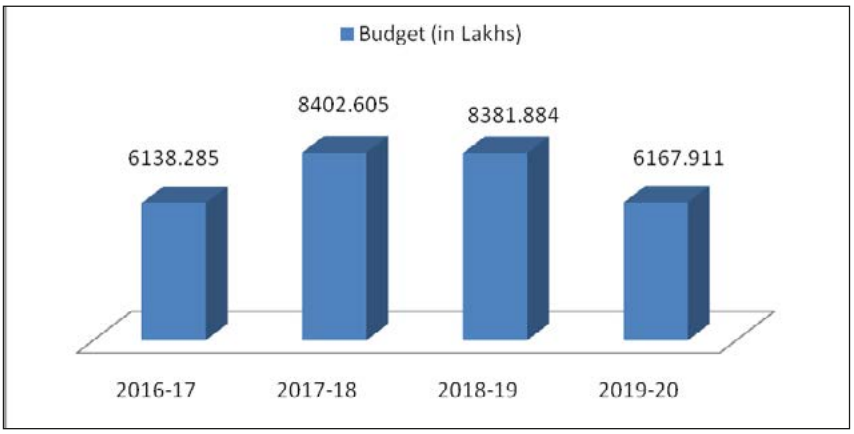
Fellowships

Name of Fellowship	Nos.
JRF (CSIR)	20
SRF (CSIR)	40
JRF (UGC)	52
SRF (UGC)	05
JRF (DST) INSPIRE	21
SRF (DST) INSPIRE	16
JRF (DST)	02
JRF (DBT)	04
RA (DBT)	02
JRF (ICMR)	02
SRF (ICMR)	16
RA (ICMR)	01

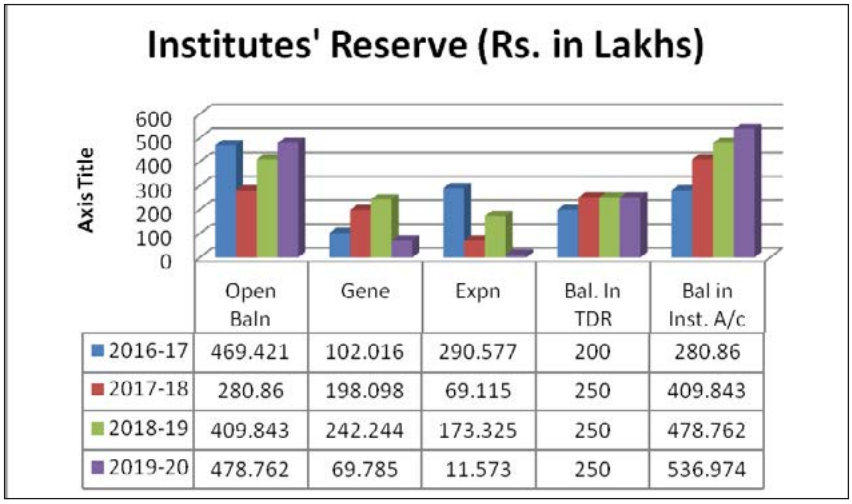
Name of Fellowship	Nos.
Women Scientist	04
Field Assistant	05
Teacher Associae	02
Post Doctoral Fellowship	06
Office Assistant	01
Coordinator	01
Young Scientist	01
DST INSPIRE Faculty	01
Caretaker	01
Work Contract	01
Ramlingaswami fellowship	01
Ramanujun Fellowship	01

Name of Fellowship	Nos.
SRA	03
Project Assistant I	77
Project Assistant II	110
Project Assistant III	12
Senior Research Fellow	01
Research Associate	04
Plant Operator	01
Information Officer	01
CSIR TWAS Fellowship	01
N.P.D.F.	01

Budget (Rs in Lakhs)

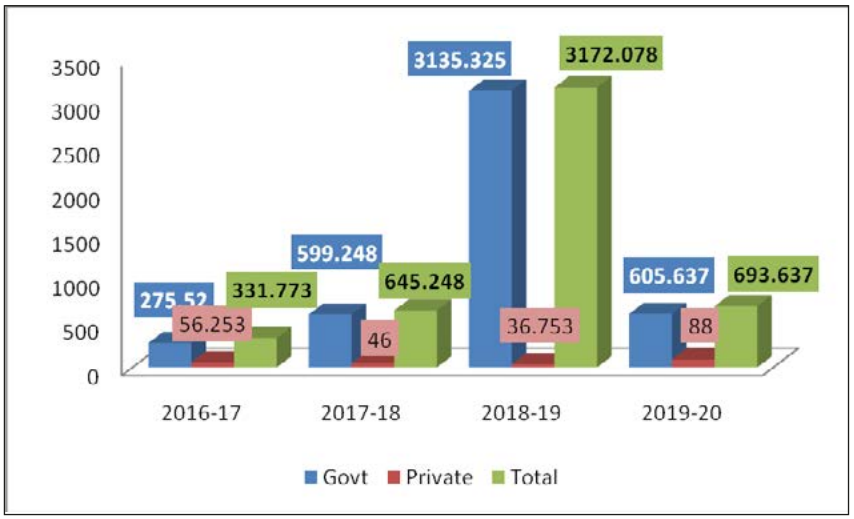


Institute's Reserve (Rs. In Lakhs)



	Open Baln	Gene	Expn	Bal. In TDR	Bal in Inst. A/c
2016-17	469.421	102.016	290.577	200	280.86
2017-18	280.86	198.098	69.115	250	409.843
2018-19	409.843	242.244	173.325	250	478.762
2019-20	478.762	69.785	11.573	250	536.974

External Cash Flow



MAJOR AGREEMENTS

CSIR-IIIM and IndusCann signed agreement on Cannabis research

CSIR-IIIM and InsdusScan, a Canada based company signed a major scientific agreement on Cannabis Research in a programme held in IIIM Auditorium in presence of the Union Minister Dr Jitendra Singh who was the Chief Guest at this function. R.R. Bhatnagar, Advisor to LG (J&K) and Dr. Shekhar C. Mande, DG CSIR & Secretary to Govt., DSIR were the guests of honour. Dr. Sanjay Kumar, Director, CSIR-IHBT, Palampur was special guest on the occasion.

Dr. Jitendra Singh while speaking on the occasion termed the signing of this scientific agreement between CSIR-IIIM and IndusScan a historic event in the for J&K and whole of India too as India is considered as the native place of this plant because in the Indus valley civilization, Cannabis was regarded as one of five sacred plants. Initially it was misused for psychoactivity and hence the plant was included in the Narcotic Drugs and Psychotropic Substances Act, 1985 list. In his lecture, Dr. Jitendra recalled the contribution of Sri Col. R.N.Chopra, son of soil and founder Director of IIIM Jammu who from 1940-1960 carried out extensive work on cannabis. He further appreciated the effort of IIIM Jammu which got the legal license for cultivation and medical research on this plant and product development. CSIR-IIIM is now globally recognized for its Cannabis work and several Industries and multinational companies are interested in collaboration with CSIR-IIIM. Dr. Jitendra Singh also expressed his satisfaction as this agreement will give an impetus for huge investment in Jammu and Kashmir.

R R Bhatnagar, Advisor to LG (J&K) appreciated the R&D activities of CSIR-IIIM, Jammu. Dr. Shekhar C. Mande, DG CSIR & Secretary to Govt., DSIR said that Cannabis has been associated with Indian culture and medicine since centuries; however, due to its misuse as psycho-active substance, it was banned worldwide 1980s onwards and put under narcotic list. By current scientific collaboration between CSIR-IIIM, Jammu and IndusScan on Cannabis research will totally transform the uses and application of Cannabis.

Dr. Ram Vishwakarma, earlier in his welcome address said that recent scientific discoveries have confirmed that most of the psychoactive properties come from? 9-tetrahydrocannabinol (THC). Recently another major compound was discovered named cannabidiol (CBD) which is totally devoid of psycho-active properties and possesses remarkable therapeutic activities. In last decade, four drugs namely Sativex (nabiximols), Marinol (Dronabinol), Nabilone (Cesamet), Epideloxhave been approved by US FDA/EU regulatory and many others in different clinical trials namely Ajulemic acid (Resunab, Phase-II), Dexanabinol (HU-211 or ETS2101, Phase-I). With all these research in last ten years, it is clear that CBD from cannabis is a miracle drug for several therapeutic indications (pain management including rheumatic, reduce nausea and vomiting, suppress seizure activity, combat anxiety, depression, psychosis disorders, anti-inflammatory properties, anti-tumoral properties and antioxidant properties that could fight neurodegenerative disorders). Since cannabis grows all over India as weed, there is an emergent great opportunity to explore this valuable plant for the production of CBD and development of drugs for biomedical applications.

CSIR-IIIM and M/s Racemix Molecules Pvt Ltd, Jammu has entered into an agreement to do collaborative research & development and industrial production of Active Pharmaceutical Ingredients (APIs) of life saving drugs on 14th March 2020.

Keeping in line with Govt move to incentivize firms to boost domestic production of Active Pharmaceutical Ingredient (APIs) and reduce dependence on imports, CSIR-Indian Institute of Integrative Medicine, Jammu has entered into an agreement with M/s Racemix Molecules Pvt Ltd, a Jammu based Pharmaceutical Company to do collaborative research & development and industrial production of APIs of the life saving drugs. Dr Ram Vishwakarma, Director CSIR-IIIM Jammu, informed that for past quite sometime, 40 percent of world market of APIs was with India. However, he added, the aggressive pricing policy of the countries like China, which started selling these APIs at very cheaper rate, caused severe effect to the Indian Pharmaceutical industries involved in the production of APIs, thereby increasing their dependence on imported APIs. Dr Ram also disclosed that this agreement signing is the follow-up action of successful developing the "know how process for fluxamime maleate" which is an antidepressant drug and now M/s Anphar is going to start the production of commercial batches in its good manufacturing practice (GMP) facility. After successful accomplishment of the lab scale synthesis of fluxamime maleate, CSIR-IIIM and M/s Racemix Molecules Pvt Ltd (a subsidiary of M/s Anphar) have signed the umbrella agreement under which they would work together for the synthesis of intermediates of API, production of commercial batches of fluxamime maleate and APIs of many other life-saving drugs. "Witnessing the current World situation where various diseases are spread world wide and most of the countries have stopped the export of drugs, CSIR-IIIM with state of the art research facilities has taken the initiative to actively support the API industry and to develop our own APIs

in our country itself. This will not only generate huge job opportunities but also develop national health security in India. This agreement will be a landmark and will work as a model to develop the API industry which can value about hundreds of billion dollars," maintained Dr Ram. The agreement was signed by Dr Ram Vishwakarma and Ankit Gupta, Director, M/S Racemix Molecules Pvt Ltd, here today, in the presence of other senior functionaries from both sides.

RURAL DEVELOPMENT AND SOCIETAL ACTIVITIES

SA1. Catalyzing Rural Empowerment through Cultivation, Processing, Value Addition and Marketing of Aromatic Plants: CSIR-Aroma Mission interventions of CSIR-IIIM, Jammu [Project No. HCP-0007]

Sumeet Gairola, Qazi Parvaiz Hassan, VP Rahul, Sabha Jeet, Rajendra Bhanwaria, SR Meena, Shahid Rasool, Phalisteen Sultan, Chandra Pal Singh, Rajinder Gochar, Habibullah, Niteen Ashok Narkhede, Vikrant Awasthi, Prashant Misra, Sumit Gandhi, Dhiraj Vyas, Abdul Rahim, Rajneesh Anand, Ram Vishwakarma

To bring a decisive and transformative change in the rural economy, market dynamics, and growth opportunity, Aroma Mission was conceptualized, which aimed to provide end-to-end technology and value-addition solutions across the country at a sizable scale. The first phase of CSIR-Aroma Mission, launched on 1st April 2020 was completed on 31st March 2020. First phase of CSIR-Aroma Mission has brought a transformative change in the aroma sector through scientific interventions in the areas of agriculture, processing, and product development by fuelling the growth of the aroma industry and rural employment. The following are some significant achievements of CSIR-IIIM during the first phase of the CSIR-Aroma Mission.

a) Brought more than 5500 ha (for all participating labs of CSIR) of the additional area under captive cultivation aromatic cash crops particularly targeting rain-fed /degraded land across the country.

b) Provided technical and infrastructural support for distillation and values-addition to farmers/growers all over the country.

c) Enabled effective buy-back mechanisms to assure remunerative prices to the farmers/growers.

d) Made progress in value-addition of essential oils and aroma ingredients for their integration in global trade and economy.

Promotion of cultivation and processing of aromatic crops and enhancing area of selected aromatic plants under CSIR-Aroma Mission

The total area of more than 1850 ha benefiting more than 2100 farmers has been bought under captive cultivation of selected aromatic crops at various locations throughout the country under CSIR-Aroma Mission by CSIR-IIIM, Jammu (Table SA1.1 & Figure SA1.1). Seven districts in Kashmir division viz., Bandipore, Baramulla, Budgam, Ganderbal, Kulgam, Kupwara, and Pulwama; Nine districts in Jammu division viz., Doda, Jammu, Kathua, Kishtwar, Rajouri, Ramban, Reasi, Samba and Udhampur; and two districts in Ladakh division viz., Kargil and Leh were covered under CSIR-Aroma Mission. Lavender, which was earlier disseminated in Kashmir valley by the institute, was now introduced to the temperate regions of Jammu as well. More than 600 farmers have taken up cultivation of Lavender on 150 ha area in J&K under CSIR-Aroma mission. Quality planting material (QPM) of *Tagetes minuta* was provided to the farmers in Kargil and Leh districts of the Ladakh division for the first time. Under CSIR-Aroma Mission, CSIR-IIIM has introduced selected aromatic crops to small and marginal farmers in remote border districts of J&K like Kupwara, Rajouri, Kargil, Jammu, Samba and Kathua where opportunities for employment are limited. QPM of the selected aromatic plants worth > 10 crores of market price was distributed free of cost to the farmers throughout the country. Till March 2020, it was estimated that these farmers produced > 12,500 kg essential oil worth > 3 crores by CSIR-Aroma Mission interventions of CSIR-IIIM, Jammu. Under first phase of CSIR-Aroma Mission, the selected aromatic crops have been successfully introduced to the small and marginal farmers at various locations of the country, which has helped in improving their socio-economic condition immensely.

Figure SA1.1 A) Lavender plantation at Doda, J&K; B) Himrosa (CK10) plantation at Mysore, Karnataka; C) CK10 plantation at Nagpur, Maharashtra; D) Lavender plantation at Arunachal Pradesh; E) CK10 plantation at Bajpur, Uttarakhand; F) Lemongrass (CKP25) plantation at Chhindwara, Madhya Pradesh; G) CK10 plantation at Puddukkotai, Tamil Nadu; H) Lemongrass (CKP25) plantation at Sultanpur, Uttar Pradesh; I) Ocimum (OG14) plantation at Rajsamand, Rajasthan

Table SA1.1. More than 1850 ha area was brought under captive cultivation of following aromatic plants at various locations throughout country by CSIR-IIIM, Jammu under first phase of CSIR-Aroma Mission.

Aromatic crop [Variety]	States where crop is extended
Lavender [RRL-12]	J&K, Arunachal Pradesh, Himachal Pradesh
Ocimum [RRL-OG-14, RRL-OB-15]	Tamil Nadu, Uttar Pradesh, Bihar, Rajasthan, Haryana, Chhattisgarh, Himachal Pradesh, Madhya Pradesh
Jammu Monarda [IIIM(J) MC-02]	Chhattisgarh, Haryana, J&K, Rajasthan, Uttar Pradesh, Ladakh
Rosagrass [RRL(J)CN-5, IIIM(J)CK-10 Himrosa]	Andhra Pradesh, Chhattisgarh, Gujarat, Haryana, J&K, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, Tamil Nadu, Telangana, Uttar Pradesh, Uttarakhand
Mentha [RRL(J)MT-94, RRL(J)ML-4]	J&K, Ladakh
Lemongrass [CKP-25, CPK-F2-38 Kalam]	J&K, Punjab, Haryana, Chhattisgarh, Uttar Pradesh, Uttarakhand
Geranium [PG-IIIM-101]	J&K, Arunachal Pradesh
Salvia sclarea	J&K, Ladakh
Rosemary	J&K
Tagetus minuta	J&K, Ladakh

Setting up a network of distillation units and catalyzing setting up of farmers' cooperatives for the marketing of the produce

Essential oils are the main economic ingredient of the aromatic plants which are extracted by employing distillation units. To enable farmers to distil the oil from aromatic plants, distillation units were installed in the clusters of villages. Installation of the distillation unit was a very vital component of the CSIR-Aroma Mission. It is the availability of such distillation facilities, which instils a sense of confidence in farmers about ensured returns from the cultivation of aromatic plants. A total of 61 distillation units of different types and capacities were installed at different locations in 12 states of India (Table SA1.2 & Figure SA1.2). A network of distillation units was developed in the UT of Jammu & Kashmir, where distillation units were installed at different locations in 14 districts. Two distillation units are under process of installation at UT of Ladakh.

Table SA1.2: Locations and types of the distillation units installed under CSIR-Aroma Mission throughout India.

State	District	Type of Distillation Unit	Capacity	No. of units
Madhya Pradesh	Chhindwara	SS FDU	500 kg	1
	Sagar	MS FDU	500 kg	1
Karnataka	Mysore	MS FDU	500 kg	1
Bihar	Aurangabad	MS FDU	500 kg	1
Chhattisgarh	Raipur	MS FDU	500 kg	1
Gujarat	Jamnagar	SS FDU	500 kg	1
Maharashtra	Jalna	SS FDU	500 kg	1
Rajasthan	Karauli	MS FDU	500 kg	1
Tamil Nadu	Pudukkottai	SS FDU	500 kg	1
Telangana	Hyderabad	SS FDU	500 kg	1
Uttar Pradesh	Sultanpur	MS FDU	500 kg	1
UT of Ladakh	Kargil	SS FDU	500 kg	1
	Zanskar	SS FDU	500 kg	1
UT of Jammu & Kashmir	Anantnag	SS FDU	500 kg	2
	Bandipora	SS FDU	500 kg	1
	Budgam	SS FDU	500 kg	3
	Doda	SS FDU	500 kg	3
		MS FDU	500 kg	1
	Ganderbal	SS FDU	500 kg	1
	Jammu	SS FDU	500 kg	4

State	District	Type of Distillation Unit	Capacity	No. of units
		SS Mobile unit	500 kg	4
		MS FDU	500 kg	1
		SS Cohabition unit	500 kg	2
	Kathua	SS FDU	500 kg	3
		MS FDU	500 kg	1
	Kishtwar	SS FDU	500 kg	1
	Kupwara	SS FDU	1500 kg	3
	Pulwama	SS FDU	500 kg	2
		MS FDU	500 kg	10
		SS Cohabition unit	500 kg	2
	Rajouri	MS FDU	500 kg	1
	Reasi	MS FDU	500 kg	1
	Srinagar	SS FDU	500 kg	1
	Udhampur	SS FDU	500 kg	1
			Total	**61**

Figure SA1.2. Transportation and installation of fixed and mobile Distillation Units under CSIR-Aroma Mission.

Skill development and product development activities under CSIR-Aroma Mission

Aromatic plants are suitable economic alternates for achieving higher income and utilizing marginal/problematic lands and can also act as insurance crops in the event of environment/climate excesses. Under the CSIR-Aroma Mission, a total of 124 awareness-cum-training programs were conducted for the growers and other stakeholders, particularly in the regions where farmers are adversely hit by the deficient/excessive rainfalls (Table SA1.3). Fifty-two awareness-cum-training programs were conducted at different locations during the year 2019-20. Experts from industries and financial institutions were also involved in training growers of various schemes for obtaining financial help (Figure SA1.3). Selected progressive farmers/ young entrepreneurs were also trained in distillation, fractionation/derivatization, extraction, quality control, product development, etc. Videos on the successful introduction and cultivation of aromatic plants and activities of CSIR-Aroma Mission were developed and released. Products such as Lavender face wash, Citronella & Lemongrass based mosquito repellent, and Lavender oil-based traveller's kits were developed along with prototypes for many other essential oil based products. For making the public aware of CSIR-Aroma Mission activities and achievements using the appropriate interface, booklet entitled "CSIR Aroma Mission Booklet entitled "Catalyzing Rural Empowerment through Cultivation, Processing, Value Addition and Marketing of Aromatic Plants" was designed, published and distributed.

Table SA1.3 Details of state wise awareness-cum-training programme conducted under CSIR-Aroma Mission by CSIR-IIIM, Jammu.

State	Type of Training (No. of days)	No. of Programme
Arunachal Pradesh	Advanced (Three days)	1
Chhattisgarh	Awareness (One day)	1
Gujarat	Advanced (Two days)	1
Haryana	Awareness (One day)	1
Jammu and Kashmir + Ladakh	Advanced (Two days)	2
	Awareness (One day)	60
	Training (One month)	1
Karnataka	Awareness (One day)	2
	Advance (two days)	1
Madhya Pradesh	Awareness (One day)	7
Maharashtra	Advanced (Three days)	1
	Awareness (One day)	6
Punjab	Awareness (One day)	2
Rajasthan	Awareness (One day)	18
Tamil Nadu	Awareness (One day)	2
Uttar Pradesh	Advanced (One week)	2
	Awareness (One day)	16
	Total	**124**

Figure SA1.3: Awareness-cum-training programme under CSIR-Aroma Mission at A) Dodda, J&K; B) Kalaktang, Arunachal Pradesh; C) Puddukkotai, Tamil Nadu; D) Mysore, Karnataka; E) Chhindwara, Madhya Pradesh; F) Rajsamand, Rajasthan; G) Rewa, Madhya Pradesh; H) Verinag, J&K; I) Jammu, J&K; J) Kargil, Ladakh

SA2. Successful cultivation of the high-value Lavender crop in Jammu division of UT of J&K, India [Project No. HCP-0007]

Sumeet Gairola, Qazi Parvaiz Hassan, Phalisteen Sultan, Rajendra Bhanwaria, VP Rahul, SR Meena, and Rajinder Gochar

Lavandula angustifolia Mill. (Syn. *L. officinalis* Chaix) or "True Lavender" is a small, non-hardy perennial evergreen subshrub belonging to the family Lamiaceae. The genus *Lavandula* comprises many important species that are geographically distributed in Mediterranean countries, Canary Islands and India. It is commercially cultivated in many parts of the world, mainly for its essential oil, which is obtained by the hydro-distillation of its attractive flowering spikes. Lavender is commercially one of the best known essential oil-bearing plants, which is grown for essential oil and dry flowers. Lavender oil mainly consists of linalyl acetate, linalool, lavandulol, 1-8-cineole, lavandulyl acetate, and camphor. Because of its delightful odour, Lavender oil has found wide applications in flavour, perfumery and cosmetic industry. Linalool and linalyl acetate contents in Lavender oil are used as the criterion for its quality evaluation. It is also used in therapeutics as antispasmodic, and carminative. Recently, as aromatherapy has become increasingly popular, Lavender oil has found application as a stress buster or brain relaxant. The global demand for Lavender oil is estimated at around 12000 tons/year, whereas domestic consumption of Lavender oil is more than 250 tons/year. Internationally the primary producers of Lavender oil are Bulgaria, France, the United Kingdom, Spain, China, Russia, Italy, Morocco, countries of the former Yugoslavia, Hungary, Romania, Poland, Turkey, Ukraine, Moldova, South Africa, and the USA. In India, Lavender was first introduced in the Kashmir Valley in the year 1983, where its commercial cultivation was found to be successful. Lavender growing in the mountains of Jammu & Kashmir (J&K) produces an outstanding quality of Lavender oil. Low production costs and superior quality essential oil coupled with high market demand have made Lavender cultivation very profitable and famous in J&K. After the successful cultivation of Lavender in the Kashmir division, CSIR-IIIM, Jammu has introduced and tried to popularize Lavender in the temperate regions of the Jammu division under CSIR-Aroma Mission. Under CSIR-Aroma Mission, high value essential oil-bearing Lavender crop was introduced to the farmers of temperate regions of Jammu viz., Doda, Kishtwar, and Rajouri districts. Till March 2022 under CSIR-Aroma Mission, Quality planting material (QPM) of Lavender, i.e., more than 8 lakh rooted plants of Lavender were provided free of cost to more than 500 farmers in the Jammu region for >140 acres of land. Besides free QPM of Lavender, free technical knowledge and essential oil distillation facilities were provided to the farmers. Field demonstration for plantation of Lavender was also given to the farmers. Detailed information about agro-technology and field management practices was provided to the farmers. Lavender cultivation in the Jammu division is immensely helping in alleviating the income of the marginal farmers of the region. Lavender has become vastly popular among small and marginal farmers of the temperate regions of the Jammu division. Farmers have produced more than 800 liters of lavender oil worth Rs. eighty lakhs between years 2018-2020.

CSIR-IIIM has developed a protocol for in vitro propagation of Crocus corms. This will be a boon to farmers because non availability of quality planting material is one of the limiting factors for Crocus cultivation and production **(Dr. Nasheman Ashraf and Team).**

Figure SA2.1: Lavender distribution and plantation at different locations of the Jammu division.

Contribution of Quality Control & Quality Assurance (QCQA) Division towards Economy / Society

SA3 QCQA Division has accrued many benefits to Society and industry

Dr. Deepika Singh and Team

Quality analysis of Water

Physiochemical testing and microbial load were analyzed to check quality of water from various public and private schools, universities, hospitals, small- and large-scale industries across whole J & K and parts of India. Quality analysis of Water was carried out as per IS 10500:2012 guidelines.

In Defense, other Sectors, Schools & Colleges

Analysis were carried out for AGE E/M Kaluchak, AGE E/M, GE, Nagrota, C/O 56 APO, AGE E/M, GE, Dhar Road, Udhampur C/O 56 APO, AGE, B/R-II Rakhmuthi Pin 900237, C/O 56 APO, Military Engineer Services, Garrison Engineer (Army), Dhar road, Udhampur, J & K, Garrison Engineer (North) Akhnoor, C/O 56 APO, Garrison Engineer (South) Akhnoor, C/O 56 APO, Garrison Engineer, 873, Engr Works Sec, C/O 56 APO, 23 RR (Rajput), C/O 56 APO, 269, Engr Regt, C/O 56 APO, HQ, 25 Inf. Div., AGE E/M (AF) Jammu, Air Force Station, Satwari, C/O 56 APO, Engr, Regt (23 Fd Coy), C/O 56 APO, 237 Engineer, Regiment, C/O 56 APO, 59 Engineer, Regiment, C/O 56 APO, Inspector General STC, BSF-Udhampur, PO Roun Domail, Udhampur and Commandant, ITB Police, 15th Bn, PO, Garhi, Udhampur and Airports Authority of India, Civil Airport, Jammu.

Complete water analysis had also been carried out in 116 samples received from various public and private sectors *viz.* Indian Oil Corporation Ltd, Bulk depot Jammu, (C-2085, C-3059); Industrial sector of J & K like Bhagwati flour mills (C-3000), Mahindra Astro India Automobile Pvt Ltd; (C-2096) Important ongoing projects like (Chenab Valley Power Project (P) Ltd., C-3024 (01-05) and Schools (Delhi Public School, C-2065, C-2071, C-3037), (J P World School; C-3039), (Heritage School, Jammu; C-3049), (G D Goenka Public School; C-3054), (Banyan International School; C-3058) & Institutes like IIT Jammu; C-3005 (01-03).

Industry & Society

NABL accredited QCQA division delivered basic and applied research outputs of international quality as per scope across the entire Union Territory of J & K as well as nation as a whole. Food, spices and condiments, animal feeds, alcoholic drinks and beverage industry got their samples tested. Analysis of heavy metals, pesticides, aflatoxins, various physicochemical parameters like total ash, acid insoluble ash, crude fiber, peroxide value and free fatty acids has been carried out. Certificate of Analysis were issued after completion of tests. 3420 analysis were completed in 405 commercial samples with the release of certified reports.

Directorate of Agriculture, Jammu

Carried out analysis of residual pesticides in 184 samples of Basmati rice received from Directorate of Agriculture, Jammu and COAs were released. It was one step forward in the promotion and popularization of Jammu Basmati rice and its export as per APEDA guidelines.

QCQA Division participated and showcased analytical capabilities and common mass aware of quality of drinking water by showing hands on experiment and putting up stall in Sanrachna-2019 organized by Parichit Foundation, Delhi held from 05-07 Dec 2019 at Kathua, J & K.

As a part of Skill Development Program (SDP) for manpower trainings were also organized for postgraduate students giving them hands on experience on modern analytical instruments.

Contribution of Chemical Engineering Division towards Economy / Society

SA4 Successful completion of Phase-I Clinical trial study ICB014-A002 (*Woodfordia fructicosa*) on Healthy volunteer for the treatment of Gastro protective agent under AYUSH Mode

Er. Anil Katare and Team

In an endeavor to make available high quality and innovative products in India, CSIR-IIIM Jammu conducted the Phase I Clinical trial titled "A Phase- I, Dose-escalation study to evaluate the safety, tolerability and Pharmacokinetic of ICB014-A002, Herbal Capsule in healthy adult volunteers" in collaboration with one of the Indian CRO company at Apollo Hospitals, Ahmadabad, Gujarat, with registered Clinical trial Registry of India (CTRI) bearing number CTRI/2018/01/011259 dated: 10/01/2018. In addition to the above, the Apollo Ethics committee approved the proposed study to conduct the same on conditionally. As per the current status of the study, it is informed that a complete Phase-I Clinical trial study was completed. The study concluded with the product was proved clinically safe to the intended use.

Contribution of Fermentation Technology Division towards Economy / Society

- Fermentation Technology Division successfully completed the Contract Research of M/S Om Sav Pharma Research Pvt Ltd, Ahmedabad through IIIM-TBI. The company has successfully scaled up the enzyme production in 500L fermenter. The down streaming and immobilization of the enzyme produced in five runs were successfully completed with consistent yields.
- Dr Hemant Patil, M/s Krishidoot Bio Hearbals, scientist and HOD Microbiology from Krishidoot Bio-Herbals, Hyderabad underwent training in Fermentation Technology Division for enzymes production and downstreaming.
- 25 participants visited Fermentation Technology Division on 15 November 2019 under ICAR sponsored Short Course on "Recent advances in production of bio-fertilizers and bio-pesticides" organized at SKUAST Jammu,
- Participated in Food Technology exhibition held in New Delhi on 13 November 2019 to showcase the nutraceutical products developed at CSIR-IIIM

Few Glimpse of Fermentation Technology Division Participation in Exhibitions

SERVICE TO INDUSTRY

SI1 Upgradation of Crude Drug Repository (CDR) and botanical standardization of raw drugs for various industry and network projects [Project No. MLP-1007 & various industry/mission projects]

Sumeet Gairola and Pankaj Kumar

A Crude Drug Repository (CDR) at CSIR – IIIM, Jammu is a national referral facility catering to the needs of industry, academia, and scientists in the form of identification of crude drugs. This referral facility is accessible to the pharmaceutical industry, traders, medicinal practitioners, natural products chemists, botanists, students, and academicians. The authentication service of crude drug specimens received from throughout India is provided through this facility. Authenticated plant material and certification of drug specimens are also provided using this facility. Permanent crude drug accession numbers are given to each specimen. Besides that, passport data about plant part, plant part code, botanical name, family, Ayurvedic/ vernacular name, received from, and project from which it is received is also kept for each of the specimens. Presently a total of 4062 authenticated crude drug specimens of various parts of the plants, belonging to 1145 taxa (168 families, 742 genera, 1133 species, three subspecies, and four varieties) used as medicine in various indigenous systems of medicine have been housed at Crude Drug Repository (CDR) of CSIR-IIIM, Jammu. Various maintenance activities were undertaken in the CDR *viz*., fumigation with pesticides, application of naphthalene balls, etc. All the specimens available at CDR were checked, and labels were updated. Valid botanical names with author citations of all the plant species were verified from www.theplantlist.org, Version 1.1 (2013). For many plant species, different synonyms are generally used, in those cases besides valid botanical names, synonyms have also been given. Specimens at CDR were arranged according to various plant parts *viz*., root, stem, leaves, flower, fruit, seed, root & rhizome, stem & leaves, fruit & seed, stem bark, root bark, heartwood, whole plant, aerial part, gum/resin, tuber, bulb, calyx and exudes (Figure SI1.1). The medicinal plants are traded in raw drug form for medicinal purposes in various industries. However, the medicinal plants also face a significant problem of adulteration due to the misidentification of the original drug from other mixed herbal samples of different species. This adulteration practice of herbal medicines often reported compromised quality, efficacy, several harmful effects on health, and even death of end-users. The use of herbal drugs for medicinal purposes needs the primary identification and authentication of the genuine herbal drug to be used for pharmaceutical purposes. Studies were conducted to ascertain the identity and botanically standardize the selected high value raw medicinal plants. Detailed botanical and pharmacognostic monographs were developed for some important raw plant drugs for various industry and mission projects (Table SI1.1 & Figure SI1.2). A total of 61 authentic raw plant drug specimens, along with all the passport data, were accessioned to the CDR at CSIR-IIIM, Jammu.

Figure SI1.1. Plant part wise arrangement of the raw plant drugs at Crude Drug Repository at CSIR-IIIM, Jammu.

Table SI1.1: List of some important raw plant drugs botanically standardized for various industry & mission projects.

Botanical name	Family	Part used
***Bergenia ciliata* (Haw.) Sternb.**	Saxifragaceae	Rhizome
***Cocculus hirsutus* (L.) W.Theob.**	Menispermaceae	Stem, leaves, root,
***Cissampelos pariera* L.**	Menispermaceae	Stem, leaves, root,
***Dysoxylum gotadhora* (Buch.-Ham.) Mabb.**	Meliaceae	Leaves
***Glycyrrhiza glabra* L.**	Leguminosae	Root
***Tinospora sinensis* (Lour.) Merr.**	Manispemaceae	Stem
***Woodfordia fruticosa* (L.) Kurz**	Lythraceae	Stem bark

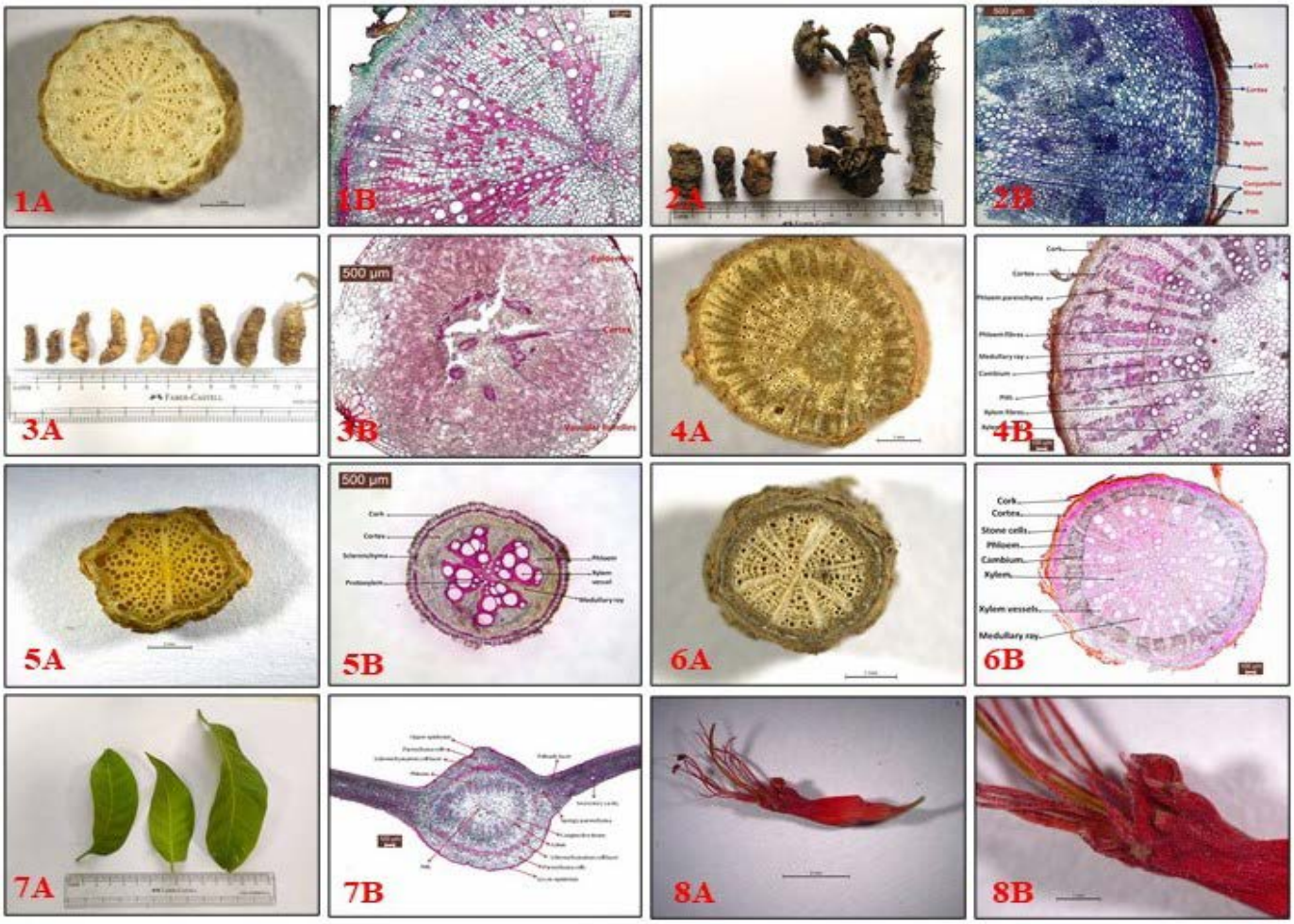


Figure SI1.2. Some representative images of the raw drugs which were botanically standardized for various industry and mission projects. 1A-1B) *Cocculus hirsutus*; 2A-2B) *Bergenia ciliata*; 3A-3B) *Trillium govanianum;* 4A-4B) *Glycyrrhiza glabra*; 5A-5B) *Tinospora sinensis*; 6A-6B) *Abrus precatorius;*7A-7B) *Dysoxylum gotadhora;* 8A-8B) *Woodfordia fruticosa*

SI2. Service to Industry (Fermentation Technology Division.)

- M/S Bills Biotech Pvt. Ltd : Production, Scale up and yield improvement of Lipstatin via fermentation
- Fermentation facility was provided to Om Sav Pharma Research Pvt Ltd, Ahmedabad for scale-up of their enzyme product
- Showcased the nutraceutical products developed at CSIR-IIIM in Food Technology exhibition held in New Delhi on 13 November 2019.

SI3. Service to Industry (Chemical Engineering Division.)

Sl. No	Title of the project	Project Type/Category	Govt./ Industry
1	Development of extract of *Trillium govanianum* (Naag Chatri)	TBI project	M/s. Himalya Botnicals (P) Ltd. Jammu
2	Development of capsule formulation of "**Watercress**"	TBI project	M/s. Glowbil Pvt. Ltd. Lasipura Pulwama
3	Skill development programme through (TBI)	Training	Private/University

Industrial Support:

The utilisation of the spare capacity of M/S IIIM-CSIR unit for manufacture of AYUSH drugs, competent technical staff, and facility to the **M/s. Indus Cann Pvt. Ltd., Mumbai and M/s. Nirog Street Pvt. Ltd., Gurgaon,** India, to the manufacture of Cannabis-based product with the brand VIJAYA Capsule for the commercialisation. Mr. Durga Prasad, Technical Assistant – Regulatory Affairs support to the filing of an application to the J&K State Food and Drug Administration, J&K, and J&K Excise Department, Jammu. Er. Anil Kumar Katare, Sr. Scientist, Plant Head, cGMP pilot plant, provided the authorization to the utilisation of the spare capacity of the unit in the area of Capsule and Liquid oral sections.

SOME OTHER IMPORTANT ACTIVITIES

1. JIGYASA TRAINING PROGRAM

cGMP Unit, CSIR-IIIM Jammu, provide opportunity to know how for K.V. School students and faculty members in manufacture of standardised extracts and botanical drug formulations, natural products etc., to evaluate encourage the students at early stage for research and eventually graduate as entrepreneurs/ researchers so that more number of young students can be setup and employment can be generated. This facility will also be used as the Technology Business Incubator (TBI), for which Department of Science and Technology has already approved a project. K.V. School students and faculty have been selected for dissertation training programme in cGMP Unit, CSIR-IIIM Jammu of Indian Institute of Integrative Medicine (TBI-IIIM), Jammu, and conducted training program in March, 2019.

Visit of K.V. School students and faculty members

2. TBI-SKILL DEVELOPMENT PROGRAM

cGMP Unit, CSIR-IIIM Jammu, provide opportunity to new entrepreneurs/SMEs engaged in manufacture of standardised extracts and botanical drug formulations, natural products etc., to evaluate their research leads and eventually graduate as entrepreneurs/students. So that, more number of industries can be setup and employment can be generated. This facility shall also be used as the "Technology Business Incubator" (TBI), for which Department of Science and Technology has already approved a project.

Biotech Industrial Training Programme under BCIL, have been selected for dissertation training programme in Technology Business Incubator of Indian Institute of Integrative Medicine (TBI-IIIM), Jammu, for the batch commencing in January/February, 2019. Training was imparted through lectures by the experts and Practicals in the area of Extraction, Formulation, QA/QC, and Utilities etc.

The main objective of CSIR- IIIM is conducting One/three/Six month's certificate course to create a stream of highly trained manpower by enhancing practical and regulatory skills of science, pharmacy and medicine graduates.

Course structure: The course will be a right mix of lectures by experts drawn from CSIR, academia and Industry and intensive hands on training on good agriculture and collection practices (GACP), current Good Manufacturing Practices (cGMP), good documentation practices (GDP), QC/QA-CMC and regulatory aspects related to production of botanical/ herbal formulations. Separate modules for practical training on analytical instruments, GMP based preparation of extracts and formulations, will be the integral part of this course.

List of the students taken advantage of training in cGMP Facility

Sr. No.	Name of Student	College/University	Duration of Training	Division
1	Rakshit Manhas	SMVDU, Katra	2 Months	cGMP
2	Diksha Sharma	SMVDU, Katra	2 Months	cGMP
3	Radhika Bandral	SMVDU, Katra	2 Months	cGMP
4	Adarsh Sharma	Chandigarh University	6 months	cGMP
5	Mohit Sharma	DAV University	2 Months	cGMP
6	Priyanshul Sharma	DAV University	2 Months	cGMP
7	Shambhavi Mishra	SHUATS University, Allahabad	1 Month	cGMP
8	Kanika Gupta	Guru Nanak Dev University	2 Months	cGMP
9	Aliza Bharti	Guru Nanak Dev University	2 Months	cGMP
10	Puneet Kaur	Guru Nanak Dev University	2 Months	cGMP
11	Nancy Sharma	Guru Nanak Dev University	1 Month	cGMP
12	Shaheen Parveen	SHUATS University, Allahabad	1 Month	cGMP
13	Madhu Singh	SHUATS University, Allahabad	1 Month	cGMP
14	Manu Dogra	NIT Srinagar	1 Month	cGMP
15	Diksha Sharma	Guru Nanak Dev University	1Month	cGMP
16	Tejinder Kour	Guru Nanak Dev University	1Month	cGMP
17	Kiranjeet Kour	Guru Nanak Dev University	1Month	cGMP
18	Arshdeep Singh	Guru Nanak Dev University	1Month	cGMP
19	Vikas Goyal	Guru Nanak Dev University	1Month	cGMP
20	Herprret Kour	Guru Nanak Dev University	1Month	cGMP
21	Navjot Kour	Guru Nanak Dev University	1Month	cGMP
22	Novneet kour	Guru Nanak Dev University	1Month	cGMP
23	Amandeep Kour	Guru Nanak Dev University	1Month	cGMP
24	Kanwal Preet Kour	Guru Nanak Dev University	1Month	cGMP
25	Karkeerat Singh	Guru Nanak Dev University	1Month	cGMP
26	Gurvinder kour	Guru Nanak Dev University	1Month	cGMP
27	Viashal Sharma	Guru Nanak Dev University	1Month	cGMP
28	Vivek Anand	Guru Nanak Dev University	1Month	cGMP

Few photographs of the students during training course

3. The cGMP Department is involved in following project:

Sl. No.	Title of Project	Project Category	Participating Agencies
1	CSIR-Phytopharmaceuticals Mission (HCP-0010) Project cost:Rs.988.00 Lakhs	R&D	CSIR
2	CSIR-Aroma Mission (HCP-0007) Project cost:Rs.2327.00 Lakhs	R&D	CSIR
3	CSIR-Sickle Cell Anaemia (HCP-0008) Project cost:Rs.1367.00 Lakhs	R&D	CSIR
4	Development of Phytopharmaceutical product for Boovine Mastitis (GAP-2141)Project cost:Rs.104.732 Lakhs	R&D	DBT
5	Science and Technology Support Project (STS-1111)	R&D	CSIR
6	Chemical Engineering (STS-0004)	R&D	CSIR
7	Technology Business Incubation Programme (GAP-2160)	R&D	DST
8	"Phytopharmaceutical Development of *Ficus semicordata*	R&D	DBT

Field Visits:

Under AROMA Mission project was taken on 22nd August 2019 to 30th August 2019 at Ahmadabad (Gujarat) and Katni (M.P.) during the field visit cum procurement of slips of aromatic crops, interaction with the farmers and local individuals done and immobilized them for moving from traditional crops cultivation to medicinal/aromatic crops cultivation.

At Field with Farmer

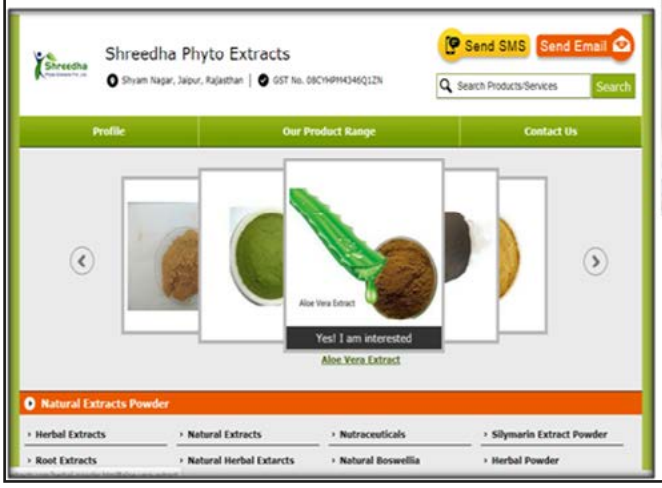
Slips of Aromatic crop

Field of Crops

ENTREPRENEURSHIP CREATED THROUGH TRAINING AT cGMP / CHEMICAL ENGINEERING DEPARTMENT

Gaurav Agarwal has been trained for 6 months on herbal drugs formulation and manufacturing at cGMP-Pilot Plant facility for Herbal Drugs. He is currently Business Development Head at Bhartiya Agrow Pharma Pvt Ltd.

Shikha Mainali has been trained for 6 months on herbal drugs formulation and manufacturing at cGMP-Pilot Plant facility for Herbal Drugs. She is currently Business Development Head at M/s. Shreedha herbal Extract Pvt. Ltd. Jaipur



Shreedha Phyto Extracts
Shikha Mainali (Sales & Marketing Manager)
No. 2, 3, Ved Vatika, New Sanganer Road Sodala, Shyam Nagar,
Jaipur - 302019, Rajasthan, India

NEW FACILITY CREATED

Lyophilizer (Capacity: 35 Litres)

CSIR-IIIM Jammu as an emerging entrepreneur in the Phytopharmaceutical. This institution set up a new facility for extraction, formulation and packing Traditional ISM herbal medicine formulation dosage forms (Tablets, capsule, liquid oral dosage forms and churna). The objectives for the installation of such facility are to develop dry powder from extract (Organic/Inorganic) for various projects. The order for purchase and procurement for the said purpose was placed to M/s. Mehrotra Biotech Pvt. Ltd. Lucknow, for Installation of Lyophilizer Unit. The make and model no. of the freeze dryer are Telstar, LYOBETA 6PL. The facility is now installed and commissioned under the supervision of Er. Anil Kumar Katare (Head, CED/cGMP) with required successful trail runs. The capacity of Lyophilizer Unit is around 35 Litres per batch. The facility is to cater to the needs of CSIR-IIIM in terms of preparation of formulation in various dosages forms such as Tablet, Capsule, Syrup or Churana etc., and also for New Chemical Entities (NCEs) that are being evaluated for IND potential. The facility may also provide a boon for small scale herbal industry (Commercialization) to take advantages of this facility which may not be accessible to them due to high cost and maintenance requirements.

Fractional Distillation Unit
(Capacity: 35 Litres)

SC/ST/OBC REPORT-I

ANNUAL STATEMENT SHOWING THE REPRESENTATION OF SCs, STs AND OBCs AS ON FIRST JANUARY OF THE YEAR AND NUMBER OF APPOINTMENTS MADE DURING THE PRECEDING CALENDER YEAR 2019

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH (DSIR) O/o INDIAN INSTITUTE OF INTEGRATIVE MEDICINE, JAMMU

	Representation of SCs/STs/OBCs (As on 01.01.2020)				Number of appointments made during the calendar year 2019									
					By	Direct Recruitment			By	Promotion		By	Deputation	
Groups	Total number of Employees	SCs	STs	OBCs	Total	SCs	STs	OBCs	Total	SCs	STs	Total	SCs	STS
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Group A	73	10	03	09	NIL	--	--	--	--	--	--	--	--	--
Group B	74	16	03	13	NIL	--	--	--	--	--	--	--	--	--
Group C	71	29	00	10	NIL	--	--	--	--	--	--	--	--	--
Group D (Excluding Sweepers)	--	--	--		--	--	--	--	--	--	--	--	--	--
Group D (Sweepers)	--	--	--		--	--	--	--	--	--	--	--	--	--
TOTAL	218	55	06	32	NIL	--	--	--	--	--	--	--	--	--

SO (Estb)

O/o Indian Institute of Integrative Medicine, Jammu- 180001

SC/ST/OBC REPORT-II

ANNUAL STATEMENT SHOWING THE REPRESENTATION OF SCs, STs AND OBCs IN VARIOUS GROUP'A' SERVICES AS ON FIRST JANUARY AND NUMBER OF APPOINTMENTS MADE IN THE SERVICE IN VARIOUS GRADES IN THE CALENDER YEAR 2019

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH (DSIR)

O/o INDIAN INSTITUTE OF INTEGRATIVE MEDICINE, JAMMU

	Representation of SCs/STs/OBCs (As on 01.01.2020)				Number of appointments made during the calendar year 2019									
					By Direct Recruitment				By Promotion			By Deputation		
Pay Band and Grade Pay	Total number of Employees	SCs	STs	OBCs	Total	SCs	STs	OBCs	Total	SCs	STs	Total	SCs	STS
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PB-3 Rs.5400	07	01	01	01	--	--	--	--	--	--	--	--	--	--
PB-3 Rs.6600	10	01	--	03	--	--	--	--	--	--	--	--	--	--
PB-3 Rs.7600	24	05	--	03	--	--	--	--	--	--	--	--	--	--
PB-4 Rs.8700	27	01	--	01	--	--	--	--	--	--	--	--	--	--
PB-4 Rs.8900	06	01	02	--	--	--	--	--	--	--	--	--	--	--
PB-4 Rs.10,000	01	--	--	--	--	--	--	--	--	--	--	--	--	--
HAG+Above	01	--	--	--	--	--	--	--	--	--	--	--	--	--
TOTAL	76	09	03	08	--	--	--	--	--	--	--	--	--	--

SO (Estb)

O/o Indian Institute of Integrative Medicine, Jammu- 180001

PWD Report I

ANNUAL STATEMENT SHOWING THE REPRESENTATION OF THE PERSONS WITH DISABILITIES IN SERVICES (AS ON 1ST JANUARY 2020)

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH (DSIR) O/o INDIAN INSTITUTE OF INTEGRATIVE MEDICINE, JAMMU

Group	Number of Employees				
	Total	In Identified posts	VH	HH	OH
1	2	3	4	5	6
Group A	73	03 (OH-2; HH-1)	--	**	02
Group B	74	02 (VH; HH)	*	**	02
Group C	71	02 (OH;HH)	--	**	01
Group D	--				
TOTAL	218	07			11

Note: (i) VH stands for Visually Handicapped (persons suffering from blinders or low vision).
(ii) HH stands for Hearing Handicapped (persons suffering from hearing impairment).
(iii) OH stands for Orthopaedically Handicapped (persons suffering from locomotor disability or cerebral palsy).

*One post under VH category is lying vacant.
**One post under HH category is lying vacant.

SO (Estb)
O/o Indian Institute of Integrative Medicine, Jammu - 180001

PWD REPORT II

STATEMENT SHOWING THE NUMBER OF PERSONS WITH DISABILITIES APPOINTED DURING THE YEAR

(As on 1st. January 2020)

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH (DSIR) O/o INDIAN INSTITUTE OF INTEGRATIVE MEDICINE, JAMMU

GROUP	DIRECT RECRUITMENT								PROMOTION							
	No. of vacancies reserved			No. of Appointments Made					No. of vacancies reserved			No. of Appointments Made				
	VH	HH	OH	Total	In Identified Posts	VH	HH	OH	VH	HH	OH	Total	In Identified Posts	VH	HH	OH
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Group A	--	--	--													
Group B	--	--	--													
Group C	--	--	--													
Group D	--	--	--													

Note: (i) VH stands for Visually Handicapped (persons suffering from blinders or low vision).
(ii) HH stands for Hearing Handicapped (persons suffering from hearing impairment).
(iii) OH stands for Orthopaedically Handicapped (persons suffering from locomotor disability or cerebral palsy).
(iv) There is no reservation for persons with disabilities in case of promotion to Group A and B posts. However, persons with disabilities can be promoted to such posts, provided the concerned post is identified suitable for persons with disabilities.

SO (Estb)

O/o IIIM, Jammu – 180001

सीएसआईआर–भारतीय समवेत औषध संस्थान, जम्मू में राजभाषा की प्रगति में हिन्दी के कार्यक्रम

वित्तीय वर्ष 2019-20 में हिन्दी अनुभाग द्वारा संस्थान में निम्नलिखित कार्यक्रम आयोजित किए गए।

1. नगर राजभाषा कार्यान्वयन समिति, जम्मू अर्द्धवार्षिक बैठकें :

भारत सरकार, गृह मंत्रालय, राजभाषा विभाग के निर्देशानुसार नगर राजभाषा कार्यान्वयन समिति (नराकास), जम्मू की अर्द्ध वार्षिक बैठकें सीएसआईआर-भारतीय समवेत औषध संस्थान, जम्मू के कॉन्फ्रेंस हॉल में आयोजित करवाई गई। बैठकों का मुख्य उद्देश्य केन्द्रीय कार्यालयों में हिन्दी का उत्तरोत्तर विकास करना तथा राजभाषा हिन्दी की प्रगति की ओर अग्रसर करने की दिशा में रहता है ।

(क) **पहली छमाही:** दिनांक 17 जून, 2019 (सोमवार) - बैठक की अध्यक्षता संस्थान के मुख्य वैज्ञानिक श्री रजनीश आनन्द ने की। इस अवसर पर श्री प्रमोद कुमार शर्मा, उप निदेशक (कार्या.) गृह मंत्रालय, राजभाषा विभाग, नई दिल्ली से उपस्थित थे। श्री रजनीश कुमार गुप्ता, रक्षा लेखा उप नियंत्रक, रक्षा लेखा प्रधान नियंत्रक (उत्तरी कमान), सतवारी, जम्मू; डॉ. वी.सी.दीप, प्रभारी सहायक निदेशक, क्षेत्रीय आयुर्वेदीय मूत्रविकार अनुसंधान संस्थान, बनतालाब, जम्मू; सुश्री संगीता पुर्सवानी, उप महालेखाकार, कार्यालय महालेखाकार (लेखा व हकदारी), जम्मू; प्रो. शरद चन्द्र, सहाचार्य, राष्ट्रीय संस्कृत संस्थानम्, जम्मू; डॉ. आर.एल.मीणा, हिन्दी प्राध्यापक व श्री संतोष कुमार, सहायक निदेशक (टं/आ.), हिन्दी शिक्षणयोजना, राजभाषा विभाग, बबलिया, गंग्याल, जम्मू एवं श्री राजेश कुमार गुप्ता, अनुभाग अधिकारी, भारतीय समवेत औषध संस्थान, जम्मू एवं नराकास के केन्द्रीय कार्यालयों के सभी कार्यालयाध्यक्ष/राजभाषा अधिकारी/हिन्दी अधिकारी/हिन्दी अनुवादक तथा प्रिन्ट व इलैक्ट्रॉनिक मीडिया के सभी संवाददाता तथा अन्य गणमान्य व्यक्ति उपस्थित थे।

संस्थान के मुख्य वैज्ञानिक श्री रजनीश आनन्द जी ने अपने अध्यक्षीय संबोधन में सभी केन्द्रीय कार्यालयों के उपस्थित कार्यालय प्रमुख एवं अन्य गणमान्य व्यक्तियों का संस्थान एवं नराकास की ओर से सबका हार्दिक अभिनन्दन किया। उन्होंने सबसे अनुरोध किया कि ज्यादा से ज्यादा हिन्दी के कामों को अपने लक्ष्य की ओर अग्रसर करें ताकि राजभाषा हिन्दी का कार्य दिन प्रतिदिन बढ़ता रहे।

(ख) दूसरी छमाही: दिनांक 20 नवम्बर, 2019 - बैठक की अध्यक्षता संस्थान के मुख्य वैज्ञानिक श्री रजनीश आनन्द ने की। इस अवसर पर गृह मंत्रालय, राजभाषा विभाग से डॉ.आर.एल.मीणा, हिन्दी प्राध्यापक उपस्थित रहे। बैठक में श्री भूपिन्दर सिंह, उप महानिरीक्षक, केन्द्रीय रिजर्व पुलिस बल, बनतालाब, जम्मू; श्री किशोर कुमार, उप महानिदेशक, राष्ट्रीय सांख्यकीय कार्यालय, जम्मू; श्री डोनीपद मन्जूनाथ, उपायुक्त, केन्द्रीय विद्यालय संगठन, क्षेत्रीय कार्यालय, जम्मू; श्री राजकुमार द्रोच, वित्त एवं लेखा अधिकारी तथा श्री पंकज बहादुर, नियंत्रक प्रशासन, भारतीय समवेत औषध संस्थान, जम्मू एवं नराकास के केन्द्रीय कार्यालयों के सभी कार्यालयाध्यक्ष/राजभाषा अधिकारी/हिन्दी अधिकारी/हिन्दी अनुवादक तथा प्रिन्ट व इलैक्ट्रॉनिक मीडिया के संवाददाता एवं अन्य गणमान्य अतिथिगण भी उपस्थित थे।

संस्थान के मुख्य वैज्ञानिक श्री रजनीश आनन्द जी ने अपने अध्यक्षीय संबोधन में नगर के सभी केन्द्रीय कार्यालयों के उपस्थित कार्यालय प्रमुख एवं अन्य गणमान्य व्यक्तियों का संस्थान एवं नराकास मंच की ओर से सबका हार्दिक स्वागत किया। इस अवसर पर उन्होंने नराकास की वार्षिक गृह पत्रिका ''ज्ञानवार्ता'' के नवाँ अंक का विमोचन किया। इस अंक को जारी करते हुए अपनी प्रसन्नता प्रकट की तथा संपादक मंडल के सभी सदस्यों का धन्यवाद किया। उन्होंने आगे कहा कि

वर्तमान अंक सभी कार्यालयों के सहयोग से ही प्रकाशित हो सका है तथा उन्होंने सभी लेखक/लेखिकाओं का भी धन्यवाद किया। सभी कार्यालय अध्यक्षों व अन्य पदाधिकारियों से निवेदन किया कि भविष्य में भी अपने कार्यालय से इस दिशा में सहयोग देते रहें तथा अपने कार्यालय में जो भी हिन्दी से संबंधित कार्यक्रम/कार्यशालाएं आयोजित करें उनके फोटोग्राफ इस कार्यालय से साझा करें ताकि उन्हें भविष्य में प्रकाशित होने वाली ''ज्ञानवार्ता'' पत्रिका के अंकों में शामिल किया जा सके। अन्त में उन्होंने कहा कि जम्मू नगर में राजभाषा की प्रगति में सभी सदस्य कार्यालयों की महत्वपूर्ण भूमिका रही है।

संस्थान के नियंत्रक प्रशासन, श्री पंकज बहादुर ने बैठक में अध्यक्ष महोदय एवं उपस्थित नराकास जम्मू के सभी केन्द्रीय कार्यालयों के कार्यालय प्रमुखों एवं नगर के प्रिन्ट व इलैक्ट्रानिक मीडिया के सभी संवाददाताओं का आभार सहित धन्यवाद किया।

2. हिन्दी पखवाड़ा, 2019 का आयोजन :

राजभाषा हिन्दी के उत्तरोत्तर विकास और अधिकारियों/कर्मचारियों में हिन्दी के प्रति जागरूकता उत्पन्न करने और रुचि जगाने के उद्देश्य से प्रत्येक वर्ष सितम्बर माह में हिन्दी पखवाड़ा मानाया जाता है। संस्थान में वर्ष 2019 का हिन्दी पखवाड़ा दिनांक 13 सितम्बर, 2019 से 26 सितम्बर, 2019 तक मनाया गया। इस दौरान विभिन्न प्रतियोगिताएं जैसे निबन्ध लेखन प्रतियोगिता, अन्तरविभागीय भाषण प्रतियोगिता, हिन्दी में मूलकार्य आदि कार्यक्रम आयोजित किए गए तथा सभी स्टॉफ सदस्यों, शोध छात्रों एवं नराकास सदस्यों ने बढ़-चढ़कर भाग लिया। विजयी प्रतियोगियों को संस्थान के निदेशक महोदय के कर-कमलों से पुरस्कार प्रदान किए गए।

3. हिन्दी कार्यशाला का आयोजन :

संस्थान में दिनांक 13 सितम्बर, 2019 को एक दिवसीय हिन्दी कार्यशाला का आयोजन किया गया। जिनकी अध्यक्षता संस्थान के निदेशक महोदय ने की और मुख्य वक्ता के रूप में प्रो./डॉ. नीलम सराफ, प्रमुख, हिंदी विभाग, जम्मू विश्वविद्यालय, जम्मू ने **'हिन्दी का वैश्विक परिदृश्य'** विषय पर व्यख्यान प्रस्तुत किया। संस्थान के सभी अधिकारियों एवं कर्मचारियों तथा शोध छात्रों ने हिन्दी पखवाड़े के उपलक्ष्य में बढ़-चढ़कर भाग लिया।

HUMAN RESOURCE

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Sr. Principal Scientist

Dr. D.M. Mondhe
Er. Abdul Rahim
Dr. Inshad Ali Khan
Dr. Gurdarshan Singh
Dr. Zabeer Ahmed
Dr. Anindya Goswami

Principal Scientist

Dr. Muzamil Ahmad
Dr. Shashank Kr. Singh
Dr. Fayaz Ahmed Malik
Dr. Sandip B. Bharate
Dr. (Ms.) Asha Chaubey
Dr. Sanghapal D. Sawant
Dr. Sheikh Tasduq Abdullah
Dr. Dhiraj Kr. Vyas
Dr. Prem N. Gupta
Dr. Sumit Gandhi
Dr. Zahoor Ahmad Parry
Dr. Qazi Parvaiz Hassan
Dr. Syed Riyaz-Ul Hassan
Dr. (Mrs.) Suphla Bajpai Gupta
Dr. Debaraj Mukherjee
Dr. Amit Nargotra
Dr. Pyare Lal Sangwan
Dr. Qazi Naveed Ahmad
Dr. Mohd Jamal Dar
Dr. Khursheed A. Bhat
Dr. Prasoon Kumar Gupta

Sr. Scientist

Dr. Rajkishore Rai
Dr. (Mrs.) Meenu Katoch
Dr. (Mrs.) Deepika Singh
Dr. Parvinder Pal Singh
Dr. Syed Sajad Hussain
Dr. Saurabh Saran
Sh. Anil Kumar Katare
Dr. Govind Yadav
Dr. Bilal Ahmad Bhat
Dr. Bhahwal Ali Shah
Dr. Sundeep Jaglan
Dr. (Mrs.) Nasheeman Ashraf
Dr. Sumeet Gairola
Dr. Prashant Misra
Dr. Bikarma Singh

Scientist

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Dr. Vikash Babu
Dr. Ravi Shankar
Dr. Utpal Nandi
Dr. Sreedhar Madishetti
Dr. Rajendra Bhanwaria
Dr. Vishav Prakash Rahul
Dr. Sabha Jeet
Dr. Nazia Abbas
Dr. Firdoous Ahmad Mir
Dr. Ravail Singh

Principal Technical Officer

Dr. (Mrs.) Kanti Rekha
Mrs.Urmila Jamwal

Medical Officer

Dr. Amit Sharma
Dr. (Mrs.) Anju Gupta

Sr. Technical Officer (3)

Dr. Ajai P. Gupta
Mrs. Pinki Koul
Mrs. Asha Devi
Sh. Rajinder Kumar
Dr. Ajay Kumar

Sr. Technical Officer (2)

Dr. Buddh Singh
Dr. Phalisteen Sultlan

Superintending Engineer (Civil)

Sh. G.P. Singh

Superintending Engineer (Elect.)

Sh. Ashwani Chopra

Sr. Technical Officer (1)

Dr. Siya Ram Meena
Sh. Sanjay Sharma
Dr. Satheesh Kumar

Assistant Executive Engineer (Civil)

Sh. S.N. Bharti

Technical Officer

Sh. Ajit Prabhakaran
Dr. M.K. Verma
Sh. Gourav Sharma
Mrs. Bhavana Vij
Sh.Vikrant Awasthi

Assistant Engineer (Mechanical)

Sh. Mukesh Jhangra

Technical Assistant

Sh. Manish Kumar
Sh. Kamlesh Singh
Sh. Sumit Kumar
Sh. Arvind Kr. Yadav
Sh. Yogesh Kumar
Sh. Amit Kumar
Sh. Rajinder Gocher
Sh. Niteen Ashok Narkhede
Sh. Uma Shankar
Mrs. Monika Gupta
Sh. Chandra Pal Singh
Sh. Durga Prasad Mindala
Sh. Ashok Kumar Bhargava
Mrs. Priya Wazir
Sh. Sumit Roy
Sh. Habibullah
Sh.Yadunandan Sen

Junior Engineer (Electrical)

Sh. Bikram Singh

Junior Engineer (Mechanical)

Sh. Narinder Kumar

Sr. Technician Gr. II (4)

Sh. Ajeet Singh
Sh. Vikram Bhradwaj
Mrs Manju Sambyal
Mrs. Raj Kumari
Sh. Vikram Abrol
Sh. Madan Lal
Mrs. Neelam Sharma
Sh. Kuldeep Singh
Sh. Rajinder Kumar Gupta
Mrs. Sunita Devi
Mrs. Parveen Sharma
Mrs. Shabnam Khan
Sh. P.R. Mehta
Dr. Anil Prabhakar
Sh. Ashwani Sharma
Sh. Partap Chand
Sh. Samar Singh
Mrs. Kiran Koul
Sh. Satya Bhushan
Sh. Rajinder Kumar
Sh. Vijay Kumar
Sh. Ashok Kumar
Sh. Kasturi Lal

Technician Gr.II (3)

Ms. Anjum Vashist
Sh. Rajesh KumarSahdev

Technician Gr. II (2)

Sh. Asad Ullah
Sh. Rahul Kalgotra
Sh. Karan Pal
Sh. Kirshan Kumar

Lab Assist. Gr. I (4)

Sh. Bishan Kumar
Sh. Jasbir Singh
Sh. Neel Kamal
Sh. Rishi Kumar
Sh. Balwinder Singh
Sh. Manoj Kumar
Sh. Ajit Ram
Sh. Girdhari Lal
Sh. Fayaz Ahmed Dar
Sh. Bhushan Lal
Sh. Balwant Raj
Sh. Tara Chand
Sh. Om Parkash

Lab Attd. Gr. I (1)

Sh. Ashok Kumar
Sh. Nagar Lal
Sh. Kuldeep Kumar

Controller ofAdministration

Sh. Pankaj Bahadur

Store & Purchase Officer

Sh. Praphul Kumar

Section Officer (G)

Sh. Rajesh Kumar Gupta

Section Officer (F&A)

Sh. Anil Gupta
Sh. Zahoor Ahmad Wani

Section Officer (S&P)

Sh. Satish Sambyal

Private Secretary

Sh. Ramesh Kumar

Assistant Section Officer (G)

Sh. Romesh Kumar Mottan
Sh. U.S. Thappa
Mrs. Kusum Bali
Sh. Ranjeet Kr. Gupta
Sh. Manoj Kumar
Ms. Nisha Vij
Sh. Rajinder Singh
Sh. Ashok Kumar
Mrs. Rekha Gupta
Sh. Mohd. Ayub Bhat

Section Officer (S&P) (Adhoc)

Mrs. Rajni Kumari

Assistant Section Officer (F&A)

Sh. Vikas Patiaya
Sh. Vinod Kumar Meena
Mrs. Lovely Ganjoo

Receptionist

Mrs. Jyoti Prabha

Security Assistant

Sh. Bhupinder Singh

Sh. Balkrishan

Sh. Subash Chander

Sr. Secretariat Assistant (F&A)

Sh. Sanchit Kumar Sharma

Sh. Roshan Lal

Sr. Secretariat Assistant (S&P)

Sh. Bua Ditta

Sh. Angrez Chand

Sr. Secretariat Assistant (G)

Sh. Sunita Kumari

Jr. Secretariat Assistant (G)

Sh. Tarsem Kumar

Sh. Kartik Kapoor

Sh. Rankush Pandita

Sh. Ishan Dogra

Jr. Secretariat Assistant (S&P)

Sh. Rakesh Choudhary

Halwai

Sh. Janak Raj

Junior Stenographer

Sh. Abshishek Gupta

Sh. Rishu Sharma

Sh. Satish Kumar

Sh. Sahil Salotra

Ms. Jyoti Devi

MTS Staff

Sh. Mohd. Farooq Bhat

Sh. Ram Lal

Sh. Chaman Lal

Sh. Ashok Kumar Balgotra

Sh. ParshotamLal

Sh. Romesh Kumar

Sh. Pawan Kumar

Sh. Rajesh Kr. Tandon

Sh. Moses Tegi

Sh. Subash Chander

Sh. Sodagar Mal

Sh. Mangal Dass

Sh. Suram Chand

Sh. Girdhari Lal
(S/o Sh. Singara Ram)

Sh. Girdhari Lal
(S/o Sh. Daya Ram)

Sh. Rattan Lal

Sh. Sukhdev Raj

Sh. Sat Pal

Sh. Bua Ditta

Sh. Ashok Kumar
(S/o Sh. Charantu Ram)

Sh. Ashok Kumar
(S/o Sh. Gharoo Ram)

Sh. Dev Raj

Sh. Sham Lal

Sh. Kali Das

Smt. Satya Sharma

Sh. Seva Ram

Sh. Sodagar Lal

Sh. Ashok Kumar

Sh. Karnail Chand

Sh. Surinder Kumar

Sh. Munna

Sh. Sodagar Lal
(S/o Sh. Babu Ram)

Sh. Bachan Lal

Sh. Daleep Raj

Sh. Roshan Lal