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ICAR NEWS
A SCIENCE AND TECHNOLOGY NEWSLETTER

RESEARCH UPDATE

PROMISING TECHNOLOGIES

Nutraceuticals from grass, *Sehima nervosum*

Plant biomass, particularly the lignocellulosic material, is the major renewable carbon reservoir that offers sustainable generation of products for multiple industrial utilities and also for non-food consumer products such as fuel, chemicals and polymeric materials.

Sehima nervosum is one of the natural grasses; is known as Saen grass in India, white grass in Australia; and has also been reported from the Central East Africa and Sudan.

As this natural grass is found inherently rich in precursors for several industrially important biomolecules, fractionation of these precursors seems to be a promising endeavour.

Production of nutraceuticals (prebiotic xylo-oligosaccharides) from the lignocellulosic biomass of the grass is promising, as this grass does not compete with food crops, and is comparatively less expensive than conventional agricultural food-stocks.

An attempt was made to maximize yield of xylan from lignocellulosic biomass of this natural grass, followed by enzymatic production of xylo-oligosaccharides (XOS).

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Chemical analysis of *Sehima nervosum* revealed presence of cellulose 37.25±0.95%, xylan 28.10±0.04% and acid- detergent lignin 4.80±0.30%. Alkali application to the natural grass from 2 to 12%, followed by incubation at room temperature resulted in increase of relative yield of xylan from 8.79% to 58.79% with potassium hydroxide and from 13.34% to 89.39% with sodium hydroxide. And alkali application coupled with steam enabled further scaling up (83.38% with potassium hydroxide and 97.11% with sodium hydroxide) of relative yield of xylan from the natural grass. The HPLC analysis of xylan revealed 59.3% xylose, 31.89% arabinose and 8.78% glucose. Fourier Transform Infra Red (FTIR) Spectroscopy revealed absorption bands similar to the typical xylan biomolecules. Commercial xylanase enzyme was applied over grass-xylan for yielding XOS at different temperatures, *p*H, incubation times and enzyme concentrations, followed by detection of XOS yields through thin layer chromatography and HPLC analysis. With increased enzyme dose, there was breakdown of both xylan and XOS, which resulted in reduction of xylan concentration and increase in xylose accumulation. Response Surface Method (RSM) of analysis was applied to minimize xylose concentration and to maximize xylobiose and xylotriose concentrations with inputs of different levels of *p*H, enzyme dose, temperature and reaction time. RSM analysis of the HPLC data showed maximum yield of xylobiose (2.20 mg/ml) at 5.03 *p*H, 45.2°C incubation temperature, 17.4 U enzyme dose and 10 hr reaction time. To obtain higher xylotriose (1.41 mg/ml) from enzymatic hydrolysis of xylan from *Sehima nervosum*, ideal conditions found from response surface model were as follows: 5.11 *p*H, 40.3°C temperature, 13.2U enzyme dose and 17 hr reaction time. Future perspective of XOS from grass depends on its economic production on an industrial scale and its validation as prebiotics either through animal model or through human clinical trials.

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Pesticides removal from drinking water

A study was undertaken for removal of organochlorine pesticides— lindane, aldrin, endosulfan (α-, β and sulphate) and DDT (p,p-DDT and p,p-DDE) from the drinking water. It was revealed that normal drinking water treatment process, which involves chlorination, followed by flocculation with alum, sedimentation and filtration, removed pesticides to the tune of ~ 28% only.

To improve pesticides removal efficiency, an intervention in the form of inclusion of different adsorbent clay minerals in the water treatment process was attempted. Normal clays like kaolinite and bentonite improved removal, and it was to the tune of ~ 78%. Use of nano-clays further improved removal efficiency to ~ 88%, and with the surface modified nano-clays, removal of pesticides was to the tune of ~ 95%. This treatment has a potential in decontaminating drinking water from pesticides.

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Water deficit management in potato

A study was conducted under the alternate-day drip irrigation for the last 3 years on the potato var. Kufri Badsah, which recorded average potato yield of 46 tonnes/ha. It required on an average 22.1 cm of irrigation water. Induced water deficit at 20 % and 40% resulted in 17.1 and 28.2 % decrease in potato yield. However, water-use eflciency, increased to 24.1 and 29.4 kg/m^3 under 20% and 40% deficits from 20.8 kg/m^3 under no deficit situation. With 20% induced deficit with daily irrigation scheduling, average yield was 45.3 tonnes/ha.

It may be inferred that 20 % water deficit is best managed by daily irrigation, and it does not cause any significant yield losses.

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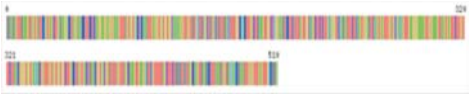
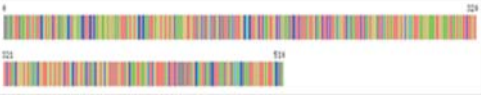
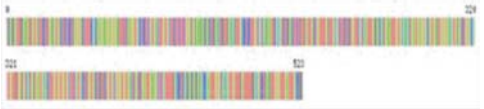
DNA barcoding for identification of insects

Identification of insects based on the morphological characteristics for the last 200 years has resulted in the description of 1.7 million insect species, which is only 10 % of the total number of insect species estimated. Thus identification of insects seems to be a monumental task, and would call for availability of more specialists and more funding. But with the advent of the molecular biology and molecular tools, identification of life-forms including insects has become quick, precise and easy. Molecular systematics is not state-specific, and it does not require trained taxonomists; besides it is rapid and helps in differentiation of even biotypes. The main advantage of the DNA barcoding is in rapid acquisition of molecular data. It is extremely useful in unambiguous identification of biological specimens and in managing species diversity efficiently in Gene Banks. Identification of invasive insect pests has also become possible with the DNA barcoding.

DNA barcoding is a technique by which species identification is carried out by analyzing sequences of small fragments of mitochondrial genome, ITS1, ITS2, 16sRNA, CYTB, ND5 and others. Mitochondrial genome has relatively faster mutation rate and results in variations in mtDNA of different species. A 648bp region of the mitochondrial cytochrome oxidase subunit I gene, in general, is used in the DNA barcoding. DNA barcodes for 62 insect species including pests (6), invasive pests (4), predators (14), parasitoids (22) and ants (16) have been developed; and also a database named "Insect Barcode Informática (IBIn)" has been developed.

Insect species	Barcode ID	DNA barcode	
Brontispa longissima (An invasive pest)	BRLON001-10		
Coccinella transversalis (Predator)	AINCC008-10		
Trichogramma achaeae (Parasitoid)	TRINB001-10		
Opisina arenosella (Lepidopteran pest)	LEPOP1001-11		

IBIn is an online database resource, developed on the insect domain, which furnishes support on the acquisition, storage, analysis and publication of the DNA barcode records for agriculturally important insects by researchers all-over in India. Insect Barcode Informática has information on the number of the insect species of the world and India, number of insects' barcoded, statistics of the order-wise information on the number of insects' barcoded in India and the world. In India, researchers working on molecular characterization of insects can log onto web site: http://202.141.78.173/barcode2/ and can submit their sequences for analysis and generation of barcodes. Indian accession number will be assigned automatically to each barcode record for submission. The details required for submission of the barcode records are taxonomic position of the insect, collection locality (place, state and country), barcode marker (name of the gene), source (reference), author's name, institute's the address and nucleotide sequence. The barcode image will be created as per the standards evolved by the BOLD for the given nucleotide sequence, and the record will be stored in the insect barcode database.

The identity of the nationally important invasive pest, papaya mealybug, was confirmed using DNA barcoding, which helped in taking appropriate biocontrol measures. Identity of the exotic parasitoid of this pest was confirmed as *Acerophagus papayae* using DNA barcode. Barcode for coconut leaf beetle, *Brontispa longissima*, a potential invasive pest, has also been generated.

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On-line Leave Management System

Leave Management System (LMS) has been designed for the on-line leave processing of the central government office(s). Front-end of the database has been designed using HTML, VBScript, Jscript and SQL programming languages to create Active Server Pages, and MS Access has been used as the backend database.

Active Server Pages were created on the Intranet using Microsoft Visual InterDev environment to insert, retrieve, delete and modify data framed in the database. On-line application is accessible only to the authorized employees. Each employee has a unique employee number and is given a password, which can be changed on the first log-in.

Leave Application displays total number of leaves, leave availed and balance. The employee has a quick reference on the balance leave account of all types of leaves: Medical leave, Earned leave, Casual Leave and Restricted holiday.

After all the required fields are entered, then the system checks by default for some more validations in the next form. After validation, the application is submitted to the respective in-charges for approval.

For the ***Modify*** option, all applications, which are not approved (means whose APPROVED STATUS is null), are displayed. The employee can select the date, and then can modify. A **Report** is generated transaction-wise and leave-date wise for the selected period. This option is available only to the administration unit. The ***History*** option displays all applications in the leave database. The employee can ***change*** the ***Password***.

Some other features in generating reports in the Leave Management System are as follows:

Daily report

- Employees who are joining today after availing leave(s).
- Employees who are on leave today (i.e., current day).
- Employees who are proceeding on leave from tomorrow.
- Employees who are proceeding on leave shortly.
- Employees whose leave is yet to be sanctioned, the name of the in-charge and Emp no is displayed along with the leave records which are not approved.
- List of employees whose leave is rejected.

Sanction order

- It is for all the employees going on leave in a particular period can be printed for administrative filing.

Balance leave

- Leave balance (CL, RH, EL and ML) for all the employees as on today.

Leave approval by In-charge

- The Officer In-charge has to be given employee number and the password. A list of his subordinates is displayed. Then 2 options are displayed: *Leave approval; Leave profile.*

Holiday List of the current year is displayed including Restricted Holidays (RHs) with the next closed holiday. When the restricted leave is applied, the application is validated with the RH-LIST.

This LMS will also be very useful for public and private sectors for recording employees leave account.

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Rapid method for endo-β-1, 4-xylanase assay

Endo-β-1,4-xylanase has several industrial applications such as bleaching of pulp and paper, in biorefinery, clarification of fruit -juices and wines, animal feed and nutraceuticals production. Earlier established Congo Red assay involves use of chemicals like Congo Red for staining and Sodium chloride for de-staining.

A simple and easy diffusion technique for rapid assay of endo-β-1,4-xylanase, bypassing staining with Congo Red or de-staining with Sodium chloride, has been developed. This involves diffusion of enzyme in the wells created on 0.9 % xylan- containing agar plates. The zone of clearance is visible with the naked eye, and is comparable with the Congo Red assay of endo-β-1,4-xylanase.

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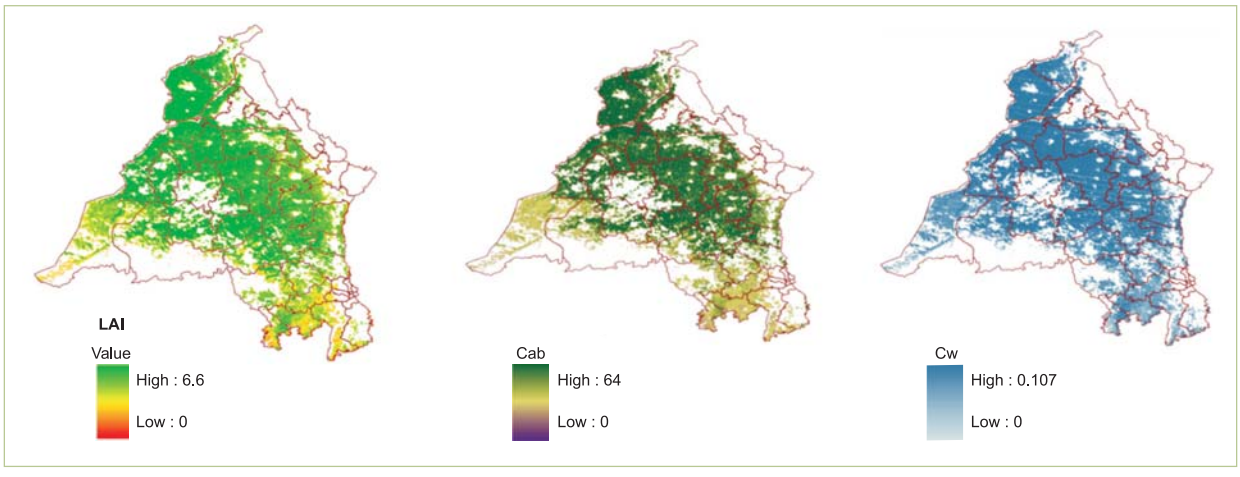
Crop Health Index for monitoring crop growth and precision farming

Monitoring of the crop growth condition in a large scale can provide decision-making information for working-out on the agricultural policy and commissariat trade. The basic requirement for the crop growth monitoring is an efficient-and-reliable approach for retrieving different biophysical parameters of the crops such as leaf area index (LAI), chlorophyll content (Cab) and water content (Cw), which can assist in monitoring crop growth and also in site-specific management for optimum crop production in precision agriculture.

canopy reflectance model describes radiative transfer in the canopy as the function of the biophysical variables, which characterize canopy architecture and optical properties of the vegetation element and soil, and has been found to be generic and reliable compared to other conventional approaches.

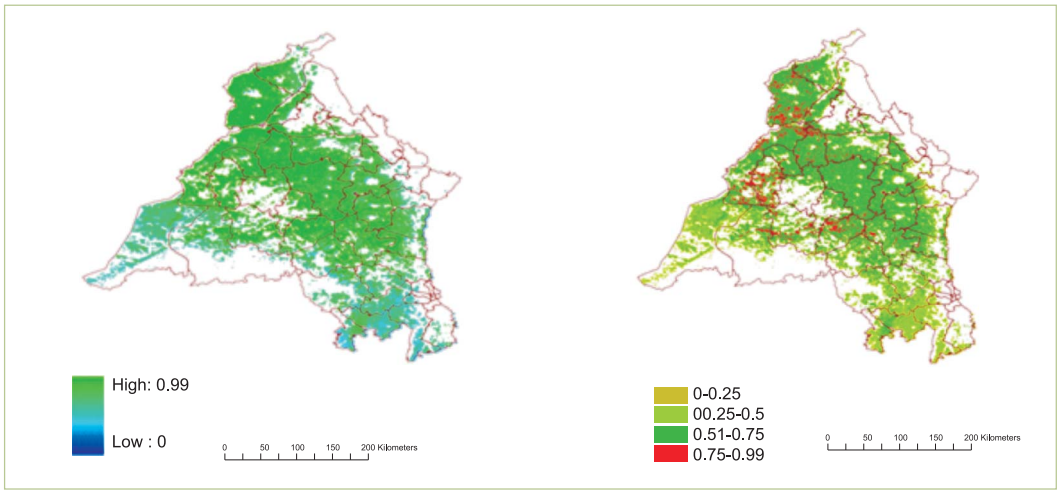
Wheat-growing area of the Trans-Gangetic Plains was masked out using times series MODIS Remote Sensing data (i.e. 500 m spatial resolution). LAI, Cab, and Cw



Retrieved LAI, total chlorophyll content (Cab) and equivalent water thickness (Cw) products of wheat through inversion of the PROSAIL model

An attempt was made to retrieve these parameters of wheat-crop, grown in the Trans-Gangetic Plains of India, from the MODIS satellite data (500-m spatial resolution) through inversion of canopy reflectance model. The

were retrieved at the regional scale through inversion of validated radiative transfer model – PROSAIL. The generated products were evaluated with ground measured values and were found well retrieved and



Crop Health Index map of wheat-crop composited from LAI, Cab and Cw products

Zonation of the wheat-growing area of the Trans-Gangetic Plains into four groups based on the Crop Health Index

comparable with the measured values; with the RMSE error of 0.3892, 4.307 and 0.0063 respectively. LAI has a direct relationship with the biomass and yield of crop; total chlorophyll (Cab) is mainly governed by nitrogen, which indirectly indicates N stress; and Cw reflects water status in the canopy, and thereby water stress. An index called Crop Health Index (CHI) was developed by compositing LAI, Cab and Cw. The composite indicator considering all these parameters may provide information about the crop health and thereby the index is named as the Crop Health Index, which can be used to prioritize zones at the regional scale for yield enhancing site-specific interventions. The CHI value obtained ranged between 0 and 1.Based on the CHI, study region was divided into four zones, corresponding to four growth conditions of the wheat-crop. Wheat area with very poor growth conditions had CHI range from 0 to 0.25, for poor growth from 0.25 to 0.5, for good 0.5 to 0.75 and for very good conditions had CHI above 0.75. When the classified CHI map was compared with the yield map of the study area, it was observed that areas with higher CHI were producing higher yields and *vice versa*.

The study demonstrated potential of remote sensing data and radiative transfer model in the retrieval of LAI, Cab and Cw at the regional scale. The basic requirement for the crop growth monitoring is the efficient tools for retrieving different biophysical parameters and their accuracy or reliability. Parameters retrieved can be directly used for crop growth monitoring and otherwise through developed CHI for site-crop management practices. The very poor and poor CHI value zones can be further considered for site-specific growth enhancing management practices for precision agriculture.

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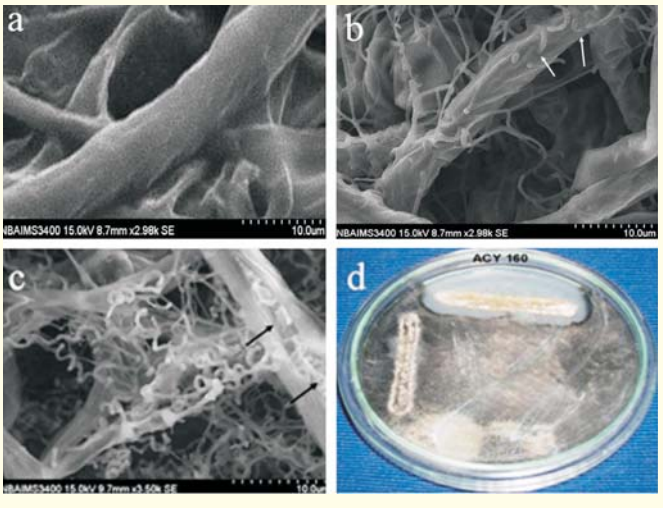
Streptomyces strain ACY160 controls chickpea charcoal root-rot

Macrophomina phaseolina Tassi (Goid) is an important root-rot pathogen, causing dry root rot/ stem canker, charcoal rot on over 400 plant species, including chickpea, in the South-East Asia. It is an endemic soil-borne fungus, and a very few chickpea varieties have shown resistance against this dry root-rot fungus.

The antagonistic potential of *Streptomyces* isolates against *Macrophomina phaseolina* and also induction of defense-related mechanisms by it in the chickpea infected with rot disease including defense-related enzymes were evaluated. *Streptomyces* sp. strain ACY160, isolated from the pathogen-suppressive soils**,** inhibited mycelial growth of pathogen up to 50% in *in-vitro* conditions and reduced significantly (33.3%) charcoal-rot incidence in the greenhouse.



Interaction between *Streptomyces* sp. strain ACY160 and *M. phaseolina*; **a.** Control; **b, c.** Colonization and hyphal destruction of *M. phaseolina* by strain ACY160; **d.** dual culture of *Streptomyces* sp. strain ACY160 and *M. phaseolina* showing inhibition zone

This strain showed hydroxamate type of siderophores, phosphate solubilizer activity, nitrate reductase activity and hydrogen-cyanide production. Chickpea seed treatment with the strain along with its soil application supported maximum crop-stand and reduced root-rot incidence (12.5%), as compared to treatment only on seeds. The strain enhanced peroxidase and phenylalanine ammonia lyase (PAL) activities and induced accumulation of phenol compounds. The maximum peroxidase activity in the plant roots was reached 120 hr after challenging and then declined. Higher activities of PAL and phenol compounds recorded at 96 hr showed significant increment up to 1.1 fold and 2.78 mg/g in the root after inoculation, and the molecular weight of 42 kDa was observed from purified peroxidase. Ascorbate peroxidase also showed

remarkable increase in activity up to 28.6 µmol/ min/g of fresh weight at 148 hr. The potential antagonist (N19) strain has taxonomically been identified by using polyphasic approach including 16S rDNA sequencing (GenBank accession number GU817410).

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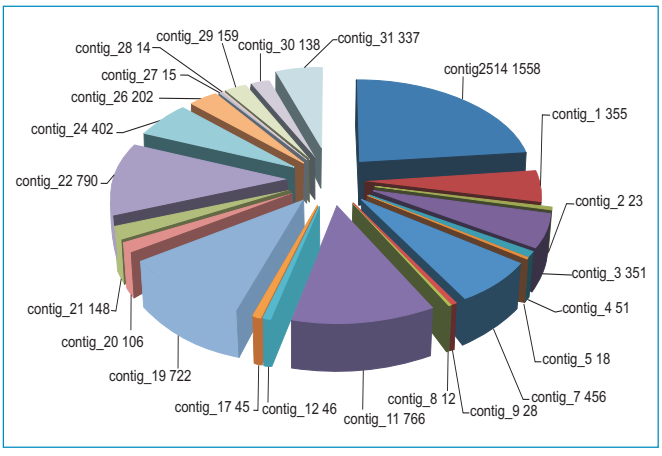
First genome sequencing from India of *Mesorhizobium ciceri* Ca181

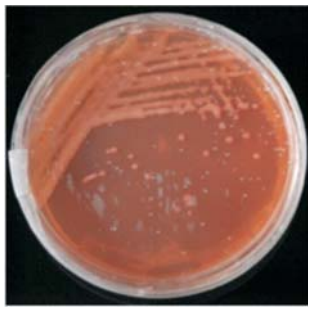
M. ciceri Ca181 was isolated from chickpea root nodules from the Haryana fields; it is an indigenous strain from India.

M. ciceri Ca181 was selected for genome sequencing as it has efficient nitrogen-fixing ability, shows good nodulation and shows high competitiveness to chickpea rhizobia. It is a gram-negative, non-spore forming, motile, rod- shaped aerobic bacterium. Its colonies are translucent, milky-white, as are seen after 6-8 days of growth on the Yeast Extract Mannitol Agar bacterial growth medium at 28° C with a generation time of 8hr.

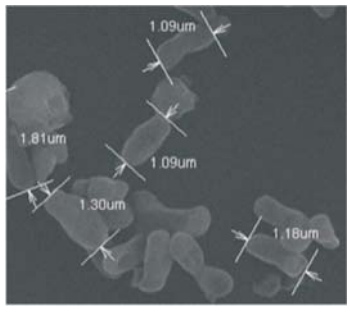


Distribution of genes in the genome of *M. ciceri* Ca181

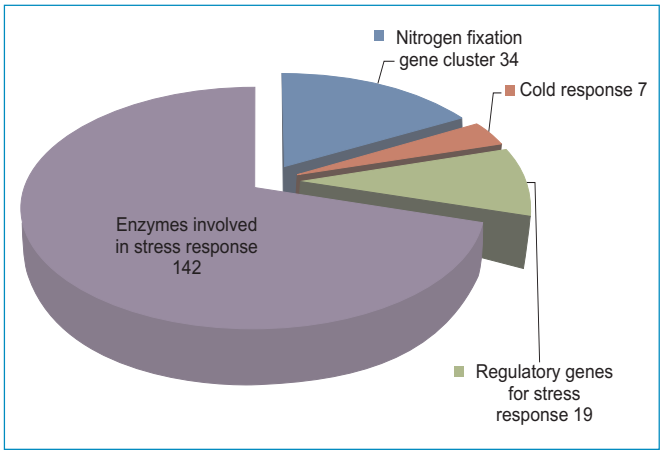
About 80% of the air is nitrogen but major crops like rice, wheat and maize are unable to utilize this for their nutrition and growth, and, therefore, large amounts of chemical fertilizers are required to achieve higher productivity. In contrast, grain-legumes, chickpea and pigeonpea are able to utilize atmospheric nitrogen for their growth with symbiotic rhizobacteria. Chickpea rhizobium (*Mesorhizobium ciceri*) is estimated to add 24-40 kg of nitrogen per hectare in a cropping season.



Milky white colonies of *M. ciceri* Ca181



SEM micrograph of *M. ciceri* Ca181



Important functional clusters of genes of *M. ciceri* Ca181 genome

About 12 billion sequences have been generated by 454- pyrosequencing, 1.2 GB by Solexa-illumina and 4,000 Kb by Sanger Sequencing. After assembly and merging of 454 and Solexa sequence data, total 23 large contigs were made, and further assembly using fosmid end sequence data resulted in nine scaffolds having 16 contigs; 7 contigs have remained unassembled. These 23 contigs make up a total 6.79 Mbp of finished genome sequence.

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ICAR scientists decoded *Tomato Genome* in partnership with International Consortium

The genome of the cultivated tomato (*Solanum lycopersicon*) and of its closest wild relative *Solanum pimpinellifolium* have been decoded by the Tomato Genome Consortium (TGC); a group of over 300 scientists from 14 different countries.

India contributed in the sequencing of the gene-rich region of the **tomato chromosome 5** (tomato has total 12 chromosomes) and provided support to generate 5-fold sequence coverage of the entire tomato genome by the Next Generation Sequence (NGS) technology.

Indian Team also participated in performing **annotation** of all predicted **proteins** using international databases as a part of the International Tomato Annotation Group (ITAG). Simultaneously, Indian researchers have taken up analysis of specific genes/gene families related to **disease resistance**, **abiotic stress tolerance** and **ripening** based on the transcriptome (RNA sequence) data and comparative genomics. The outcome is expected to accelerate improvement of tomato varieties by molecular breeding.

The sequence showed that the genome of tomato had "**triplicated**" suddenly about **60 million years ago**, close to the mass extinction that led to the disappearance of dinosaurs. Subsequently, most of the triplicated genes were lost, while some of the surviving ones have specialized and now control important characteristics of the tomato-plant such as those controlling fruit characteristics, including ripening time, firmness and red pigmentation.

Indian Initiative on the Tomato Genome Sequencing was a part of the TGC. It involved **24 scientists from India** from three institutions—**University of Delhi**, South Campus; **National Institute of Plant Genome Research**; and ICAR institution, **National Research Centre on Plant Biotechnology**, Indian Agricultural Research Institute, Pusa Campus. The Indian project was funded by the **Department of Biotechnology**, Government of India, and supported by the **ICAR**.

The sequence will serve as the reference for the other Solanaceae species and for comparative genomic studies both within the Solanaceae and with other higher plant taxa**.** The genome sequence and related resources are freely accessible on the websites http://solgenomics.net and http://mips.helmholtz-muenchen.de/plant/tomato/index.jsp.

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Seed production of hybrid bittergourd

A low-cost net-house technology for seed production of bittergourd hybrids (PH1, PH2) has been standardized, as the crop suffers severely in the open fields from pests.

Insect- proof structure constructed with galvanized iron-frame covered with insect-proof net (35-40 mesh/inch^2) prevents entry of insects, hoppers, aphids, and also restricts transmission of diseases, thus reducing indiscriminate use of pesticides on the plants. The approximate cost of the net-house construction with galvanized iron-frame (30m × 7m × 8m) is about ₹50,000.

In the net-house, seed-production technology of hybrid bittergourd promotes healthy and insect-free crop. In addition, plants produce more crossed fruits (2-4 fruits/vine) with higher fruit weight (10 - 20 g more), seed yield/fruit (more filled seed) and quality. On an average, 12-14 fruits/vine with fruit weight of 160- 200 g were produced in the net- house as compared to 8-10 fruits with fruit weight of 80-120 g in the open fields. And on an average, a yield of 4-5 kg of hybrid seed/100 m^2; of net-house could be achieved in a year; through which a farmer could earn ~ ₹10,000 per year at the rate of ₹2,000 per kg of seed.

The net-house can be retained for 3-4 years with minor repairs, and it can also be used for other activities, viz. raising healthy seedlings in the remaining period.

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Central Soil and Water Conservation Research and Training Institute, Dehradun

India was among the first few countries to have taken timely cognizance of the problem of soil erosion. This Institute began as the regional centre in 1954, and was reorganized in 1974 under the ICAR as the Central Institute— the *Central Soil and Water Conservation Research and Training Institute*. It has now eight Regional Centres at Agra, Bellary, Chandigarh, Datia, Koraput, Kota, Udhagamandalam and Vasad, which along with the headquarters at Dehradun cater to location-specific needs of different regions. The Institute has four divisions—**Soil Science and Agronomy; Hydrology and Engineering; Plant Science; and Human Resource Development and Social Sciences**.

The principal mandate of the Institute is to conserve natural resources, especially soil and water, dovetailed with production from arable as well as non-arable lands. ***The Institution has been identified as the nodal agency to impart long-duration specialized training programmes to Central and State Government Officers and Graduate Assistants in the field of Soil and Water Conservation and Watershed Management as per the specific demands of the organizations.***

MANDATE

- Undertake research and develop strategies for controlling land degradation under all primary production systems and for rehabilitation of degraded lands in different agro-ecological zones of the country.
- Act as a repository of information on the status of soil degradation/soil and water conservation.
- Provide leadership and co-ordinate research network with SAUs / Institutions / NGOs / State Departments for developing location-specific technologies in the area of soil-and-water conservation.
- Act as a national and international centre for training in research methodologies and updated technologies in soil-and-water conservation, watershed development and its management.
- Provide consultancy and collaborate with national and international institutions in the field of soil-and- water conservation.

MAJOR ACHIEVEMENTS

Research

The Institute has evolved strategies for resolving problems of ravines, landslides, mine-spoils and torrents. Reclamation technologies for torrents, gullies, landslides, mine- spoils, gravelly / bouldery soils, sloping lands, watershed restoration, runoff harvesting, alternate land uses, diversification, biodiversity (ecological successions), bioremediation, management of common property resources and community participation were demonstrated successfully.

- Estimated production and monetary losses due to water erosion in the rainfed areas.
- Validated runoff and erosion prediction models in different agro-ecological regions.
- Completed zonation of Eastern Ghats and Western Ghats for macro-level planning.
- Using remote sensing and GIS in terms of resource-potential planning, delineation and characterization completed of Mahi ravines.
- Assessed status of soil erosion in coastal belt of India.
- Computed Soil Loss Tolerance Limits (T value) for different agro-ecological regions of India.
- On the degraded lands in Doon Valley, completed evaluation of shade-loving intercrops under the mango (*Mangifera indica*) and litchi (*Litchi chinensis*).
- Developed silvipastoral system under the various management practices for degraded lands.
- Identified conservation measures for new tea plantation areas.

Vertical drain in tea plantation for safe disposal of runoff in the Nilgiri hills

- Multitier cropping systems identified for conserving resources and for augmenting livelihood of small holders.
- Identified different nutrient management systems for soil health and productivity and conservation for export-oriented vegetable crops in the Nilgiris.
- Developed economic fortification of existing forest and horti land use system through medicinal plants in the ground flora.
- For Chambal ravines, intercropping systems identified for contingency crop planning.
- Methodology standardized for design of staggered contour trenches in the degraded areas.
- Evaluated techniques for assessing groundwater recharge.
- Assessed effects of conservation structures on the groundwater recharge.
- Designed and developed site-specific artificial groundwater recharge filters.
- Assessed hydrological behaviour of small watersheds and sustainability of production systems.
- Developed rain-water harvesting and recycling model for Shivalik foothills.

Recharge filter – A cost-effective technology for augmenting groundwater in arable and non-arable lands in the arid and semi-arid regions of Gujarat and Rajasthan

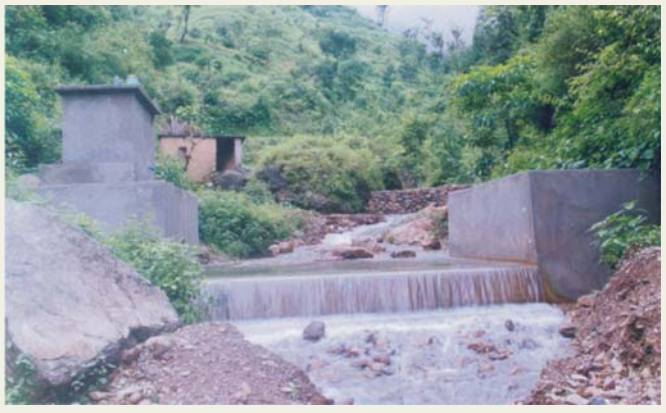
- Technology developed for rehabilitation of mine-spoil affected areas.
- Bio-engineering technology developed for torrent training.
- Geotextile-based technology developed for slope stabilization and erosion control.
- Developed cost- effective technology for treatment of *choes*.
- Combated land degradation through cycling of organic matter under different land-use systems.
- Indicators developed for assessing impact of watershed interventions in different regions.
- Multi-Objective Decision Support System (MODSS) developed for watershed development programmes.
- Integrated farming system developed for Mid-Himalayas.
- Carried out economic analysis in the Nilgiris for soil-and-water conservation measures.
- Constraints analysis and methodology carried out for transfer of technologies in the watershed management programmes.

Technologies Generated

The Institute has developed a number of resource-conserving technologies for arable and non-arable lands, which have potential to check land degradation, minimize soil erosion, preserve soil fertility, sustain productivity in the long run, conserve *in-situ* rainwater, harvest and recycle inevitable runoff, mitigate droughts, moderate floods downstream and to ensure environmental security. In the process of development, the Institute kept up the efforts for transfer of technologies through its various outreach programmes – Operational Research Projects on Watershed Management, Lab-to-Land Programmes, Model Watersheds under Macro-Management of Agriculture (Ministry of Agriculture), Integrated Wasteland Development Programme (Ministry of Rural Development), Farmer's Participatory Action Research Programme (Ministry of Water Resource), Sustainable Livelihood Security Programme (under the National Agricultural Innovation Project, ICAR), National Bamboo Mission (Ministry of Agriculture) and other programmes directly benefitting farmers. Some important technologies generated are as follows:

- Bio-engineering technology for treatment of torrents in Shivaliks.
- Water-mill based integrated farming system (IFS) for the north-western Himalayas.
- Vegetative barriers for erosion control in the western Himalayan region.
- Conservation ditching for efficient resource conservation and enhanced productivity of semi-arid Vertisols.

Conservation Technologies



Monitoring station for appraisal of soil erosion by water in lower mid-Himalayas

A good crop of *Aloe vera* in tree interspaces of *ber* orchard to sustain productivity and provide alternative source of income to farmers of ravine region

Conservation technology demonstration in tribal dominated Eastern Ghats Highland Zone of Odisha for livelihood and environmental security

Grewia optiva + Hybrid Napier for conservation and productive utilization of non-arable land in Doon Valley

Castor+greengram intercropping for delayed onset of monsoon in the south-eastern Rajasthan for resources conservation,insurance against crop failure,and maximizing production and returns

An integrated farming system comprising water mill, fish farming, poultry, pig-rearing and agriculture suitable for Uttarakhand, Jammu and Kashmir and Himachal Pradesh

- Bio-fencing technology for the Vertisols of the semi-arid region.
- Compartmental bunding for *in-situ* rainwater conservation in medium to deep black soils.
- Improved design of mechanical spurs for control of torrents in the lower Himalayas.
- Technologies for rehabilitation of mine-spoil areas in the hilly regions.
- Conservation bench-terrace system – a viable alternative to conventional system in sub-humid climates.

- Potassium application for resource conservation and enhanced productivity in the north-west Himalayan region.
- Balanced and integrated nutrient management in dominant cropping systems for enhanced crop-water productivity in the farmer's field of the north-west lower Himalayan region.
- *In-situ* sunnhemp green-manure mulching in rainfed maize- based cropping system for higher productivity.
- Utilization of degraded lands for mango-based agricultural system in the north- western Himalayas.
- Utilization of degraded lands for peach-based agri-horti system in the north-western Himalayas through micro- soil improvement.
- Improved tillage and mulching practices for resource conservation and higher yields of sorghum in red soils.
- *Jhola Kundi*: a low- cost water- harvesting technique for augmenting production of *jhola* lands in the Eastern Ghats' High Land Region of Odisha.
- Contour furrows for enhancing productivity in medium to deep black soils of the south-eastern Rajasthan.
- Stabilization of bench-terrace risers with tea-crop.
- Recharge filter – a cost-effective technology for augmenting groundwater.

Human Resource Development

The Institute conducts capacity-building courses regularly of varying durations for policy-makers, NGOs, field functionaries and farmers in the field of soil- and-water conservation and watershed management.

Since 1956, it has been organizing regular training courses of 22 weeks, twice a year, in soil-and-water conservation and watershed management for officers and graduate assistants from various state agencies and from other countries. The Institute also conducts specialized tailor-made short-term training and sensitization courses for officers/officials sponsored by various agencies in India and abroad.

Terraced fields with *kharif* vegetable crop cucumber in Fakot watershed of Uttarakhand

Integrated Wastelands Development Programme

In the late nineties, under the Integrated Wastelands Development Programme (IWDP) of the Ministry of Rural Development (MoRD), Government of India, six model watersheds located in six states, representing different agro-ecological regions of the country, were developed by the Institute following participatory approach. Under environmental benefits, runoff from the watersheds was reduced by 9% to 24% and reduction in soil loss varied from 32% to 90%, with an average of 72%. The Induced Watershed Eco-Index showed 12% improvement; indicating that additional watershed areas were rehabilitated through green biomass. Crop Productivity Index increased by 12% to 45% with overall increase of 28% in crop productivity. Crop Diversification Index (CDI) also increased by 6% to 79% in the watersheds with average increase of 22%. With higher CDI, the risk in farming could be minimized. Cultivated Land Utilization Index also improved significantly (2% to 81%) with an average value of 27%. These programmes created additional mandays casual employment (average 17,004 mandays) during the project. The average annual family income increased by 8% to 106% with an overall increase of around 49%. **The projects were found economically viable ventures having benefit:cost ratio of more than 1.14 to 1.69.**

Watershed Management

The concept of watershed planning, development and management, which was evolved and demonstrated by the Institute in 1970's, has emerged as a new paradigm for efficient management of land, water and other natural resources following bottom-up participatory approaches. The success of watershed management concept in flood and drought moderation, groundwater augmentation, increased biomass production, employment generation and improvement in the socio-economic conditions of the local people was amply demonstrated through four model operational watershed projects implemented at Sukhomajri and Nada (Haryana), Fakot (Tehri-Garhwal hills of Uttarakhand) and G.R. Halli (Chittradurga, Karnataka). *With the experience gained from these watersheds, the ICAR had entrusted CSWCRTI, Dehradun, and CRIDA, Hyderabad, during 1980-86 with the development of 47 model watersheds in 16 states in collaboration with SAUs and State Departments through active participation of the local community.* Participatory integrated watershed development programmes like NWDPRA, IWDP and NAEP were undertaken during

Best Institute Award

The Institute was bestowed with the most prestigious 'Sardar Patel Outstanding Institution Award – 2005' for the best performance in the Agricultural Research and Education

Best Annual Report Award

The Institute won the ICAR Trophy for 'Best Annual Report 2009-10' in the big Indian Council of Agricultural Research Institutes' category.

1988-91 and previously launched rural development programmes such as RVPs and FPRs, WDPSCA, EAS, DPAP and DDP were converted to participatory integrated watershed management approach from 1990's onwards, covering several thousand watersheds. Up to March 2007, **56.54 m ha were treated in the country with an expenditure of ₹19,470.57 crore under various watershed development programmes** of the Ministries and other agencies.

THRUST AREAS FOR XII PLAN

To carry out research and training in the recently developed fields using the state-of-art technology, besides on-going programmes, the following new initiatives will be taken up by the Institute during the XII Plan.

- *Platform Research*: Water, Climate Change (NICRA, NBAIM) and Conservation Agriculture
- Assessment of soil erosion through redistribution analysis of ^{137}Cs fallout in humid subtropical region of India.
- Development of sloping agricultural land technology (SALT) for resource conservation and economic upliftment.
- Resource budgeting in agroforestry by modifying WANulCAS model.
- Moisture conservation techniques for tree-borne oilseeds in Bundelkhand.
- Study influence of aromatic grasses and tree management on the soil moisture and health of bouldery lands.
- Hydrological behaviour and production potential of land-use systems in the agro-ecological regions.
- Design of trenches for degraded lands in the agro-ecological regions.
- Carbon sequestration potential of tree-based production systems in Chambal ravines.
- Soil organic carbon in transit under erosion process.
- *In- situ* rain-water harvesting for establishing fruit- tree-based agroforestry system in saline sodic Vertisol.
- Efficacy of resource-conservation measures on the bamboo productivity in the Himalayan foothills.
- Extraction of river-bed material from rivers for monitoring river morphology.
- Conversion of ITKs to MTKs on the soil-and water-conservation.
- Establishment of Advance Skill Development Centre for Soil-and-Water Conservation and Watershed Management at Dehradun headquarters with network at all the eight Regional Centres.

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Cucumber-based probiotic drink

Probiotic food contains gut-friendly microflora *Lactobacillus acidophilus, L. bulgaricus, L. reuteri, L. plantarum, L. casei, Bifidobacterium bifidus, Streptococcus salivarius, S. thermophilus* and yeast *Saccharomyces boulardi* that helps maintain beneficial microbial population in the digestive tract, which, otherwise, is destroyed due to excessive use of antibiotics. Numerous studies have shown that imbalance of friendly to unfriendly gut-bacteria can cause or aggravate various health conditions. Moreover, supplementation aimed at increasing the number of friendly gut-bacteria have been shown to help combat many types of diarrhoea, irritable bowel syndrome as well as exerting positive effects on the immune system.

Vegetables-based probiotics have a worldwide importance due to their low calorie and higher nutritional value. Cucumber is known for its digestive and cooling property on the stomach; a probiotic drink through lactic acid fermentation of cucumber using salt (2%) and mustard seeds (0.5%) has been developed.

The ready-to-serve probiotic drink supplemented with capsicum flavour, having TSS as low as 2.4 , *p*H 3.6, acidity 0.2%, tannins 6mg/100ml and 10^6 counts/ml of *Lactobacillus* sp., has high sensory acceptability (obtained 9 out of 10 marks). It could also be stored for 4 weeks without any deterioration in quality under refrigeration.

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New wheat HD 3043 released

This variety is a semi-dwarf plant type (105 cm), maturing in approximately 143 days, and, therefore, is better equipped to tolerate climatic vagaries. It is suitable for cultivation under restricted irrigated conditions of the North Western Plains Zone (NWPZ) and showed an average yield of 4.28 tonnes/ha, and a yield potential of 6.6 tonnes/ha. It yielded 7.8 to 35.4 % higher than checks, C 306, PBW 175, PBW 396 and WH 1080. The new wheat has shown a high level of resistance against stripe rusts and leaf rust, and its adult plants were found resistant against brown and yellow rusts. It had least incidence of flag smut, Karnal bunt, foot-rot as compared to its checks, including PBW 644. It has the best HMW sub-units combination for bread-making with *Glu-1* score of 8/10; is suitable for bread industries.

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Seed production of summer squash in north Indian plains

Seed production of summer squash was limited mainly to hills of Himachal Pradesh and Uttarakhand owing to the incidence of summer squash mosaic virus in the northern plains during summer.

Twenty days old seedlings of summer squash (var. Australian Green) were transplanted simultaneously under the insect-proof net-house and the open fields on raised beds with drip fertigation system. The net-house grown seed-crop was free from summer squash mosaic virus in comparison to 60% virus incidence reported under open fields. Even significantly higher number of fruits per plant, higher seed yield per fruit, higher number of seeds per fruit and higher seed yield per hectare were observed in the net-house as compared to open fields.

Insect-proof net- house cultivation of summer squash

Summer squash seed crop (var. Australian Green) during summer of 2011

Crop conditions	Date of transplanting	Average number of fruits/plant	Average seed yield/fruit (g)	Average no. of seeds/fruit)	Average seed yield (kg/ha)	Incidence of summer squash mosaic virus (%)
Insect-proof net-house	12.02.2011	1.2	57.66	406.6	691.92	0.0 %
Open field	12.02.2011	0.5	23.05	144.4	115.25	60.0%

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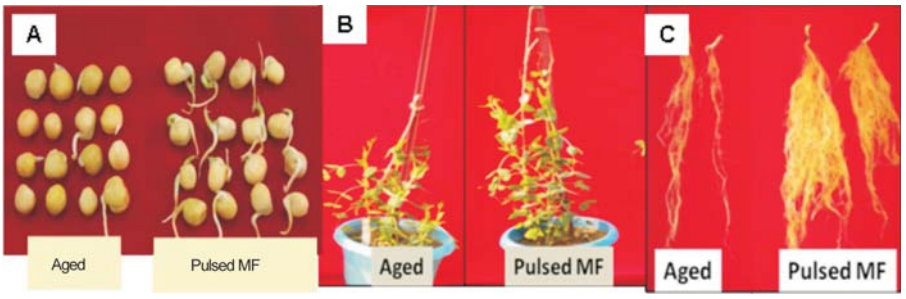
Magneto-priming for reclaiming aged garden-pea seeds

Magneto-priming (pre-sowing magnetic field(PMF) exposure to dry seeds) technology was standardized for reclaiming aged and low vigour garden-pea seeds. Naturally aged carry-over breeder seeds of 2004 produce of garden-pea Bonneville, kept under controlled storage (20°C and 40 % relative humidity), were exposed to 100mT (1 hr) pulsed magnetic field (2, 3 and 6 min on-and- off cycles). Pre- exposure with 6min on/off was found most effective; it increased germination by 8.5 % and vigour by 90 % compared to unexposed aged seeds.



Effect of pulsed magnetic field exposure on germination of seeds (**A**), growth (**B**), and root development (**C**) of garden-pea (var. Bonneville)

Plants from PMF-treated seeds showed significant increase in plant height, number of branches/plant, number of leaves and leaf area per plant and root growth compared to plants from unexposed seeds, thus ensuring establishment of plants.

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Mushroom new species, *Volvopluteus earlei*

Volvopluteus earlei spores were obtained from Andaman and Nicobar Islands and Vadodara (Gujarat), and its multispore cultures were raised at 32 ± 2°C using Malt Extract Agar medium. The strains were identified by blasting PCR amplified sequences of the ITS region of 5.8S rDNA. They were identified as *Volvopluteus earlei,* a new species, which was considered earlier as *Volvariella* sp. The strains produced fruiting bodies only on the chemically -treated chopped paddy-straw at a comparaively lower temperature (22-25°C). Fruiting bodies were larger in size and showed a predominant thick volva, which is usually very thin in *V. volvacea*.

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Indoor compost production

Methodology for the total indoor compost production using consortium of thermophilic fungi (*Scytalidium thermophilum, Humicola insolens, H. grisea*) has been standardized. In this, compounding mixture after its thorough wetting for 3 days was directly filled in the Phase II tunnel, escaping Phase I conditions.

Scytalidium thermophilum

Compost was subjected to pre-pasteurization, pasteurization and post-pasteurization conditioning. Entire operation lasted only for 10 days (3days mixing + 7days in tunnel). All the trials conducted gave excellent results. Wheat-straw to final compost ratio was 1:3.5, and there was no environment pollution using the technique.

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Chitin-fortified *Hypocrea* formulations to manage tomato root-rot

Tomato root-rot caused by *Rhizoctonia solani* is one of the major constraints for successful tomato cultivation in India; the existing commercial tomato cultivars do not provide sufficient disease resistance. Even though effective fungicides are available to manage the pathogen, but increased environmental concerns over their use have necessitated upsurge for biological disease control. Inducing plant's own defense mechanisms by prior application of biotic and abiotic inducers is a novel plant-protection strategy. Although activation of the systemic resistance has been reproducible in the laboratory for many vegetable crops by utilizing a wide range of activating materials; it is not yet a proven and widely accepted technology in fields. In a study, defense system of tomato was boosted by utilizing antagonistic *Hypocrea* strains showing significant *in-vitro* production of chitinase, β 1, 3 glucanase and protease and different concentrations of colloidal chitin.

In the greenhouse, liquid formulations containing colloidal chitin and *Hypocrea* in various combinations resulted in 54-68% disease reduction in comparison to control. The maximum control of root-rot index was observed in tomato seedlings that received root-dip application of chitin (1%) fortified *Hypocrea* formulations. Control treatments had 73% of root- rot index with majority of the plants either being stunted or dead. Significantly enhanced plant growth attributes

(plant biomass, yield, root and shoot length) and increased accumulation of total phenols (TP), peroxidase (PO), polyphenoloxidase (PPO) and phenylalanine ammonia lyase (PAL) were observed in chitin-supplemented *Hypocrea* formulation-treated plants challenged with *Rhizoctonia solani*. In the fields, the system was successful in containing tomato root- rot by 52%.

Chitin- fortified bioformulation is an effective option to manage root-rot of tomato in an eco-compatible manner, and it offers enormous practical potential in reducing tomato root-rot.

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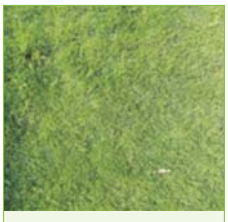
Identification of promising turf grasses for landscaping

Turf grass, earth's living skin, has an important role in cleaning environment. In urban areas, turf grasses help in reduction of carbon-dioxide emissions, mitigating heat island effect, reducing energy consumption and contributing to efforts for reducing global warming trends; 230 m^2 lawn can absorb carbon-dioxide and release enough oxygen for a family of four. The cooling effect of irrigated turf reduces amount of fuel that needs to be burned to provide electricity, which powers air conditioners. A healthy lawn can reduce rainfall runoff up to 80 times efficiently than impervious surfaces such as driveways, sidewalks, parking lots, etc and by over 60% compared to bare soil. Turf grass acts as a natural filter, reducing pollution by purifying water

Turf grass species and varieties

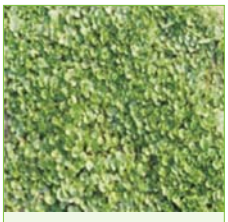


Agrostis palustris L.

GP : 93.43
SL : 7.73
RL : 3.13
RWC : 56.69
SD : 277.33
RD : 3.63

Eragrostis curvula (Schrad.) Nees

GP : 36.31
SL : 15.40
RL : 8.67
RWC : 77.02
SD : 108.00
RD : 2.83



Dichondra repens Forst

GP : 91.87
SL : 3.66
RL : 2.60
RWC : 82.56
SD : 236.67
RD : 7.33

Paspalum notatum Flugge

GP : 31.28
SL : 2.06
RL : 1.30
RWC : 65.20
SD : 128.00
RD : 8.73

Argentine bahia

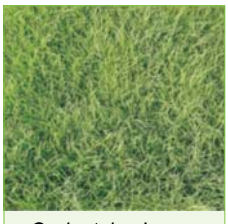
GP : 22.13
SL : 3.10
RL : 1.43
RWC : 84.14
SD : 114.00
RD : 11.33

Poa pratensis L.

GP : 76.45
SL : 7.10
RL : 4.60
RWC : 70.35
SD : 127.33
RD : 7.13

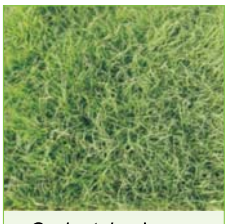
C. dactylon L.var Bargusto

GP : 45.63
SL : 12.40
RL : 6.60
RWC : 77.73
SD : 102.67
RD : 9.97



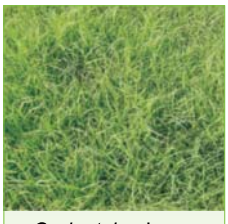
C. dactylon L. var. Palna

GP : 56.53
SL : 5.30
RL : 1.40
RWC : 68.49
SD : 215.00
RD : 11.60



C. dactylon L. var. Panam

GP : 67.83
SL : 10.70
RL : 5.63
RWC : 71.07
SD : 71.00
RD : 14.87

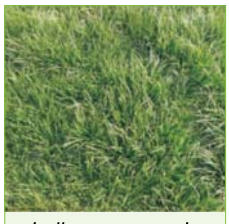


C. dactylon L.var. Panama

GP : 53.52
SL : 11.60
RL : 8.00
RWC : 72.24
SD : 57.67
RD : 15.80

C. dactylon L. var. Selection1

GP : 48.52
SL : 5.70
RL : 1.20
RWC : 54.35
SD : 110.33
RD : 5.90



Lolium perenne L.

GP : 85.28
SL : 13.66
RL : 4.73
RWC : 86.41
SD : 207.67
RD : 9.47

GP: Germination percentage; SL: Shoot length; RL: Root length; RWC: Relative water content; SD: Shoot density /10cm^2; RD: Root density /10cm^2

Turf grasses are considered an integral part of landscape ecological systems worldwide. Most of the work on turf grasses has been done in the USA, Australia, Japan, Singapore, etc. These grasses are narrow leaved grass species which form a uniform, long-lived ground cover and can tolerate traffic and low height of mowing. They are widely used in developing lawns, sport fields and aesthetic fields. Proper selection and care of the turf grass depends upon the knowledge of the environmental adaptations, cultural requirements and quality features of the grass species. Because of the increasing urbanization, consciousness about healthy environment, turf grasses will emerge as a big venture in the upcoming era. Despite enhanced interests on turfs, all available varieties of the grasses in India are imported and are often poorly adapted to prevailing climates. This impelled for beginning a collection activity of turf grass species with the ultimate goal of identifying promising materials for development of lawns suitable for various conditions.

passing through its root zone. In India, most of the turf grasses, *Cynodon dactylon*, *Poa pratensis*, *Lolium perenne*, *Dichondra repens,* are used for landscaping airports.

Research on the evaluation of different turf grass species and varieties for various growth- related qualitative and quantitative traits has been initiated under the Delhi conditions. Seeds of warm and cool season turf grasses — *Agrostis palustris* L., *Eragrostis curvula* (Schrad.) Nees, *Dichondra repens* Forst*, Paspalum notatum* Flugge*, Argentine bahia, Poa pratensis* L.*, Cynodon dactylon* L. var. Bargusto, *C. dactylon* var. Palna, *C. Dactylon* var. Panam, *C. dactylon* var. Panama, C. *dactylon* var. Selection 1 and *Lolium perenne* L. were procured from the NBPGR, New Delhi.

All turf grasses under study have exhibited fine leaf texture, excepting *Eragrostis curvula* that is medium coarse in texture; *Paspalum notatum* and *Argentine bahia* are with coarse texture and *Poa pratensis* is of medium-fine texture.

The maximum germination was observed in *Agrostis palustris* (93.43 %), followed by *Dichondra repens* (91.87 %) and *Lolium perenne* (85.28 %). High germination rate of any turf grass is important for uniform growth of any landscape area. The longest shoot was recorded in *Eragrostis curvula* (15.4 cm), followed by *Lolium perenne* (13.66 cm) and *Cynodon dactylon* var. Bargusto (12.4 cm), and *Argentine bahia* has shortest shoots (3.1 cm). There are various environmental and genetic factors, which influence shoot growth rate; one of them being ethylene, which has been reported to influence shoot growth in turf grasses under stress. *Eragrostis curvula* showed maximum root length (8.67 cm), followed by *Cynodon dactylon* var. Bargusto (6.6 cm). Rooting characteristics of turf grasses have a profound influence on their response to abiotic stresses. Turf grasses with longer root, require less water, and are more tolerant to drought. Hence, grasses like *Eragrostis curvula* and *Cynodon dactylon* can be used in drought-prone areas. The relative water content was found maximum in *Lolium perenne* (86.41) which was at a par with *Argentine bahia* (84.14) and *Dichondra repens* (82.56). High relative water content promotes photosynthetic competency in many turf grasses under various climates. Since shoot density is a key trait to assess turf quality. The highest shoot density/10cm^2 was exhibited by *Agrostis palustris* (277.33) which was at a par with *Dichondra repens* (236.67). Maximum root density/10cm ^{2} was observed in *C. dactylon* var. Panama (15.80). Because of deep root system and more root density, turf grasses can withstand considerable period of lack of irrigation. This may be important to turf managers who are faced with water shortages. However, minimum was exhibited by *Eragrostis curvula* (2.83) which was at a par with *Agrostis palustris* (3.63). *Dichondra repens* can be used as a ground cover throughout the year as it requires no mowing. This will be useful and attractive to sow between pavers of stepping stones, in places where common lawn grasses may not grow, for steep banks and other inaccessible positions.

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Nutrient-rich value-added product – Pusa Soy Nut

India produces annually about 10 million tonnes of soybean. Being rich in basic nutrients, soybean has emerged as one of the most economical and nutritious foods, having potential to combat diseases ascribed to malnutrition and undernutrition in the developing countries. The isoflavones present in the soybean can prevent risks of diseases such as breast cancer, cardiac arrest, osteoporosis, kidney stones and menopausal blues. It, however, also contains trypsin inhibitor, which significantly reduces protein digestibility. And the off-flavour associated with soy-based foods is also the prime deterrent for utilization of soybeans.

From yellow and black soybeans, plain, salted and spicy roasted soy nuts, crunchy- to- eat, have been developed. The technique of making Pusa Soy Nut is very simple. It can be started as a small-scale business with a low capital investment. Any unskilled person even can start this business for a good earning.The roasted nuts were evaluated for different quality characteristics, and were found highly acceptable on sensory evaluation. No substantial loss in the nutritional value of the soybean was observed during roasting. Nutritional properties were found higher in black soy nut than yellow soy nut.

The product is rich in quality protein and fat. It has high contents of antioxidants and flavanoids and is rich in micronutrients, Ca and Fe, and is free from any chemical preservative. The antinutritional factor trypsin inhibitor activity (TIA) has also been reduced by 90%, thus protein in the soy nut is highly digestible.

From one kg of soybean at 10% moisture content, about 925 g of soy nuts can be prepared. Economic analysis of soy nut processing indicated that at least 3 times value-addition can be done through conversion of soybean

Nutritional quality of roasted soy nuts

Nutritional parameter	Black Soy Nut	Yellow Soy Nut
Moisture, %	3.40	2.84
Protein, %	37.62	35.48
Fat, %	18.00	18.52
Carbohydrate, %	35.00	37.00
Ash, %	4.80	4.60
Fibre, %	1.70	1.60
Iron, mg/100g	13.00	11.00
Calcium, mg/100g	82.00	73.17
Flavanoid, mg/100g	95.14	46.98
Antioxidants, µM Trolox/g	35.35	28.18

into soy nut. Therefore, soy nut can be a promising and profitable venture to initiate a business. Additionally, it can be a great resource in achieving nutritional security in the country where there are serious problems due to protein malnutrition and micronutrient deficiencies.

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Nutraceutical Oyster Peptide extract (OPex) from *Crassostrea madrasensis*

Oysters are a good source of high-quality easily digestible protein and essential amino acids, and hence are quite beneficial for human health.

A peptide-based nutraceutical, OPex , from edible oyster (*Crassostrea madrasensis)* has been developed. OPex is a 100% natural blend of oyster peptides and its protein concentrate that has been scientifically proved to possess several bioactivities; mainly anti-inflammatory, antioxidant and antibacterial.

This is the first report in the country when a peptide-based nutraceutical has been developed from oyster; further experiments are underway to improve the product, and possibilities of chemical synthesis of bioactive peptides are also being explored.

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Neurons generation from caprine mesenchymal stem cells

"Neurons" have been generated from mesenchymal stem cells, which can be isolated from many body tissues, including bone-marrow.

Mesenchymal stem cells were isolated from the bone-marrow of goat and were propagated in the laboratory in a special medium. After proper characterization, these cells were placed into a specific cocktail (differentiation medium), which led mesenchymal stem cells to generate "neurons", which were judged by the expression of the neuron-specific markers.

The stem cells (MSCs) can be differentiated into different body cells such as adipocytes, osteoblasts, chondrocytes tenocytes, etc. And they can also be differentiated into functional neurons. The MSCs have a wide range of applications in the regenerative medicine as they have a strong immunosuppressive effect. These cells were routinely used for repair of damaged muscles, tendons, wounds and bone-fractures in animals.

This is the first report in India where neurons have been generated from bone-marrow derived mesenchymal stem cells, which can be used for treating neural disorders, especially of companion animals.

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WAY FORWARD

AGRICULTURE is both a consumer and a producer of energy. In India, between 1970 and 2005, total energy use showed an increase of 4-5 times for production of principal crops. Use of commercial energy also increased significantly, electrical energy from 0.19% to 38.1% and diesel from 2.4 to 18.3%, and use of chemical fertilizers from 16.4% to 29.7% (*NAAS Policy Paper,* 41). At present, there are about 18 million electric motors and 8 million diesel-engine pump-sets for lifting water; consuming annually about 95 billion kWh of electricity and 4.0 billion litres of diesel.

Energy use and energy productivity of some major crops in India

	Crop	Total Energy (MJ/ha)	Energy Productivity (kg/MJ)
Food-grains	Paddy	13,076	0.239
	Wheat	14,657	0.196
	Maize	9,956	0.215
	Sorghum	4,745	0.200
Pulses	Greengram	4,315	0.118
	Blackgram	3,870	0.105
	Bengalgram	5,464	0.190
Oil-seeds	Mustard	8,051	0.119
	Soybean	6,382	0.171
Cash crop	Sugarcane	59,192	1.039
	Cotton	9,972	0.094
	Potato	31,352	

Source: AICRP on Energy Requirement (ICAR)

Average energy consumed in crop production varies from crop to crop and within cropping systems. Sugarcane and potato are the most energy-consuming crops, and sugarcane-sugarcane and paddy-wheat-maize are the most energy-consuming crop rotations. The energy requirements for hill agriculture, horticulture and tribal agriculture would even be higher. In livestock production systems for meat, energy intensity is higher than that in crop production, and energy intensity in the ascending order is of aquaculture, poultry, swine, sheep and goat.

In this scenario, acceptability would particularly be for those farming systems that are energy neutral or are energy-positive without compromising on the agricultural productivity. Along with the development of energy-efficient equipment, resource-conservation technologies, raised-bed farming and irrigation in furrows, use of zero-till drill, rotavators, drips, sprinklers and automated irrigation and fertigation systems would contribute in large measure for conservation of energy. Enhanced use of biogas, biofuels, solar energy for cooking, water heating, crop drying, photovoltaic gadgets, wind and hydro-electric power can help meet partly energy needs.

Annually, about 1,000 mmt of crop residues and processing byproducts are produced in India, having an estimated energy potential of 17,000 MW. Traditionally, agro-residues serve as the main source for meeting domestic energy

Dr S. Ayyappan, Secretary (DARE) and Director General (ICAR)

requirements and for other thermal applications. Biofuels are likely to account for 25% of the global energy consumption by 2050. First-generation biofuels such as corn-ethanol and sugarcane-ethanol are more efficient than fossil fuels. Brazilian sugarcane-derived ethanol is 8–10 times more energy efficient. However, in India, biofuel production is strongly linked with the issue of food security, and therefore, only surplus biomass can be used for energy production.

Technological developments have indicated that high quality fuels (solid, liquid, and gaseous) can be produced from agricultural residues and byproducts. At present, indigenous technology based gasifiers (up to 500 kW capacity) are being manufactured. Recent experience at the CIAE, Bhopal, has demonstrated that viable decentralized biomass-based power generation plants of 50-100 kW capacity could be set-up to meet local demands. Solar thermal and photovoltaic technologies can be utilized effectively for crop and livestock husbandry under cold climates, on-farm drying and cooling of agricultural produce, and also for irrigation in remote areas. There is need only to right-size these technologies for wider adoption.

Efforts need to be intensified for converting surplus biomass into bio-ethanol and bio-diesel on a globally competitive scale. Of all options, direct substitution of fossil fuels by bioenergy represents the largest and the most sustainable alternative. Synergy of fossil-fuel-based power plants and crop-production systems, especially employing protected agriculture, can improve considerably carbon sequestration, thereby reducing carbon foot print. In the XII Plan, the Council has proposed two research consortia platforms – Waste Management and Agri-energy. It is expected that research outcomes would go a long way in supplementing energy. In addition, bioenergy offers opportunities for generation of employment in rural areas.

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