

TECHNOLOGY PROFILE



CSIR - Institute of Himalayan Bioresource Technology
Palampur – 176061 (H.P.)



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© 2nd July 2019, Director, CSIR-IHBT, Palampur (H.P.)

Published by: Director

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Printed by

Excel Printing Universe, New Delhi-110 067

E-mail: printing@groupexcelindia.com

Technology Profile

Life on this planet, including that of humans, is heavily dependent on biodiversity, primarily for necessity of food, shelter, clothing and medicine, and to the varied fancy needs of aromas, cosmetics, and so on. Scientific tools provide opportunities to unravel further on, to express it and create technologies, which are also the new drivers of our understanding.

In modern times, specific technologies are the desired goals to harness bio-wealth to address the societal challenges and needs. CSIR-IHBT has endeavoured consistently in this direction to develop products from bioresources, such as enzymes, ready-to-eat/ fortified foods, energy drinks, mineral supplements, safe and low calorie sweeteners, and region specific agro-technologies for crops of industrial importance, as well as technologies for waste utilisation.

A total of 41 technologies developed by our institute are categorised into four sections namely biotechnology, food-technology, chemical-technology and agro-technology.

An effort has been made to keep the technology write-up informative, yet simple to serve the diverse audience. We trust that these technologies would fulfil not only various national mission programme on Make in India, Swasth Bharat, Swachh Bharat and so on, but would have international ramifications as well. While these technologies offer impetus for development of entrepreneurship, the institute encourages and offers opportunities to incubate for start-ups, and implementation through farming community, Micro, Small & Medium Enterprises (MSMEs), and industries at large to generate bio-economy based on bioresources.

We shall be happy to have constructive feedback from our stake holders to improve the compendium further.

Wishing our readers a happy reading!



(Sanjay Kumar)



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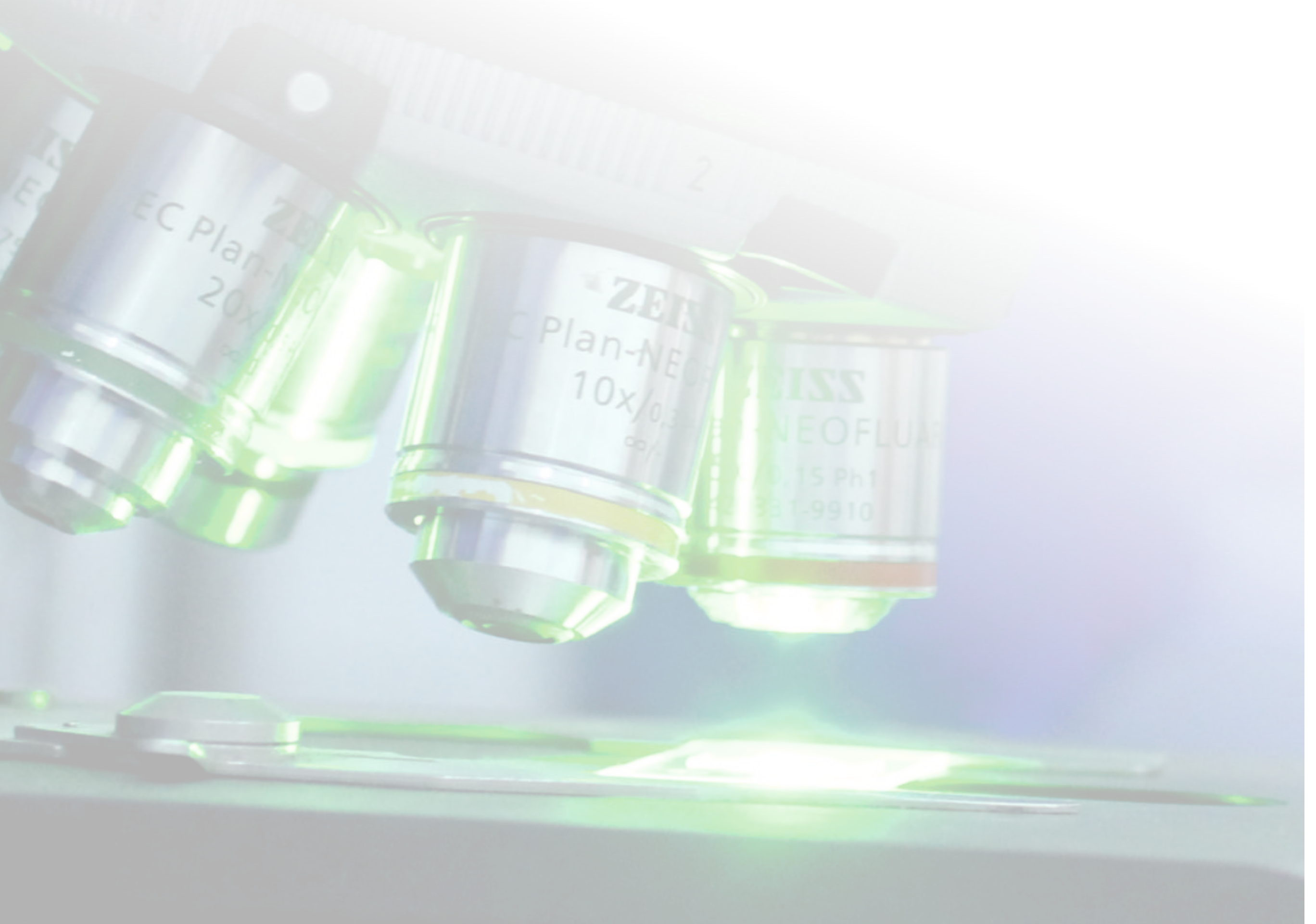
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BIOTECHNOLOGY





ZEISS
EC Plan-NEOFLUAR
20x/0.40
∞/0

ZEISS
EC Plan-NEOFLUAR
10x/0.30
∞/0

ZEISS
NEOFLUAR
0.15 Ph1
331-9910

Superoxide dismutase: an enzyme for diversified industrial applications

Potentilla atosanguinea
(at 4500m amsl)

Superoxide radical ($O_2^{\cdot-}$) is a toxic species of oxygen which is generated in a number of metabolic reactions in all aerobic organisms such as plants and animals including human. If $O_2^{\cdot-}$ is not removed, it reacts with hydrogen peroxide to produce a highly reactive hydroxyl free radical, which is known to cause many diseases. Immediate removal of $O_2^{\cdot-}$ is essential to protect cells and organisms. Superoxide dismutase (SOD) is the enzyme that catalyzes the scavenging of $O_2^{\cdot-}$.

Contributions of CSIR-IHBT:

A thermostable SOD has been identified from a Himalayan polyextremophile plant *Potentilla atosanguinea* G.Lodd. ex D.Don, which was further engineered by mutation of a single amino acid to enhance the thermostability of the enzyme to two-fold. An *in vitro* expression system is developed in *Escherichia coli* for enzyme production at pilot scale.

Unique features of CSIR-IHBT SOD:

- SOD tolerates autoclaving [retains~75% of the un-autoclaved activity (specific activity) as measured at 5 °C to 10 °C].
- It functions across <0 °C to >50 °C with varying activities at different assay temperatures.
- Stable at room temperature.

Market potential:

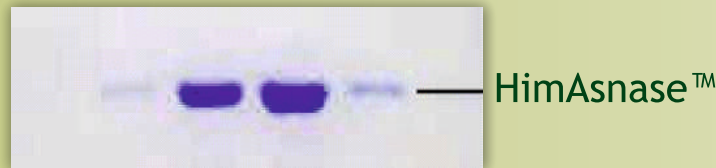
World enzyme demand (industrial and specialty) is projected at USD 7 billion

Applications:

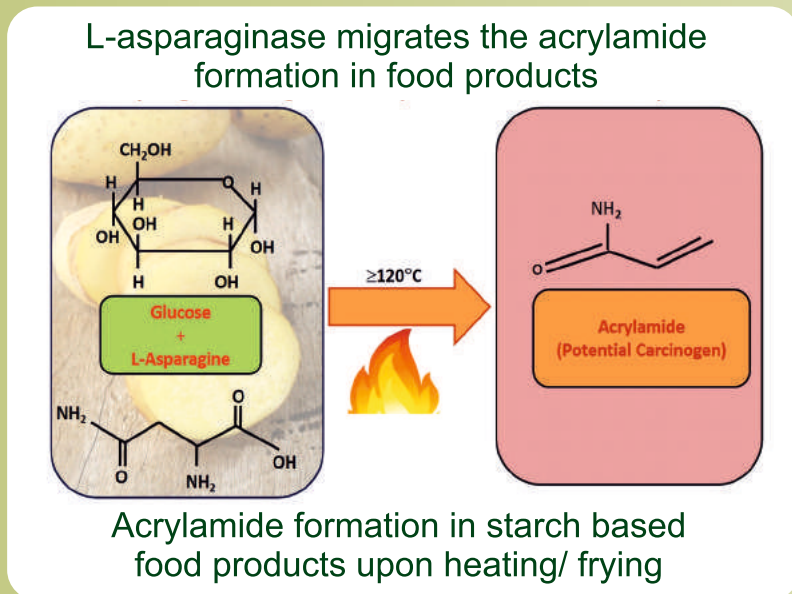
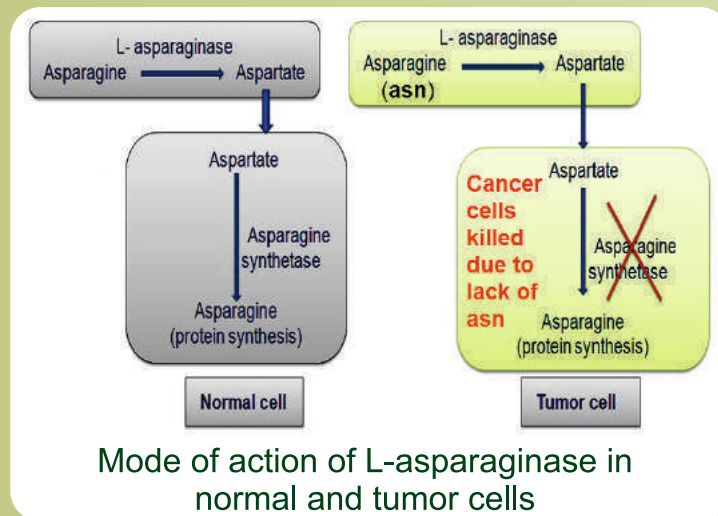
SOD has high demand in cosmetic, food, pharmaceutical and other industries (products like anti-ageing creams, extended shelf-life of fruits and vegetables, cryo-surgery, preservation of organelles, etc.).

Patent granted: 6485950/US/2002





Expression of recombinant L-asparaginase in *E. coli*



L-Asparaginase (HimAsnase™): an enzyme with no glutaminase activity

Asparaginase hydrolyzes L-asparagine to L-aspartic acid and ammonia. Specifically in the leukemic cells, this results in the depletion of asparagine that is required for growth of some tumour cells, due to lack of asparagine synthetase activity in these cells.

Asparaginase therapy is an important component of acute lymphoblastic leukemia (ALL) treatment. High glutaminase activity is responsible for associated side effects and hypersensitive reactions. Therefore, asparaginase with low or no glutaminase activity is desired.

L-asparaginase has enormous applications in reduction of acrylamide (a potential carcinogen) formation in starchy food products (potatoes chips, French fries). Asparagine is the precursor for acrylamide synthesis and since L-asparaginase removes asparagine from the food products, acrylamide synthesis is consequently eliminated.

Unique feature of IHBT HimAsnase™:

- Asparaginase with no glutaminase activity. It functions across $0\text{ }^{\circ}\text{C}$ to $50\text{ }^{\circ}\text{C}$ with varying activities at different assay temperatures.
- An efficient Asparaginase enzyme which has wide temperature functionality.
- Gene for asparaginase has been cloned and successfully expressed in the *E. Coli* for commercial production

Major applications:

- Pharma sector for treatment of ALL, childhood blood cancer and pancreatic carcinoma.
- Food processing for reduction of acrylamide (a potential carcinogen) formation during high temperature heating.

Market potential:

Global therapeutic enzymes market is estimated at USD 6 billion

DNA barcode technology for plant authentication

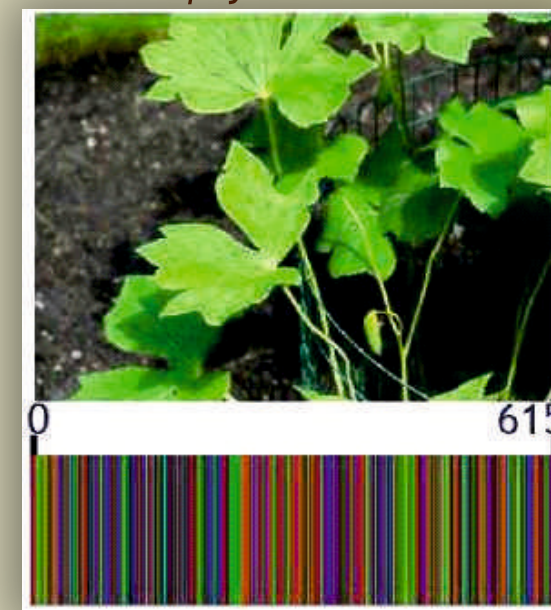
There is a huge demand of botanical drugs in various indigenous systems of medicines, worldwide. One of the pressing issues confronting quality products for herbal/ pharmaceutical industries is the correct identification of plant material procured for preparation of botanical drug/ phytomedicines. DNA barcoding helps in its rapid authentication and to check undesired adulteration.

Market potential:

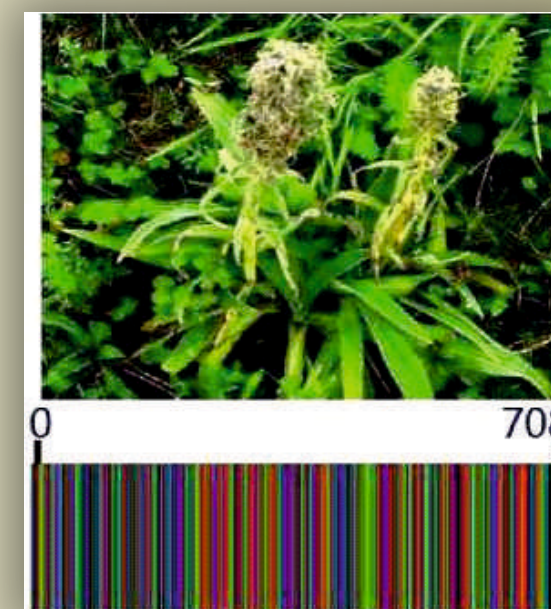
In India, medicinal plant trade is estimated at 128 thousand tonnes valued at Rs. 4200 crores annually and contributes to 8% of total global market export. Indian pharmaceutical market is expected to further grow up to USD 55 billion by year 2020. DNA based plant identification system is a reliable method for authentication of raw plant materials and an important test for quality check.

Salient feature: The technology is a reliable method of authentication of plant material at species level.

Podophyllum hexandrum



Arnebia benthamii



DNA barcodes of representative species

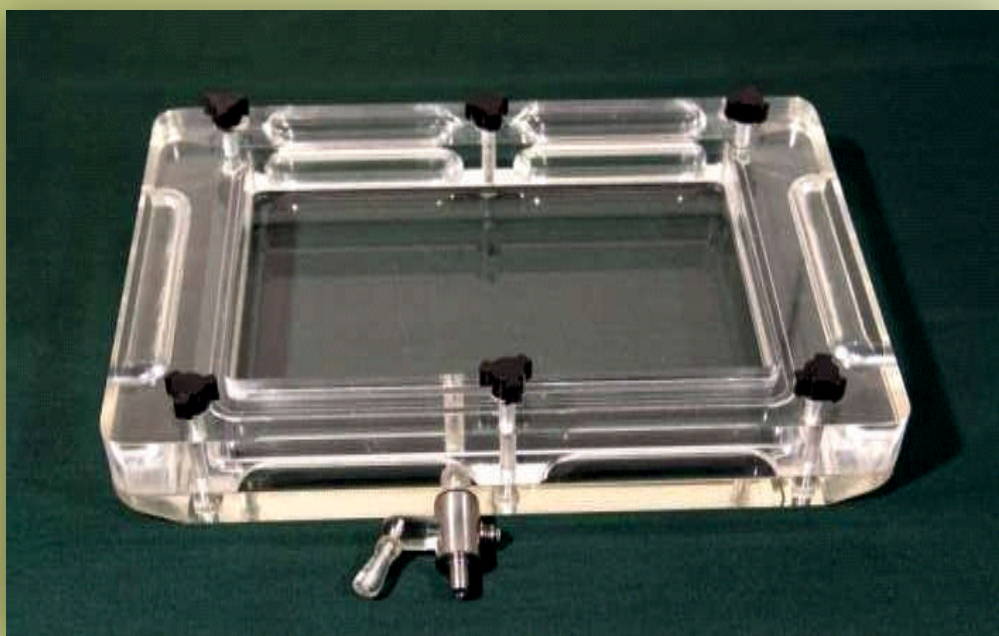
GEPROTED™: gel processing and transfer device

Generally, gel matrices encounter a common problem of breakage of gels during processing or transfer. GEPROTED™ device ensures undamaged transfer and transportation of gel from the device onto the membrane while performing northern and southern analyses.

Salient features of the technology:

- Ensures intactness of the gel during various steps involved in the process after electrophoresis and its transfer onto the membrane.
- An ideal aid for performing northern and southern hybridizations
- Solutions can be drained out without tilting of device.
- Suitable for processing not only for agarose gel but also for other gels such as polyacrylamide gels.
- Suitable for staining the gels using the recommended staining procedures.
- Safe system for gel transportation from one place to another.
- Safe system for photography of the gel.
- Transparent system for easy visibility.

Patent granted: 528079/NZ/2005; 1368642B1/EP/2007; 2001250639/AU/2007; 368642/GB/2007; 1368642/BE/2007; 233351/IN/2009; 7749369/US/2010



GEPROTED™ device

iRIS™: a solution for easy isolation of RNA

Isolation of RNA from plant tissue is challenging. A simple and rapid (45 min) system for RNA isolation, suitable for downstream applications has been developed (iRIS™).

Unique features of iRIS™:

- System works well for those tissues for which some of the commonly available commercial kits failed.
- It is extremely useful in isolating RNA from tissues recalcitrant to guanidinium extractions.
- Isolates RNA from as little as 10-100 mg tissue.
- Solutions and protocols have been developed to isolate RNA from various plant species belonging to diverse genera and those rich in various types of secondary metabolites, colours and polysaccharides.
- Evaluated to be efficacious in different plant species groups (dicots, monocots, herbs, shrubs, trees).

Patent granted: 2007113614A1/WO/2007; 2006341291/AU/2012; 20068005561.3/CN/2012; 2004822/EP/2013; 259562/IN/2014



iRIS™ system
Quality of RNA isolated from a wide range of plant tissues



Steriflow™: Mini laminar flow unit

Steriflow™: mini laminar flow unit

Steriflow™ is a laminar flow cabinet that helps in facilitating sterile working environment. Equipped with HEPA filter it ensures sterile air into an easily, cleanable working bench.

Social outreach:

The laminar flow cabinets generally available in market are expensive and out of reach for most schools and colleges located in remote area. Steriflow™ at an affordable price, can be used for setting up of small and medium-sized enterprises (SMEs) and micro, small and medium enterprises (MSMEs) involving plant tissue culture. It can be also used by cottage industry that involves sterile working environment.

Salient features of the product:

- A portable device weighing 14.5 kg.
- Can be used as a desktop model
- Made of wooden plates and Perspex sheets.
- Fitted with a HEPA filter of 0.22 μ M, UV lights and a steel platform for working

Patent granted: 6623538/US/2003; 20032363/ZA/2003; 88039/SG/2004; 518003/NZ/2004; 782243/AU/2005; 129354/MY/2007; 12713/LK/2009

Culture vessel for rooting of microshoots

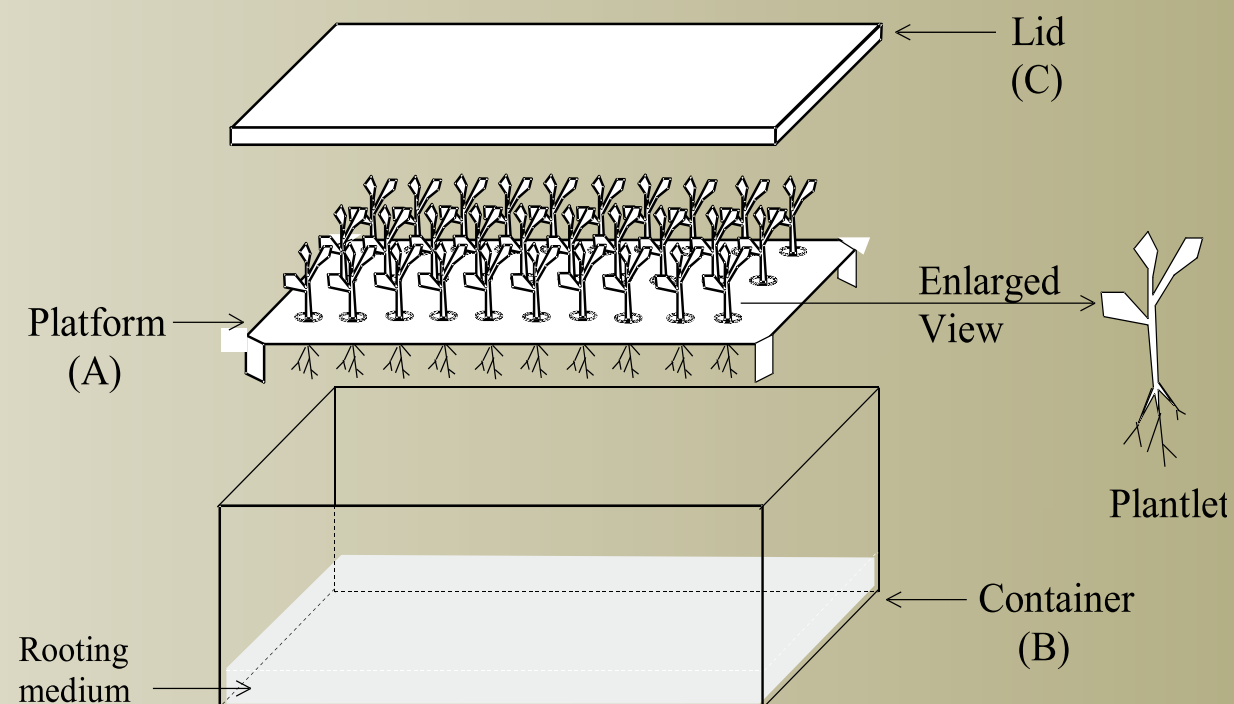
Root induction during hardening of micro-shoots is a pre-requisite for micro-propagation of plants. Removing agar from roots of tissue culture raised plantlets is difficult and often damages the roots of the plants.

Market outreach:

An easy method of rooting for tissue culture raised plants can cut down on labour cost by 50%. Hence, it can be used for plants where liquid culture systems have been developed.

Salient features of the product:

- Large scale handling of micro-shoots
- Reduction in cost due to the use of small quantities of liquid medium
- Ease of operations
- Minimized damages to roots The culture vessel can be used to induce rooting in difficult to root plants like rose and tea in liquid medium



Culture vessel for rooting

Arnebia euchroma

In vitro system for production of naphthoquinones from *Arnebia euchroma*

Root of *Arnebia euchroma* (Royle) I.M. Johnst. (*Ratanjot/Gaozaban*) yields red coloured naphthoquinone pigments, which are traditionally used as a natural colour in food and cosmetics, and have good therapeutic potency (as antibiotic, antipyretic, antihelminthic and antiseptic). Using bioreactor based plant cell culture technology, CSIR-IHBT has developed an eco- friendly process to produce naphthoquinone pigments from *Ratanjot*, which is a critically endangered Himalayan medicinal herb.

Market potential:

- Global market for dyes & pigments was estimated at USD 31 billion in 2015 and projected to reach USD 42 billion at a CAGR of 5.0% by year 2021.
- Annual demand of dried roots of *Ratanjot* is about 200 tonnes.

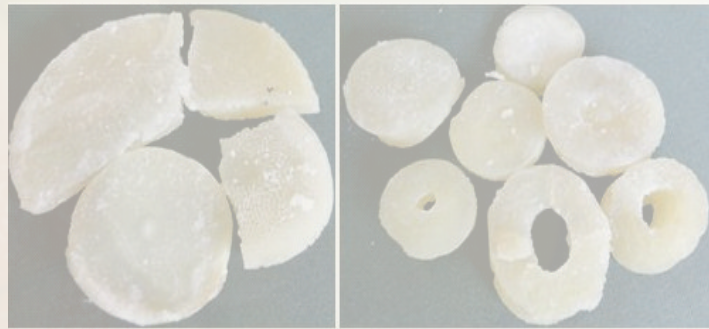
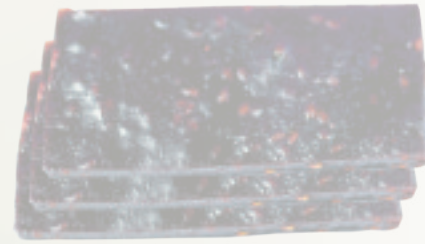
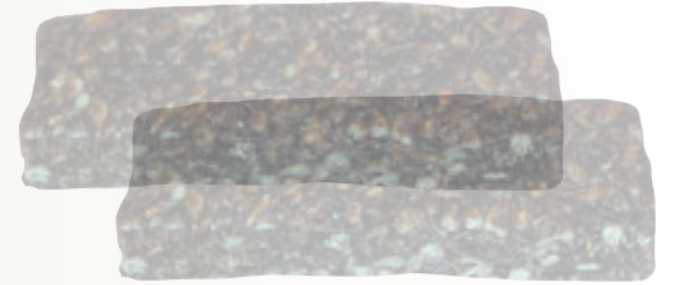
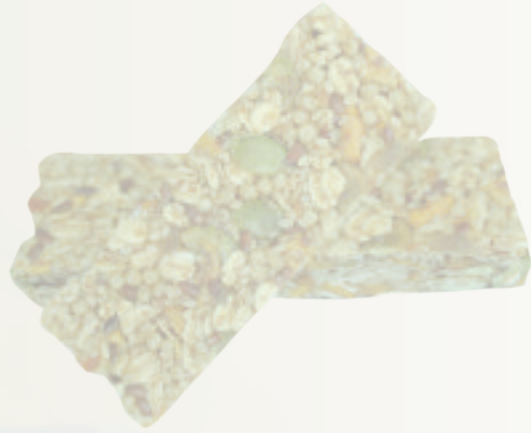
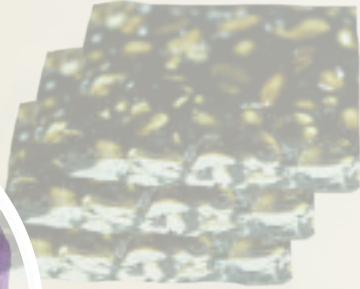
Salient features of the technology:

- Bioreactor based production system of naphthoquinones takes 30 days, compared to 3-4 years in plants in the wild.
- *In vitro* production of naphthoquinones pigments eliminates dependency/ destruction of natural plant population for raw material.



FOOD TECHNOLOGY





Shiitake mushroom: vitamin D2 enriched

Cultivation of shiitake mushroom

Shiitake (*Lentinula edodes*) is an edible mushroom which has high medicinal value. Vitamin D is essential for bone health and to boost immune system. A technology for enhanced production of ergocalciferols (Vitamin D2) in Shiitake mushroom has been developed.

Market potential:

Shiitake mushroom has high global demand and is expected to reach approximately 4500 tonnes by year 2025, with an estimated market value of USD 35.4 billion. International demand for vitamin D2 is estimated to reach USD 140 million by 2025 growing annually at 1.2%.

Salient features of the technology:

- Captive cultivation for Vitamin D2 enriched mushroom in 2 months
- Yield of 0.5-0.6 kg fresh fruiting body per kg of dried substrate
- Encapsulated 500 mg shiitake powder meets 50% recommended dietary allowances (RDA) of Vitamin D2



Shiitake mushroom and powder

Gluten free foods from buckwheat

Buckwheat, a pseudo-cereal, is a gluten free crop that belongs to the genus *Fagopyrum*. In Himalayas, it grows in high altitude, cold desert regions. A variety of ready to eat (RTE) products containing buckwheat provides choice of gluten free food.

Market potential:

Gluten free food product market is fast growing and is expected to reach USD 6.4 billion by next decade. It is estimated that currently about 80 million people are gluten intolerant and suffer from celiac disease in India. Buckwheat is a boon for gluten intolerant population suffering from celiac disease.

Salient features of the technology:

- Large scale handling of micro-shoots
- Buckwheat flour and puffs as gluten free ingredients in RTE foods
- Standardized processes for production of instant products (noodles, pasta and extruded snacks)
- Products are free from additives and chemical preservatives
- Buckwheat products contain beneficial polyphenol - rutin up to 0.4% of dry weight
- Average shelf life of buckwheat products is up to 4 months



Buckwheat-based bars



Buckwheat-based noodles

Iron and zinc enriched spirulina-based bars

Spirulina, a blue green alga (cyanobacterium) has been consumed worldwide as a health food and a dietary supplement. Spirulina contains essential fatty acids gamma linolenic acid (an omega 6 fatty acid), antioxidant phycocyanin and is a concentrated source of protein, vitamins, provitamin A (β carotene), and minerals (iron and zinc).

CSIR-IHBT has developed ready to eat foods incorporating Spirulina for fortification of iron and zinc utilizing different food matrices such as peanut, sesame and cereals that meets at least 20% of recommended dietary allowances (RDA) of iron and zinc.

Market potential:

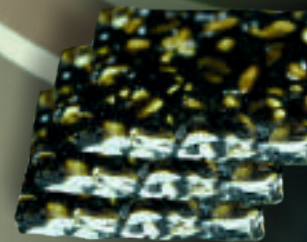
Spirulina and algae based functional foods market is pegged at USD 2 billion and is growing annually at 5.6%. Algae based functional food is expected to reach USD 4 billion by year 2025. India is second largest exporter of food grade Spirulina biomass.

Salient features of the technology:

- Meets 25% RDA levels of iron and zinc per 30g serving
- Preservative and additive free
- Meets 8% RDA level of beta carotene (pro-vitamin A) per serving
- Meets 6-8% RDA of proteins per serving
- Source of nutraceuticals- Phycocyanin (4 mg per serving)
- Shelf life of the product is up to 3 months

Target population:

- Pre-schoolers
- School going children
- Adolescent girls
- Pregnant and lactating mothers





Iron enriched fruit bars and candies

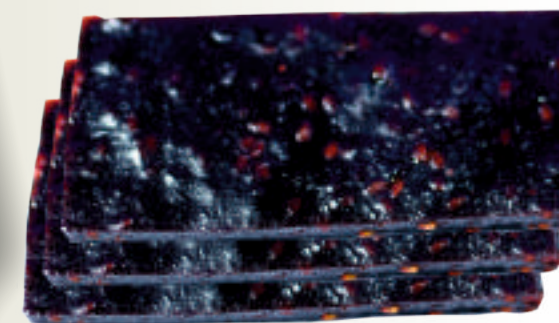
Deficiency of micronutrient iron is a major health concern in India. According to National Family Health Survey 4 (2015-16), 58% children below age 6 and 53% of women of reproductive age between 18 and 49 years are anaemic due to iron deficiency. CSIR-IHBT has developed cost-effective technology for production of ready to eat (RTE) foods to address iron deficiency by providing a minimum of 20% recommended dietary allowances (RDA) of micronutrients.

Salient features of the technology:

- Products provides 25-30% RDA of bioavailable iron per 30g serving
- Utilizes natural bio-resources such as crop residues and spice mixes
- Free from additives and preservatives
- Shelf life of the products is upto 6 months

Target population:

- Pre-schoolers
- School going children
- Adolescent girls
- Pregnant and lactating mothers



Iron enriched fruit bar

Multigrain high protein mix

A low cost technology for commercial production of protein rich beverage mix, addressing protein and energy malnutrition. The product is a multipurpose food for use in beverage and smoothie mix that can be consumed with milk/water/fruit juices and as a protein fortifying food ingredient in breads and ready to eat foods.

Market Potential:

The global market for protein fortified foods and beverages is estimated to reach USD 59.3 billion with a compound annual growth rate of 5.9% by year 2022 of which one fifth to be contributed by Indian market at USD 12 billion.

Salient Features of the technology:

- Developed using 100% natural and nutrient dense ingredients (wholegrains: millets, cereals, pseudo-cereals and pulses)
- Provides 200-250 Kcal energy and 10 g protein per 50g serving
- Meets 22% recommended dietary allowances (RDA) of proteins, 10% RDA of dietary fibre, 15% RDA of Iron and calcium
- Free from preservatives, maltodextrin and thickeners
- Non- hygroscopic and free flowing
- Shelf life of the product is up to 10 months



Multigrain high protein beverage

Multigrain high protein mix

Protein and fibre enriched cereal bars

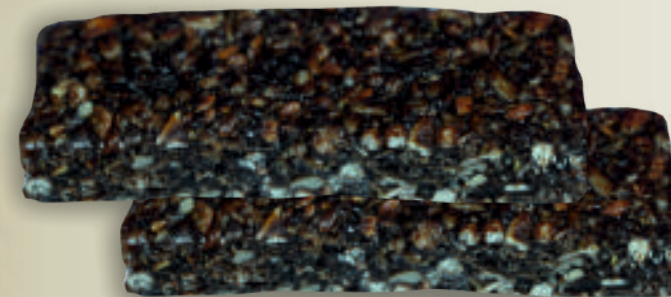
Protein malnutrition is a major health concern affecting Indian population mainly children below 6 years and women of reproductive age (15 to 49 years). According to National Family Health Survey 4 (2015-16), 38% of children below 6 years are underweight/ stunted, and almost 60% of women do not obtain the daily protein requirements. CSIR-IHBT developed a low cost technology for commercial production of protein and fibre enriched cereal bars that meets at least 20% recommended dietary allowances (RDA) of protein and fibre.

Market potential:

The global protein and energy bars market is currently USD 2.3 billion growing annually at 8.4% and expected to reach USD 3.5 billion by year 2025.

Salient features of the technology:

- Ready to eat food with 150 -200 Kcal energy and 6-8 g protein per 40g serving
- Developed using 100% natural ingredients like wholegrains, millets, pulses, dehydrated fruits and nuts
- Preservative and additive free
- 4 g fibre per serving
- Low saturated to unsaturated fat ratio (1:4); Low sugar content (<7g)
- Shelf life up to 4 months



Tea catechins

Tea leaves contains 15-20% of total polyphenols of which catechins constitute up to 80%. Epigallocatechin (EGC), epicatechin (EC), epigallocatechin gallate (EGCG) and epicatechin gallate (ECG) are the major catechins, which are high value antioxidants with nutraceutical properties.

Market potential:

The global market of polyphenols is estimated to reach USD 210 million by year 2022 at a CAGR of 15%.

Salient features of the technology:

- Green technology for catechins production from green tea leaves
- Product is free from toxic chemicals and solvents
- Shelf life of catechins is 12 months

Patent granted: 9266818B2/US/2016, 104105685A/CN/2016, 2015508070A/JP/2017



Catechins powder



Catechins capsules

Tea wine

Wine is an un-distilled fermented beverage mainly produced from grapes and fruits. A tea based wine has been prepared to harness the health benefits of tea. Tea wine is a good source of antioxidants. It is a unique product that can be prepared from premium as well as low grade teas. Wine can be made sweet and dry on demand with varying alcohol content ranging from 9% to 15%.

Market potential:

Estimated global market of wine is USD 302 billion with an annual growth of over 5%.

Salient features of the technology:

- Low alcoholic beverage with high quality, either sweet or dry
- 1 ml of tea wine contains 400-600 μg of trolox equivalent antioxidants
- Can be prepared using under-utilized fruits along with low grade teas
- A self-preservative herbal product with valuation increases on maturation

Patent granted: 6793957B2/US/2004



Ready to serve tea concentrate

Tea is the second most consumed beverage after water that has gained wide interest due to numerous health benefits. A process has been developed to prepare concentrates from green and black tea with refreshing taste and natural health attributes of tea. These concentrates can be reconstituted with hot as well as cold water.

Market potential:

Estimated global market of tea concentrates and ready to drink teas is USD 76 billion in 2017 with annual growth of 7%.

Salient features of the technology:

- 1 ml of tea concentrate contains 3-4 mg of trolox equivalent antioxidants
- Shelf-life is upto six months
- No added chemical preservatives or colors in the concentrates
- Green as well as black tea can be used
- Can be served with/without sweetener



Tea concentrate

Ready to drink tea



Ready to eat crispy fruits and vegetables

The technology for production of crispy fruits/ vegetables can help reduce the post-harvest losses, which are estimated to be about 25% of its production due to inadequate storage and processing facilities. Crispy fruits are high grade consumers products, made available in packaged form.

Market potential:

India is the second largest exporter of processed and preserved fruits and vegetables. Indian dehydrated fruit and vegetables market is estimated to reach USD 3 billion by year 2022 with a compound annual growth rate of 12%.

Salient features of the technology:

- Retains near to original nutrition, texture, taste, aroma and color
- No added preservatives or additives in the product
- Refrigeration is not required for storage
- Shelf life is greater than 6 months at room temperature
- Excellent reconstitution capacity – regains near to original taste, texture and aroma

Patent filed: 0032NF2018/IN



Corn



Sapota



Beetroot

Canning technology for ready to eat (RTE) foods

CSIR-IHBT has developed an indigenous technology for commercial production of RTE foods. These food products are free from chemicals and preservatives and are in line with the changing consumer preference for healthy, convenient and on the go foods. The technology was used for successful revival of traditional ethnic foods such as Kangri dham.

Market potential:

Indian RTE market is estimated to reach Rs. 2900 crores by year 2022 at a CAGR of 25%.

Salient features of the technology:

- Chemicals and preservatives free
- Shelf life up to 12 months
- Retains the original aroma and taste
- Retains the health benefits of the products such as prebiotic effects
- Process standardized for products such as *Kangri Dham* (an ethnic food of Kangra region of Himachal Pradesh), *Khichadi* (a mix of rice and pulses) and *Halwa* (a sweet dish made of semolina, flour and other similar ingredients)

Patent filed: 0031NF2017/IN



Food products from bamboo

Bamboo shoots such as of *Dendrocalamus hamiltonii* and *Bambusa tulda* are edible and are rich source of fibre and minerals. The technology is standardised for production of RTE foods such as candies for general consumption.

Salient features of the technology:

- Cost effective process for development of candies
- Product is free from additives and preservatives
- Shelf life up to 4 months
- Low fat and high fibre food products
- Products are rich source of minerals (calcium, potassium and phosphorus)
- Other bamboo based products include bamboo flour, bamboo pickle, RTE bars
- Higher economic returns to farmers from value addition



Edible bamboo shoots



Cut bamboo shoots



Bamboo candies

Technology for dietary fibre extraction from apple pomace

Apple pomace, a residue obtained after apple juice extraction, is generated in huge quantity (about 3000-5000 MT per annum) from apple beverage industries. An indigenous technology for extraction of dietary fibre from apple pomace has been developed to convert this highly perishable residue causing environmental pollution to high economic value ingredient.

This dietary fibre finds several applications in food and additives industries. A patented prototype has been developed to separate the seed without any damage from pomace at industrial scale. Quality edible oil can be extracted (with a recovery of 15% -20%) from separated seeds which is rich in polyunsaturated fatty acids.

Market potential:

The dietary fibre market is expected to reach USD 5.9 billion by 2022 at a CAGR of 13.7%

Salient features of the technology:

- Fibre content recovery up to 60%
- Extracted fibre is light in colour and bland in taste
- Fibre obtained has free flowing texture

Patent granted: 9011952/US/2015; 2591465/RU/2016





CHEMICAL TECHNOLOGY





Technology for the production of aescin from horse-chestnut

Aescin, a mixture of saponins used in the treatment of varicose veins and edema, is extracted from seeds of horse chestnut (*Aesculus indica* (Wall. ex Cambess.) Hook.) which grow from Kashmir to Arunachal Pradesh at an altitude of 900-3600 m. Aescin reduces capillary fragility and helps to prevent leakage of fluid into surrounding tissues, which can cause swelling. It is also used in cosmetics, skin ointment and treatment of hemorrhoids. Demand of pure aescin and standardized extracts of aescin in India is met through imports and hence products developed has good market potential.

CSIR-IHBT has developed a simplified process for extraction of aescin with >90% of purity from horse chestnut and standardized extract having 20% aescin. A formulation in the form ointment for the treatment of varicose veins and inflammation has been developed.

Patent granted : 1487847B1/FR/2006; 1487847B1/BE/2006; 1487847B1/NL/2006; 1487847B1/SE/2006; 1487847B1/EP/2006; 1487847/DE/2007; 231553/IN/2009; 2002247935/AU/2009; 66228B1/BG/2012



Aesculus seeds

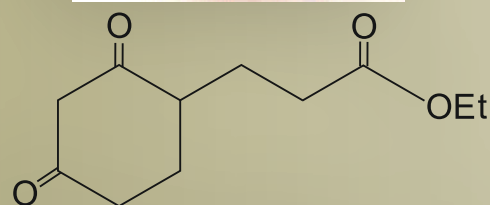


Aesculus powder

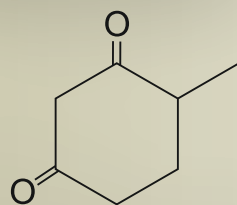


Formulation for varicose veins

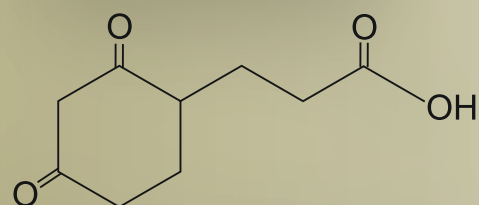
Process for cyclohexane-1,3-diones synthesis



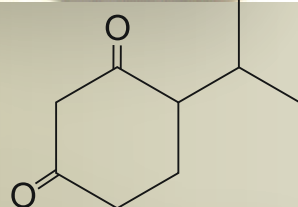
4-Ethyl propionate-cyclohexane-1,3-dione



4-Methyl-cyclohexane-1,3-dione



4-Propionic acid-cyclohexane-1,3-dione



4-Isopropyl-cyclohexane-1,3-dione

The cyclohexane-1,3-diones, the basic unit found in several herbicides (Tralkoxydim, Mesotrione, etc.), are potential drug candidates (NTBC for Tyrosinemia type-I), used in diagnostic kit (DAz-2 for detecting sulfenic acid) and as a fine chemicals for several synthetic applications. A simple and scalable process has been developed for different cyclohexane-1,3-diones synthesis from easily available and low cost starting materials following economic approaches.

Salient features of the technology:

- Energy efficient process: Performed under low to room temperature condition
- Easy to scale-up
- Low cost and easily available starting materials

Market potential: Precursor of B-ring in Steroids, Plant Growth Regulators and Herbicides in Corn, Wheat, Soyabean etc., Crop protection and the market value is approximate 12.0 million USD.

Patent granted: 2011117881A2/WO/2011; 8916723/US/2012; 289113/IN/2017

Process for 5-hydroxymethylfurfural (5-HMF) production from biomass

5-HMF is a feedstock chemical for bio-polymer (FDCA: furan dicarboxylic acid), bio-fuel (DMF: 1,2-dimethyl furan), food additives (flavour and health care), textile (substitute of toxic formaldehyde in resin) and pharmaceuticals. The increasing global revenue value is the indicator of its growing market demand. A wide array of biomass such as rice straw, sugarcane bagasse, corn cob and potato waste has been used for scalable production of 5-HMF up to 1 kilogram level per batch.

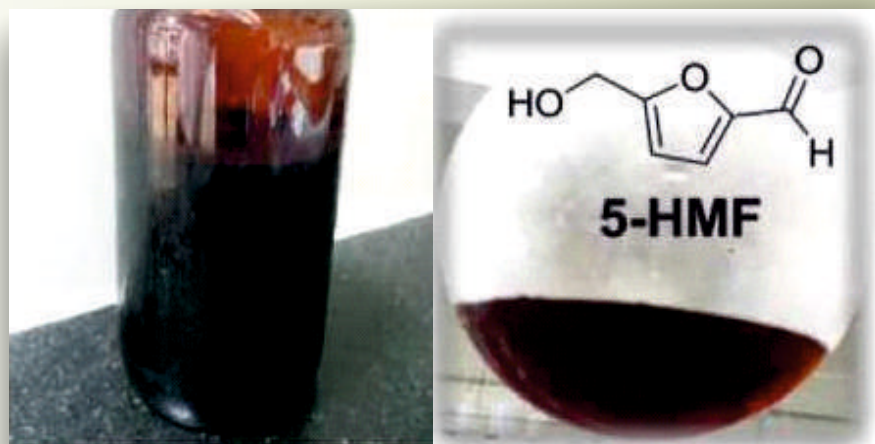
Advantages of the process:

- Energy efficient, economical and scalable process
- Does not require tedious purification to achieve high purity

Application/ Uses:

Feedstock for bio-fuels (DMF), bio-polymers (PEF), fuel additives and fine chemicals production.

Patent filed: 0032NF2018/IN



Rice straw



Sugarcane bagasse



Corn cob



Potato waste

Natural colours from plants and vegetables sources



Synthetic colours and dyes are hazardous and are known to cause allergy, toxicity and carcinogenicity. There is an increased interest to identify natural colours which are safe for human consumption. Some of these are attributed to have health benefits as well. An eco-friendly, green process has been developed for extraction and purification of natural colours from different plants and vegetables sources.

Market potential:

- The global market for natural food colour is anticipated to reach USD 2.5 billion by year 2022, with a compound annual growth rate of 6.7%.
- Health benefits associated with natural food colours, coupled with the regulations concerning their application in consumables are major factors driving the market growth.

CSIR-IHBT technology for production of natural colours:

Non-toxic; Non-hygroscopic; Crystalline in nature; Stable at high temperature (100-160°C); Soluble in water and organic solvents

Application/ Uses:

Food and Beverages, Cosmetics, Textiles, Pharmaceuticals

Green process for nanocurcumin synthesis with enhanced solubility

Curcumin is an important therapeutic with significant anti-oxidant and anti-inflammatory activities. But poor bioavailability restricts its medicinal use. An indigenous green chemical process has been developed for the synthesis of nanocurcumin. The process developed is based on the use of plant leaf extract as surfactant for the encapsulation of curcumin into a polymeric shell, and its controlled and sustained release. The process enables enhancement of solubility and stability of curcumin in aqueous medium.

Market potential:

Curcumin market is expected to reach USD 99 million at a CAGR of 9.5% by year 2024.

Salient features of the technology:

- Green chemical process
- Particle size is less than 100 nm
- FDA approved polymer
- Increased solubility and stability of nanocurcumin
- Slow and sustained release of curcumin

Patent filed: 0066NF2018/IN



Turmeric



Curcumin



Nanocurcumin





Low cost kiln for production of Bamboo charcoal



Bamboo charcoal

Bamboo charcoal is structurally dense, porous and has very low moisture content with only traces of harmful chemicals. It burns at higher temperature, emits little smoke, produces less soot and is comparatively lighter with higher calorific value and low ignition temperature compared to wood charcoal. It also has high absorption affinity for various liquids and gases. Therefore, bamboo charcoal is used in filters, gas masks, deodorizers, decolorizing agents and in the production of activated charcoal. A process and a kiln has been developed to produce bamboo charcoal.

Market potential:

The global market of charcoal was about USD 5.8 billion in 2017 and is projected to grow at a CAGR of 2.0%. Out of this, activated charcoal was worth USD 4.7 billion in 2015 and its market is growing at 9.4% per annum.

Salient features of the technology:

- Low cost kiln design for charcoal production suitable for rural areas
- Charcoal produced using *Dendrocalamus hamiltonii* and *Bambusa tulda*
- Charcoal produced from bamboo wastes and un-utilized twisted pieces of culms with >30% conversion rate.
- Calorific value of 6450-6640 Kcal/kg. This is comparable to charcoal from oak and pinewood.
- Activated carbon was produced from this charcoal with 16% conversion rate.

Patent filed: 0035NF2011/IN

Incense cones from herbs and flowers

Incense burning usually emits dense smoke containing particulate matter, production of gases such as carbon monoxide (0.4-2.6 parts per million), carbon dioxide (396-517 parts per million) and produces volatile organic compounds (260-610 parts per billion). Incense smoke not only contains carcinogens (polycyclic aromatic hydrocarbons, carbonyls and benzene) but also irritants which leads to a number of respiratory diseases. CSIR-IHBT developed an environmental friendly herbal incense cones by utilizing herbs and flowers including the temple floral offerings.

Market potential:

The present Indian agarbatti and dhoop market is USD 225 million and is expected to grow at 9% reaching USD 325 million by year 2025. India ranks first in the production of incense cones and agarbattis. It is estimated that around 800 million tonnes of flowers are offered at various places of worships which offer a sustainable raw material source for incense production.

Salient features of the technology:

- Phthalate free; charcoal free
- Shelf life is up to 12 months
- Low CO (0.1-0.2 ppm) and VOC (200-210 ppb)
- Variety of incense cones standardized for various aromas such as Dhoop, Loban, Rose, Sandalwood, Guggal, etc.







AGROTECHNOLOGY





Stevia: agro- and processing technology

Excessive intake of cane sugar leads to complications like diabetes and obesity. Stevia (*Stevia rebaudiana* (Bertoni) Bertoni) is a safe alternative source of low caloric natural sweetener. Stevia leaves contain sweet-tasting and low-calorie diterpenoid steviol glycosides (Sgs). Amongst the known SGs, the most important glycoside is rebaudioside-A, which is about 300 times sweeter than sucrose. CSIR-IHBT has standardised agro and processing technology of stevia.

Market potential:

Global market for stevia is currently estimated at USD 490 million at a CAGR of 9.5% and expected to reach USD 800 million by year 2025.

Salient features of the technology:

- Improved variety having high rebaudioside-A (~7.4%)
- Good Agricultural Practices for different agro-climatic conditions
- Green process technology for the production of white steviol glycosides powder, ready to serve stevia liquid and powder sachet
- High quality steviol glycosides powder with purity of >95%



Nursery of stevia



Steviol glycosides: powder, sachet and liquid drops

Monk fruit (*Siraitia grosvenorii*): low calorie natural sweetener

Monk fruit (*Siraitia grosvenorii* (Swingle) C.Jeffrey ex A.M.Lu & Zhi Y.Zhang) is known for its intense sweet taste and as a non-caloric natural sweetener, attributed by its cucurbitane-type triterpene glycosides known as mogrosides. The extracted mixture of mogrosides is about 300 times sweeter than sucrose.

Market potential:

- According to World Health Organization (WHO) report, 346 million people are diabetic, worldwide. India has about 62.4 million people with type 2 diabetes.
- The global market for monk fruit sugar is expected to reach USD 379 million at a CAGR of 4.5% by year 2026.

Technology package:

- CSIR-IHBT, Palampur has introduced monk fruit from China through ICAR-NBPGR, New Delhi (Import Permit No.168/2017)
- Standardised agronomic practices
- Post-harvest management
- Quality planting material



Flowers of monk fruit



Fresh and dried monk fruits

Heeng (*Ferula assa-foetida*): agrotechnology

Heeng or Asafoetida (*Ferula assafoetida* L.), is an herbaceous perennial herb indigenous to Iran, Afghanistan and Turkmenistan. It produces pungently flavoured oleo-gum resin in its fleshy roots which is well-known as condiment and has medicinal properties related to digestive system. The resin is believed to be anthelmintic, antiperiodic, antispasmodic, carminative, deodorant, expectorant, laxative, sedative and stomachic.

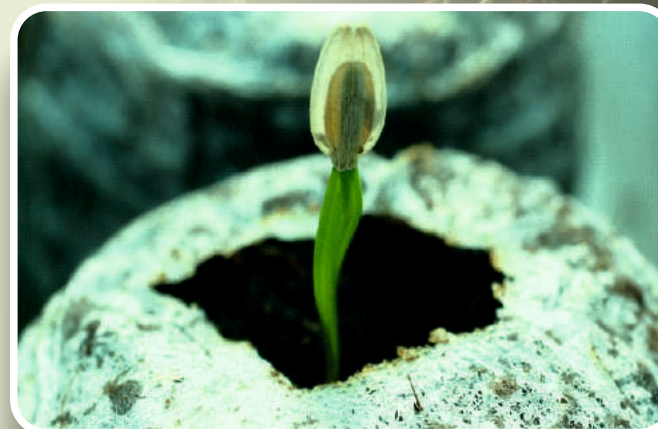
Market potential: India imports about 1145 tonnes of raw Asafoetida (Heeng) annually from Afghanistan, Iran and Uzbekistan and spends approximately 77 million USD per year on its import.

Contributions of CSIR-IHBT:

- CSIR-IHBT has procured seeds of *F. assa-foetida* (six accessions) from Iran through NBPGR-ICAR, New Delhi (Import Permit Nos. 318/2018 & 409/2018)
- Standardised agrotechnology
- Quality planting material



Heeng seeds



Germinating seed



Plants in the nursery



China hybrid tea (*Camellia sinensis*): agrotechnology package

CSIR-IHBT has contributed in rejuvenation of dilapidated tea plantations and developed improved methods of plantation management (*viz.*, pruning cycle, plucking standards, fertilizer application, weed management, disease and insect pest management, and post-harvest management), and has standardized a set of agrotechnology package for production of quality flavoury tea (*Camellia sinensis* (L.) O. Kuntze).

Market potential:

- Global tea market was valued at USD 4.6 billion in 2016, and is projected to reach at USD 6.7 billion by year 2023, growing at a CAGR of 5.5%. Flavour tea production is limited to Darjeeling.
- Himachal Pradesh and Uttarakhand are suitable for tea cultivation and have great potential to extend China hybrid tea cultivation.

Expertise available at CSIR-IHBT:

- High yielding quality clone '*Him Sphurti*' with 25% higher production
- Mechanical harvesting of tea leaves, mechanical skiffing, pruning and pit making
- Quality tea manufacturing process both for green and black tea
- Processes for value addition to low grade teas and teas dust to diversified tea based products

CSIR-IHBT provides

- Training & skill development on modern agro-practices and tea processing
- Quality planting material of high yielding quality clone

Damask rose (*Rosa damascena*): agro- and processing technology

Damask rose (*Rosa damascena* Mill.L.) is an important source of rose products viz., rose oil, rose concrete, absolute and rose water which are base material for the perfumery industry. There is an extensive demand of essential oil of Damask rose in the domestic and international market and farmers have started taking up its cultivation on commercial scale.

Market potential:

- The global demand of damask rose products (oil, concrete and absolute) is 45 tonnes per year.
- Bulgaria and Turkey being the major producers of rose oil.

Salient features of CSIR-IHBT technology:

Two cultivars namely '*Jwala*' and '*Himroz*' were developed with flower yield of 25-30 q/ha and essential oil yield of 650-800 g/ha

CSIR-IHBT support to farmers:

- Planting material of rose cultivars to the farmers
- Technology for essential oil extraction
- Trainings on agro-technology and processing technology



Freshly harvested flowers



Rose products



Field view of Damask rose

Wild marigold: agro- and processing technology

Wild marigold (*Tagetes minuta* L.) grows well at altitudes ranging from 1000 to 2500 m amsl and is cultivated for its essential oil that is valued in aromatic industry. The crop grows successfully in areas of low water availability and is not destroyed by wild animal and monkeys. CSIR-IHBT has developed 'Him Gold', a selection of wild Marigold which produces essential oil of high grade. Due to increasing industrial demand of its oil in perfumes, hair lotions, flavoring agents in foods and beverages, there is a growing interest in its cultivation among farmers.

Market potential:

The global demand of *Tagetes* oil is 20 tonnes, while the current production is little over half of its demand.

Salient feature of HimGold variety:

'Him Gold' has herb yield of 120 q/ha and 0.3% essential oil yield

CSIR-IHBT support:

- Technology for essential oil extraction & trainings on agro-technology and processing technology
- Seeds of high yielding variety '*Him Gold*' to farmers



Lilium: agrotechnology

Lilium is a high value bulbous crop that ranks fourth in international demand in flower trade. In India, the annual demand of about 4 million bulbs is met largely through import from the Netherlands, that makes it's cultivation less remunerative due to high procurement cost. Tropical climate of Indian plains restrict flower production in subsequent years and requires cold storage for bulbs during summer months, thus adding to the cost. Lilium flower and bulb production in high Himalayas such as Lahaul valley of Himachal Pradesh has been shown to be promising. The chilling requirement of bulbs is met naturally during the winter months in these areas.

Market potential:

The global trade of lilium in the International market is estimated at USD 155 million. Off-season flower production and bulb production in non-conventional areas such as Lahaul provides a lucrative enterprise for farmers and can substitute its import.

Advantages of lilium cultivation:

- Off-season cut-flower production fetches premium returns to the farmers
- Suitable for flower and bulb production under open cultivation conditions in Himalaya.

CSIR-IHBT support to farmers:

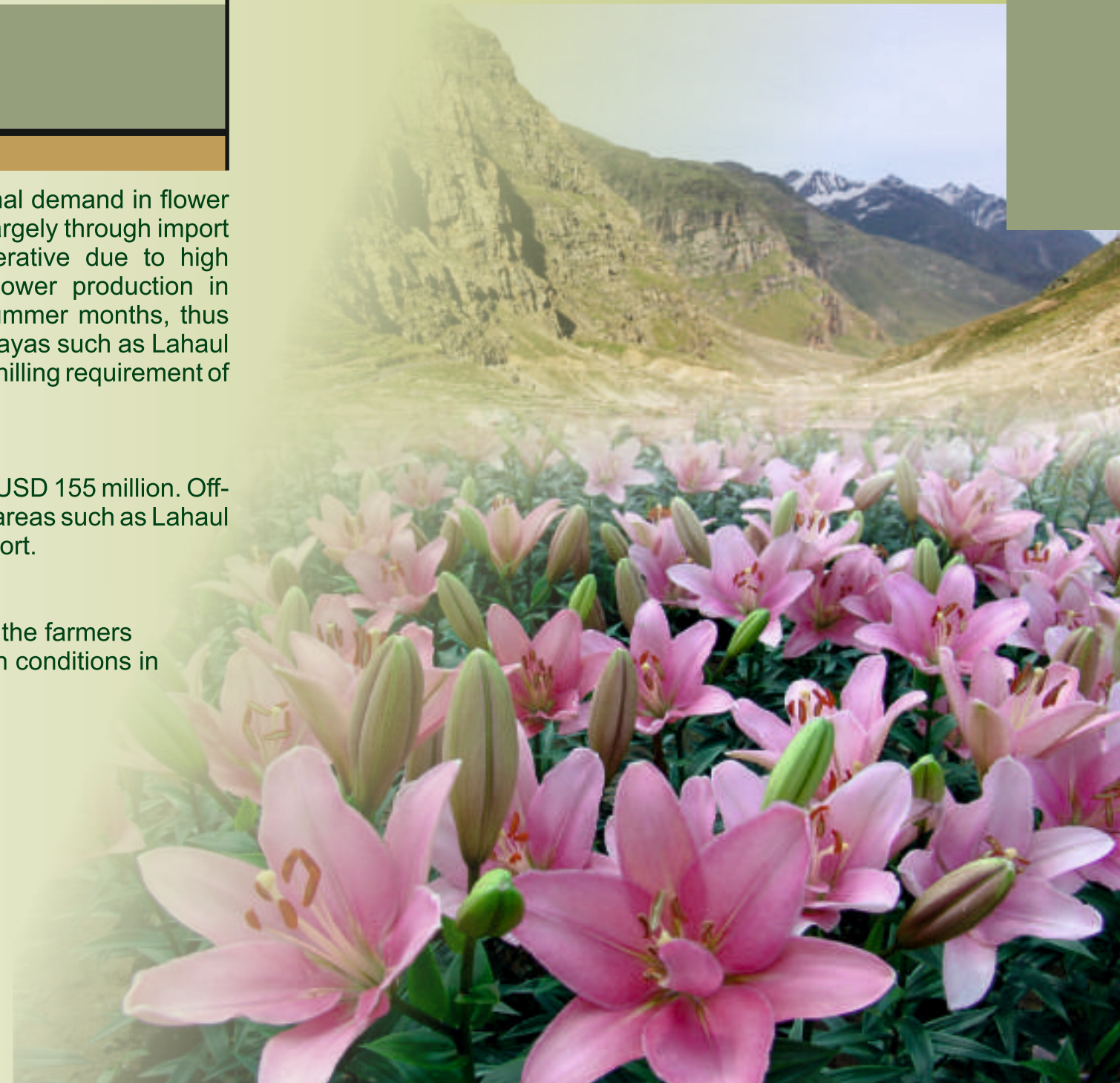
- Bulbs of lilium to the farmers
- Trainings on cultivation practices



Bulb of lilium



Micro bulbs



Field view of lilium crop

Calla lily: agrotechnology

Calla lily (*Zantedeschia elliottiana* (W.Watson) Engl.) flowers are popular floriculture plants in demand for their exotic blooms, glossy foliage. Used both as cut flowers as well as potted plants, calla lilies are suitable for open cultivation under conditions of low and mid hills.

Market potential:

Major producers of calla lily are New Zealand, United States, Kenya and Taiwan. Trade of Calla lilies in the Indian market is currently estimated at Rs. 150 crores with an expected annual growth of 20%.

Calla lily varieties developed by CSIR-IHBT:

Two cultivars of calla lilies, representing species of commercial importance *Z. elliottiana* (*Him Sumukh*) and *Z. aethiopica* (*Him Shweta*) are developed through hybridization and selection approach. *Him sumukh* has yellow trumpet shaped blooms, while *Him Shweta* is evergreen with white flowers. These cultivars are vigorous in growth and suitable for open field cultivation in low and mid hills, under protected/ partial shade conditions in plains and as per the flower colour preference in the market. Vase life of cut flowers is more than 10 days.

CSIR-IHBT provides

- Planting material
- Training on cultivation practices



Him Shweta



Him Sumukh

Gerbera: agrotechnology

Gerbera (*Gerbera jamesonii* Bolus ex Hook.f.) ranks among top ten cut flowers in the international market. In India, most of the Gerbera cultivars for commercial cultivation are imported. Gerbera is suitable for protected cultivation in plains, low and mid hills.

Market potential:

Gerbera is cultivated in India in over 900 acres. Trade in domestic market is estimated at Rs. 985 crores with an annual growth rate of 15%.

Gerbera cultivars developed by CSIR-IHBT:

Five cultivars, developed through hybridization and selection approach for commercial cultivation, have standard flower size, double and semi-double flower heads and bright colours such as light yellow (*Him Saumya*), red purple (*Him Gaurav*), yellow orange (*Him Aabha*), red bicolour (*Him Apoorva*) and bright yellow (*Him Keerti*). The yield of flowers in cultivars is more than 20 flowers/plant/year and are as per the flower colour preference in the market. The technology is positioned for import substitution of Gerbera cultivars from abroad. Tissue culture as well as nursery production protocols are available for Gerbera varieties. Vase life of cut flowers is more than 12 days.

CSIR-IHBT support to farmers:

- *In vitro* cultures for mass multiplication at entrepreneurs level
- Training on cultivation practices



Him Saumya

Him Gaurav

Him Aabha

Him Apoorva

Micropropagation protocols: industrially important crop plants



Micropropagation of bamboos & saffron



Bulbs of saffron

Using micropropagation techniques for raising large scale clonal populations of disease free quality planting materials has exclusive potential for industrially important crops. While the technique is independent of constraints posed by seasons or other field conditions, it requires protocols optimization for growth, hardening, cost factors for financial viability.

Achievements of CSIR-IHBT:

Micropropagation protocols have been developed for scented rose, potato, bamboo species, saffron and large cardamom to meet the increasing demands of industry, forestry and entrepreneurs.

Salient features of the protocol:

- The protocols are cost effective and efficient.
- The micro propagated clonal plants have more than 85% survivability under field/farm conditions.
- The protocols are up-scalable

Market outreach:

Quality planting material raised through Tissue culture techniques is a big support to farmers, entrepreneurs and industry. Through material transfer agreements (MTAs), the institute provides germplasm of industrially important crops (scented rose, bamboos, potato, apple rootstock, etc.), offers training and incubation facility to entrepreneurs to support growth of industry.

Micropropagation protocols for *Picrorhiza kurroa*

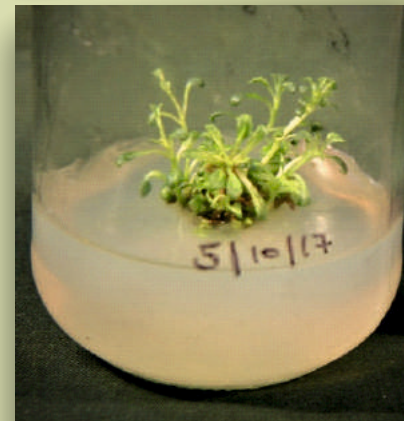
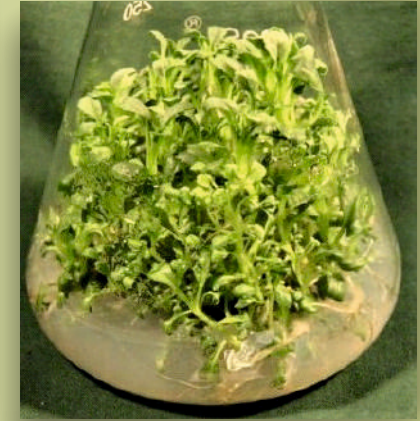
Micropropagation is an effective method for large scale propagation of plants with declined status in their natural habitat listed as rare, endangered or threatened (RET) categories. The method is useful for generating a sustainable resource base, for *ex situ* conservation and their rehabilitation in nature. Therefore, micropropagation protocols have been developed for *Picrorhiza kurroa* Royle ex Benth., which is a medicinally important plant of Himalayas falling under the RET category.

Salient features:

- An efficient micropropagation protocol for *P. kurroa* with up to 85% survival rate under natural habitat.
- The protocol developed is non-destructive, cost effective, efficient and up-scalable.

Market outreach:

P. kurroa is an important constituent of several herbal formulations, popularly used for hepatoprotection. The global demand for *P. kurroa* is about 375 tonnes, of which 70 tonnes is contributed by India, largely uprooted from wild. The plant is now listed as endangered. Through standardised protocols, several thousands of tissue culture raised plants of *P. kurroa* have been transferred to natural habitat, and serves as a viable model for its fast multiplication, growth and as resource base for pharmaceutical industry and forestry.



Production technology for quality rootstock for apple



Healthy rootstocks are key to vigour and robust tree canopy. Several viruses and viroids accumulate over a period of time due to their clonal and vegetative propagation, which pose a major constraint in production of quality apples. The viruses and viroids are passed on to the scion material upon grafting, which reduce the quality and quantity of the produce, inflicting losses to the growers (lower quality stocks, reduced plant growth and fruit yield) and consumers (high price and lower fruit quality). In order to sustain and manage quality of apple production, there is a need for certified quality planting material, free from virus infection.

Salient features of the technology:

- At CSIR-IHBT, a meristem tip culture protocols has been developed to eliminate apple viruses. The protocol is non-destructive, cost effective, efficient and up-scalable.
- The institute has developed highly sensitive multiplex diagnostic protocols for four major viruses *viz.*, Apple mosaic, Apple pitting, Apple stem grooving and Apple chlorotic leafspot viruses and for a viroid - Apple scar skin.

Market potential:

- Certified planting material of apple rootstocks has a huge demand. There is a need of 5-6 lakh plants/ year for the farmers. Currently, national production is less than 50% of the demand.
- Virus tested planting material guarantees 20% more branches and 40% more spurs for better fruit production.

Virus infected rootstock

Meristem tip culture



Virus tested rootstocks

Biofertilizers

Biofertilizers, containing living microbes, promotes plant growth by increasing the supply or availability of primary nutrients to the host plant. Biofertilizers either reduce or replace the extensive use of harmful chemical fertilizers, improves soil health and makes a way for sustainable agriculture.

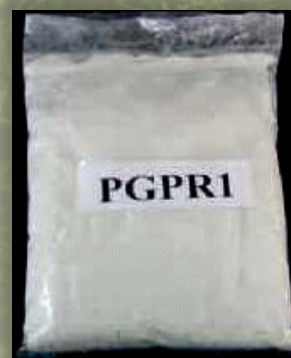
Contributions of CSIR-IHBT:

- CSIR-IHBT has identified novel soil microbes from unique Himalayan niches with plant growth promoting attributes
- ACC-deaminase activity and high auxin production
- Efficient phosphate solubilization
- Enhanced siderophore production
- Stress tolerance against desiccation, acidity and alkalinity, low and high temperature regimes

These microbes have been fully characterized and their potential have been successfully tested under trials at experimental farm fields spanning across Himachal Pradesh and Punjab, and in several important crops like potato, garlic, onion and pea.

Market potential:

Biofertilizers market is valued currently at USD 957 million and is projected to witness a significant growth rate at 14.6% CAGR and expected to reach USD 2 billion in next 5 years.



PGPR for application

Field trial in onion farm



Vision

To be a global leader on technologies for boosting bioeconomy through sustainable utilization of Himalayan bioresources



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