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हर कदम, हर डगर किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद
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ICAR NEWS

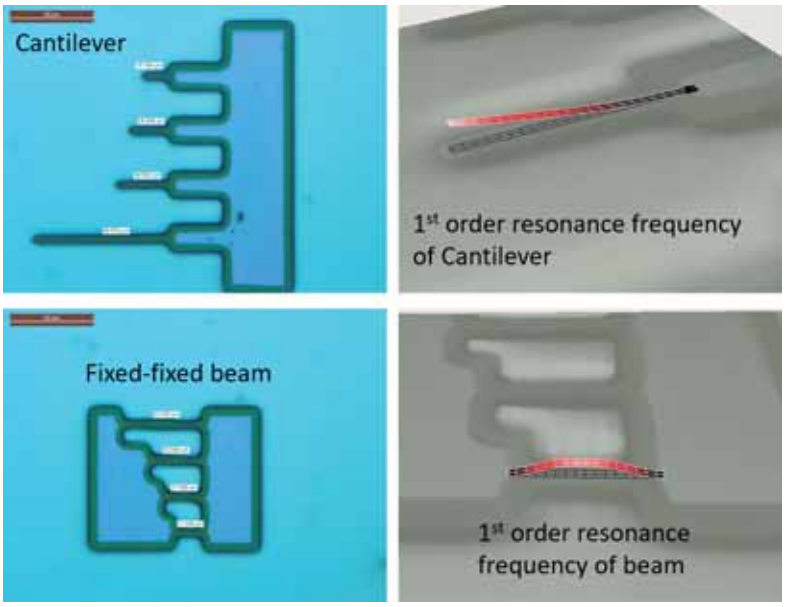
A SCIENCE AND TECHNOLOGY NEWSLETTER

RESEARCH UPDATE

PROMISING TECHNOLOGIES

A Novel Bioengineering Approach for Selective Detection of Female Sex Pheromone of Agriculturally Important Insects

Plant pests exert serious effects on food production due to which the global crop yields are reduced by ~20-40% per year as estimated by FAO. Herein, the MEMS devices are covalently functionalized for robust and efficient optical sensing of the female sex pheromones of the pests like *Helicoverpa armigera* and *Bactocera oleae* for the first time in literature. The functionalized devices are also capable of selectively measuring the concentration of this pheromone at femtogram level which is much below the concentration of pheromone at the time of pest infestation in an agricultural field. Experiments were also performed in a confined region in the presence of male and female *Helicoverpa armigera* pests and



Fabrication of SiO_2 based MEMS devices

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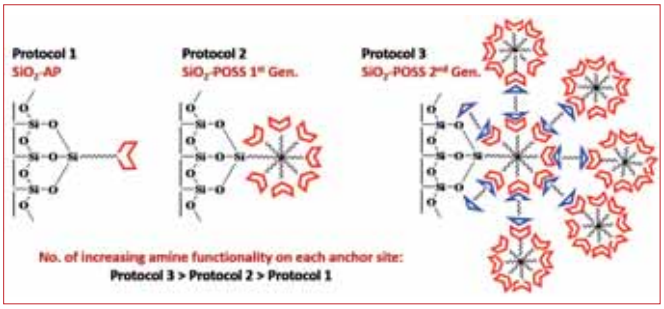
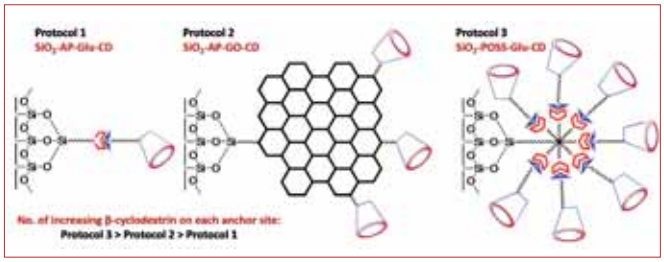
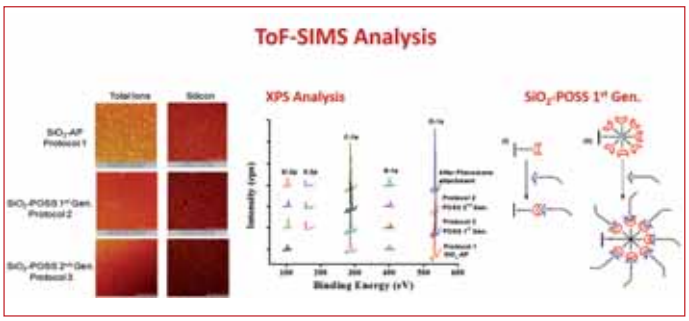


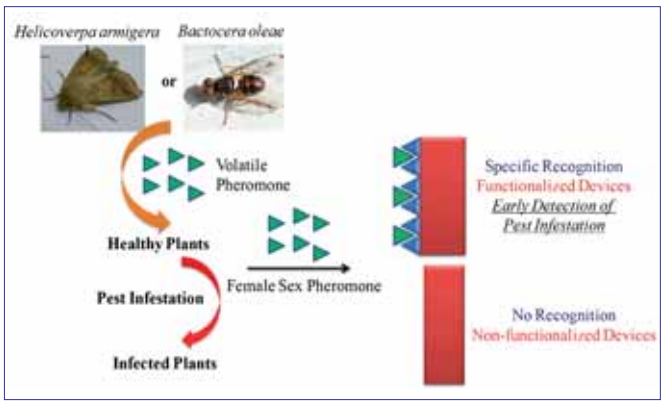
Chemically functionalized MEMS devices for *Helicoverpa armigera*



Covalently functionalized MEMS devices for *Bactocera oleae*



Proof of covalent functionalization



Summary

tomato plants which directly mimics the real environmental conditions. Again the reversible use and absolutely trouble free transportation of these pheromone nanosensors heightens their potentials for commercial use. Overall, a novel and unique bioengineering approach for the selective and reversible sensing of female sex pheromones of certain hazardous pests is reported herein which may be efficiently and economically carried forward from the research laboratory to the agricultural field.

- These devices have no chemical specificity towards any analyte.
- Hence they need to be functionalized for sensitivity towards the insect pheromones.

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In-package use of ethylene absorbents extends shelf-life of nectarine

Nectarine (*Prunus persica* var. *nectarina*) is a smooth-skinned peach belonging to family Rosaceae. Nectarines have arisen from peach tree spontaneously as bud sport. In fact, nectarine is considered as a natural mutant of peach. The expression of a recessive allele is thought to be responsible for the smooth peel of nectarine fruits. Nectarines are grown throughout the warmer temperate regions of both the Northern and Southern hemispheres between latitudes 30° and 45° N and S. Nectarines have red, yellow, or white pulp but most varieties of nectarine bear attractive red colour of varying shades. Its fruits contain fairly good amount of antioxidants vitamins

Bunch bearing Silver Queen nectarine


Mature fruits, ready for harvest


Harvesting of fruits


Sorting and grading


Ethylene absorbent sachets


Fruits packed with ethylene absorbers

such as C, A, E and flavonoids, polyphenolic antioxidants like lutien, zeaxanthin and β-cryptoxanthin.

Due to its smoothness and attractive colour, nectarine fruits are becoming popular among consumers and hence, peach orchards are being replaced by nectarine at a faster rate in different parts of India. It is commercially cultivated in Himachal Pradesh, Uttarakhand, Jammu and Kashmir and some regions of Meghalaya. The best quality nectarines are obtained from Ramgarh areas of Nainital (Uttrakhand) and Rajgarh areas of Himachal Pradesh. Major constraint in nectarine handling is its limited shelf-life of about 3-4 days at ambient conditions which can be extended up to 2-3 weeks under cold storage condition (0-2R° C, 85-90% RH). However, such facilities are lacking in India, and if facilities are available, continuous supply of electricity is still a problem in several parts. There are several postharvest interventions to enhance the storage life of fresh fruits but among them the most convenient and economical method is the in-package use of ethylene absorbent sachets. Hence, the use of $KMnO_4$ based ethylene absorbent sachets has been made which were placed inside the packing boxes during the transportation of 'Silver Queen' nectarine.

How ethytlene absorbents extend shelf-life?

Being a climactic fruit, nectarine shows a sudden upsurge in respiratory rate and ethylene production after harvest. Ethylene not only hastens ripening, but also results in production of cell wall softening enzymes such as poly galacturonase (PG), pectin methyl esterase (PME), cellulase and β- galacturonase. As a result of increased activities of these enzymes and senescence, shelf-life of the fruits is further reduced drastically due to rough handling and poor storage conditions.

In-package use of ethylene absorbents (EAS) has been found invariably efficient in enhancing the postharvest life and quality of fruits. Commercial use of ethylene absorbents containing potassium permanganate ($KMnO_4$) which when placed in packaging boxes or containers oxidizes ethylene (C_2H_4) into carbon dioxide and water. Due to absorption of ethylene, detrimental effects of ethylene on fruits such as enhanced fruit ripening, softening and quality degradation are reduced, which helps in enhancing postharvest shelf or storage life of fruits, thereby helping in extending the marketability of fruits.

What is the technology?

Harvest the fruits at appropriate maturity. After harvesting, remove the diseased, cull, under-developed or unattractive fruits. After grading, pack the fruits in suitable CFB boxes by placing the $KMNO_4$ based ethylene absorbents. Then these packages are ready for transportation/storage. Such fruits stay for about 12 days at super market conditions (20±1° C and 90±2% RH) and

Table 1. Influence of in-package placement of ethylene absorbent on nectarine fruits

	PLW (%)	Firmness (N)	TSS (°Brix)	Total antioxidant (µmoles TE/g FW)	Total phenol (mg GAE/100g FW)
Ethylene absorbent	10.07	6.3	8.9	18.610	13.24
Control	14.54	3.5	9.5	16.020	11.73

for about 28 days in cold storage condition (2±1° C), having better quality than those packed without ethylene absorbents (Table 1).

Advantages of the technology

- It is a farmer friendly technology.
- No technical skill is required.
- Higher efficacy in maintaining firmness than other techniques.
- It is an eco-friendly technology.
- No toxic effects either on fruits or human health.
- Potassium permanganate is very cheap and sachets can be easily made at home.

Placing of ethylene absorbent sachets in packaging boxes is a reliable and cost effective technology as extra investment is not required for this. By adopting this technology, quality of the fruit can be retained for a period of 28 days and hence the marketability period also gets enhanced and farmers can get better returns for their produce.

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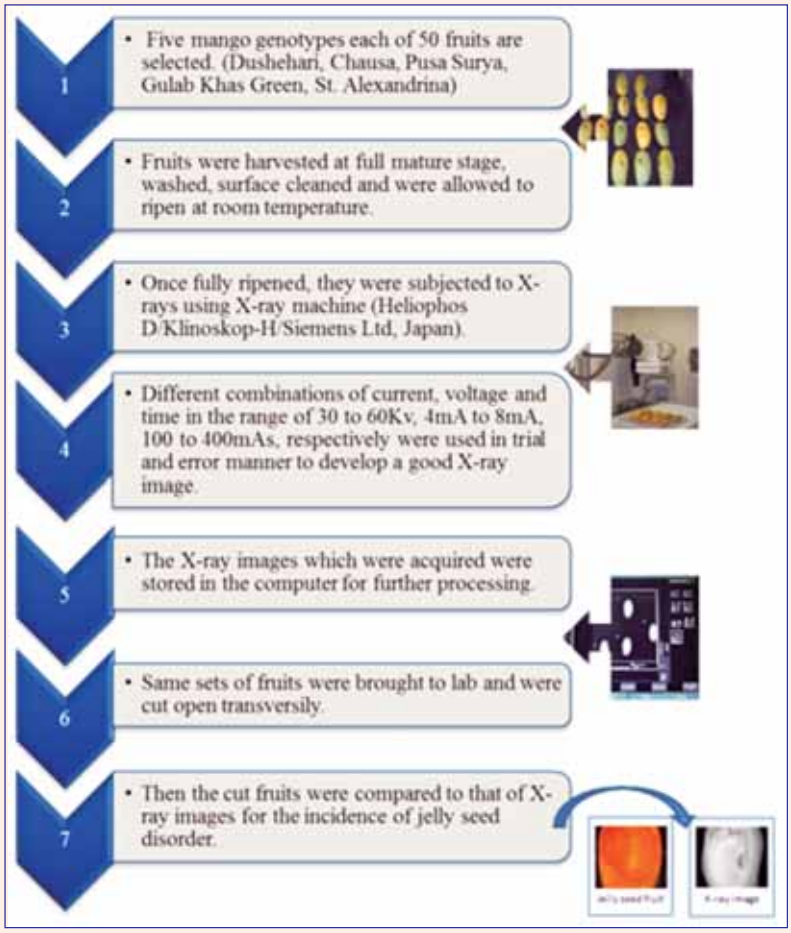
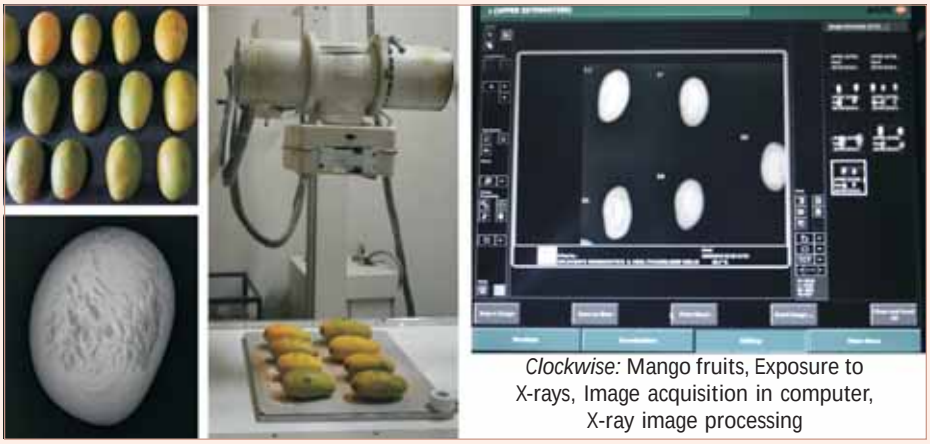
X-ray Imaging for Detection of Jelly Seed Disorder in Mango

Mango (*Mangifera indica* L.) is the choicest fruit of India in terms of not only production but also economic importance and acceptability by the consumers. India is the largest producer of mangoes in the world and it covers nearly 36% of total fruit area and 39.6% of production in India. Even though India is the largest producer and has more than 1600 mango genotypes, its contribution to the mango export earnings from agriculture products is less than 2%. Problems such as internal disorders, insect infestation and pesticide residue alongwith inadequate postharvest technology and management system are the major bottlenecks in the expansion of mango trade from the country. During the last few years, jelly seed disorder has caused havoc in certain areas, thereby hindering the export and consumption of mango.

The jelly seed disorder is associated with the ripening process, being unique by mesocarp breakdown in the vicinity of the seed and development of off flavour. When in an advanced state, affected tissues may become discoloured and the fruit almost entirely

Methodology





Clockwise: Mango fruits, Exposure to X-rays, Image acquisition in computer, X-ray image processing

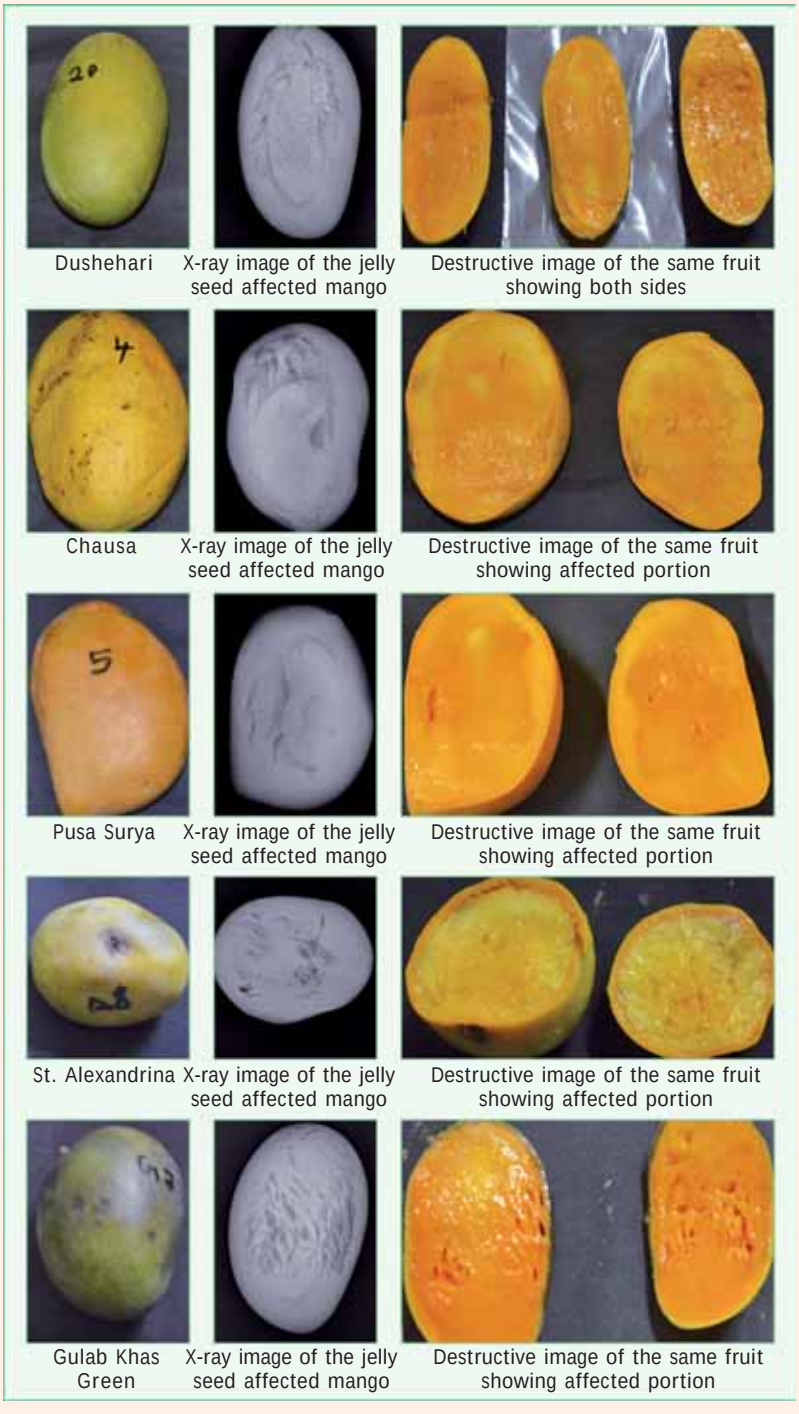
X-ray machine parameters

Current (kV)	30–60
Voltage (mA)	4–8
Exposure time (mAs)	100–400

affected. Unfortunately, fruits affected by jelly seed can't be identified physically and consumers come to know only when fruits are cut open. Only then, they find that few fruits in the lot are not worth consuming. Now, with the increased awareness of consumers on quality of produce, necessitates producer, seller or exporter of any commodity to pay special attention on quality of products for marketing.

With the advancement in technology, the dream of use of several non-destructive techniques such as Nuclear Magnetic Resonance (NMR), X-ray and Computed Tomography, Near Infra-Red (NIR) Spectroscopy, Electronic nose, Ultrasound etc. for screening of many ailments in fruits has come true. Among them, X-ray imaging is one of the non-destructive techniques, which is widely applied in quality estimation of fruits. X-ray inspection has a distinct advantage over other detection techniques, as it performs non-destructive imaging of interior features of sample, which detects internal defects and can be easily handled. This has become increasingly common in recent years in food industries of processed foods, packaged foods, canned foods, etc. due to more emphasis on food safety.

X-ray is a radiation which is a kind of electromagnetic wave whose wavelength is shorter than ultraviolet and microwaves. Use of X-ray radiation for food products has no problem in microbiological safety and nutritional quality of irradiated food. Even though X-ray imaging has great potential in resolving the problems associated with mango export, very little work has been done for the detection of internal breakdown disorders in mango using X-ray imaging, and no research work on jelly seed detection using X-rays has yet appeared in the literature. Hence, an attempt was made to explore the possibility of detecting jelly seed disorder using X-ray imaging.



Mango genotype	Jelly seed affected portion (%)	Mango fruit	
		Length (mm) Min-Maximum	Width (mm) Min-Maximum
Dushehari	57	90.43–120.56	49.12–67.36
Chausa	51	86.41–92.36	65.67–77.60
Pusa Surya	37	92.13–113.67	78.12–89.74
Gulab Khas Green	60	70.45–79.10	61.23–71.24
St. Alexandrina	42	45.21–56.14	59.80–68.11

It was found that using X-ray source of 48Kv, 6.5mA, with exposure time of 320mAs gave the best contrast images of jelly seed internal disorder in chosen mango genotypes. The fruits susceptible with jelly seed disorder in X ray image showed dark grey areas around the stone, while that of good fruit showed light grey areas in full mango image. Jelly seed incidence was highest in Gulab Khas Green followed by Dushehari and least incidence was in Pusa Surya. Hence, it can be concluded that X-ray imaging is a useful method for detecting jelly seed disorder in mango and this techniques can be incorporated into supply chain for better consumer acceptance.

X ray image of good fruit a), Jelly seed affected fruit b)

Special advantages of this method

- Most reliable in detecting the Jelly Seed disorder in mango fruits.
- This techniques is comparatively cheaper than other non-destructive techniques.
- It is easy to work with the X-ray machine.
- Interpretation of the data in the form of images is more accurate.
- It can be integrated with sorting system in supply chain of mango.
- Value of the product will be higher as 100 % surety is assured on quality.

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Trace mineral supplementation in bucks for puberty advancement and improvement of semen characteristics

Attainment of puberty in small ruminants depends on their age, body weight, nutritional status, genetic and environmental conditions. Organic minerals was found to be more efficiently utilized in the body due to more bioavailability with better absorption rate and suggested to improve semen production, sperm motility and male fertility. In this regard, a series of studies were carried out at ICAR-National Institute of Animal Nutrition and Physiology, Bengaluru to understand the role of organic zinc (Zn) and copper (Cu) in advancing male puberty and semen characters in indigenous goats (Osmanabadi). The dietary treatments comprised of control (G1) (basal diet; without trace mineral supplementation), in addition to control diet, various doses of Zn, Cu and combination was supplemented to test groups (G2-G10). Results showed that goats fed with organic trace mineral reached puberty at 28-35 days early as compared to that of control group. In addition, significant ($p<0.05$) improvement in testosterone hormone level, semen production (semen volume, sperm concentration) and semen quality (sperm motility, velocity and sperm membrane integrities) was recorded in treated goats than control. The present study confirmed that, additional feeding of organic Zn and Cu to growing male goats advanced onset of puberty and improved semen quality.


Live and dead spermatozoa


Hypo osmotic swelling and Acrosome integrity positive spermatozoa

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Training programme for the officers of the Indian Economic Services (IES)

An Induction Level Training Program for Officers of the Indian Economic Service (IES) was organized by ICAR-NIAP (New Delhi) during 19-23 September 2016. The programme covered the subject – Core Issues Related to Agricultural Sector, and it was attended by 20 officers from 12 different organizations of Govt. of India. During the entire training programme, twenty-five topics on important issues related to core issues on agriculture were covered. Topic-wise pre-training and post- training assessment was carried out.

Post training knowledge level assessment: It was observed that they had mostly medium to low level of knowledge in most of the topics related to agriculture. The overall assessment indicated that about 67% of total participants had medium level of knowledge while 33% had low level of knowledge of core issues in agriculture.

Post training assessment: The feedback was collected and analysed on following aspects from the participants for further improvement.

Assessment of coverage of topics: ICAR-NIAP invited resource persons from national and international organizations**.** Trainee participants were of the opinion that the coverage of different topics with detailed deliberations were very informative and interesting. Most of them were of the opinion that 76% participants believed topics were well covered, while 24% of them rated as fairly covered well. Some of the participants were of the opinion that since duration of the training is short (5 days) only, number of topics should have been lesser. While others emphasized that exposure to more number of topics with the discussion on key policy helped them in understanding the core issues.

Usefulness of training: Participants opinion on usefulness of the topics has indicated that 66% found the topics most useful, followed by 34% who considered as just useful and no one rated the topics to be not useful.

Usefulness of exposure/ field visits: Trainees were also taken for exposure/field visits like the Museum at NASC Complex, NRL, IARI, New Delhi, Mahanlobi's forecasting center, IASRI, NBPGR Gene Bank and ASHOKA Super Computer. All the participants have indicated the exposure visits were very informative and interactive and asked to increase number of exposure visits.

Overall rating of the training programme and faculty: Their post-training, knowledge gain was of high category (67%), followed by very high (19 %), medium (13 %) and low (1 %). Approximately, 86 % participants were very satisfied with the training; 14% were either partially satisfied. Majority of them were of the opinion that training programme duration should be for 10 days.

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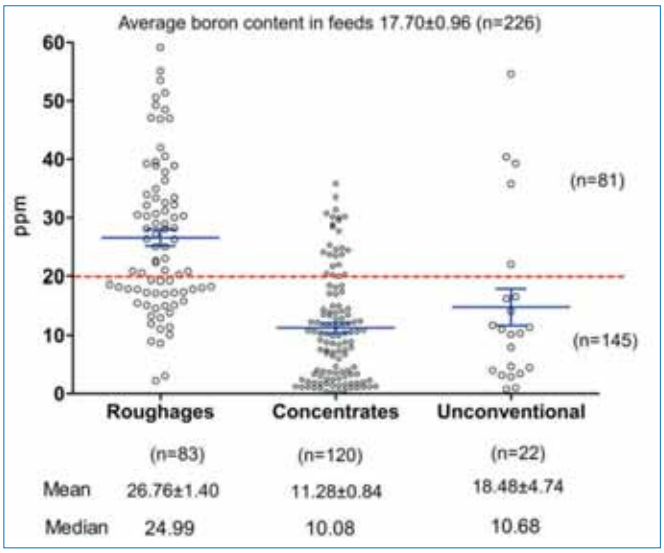
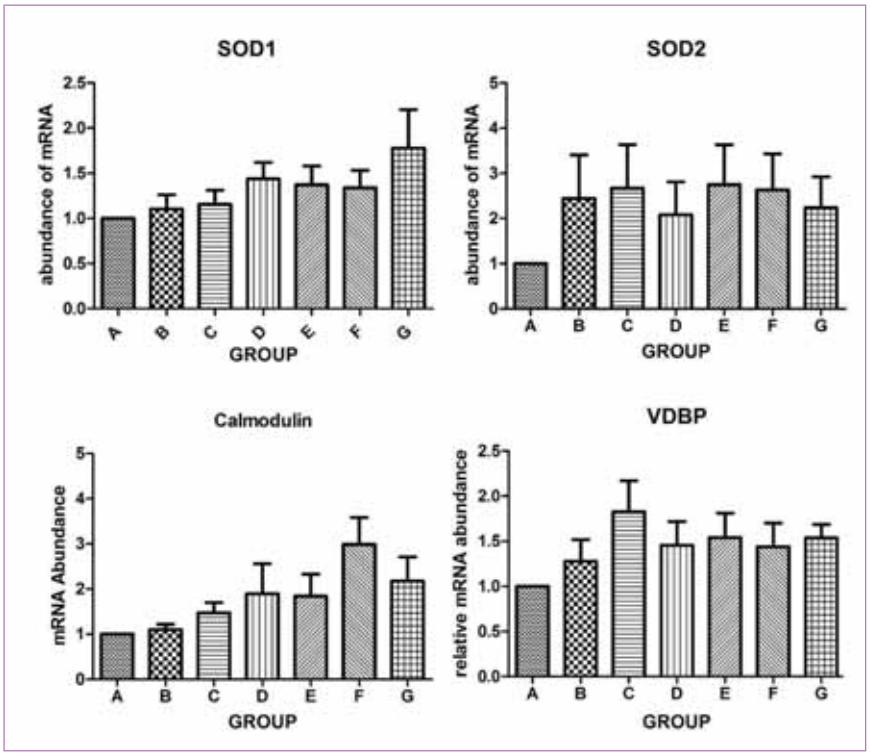
Boron – An important micronutrient for animals

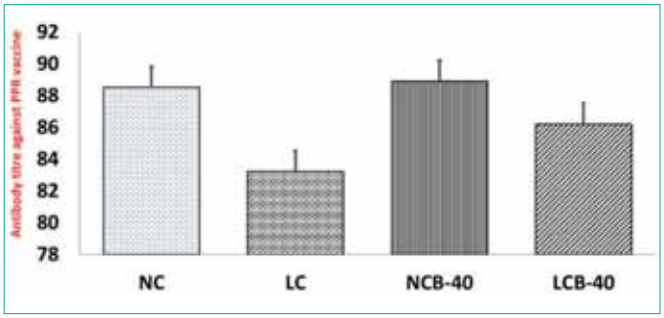
Of late, there are increasing reports suggesting the role of Boron(B) in animals. Boron has atomic number of 5 with atomic weight of 10.81 and is the V element in the periodic table of Group IIIA elements which possess the property of both metal and non-metals. The compounds of B (boric acid, borax) are generally used for bleaching, as fungicide and as micronutrient supplement for plants. A study was carried out at ICAR-NIANP, Bengaluru to quantify B in animal feeds and to understand its role in calcium (Ca) utilization and immunity in animals. Results indicated that most of the feed samples analyzed have less than 20 ppm and fodders contained higher level of B. Study in rats fed on semi-purified diets supplemented with graded levels of B (0,5,10,20,40 ppm) at normal and low levels of dietary Ca showed increased (P<0.05) gut absorption of Ca and significantly(P<0.05) lowered serum levels of triglycerides and HDL-cholesterol. The erythrocytic superoxide dismutase (SOD) and total antioxidant capacity were enhanced (P<0.05) with higher level of B supplementation. The hepatic mRNA expression levels of SOD, Calmodulin and Vitamin D binding protein (VDBP) were increased (P<0.05) with B supplementation in diets. This indicated the role of B in promoting Ca utilization, immunity and antioxidant defense mechanism in animals. Study in sheep supplemented with B (40 ppm) has showed better performance in terms of improved Ca utilization, immunity and growth. Experiment in layer poultry also has showed improved egg production and less number of cracked eggs, when B (40 ppm) was supplemented to diet with inadequate Ca level. These findings support the relevance of B to improve Ca utilization in animals. Further, it was evident that the physiological response to B supplementation was found better under calcium-deficit conditions.



Distribution of Boron (ppm) in commonly used feeds



Relative mRNA expression levels of gene related to immunity and Calcium homeostasis in rats



Antibody titer against PPR vaccine in sheep

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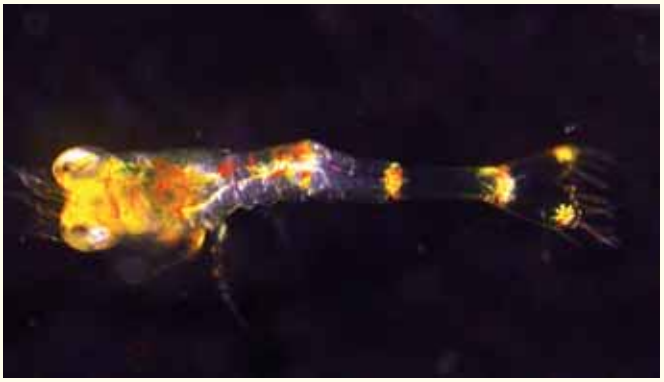
Breakthrough in captive brood stock development and breeding of marine ornamental fish Sea-goldie and camel shrimp

The successful larval rearing of the camel shrimp or hingebeakshrimp *Rhynchocinetes durbanensis,* was achieved at Vizhinjam Research Centre of ICAR-CMFRI. This shrimp belongs to the family Rhynchocinetidae.It grows up to 4-5 cm in length and fetches $10-12 in the international market and in the local market it is sold at ` 500-700 per piece. It has red and white lines on a translucent body with many white ocelli (spots) as well as a Y-shaped white mark on the upper front part of its carapace. The shrimp is found in crevices in the coastal waters and their trade is entirely based on wild caught ones and there are no published reports of successful captive breeding available.

Brood stock of camel shrimp

Juvenile camel shrimp developed in 60 days

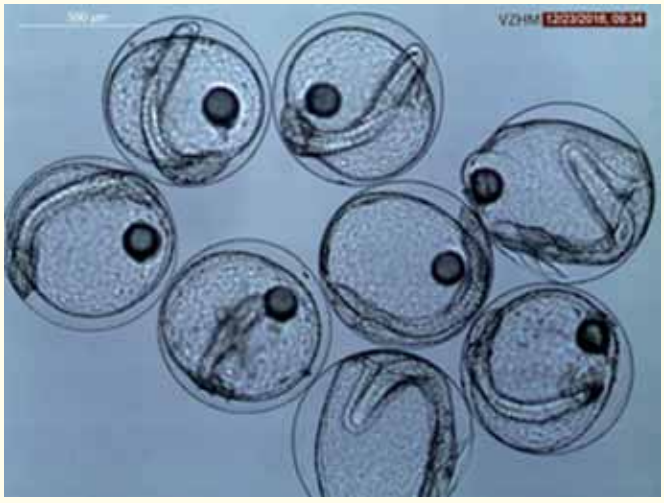


First Zoea

Brood stock was developed using wild caught juvenile shrimps. Ovigerous females carry around 100 to 200 eggs which hatched out into zoea larvae with stalk-less eyes and by 40th day the larvae developed pleopod buds. Over a period of 60 days, it moulted several times to become juveniles having colouration and features quite similar to adults.

In another development, the successful captive brood stock development and spawning of the ornamental Serranid commonly called the Sea goldie, was also achieved. This species *Pseudanthias squamipinnis* belongs to the family Serranidae under the Subfamily Anthiinae and is one of the most expensive reef fishes traded in the marine aquarium export trade. It fetches around $25 per fish in the international market.

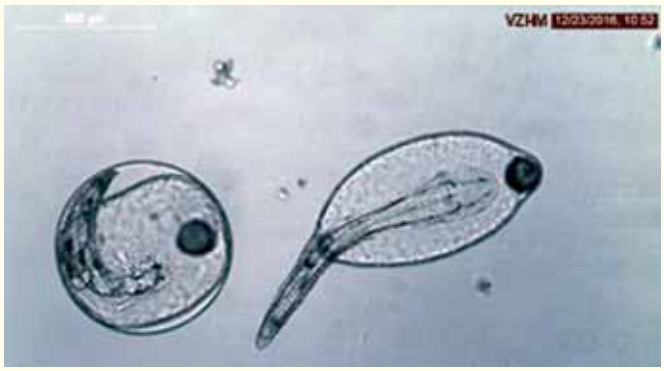
Pseudanthias squamipinnis



Developing eggs in 8 hours

Being a protogynous hermaphrodite with complicated breeding habits, reports on captive broodstock development and successful larval rearing are not available. At Vizhinjam Research Centre, broodstock of this species was developed in 5 ton Recirculation Aquaculture System (RAS). A total of 12 wild caught juveniles were stocked in the tank during the month of May 2016. Spawning took place after 7 months of rearing in the RAS on December 22, 2016 and eggs hatched out the next day after an incubation period of about 14 hours. About 4000 eggs at the stage of optic vesicle stage of embryo development were collected from the broodstock tank with ahatching rateof 98%. While newly hatched

Eggs hatching after 12 hours



Newly hatched larva of *Pseudanthias squamipinnis*

eggs measured 650 microns the newly hatched larvae measured 1400 microns. As a first, globally standardization of larval rearing protocol is under progress at the centre. Development of successful larval rearing protocols which can be adopted by aquarium hobbyists and entrepreneurs can give a big fillip to the marine ornamental fish trade in India. Both the research work were done under the All India Network Project (AINP) on Mariculture.

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Perinatal nutrition for faster growth rate in Broilers

The perinatal nutrition involving *in ovo* (last few days of pre hatch) and neonatal (first few days post hatch) supplementation of specific nutrients is one of the most

In ovo injection of nutrients

promising intervention strategies in broiler industry for achieving faster growth rate. Early nutrient fortification improves the efficiency of nutrient utilization, early gut development, improved immune response and increased muscle development and breast meat yield. In a series of experiment conducted at ICAR-National Institute of Animal Nutrition and Physiology, Bangalore with lysine, methionine and threonine amino acid and mineral supplementation during perinatal phase significantly improved growth performance of broiler chicks, while improvement of cell mediated immune response was observed with zinc and selenium supplementation. In ovo supplementation of threonine, arginine and glutamine increased the gut development at the time of hatch.

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ICAR-Indian Institute of Water Management Bhubaneswar

The ICAR-Indian Institute of Water Management (erstwhile Directorate of Water Management or Water Technology Centre for Eastern Region) was established on May 12, 1988 at Bhubaneswar as a National Research Center during VIIth Five Year Plan with the aim to cater to the research and development need of agricultural water management for eastern region. Subsequently, the research need and mandate has been expanded to national level.

MANDATE

- Strategies for efficient management of on-farm water resources for sustainable agricultural productivity.
- Coordinate research for generating location-specific technologies for efficient use of water resources.
- Centre for training in agricultural water management.

The scheme of AICRP on Water Management (AICRP-WM) and AICRP on Groundwater Utilization (AICRP-GWU) were transferred to this Institute on April 1, 2002 and September 18, 2003, respectively from ICAR-RCER, Patna. During XIIth Five Year Plan, these two AICRPs were merged together with revised themes and renamed as AICRP on Irrigation Water Management (IWM) comprising 26 cooperating centers with adequate emphasis on surface water, groundwater and wastewater management. The institute also coordinates Agri-Consortia Research Platform on Water. During the Xth Five Year Plan, the institute has coordinated the capacity building program 'Scaling of Water Productivity in Agriculture (SWPA) for livelihoods' sponsored by Ministry of Agriculture, Govt. of India. The institute is also actively engaged in capacity building and developing framework for district irrigation plan as a recent initiative of *Pradhan Mantri Krishi Sinchaee Yojana* (PMKSY) of GoI.

With a dedicated team of well experienced scientists having made significant research contributions in the past, it is envisioned that the institute would make major strides in the forthcoming years towards the cherished goal of emerging as the Institute of Excellence on agricultural water management for Asia and the World.

INFRASTRUCTURE

The institute's main campus-cum-laboratory building, guest house and residential complex is located at Chandrasekharpur, Bhubaneswar and spread over 5.71 hectare. It is situated at about 8 km north of Bhubaneswar railway station and about 15 km away from Biju Patnaik International Airport, Bhubaneswar. The research farm of the Institute (63.71 ha of farm land) is

located at Deras, Mendhasal and is 30 km away from main campus.The Institute focuses its research activities under four major research programs, viz., Rainwater management, Canal water management, Groundwater management and On-farm technology dissemination.

The Institute has four well-equipped laboratories, viz. soil-water-plant relationship laboratory, irrigation and drainage laboratory, hydraulic laboratory, and plant science laboratory with all the latest equipment for

Soil-water-plant relationship laboratory

research activities. An engineering workshop also caters to the needs of the institute. In addition to these, three field laboratories also exist at the research farm, viz., meteorological laboratory, pressurized irrigation system, and agricultural drainage system. The institute has its own web server and regularly updated website (*www.iiwm.res.in*). The entire network administration of the computers, internet and website management is looked after by the ARIS cell. The ARIS cell also accommodates a fully developed GIS laboratory.The Institute also has a well-established library, conference hall, committee room, training hall, guest house etc. Besides, AICRP coordinating unit, Statistical hub, PME Cell,video conferencing facilities are also functioning. Presently the institute has 28 scientists and 30

Library

Guest house

administrative, technical and supporting staff.

Facts about Water

- India has an annual average precipitation of 1170 mm and about 70% of the total area of the country experiences annual rainfall of 750 mm or more.
- India has the largest gross irrigated area (88 Mha) in the world.
- More than 80% of the surface water developed is used by the agricultural sector. On the other hand, inefficient and dilapidated canal irrigation systems have led to a spurt in groundwater development.
- India is the largest user of groundwater in the world with over 60% of irrigated agriculture and 85% of drinking water supplies dependent on aquifers.
- It is estimated that in 2010 total water use was 761 BCM of which 91%, or 688 BCM, are for irrigation.
- In India, water availability per capita has declined from 5000 m^3 /year in 1950 to around 2000 m^3 now and is projected to decline to 1335 m^3/year by 2025 leading to far less water availability for agriculture.
- Agriculture in India will face stiff competition for water from other sectors. By 2025, agricultural water use is expected to fall to 70% of total use, against 82% at present.

SALIENT ACHIEVEMENTS

Optimum dyke (bund) height to conserve rainwater in rice field: Proper bunding of rice fields help in conservation of rainwater. Rice fields with bund height of 6 cm can store about 57% of the rainwater and bund height of 30 cm storing 99% of rainfall. Consequently, the supplemental irrigation requirement declines significantly with increase in bund height. While 6 cm high bunded plot required four supplemental irrigations (each of 6 cm depth), 10-14 cm high bund required three irrigations, and plots with 18 cm high bund required only two supplemental irrigations.

Design and development of indigenous rubber dams for watersheds: Indigenous rubber dams were constructed, installed and evaluated in watersheds at

different locations in the country. This is an innovation in material science which has been applied for water conservation, flood control and regulating flow of water in stream. Rubber dam can be inflated by supplying water into it through inlet pipe and deflated through an outlet. In inflated condition, it acts as barrier to flow of water in the stream. Thus the stored water can be utilized for irrigation purpose. At the time of heavy flood, to avoid damage to the structure, water stored in upstream side can be released through deflation.

Rubber dam

Micro level water resource development through tank-cum-well system: To capture rainwater and its utilization, the tank-cum-well system technology along the drainage line in a watershed is suitable for plateau areas having slope of 2-5%. The well is constructed at about 100 to 300 m downstream of the tank to tap the water that is lost by seepage from the tank. In general, for a catchment area of 500 ha, set of 15 tanks and wells can irrigate 60 ha area. The cost of implementation of the technology is ` 100,000/ha of gross irrigated area. The technology has a potential to generate ` 30,000/- extra gross income per year with additional employment generation of 115 man days per ha. It can increase the cropping intensity up to 166%.

Two stage rainwater conservation in medium rice lands: Conservation of rainwater in two-stages in the rainfed diked rice fields and its multiple use in refuse of 2 m depth occupying 10% of the total rice field area significantly enhanced: land productivity from 1.8 t/ha to 5.74 t/ha, water productivity from 2.06 Rsm^{-3} to 3.76 Rsm^{-3} and cropping intensity from 100 to 200%. The Benefit Cost (B/C) ratio of the system was 2.78. The system has vast potential in diked rice fields of ER with annual rainfall of more than 1000 mm and in similar conditions elsewhere.

Two stage rainwater conservation

Crop diversification in rainfed uplands: Productivity of rainfed upland was enhanced through crop diversification during rainy season. Highest rice equivalent yield was obtained from maize cob (7260 kg/ha), followed by groundnut + pigeon pea (7025 kg/ha), maize + cowpea (6750 kg/ha), and groundnut (5690 kg/ha), respectively.

Lining of runoff recycling tanks for seepage control: Two methods of lining of tanks for seepage control has been developed: one by finding an alternative to expensive kiln burnt bricks and another by using LDPE film overlain by mud block, an inexpensive but stable material. Compressed mud block with 4% cement additive is a very good alternative to brick lining. These compressed mud blocks can be made by manual soilblock press designed by Housing and Urban Development Corporation.Hydraulic conductivity of these compressed mud blocks is about 73% less and the cost is about 50% less. A design of tank linked with mud block and LDPE film has been developed.

Rice straw mulch for moisture conservation: Significant soil water is lost under increasing evaporative demand especially in late post-monsoon period affecting crop yield of groundnut, pointed gourd and potato. Application of straw mulch @ 5 t/ha with irrigation schedule of IW/CPE of 1.2 in groundnut, 20 t/ha in pointed gourd and 5 t/ha in potato increased production. In pointed gourd, it increased fruit production by 77 to 323% from first year to fourth year of cultivation over no mulch cultivation. Mulching also maintains low soil temperature; control weeds; raises soil pH, soil organic matter content, and electrical conductivity; improves available phosphorus and potassium.

Alternative canal delivery schedule for improved system's performance: An alternative canal delivery schedule was established for deltaic area irrigation system of Odisha through simulation model and a field

experiment. Rotational schedule of '15 days on' followed by '15 days off' during monsoon and '7 days on' followed by '7 days off' during dry season was found better than the prevailing continuous schedule. It is to be adopted at distributary level. Efficient rotational delivery of canal water for *rabi* crop resulted in saving 10.3% water as compared to the continuous delivery system.

Augmenting water resource of minor irrigation projects through secondary storage reservoirs: Provision of secondary storage reservoir in the command of the flow based minor irrigation systems to augment the water resource and its optimal surface area was determined. In a study system, secondary reservoir has resulted in increase in irrigation intensity (7.7%) and standardized gross value of production (171.7%), output per cropped area (76.5%) and output per command area (171.7%). The proposed intervention was found economically viable with a B/C ratio ranging from 1.68 to 1.86 and internal rate of return (IRR) from 22.52% to 24.43%**.** Multiple use management of water in the secondary reservoir through fish culture and irrigation of *rabi* crops resulted in increased yield and net return to farmers.

Participatory irrigation management: Group Dynamics Effectiveness Index (GDEI), an effective tool for assessing the effectiveness and functioning of water user association (WUA) was formulated and used for assessing 17 selected groups (*Pani panchayats* of major irrigation, minor flow irrigation, minor lift irrigation and small WUAs). WUAs of lift irrigation system was found to be the most effective and major irrigation system as the least effective one.

Raised and sunken bed system: The raised and sunken bed technology for crop diversification in canal command of high rainfall area resulted in elevation of 50% land for growing vegetables and remaining land for rice/ *Colocasia.* Average annual income of small farms of 0.4 ha increased 5 to 7 times.

System of rice intensification (SRI): For 'more crop per drop', the System of Rice Intensification (SRI) practices optimized for eastern region of the country. SRI with 20 x 20 cm spacing gave 36-49% higher yield (about 6 t/ha) and saved about 22-35% of irrigation water compared to conventional transplanted crop. Water productivity increased by 73% under SRI, highest grain yield and water productivity is at irrigating crop at 3-days after disappearance of ponded water (6.35 t/ha and 6.47 kg ha-mm^{-1}). Under rainfed condition, by integrating SRI methods of rice cultivation and small dugout pond to conserve rainwater for multiple use (paddy + pisciculture + horticulture), *kharif* paddy yield increased from 2.9 t/ha to 6.2 t/ha with fish yield of 2.6 t/ha; net water productivity of this system enhanced from `0.3m$^{-3}$ (conventional rainfed rice) to `18.9m^{-3} of water.

SRI field

Drip Irrigation in Rice: The performance of drip irrigation (DI) in rice was evaluated. DI laid out at 1.0 m lateral spacing produced 6-13% less grain yield, using 35-40% less irrigation water, resulting in 40-50% higher irrigation

Raised and sunken bed system

Drip irrigation in rice

water productivity compared with surface irrigation (SI) in rice. Introduction of baby corn after irrigated (aerobic) rice under drip system produced the net profit of ` 1.65 lakh per ha with benefit-cost ratio of 2.17 compared with net profit of ` 0.76 lakh per ha with benefit-cost ratio of 1.62 under SI in rice-rice cropping sequence.

Agriculture Water Management Portal (AWMP): A web-based information system *viz*. Agriculture Water Management Portal (AWMP) (http://www.iiwm.res.in/awmp) has been developed using ICT application in agriculture to serve as a knowledge sharing platform among different stakeholders; password protected data management module for Chief Scientists of AICRP-IWM centres in the country has been created for uploading information. The module for Nodal Officer at PC unit has been developed for accessing and monitoring information submitted by individual centres.

Agriculture Water Management Portal

Bio-drainage of waterlogged lands in high rainfall areas: The use of bio-drainage vegetation appeared feasible in deltaic areas both in inland topographical depressions and in areas where the natural drainage is incapacitated by sea water intrusion. *Eucalyptus* for inland sites and *Casuarina* for coastal areas due to their salt tolerance ability were found suitable as bio-drainage vegetation. The space in between the bio-drainage trees utilized for cultivation of other crops, i.e. paddy during *kharif* and watermelon, green gram, black gram, cow pea and groundnut during *rabi* season. Accelerated drainage through bio-drainage advanced watermelon cultivation in *rabi* season by 15-20 days with an additional benefit of ` 15,000/ha due to better market price and avoiding market glut.

Casuarina as bio drainage plantation

Crop/ management options for enhancing productivity of waterlogged areas: Package of practices for water chestnut, swamp taro and Cat tail (*Typha,* locally known as 'Hogla') were developed. Integration of fish *(magur)*

Swamp taro

Water chestnut

with water chestnut yielded about 1.8 t/ha of fish and 8 t/ha of water chestnut. Further, use of over-aged rice seedlings (60 days) to avoid damage due to submergence and application of 40 kg/ha of N through mud ball was observed to significantly increase grain yield.

Ensuring high water productivity in commercial aquaculture: The total water and consumptive water requirement of commercially important carp polyculture and monoculture of *Penaeus monodon* and *Litopenaeus vannamei* (brackish water shrimp) at varying intensity levels have been computed to ensure higher water productivity and profitability in commercially important grow-out aquaculture. The desirable density that gives significantly higher yield, and water productivity is 8000 fingerlings/ha, 200000 post-larvae/ha and 500000 post-larvae/ha in case of carp polyculture, monoculture of *P. monodon* and *L. vannamei* respectively. At desired density, the recorded yield (t/ha) was 3.6, 4.6 and 10.3 while the net consumptive water productivity (NCWP, Rsm^{-3}) was 9.0, 39.0 and 73.3 in case of carp polyculture, monoculture of *P. monodon* and *L. vannamei* respectively. The estimated total water use (TWU, ha-m) is 4.0, 3.3 and 3.4 while the consumptive water use index, CWUI (m^3/kg biomass) is 5.7, 4.8 and 2.0 respectively for carp polyculture, monoculture of *P. monodon* and *L. vannamei.*

A shrimp culture in ponds

Water footprint: Water footprints computation in agriculture (crop, livestock and fisheries) and their farm level accounting procedure have been developed.

Conjunctive use of groundwater and canal water: Conjunctive use of canal water and groundwater in middle and tail reach of the canal command increased cropping intensity upto 200%. Open wells of 8-10 m depth; 4-5 m diameter can command 2-3 ha areas, whereas shallow tube wells 4" diameter, up to 20-40 m depth can command 4-5 ha in coastal alluvial areas.

Groundwater recharge in hard rock area: A regional groundwater recharge model was developed for 4200 ha hard rock area. Optimal combination of 20 large, 382 small water harvesting structures and 340 dug wells were proposed for watershed of 3132 ha area. These structures would recharge on average of 12-18% of rainfall annually.

Groundwater pumping options in coastal areas: Technology of shallow tube well for coastal areas having saline groundwater below 10m depth (coastal area within 2-5 km away from coastline) was developed. The depth, diameter of shallow tube well and pump size should be restricted within 10m and 5 cm and 2 hp respectively. It can command 1-1.5 ha for *rabi* crops. In coastal tract (coastal regulatory zone III) of Odisha, groundwater pumping options has been standardized. Pump size should be restricted within 1-3 hp with well density of 3-4 numbers per square kilometre to check the detrimental effect of saline water ingression.

Groundwater and energy use: Providing quality electricity for pumping of groundwater at higher prices than subsidizing electricity for irrigation is considered as a better option. Increasing cost of electricity by 100 % will increase irrigation cost only by 4-15% in hard rock region and 11-30% in alluvial region of Odisha. Even, irrigation cost at `5.3/- per unit of electricity will be less than (almost half) that of irrigation cost using diesel energy.

Modelling for optimal use of land and water: A simulation-optimization model was developed using response matrix approach by linking the simulation model with the optimization model for optimum land and water utilization. Visual MODFLOW was used to develop groundwater flow simulation model for Kathajodi-Surua Inter-basin within Mahanadi deltaic system. The results of simulation-optimization modelling system indicated that if the suggested optimal cropping patterns are

Study area with grids in MODFLOW set-up

adopted in the study area, the net annual irrigation water requirements will be reduced by 28, 35 and 40%, and net annual income will be increased by 28, 23 and 17% during wet, normal and dry scenarios, respectively.

Groundwater depletion study: Using 129 monthly gravity solutions from NASA's Gravity Recovery and Climate Experiment (GRACE) satellites during 2003-2014, changes in terrestrial water storage (TWS) were investigated. In India's grain bowls-the Ganges basin and Punjab state, a substantial groundwater depletion of 12.5 and 21.0 cm of water equivalent height per decade, respectively was found. Most of this loss has primarily been due to the indirect impacts of droughts in 2004, 2009 and 2012.

Development of small-scale online hybrid filter: A four chambered small scale on-line (through pump) hybrid (coarser and finer material) filter has been designed and developed to reduce sediments, microbial load and heavy metals from the municipal wastewater. It was evaluated using municipal wastewater for cultivation of horticultural crops at farmers' field.

Small-scale online hybrid filter

Paper mill sludge for higher productivity and water use efficiency in acidic soils: Paper mill sludge, a low cost liming material could ameliorate acidic soils and increased the yield of different crops by 34-68% and water use efficiency by 30-60%. An additional income of `20,000/ha/year could be generated by using paper mill sludge in acidic soils.

FUTURE THRUSTS

- Promotion of basic and strategic research on agricultural water management using frontier tools like remote sensing, GIS, information technology, nanotechnology etc.
- Efficient irrigation water management through DSS, canal automation, sensor technology, ICT etc.

Research farm

- Improvement in pressurized irrigation system through development in material science to check clogging, reduce cost and energy requirement for higher water requiring crops.
- Improvement in efficiency of pumping system using the knowhow of automobile and other related industries in making efficient engines.
- Spatial and temporal mapping of availability of wastewater and its safe utilization in agriculture through biotechnology and material science innovations.
- Strategies for mitigation of drought, flood and other natural calamities in the changing climate scenario.
- Developing water saving technologies in livestock and fisheries sector.
- Development of water-land-soil resource index map to demarcate critical target areas for food and nutritional security.

Weather station

- Development of institutional mechanism for water governance and policy with inbuilt flexibility to adopt changing socio-economic scenario.

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Swarna Safal – An improved vegetable Faba bean for Jharkhand

Faba bean (*Vicia faba*) is an important winter vegetable legume of Jharkhand. An improvement programme was initiated through collection, evaluation and utilization of genetic variability of the crop, which resulted in improved vegetable Faba bean line HAVFB-41. In 2008-11, HAVFB 41 proved its worthiness with respect to green pod yield (24.25 tonnes /ha) ; 24.04% yield increase over the check variety Pusa Sumeet (19.55 tonnes/ha). During 2012-14, the variety exhibited its superior performance regarding green pod yield and quality at farmers' fields in three agro-climatic zones of Jharkhand. The line comes to 50% flowering stage in 35-40 days after sowing. The green pods are ready for harvest in 89-94 days after sowing. The green pods are 3.0-3.3 g in weight and 5.4-6.0 cm in length. HAVFB-41 has been found resistant to chocolate spot (*Botrytis fabae*) and least infested by pod borer in field conditions. Per 100g edible portion, green pods contained 2.95g protein, 5.81g carbohydrate, 25mg calcium, 115mg phosphorus, 194mg potassium, 32mg magnesium, 33mg sulphur, 0.65mg copper, 0.39mg manganese and 0.11mg iron. Due to its high nutritive value, better yield potential and consumer preference,

Field view of Faba

Swarna Safal at flowering and pod bearing stage

Reaction of Faba bean lines/varieties to major insect pests

Variety	Swarna Safal	Pusa Sumeet
Pod borer (*Helicoverpa armigera*) damage (%) at pod formation stage	0.07	0.2
Pod borer (*Helicoverpa armigera*) damage (%) at pod filling stage	0.0	0.0
% of Leaf miner infestation at vegetative stage	0.0	0.0
% of Leaf miner infestation at pod formation stage	0.0	0.0
% of Leaf miner infestation at pod filling stage	7.7	4.5

Reaction of Faba bean lines/varieties against chocolate spot (*Botrytis fabae*)

Lines/Varieties	Disease scoring (0-9 scale)						Reaction
	2013-2014			2014-2015			
	Dec. 13	Jan. 14	Feb. 14	Dec. 14	Jan. 15	Feb. 15	
Swarna Safal	0	1	3	0	1	3	R
Pusa Sumeet	0	3	6	0	3	6	MS

R= Resistant, MS= Moderately Susceptible

Premium attributes of Swarna Safal

Attribute	Swarna Safal
Pod weight	3.04-3.38 g
Pod length	5.47-6.09 cm
Pod colour	Green
Pod shape	Straight, round
Days to 50% flowering	35-40 days
Days to first harvest	89-94 days
Plant height	85-113 cm
No. of branches/plant	4.55-6.99
Fresh pod yield	20-25 t/ha
Flower colour	White
Dry seed coat colour	Light brown
Dry seed shape	Round
Carbohydrate	5.81 g/100g
Protein	2.95 g/100g
Calcium	25 mg/100g
Phosphorus	115 mg/100g
Potassium	194 mg/100g
Magnesium	32 mg/100g
Sulphur	33 mg/100g
Iron	0.11 mg/100g
Manganese	0.39 mg/100g
Copper	0.65 mg/100g
Tannin	943 mg/100g

this line HAVFB41 has been released as Swarna Safal (IC 617240) by the State Variety Release Committee of Jharkhand in 2015 for large-scale commercial cultivation in Jharkhand.

Green pods of Swarna Safal ready for harvest

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Rangkuai: A Local Mango variety from Indo-Burma frontier

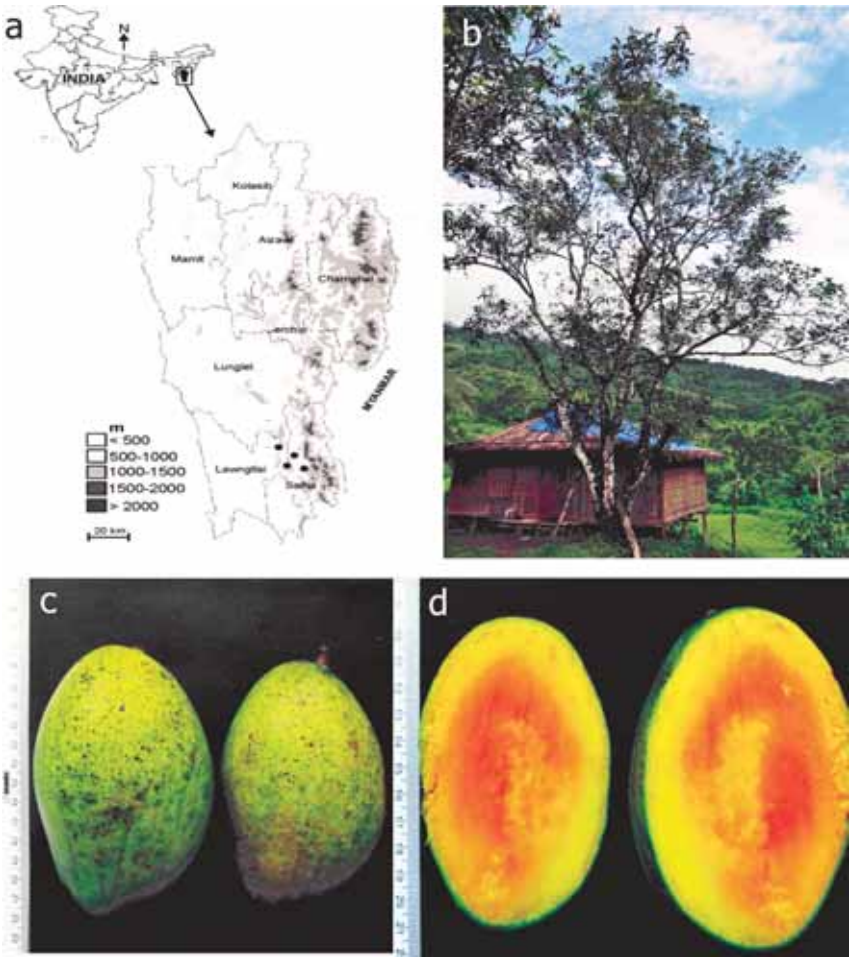
Indo-Burma region is the centre of origin of mango (*Mangifera indica*). The North-East Indian state of Mizoram lies on the boundary of this region having a considerable diversity of this crop. ICAR RC NEH Region, Mizoram Centre in collaboration with KVK, Lawngtlai has identified a chance seedling of mango locally known as *Rangkuai* from the village Sihtlangpui, Lawngtlai district of Mizoram (22.11° N and 92.93° E).

In the village Sihtlangpui, the first seedling of this variety was introduced by some villager in 1977. The variety is known for its quality and taste in the region and over the years this variety has shown some unique traits. *Rangkuai* is mainly confined to the bank of river *Koladyne* (also called *Chhimtuipui*) passing across Lawngtlai and Saiha districts of Mizoram. It is believed that *Rangkuai* performs best in terms of quality in this geographical pocket of the state compared to other regions. The tree comes into bearing within 5-6 years of planting. The tree is generally vigorous in nature with a height of 10-15 meter with a regular bearing habit.

Tree starts flowering during March-April every year and fruits are harvested in third week of June onwards

Parameters*	
Fruit weight (g)	300-350
Fruit length (cm)	10-12.5
Fruit breadth (cm)	6.5-7.5
Seed length (cm)	7.5-8.1
Seed breadth (cm)	4.3-2.1
Pulp recovery (%)	65.2-70.1
TSS (ºB)	13-15
Acidity (%)	0.9-1.2

* Range of all parameters was derived from 20 fruits selected randomly.



Map with dotted points showing the site of presence of the variety **(a)**, Oldest mother tree of *Rangkuai* as reported by villagers **(b)**, Whole fruits of the variety **(c)**, Fruit cross section with stone **(d)**.

upto August. Fruits are of big size (3 fruits/kg) with medium sized stone. Fruit is sweet in taste, juicy pulp, less fibred and good aroma. Colour of the skin is greenish with white patches when immature and becomes light yellow during maturity. Single fruit costs approximately ` 30 in the market during the season. Some of the fruit parameters recorded are given below in the table. From the superior performance of this variety in this region over the years, it can be suggested as a potential breeding material for North-East India from quality and adaptability point of view.

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Chilgoza Pine – A Priced Edible Nut of Himachal Tribals

Kinnaur, the tribal district of Himachal Pradesh is blessed with a unique forest tree which is known as Chilgoza (*Pinus gerardiana*), commonly known as Neoza. It belongs to genus *Pinus* that maintains a very unique position of being an integral part of the vibrant, but fragile ecosystems of the great Himalayas in the Indian sub-continent. It is named after Captain Patrick Gerard, a British army official who discovered it while posted in the region in the 19th century. This is the only pine which is of immense social forestry importance because the livelihood of most of the tribals depends on the earning from its nuts. The slender Chilgoza seeds are highly nutritious. Further, it also forms an important part of their diet as well as a traditional item besides being a cash crop. Chilgoza are highly valued in Kinnaur for not only are they part of community ownership but also provide livelihoods means as one tree fetches annually about ` 8000-10000/- for the villager. The seeds are also

Distribution of Chilgoza trees in fragile eco system

a preferred choice in the confectionery industry as they are easy to insert into cakes and sweets compared to other nuts.

Flowering and fruiting: It is compact, small to medium sized evergreen tree, flowers in May-June and female cones mature during September-October of the following year. The tree starts bearing cones at the age of about 20 years and one tree on an average yields 7-10 kg of nuts with an average of 148 nuts per cones and a good seed year alternates with poor ones.

Unique nutrition and health properties: Edible nuts of chilgoza are comparable with pecans, peanuts and walnuts with respect to nutrition. Its kernels contain high quality proteins, carbohydrates and cholesterol free fat with abundance (93%) of unsaturated fatty acids like Omega-6 and Omega-9, besides, other chemical constituents. Chemical composition of fresh and dried chilgoza nuts collected from Kinnaur district were also analysed.

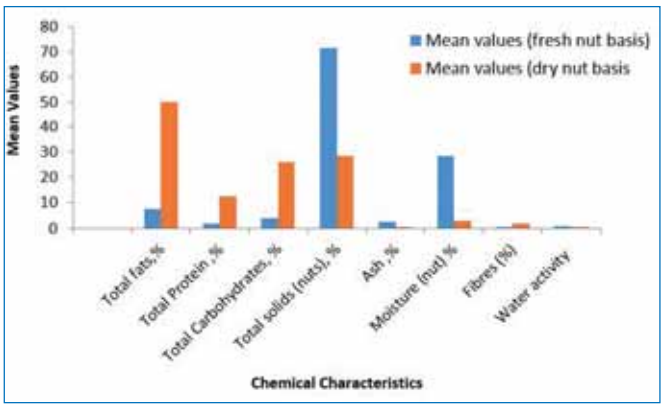
A young tree, Chilgoza bearing tree and the tree

Chemical Characteristics	Mean values (fresh nut basis)	Mean values (dry nut basis)
Surface colour	Brown 200D	Brown 200D
Total fats,%	7.41	49.9
Total Protein, %	2.09	12.40
Total Carbohydrates, %	4.12	26.0
Total solids (nuts), %	71.41	28.59
Ash, %	2.72	0.40
Moisture (nut) %	28.6	3.02
Fibres (%)	0.33	1.85
Water activity	0.907	0.098

Chilgoza nut is prized for its carminative, stimulative and expectorant properties and is particularly popular among the Arabs.

Contemporary uses

Chilgoza is a highly priced 'dry nut' in the Indian subcontinent and is known as a nutritious snack (food) and an essential ingredient in multiple oriental and Mediterranean dishes. In addition to being eaten raw, it can be an important ingredient in a variety of dishes including bread, candies, cookies, sauces and cakes as well as vegetable and meat dishes. The boat shaped sharp end nuts of chilgoza can be preferred by confectionary because they are easier to insert into cakes and sweets



Chemical characteristics of Chilgoza nuts

as compared to blunt nuts of *Pinus pinea* in various western countries. Chilgoza nuts oil can also be used in cosmetic beauty products and massage oil as the other pine nuts. Further, its nut flour can be used in wide variety of culinary uses. It can also be a gourmet substitute for wheat of rye flour and can be used in pastries and pan cakes for giving them rich nutty flavour. Even its crushed nuts mixed with milk and sugar forms a pine nut milk, drink or pine nut cream rich in nutty flavour. Besides these uses, by product of chilgoza nut in the form of flakes can be used in chocolates and crunch bar production.

Traditional technology of nut extraction: Although the forests of Chilgoza in Kinnaur are maintained by State Department of Forests, but the tribals have rights to harvest the crop from surrounding area of village. The cones are harvested by wrenching them off the trees with the help of long poles with a hook attached to one end. However, in some places the residents cut the shoot where cones are attached, as a result of which crop of next year got reduced considerably. Harvested cones are kept on the *Kacha* roof of the houses for drying which takes months together for the extraction of nuts. For extraction of nuts sharp edged saw is used to cut the cones apart as a result of which most of the nuts get damaged.

Other traditional technology includes the staking of cones in the heap while still unripe and roasting over an open fire. The resin in the cones catches the fire and resultant heat open the cones and releases the nuts. But the quality of the nuts gets severely affected due to high temperature of burning. After extraction, nuts are packed in gunny bags and sold to local traders as well as in the distant markets at cheaper rates without proper grading and packing. If nuts remain in the store for more

Traditional nut extraction of freshly harvested cones

than two months then they start spoiling due to fungal as well as nut weevil attack.

As a result, farmers try to sell the nuts as early as possible to local traders or to distant market at throw away prices. Thus, farmers spend more than one month for drying and extraction of nuts from the cones.

A complete technology package for the drying and extraction of nuts, therefore has been developed to improve the quality and ensure round the year marketability of the produce. The developed technology will reduce the nut extraction time from months to only a few days. The pre treatment of nuts like surface colour improvement and impregnation with salt will add variety to the nuts. Drying and packaging of nuts will extend the shelf-life of the nuts from few months to years. As a result, tribals will be able to sell their produce throughout the year at the price of their choice. The Bureau of Indian Standards (BIS) has included these standards in its list of standards, vide IS number IS-16117:2013, as a mark of national trade standards.

Freshly extracted nuts and their traditional packaging

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Invasion of rugose spiraling whitefly in India

The invasive rugose spiraling whitefly (RSW) *Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae) was found infesting coconut, banana, custard apple and several ornamental plants in Tamil Nadu, Andhra Pradesh and Kerala for the first time in India. Aphelinid parasitoid, *Encarsia guadeloupae* Viggiani (Hymenoptera: Aphelinidae) was also recorded during the survey which fortuitously introduced along with spiraling whitefly (*A. dispersus* Russel) during 1995. The identity of the pest species and its parasitoid were determined through morphological as well as molecular tools. The severity of infestation reached alarming situation causing extensive damage in coconut palm and banana, and thus assumed major pest status. Leaves are damaged by direct feeding especially on underside of the leaflets and production of prodigious quantities of honey dew excretion which in turn is completely darkened by sooty mold development on the upper surface of leaves. In coconut, RSW prefers to colonize on hybrid and dwarf varieties, especially Chowghat orange dwarf, Malaysian orange dwarf and Ganga Bondam semi-dwarf. Nymphs and adults suck the sap from the leaves and showed typical concentric waxy spiraling symptoms on various parts of host plants. Across the survey locations, the severity of infestation ranged 40 to 60% in coconut and 25 to 40% of leaf in banana and the population including all the immature stages varied from 18 to 43 nymphs/sq.cm of leaf and was noticed to be very high at the midrib region. The continuous dry spell, availability of host plants in large area and absence of natural enemies might have favoured its multiplication.

RSW adults are about three times larger (approx. 2.5 mm)


Honey dew excretion of the whitefly


Elliptical eggs of whitefly are creamy white to dark yellow in colour


Profuse quantity of wax filaments is produced at immature stage


Adults show large body size and presence of a pair of irrigular light brown bands across the wings


Adults emerge out by cutting the circular lid at the thoracic region


Adult tiny wasps

than the commonly found whiteflies and are lethargic by nature. It is closely related to giant whitefly, *Aleurodicus dugesii* Cockerell. The female of RSW lays eggs on the underside of leaves in a circular pattern or concentric waxy spiraling giving rise to their name and covers them with wax. Eggs are elliptical and creamy white to dark yellow in colour and immature stages are creamy brownish yellow in colour which turn slightly dark before adult emergence. Immature stages of RSW produce profuse quantity of wax filaments both tufts of fluffy and long crystal like glassy rods. The adult whitefly after emerging mostly congregates and reproduces near the midrib of undersurface coconut leaflets. RSW adults can be distinguished by their large size and the presence of a pair of irregular light brown bands across the wings. Males have long pincer like structures at the end of their abdomen.

Across the survey regions, *E. guadeloupae* was found to be more predominant one with maximum parasitism (20-60%). Parasitized RSW nymphs turn dark brown in colour and adults emerge by cutting the circular lid at the thoracic region. Adults tiny wasps can be identified by their yellow scutellum against their dark brownish body. Besides, *Mallada* sp. and few predators and coccinellids were also recorded. Until now, it has not been reported from the Oriental region, therefore, this record of pest and its natural enemies represents its first record of its presence in India as well as in the Oriental region. RSW was first described from Belize and it was reported as pest for the first time from Miami-Dade County in United States of America (Florida) from gumbo limbo (*Burera simaruba* L.) in 2009. This whitefly is believed to have originated from Central America and its incidence limited to Belize, Mexico, Guatemala and Florida in Central and North America. RSW is a highly polyphagous pest which has been found to feed on more than 120 plant species which include edible plants, palms ornamentals, palms, fruits and weeds of native and non-native species. This pest has been classified as a serious threat for coconut cultivation including many other host plants in Florida.

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WAY FORWARD

Agriculture since the very beginning of human civilization has evolved from bio-prospecting, selection and development of a few species from plant and animal kingdoms, to meet basic needs for food, fibre and fuel. Components of agro-biodiversity include all biotic factors related to agriculture, such as, plants, animals, fish, insects, birds and microbes. Agro-biodiversity eventually forms the foundation of sustainable agricultural growth and development as it provides the raw materials (genetic diversity) upon which agriculture depends. Unfortunately today, human-led developmental activities coupled with climate change is eroding genetic diversity at an alarming pace, leading to irreversible and irreparable loss. Conservation, management and sustainable utilization of agro-biodiversity (agriculturally important plants, animals, fish, insects and microbes and their wild progenitors/ relatives) therefore require urgent attention.

Important Indian Central Acts Relevant to Biodiversity

Fisheries Act, 1897	Territorial Water, Continental Shelf, Exclusive Economic Zone and other Maritime Zone Act, 1976
Destructive Insects and Pests Act, 1914	Water (Prevention and Control of Pollution) Cess Act, 1977
The Indian Forest Act, 1927	Maritime Zones of India (Regulation and Fishing by Foreign Vessels) Act. 1980
Agricultural Produce (Grading and Marketing) Act, 1937	Forest (Conservation) Act, 1980
Indian Coffee Act, 1942	Air (Prevention and Control of Pollution) Act, 1981
Import and Export (Control) Act,1947	Agricultural and Processed Food Products Export Development Authority Act, 1985/1986
Rubber (Production and Marketing) Act, 1947	Environment (Protection) Act, 1986
Tea Act, 1953	Spices Board Act, 1986
Mining and Mineral Development (Regulation) Act, 1957	National Dairy Development Board Act, 1987
Prevention of Cruelty to Animals Act, 1960	Rules for the manufacture, use/ import/export and storage of hazardous microorganisms/ genetically engineered organisms or cells, 1989
Customs Act, 1962	Foreign Trade (Development and Regulation) Act, 1992
Cardamom Act, 1965	The Geographical indications of Goods (Registration and Protection) Act, 1999
Seeds Act, 1966	Protection of Plant Varieties and Farmers' Rights Act, 2001
The patents Act, 1970	Biological Diversity Act, 2002
Wildlife (Protection) Act, 1972	Plant Quarantine (Regulation of Import into India)
Marine Products Export Development Authority Acts, 1972	The Food Safety and Standards Act, 2006
Water (Prevention and Control of Pollution) Act, 1974	Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006
Tobacco Board Act, 1975	

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There are five independent National Bureaux in India to address agro-biodiversity issues. These are the National Bureau of Plant Genetic Resources, New Delhi; National Bureau of Fish Genetic Resources, Lucknow; National Bureau of Animal Genetic Resources, Karnal; National Bureau of Agriculturally Important Microorganisms, Mau; and National Bureau of Agriculturally Important Insects, Beangaluru. These Bureaux are the nodal organizations for carrying out management of the agro-biodiversity in India, in partnership with other relevant national and international organizations. Besides the Bureaux, other National Research Centres/institutions under the ICAR also cater to activities on plant, animal, fish, agriculturally important microbes, mushroom and insect genetic resources.

Keeping in view the plurality and multi-functionality in agro-biodiversity system management, ICAR has now conceived an integrated approach to tackle the issues with all stakeholders on a common platform. In the XII Plan Period, ICAR is implementing a consortia research platform for effective agro-biodiversity management. The platform shall have five sub-projects addressing genetic resources management issues related to plants, animals, fish, microbes and insects. The respective Bureaux will coordinate these management functions involving the other stakeholders in their domain.

Thus, agro-biodiversity management is now getting utmost attention in the country and through an integrated system, it is hoped that farmers, breeders and users of genetic resources will harness these resources in a sustainable and effective manner in the future to address the issue of food, nutrition and health for all.

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