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# ICAR NEWS

A SCIENCE AND TECHNOLOGY NEWSLETTER

## RESEARCH UPDATE

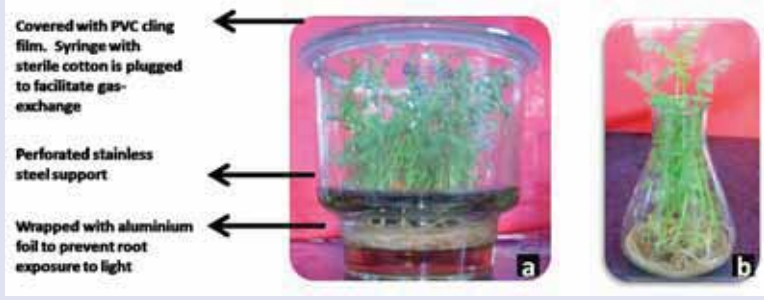


## PROMISING TECHNOLOGIES

# Mass collection of chickpea root-exudates with a novel technique

Chickpea (*Cicer arietinum*) is an important legume-crop grown in rainfed areas, and its economic success relies on its symbiotic nitrogen fixation with root-nodulating bacterium, *Mesorhizobium ciceri*. In root-exudates, flavonoids and isoflavonoids are of the central importance in the nodulation process of legume-host. Among various flavonoids synthesized by the plants, host specificity of legumes is mediated by a specific type of flavonoid that can induce or suppress nodulation on a particular host. Chickpea root-exudates composition is influenced by the genotype, and which in turn determines the symbiotic efficiency of *Mesorhizobium*. Quantitative and qualitative distribution of flavonoids in different genotypes can be a tool for selecting perfect combination of chickpea genotype and *Mesorhizobium*. Hence an attempt was made to determine genotype-mediated variations in root-exudates (particularly flavanoids) in chickpea genotypes with the varying nodulation potential.

A pot experiment was conducted to study the influence of chickpea genotypes on the symbiotic potential of *Mesorhizobium*. Two chickpea genotypes (BG 256, ICC 4948) were inoculated with




Hydroponic set-up for mass recovery of chickpea root-exudates under *in-vitro* conditions: *(a)* a newly developed method – simple, with a single collection point, devoid of external contamination; *(b)* conventional set-up – requires pooling of leachates from several replications, frequent replenishment of nutrient solution, and this is prone to external contamination also

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Interaction of *Mesorhizobium ciceri* with chickpea genotypes under phytotron condition

| | Nitrogenase activity (n moles $C_2H_4$ produced/ mg dry weight nodule/h) | N uptake (mg /plant) |
|---|---|---|
| BG 256 | 407.47 | 16.13 |
| ICC 4948 | 55.31 | 13.66 |

*Mesorhizobium ciceri* (F-75). A significant difference in nitrogenase activity as well as N uptake was observed in genotypes with *Mesorhizobium* inoculation. Nodulation and N uptake were found positively correlated with nitrogenase activity. The results clearly indicated that variations in symbiotic potential of *Mesorhizobium ciceri* were governed by the host genotype.

To assess genotype-mediated variations in the composition of root-exudates, a simple hydroponics set-up was done for mass collection of chickpea root-exudates in *in-vitro*. Chickpea-seeds were surface sterilized and were pre-germinated on water-agar. Pre-germinated seeds were transferred onto sterile stainless steel perforated plate placed in a pre-sterilized glass desiccator containing 150 ml of sterile Jenson's nutrient solution. The lower part of the desiccator was wrapped with aluminium -foil to avoid direct exposure to light of roots. The top surface of the desiccator was covered with sterile PVC cling-film for direct light exposure and to avoid contamination. A syringe plugged with sterile cotton was inserted to regulate gas exchange. This set-up was kept in the greenhouse under natural light. After 4 weeks, exudates (@ 60 ml) were collected, centrifuged at 12, 000 rpm for 10 min and supernatant was filtered through Whatman No. 1 filter paper. The sample volume was reduced (@ 5 ml) under vacuum evaporation, passed through 0.45 µm syringe filter and stored at –20° C for further use.

This simplified technique is unique in terms of its suitability for mass collection of root-exudates from large seeds. The collection in this manner can check non-specific leakage of metabolites by physical damage on the root surface. This method can be applied for near-perfect analyses of all low molecular compounds — flavonoids, amino acids, sugars and organic acids at a single collection point. Mass collection of root-exudates can minimize errors accrued by frequent sample collections.

Root-exudates volume was reduced in rotary evaporator and flavanoid(s) component was extracted with ethyl acetate and analysed using HPLC (high performance liquid chromatography). Significant difference in flavonoid(s) profile was noticed in root- exudates of both the genotypes. Concentration of flavonoids (genistein - 905 ppm and formononetin - 3,134 ppm) was high in BG 256, which showed high nitrogenase activity. These two flavonoids were below detectable limit in ICC 4948, exhibiting low nitrogenase activity. The results indicate that changes in flavonoids composition of root-exudates may be responsible for differential nodulation potential of chickpea genotypes, as they act as chemo-attractants for *Mesorhizobium*.

Flavonoids activate NodD dependent up-regulation of *nod* genes that synthesize nod factor required for symbiotic event. Assessment of variability in symbiotic potential is important to select high-nodulating lines for variety improvement programmes. In addition to flavonoids, realistic analyses of other low molecular compounds including sugars, amino acids and organic acids in a single sampling unit can also be done. The consistent performance of this simple technique can turn this to be the method of choice for comprehensive analyses of root-exudates composition in a given environment.

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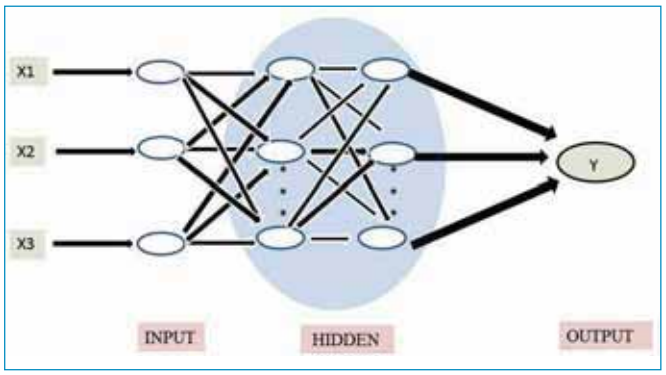
# Artificial Neural Network for early prediction of post-thaw bull-semen motility

Based on the Artificial Neural Network (ANN) methodology, a concept has been developed for early prediction of post-thaw motility (PTM) of bull-semen before the freezing. Semen samples collected from 82 mature crossbred (Holstein-Friesian × Sahiwal) bulls, maintained at the Bull Rearing Unit of the Institute from December 2010 to November 2011, were used for the study.

Immediately after collection, ejaculates were stored at 34°C in water -bath to evaluate fresh semen quality traits, including semen volume (ml) and sperm concentration




ANN model. X1: Number of ejaculates, X2: Volume of semen, X3: Spermatozoal concentration, Y: Post- thaw motility

Descriptive statistics of whole data set

| Traits | Count | Mean | Max | Min | SD | CV% |
|---|---|---|---|---|---|---|
| No. of ejaculates | 82 | 110.061 | 327 | 10 | 76.02539 | 69.0757 |
| Volume | 82 | 4.442608 | 9.127862 | 1.574286 | 1.190896 | 26.80624 |
| Concentration | 82 | 1024.635 | 1879.784 | 291.6364 | 300.1367 | 29.29207 |
| PTM% | 82 | 33.66077 | 54 | 10 | 12.40201 | 36.8441 |

Phenotypic correlation matrix between different traits

| Traits | No. of ejaculates | Volume | Concen-tration | PTM% |
|---|---|---|---|---|
| No. of ejaculates | 1 | 0.3274 | 0.0398 | 0.2259 |
| Volume | | 1 | -0.1947 | 0.4602 |
| Concentration | | | 1 | 0.2114 |
| PTM% | | | | 1 |

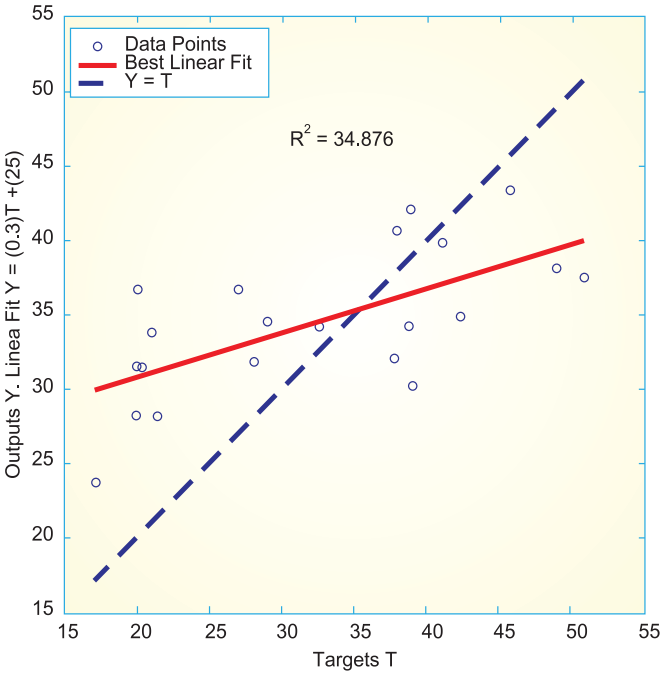
(millions/ml). A multilayer feed forward network with back propagation of error learning mechanism was developed for predicting PTM. The Neural Network Toolbox (NNT) of MATLAB 7.8.0 was used to develop ANN models. ANN models were developed with one or two hidden layers, with different number of neurons (2-20) in each layer, and a maximum of 2,000 epochs were fixed with a goal of 99% accuracy. The training data set used to train the network and the model consisting of two hidden layers having 15 and 12 nodes in the first and second layer, respectively, gave maximum prediction accuracy of 38.58 %. When the model was validated with the test data set, a maximum $R^2$ value of 34.87 was obtained. The correlation between actual and predicted PTM was found 61.85 %. The higher $R^2$ value and lower RMSE (root mean square error) estimate obtained for ANN revealed that its prediction efficiency for both training and test data sets was comparatively higher than the MRA model. As it is important to avoid freezing of poor quality semen, the prediction of PTM before freezing may help discard it, which would reduce wastage of time, money and skilled labour. Based on the results it is concluded that ANN methodology can be used for prediction of PTM in crossbred bull-semen.

Performance of selected ANN models developed for prediction of post-thaw motility (%) in crossbred bulls

| No. of hidden layers | No. of neurons | | $R^2$ value |
|---|---|---|---|
| | hidden layer 1 | hidden layer 2 | |
| 1 | 16 | | 27.14 |
| 1 | 19 | | 28.94 |
| 2 | 10 | 5 | 26.06 |
| 2 | 1 | 5 | 27.05 |
| 2 | 15 | 7 | 28.93 |
| 2 | 5 | 5 | 28.93 |
| 2 | 4 | 10 | 29.37 |
| 2 | 7 | 7 | 29.41 |
| 2 | 3 | 6 | 29.81 |
| 2 | 20 | 15 | 29.93 |
| 2 | 13 | 2 | 34.45 |
| 2 | 15 | 5 | 34.48 |
| 2 | 15 | 12 | 34.87 |

Comparing effectiveness of MRA (Multiple Regression Analysis) and ANN models

| Criteria | Training data set | | Test data set | |
|---|---|---|---|---|
| | MRA | ANN | MRA | ANN |
| Number of records | 61 | 61 | 21 | 21 |
| RMSE | 10.8079 | 10.0887 | 8.6168 | 8.4353 |
| $R^2$-value | 29.5163 | 38.5838 | 32.0434 | 34.8761 |




Regression of ANN predicted (A) on the actual (T) PTM values of bull-semen for test data set

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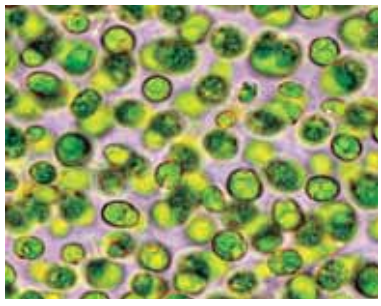
# Microalgae – a sustainable feed source for biodiesel

Energy requirements of the world are met mainly through fossil fuels — gasoline, petroleum-based diesel and natural gas. Such resources are insufficient for meeting future energy demands and also challenges faced by the rapid growth in human population and technological developments. This anticipated decreasing supply of fossil fuels coupled with environmental safety concerns has encouraged use of bio-based fuels as renewable energy sources.

Microalgae represent excellent candidates for fuel production because of the advantages of their higher photosynthetic efficiency, larger biomass production and faster growth, compared to other energy crops. They can provide diverse types of renewable biofuels– including biomethane (by anaerobic digestion of algal biomass);biodiesel (from microalgal oil); bioethanol (by fermentation of microalgal carbohydrates); and photobiologically produced biohydrogen. Technology for biodiesel production has been known for many years, and it is noteworthy to mention that high quality oil produced by these microalgae can be converted to biofuel using the existing technologies.



Lipid-rich *Chlorella sorokiniana,* and its mass production

Three microalgae, *Chlorella sorokiniana*, *Botryococcus* sp. and *Chlorella* sp., were evaluated for lipid yield and biodiesel quality parameters under outdoor cultural conditions. They were initially grown in plastic-trays and were further scaled up in raceways with commercial medium containing NPK fertilizers (i.e., urea, single superphosphate and muriate of potash) in appropriate ratio in greenhouse at 25°C and natural sunlight (60.8-67.5 µmol photons/ $m^{-}$/s). Batch cultures were maintained by inoculating a known volume of fresh medium every 2 weeks for use as a seed-culture. Biomass was harvested after 21$^{th}$ day. Maximum biomass productivity of *C. sorokiniana, Botryococcus* sp. and *Chlorella* sp .was recorded to be 60.8, 49 and 46 mg/ L/ d, respectively, on the dry-weight basis under optimum cultural conditions in the mass-production system. Lipids were extracted from dry cell weight using modified Bligh–Dyer extraction method, followed by transesterification with sodium methoxide using modified protocol. The total lipid content of *C. sorokiniana, Botryococcus* sp. and *Chlorella* sp. was in the range of 410 to 450 mg/ gDW (41–45% w/w), 330 to 410 mg / gDW (33–41% w/w) and 270 to 301 mg/ gDW (27–30% w/w).

Extracted lipids from three strains were characterized using FTIR (Fourier Transforms Infrared Spectroscopy) and $^{1}H$ and $^{13}C$ NMR(Nuclear Magnetic Resonance), and the specific peaks indicated presence of triacylglycerol in the lipids. After transesterification, the samples were further analyzed using GC-MS, FTIRand $^{1}H$ and $^{13}C$ NMR to check quality in terms of biodiesel. Fatty acid methyl esters (FAME) analysis illustrated that methyl palmitate and methyl oleate, comprised almost 69%, 63% and 71% of the total FAMEs in *C. sorokiniana, Botryococcus* sp. and *Chlorella* sp., respectively. These values comply with the standards of biodiesel quality. Such selected microalgal strains can prove promising feed-stocks for biodiesel production.

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# Grassland development on the common property resources for more fodder

On about 70 hectares in village Soda, district Tonk, Rajasthan, grassland development was initiated on the common property resources (CPR) with the collaborative efforts of *Jal Grahan Samiti*, Soda, and the Indian Institute of Rural Development (an NGO), Malpura, and Western Regional Research Station (IGFRI), Avikanagar. Protection of the area, development of water- harvesting structure, removal of unwanted bushes and required earth-work

was done by *Jal Grahan Samiti* during 2013. The IGFRI provided technical support along with the planting materials of anjan grass (*Cenchrus ciliaris)*, dhaman grass (*C. setigerus)*, dinanath grass (*Pennisetum pedicellatum*), hamata (*Stylosanthes hamata*) and fodder tree soobabul (*Leucaena leucocephala*), ardu (*Ailanthus axcellsa*) and neem (*Azadirachta indica*) for overall and systematic development of the area.

The establishment of grassland through improved grass varieties was undertaken during *kharif* 2014. Ten random cutting samples of 5m × 5 m area were taken for estimating productivity of different grasses at maturity. The estimated average dry fodder productivity was 4.3 tonnes/ha for improved grasses and 2.4 tonnes/ha was for natural grasses. Thus the productivity of the improved grassland area enhanced by 1.7 times during establishment year, and it is expected to enhance about three times in the subsequent years. *Cenchrus* grass being range species, regenerates quickly even with small quantity of moisture throughout the year, and is found sufficient for grazing of animals. Initially, the grassland would be used under cut- and- carry system for fodder production. After establishment of the grassland (one year), grazing of sheep would be allowed. Cattle would be allowed for grazing after 3 years, ensuring establishment of tree-saplings. The modus operandi for utilization of all kinds of produce from the grassland would be finalized by the *Jal Grahan Samiti*. Seed production of grasses has been started in the participatory mode, and would be used for development of grasslands in other areas. Tractor-operated portable belling machine demonstrations were done for belling of grass produce at the site. Belling of the grass reduced volume of the grass up to one-third; and thus it can be stored in a lesser area, reduce transportation cost and become easy in handling. A MOU has been signed between *Jal Grahan Samiti* and the IGFRI for development of this site as a model grassland. The site will be used as resource for conducting training and exposure to representatives of *Goushalas, Jal Grahan Samities,* watershed department, forest department and other clientele agencies.

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# Low-cost bio-sorbents for amelioration of heavy metal contaminated wastewater

Two types of cation-exchange bio-sorbents were developed by chemically modifying water-hyacinth leaf biomass (WLB) powder and *Azolla* biomass through esterification with sodium hydroxide (NaOH), followed by citric acid treatment. The modified bio-sorbents were characterized by determination of active sites of adsorption and point of zero charge (PZC) estimation, and were used for removal of Cu (II) ion from aqueous solution. It has been found that both bio-sorbents are very effective in removal of copper to the tune of more than 95%. Kinetic test demonstrated that sorption equilibrium was reached within 10 min and 25 min for WLB and *Azolla* biomass, respectively. Equilibrium data were analyzed using Langmuir, Freundlich, Dubinin – Radushkevich and Temkin isotherm models, and found that biosorption data were better fitted by the Langmuir and Temkin adsorption isotherm models as compared to other models for both the bio-sorbents. Regeneration studies showed that bio-sorbents can be effectively utilized for recovery of Cu(II) ions and both bio-sorbents can be reused up to five cycles. Potentiality of these biosorbents as a filtration medium for wastewater amelioration and their utilization in developing low-cost recirculatory aquaculture system needs to be explored.

Water-hyacinth leaf biomass (WLB) powder

*Azolla* biomass

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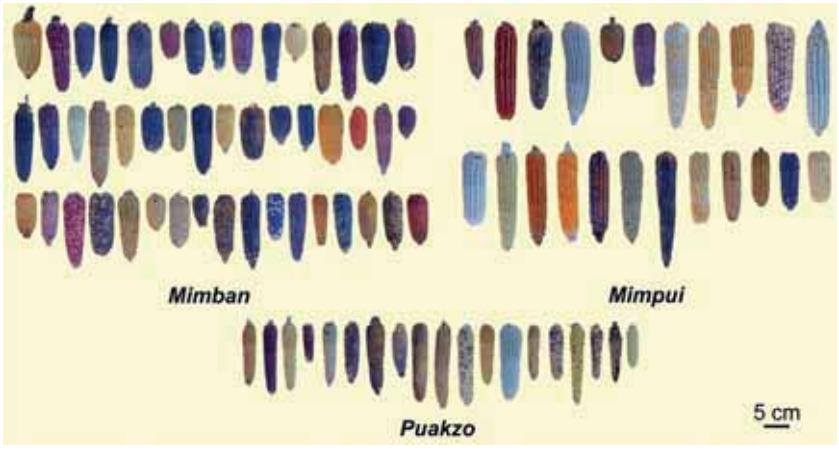
# Maize landraces from Mizoram

Even though diversity of maize is impressive in Mizoram, but it has largely remained underexplored and uncharacterized. Till 2013, Mizoram maize landraces conserved in the National Gene Bank were only 271 accessions, and a very few were collected from the remote areas of the then Chimtuipui district (lands of *Mara, Lai* and *Chakma*).



Variability in cob shape, size and colour in maize landraces from Mizoram

An exploration was undertaken during December 2014 for collection of maize germplasm from the state, and a total of 243 maize accessions were collected from six districts: Lunglei (76), Lawngtlai (47), Saiha (36), Serchip (30), Aizawl (28) and Kolasib (26). Of these, 108 accession are *Mimban* (sticky/ starchy), 55 are *Mimpui* (have large cobs, *pui* = great), 31 are *Puakzo* (popcorn type, also known as *Kan puah*) and the rest 49 represent various maize landraces.

Maize is locally known as *Vaimim* in Mizoram. Farmers used to categorize/ name landraces based on the grain colour (*sen* – red, *eng* – yellow, *var* – white, *dum* – black and *tial* – variegated), cob size (*te* – small, *lian* – big and *sei* – long) and crop duration (*tlai* – late and *mah* – early). A few sweet (*thlum*) corn landraces were also collected from the districts of Serchip, Lawngtlai and Lunglei. Other notable landraces were *Char hang* (boiled cobs are eaten), *Liam diak*, *Tharrang* (three months crop), *Mimdum* cultivars with 4-5 cobs/plant and landraces such as *Miria, Darngawn, Chhingzo, Matu vaimim, Char hang, Ram thim, Liam diak, Thlathum, Zongam, Tharkhlei, Razna* (introduction from Myanmar), *Tharrang, Chalthang, Tiachai, Lalchawngpui* and *Tlang lao*.

Farmers generally preserve landraces for the next year sowing by storing selected healthy cobs just above the fire place, avoiding overheating and damage to embryos. Fumes from the fire usually keep the seeds free from attack of insect-pests and fungus.

Significant change in pattern of annual precipitation has been observed in the recent- past in Mizoram. As maize is grown as a rainfed crop (March-October), uneven distribution and deficiency of monsoon rainfall had negative impact on maize production. The area under maize is decreasing as farmers are preferring cultivation of pulses and sugarcane over maize.

The maize landraces collected from this exploration along with those conserved in the National Gene Bank may serve as a valuable resource for selecting genotypes tolerant to drought and heat stress through precise phenotyping and genomics approaches.

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# Conserving Bachaur – The native cattle of Bihar

India possesses 199 million of cattle population —166 million indigenous and 33 million crossbred, and the country has been enriched with 37 cattle germplasm that are registered with the National Bureau of Animal Genetic Resources, Karnal, Haryana.

Bachaur in Bihar is one of the recognized indigenous breeds of cattle in India; distributed in the Gangetic plains of north Bihar, comprising Sitamarhi, Darbanga, Sheohar and Madhubani districts. The breed has acquired its name, 'Bachaur' ,from its breeding tract, which falls under erstwhile Bachaur parganas of Bihar. Being one of the heavily populous states of India, the economy of Bihar depends totally on agriculture and allied sectors. Bachaur plays a crucial role in converting agricultural byproducts into efficient draught power, and thus has propelled livelihood status of livestock-farmers slowly into a comfort zone.

Bachaur breed is small in stature. Its coat colour is generally white with splashes of grey hair on the forehead and on the neck region. There are, however, some cattle in the breeding tract with varying degrees of brown-coat colour also.

*a*.Bachaur cow *b*.Bachaur bull *c*.Bachaur calf *d*.Bachaur bullock

Average height at withers, body length and at chest girth of the adult Bachaur cattle, pooled over different age groups, is found to be 119.23±0.47 cm, 116.99±0.48 cm and 150.88±0.55 cm for males, and 112.53±0.25 cm, 109.71±0.25 cm and 140.46±0.32 cm for females, respectively. Body weight as estimated based on Shaeffer's formula ranges from 173.83 kg to 308.65 kg for Bachaur bullocks and 167.20 kg to 253.48 kg for Bachaur cows. Its body weight indicates that it is one of the small-sized cattle breeds of India. Incidentally, most of the species of livestock and their breeds distributed in the Eastern region of the country are smaller or medium sized, and Bachaur is no exception.

The mean lactation yield of Bachaur cows is estimated at 752.10±5.82 kg with an average peak yield of 4.70 kg per day, depending on the resources available with farmers. The range of lactation length of the cows varies from 220 days to 280 days in the breeding tract with a mean of 258.79±2.26 days. Considering its small stature, milk production potential of Bachaur cannot be rated inferior; though Bachaur is considered as one of the draught purpose cattle-breed.

Though Bachaur cows fulfills household milk requirement of cattle-farmers in the breeding tract, the main purpose of keeping these cattle is its draught power. Most of the farmers in the breeding tract depend fully on Bachaur cattle for farm operations as the trained bullocks can be used continuously for 6 to 8 hours in a day for ploughing. Besides farm operations, Bachaur cattle fetches high price in the local market. Its dung-cakes are widely used for fuel after drying.

Bachaur cattle is inseparable from farmers of the breeding tract due to its draught power, but chaotic breeding system prevailing there raises question on its long-term survivability. Various operators, organized and unorganized, public and private individuals, operating in the breeding tract of Bachaur, are opting for artificial insemination that would lead to its genetic dilution, and subsequently would endanger the breed. Hence, it is high time to take up needed steps for preserving Bachaur germplasm by setting-up an organized farm and establishing proper linkage of Bachaur farmers with farm for exchange of Bachaur genetic material for continuous development of the breed.

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# Probiotic soymilk powder

Soymilk fermented with the appropriate doses of probiotic bacteria has been successfully dried by spray-drying as well as by freeze-drying to have probiotic soymilk powder. This fermented milk provides numerous health benefits like reduced flatulence, no undesirable pathogens, improved flavour of the product, improved texture and other advantages over non-fermented milk. Unpasteurized fermented milk also provides protection against intestinal infection and helps replenish intestinal flora. Fermentation of soymilk using *LAB* strains has been found providing probiotic characteristics to soymilk powder. Addition of cryo-protectants during freeze-drying and spray-drying has been found to enhance survivalability of probiotic cultures in soymilk powder. A higher survival has been observed when spray-dried fermented milk was stored in a sealed aluminium foil bag at 4°C. During storage at 4°C for 6 months, the viability of all samples was stable with viable cell count of $10^7$ -$10^8$CFU/g. Probiotic soymilk powder also exhibited antioxidant, antimicrobial, bile tolerant and acid tolerant properties.

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# ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram

***Mission: To integrate root and tuber crops as a sustainable farming system component to ensure food and nutritional security of the Nation, and livelihood improvement of the rural population***


**Mandate**

To generate research information on tropical tuber crops that help enhance productivity and improve utilization potential.

To facilitate production and utilization of tropical tuber crops in the country, the ICAR-Central Tuber Crops Research Institute (ICAR-CTCRI), an ISO (ISO 9001:2008) certified research institution, was established at Thiruvananthapuram in 1963 under the aegis of the Indian Council of Agricultural Research (ICAR). The Institute has a Regional Centre at Bhubaneswar, Odisha, which was established in 1976.

## INFRASTRUCTURE

The Institute has state-of-the-art laboratories for DNA Sequencing, Molecular Marker Study, Tissue Culture, Bioinformatics, Soil Fertility and Plant Nutrition, Soil Physics, Geoinformatics, Transgenics, Virus Diagnostics, Biopesticides, Food Processing and Starch Biochemistry.

It has an established full-fledged Local Area Network and VPN connectivity for Global Access to the servers. Its Agricultural Knowledge Management Unit (AKMU) has 17 workstations with centralized facilities for printing, scanning etc. The Unit has become one of the nodal points of the National Knowledge Network of India (NKN) for effective sharing of scientific resources.

The group called tropical "root and tuber crops" consists of both dicots like sweet- potato (*Ipomoea batatas*), cassava/tapioca (*Manihot esculenta*) and monocots like yams (*Dioscorea* spp.) and edible aroids like taro (*Colocasia esculenta*), tannia (*Xanthosoma sagittifolium*) and elephant foot- yam (*Amorphophallus* sp). Technically, the important edible products harvested from yams are tubers; from cassava and sweet- potatoes are roots while from aroids are corms or cormels.

Root and tuber (R&T) crops are the third important food crops for mankind, after cereals and legumes, and are the staple or subsidiary food for about one-fifth of the world population. Individually, cassava, sweet- potato and yam rank among the most important food-crops worldwide, and in terms of annual volume of production, cassava and sweet-potato rank among the top 10 food-crops produced in the developing countries. R&T crops contribute to about 6% of the world's dietary calories, and are also an important source for animal- feed and as a raw material for industrial products. Many of the poorest farmers and most undernourished households in India depend on R&T crops as a contributing one, if not the principal source to food and nutrition. These farm households value R&T crops as these give stable yields under conditions in which other crops generally fail.

Genetic analyzer model 3500

Graphite furnace AAS

FT-NIR spectrometer, Perkin Elmer, Frontier

### ICT Initiatives

Three crop models — SPOTCOMS, MADHURAM and SIMCAS — have been developed to predict accurately crop growth and yield in response to environmental factors such as water stress, nutrient application etc. And databases developed by the Institute include TUBERSEARCH and TUBERHELP.

The Institute has also developed decision support systems for site-specific nutrient management (CASSNUM), variety identification (VARIETY FINDER) as well as for pest, disease and nutrient deficiency identification (OUSHADHAM and CASSAVAPROTECTOR). Tuber information cafe is another online tool that gives all vital and necessary informations about all tuber crops cultivated in India. Online cassava market is a very novel online tool, which is a virtual meeting place for buyers and sellers of cassava and cassava products. This enables them for interaction and sale of their products. A CASSAVAEXPERT SYSTEM has also been developed that provides solutions to various problems faced by cassava-farmers. The latest application of ICT in tuber crops R&D is the development of an electronic crop (E-crop) ; an electronic equipment to give real-time agro-advisory to clients.

Besides, the Institute has a modern library with more than 18,000 volumes, and with the current subscription of 42 journals.

## SALIENT ACHIEVEMENTS

### Germplasm accessions

The Institute has been recognized as the national germplasm repository of tropical tuber crops by the ICAR-NBPGR. It maintains more than 5,700 accessions as *ex-situ* in field gene bank and *in-vitro* active germplasm collection of 1,923 accessions of cassava, 1,437 of sweet-potato, 1,146 of yams, 986 of aroids and 272 of minor tuber crops. Along with, about 1,250 accessions of tropical tuber crops are being maintained *in-vitro* also.

### High-yielding varieties

Fifty-three high-yielding varieties of different R&T crops developed and released include 16 of cassava, 16 of sweet-potato, 12 of yams, 6 of taro, 2 of elephant foot-yam and 1 of Chinese potato. High-yielding and high-starch containing cassava varieties, H165 and H226, have contributed in a big way in the establishment of starch and sago industries in and around Salem district of Tamil Nadu. For starch industry, three triploid varieties — Sree Harsa, Sree Athulya and Sree Apoorva — with high dry matter and extractable starch content were developed. And even the first cassava mosaic disease (CMD) resistant variety, Sree Padmanabha, was developed and released by the Institute. Short -duration cassava varieties, Sree Jaya and Sree Vijaya, ideal for cultivation in rice fallows of Kerala, have also been developed by the CTCRI. Highest productivity of cassava in the world of 36 tonnes/ha is a testimony of good quality Indian varieties.

High-yielding varieties of sweet-potato, Gouri and Sankar, released by the Regional Centre, Bhubaneswar, are suitable for cultivation in the eastern and north-eastern states. A high-carotene sweet-potato variety, Sree Kanaka (β-carotene 9-10 mg 100 g fresh weight), was released for popularizing in poverty stricken, nutrient-deficient regions of the country. An anthocyanin-rich greater yam variety, Sree Neelima, released is with good culinary and nutritive quality. Sree Dhanya is a novel dwarf white yam which reduces cultivation cost due to its non-climbing habit. *Sree Shilpa, with its medium-sized, smooth and oval tubers and excellent cooking quality, is the first hybrid of greater yam, produced in the world*. A high-yielding greater yam accession, DA 199, with an average yield of 40 tonnes/ha has been

H 226, most important industrial cassava variety

Sree Kanaka, a high-carotene sweet-potato variety

Sree Athira, first elephant foot-yam hybrid in the world

released under the name Sree Karthika. Sree Padma with high yield (41 tonnes/ha) and Sree Athira, the first hybrid, are improved elephant foot- yam varieties, while Sree Kiran is the first hybrid taro, with good cooking quality, released in India yielding 17.5 tonnes of tubers/ ha.

Muktakeshi, a taro variety resistant to leaf-blight

## Production technologies

Management practices for intercropping cassava with coconut, arrowroot with coconut, yams with maize, and yams and edible aroids with coconut, banana and rubber have been standardized. Precision nutrient-management technologies such as drip fertigation for cassava and elephant foot -yam and drip irrigation for elephant foot-yam have been developed. Soil-fertility management practices for all these crops have been substantially improved with the development of soil-test based fertilizer recommendations as well as site-specific nutrient management (SSNM) practices, developed using calibrated QUEFTS model. The model based approach resulted in the development of nutrient recommendation zonation maps as well as customized fertilizers for cassava, elephant foot- yam, sweet-potato and yams.

The long- term fertility experiment in cassava clearly proved superiority of balanced integrated application of farmyard manure @12.5tonnes/ ha along with NPK @ 100:50:100 kg/ ha in enhancing tuber yield, tuber quality and soil chemical properties. Research work conducted

### Techno Incubation Centre

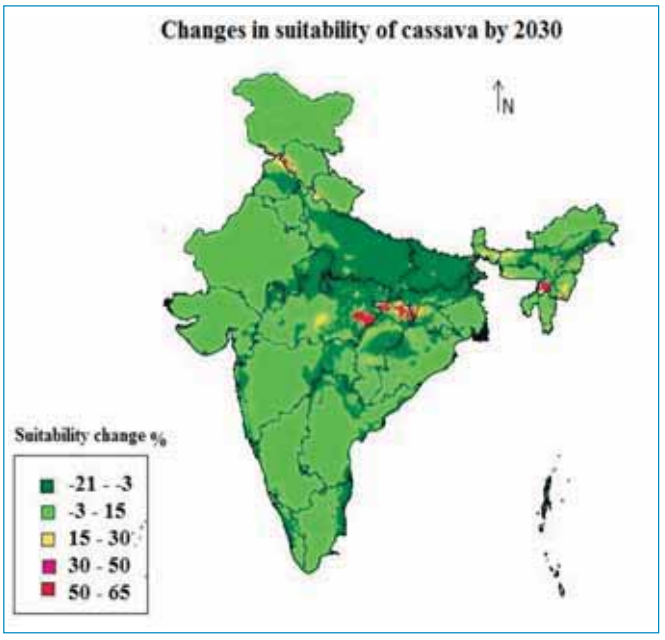
The ICAR-CTCRI received financial support of ₹10 million from the Govt of Kerala under the Small Farmers' Agribusiness Consortium for setting-up of the Centre.

The Centre has three major processing units — (i) Flour Production Unit (FPU); (ii) Snack food Manufacturing Unit (SMU); and (iii) Fried Chips Manufacturing Unit (FCMU) — to undertake the following activities: (a) edible grade flour production from cassava- tubers and its further processing into value-added snack foods, including fried snack foods and oil-free extruded ready-to-eat snacks; (b) production of low glycaemic pasta products as food for diabetic and obese people as well as nutritionally enhanced pasta for children and youth; and (c) manufacturing fried cassava-chips and strips with good texture and taste, respectively.

Training is also a major activity at the Techno-Incubation Centre. The prospective entrepreneurs would also get an idea on the essential infrastructural requirement for setting-up a processing



since the past 12 years helped develop organic farming technology for cassava, yams, elephant foot- yam and taro. Low-input management strategy was developed for cassava; and a K-efficient cassava variety has been released as Sree Pavithra. Nutrient-rich organic manure through composting of cassava starch factory solid waste (thippi) has been developed. Zeolite materials with high cation exchange capacity have been synthesized from fly-ash for enhancing soil nutrient retention. Methodology for climate change impact assessment of cassava, sweet-potato, elephant foot-yam and yams, using ECOCROP model, has been developed, and the model was calibrated for these crops for Indian conditions using geoinformatics tools.




## Protection technologies

In these crops as being vegetatively propagated, biotic causal agents are transmitted/transported very easily, and this leads to serious problems. The important biotic constraints are mosaic disease, tuber-rot, mite, whitefly and mealy bug in cassava; weevil in sweet-potato; anthracnose and mosaic in yam; leaf-blight in taro; collar-rot and mosaic in elephant foot-yam. Packages for eco-friendly management of important fungal diseases like cassava tuber-rot, elephant foot-yam collar-rot, taro blight and for insect-pests of sweet-potato, cassava and stored product have been developed.

Sweet-potato variety, Sree Bhadra, has been identified as a trap-crop for nematode management. Insecticidal principles from secondary metabolites of seeds, leaves and tuber-rinds of cassava have been isolated and

### Organic Farming of Tuber Crops

Series of field experiments were conducted to compare varietal response, yield, quality and soil properties under organic farming over conventional system for these crops. The industrial as well as domestic varieties of cassava, the elite and local varieties of elephant foot-yam and taro and the three species of *Dioscorea* (yams) responded similarly to both the systems. Elephant foot-yam was the most responsive to organic management, followed by yams and cassava. Organic management promoted yield by 10-20% . The tuber quality improved with higher dry matter, starch, crude protein and K, Ca and Mg contents. In taro, slight yield reduction (5%) was noticed under organic farming. The anti-nutritional factors, oxalate content in elephant foot-yam and cyanogenic glucoside content in cassava, lowered by 21 and 12.4%, respectively, in organic farming. Cost-benefit analysis of elephant foot-yam under organic farming indicated net profit 28% higher with additional income of ₹ 47,716/ ha . A learning system has been developed, using artificial neural networks (ANN), to predict performance of elephant foot-yam organic production system under various agroclimates.

Organically grown cassava

Organic elephant foot-yam tubers

Cassava mosaic disease

Cassava tuber-rot

Mealy bug

formulated as biopesticides against a spectrum of insect-pests of field crops. Varieties of sweet- potatoes have been identified against weevils, and kairomones responsible for chemo-signalling to weevils have also been isolated.

Diagnostic techniques have been standardized for important viral and fungal diseases — cassava mosaic disease, cassava tuber-rot, sweet-potato feathery mottle, sweet-potato leaf curl, dasheen mosaic of elephant foot-yam and taro, yam mild mottle virus, yam badna virus, anthracnose in yam, taro leaf-blight and collar-rot in elephant foot-yam.

Dipsticks were developed manually based on *DsMV* specific IgG-gold conjugate. The test was found highly sensitive and was capable of detecting virus with very low titre. Full genome of cassava mosaic viruses (*ICMV* , *SLCMV*), sweet-potato leaf-curl virus and dasheen mosaic virus have been sequenced. Transgenic plants resistant to cassava mosaic virus have been developed using *Rep* gene of Indian cassava mosaic virus. They showed delay in symptom expression.

## Post-harvest technologies

A major problem in post-harvest utilization of cassava is poor shelf-life of its tubers, which is a serious concern for cassava industry. The very low protein content in cassava (0.3-0.6%) is another drawback in its use as a food. An array of value-added technologies, which include technologies for nutritionally fortified snack foods, for fried chips manufacturing and for minimal processing of cassava for exporters, have been developed. Gluten-free spaghetti has been developed from blends of sweet-potato flour with native and pretreated rice-flour. Spaghetti with a low glycaemic index (55.7) has been developed from annealed rice flour- sweet- potato flour-whey protein concentrate-*gaur* gum blend. A low-starch digestibility (glycaemic index: 54.58) noodle has been developed using NUTRIOSE® FB06. Technology was perfected for developing high-protein starch noodles from sweet-potato starch (SPS). Besides, the resistant starch content in the SPS noodles could be enhanced through fortification with banana starch (40%) and resistant-starch (RS) enhanced (annealed) cassava starch (50%), which also had low *in-vitro* starch digestibility and medium glycaemic index. Bioactive compound fortified

### Biopesticides from Cassava

A Pilot plant to scale-up production of biopesticide and biofumigant from cassava-leaf and tuber-rind has been designed and fabricated. The formulation *Menma* is very effective against borer pests — pseudostem weevil and rhizome weevil in banana; red palm weevil in coconut etc. Sucking pests such as mealy-bug, thrips, scale insects, mites etc. in horticultural crops can be very effectively controlled by formulation *Nanma*. Waxy coating around mealy-bug gives it protection from insecticide application, but *Shreya* can dissolve mealy substance and kill it. Biofumigants isolated from cassava-leaves are effective against stored product pests.

Biopesticide plant

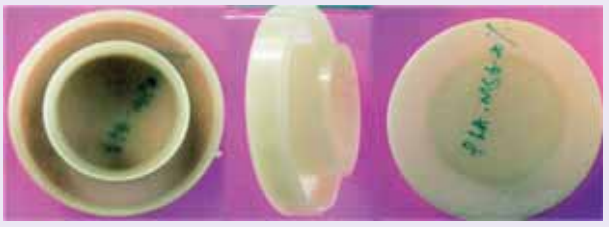
Large-scale field trials covering over one lakh banana-plants in different districts of Kerala under the RKVY project have established the efficacy of bioformulations against pseudostem and rhizome weevils in banana.

### Green Technologies from Cassava Starch

The Institute has developed and patented a technology (NRDC 9810152, European patent 1996) for manufacturing starch-based biodegradable plastics. Cassava starch was blended with polyolefin to make functional plastic articles while inducing biodegradability in appropriate environment. The starch incorporated **plastic films** (up to 25-40%) possess adequate mechanical strength and flexibility, and can be processed just like normal plastics, i.e. heat-sealed, printed, coloured etc. The granules and finished products can be stored almost like synthetic plastics and are biodegradable under soil burial conditions. It is patented in India and abroad. The technology can be easily adopted by the existing plastic manufactures using conventional machines. The plastic film can be used for preparing disposable carry bags, aprons, gloves, caps as well as nursery bags, mulch bags, garbage bags etc. Further refinement of native and modified cassava starch-based biodegradable films with increased hydrophobicity, better barrier properties and improved physico-mechanical properties are in progress.

Biodegradable plastic

Superabsorbent polymer



Starch-based moulded articles

Poly (lactic acid) – cassava starch composite based moulded articles were prepared by injection moulding and blow-film methods. These can be used as disposable articles for various purposes. A semi-synthetic cassava (tapioca) starch based superabsorbent polymer has been developed. The polymer is effective in soil-moisture retention and it also improved soil properties such as porosity, water-holding capacity and nutrient status. It can be used as a soil additive, especially under controlled conditions such as in greenhouses for plant nurseries, ornamental and medicinal plants for saving on irrigation water.

From cassava starch, bioethanol can be produced. Fresh cassava-tubers, dry chips/flour or starch can be used for production of ethanol. The process consists of three steps — liquefaction, saccharification and fermentation. One tonne of fresh cassava tubers with a starch content of >26-28% would yield around 140-150 litres of 96% alcohol while one tonne of dry chips / flour would yield around 430-440 litres of 96% alcohol under ideal conditions (Old patented technology). The CTCRI has recently developed an improved technology for bioethanol production from cassava starch using novel enzymes, derived from genetically engineered microorganisms. This process is time saving and less energy consuming, and can yield 680 litres ethanol from 1 tonne of dry chips/ flour.

sweet-potato flour and starch noodles with high antioxidant activity were developed using betanin, anthocyanin, carotene, curcumin or their combinations. Betanin (1%) fortified flour noodles was found best with high antioxidant activity and sensory quality. Betanin+ anthocyanin (0.5% each) fortified starch noodles showed a very high antioxidant activity. A cassava-rice based extruded product developed under a contract research project sponsored by M/s Kalady Rice Millers Consortium has been released by the firm in brand name 'LALA' on 31 July 2014. Besides, a number of industrial products like high fructose syrup, cold-water miscible starch, modified starches with altered viscosity, higher gel strength, improved film-forming capacity, clarity, lower retrogradation tendency and higher tack have been developed; they have wide applications as binders, fillers, emulsion stabilizers, consistency modifiers and adhesives. Several green technologies like biodegradable plastic, superabsorbent polymer, and bioethanol have also been developed from cassava starch.

## THRUST AREAS

### Flagship projects

#### Cassava mosaic disease – variability, diagnostics, vector relation and management

Cassava mosaic disease (CMD), caused by the Indian cassava mosaic virus (ICMV) or the Sri Lankan cassava mosaic virus (SLCMV), is a very serious disease that limits cassava yield. It occurs in more severe form in Tamil Nadu and also in Kerala, and causes yield losses ranging from 20 to 50% or even up to 80%. The main reason for the spread

**Sweet-potato noodles**

Banana starch fortified noodles

Annealed cassava starch fortified noodles

of the disease is indiscriminate and repeated use of the infected planting material and through whiteflies. Most of the varieties presently cultivated are highly susceptible to CMD. Continuous vegetative propagation resulted in very high virus load and led to clonal deterioration of these varieties. In the recent times, disease severity has increased enormously which has led to the degeneration of planting material and reduction in yield. Hence, there is an urgent need to address this complex issue. The strategies include identification of pathogen variability, development of quick-and-easy diagnostic techniques to detect pathogen, development of resistant varieties through breeding and transgenic approach and identification of markers linked to CMD resistance, role of vectors and their biotypes and management of this disease through production of virus-free planting material, nutrient management, vector management and finally by developing integrated disease management strategies.

### Development of cassava starch-based novel products and functional foods from other tuber crops

The project aims at developing cassava starch-based biodegradable films and thermoplastic starch for packaging applications and starch-based functional polymers for food, pharmaceutical and agricultural applications. Development of functional and nutritionally fortified snack foods is also planned.

### Other priority research projects

- Conservation and utilization of germplasm of tuber crops for sustaining production.
- Genetic improvement of tuber crops through conventional breeding and molecular approaches.
- Integrated crop, water and nutrient management for improving productivity of tropical tuber crops.
- Studies on the impact of climate change and devising mitigation strategies for sustaining productivity of tuber crops.
- Ecofriendly strategy for management of insect- pests in tuber crops.
- Development and refinement of an integrated disease management and forecasting system for improved tuber crops production.
- Development and refinement of post-harvest handling, storage and processing techniques for minimization of losses in tropical tuber crops and production of value-added products.
- Improving knowledge and skills of stakeholders for sustainable production of tuber crops.

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# New white onion variety for *kharif*

In the recently held Annual Group Meeting of the All-India Network Research Project on Onion and Garlic at Davengere, Karnataka, on 6-7 February 2015, white onion line developed by the Directorate of Onion and Garlic Research has been recommended for release. This line NRCWO 3 has been named 'Bhima Safed'.

It is suitable for cultivation in Chhattisgarh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Rajasthan and Tamil Nadu. This is a medium maturing (110-120 days) variety with white, round to oval bulbs of mainly 70-80 g. It has 11-12% TSS, and is thus suitable for both table and processing purpose. Its average yield in the multilocation trials in the recommended zones was 18.5 tonnes/ha. It has less than 5% doubles and bolters.

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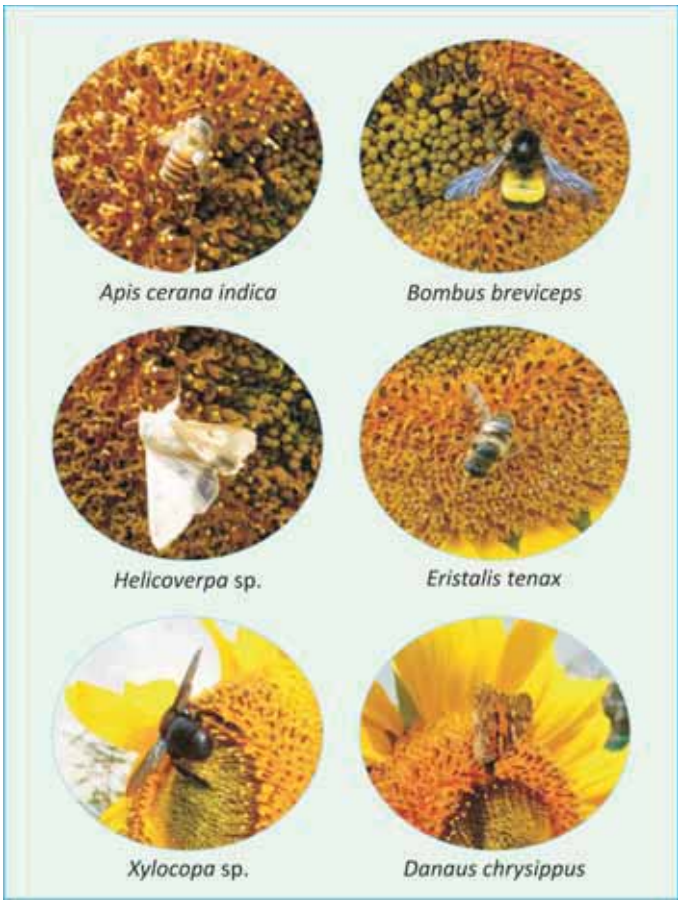
# Pollinators' complex of newly introduced sunflower-crop in Sikkim Himalaya

Sunflower (*Helianthus annuus*) is the second most important oilseed crop of the world after soybean. In view of its non-cholesterol and anti-cholesterol properties, the demand for sunflower oil in the world market is increasing steadily. It contains 45-50 % good quality oil and quality protein in cake. In Sikkim, it is recommended for cultivation after harvest of *kharif* rice in November.




Sunflower seeds are produced by exploitation of Cytoplasmic Genetic Male Sterility (CGMS). CMS line (A line) is pollinated with maintainer line (B line) for its maintenance and with restorer line (R line) for hybrid- seed production. In both cases, pollen is transferred across the line. As sunflower pollens are heavy and sticky, they cannot be carried by wind. So, the pollinators are the main agents responsible for transfer of pollen from male to female line. Most worker honey- bees are specialized either as nectar or pollen foragers; and insufficient pollination can significantly reduce yields.

Recently, it has been shown clearly that non-*Apis* bees are beneficial in sunflower pollination in their behavioural interactions with honey-bees. This improved efficiency of honey-bees to pollinate the crop. The time taken by the pollinator on a flower is crucial as it indicates its pollinating potential. This is influenced by the presence of sufficient reward (pollen or nectar) as well as the competing individuals.

At Sikkim Centre, sunflower has recently been introduced for studying its performance. Since pollinators play a major role in the production of this crop, a field experiment was carried out in 2014 to identify diversity of sunflower pollinators. Observations were made during day time, from 06:00 h to 15:00 h to record and identify visitors to sunflower. The time taken by an individual

during each foraging bout and the number of visits to a flower- head by a species in an hour was also recorded.

Overall, individuals belonging to 12 insect species were observed visiting sunflower flower-heads. These included four Lepidopteran species, three Hymenopteran species, four Dipteran species and one Coleopteran species. Among these, 4 visitors, *Apis cerana indica, Eristalis tenax, Helicoverpa* spp. and *Bombus breviceps* were the frequently visiting ones. Though foraging time of *Helicoverpa* spp. (130-360 seconds) and *Bombus breviceps* (120-450 seconds) was more in comparison to *Apis cerana indica* (40-222 seconds) and *Eristalis tenax* (80-180 seconds) in one bout but frequency of visits was more by the latter. Out of these four frequent visitors, *Apis cerana indica* and *Bombus breviceps* are both nectar and pollen collectors, which may be considered major pollinators of sunflower in Sikkim. The pollination efficiency will give actual contribution of these pollinators.

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# A natural colourant-cum-nutraceutical supplement, Lalima, from *karonda*

Colour is an important component of the appearance of the food items, which governs food quality. One way of colouring food through natural means is addition of a strongly coloured food to the intended food item to be coloured. For industrial food production, low concentration of pigments in most foods leads to addition of a large amount of pigmented food item to get desired shade. Therefore, there is a need to extract pigments. Naturally extracted pigments/colours are acceptable to consumers besides the colour derived from them is bioactive.

In India, *karonda* or Cranberry Bengal currant (*Carissa carandus*), a hardy, evergreen, spiny and indigenous shrub, is usually grown as a bio-fence. To some extent, it is also used as a condiment or additive to Indian pickles and spices. It has been reported to have antioxidant, antirheumatic, antibacterial and anticonvulsant activities. The health benefits of fruits are attributed to phytochemicals, referred to as antioxidants. Despite, its multiple usefulness, it remained an underexploited fruit, probably, owing to its small berry size and sour taste. Keeping in view the rising awareness among consumers for health foods, alternative use of this has been thought of. *Karonda* genotype, CIAH Selection1, which turns dark-red on maturity; could be a likely candidate as a source of natural food colourant and of antioxidants for its potential domestic and industrial application.

A natural 'food colourant-cum-nutraceutical supplement' was prepared from ripe-*karonda* fruits. For colour extraction, after washing and cleaning, ripe- fruits were cut into halves. Seeds were removed before dehydration at 55 °C. The dehydrated fruits were grounded into powder with an electric mill with 0.5-mm sieve. Powdered fruit-pulp was cold extracted thrice with ethanol and supernatants were pooled together, filtered through 2.5µ filter and air- dried at 45 °C. The dried concentrated 'colour pigment' which predominantly contained anthocyanin and phenolics was then dissolved in water to get ready-to-use 'food colourant- cum- nutraceutical supplement'. Benzoic acid @ 600ppm was added to enhance shelf-life of the product. The formulation has been christened as 'Lalima'.

To make it user-friendly, formulation was packed in 10- ml plastic dropping bottles; packed bottle has pigment extracted from 10g dried fruits, and 1 ml of this pigment suspension formulation is sufficient to give pleasing red colour to one serving (100 ml) of any colourless beverage such as lemon- based beverages. One serve of such supplemented beverage may additionally contain 469.2 µg anthocyanin

(cyaniding-3-glucoside equivalent), 14.1 mg phenol (gallic acid equivalent), 12.7 mg flavanoids (rutin trihydrate equivalent) with total antioxidant activities (CUPRAC) of 390 µM Trolox Equivalent. Lemon *sherbat* supplemented with 'Lalima' was found more acceptable in terms of flavour and appearance among testers than plain lemon *sherbat*. The development of technology for value-addition of the food items through alternative uses of *karonda* would help regulate availability of such antioxidant-rich sources for nutritional security.

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## Manually guided power-weeder

This power-weeder is for narrow row space field crops. It consists of a 1.8-hp petrol engine, a drive-shaft, a handle with integral throttle trigger, a gear-head and a weeder assembly.

Its weeding assembly consists of two sets of discs with four weeding tines, fixed radically on the cylindrical disc at equi-distance along the disc circumference. The disc assembly is fixed on the bush, which is attached to drive-shaft from gear-head. Each tine is made of 5-mm thick mild steel flat. The field capacity of the weeder is 0.24 ha/day. Its weeding efficiency is 89.7 % and plant damage by it is less than 1%. It gives 66 % saving in cost of weeding in comparison to manual weeding with hand-hoe.

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## Automated soil-processing facility

An automated soil-processing trolley has been developed, which enables creation of uniform test-bed of soil for more precise experimentation in the soil- bin at the different soil compaction levels. The trolley comprises a rotary tiller, a leveller and a compaction roller for tilling, levelling and compacting soil in a rectangular bin. Hydraulic circuit has been designed and integrated with the trolley which facilitates operational control of the rotary tiller, leveller and compaction roller with ease. Use of hydraulic power also permits variations in compaction roller pressure to achieve the desired compaction level and adjustment of the depth of the operation of the tool to be tested.

A hydraulically-operated instrumented cone penetrometer has also been designed and installed in the soil- bin for accurate measurement of characteristics of the test-bed of soil. The soil-cone penetrometer probe and cone-tip have been designed as per the ASABE standard S313.2. An 'S' type load cell of 2-kN capacity has been mounted between the probe and the piston- rod, which is capable of measuring cone index values up to 300-mm soil depth. A linear potentiometer has been used to achieve automatic recording of profile depth simultaneously at a constant penetration rate of about 30 mm/s.

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# Animal-dung-based high total soil concentration biogas plants

The larger capacity fixed-dome biogas-plants have been developed. The designs are available for 20-500 $m^3$/d capacity for the animal-dung substrate. The digester of the plant is well-shaped, where gas is stored in a fixed dome. The plant operates efficiently under mesophilic temperatures. Since the effluent contains high total solids concentration (TSC) in the range of 16-18% (weight basis), effluent handling problem is eliminated to a great extent. Even non-functional floating drum biogas plants could be made functional by converting them into fixed dome structure. Initial cost of installation of the plant is ₹ 8,000 per $m^3$ capacity (Base Year 2013). The cost is reduced significantly with increased plant size. Cost of plant is about 50% less than floating drum biogas plant of the same capacity. More than 250 units having varying capacities in the range of 20-100$m^3$/d have been installed on the Dairy Farms for Punjab. Majority of units are coupled with electricity generating units using biogas as a fuel. The technology developed converts animal-dung into gas and additionally delivers enriched manure. There is no emission of methane from the dung.

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# Energy consumption for producing large cardamom in Sikkim

Large cardamom, a member of the family Zingiberaceae is the main cash crop cultivated in the sub-Himalayan state of Sikkim. India is the largest producer of large cardamom with 54% share in the world production, and Sikkim contributes up to 88% of India's production. A total of 16,949 holdings of large cardamom are available in Sikkim.

The total power availability on Indian farms has increased from 0.293 to 1.841 kW/ha at a Compound Aggregate Growth Rate (CAGR) of 4.58% during the last forty-one years. The overall mechanization level in India is only 40-45% even though 90% of the total farm power is contributed by the mechanical and electrical power sources.

Cardamom is grown up to 1,000-2,000 m above mean sea level; it is normally cultivated in the lower altitudes of cooler areas (near to the snow-line) and higher altitudes of warmer areas. During severe winter, its plants remain dormant and withstand up to 2°C. The indication of the time of harvest is when seeds of the top most capsules turn brown. To enhance maturity, bearing tillers are cut to a height of 30-45 cm and left for another 10-15 days for full maturity. The spikes are harvested using special knives. The harvested spikes are heaped and capsules are separated and dried. Traditionally, large cardamom was cured in a *bhatti* where capsules were dried by direct heating. Under this, cardamom came in direct contact with smoke, which turned capsules to a darker browner black colour with a smoky smell.

Energy coefficients for various inputs and equipment for large cardamom production in terraces

| Equipment input | Major construction material of | Approx weight (kg) | Average useful life (h) | Energy coefficient | |
|---|---|---|---|---|---|
| | | | | MJ/kg | MJ/h |
| Human energy | - | 55 | | | 1.96 |
| Bullocks pair energy | - | 450 | | | 8.05 |
| Seed | - | 8 | | 5.88 | - |
| Farmyard manure | - | 5,000 | | 0.30 | - |
| Bio-pesticides | - | 1.5 | | 120 | - |
| Animal- drawn traditional wedge plough | Steel, wood | 12 | 150 | 37.6 | 1.32 |
| Manual hoe and spade for planting | Steel,wood | 1.50 | 150 | 7.50 | 0.08 |
| Manual sickle for removing weeding | Steel, wood | 0.40 | 150 | 6.25 | 0.05 |
| Manual traditional knife for harvesting large cardamom | Steel | 0.20 | 100 | 8.00 | 0.44 |
| Traditional *bhatti* for drying large cardamom | bricks | 1500 | 500 | 62.7 | 10.05 |
| Manual transport in polythene lined jute bags | Jute | 0.15 | 100 | 62.7 | 5.50 |

Cost auditing of large cardamom crop package of improved equipments for terraces in Sikkim

| Equipment/Practice | Unit price, (₹) | Field capacity, ha/h (sq.m/h) | Time, h/ha | Cost of operation, ₹/h | Cost of operation, ₹/ha |
|---|---|---|---|---|---|
| Seedbed preparation | | | | | |
| Animal-drawn traditional wedge plough (110 mm) | 700 | 0.015 (150) | 80 | 38 | 3,000 |
| Planting | | | | | |
| Manual traditional hoe and spade | 150 | 0.009 (90) | 120 | 20 | 2,400 |
| Weeding and interculture | | | | | |
| Manual traditional hoe/sickle | 150 | 0.006 (60) | 180 | 20 | 3,600 |
| Harvesting | | | | | |
| Traditional sickle | 150 | 0.009 (90) | 120 | 20 | 3,250 |
| Drying | | | | | |
| Traditional *bhatti* for drying (100 kg drying in 3-5 days) | 3,000 | 100 kg/batch | 40 | 30 | ₹1,800/ha (₹ 12/kg) |
| Total | ₹4,150 | | | | 14,310 |

Energy input is considered as one of the most important yardsticks for land productivity. The animals are the main source of power for seed- bed preparation and sowing of crops in terraces. To evaluate energy input cost and returns from large cardamom crop and to develop light weight, energy-efficient farm- power and machinery and cost- effective package and management practices, a study was conducted at the village-Sangtok in North Sikkim district with the existing traditional animate source-based system during draught animal power survey of different districts in Sikkim between 2010 to 2013.In the Sangtok village, large cardamom-growing farmers used seed rate of 8 kg/ha, farmyard manure @ 5 tonnes/ha and the resultant yield was 200-300 kg/ha during two years crop period. The ploughing operations were accomplished in three passes. The planting of crop was performed using traditional hoe and spade in a total of 120 h for one hectare. For weeding, three persons were engaged for a total of 180 h to complete intercultural operation in 1 ha. In mid-November, harvesting of cardamom was done using local harvesting knife, especially made for this crop which totalled 120 h. The total energy consumption was found 3,352 MJ/ha, which included input energy and energy used for different unit operations. The unit operations based on animate sources were ploughing , planting,, weeding, harvesting, drying and transportation and required energy values were 802.40, 235.20, 352. 80, 235.20 MJ/ha, respectively. The energy from inputs (seeds, FYM, biopesticide) was also worked out on the basis of energy coefficients values. Cost auditing of large cardamom using traditional equipment for terraces in Sikkim included cost of operation and equipment used with the time of unit operations.

The cost of production of large cardamom in terrace condition of Sikkim was ₹23,998/ha, which included traditional equipment/*bhatti* (₹4,150/) and ₹14,310 as the cost of operations for different related agricultural works. The total cost of production of large cardamom (₹23,998/ha) includes 30% cost for inputs (seeds, farmyard manure, biopesticides).

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# WAY FORWARD

DESTRUCTION and fragmentation of the natural habitats have forced wildlife to be restricted on the small patches, leading to severe conflict between humans and wildlife, and in turn, is causing heavy damage to natural resources and also threatening human-health and safety. Crop-raiding by animals, particularly, elephants, blackbuck, wild boar, monkey, *langur*, *nilgai,* has been widely reported from all-over the country. To date, there has been comparatively very little systematic research carried out to investigate pattern of crop-raiding activity by wild animals, its potential impact on farmers' food and household economic security, and ways and means to manage it. Most of the researches have been focused on the issues related to crop damage by rodents and birds; information on the damage by higher vertebrates, such as primates and ungulates, often cited as troublesome 'pests' in the agricultural areas, has been scant and scattered.

Reports are that *nilgai* population has increased because of prolonged breeding activity, high rate of multiple births and lack of predators. *Nilgai* damage is mainly owing to their foraging and trampling of crops during resting and movement. At a low population density level, they caused damage to the tune of 20-30% in wheat; 40-55% in pulses and 25-40% in cotton, and at a high population density, the damage reached over 60%. Likewise, the wild boars were reported to have inflicted 23-38%, 5-14%, 12-35% and 6-26% damage to major crops in Uttar Pradesh, Himachal Pradesh, Rajasthan and Madhya Pradesh, respectively. Herein, it has become very important to understand vertebrate pests basic ecology, behaviour and pestilence to develop technologies to mitigate further losses to the agricultural production systems by them.

With the rising concerns regarding higher vertebrate pests in agricultural sector, management strategies are warranted to combat unprecedented damages to crops by them. While farmers are helpless and suffer losses due to animal menace; these vertebrate animals are also protected under law, and therefore introduction of legal issues is a concern too. Hence, their management through non-lethal approach is a pre-requisite to minimize crop losses as well as man-animal conflict.

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

### Higher Vertebrate Pests

The strategic higher vertebrate pests, raising concerns for Indian agriculture, are '*nilgai*' (*Boselaphus tragocamelus*), wild boar (*Sus scrofa),* monkeys (*Macaca* spp.) and also elephants. For instance, *nilgai* is found in the Himalayan foot-hills, Karnataka and Andhra Pradesh, and central India, and is listed under the 'IUCN-least concerned' category, and Wildlife Protection Act, 1972, has grouped it under Schedule IV. Existing reports indicate their population density varying from 0.22 – 0.34 individuals/km$^2$ (Indravati Park); 0.39 – 1.47 km$^2$ (Gir Lion Sanctuary); 0.44 – 7.81/km$^2$ (Panna National Park); and 6.6 – 11.36/km$^2$ (Ranthambore National Park). Wild boar is also listed under 'least concerned' category of the IUCN, and is under Schedule III of the Indian Wildlife Protection Act. In recent years, the species is majorly indulged in crop-raiding and has become a major pest of agricultural system. Unlike the other two, monkey menace has been reported across the country and has been causing severe agricultural damages in the fringe areas of the forested ecosystems. *Rhesus macaque*, which is a least concerned species as per the IUCN, has been put in the Schedule-II of the Indian Wildlife Protection Act (amended up to 2002).

Keeping in view the severity of the problem in agriculture-associated wild animal species, the Indian Council of Agricultural Research has launched an All-India Network Project on Vertebrate Pest Management in 2015, integrating also management of birds and rodents, with a sole objective to minimize crop losses *vis-a-vis* farmer-animal conflict in agricultural landscape.

During the launch, a brainstorming session was organized, to plan deal with these animals within the framework of losses in agricultural production, legal instrument and man-animal conflict, which came out with risk-management strategies, possible technology options, and policy imperatives for management of higher vertebrates. Along with, it is envisaged that institutional arrangements are also utmost important to achieve such a stupendous task of mitigating animal menace in larger interest of food security and in balancing the Nature.

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