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ICAR NEWS

A SCIENCE AND TECHNOLOGY NEWSLETTER

RESEARCH UPDATE

PROMISING TECHNOLOGIES

A potentially polyembryonic dwarf rootstock for mango cultivar *Pusa Arunima*

Horticulture is known as a highly potential sector for employment generation, house hold nutritional security and income generation to the growers. Mango is one of the most important tropical fruits of the world, and is known as 'King of fruits' in India.

Inspite of vast achievements in mango, several constraints still exist such as large tree size, low planting density etc., causing low yield efficiency. New emerging challenges like poor fruit productivity per unit area continues to be a worry in mango cultivation. Maintaining mango under high density requires heavy annual hedging and pruning which often affects terminal flowering and subsequent inhibits yield efficiency. Vigour management plays an important role in mango, especially for high density planting and orchard management in terms of canopy management, harvesting and plant protection measures.

Pusa Arunima on K-2 rootstock after 11 years

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Pusa Arunima on Kurakkan rootstock after years

Pusa Arunima on Olour rootstock after 11 years

Fruit of K-2 rootstock

In our country, mango is generally propagated on non-descriptive seedlings which causes variations not only in yield of scion cultivar but also in fruit quality and tolerance power to many abiotic and biotic stresses. Hence we need to improve productivity of mango orchard per unit area for realizing more farmer's income by accommodating more number of trees per unit area. The best long term solution to impart dwarfism in mango is use of rootstock which can reduce vigour of mango scion varieties up to more than 30%. Among available north Indian varieties, *Pusa Arunima*, is the most important, known for its coloured fruits with good acid, sugar blend and highest shelf life. Our present, research was aimed to realize the new dwarfing mango rootstock for *Pusa Arunima*, therefore we evaluated the performance of *Pusa Arunima* variety on five polyembryonic rootstocks viz., Kurakkan, Olour, K-5, K-3 and K-2 during 2008-2019.

Comparative yield and fruit quality of mango cultivar Pusa Arunima on K-2, Kurakkan and Olour rootstocks

Parameter	Rootstock		
	Kurakkan	Olour	K-2
Fruit/tree*	77.00	106.00	74.00
Yield/tree (kg)*	17.66	23.46	16.34
Fruiting density/m^3 CV*	1.00	1.03	2.03
Yield efficiency/m^3 CV*	0.24	0.22	0.44
Fruit weight (g)*	226.21	222.14	221.36
Pulp content (%)*	61.30	65.98	63.71
Stone weight (g)*	33.67	34.55	33.14
TSS (^{0}B)**	22.56	23.58	23.13

*Mean of four years

Vegetative growth of *Pusa Arunima* on K-2 rootstock as compared to other rootstock

After 11 years of growth, trees of *Pusa Arunima* had 2.67 m height as compared to 4.08 m on Olour and 3.80 m on Kurakkan, which 29.73% and 34.55% lesser than Kurakkan and Olour, respectively. Likewise, canopy diameter of *Pusa Arunima* trees was noted to be 3.22 m north to south as of 4.58 m and 4.02 m on Olour and Kurakkan, which was 19.90% and 29.69% less than Kurakkan and Olour, respectively. Similar reduction was noticed in east and west canopy diameter and trees on K-2 rootstock having only 3.32 m east to west canopy diameter. Moreover, a drastic reduction was noticed in canopy diameter in trees grafted on K-2 rootstock as of

Comparative growth performance of mango cultivar Pusa Arunima on K-2, Kurakkan and Olour rootstocks after 12 years of planting

Parameter	Rootstock			Percent reduction
	Kurkkan	Olour	K-2	
Plant height (m)	3.80	4.08	2.67	Over Kur= 29.73 Over Ol= 34.55
Canopy diameter (m) (N-S)	4.02	4.58	3.22	Over Kur= 19.90 Over Ol= 29.69
Canopy diameter (m) (E-W)	4.13	4.55	3.32	Over Kur= 19.61Over Ol=ur 27.03
Canopy volume (m^3)	135.48	178.36	60.25	Over Kur= 21.75 Over Ol=66.22

Kur; Kurakkan, Ol; Olour

trees on Olour rootstock (66.22% inhibition) and Kurakkan (21.75% inhibition) (Table 1).

Yield and fruit quality performance of *Pusa Arunima* on K-2 rootstock

According to per tree the number of fruits and yield was recorded highest on Olour rootstock, but highest fruiting density (2.03 fruits/ m^3 CV) and yield efficiency (0.44 kg/m^3 CV) was found when trees of *Pusa Arunima* were raised on K-2 rootstock. Trees on K-2 rootstock had 103% and 97.09% higher fruiting density than trees on Kurakkan and Olour rootstocks, respectively. Likewise, there was 83.33% and 100% more fruiting efficiency than Kurakkan and Olour rootstocks. It is pertinent to mention that fruit quality parameters such as fruit weight, pulp content, stone weight and TSS were also found equally good on K-2 rootstock.

Growth habit of K-2 rootstock

It can be inferred that K-2, a polyembryonic genotypes of mango is able to restrict vegetative growth of mango cultivar *Pusa Arunima* without deteriorating the fruit quality. Hence this rootstock could be used as potentially dwarf rootstock for this variety for high density orcharding (4 m x 4m spacing based on canopy spread after 11 years' growth). This rootstock can also be tried for other mango varieties under different agroclimatic conditions.

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Interventions in tribal villages by ICAR-Sugarcane Breeding Institute

ICAR-Sugarcane Breeding Institute (SBI) at Coimbatore and its Regional Centres in different states of India is playing a pivotal role in sugarcane improvement in the country since its inception in 1912. The Institute has also stretched its activities for the betterment of tribal people through Tribal Sub Plan, being implemented at this Institute since 2014. Tribal Sub Plan is a comprehensive strategic approach adopted by the Government of India for welfare and development of Scheduled Tribes (STs).

APPROACH

Every village we visited was different so we got acquainted with their social setup through frequent visits.

Requirement Analysis: As an initial step, requirement of the tribal people was analyzed through personal interactions and focus group discussions conducted in villages with tribal headman and villagers. Participatory rural appraisal techniques like transact walks, livelihood analysis, gender analysis, matrix ranking, venn diagrams, seasonal analysis conducted with the tribal people gave us a vivid picture of the village setting.

***Holistic Approach*:** After information was analyzed we prepared problem-cause diagrams for each village. Subsequently, the problems (both felt and unfelt) were prioritized and crucial ones were considered for immediate action. A work plan was prepared for each beneficiary village taking into account the felt needs of people, resources available, expertise required and manpower availability. The technological interventions were carefully chosen so as to have a sustainable livelihood for tribal villagers, drudgery reduction for tribal women and employment generation for tribal youth.

BENEFICIARY VILLAGES

The year-wise 17 beneficiary tribal villages identified

since 2014 for implementation of the project are given below:

2014-15: *Thondamuthur range*: *Attukkal*; *Boluvampatti range*: *Sarkarporethy*, *Sadivayal*, *Vellapathy*.

2015-16: *Attapadi* hill range: *Vellamari*, *Agali*, *Palakkad* district, Kerala; *Boluvampatti* hill range: *Pottapathi*, *Seengampathi.*

2016-17: *Karamadai* Forest Range: *Kuzhiyur.*
2017-18: *Palamalai hill* range, *Periyanaikenpalayam*: *Pasumani*, *Pasumanipudur*, *Mankuzhi*, *Perukkapathy*, *Perukkapathy pudur*, *Kunjoorpathi*; *Pilloor* Dam Reserve Forest Area: *Keththakadu*, *Veerakkal*, *Maanaar*, *Korapathi.*

INTERVENTIONS

Sustainable Horticultural Village – *Attukkal*

- Encouraged by response of villagers in *Attukkal*, we aimed to create a 'Sustainable horticultural village'. With 61 families settled in 54 houses in an area of around two acres in the foothills, this village was best suited for interventions in horticultural crops. Responsive attitude of the tribal people "Irulas" in this village became our motivating factor.
- With ample scope for area or water facility, we restricted our support in terms of supply of seedlings of coconut (42), nerium (102), sapota (31), *mosambi* (5), curry leaf (50), acid lime (31), custard apple (4), jasmine (5), guava (3), betel nut (37), gooseberry (20) and pomegranate (5). We helped them in planting saplings scientifically by proper potting mixture, well protected with bamboo cages with little support for watering.

Sustainable Mechanized Village – *Vellamari*

- TSP was implemented in *Vellamari*, *Palakkad* district, Kerala with emphasis on mechanization in agriculture. There are 196 households in this village owning 110 acres of cultivable land where crops like coconut, arecanut, banana, vegetables, wild jasmine, pulses etc. are cultivated. It was seen that the usage of machineries was minimum except for spade, hand hoe and sprayers.
- Therefore we took the initiative of converting this village into a 'Sustainable mechanized village' and made them form a group called '*Vellamari Adivasi* Development Group' and got it registered with *Agali panchayat*. We supplied a four wheeler drive mini-tractor with accessories viz., trailer, cultivator, rotavator and other minor implements like brush cutter, sprayers, spade etc. On-farm training and demonstration on usage of these machineries were also organized.

Sustainable Horticultural Village – *Sarkarporethi*

- Sarkarporethi is a tribal village in Boluvampatti range with around 20 acres of cultivable land owned by 22 families and their demand was mainly for horticultural plants and minor irrigation facility. Lemon air layering plants (200) and jasmine plants (1500) along with nutrient mixture, saplings of red rose, moringa, clove, nutmeg, pepper, litchi, rambutan, egg fruit, surinam cherry along with garden tools were supplied to them in 2015. Villagers were enthusiastic but water shortage was a stumbling block.

Sustainable Agricultural Village – *Kuzhiyur*

- Kuzhiyur is a tribal village in *Karamadai* range with more than 80 acres of arable land owned by 65 families. The villagers are enterprising and had tried their hands on many avenues for improving their livelihood. We had distributed four wheeler drive tractor with accessories like trailer, tiller and rotavator, multipurpose thresher, improved seeds of pulses and vegetables, coconut seedlings, lime air layered plants,

sewing machines (6), bullocks (3), milching animals (3), power sprayers (10), mini flour mill and brush cutter to the village. Other agri-inputs were made available to the villagers to improve their agricultural productivity and livelihood.

- Subsequently, items namely country plough, field operation kits (Rose can-5 litre, crowbar, digging fork, spade, hand hoe, measuring tape 30m, plastic pan, plastic shears, bill hook) tarpaulin sheets, multipurpose pans also were given to villagers from time to time.

Interventions in Palamalai Hills

- Surveys were conducted in 21 villages of *Palamalai* hill range and finally six villages (*Perukkaipathi*, *Perukkaipathipudhur*, *Kunjoorpathi*, *Maankuzhi*, *Pasumani*, *Pasumanipudhur*) were selected. Water is a limiting factor here and is totally rainfed. However, terrace cultivation with crops like horsegram, sorghum, cowpea ragi etc. are being done. Our interventions in this tract were supplying sewing machines (23), honey bee-hives (40), power sprayers (7), farm operation kits, crow bars, country plough, tarpaulin sheets andinduction stoves (40).

Interventions in Pilloor Dam areas

- Tribal villages in the entire hill range covering over 11 villageswere surveyed and finally four villages (*Maanar*, *Korapathi*, *Veerakkal*, *Gethakkadu*) were selected. Banana is the main crop as they have access to good water. Vegetables and other field crops are grown in limited area. Our interventions in this tract were supplying sewing machine (1), power weeder, brush cutter, multipurpose pans, field operation kits, country ploughs, sprayers, taurpaulin sheets, multipurpose pans.

TRAINING PROGRAMMES

We organized 12 one-day training programmes in adopted tribal villages on seed production/nursery, kitchen gardening, vermicomposting, use of agricultural machinery, health and hygiene, demo cum training on use of brush cutter, apiculture including honey extraction, food and nutrition and awareness campaigns on cleanliness and parthenium eradication.

SUCCESS STORY - I

Drudgery reduction for tribal Women–Double Potted *Chullahs*

- *Attukkal* village was adopted by the institute during the first phase of the programme (2014-15). As a drudgery reducing measure for tribal farm women, double potted fuel efficient *chullahs* were supplied to 30 tribal women. These *chullahs* can be used for cooking and water heating. The overall dimension is 55x30x25 cm with a fuel inlet of 15.5x15 cm and an air inlet of 15.5x15 cm with six legs. The double pot portable chullha (chimney-less) is made with two walls. It costs ₹ 450 per unit and has an efficiency of 26%.
- Feedback from tribal women was that these chullahs apart from fuel efficiency, reduced the time taken for cooking and the food retained heat for a long duration than conventional chullahs being used by them.

SUCCESS STORY-II

Development of tailoring skills among women from marginalised communities

- Development of tailoring skills among tribal women is a field action project which was started in April 2016, with the objective of training women from marginalised tribal groups and help them gain employment or self-employment. Women from these groups have responded to this activity enthusiastically as it is helping in developing skills, and gaining self-confidence to earn money. Six sewing machines were given to them, of which two tribal women had opened a tailoring unit in *Melbaaviyur* village and they reported that they earn

₹ 3500 to ₹ 4000 per month. As a follow-up of skill development, these tribal women had furthered their skill with training through a local tailor. They were guided to start their own ventures and further advance short term training will be given to them if needed. Taking cue from this success story, we have upscaled this activity in *Paalamalai hills*.

- In March 2018, we had provided 23 sewing machines for 23 tribal women in *Neelampathi*, *Ikkapathi*, *Mottiyoor*, *Ukkaiyanoor*, *Perukkupathi* and *Pasumani* who were certificate holders in tailoring as a means to improve their livelihood. These women had stitched school uniforms in June 2018 for two schools in *Periyanaickenpalayam* and got orders for 2019 as well. This is the first time that these tribal women, whose livelihood had so far been farming on small patches of land in the reserve forest fringes or picking up dry leaves and wood, have managed to find themselves a non-seasonal profession.

SUCCESS STORY - III

Mini flour mill at *Kuzhiyur*

- Major crops grown in *Kuzhiyur* tribal village are horse gram, ragi, sorghum and beans. Villagers had to travel large distances to grind millets raised by them and wheat procured from PDS outlets. A mini-flour mill was given to *Kuzhiyur* tribal village, wherein developmental activities are being done by the Institute since 2016. The flour mill has been put to use to grind over one metric tonne of wheat, ragi, sorghum and other minor millets.
- This facility is now being used by villagers in *Kuzhiyur* as well as tribal people from nearby villages. Money obtained is deposited in common savings bank account of a self help group run by the tribal women of *Kuzhiyur* village.

SUCCESS STORY - IV

Apiary in *Palamalai* hills

- Bee-hives – A mode of income and a tactic to ward off elephants: To prevent crop damage by elephants and create business opportunities, we gave 40 honey-bee hives to *Paalamalai* tribal villages in the Western Ghats. During our earlier interaction with the tribal villagers, we learnt that villagers were worried about their livelihoods as the elephants pose a threat to their cultivation. Also, we could notice availability of varied sweet smelling flowers like *Pavetta indica*, wild jasmine and a variety of creepers. So, we thought to make villagers produce honey by rearing honey bees.
- Honey bee-hives were ordered from a cultivator in *Erode* and was transported at night as the bees are night blind and are also sensitive to change in surroundings. Another 50 bee-hive units were given to *Agali* village as well.
- In '*Kisan Samriddhi Mela*' organized by the Institute during 24-26 August 2018, tribal villagers had a shared stall wherein *Palamalai* (honey) was displayed for sale at a cost of ₹ 110 for 250 gm. The stall was a crowd gatherer with the entire stock getting over in two days.

Conclusion

Each village we visited was totally different and understanding their social set-up took considerable time. Frequent visits and focus group discussions with tribal village head and the villagers helped us to chart out the technological interventions uniquely for every village as per their requirements. It was a challenging sojourn throughout, at times even encountering wild beings. However, benefits for tribal people accrued during the journey made us go an extra mile to create a smile in their lives.

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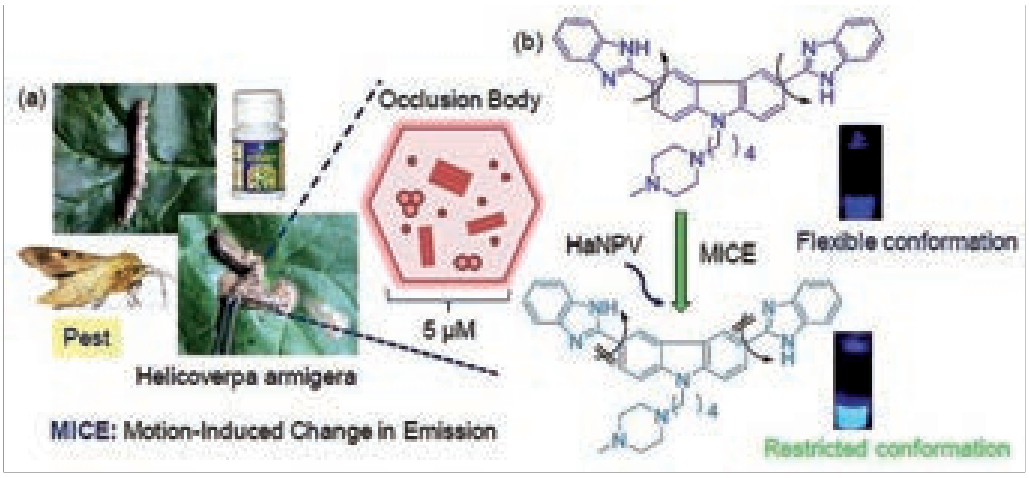
On-field detection of *Helicoverpa armigera Nuclear Polyhedrosis Virus* using Luminescent Amphiphilic probe

Helicoverpa armigera (Hubner) is one of the harmful and polyphagous pest species which is known to affect a wide range of agricultural crops such as tomato, cotton, legume sunflower, groundnut, wheat, tobacco, corn, vegetables, fruit crops and tree species. The insect has a high reproductive rate as well as resistant to a number of commercially available insecticides. Hence environmentally friendly alternatives to control these hazardous pests are most sought after. *Helicoverpa armigera* Nuclear Polyhedrosis Virus (HaNPV) of class baculovirilae is specific to the host *H. armigera*. The occlusion body of HaNPV virus which includes viral particle



(a) (HaNPV) occlusion bodies (OBs) from deceased pests. **(b)** Structure of amphiphilicprobe1 involved in the present study (MICE = motion induced changes in emission).

and the protein coat are transmittable structural units during the larval infection and registered by EPA as pesticide active ingredient of the virus. The quality of the virus during large scale production depends on many factors such as procedure followed during culture, pH and ionic strength of water and prevention of contamination of end product with foreign insect pathogen which reduces the productivity of HaNPV and poses a hazard to the production staff or end users. However, rapid and cost effective methods for quantification of the virus in commercial formulation as well as in agricultural fields is yet to be evaluated.

Dr Nilanjan Dey, Professor Santanu Bhattacharya, IISc, Bengaluru and Dr Deepa Bhagat, ICAR-NBAIR, Bengaluru have developed an easy-to-synthesize carbazole-based fluorescent probe for ratiometric optical sensing of HaNPV both at physiological pH in water and in different commercial formulations. The probe involved in the present study non-specifically binds to the surface of the occlusion bodies of HaNPV through electrostatic interactions. Thus, the addition of HaNPV to the color of the probe solution from blue to cyan (observed under UV). However, no detectable change in the emission color was observed upon addition of any competitive analytes, commonly present in commercial formulations, such as charcoal, sugar, NaCl, glycerol, and Ranipal®. HaNPV is applied in agriculture field by conventional spraying method using the water-dispersible formulation.

Therefore detection of presence of HaNPV in the plant extract or on leaf surface of crop helps farmers to determine time intervals required between two successive spraying. The authors have estimated that the soluble HaNPV content in 16 different crop samples known to be infected by *H. armigera.* On treatment with probe, leaves with HaNPV, showed cyan colored emission unlike the control leaves.

The authors developed low-cost, reusable paper strips for on-location detection of HaNPV. The paper strips coated with probe shows blue colored emission, while it becomes cyan in color as soon as exposed to HaNPV. The sensing studies using color-strips don't require maintenance of proper temperature or pH (or even electric source), making this method suitable for on-site detection. As operational procedure is very simple in this case, even end-users with no basic knowledge in science can use them without much difficulty. The paper strips are stable at room temperature (open-air condition) for several months. Moreover, as the strips are tiny and easily portable, farmers can use them whenever required in the field (no establishment cost).

The present work demonstrates a unique protocol where the presence of biopesticide HaNPV can be assayed by a color-changing response both in commercial formulations and agricultural crop extracts.

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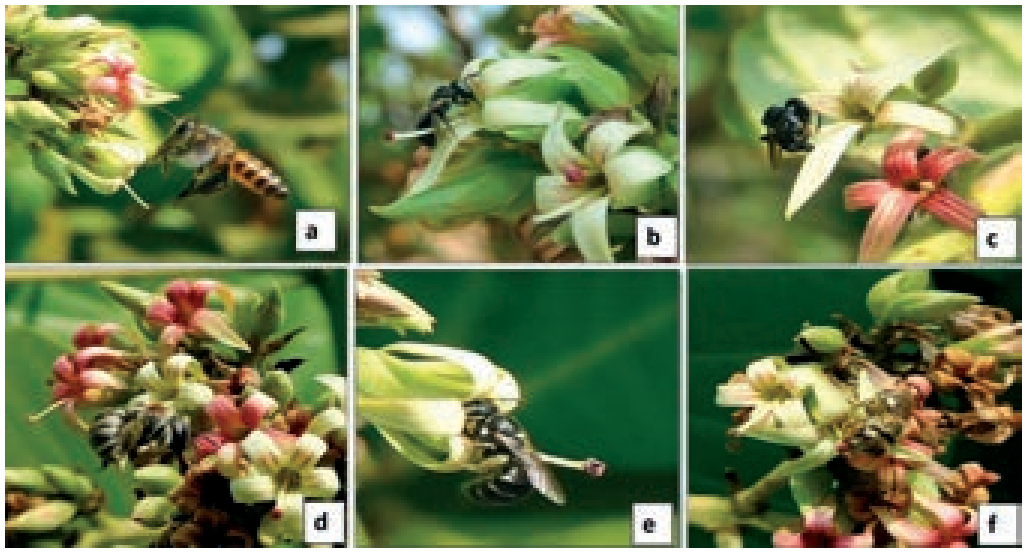
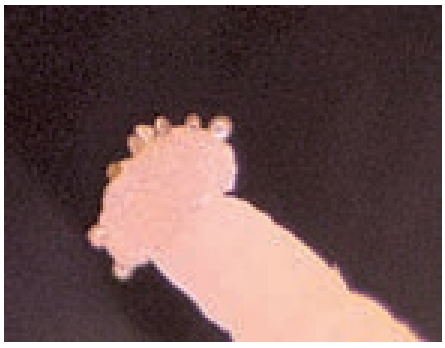
– Editor

Native bees a – potential pollinatiors of cashew

Cashew (*Anacardium occidentale* L. Family: Anacardiaceae), a commercial tree crop, is andromonoecious having sticky pollen. Each flower has a long stamen and 7-9 staminoids. In the hermaphrodite flowers, style is longer than the large stamen and assumes the same position, thus makes self-pollination difficult and requires cross pollination by insects. Fruit set in cashew is mainly influenced by the activity of pollinators and not the wind. Cashew flowers are visited by a diverse group of insects and its yield is often pollinator-dependent. Bees, ants, wasps, butterflies, flies, and moths have been reported as pollinators in different cashew growing regions of the world.



Pollinators of cashew **a.** *Apis cerana indica*, **b.** *Braunsapis picitarsus*, **c.** *Tetragonula* sp., **d.** *Pseudapis oxybeloides* **e.** *Ceratina hieroglyphica*, **f.** *Seledonia* sp.

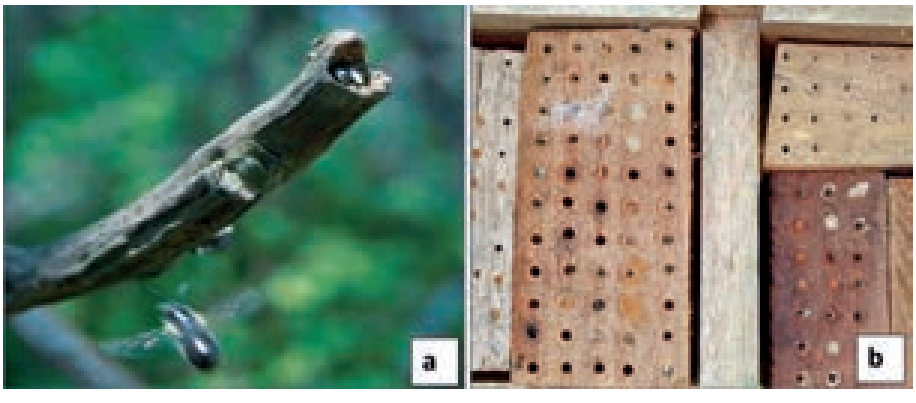


Pollen grains deposited on cashew stigma by bees

Each region has its own native bees which are very important for crop pollination and need to be studied thoroughly. Among the 40 species recorded as flower visitors of cashew at ICAR-Directorate of Cashew Research, Puttur, Karnataka, 64% comprised of bees of families Apidae and Halictidae, while the rest were megachilids, scolids, bombylids, syrphids, sciarids, calliphorids, and butterflies. Among them, 8 species of Apidae and 5 species of Halictidae were recorded as pollinators of cashew. Species abundance was high for *Braunsapis picitarus* (Cameron) (20.0%) followed by *Pseudapis oxybeloides* Smith (17.6%) and *Apis cerana indica* F. (16.7%).

Peak foraging period of pollinators occurred during 11.00 - 13.00 hrs when much of the hermaphrodite flowers remained open and a high proportion of anther dehiscence was seen in male flowers, which is advantageous for effective pollination in cashew. Certain bee species visited cashew flowers mainly for pollen, while, few visit for nectar and extra floral nectarines. Nectar was the major foraging reward for *A. c. indica* and *Apis florea*, while, it was pollen for *B. picitarsus*, *P. oxybeloides*, *Ceratina hierogyphica*, *Lasiolossum* sp. and *Seledonia* sp. But for *Tetragonula* sp., the foraging reward was nectar from extra floral nectarines followed by pollen and nectar. Fresh flowers were mostly preferred by all the bee species.

Nevertheless, multiple bee species visited the same hermaphrodite flower multiple times thus ensuring pollination in field. The mean number of pollen grains deposited per stigma upon bee visit was 0.2 during 10.00-10.30 hrs and 2.65 during 16.00 to 16.30 hrs indicating



a. Natural nest of *B. picitarsus*, **b.** Artificial nesting sites of *B. picitarsus*

multiple bee visits during the day. However, it was noticed that around 42% cashew flowers opened on the same day were devoid of any pollen even at the end of the day indicating pollination deficit in cashew in the study region. Mean pollen count per bee collected after multiple visits was high for *P. oxybeloides* (786.6) followed by *B. picitarsus* (804.9), *Seledonia* sp. (786.6) and *C. hieroglyphica* (187.1) compared to *A. c. indica*. These bees exhibited strong affinity to cashew flowers and collected more pollen during peak flowering period and hence could be efficient pollinators of cashew.

Controlled exposure of bees to inflorescences of cashew variety, Bhaskara during different time periods indicated the maximum nut set under combined hand pollination and open pollination followed by inflorescences exposed to bees between 11.00 and 13.00 hrs. While there was no nut set in the caged ones and those exposed between 16.00 hrs - 08.00 hrs. Further, observations on the nesting biology of *B. picitarsus* helped in developing suitable artificial nesting sites for breeding and conservation of these promising native bees.

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ICAR initiatives on Antimicrobial Resistance

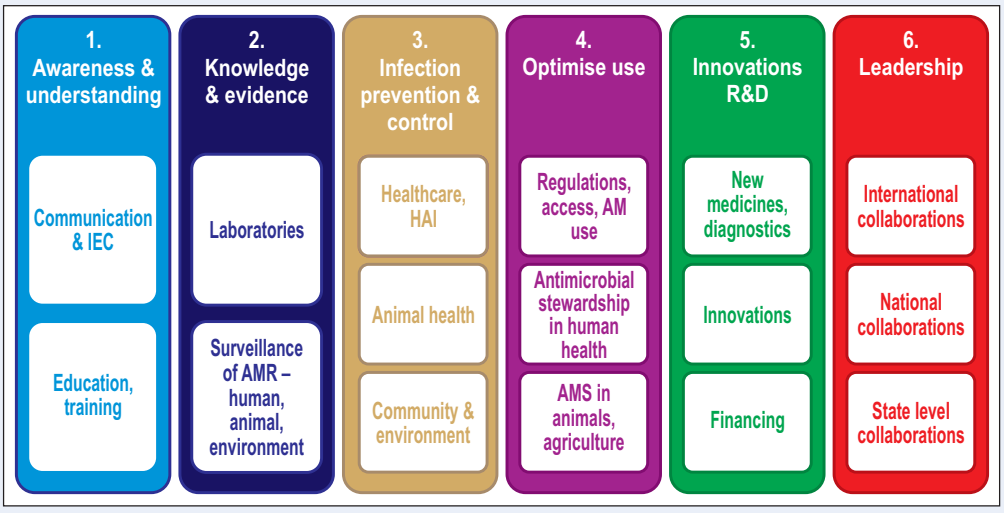
Antimicrobial agents, the wonder drug, has become an indispensable choice of modern medicine, since the introduction of penicillin in clinical practice in 1942. Over the years, this magic bullet has saved millions and helped us tame the killer diseases once thought invincible. But the time has come when resistance started to crop up and spread among the pathogens against even newer and higher generation antibiotics making them in effective. Antimicrobial resistance (AMR) is considered as one of the biggest threats to modern civilization which can jeopardize global health, economy and human development. It has been pointed out atvarious global forum that antibiotics are rapidly losing their potency and efficacy to fight infection; the possibility of the reemergence of once subdued killer diseases as a global annihilator cannot be thus excluded. Even today, AMR has the enviable positionfor being one of the leading infectious causes of mortality in human. We are indeed heading towards a point-of-no-return which was described by many as "post-antibiotic apocalypse" when the minor infection and surgeries which have been manageable and treatable for all these years, will turn out to be lethal. WHO Director-General, Dr Margaret Chan rightly said "The world is on the brink of losing these miracle cures," when she referred to this rising menace of global health. Considering the dimension and magnitude of the problem, the issue was discussed in United Nations General Assembly in New York in September 2016. AMR is the fourth health-related issued to be discussed at the General Assembly preceded by HIV, non-communicable diseases, and Ebola.

Inadvertent and irrational use of antimicrobials is considered as the single most important driver for development of antimicrobial resistance. There are

various factors which are crucial in development and dissemination of bugs apart from overuse of antimicrobials in human health, agriculture, livestock rearing and aquaculture. Persistence of antimicrobial residues in the refusals of the pharmaceutical production units, population, overcrowding, poor bio-security measures, lack of personal hygiene – all these are implicated in AMR in one way or other. The impact of AMR is not limited within the health sector, as generally presumed, but it has a far-reaching consequence to cause irreversible damage to global economy and food security. The famous report on AMR by O'Neill, in 2016 was an eye-opener in this context.

Currently, AMR is responsible for about 700,000 deaths annually world wide and is expected to reach 10 million by 2050, if adequate measures are not taken. AMR will have a shattering impact over world economy causing a loss of $100 trillion by 2050, thereby decreasing the global GDP by 3.5%. It is the AMR for which around 28 million people will be slipped under poverty, as the World Bank

report stated. Livestock production will be dwindled by 7.5% to have an adverse impact on food security. The crisis will be more intense in the developing and underdeveloped economies with more loss of lives. This has been highlighted by a report which showed that WHO South East Asia region comprising of the countries like, Bangladesh, Bhutan, Democratic Peoples' Republic of Korea, India, Indonesia, Maldives, Myanmar, Nepal, Sri Lanka, Thailand and Timor Leste – home to around 1.8 billion people is at the highest risk to be affected by AMR. Thus AMR is seen as the prominent threat to UN Sustainable Development Goals.



Leaders across global political communities vowed to put efforts together for control and containment of AMR. In 2015, WHO came with the Global Action Plan (GAP) to ensure, 'for as long as possible, continuity of successful treatment and prevention of infectious diseases with effective and safe medicines that are quality-assured, used in a responsible way, and accessible to all who need them'. This was approved in sixty-eighth World Health Assembly in May 2015. Broadly, WHO GAP sets out five major objectives:

1. To improve awareness and understanding of antimicrobial resistance through effective communication, education and training;
2. To strengthen knowledge and evidence base through surveillance and research;
3. To reduce incidence of infection through effective sanitation, hygiene and infection prevention measures;
4. To optimize use of antimicrobial medicines in human and animal health; and
5. To develop economic case for sustainable investment that takes account of the needs of all countries and to increase investment in new medicines, diagnostic tools, vaccines and other interventions.

Subsequently, The Food and Agriculture Organization (FAO) and the World Organization for Animal Health (OIE) endorsed the WHO GAP. Finally in 2016 in UN General Assembly world leaders put their shoulder together to give a clarion call to resolve this burgeoning problem. Next year, India came with the National Action Plan on AMR with multi-sectorial One Health approach. The strategic objectives of NAP on AMR of India are depicted below.

The genesis and structure of INFAAR, an ICAR initiative to combat AMR

ICAR and its scientists actively took part in shaping the National Action Plan (NAP) on AMR. On 5th December 2016, ICAR organized a meeting on NAP-AMR with leading experts of country to discuss issues pertaining to AMR in livestock sector at its headquarters at NASC, New Delhi. India's national action plan on AMR is a robust one which kept no stone unturned to make a sincere effort to resolve the problem which has already gripped developing countries like ours. Surveillance and monitoring of AMR resistance form an integral part of the NAP, as does the antimicrobial usage. The NAP warrants an evidence-based database on both AMU and the dynamics of AMR emerging in all the three sectors - human, agriculture and environment, so that appropriate remedial measure may be taken in advance to extenuate the problem before it moves into a complete slugfest. The crux of the problem is gaining useful denominator data, particularly, in livestock sector where a large section still relies on local quacks, pharmacists or unorganized veterinary practitioners. Although it is relatively easy to get data on AMU from the veterinary hospitals/polyclinics where such records are being maintained on daily basis, it will be really hard to get accurate information from unorganized sector particularly, at the local level. As the resistance rate of vary common pathogens frequently over short distance or period, a nationwide surveillance programmme is required-using uniform SOP and sampling frame, to get meaningful data. Taking such consideration into account, ICAR with the support of FAO has started a network programme on AMR surveillance in food animals and aquaculture, first of this kind in the world. In a FAO-ICAR collaborative meeting on establishment of a national network of veterinary laboratories for AMR held in

Kolkata, India from 7-8 March 2017, this programme came into existence with the name INFAAR (Indian Network for Fishery and Animals Antimicrobial Resistance) with an aim to explore the resistance pattern of the indicator and pathogenic bacteria isolated from food animals and fishes. The operational mechanism for INFAAR was finalized on 14th July 2017, in ICAR-CIFE, Mumbai. The first meeting of advisory committee/board was held in March 2018 where various administrative issues and functionalities of INFAAR as well as institutes to participate in INFAAR network, was decided. Initially, to kick off, veterinary/animal science institutes which includes 10 ICAR institutes (ICAR-CIRG, Makhdoom; ICAR-NIVEDI, Bengaluru; ICAR-NEH, Barapani; CSWRI, Avikanagar; ICAR-NDRI, Karnal, ICAR-NRC Equine, Hisar; ICAR-IVRI, Izatnagar and ICAR-IVRI, Kolkata centre, ICAR-CARI, Izatnagar and ICAR-DPR, Hyderabad) one Central (College of Veterinary Science, CAU Aizwal) and 2 state veterinary/agriculture universities (SVVU, Gannavaram and SDAU, Dantewada) and 8 fishery institutes (ICAR-CMFRI, Kochi, ICAR-CIFRI, Barrackpore, ICAR-CIFT, Kochi, ICAR-CIFE, Mumbai, ICAR-NBFGR, Lucknow, ICAR-CIBA, Chennai, ICAR-CIFA, Bhubaneswar, ICAR-DCFR, Bhimtal) were included in the network with ICAR-IVRI, Izatnagar and ICAR-NBFGR, Lucknow as the coordinating centres/institutes for veterinary and fishery sectors, respectively. A training programme was organized for PI/Co-PI of veterinary institutes under INFAAR network project on antimicrobial susceptibility testing and WHO-NET for AMR surveillance and database management in AMR surveillance at ICAR-IVRI, Izatnagar during 23-25, July 2018. Subsequently, such training was also imparted to PI/Co-PI of fishery institutes on 17-18 August 2018 in ICAR- NBFGR, Lucknow. With this INFAAR made a strong footprint to kick off its journey to tackle AMR in livestock and aqua culture. The long term goal of the program aims to identify strategies to prevent and reduce the development and spread of AMR in animal and aquaculture sectors. Successful implementation of the programme will be a key component of the National Action Plan on AMR for protection of human health, animal health and food safety in India.

FAO–ICAR training on WHONET software for data management of (AMR) organized at ICAR-NBFGR, Lucknow on 17th-18th August 2018

The first annual review meeting of INFAAR was organized by ICAR in collaboration with FAO at Goa from 21 to 22 September 2018 to discuss various issues pertaining to technical programme/work plan carried out by each center under INFAAR programme. Subsequently this year during 21 to 25 January 2019, ICAR organized FAO Assessment Tool for Laboratories and Antimicrobial resistance Surveillance Systems (FAO-ATLASS) for assessors training for PIs under INFAAR at ICAR-CIFT, Kochi.

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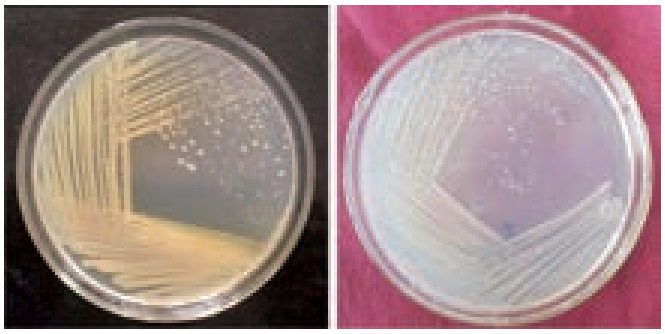
Bioethanol from lignocellulosic waste: a stepping stone towards energy security

The world is facing depletion of global fossil fuels resources, like petroleum, natural gas, or charcoal, while energy requirements are continuously growing up. Fossil fuels should be replaced, partially by biofuels once the current fuel supply is suspected to be unsustainable in the foreseen future. Bioethanol is obtained by using bio-based resources. It is one of the most attractive biofuel and considered as 'green' fuel. Bioethanol is an oxygenated fuel and can be widely used for transportation purpose across the world. Use of biofuels can significantly lower the emission of exhaust gases thereby resulting in a clean and eco-friendly environment. The biological materials obtained from forest, agricultural residues and other wastes from food and agro industries are usually referred as biomass. Bioethanol is produced by action of microorganisms on fermentable sugars



Bacterial strains used for hydrolytic enzymes production for saccharification of biomass (a) Cellulase producer *Bacillus stratosphericus* N12 and (b) xylanase producer *Bacillus altitudinis* Kd1

present in the biomass.

First generation biofuel vs second generation biofuel

The first generation bioethanol is produced mainly from different food crops such as corn, wheat, sugarcane, rice and barley. Usage of these crops for ethanol production has led to shortage for food. The lignocellulosic material has emerged as an attractive low cost material for ethanol production, and has been termed as second generation bioethanol, therefore, there is no crisis for any food material.

Approaches

Basically there are three types of fermentation processes which are commonly used. These are i) Separate hydrolysis and Fermentation (SHF), ii) Simultaneous Saccharification and Fermentation (SSF), iii) Simultaneous Saccharification and Co-Fermentation (SSC).

Methodical technique for bioethanol production

Separate hydrolysis and Fermentation

5 g untreated *P. deltoides* wood biomass was taken in 250 ml of flask. To this 50 ml of 2% NaOH +H_2O_2 (9:1)

Wood biomass (grinded 2mm size) used as substrate for bioethanol production

Fermentation

was added and kept at 65°C in water bath for 3 h. After 3 h supernatant was separated out from solid biomass by centrifugation at 10,000 rpm for 20 min. Enzymatic saccharification of the alkaline peroxide pretreated left over solid biomass was done by adding hydrolytic enzymes at 1ml/g of residue. After 72 h saccharified biomass was centrifuged at 10000 rpm for 20 min and clear hydrolysate was collected. The saccharified syrup was pooled together with supernatant of alkali pretreated wood, followed by detoxification by overliming with Ca $(OH)_{2.}$ To the calcium hydroxide treated (detoxified) supernatant 0.5 % yeast extract and 0.5% peptone was added and autoclaved at 121°C, 15 lbs for 20 min. To the fermentation media 10% (1 OD) inoculum of fermenting microbes was added and kept for 72 h (3 days) at 25°C.

Ethanologens used as monoculture and co-cultures

Saccharomyces cerevisiae-I, *Saccharomyces cerevisiae*-II , *Pichia stipitis* , *Candida shehatae, Zymomonas mobilis*, *S. cerevisiae*-I + *P. stipitis* , *S. cerevisiae-I + C. shehatae*, *S. cerevisiae*-II + *P. stipitis* and *S. cerevisiae*-II + *C. shehatae*. Bio-ethanol was estimated in terms of g/l of fermented liquor and g/g of biomass on dry weight basis.

$$\text{Fermations efficiency} = \frac{\text{Ethanol produced (g/g)}}{\text{Theoretical yield of ethanol}} \times 100$$

Theoretical yield was referred as standard value of 0.511 g/g of sugars. Development of a technology for effectively converting alkaline hydrogen peroxide pre-treated lingo-cellulosic biomass to simple sugars by potential in-house enzymes produced from microorganisms and intern fermenting them to appreciable concentration of ethanol thus envisaging sustainable energy production and improved environmental quality.

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Co-composting of organic manure for soil quality management

Biochar is carbon rich charcoal-like substance created by heating biomass (organic matter) in limited oxygen condition, through a process known as pyrolysis. Laboratory incubation study was conducted to assess the efficacy of different organic manure amended with biochar on soil acidity management. Poultry manure, pig, goat, FYM and vermicompost were used to prepare biochar co-compost. Both biochar and organic manure were mixed at 1:2 and kept for 15 days. This mixture of biochar manure co-compost was analyzed for pH (poultry manure biochar co-compost 9.35; pig manure biochar co-compost 9.16; goat manure biochar co-compost 9.04; FYM biochar co-compost 8.97 and vermicompost biochar co-compost 8.86). The effect of these biochar manure co-compost addition on chemical properties of acidic soil such as soil pH was observed to determine the liming potential. This study was conducted by incubating acidic soil (clay loam) of pH 5.2 with biochar co-compost. The co-compost prepared was applied at three rates (0, 2.5, and 5.0 t/ha) with soil and was incubated for two months. At 5.0 t/ha application rate poultry manure biochar co-compost had shown a relatively larger increase in soil pH with initial pH 5.2 to final 6.8 followed by pig manure biochar co-compost (pH 6.6), goat manure biochar co-compost (pH 6.4), FYM biochar co-compost

(pH 6.2) and vermicompost biochar co-compost (pH 6.0). Co-compost type, application rate, and their interaction had significant effects ($p<0.05$) on soil pH. Thus these manure biochar co-compost can be effectively used for management of acid soil in Sikkim.

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Black soldier fly – a detritivorous insect for solid waste management

Black soldier fly as decomposer of wastes

Black soldier fly (BSF) (*Hermetia illucens*) is a detritivorous insect that is neither a pest nor a vector and does not cause any harm. The larval stage of BSF is capable of bioconversion of organic wastes in a short time. The organic waste biomass can be reduced to tune of 50–95%. BSF rearing on organic wastes reduces odours emanating from wastes due to quicker conversion of biomass, reduces housefly and other flies breeding and also reported to reduce pathogenic microflora. BSF ability to decompose farm wastes is attracting farmers, private firms, urban residential people and poultry farmers. BSF compost produced on kitchen waste is superior to farmyard manure, vermicompost and sheep manure, due to high amount of N, P, K along with other micronutrients and can be prepared in 60 days. BSF compost has been recorded to be very good for establishment of nursery plants like tomato, chilli, brinjal, cabbage and horticultural crops. BSF leachate is also equally nutritive that can be used for fertilizing soil through irrigation water. NBAIR has termed BSF compost as 'Black Gold' due to its nutrient richness.

Pupae of black soldier fly

Compost produced by black soldier fly

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Central Marine Fisheries Research Institute

All set for a blue revolution

The Central Marine Fisheries Research Institute was established by Government of India on February 3,1947 under the Ministry of Agriculture and Farmers Welfare and later, in 1967, it joined the ICAR family and emerged as a leading tropical marine fisheries research institute in the world. Initially the institute's focus was on creating a strong database on marine fisheries sector by developing scientific methodologies for estimating the marine fish landings and effort inputs, taxonomy of marine organisms and the biological aspects of the exploited stocks of finfish and shellfish on which fisheries management were to be based. This focus contributed significantly to development of marine fisheries sector from a predominantly artisanal, sustenance fishery till the early sixties to that of a complex, multi-gear, multispecies fisheries.

One of the major achievements of CMFRI is development and refinement of "Stratified Multistage Random Sampling Method for estimation of marine fish landings in the country with a coast line of over 8000 km coastline and landing centres. Currently, the institute is maintaining the National Marine Fisheries Data Centre (NMFDC) with over 9 million catch and effort data records of more than 1000 fished species, from all maritime states of India.

The Institute's multi-disciplinary approach to research in marine capture and culture fisheries has won it recognition as a premier institute comparable to any well-established marine laboratory in the world. Presently the institute has 3 Regional Centres located at Mandapam, Visakhapatnam and Veraval and 8 Research Centres at Mumbai, Chennai, Calicut, Karwar, Tuticorin, Vizhinjam, Mangalore and Digha. Besides, there are also fifteen field centre and 2 KVKs (Ernakulam and Kavratti, Lakshadweep) under the control of the institute. The nearly five fold increase in marine fish production and the increasing contribution of marine fisheries to the GDP growth are supported by the robust research efforts and its impact on fisher folk,fish farmers, fisheries policy planners and managers.

VISION

Sustainable marine fisheries through management

CMFRI Laboratory

CMFRI Laboratory

intervention and enhanced coastal fish production through mariculture for improved coastal livelihoods.

MISSION

To develop an information based management system for changing over from open access to regulated regime in marine fisheries, augment coastal fish production through mariculture and sea ranching and restore critical marine habitats.

MANDATE

- Monitor and assess marine fisheries resources of the Exclusive Economic Zone (EEZ) including impact of climate and anthropogenic activity and develop sustainable fishery management plans.
- Basic and strategic research in mariculture to enhance production.
- Act as repository of geo-spatial information on marine fishery resources and habitats.
- Consultancy services and human resource development through training, education and extension.

OBJECTIVES

- Marine fishery resource assessment.
- Productivity and production enhancement through mariculture.
- Conservation of marine biodiversity.
- Transfer of technology, training and consultancy.

Major research focus and its impact on marine fisheries sector in India

Support to strengthen marine fishery management regime in India

From beginning, CMFRI has focussed on gathering information of the marine fishery resources of India. Through its sustained efforts a database on fisheries landings and effort statistics has aided the developing effective fisheries management plans with stakeholders participation; proactive measures to ensure regulated and sustainable fisheries and aiding efforts in marine fisheries management realm by preparing policy guideline documents based on the research programmes of the Institute. The National policy on Marine Fisheries (NPMF) 2017 notified by the Ministry of Agriculture and Farmers' Welfare was developed with wide stakeholders' consultations by the institute and is a major step towards a framework for a sustainable marine fisheries development model in the country. Marine fisheries policies for the state of Kerala and Lakshadweep Islands, Karnataka, Goa and Andhra Pradesh are formulated with the reassert and policy inputs from CMFRI scientific expert teams. CMFRI has prepared a document entitled Indian Marine Fisheries Code which guides the establishment of a sustainable marine fisheries resources management model for India in accordance with Food and Agriculture Organization's (FAO) Code of Conduct for Responsible Fisheries (CCRF). Other contributions of CMFRI recognized as major inputs for the national level policy making are policy guidance on Fish Aggregating Device (FAD); based on which Government of Karnataka banned an FAD assisted cuttlefish fishery that was contributing to growth and recruitment overfishing of cuttlefishes and leading to loss of livelihoods and income to local fishers, guidance on National Plan of Action (NPOA) for sharks in India for increasing awareness of the need to ensure their sustainable exploitation and conservation, guideline on temporal and spatial measures of effective Trawl Ban for Government of Kerala, recommendation on Minimum legal size (MLS) of commercially important marine fishes aimed at restricting juvenile fishing for various coastal States (Based on which Government of Kerala notified MLS for 58 commercially important species in the Gazette), recommendations on use of technology in agricultural insurance' to NITI Aayog, guidelines for Mariculture Policy in India etc. CMFRI also coordinated and provided scientific inputs for India's first Marine Stewardship

Mobile app for online fish sale

As an adaptation strategy to improve income of fishermen and to help them cope up with adverse climatic events, the ICAR-CMFRI has developed a multivendor E-commerce website (*www.marinefishsales.com*) and associated android app (*marinefishsales*) through the National Innovations on Climate Resilient Agriculture (NICRA) project. The website and mobile app is aimed at helping fish farmers and fishermen to sell their farmed fish and marine catch directly to customers online and to fetch better income without depending middlemen.

Council (MSC) certified fishery, for the short-neck clam in the Ashtamudi Lake, Kerala.

Integration of Satellite Technologies into Fisheries Management

To effectively utilize satellite technology for managing marine fisheries sector the Institute has joined hands with the Indian Space Research Organization (ISRO) with the aim to identify and forecast Potential Fishing Zones (PFZ). GIS based resource mapping of distribution and abundance of fin fishes and shellfishes off the Indian coast and using the GIS technology for mapping of marine fish landing centres. The CMFRI special publication on 'Handbook on Application of GIS as a Decision Support Tool in Marine Fisheries' and the GIS based inventory of 1278 marine fish landing centres of Indian coast prepared by CMFRI, was even sought by Indian Navy.

Ecosystem Approach to Fisheries Management (EAFM)

CMFRI's initiative in promoting EAFM is based on the fact that the country needs to shift from traditional single species management approach to a more advanced one addressing ecological and human well-being with good governance. An Ecosystem Based Fisheries Management (EBFM) model has been successfully developed for the South-west, North-west, Gulf of Mannar coasts and can be used to facilitate well managed fisheries.

Addressing climate change concerns in marine fisheries sector

Climate change is now recognized as one of the greatest long-term challenges to marine ecosystems and fisheries. Under the National Innovations on Climate Resilient Agriculture (NICRA), a network project of Indian Council of Agricultural Research (ICAR), to deal with climate change in marine ecosystem CMFRI has focussed on preparing the marine fisheries sector to minimize the impact of climate change. It is also aimed at addressing critical knowledge gaps about climate change impacts, improve monitoring and translating the knowledge into active management responses. Relationship between temperature and abundance of resources such as threadfin breams and the effect of projected rise in sea surface temperature due to climate change by modeling the biomass dynamics using a variant of SEAMICE models for the south Kerala region has been done. The carbon foot print, blue carbon potential of mangroves and sea grass and life cycle assessment of fishing operations indicated that fishing operations for Kerala coast had

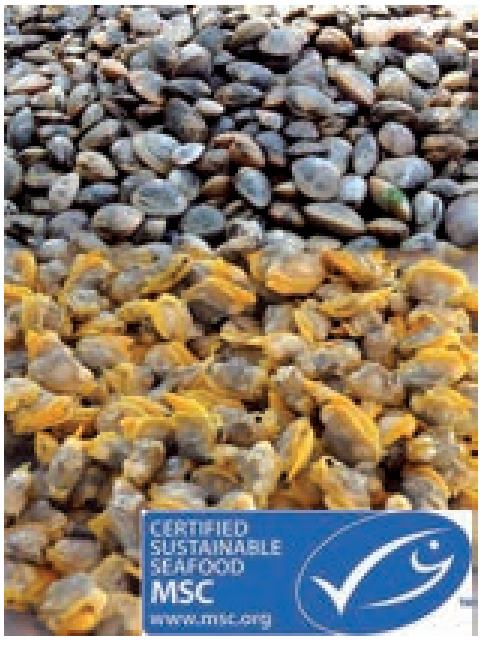
CMFRI Research Vessel – Silver Pompano

Fish Cage

Hatchery technologies

Technologies for seed production and grow-out culture of cobia (*Rachycentron canadum*), groupers (*Epinephelus coioides*) silver pompano (*Trachinotus blochii*), Indian pompano (*Trachinotus mookalee*) and pink ear emperor (*Lethrinus lentjan*) have been developed and demonstrated by CMFRI, while efforts are on to bring more promising species under farming. In addition, five species of snappers and carangids have been prioritized for developing seed production technology. Hatchery production technology for mussel, edible oyster and 14 varieties of marine ornamentals, including Marcia's anthias, clowns, damsels, hybrids, camel shrimp and cleaner shrimp has been achieved. The indigenously developed Re-Circulatory Aquaculture System (RAS) is also functioning at the Institute to boost seed production round the year.

Cobia fingerlings in cage



Yellow clam or short neck clam fishery of Ashtamudi Lake – First Marine Stewardship Council (MSC) certified fishery of India with CMFRI's support

highest emissions during harvest phase followed by post-harvest and pre-harvest phases. Multivendor e-commerce portal and Mobile App, low cost feeds for Integrated Multi-trophic Aquaculture (IMTA) and Participatory mode of coastal vulnerable resource mapping are few of our initiatives. Through adoption of a number of coastal villages and converting then as "Climate Smart Villages", organizing field demonstrations on technologies for climate change adaptation and mitigation, livelihood sustainability enhancement through provision of know-how and alternative income generating activities are some interventions carried out by CMFRI.

Fishery socio economics, marketing, trade and fisheries governance

Focussed studies on economics of fishery enterprises and socio-economic conditions of fisher folk. Valuation, estimation and analysis of marine fish landings and its economic performance, supply chain management, price behaviour of marine fish varieties, fish consumption patterns, impact of GST on fisheries sector and vulnerability of coastal villages are being estimated annually both at landing centre and retail market levels for different maritime states. An estimation of value of marine fish landings in India, during 2011-2017 indicated an increase of fish landings at landing centre level from ₹24,369 crores in 2011 to ₹52,431 crores in 2017, with an annual increase of 14.5%, while at retail centre level, increased from ₹38,147 crores to ₹78,404 crores with an annual increase of 15.08%.

Innovations in mariculture

Globally, mariculture is the fastest growing animal food producing sector and an increasing source of protein for human consumption. Envisaged to be the future of Indian marine fisheries mariculture has not yet developed into a major contributor of seafood production in India. However, ICAR - CMFRI remains on forefront to promote various mariculture activities such as cage fish farming, seaweed farming, bivalve and pearl farming, ornamental fish culture, integrated multi-trophic aquaculture, etc. The Research and Development programme on marine cage farming in India which was initiated by CMFRI with the grants received from the Ministry of Agriculture has been successfully demonstrated technically all along the Indian coast with the financial support of National Fisheries Development Board (NFDB). By year 2018, 1609

Integrated multi-trophic aquaculture, a novel method

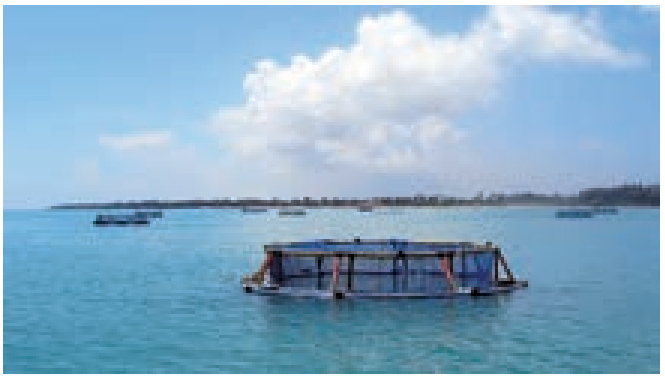
Integrated Multi-Trophic Aquaculture (IMTA) is the practice which combines appropriate proportions of finfish/shrimp with shell/ herbivorous fish and seaweeds in farming to create balanced systems for environmental and economic stability. The CMFRI has successfully conducted the demonstration of IMTA under participatory mode with fishermen groups by integrating seaweed with cage farming of cobia. It has been proved that in one crop of 45 days the seaweed rafts integrated with cobia cage will give an average yield of 260 kg per raft against a control, which yielded 150 kg per raft.

Cobia fingerling

cages were installed in different marine locations in India under the technical support and guidance of CMFRI. Continuous refinement of technology is taking place through various research projects of CMFRI and All India Network Project on Mariculture (AINP-M) funded by ICAR, Government of India. The successful seed production of a marine ornamental, camel shrimp, *Rhyncocinetes durbanensis* was achieved at Mandapam Regional Centre of CMFRI. The Tribal Sub Plan (TSP) programme of the institute has extended technical support in cage farming to several tribal groups in the states of Gujarat, Maharashtra, Karnataka and Kerala and helped them to attain better livelihood skills and income through fish farming.

Marine Biotechnology

Bioprospecting of marine and oceanic resources, through which the institute has produced several nutraceuticals useful for treating life style diseases and dietary supplements from seaweeds, has been recognised. The Institute has developed and commercialized nutraceutical products Cadalmin™ Green Algal extract (Cadalmin™GAe) and Antidiabetic extract (Cadalmin™ADe to combat rheumatic arthritic pains and type-2 diabetes, respectively. Nutraceuticals from seaweeds to combat dyslipidemia, obesity, hypo-thyroid have also been developed and out-licensed to pharmaceutical companies. â Nodadetect a single tube RT lamp diagnostic for â-Noda virus detection in marine fish of mariculture interest has been developed by the institute. This highly specific, sensitive and rapid method of screening marine broodstock fish ensures certified specific pathogen free eggs and larvae. To understand the population genetic structure of fishery resources in Indian waters specific studies were carried out. The complete mitogenome characterisation of *Etroplus suratensis* from Vembanad Lake, genetic stock structure



Open Sea Cage Farms

investigations in *Lutjanus argentimaculatus* and Indian oil sardine *Sardinella longiceps* and bioprospecting for biotic and abiotic stress responsive genes from *Crassostrea madrasensis* and their characterisation have yielded valuable baseline data.

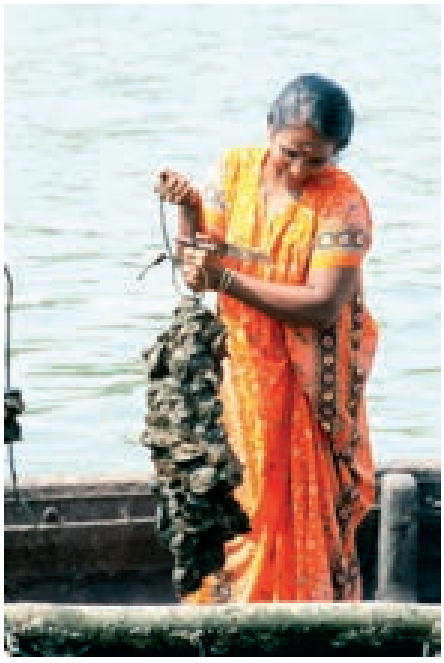
CMFRI'S MAJOR CONTRIBUTIONS : AT A GLANCE

- Estimation of multispecies multi-gear marine fish landings for more than 1200 species covering 1511 fish landing centres on a GIS platform from the EEZ of India for marine fish stock assessment following the self-developed stratified multi-stage random sampling design and maintaining a National Marine Fishery Resources Database which is generated based on continuous and perpetual field data collection on marine fishery resources over decades
- Annual estimation of marine fish landings at landing centre and retail market level carried out to work out the contribution of fisheries sector to the agricultural and National GDP.
- ICT initiatives include '*Fish Watch*', a web portal for real time landing and market information from the landing centres; *Choose Wisely*' – a sustainability labeling code developed by CMFRI which was adopted

Cage Farming Harvest

by the ITC chain of restaurants all over India serving seafood; *m@krishi* service supported by TCS in collaboration with CMFRI provided and tested a platform to inform fishermen in Maharashtra on potential fishing zones (PFZ) through mobile phones in local language; *Litter atlas* an interactive map on litter status of Indian beaches

- National quinquennial census of marine fisher population and infrastructure facilities and estimated value of marine fisheries and fishing fleet economic efficiencies
- Optimized fishing fleet size of various craft-gear combinations for rational exploitation of marine resources in all maritime states of India
- Monitored biology and health of commercial marine fish stocks (133 stocks) of India. Developed and applied several analytical models to assess the finfish and shellfish stocks in all maritime states for providing Fishery Management Plans and advisories on seasonal fishing bans and potential yields
- Developed hatchery and grow-out technologies for shrimps, pearl oysters, oysters, mussels, clams, ornamental fishes, sea bass, cobia, pompano and groupers (totaling 37 species)



Oyster farmer with ready to harvest farmed oyster rens

- Established commercial farming of mussels and oysters in coastal areas with an annual production of over 10,000 tonnes benefitting nearly 6000 women self-help groups
- Identified and mapped new and non-conventional deep sea marine resources by vessel based surveys, including abundance maps of oceanic squid resources. The Institute has so far described 255 marine species new to science from various groups of fishes
- Used modern biotechnological tools for development of marine nutraceuticals (GMe, GAe, Ade and Ate) for human well-being and functional feeds (Varna and Varsha) for mariculture species
- Assessed major marine and island habitats and evaluated their biodiversity; and developed restoration protocols through artificial reef deployment
- CMFRI conducts regular training programmes in fisheries and marine biology. So far, the institute has produced over 300 Masters and 160 PhD degree holders
- Provided science back-up for India's first eco-labelled (MSC certified) fisheries (short-neck clam) meeting

Recirculation Aquaculture Facility at CMFRI Mandapam Centre

Nemipterus japonicus haul in Kochi, Kerala

Anti-diabetic extract

Anti-obesity extract

CMFRI pearl string

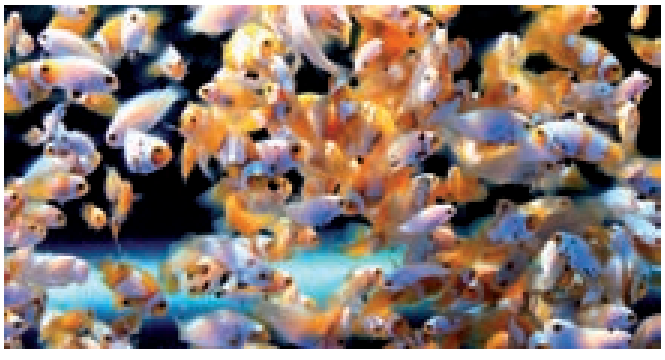
global standards of fisheries management

- Delineated the scientific reasons behind the recent decline in oil sardine fishery along the south-west coast of India, to support formulation of management guidelines to improve the status of the fishery.

OUTREACH ACTIVITIES

Agricultural Technology Information Centre (ATIC) of CMFRI serves as a 'single window delivery system' for technologies and services developed by the institute. There are two Krishi Vigyan Kendras (KVK) functioning under the institute presently. KVK-Ernakulum has developed and disseminates location specific technological modules and acts as Knowledge and Resource Centre for agriculture, fisheries and allied activities.

Administrative control of KVK at Kavarathi, Lakshadweep Islands has been recently taken up by the institute from CIARI, Port Blair. The main focus will now be for enhancing farmers' income and employment opportunities especially for women, through value-added products development and facilitate increased market access.



Designer crown fish – the new ornamental fish variety

Ornamental Fish – Anthias

Academic collaboration and training

Collaborations with a number of research and academic organizations inside and outside the country have included the Plymouth Marine Laboratory, UK; Nansen Environmental and Remote Sensing Centre (NERC), Norway; Michigan State University, USA; Rhodes University, South Africa and Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia besides fisheries related institutes and academic universities in the country.

Way forward

Sustainability of fishery resources is core to a healthy and vibrant marine fisheries sector in India. To grow further, the following focus areas have been identified:

- Fishery modelling and forecasting
- Green auditing – valuation of marine bio-diversity and ecosystem services
- Nanotechnological approaches in mariculture and environment management.

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Development of protein enriched gluten free rice pasta

Celiac disease (CD) is an auto immune enteropathy triggered by the ingestion of gluten-containing grains (wheat, barley, rye, and oats). The prevalence of CD worldwide is increasing and affecting almost most of the population. Thus, with the increasing numbers of people intolerant to gluten, the need is rising for high quality gluten-free products. Presently, the only treatment for CD consists of a lifelong gluten-free diet. The replacement of gluten presents a significant technological challenge, as it is an essential structure-building protein, which is necessary for formulating high-quality baked goods as pasta. The only way to prevent this is by eating gluten-free foods. Among these, rice flour is one of the most utilized raw material in gluten-free production. But, functional properties of rice flour are insufficient for creation of highly developed and stable structure. For improvement of rice flour functionality several different modification procedures were employed including protein and fibre.

Rice is one of the leading food crops in the world. For about 50% of the world population, mostly in Asian countries, rice is the staple diet and provides 35–59% of energy consumed from foods. The functional properties of rice grains such as pasting profiles, texture, water holding capacity and cooking characteristics are important factors which determine the end use and marketing of rice grains flour. It has also many beneficial properties as it is easy to digest, has mild taste and hypoallergenic properties and also provides 45% of calories and 40% total protein requirement of an average population. Gluten-free pasta represents a challenge for food technologists and nutritionists since gluten-free materials used in conventional formulations have poor functional and nutritional properties. So a novel extrusion-cooking process used to improve the textural characteristics of rice-based pasta that enrich with apricot protein isolate. The very less work on apricot kernel press cake as well as isolation of protein isolates from apricot kernel press cake and its utilization for product development has been done. Therefore, the present study was hereby proposed and done at Dr YS Parmar University of Horticulture and Forestry Nauni, Solan Himachal Pradesh for development of protein enriched gluten free rice pasta.

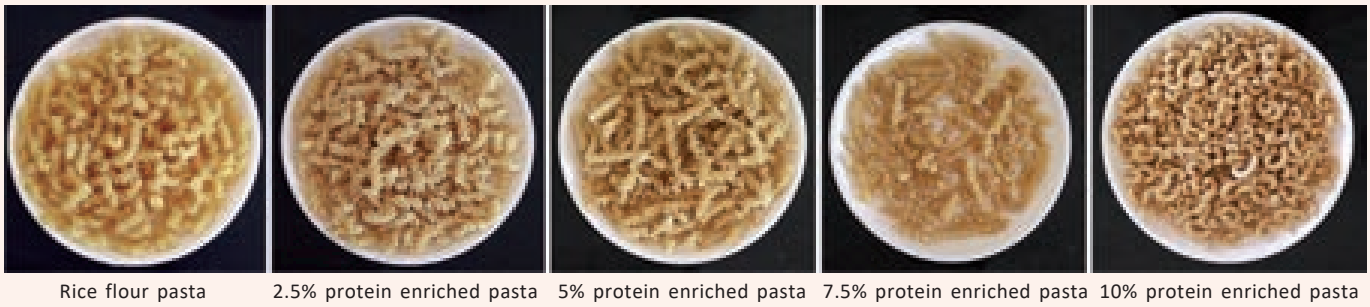
Methodology

Single screw extruder (La Monferrina make Dolly model) was used for preparing pasta. The amount of water was calculated as per Mondelli equation. Premixing of rice flour with protein isolate was done by planetary mixer (M/s Artisan Engineering works), followed by mixing in Dolly type extruder, and kneading the mixture by rotating screw in opposite direction of extrusion process. The temperature of extruded dough was 40±2°C and 1.7 mm diameter die was used to shape the dough and formation of pasta.

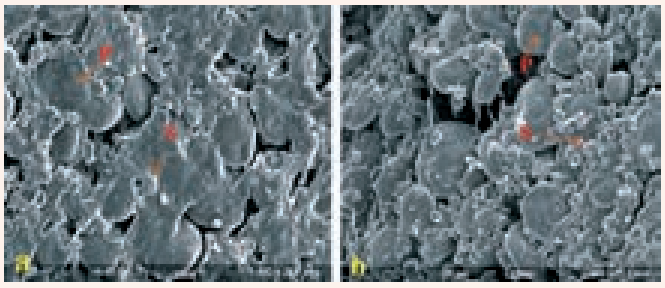
Quality characteristics of developed pasta

Gluten free pasta was prepared from rice with supplementation of protein isolate at different concentration (2.5%, 5.0%, 7.5% and 10.0%). Showed the effect of cooking time on the quality of pasta. The picture clearly showed that with the prolonging the cooking time of the pasta it become mashy specially in rice flour pasta. Hence 5 min was considered an optimize time for pasta preparation.

The cooking quality of pasta is based on evaluation of texture. Cooked pasta is desired to be not sticky or mudy when eaten and should exhibit some frimness to the bite. During pasta processing, gluten proteins present as irregular globular structures that build a three-dimensional network when flour is mixed with water. After kneading, gluten a network is formed composed of layers of thin film, penetrated by the starch granules. The



Rice flour pasta | 2.5% protein enriched pasta | 5% protein enriched pasta | 7.5% protein enriched pasta | 10% protein enriched pasta



Scanning Electron Microscopy (SEM) of protein enriched gluten free rice pasta

surface of freshly extruded pasta has a continous protein film, while the inner portion has a compact structure of starch granules embedded in an amorphous protein matrix aligned in layer parallel to protein film. After cooking pasta starch got gelatinized and protein coagulated and caused major structural changes and hence influenced the final texture. During cooking pasta, protein absorbed water and swell more rapidly than starch. Hydration of protein fraction of pasta before the beginning of starch gelatinization appeared important to produce a firm, good quality pasta. Scanning electron microscope (SEM) is one of the most versatile method for the examination and analysis of the microstructure, chemical composition and physical (size and shape) characterizations. It shows arrangement of starch granules and protein network in the matrix. The SEM was conducted at magnification of 1000 x and 1200x. The Fig 1 showed that the pasta had some medium to large ellipsoidal, irregular, cubical and polygonal shape cluster bodies represent the presence of starch molecules in the sample. The external chalky and opaque appearance in the pasta, resulting from air spaces between the starch granules. Whereas, cracked and flaky plate like structure surface represents the presence of protein and indicated the presence of protein content in the pasta. Protein remains with irregular edges and starch granules were distributed in the direction of force applied during the extrusion process and at the final stage of processing forming the protein-starch matrix.

Conclusion

The cost of production for gluten free protein enriched pasta was ₹ 55.60 per/kg which was very less as compared to market semolina pasta. It is concluded that incorporation or addition of protein isolate for development of different food products like pasta seems to be a profitable venture for utilizing the waste and boosting income of farmers, apart from providing many health benefits to people.

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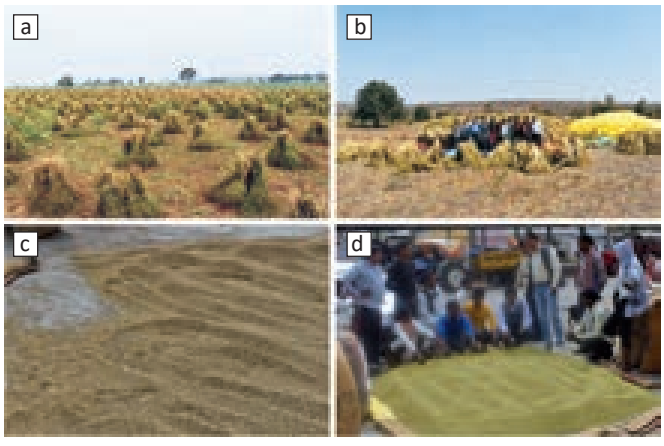
Post-harvest method for coriander (*Coriandrum sativum* L.) in Madhya Pradesh

Diversity in seed spice crops was explored in Ashok Nagar, Guna, Gwalior and Shivpuri districts of Madhya Pradesh and Bara district of Rajasthan(latitude 24° 34' - 26° 07N and longitude 77° 03' - 78° 02'E) during, 1 to 9, March 2019. This area being confluence zone between central and western part of India, is the hot-spot for diversity in seed spice crops especially for coriander, cumin, fenugreek, *ajwain* and other species. 53 accessions comprising of dhania (*Coriandrum sativum*- 39), ajwain (*Trachyspermum ammi*-7), methi (*Trigonella foenum-graecum*-2), kasuri methi (*Trigonella corniculata*-1), sowa (*Anethum sowa*-1) and *kalaunji* (*Nigella sativa*-3) were collected. In India coriander (family Apiaceae) is an annual spice crop, grown in home gardens throughout the country, and cultivated mainly in parts of Andhra Pradesh, Assam, Madhya Pradesh, Gujarat, Odisha, Rajasthan, Uttar Pradesh and Tamil Nadu. Some of the named coriander landraces *viz, Kumbhraj, Mithi Dhana, Kudi Dhana, Deshi Dhana, Dhana* and *Ramela* were collected from Madhya Pradesh and Rajasthan. The collected germplasm showed good variability in seed shape (round, oval), size (small and large) and colour (brown, light brown, green, dark green and parrot green). Coriander seed weight (100 seed wt.) was also recorded. Maximum



a. Harvested material kept for sun drying, **b.** Harvested material kept for drying under cellophane sheet, **c.** Brown seeds after sun drying, **d.** Green seeds after drying under shades

Variability in seed shape, size and colour of corriander germplasm collected from Guna and Shivpuri districts of Madhya Pradesh

seed weight was recorded for *Desi Dhana* (1.65 g) and minimum for *Kumbhraj* (0.97 g).

Coriander is mostly used for flavouring and as seed powder in curries. Farmers and traders of Ashok Nagar, Guna, Kumbhraj and Shivpuri (Madhya Pradesh) informed that mature seed with green colour after drying has good demand in beverage industry for increasing flavour in beverages. A processed green coloured coriander seed is purchased by beverage industry located in Ashok Nagar, Guna and Shivpuri districts of Madhya Pradesh for making several alcoholic beverages in large scale. For preparing flavoured beverages, the indigenous drying method for processing of "green coriander seed" has been developed by local farmers through several years of trials and practices. For green coloured seeds the most preferred landraces are *Kumbhraj, Mithi dhana* and *Kudi Dhana*. To retain the green colour and aroma in mature seeds, the plants are cut in early morning and dried under cover of a cellophane sheet for 1-2 days. Generally coriander seeds are harvested (110-130 days after maturity) when fruits attain yellow to golden yellow colour. Farmers have informed that harvesting of coriander landraces- *Kumbhraj, Mithi Dhana* and *Kudi Dhana* are done on priority due to early maturity (90-100 days) as well as fetching higher price in the market. Generally the price of brown coloured seeds varies from ₹ 4,000 to ₹ 6,000 per 100 kg. Farmers informed that the rate of light green and dark green processed seed are fetching much higher price (₹ 10,000 to ₹ 12,000 per 100 kg) in local *mandi* because of presence of high aroma in seeds in comparison to normal ones (yellow and brown coloured seeds). Only few farmers of the area are adopting this method and earning good income. The aromatic green seeded coriander was available with several traders in *mandis* of Ashok Nagar, Shivpuri, Guna and Kumbhraj. However, there is an urgent need to refine post-harvest method for popularization and doubling the income of coriander farmers in different parts of other states.

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PUSA SONA – A new high yielding onion variety suitable for salad and export

Onion is one of the most important vegetable having round the year demand in almost every household. In India, it is grown in 1.32 million ha with a production of 20.93 million tones. The average productivity is 7.0 t/ha, which can be improved by adoption of high yielding onion varieties/hybrids, suitable crop management practices and better plant protection measures.

Pusa Sona is a recently developed high yielding onion variety from Division of Vegetable Science, ICAR-IARI, New Delhi. The variety was tested across India through All India Network Research Project on onion and Garlic and found suitable for commercial cultivation during *rabi* season in zone II, comprising Delhi, Rajasthan, Haryana,

Pusa Sona

Jammu region of J and K and Punjab. The variety was notified through Central Sub-Committee on Crop Standards, Notification and Release of varieties of Horticultural Crops on 5th February, 2019.

Bulbs of this variety are globular in shape, large in size and creamish yellow in colour. The bulbs are juicy and the average total soluble solids content is around 10.0 ± 2° Brix. Pungency is medium (5.0 Pyruvic Acid ìmol/g). Therefore, the variety is most suitable for slicing and table purpose (fresh consumption as *salad* or *raita* preparation). This variety becomes ready for harvesting in approximately 130 days after transplanting. Average equatorial diameter of bulbs ranges from 5.0 – 6.2 cm, polar diameter ranges from 5.2 - 6.5 cm and single bulb weight ranges from 70.0 – 135.0 g, yield potential is 33.0-35.0 t/ha, whereas the national onion productivity is 17.0 tons/ha. The bulbs of this variety being large, cream coloured and mildly pungent, they are suitable for export to Europe and USA.

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PUSA SHOBHA – A high yielding onion variety for value addition

Onion is a ubiquitous vegetable in almost every culinary preparation in Indian household. Apart from their use as adjunct to add flavor and taste, they are used raw as *salad* or *raita* preparation, processed in vinegar, converted to pickle, dehydrated and various processed product. They are also valued for their medicinal properties and important ingredient of traditional Indian medicine system since time immemorial. Different types of onion are grown in various parts of the world having regional adaptation and preference. In India, mostly the red and dark skinned short day or intermediate day type onion dominates cultivation. However, these days, other skin color onion like brown, cream and white color onion are also gaining popularity in localized pocket either for their medicinal properties, localized or export demand.

Pusa Shobha is a brown skin colored variety with white flesh, developed at Division of Vegetable Science, ICAR-IARI, New Delhi and notified for commercial cultivation during *rabi* season in zone III (Delhi, UP, Haryana, Bihar and Punjab), IV (Rajasthan and Gujrat) and V (MP, Chattishgarh and Orissa) during 2018.

The bulbs of this variety are compact, flat globe, brown in colour. The flesh is white with average total soluble solids around 17± 2^0 Brix and suitable for storage, drying, processing and export. Pusa Shobha belongs to mid-maturity group and the bulbs become ready for harvesting in 140-160 days after transplanting. Average bulb weight ranges from

Pusa Shobha

70.0 – 100.0 g. The bulbs of this variety are mildly pungent (5.09 Pyruvic Acid ìmol/g). It has higher mineral content and 100 g dry bulbs contain. 19.45 mg Calcium, 38.7 mg Magnesium, 0.57 mg Zinc and 0.73 mg Iron. The bulbs have medium phenol (60.0 -100.0 mg galic acid equivalents/100g) and quercetin (14.0 - 18.0 mg/100g FW) content. The bulbs posses high antioxidant activity (2.0 - 2.6 ìmol Trolox/g FW FRAP value, 6.1 - 6.8 ìmol Trolox/g FW CUPRAC value). The average yield is 25.04 t/ha, which is 64.08% higher than check variety tested in different networking centre across India.

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New brinjal varieties for higher nutrition and health

Pusa Safed Baingan 1

- White oval round fruited variety notified (S.O. 692 (E), dated 5th Feb, 2019) for cultivation during kharif season under North Indian Plains.
- It can be grown in other brinjal growing areas.
- It is an early maturing variety (50-55 days from transplanting to first fruit harvest).
- Plants are semi spreading, spines are absent in stem, leaves and calyx.
- Light purple pigmentation present on younger leaves with green mid-rib and veins.
- Flowers are light purple in colour.
- Fruits are oval in shape weighing 50-60 g having green non-spiny calyx and mostly born in cluster.
- It is responsive to both high and a normal fertile soil and 250 g seed per hectare is sufficient for nursery rising.
- The potential yield of the variety is 35 t/ha. The performance of the variety is given in Table.
- It has high total phenol content (31.21 mg GAE/100 g) as compared to Pusa Uttam (21.57 mg GAE/100 g) and Pusa Kranti (19.67 mg GAE/100 g).
- It is rich in antioxidant activity (3.48 CUPRAC µ mol trolox/g, 2.58 FRAP µ moltrolox/g) as compared to *Pusa Uttam* (2.03 CUPRAC µ mol trolox/g, 1.13 FRAP µ moltrolox/g) and *Pusa Kranti* (1.97 CUPRAC µ mol trolox/g, 1.03 FRAP µ moltrolox/g).

Pusa Safed Baingan

Mean performance of brinjal variety *Pusa Safed Baingan* 1 at ICAR-IARI, New Delhi

Name of entry	Days to 50% flowering (After planting)	No. of fruits/ plant (Avg. of 5 plants	Avg. Fruit wt (g) (Average of 20 fruits)	Total fruit yield (t/ha)	Maturity (days after transplanting)
Pusa Safed Baingan 1	38.45	38.50	56.36	34.80	51.47
Pusa Bindu	39.78	15.83	105.48	26.78	53.47
Aruna	39.48	27.45	55.48	24.32	61.47
Pusa Ankur	*44.78*	*20.45*	*64.58*	*21.12*	*58.78*
CD at 5%	7.50	3.28	8.64	4.28	5.98
CV (%)	9.78	7.12	6.06	8.23	5.67

Mean performance of green oval brinjal variety *Pusa Hara Baingan* 1 at ICAR-IARI, New Delhi

Name of entry	Days to 50% flowering (After planting)	No. of fruits/ plant (Avg. of 5 plants	Avg. Fruit wt (g) (Average of 20 fruits)	Total fruit yield (t/ha)	Maturity (days after transplanting)
Pusa Hara Baingan 1	43.25	12.59	219.22	44.25	56.69
Pusa Uttam	41.58	8.94	205.69	29.56	59.84
KS-224	42.69	12.68	150.58	30.56	61.56
CD (5%)	2.69	2.14	15.58	5.21	2.41
CV	14.25	3.02	6.98	12.36	9.63

Pusa Hara Baingan

Pusa Hara Baingan 1

- Green coloured oval fruited variety notified (S.O. 692 (E), dated 5th Feb, 2019) for growing kharif season under North Indian condition.
- Plants are non-spiny with erect branches and light purple pigmentation present on younger leaves, mid-rib and veins.
- The plants start flowering 40 days after transplanting and ready for harvest in 55-60 days from transplanting).
- Fruits are big oval, green with light purple patches and 210-220 g having green non-spiny calyx.
- The potential yield of the variety is 40-45 t/ha (yield data shown in Table).
- The variety has high antioxidant activity (3.41 CUPRAC μ mol trolox /g, 3.07 FRAP μ mol trolox /g) as compared to *Pusa Uttam* (2.03 CUPRAC μmol trolox/g, 1.13 FRAP μ moltrolox/g) and *Pusa Kranti* (1.97 CUPRAC μ mol trolox/g, 1.03 FRAP μ moltrolox/g).

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VRSG-7-17: A new aromatic sponge gourd

An aromatic sponge gourd (*Luffaylindrical*Roem. Syn. *Luffa aegyptica*) genotype has been developed to popularize/promote this cucurbitaceous vegetable across India. Recently, ICAR-Indian Institute of Vegetable Research (IIVR), Varanasi has generated a unique material of sponge gourd (VRSG-7-17) with characteristic aroma which resembles with the typical aroma of '*Basmati* rice' in its various plant parts *viz.,* leaves, flowers, fruits, blossom end of fruits, plant vine and peel. Gas Chromatography-Mass Spectroscopy study conducted at CSIR-Central Institute for Medicinal and Aromatic Plant, Lucknow revealed the presence of high concentration of aroma compound viz., Hexenal and 3-Octanone in VRSG-7-17. Interestingly, all the duo volatiles were either absent or found in very low concentration in the control sample Kashi Shreya (VRSG-194). Other volatile compounds identified were cis-3 Hexenol, 1-Octane-3-ol, 1-Hexenol and Limonene etc. The fruits of this novel sponge gourd genotype (VRSG-7-17) also retained its special aroma even after cooking and/or boiling. Apart from these, the genotype VRSG-7-17 has also been observed for high fruit yield (1.375 kg / plant) with medium sized light green coloured fruits which matured at 58 to 60 days after sowing. The genotype is also tolerant to downy mildew disease, moderately susceptible to *Sponge Gourd Mosaic Virus* and is tolerant to melon weevil and is less susceptible to leaf miner under field conditions.

VRSG-7-17

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Black soldier fly – a promising protein supplement in aquacultural feed

Global aquaculture industry demands alternatives for fish meal and fish oil used in fish feeds due to the decreasing production and increased cost. Black soldier fly (BSF), *Hermetia illucens* can efficiently convert protein free organic wastes into protein rich biomass that could serve as partial or complete replacement of fish feed with BSF as protein supplement. BSF prepupae was estimated to contain 32.53% crude protein, 22.1% crude lipid, 23.81% carbohydrates. Growth performance of Tilapia, monosex Tilapia (*Oreochromis niloticus*) was evaluated using the pellet feed formulated using black soldier fly. Fishes fed with fish meal diet and BSF incorporated diet showed significantly higher final weight and mean weight gain compared to other treatments. Percentage weight gain of fishes and feed conversion ratio of fishes fed with BSF diet was statistically on par with that of control fish meal diet. BSF diet was statistically on par with commercial fish meal. The present study indicates that BSF could be a suitable protein source for fish feed formulation in aquaculture practices.

Black Soldier Fly Pellet fish feed

Black Soldier Fly Prepupae

Tilapia fishes feeding on BSF feed

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WAY FORWARD

AGRICULTURE is crucial for ensuring food, nutrition and livelihood security. More than 80% of Indian farmers are marginal (cultivating land up to 1 hectare) and small (cultivating between 1 hectare and 2 hectares) with poor coping capacity, particularly when we talk about sustaining production and productivity. Sustainable agriculture is an agriculture that sustainably (i) increases productivity, (ii) increases resilience (adaptation), (iii) reduces/removes GHGs and (iv) enhances achievement of national food security and development goals.

Agriculture contributes to climate change primarily through emission and consumption of GHGs. Methane is produced in soil during microbial decomposition of organic matter under anaerobic condition. Rice fields submerged with water are the potential sources of CH_4 production. Continuous submergence, higher organic C content and use of organic manure in puddled soil enhance the CH_4 emission. The enteric fermentation in ruminants is another major source of CH_4 emission. Burning of crop residues also contributes to the global methane budget. Main source of carbon dioxide in agriculture is soil management practices such as tillage, which triggers emission of this gas through biological decomposition of soil organic matter. Use of fuel for various agricultural operations and burning of crop residues are other sources.

Globally, out of total GHG emissions of 55 billion tons (Bt) CO_2 eq. India's contribution is only 5%. Agriculture contributes globally 11-12% of the total GHGs emission out of which the share of Indian agriculture is about 1%. Energy sector in India contributes the highest amount GHGs (65%) followed by agriculture (18%) and industry (16%). Indian agricultural sector, including crop and animal husbandry, emits about 420 Mt of CO_2 eq. Enteric fermentation i.e., emission from ruminant animals contributes the highest (56%) amount of the emission from this sector, followed by agricultural soil (23%) and rice fields (18%). Burning of crop residues in field and livestock manure management contribute 2% and 1% of the emission, respectively. Since 1970, the GHG emission from Indian agriculture has increased by about 80%. The increased use of fertilizers and other agri-inputs are major drivers for this increase in emission.

GHG emissions are expected to continue to increase due to higher demand for food as population grows. As societies in developing countries become wealthier there is shift in diet and meat consumption increases. By 2030, GHG emissions from agriculture are expected to be almost 60% higher than in 1990. The largest increase will be in N_2O emissions from soils (75%), as fertilizer use rises rapidly. Emission of CH_4 from other agricultural sources (predominantly biomass burning) will also grow greatly (70%), but these emissions will still account for only 5% of the total agricultural emissions. Emissions from manure management will still be significant and may become greater on the order of 31% for N_2O and 47% for CH_4 from this source.

If demands for food increase, and diets shift as projected, then annual emissions of GHGs from agriculture may escalate further. But improved management practices and emerging technologies may permit a reduction in emissions per unit of food (or protein) produced, and perhaps also a reduction in emissions per capita food consumption. The projected trends of GHGs emission (Mt. CO_2equivalent) from Indian agriculture have indicated that under the business-as-usual scenario, the emission will increase by 17% by 2030 compared to that in 2010.

Dr T Mohapatra, Secretary (DARE) and Director General (ICAR)

The key challenge to limiting GHG emissions from agriculture is to expand efficiency of external inputs i.e., energy, irrigation water, fertilizer, and pesticides used for production and reducing the loss of produce. Mitigation strategies that reduce GHG intensity from agriculture, by changing production practices without hampering yields and by shifting demand to lower-GHG intensive products can result from broadly three types of interventions: (i) Efficient Supply chain management: Reducing emissions intensity along entire agricultural supply chain, including avoided land use change. (ii) Sustainable agricultural production: Reducing wastage of food or shifting away from high-carbon intensity agricultural products such as livestock production and (iii) Sequestering carbon in agricultural systems.

Agriculture offers opportunities for mitigation from supply-side (management of land and livestock) and demand-side (C sequestration). Agriculture can mitigate GHGs cost-effectively through the adoption of changes in agricultural technologies and management practices through (i) crop management: improved variety, rotation, diversification; (ii) nutrient management: type of fertilizer, better timing of fertilization, use of nitrification inhibitor; (iii) tillage/residue management: reduced tillage, residue retention; (iv) water management: improved water application, drainage; (v) land use changes: agroforestry, bio-energy crops and (vi) improved livestock management:low nitrogen feed, nitrate as feed additive, vaccination against methanogenic bacteria in the rumen, specific breeding programs to increase milk yields of dairy cows and ruminant feed efficiency and anaerobic digestion of animal dung for biogas at farm scale.

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