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ICAR NEWS

A SCIENCE AND TECHNOLOGY NEWSLETTER

RESEARCH UPDATE

PROMISING TECHNOLOGIES

Agriculturally important micro-organisms bio-encapsulated for smart delivery in crops

Biofertilizers are available in different formulations; common ones are as liquid, peat, granules and freeze-dried powders. A perfect formulation, however, does not exist; each type has its own advantages and limitations. Lately, a promising advancement has been made in developing technique that allows encapsulation of microbial strains in a nutritive shell or a capsule, and then delivering them to the targeted site. While encapsulation techniques were fairly successful in the laboratory, attempts to emulate their performance largely failed in the field.

Development and successful field testing of biocapsules, containing plant growth promoting rhizobacterium (PGPR), *Bacillus amyloliquefaciens* IISR GRB 35, have been achieved. The process involves encapsulation of PGPR in a gelatine capsule. Total weight of this biocapsule is only 1g. Making of the formulation is also simple and does not require sophisticated

Gelatine capsules containing PGPR *Bacillus amyloliquefaciens* IISR GRB 35

Indian Council of Agricultural Research
Krishi Bhavan, New Delhi 110 001, India
www.icar.org.in

The patent for this invention entitled 'A novel method of storing and delivering PGPR/microbes through biocapsules' has been filed (Application No.3594/CHE/2013 dated 13/08/2013). Considering the fact that encapsulation technologies involve high production cost, more handling work at the industry level, and special equipments, the success of this microbial delivery system in the field, its low production cost and ease of handling and storage apparently means that the technology is affordable and cost-effective, and would be readily adopted by manufacturers and farmers.

equipment and conditions. Addition of buffering and protecting agents save the product from desiccation and ensures its protection against environmental stresses; capsules can be stored at a room temperature. The capsule contains PGPR in an immobilized/inactive condition with a population of 10^9CFU/g. Cells can be activated by dissolving the capsule in 100 mL of sterile distilled water or boiled and cooled water, followed by incubation for 1h at a room temperature. Further incubation from 12 to 24h is done at a room temperature with intermittent mixing or shaking, which results in increased population to 10^{10} CFU/g; that is diluted to 10^9 CFU/ mL prior to use. After dilution, seeds or seedlings or rhizomes are soaked in the suspension for 30 minutes before sowing/ transplanting into the main field. The remaining suspension can be used as a soil drench.

Since the population remains constant at 10^9 CFU, the number of capsules required would be markedly less compared to talc formulation, and thus the investment cost also.

Normal requirement of talc formulation of PGPR for ginger-crop is 20 kg/ ha. It can be replaced with just 40 biocapsules, weighing 40g. Other advantages of the capsules are the reduced cost of handling and transport, no harmful by-products, less requirement of inorganic and inert materials; and the most important is that capsules can be stored at a normal temperature. Shelf-life of the encapsulated PGPR at room temperature was found to be staggering 16 months compared to 3-8 months of talc-based formulations. What makes the technique very special is that it can be used to deliver all kinds agriculturally important microbes — N fixers, nutrient solubilizers/ mobilizers, PGPR, fungal spores, biocontrol agents like *Trichoderma*, *Burkholderia* etc. to any crop.

Presently no such commercial product is available in the world market, thus the successful laboratory and field testing of this novel microbial delivery system would represent a giant leap in biofertilizer formulation and production.

M. Anandaraj
ICAR-Indian Institute of Spices Research
P. O. Box 1701, Marikunnu P.O., Calicut (Kerala) 673 012
e-mail: arajiisr@gmail.com; anandaraj@spices.res.in

Organic mushroom production from banana-crop residue

Banana pseudostem and petiole, and arecanut husk have been used for mushroom-bed preparation. For the bed preparation, leaf-harvested banana petioles, midribs and outer portions of the pseudostem are cut into small pieces and are disinfected by steaming, using specially designed cooking vessel. This method ensures organic-mushroom production by avoiding formalin as a disinfecting agent.

The steamed material is dried to the desired moisture level and used for filling and preparation of mushroom beds. Then the spawn is spread on the beds at 8 to 10 cm thickness. Using 250 g of spawn, about 1.5 kg of oyster mushroom can be harvested through 3 to 5 pickings.

A studio person of Kakkoor Panchayat, Kozhikode district,

Organic mushroom production using banana-crop residue

Mushroom is considered a miracle food in nature; high in nutritional and medicinal value. It is often designated as a vegetable meat, as it is the only vegetable with complete protein constitution; containing all amino acids as of meat. The high content of organic iron and B complex makes it a choice food for pregnant women. The ability of mushroom to lower cholesterol and balance Na:K ratio, makes it suitable for people suffering from hypertension. Low energy content and anti-cancer properties of mushroom makes it the best choice for diabetic and cancer patients. Further acceptance of mushroom as a delicacy by both the vegetarian and the non-vegetarian in the family has increased its demand. The demand of mushroom-spawn from all-over Kerala has increased due to increased numbers of mushroom-growers in the state.

Kerala, turned into a successful small-scale entrepreneur by applying banana-crop residue for mushroom cultivation. He used mushroom packing of 100 g to be sold at ₹300/kg.

Since October 2015, the ICAR-KVK has dispatched about 170 kg spawn (700 packets @ 250g each) and trained about 500 persons through on-campus and off-campus trainings organized at *Krishi Bhavans*, Farmers Training Centres, Registered societies and NGOs.

P. Ratha Krishnan
ICAR - KVK
ICAR-Indian Institute of Spices Research
Kozhikode (Kerala) 673 528

Biotechnological interventions for improving pulses productivity

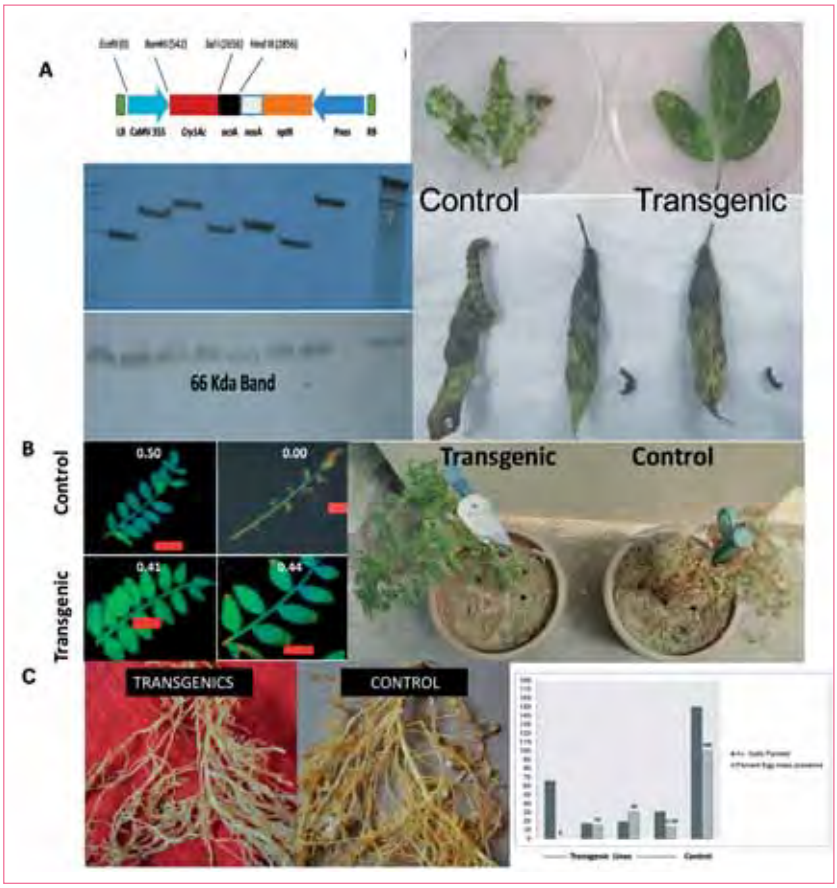
Considering receding soil moisture, marker-assisted breeding (MABC) is the only viable strategy to enhance maximum utilization efficiency of the available soil moisture in **chickpea**. A "QTL-hotspot" region containing 13 robust quality trait loci (QTLs) for 12 traits with 58.20% PVE was transferred through marker-assisted backcrossing (MABC) into DCP 92-3, a leading chickpea variety of the north-western plains zone in India using donor parent ICC 4958. After undertaking three backcrosses, followed with foreground and background selection and two rounds of selfing, six BC_3F_3 plants, homozygous for quality trait loci linked to ICCM0249 and TR11 flanked markers, could be selected. The advanced backcross homozygous line for tightly linked markers would be analyzed molecularly and phenotypically for desired traits before multiplication for field evaluation.

Pigeonpea was the first food legume-crop to have complete sequenced genome, followed by chickpea. In pigeonpea, sets comprising 3,09,502 and 1,89,895 SSRs were identified through microsatellite survey of two draft genome sequences. Chickpea has ~28,000 genes; of which only 187 genes are found involved in disease resistance, and the exact location of these genes in the genome would make it possible to either clone or introgress them into elite cultivars. The utility of genomic resources can be further extended for high throughput genotyping to develop high density linkage maps with available SNPs and SSRs. Similarly, genome-wide studies of TF, miRNA, siRNA, NBS-LLR for biotic and abiotic stresses related genes would enable systematic analysis of previously unexplored genomic regions for targeted integration breeding approaches, and would thus improve the efficiency of MAS programmes. With this background, the initiatives have been undertaken for utilization of chickpea genome sequence for crop improvement, where 3,000 global chickpea accessions will be re-sequenced and evaluated for agronomic traits in multiple locations in India to identify genes underlying these traits through

genome-wide association studies. Transcriptomic and proteomic approaches in contrasting susceptible and tolerant chickpea genotypes in response to herbicide imazethapyr have also been completed.

In pulses, traits like insect (*Helicoverpa armigera*) resistance, nematode (*Meloidogyne* spp.) resistance and enhanced drought tolerance are being engineered in chickpea, pigeonpea and fieldpea.

Lepidopteran pests like borers in soybean, cotton, brinjal etc. were shown to be controlled by *Bacillus thuriengiensis* (BT) protein. Hence, efforts to develop gene transfer protocols for generating large number of independent transgenic events in pigeonpea and chickpea genes were taken up. Codon optimized, truncated *Bt* gene (*cry1Ac*) and domain shuffled (*cry1Aabc*) gene were used to generate transgenic chickpea (cv. DCP92-3) and pigeonpea (cv. Asha) lines utilizing *Agrobacterium tumefaciens.* Transgenic chickpea (*ca*. 500 lines) and pigeonpea lines (*ca*. 500) harbouring *Bt* gene(s) have been generated and a few efficacious lines have been characterized. Insect bioassays (detached leaf, pod and whole plant bioassay) of generated chickpea and pigeonpea lines using larvae of pod borer indicated higher mortality (90-100%) in some of the lines; which have been selected for confined field trial.



A. Characterization and insect bioassay of transgenic pigeonpea lines; **B.** Quantum yield and phenotype of transgenic chickpea lines under water-limiting stress; **C.** Gall formation in transgenic fieldpea lines and control

Chickpea is largely cultivated on the residual soil moisture, and hence terminal drought is the most serious constraint. Four transgenic chickpea lines have been developed using transcription factor, *At*DREB1A, driven by stress inducible promoter *rd29a.* Phenotyping of transgenic chickpea lines exhibited higher relative water content (RWC) in leaves under declining soil moisture at the root zone (approx. 7% closer to wilting point) along with longer chlorophyll retention as compared to the control.

Among plant-parasitic nematodes, root-knot nematodes (RKNs) (*Meloidogyne* spp.) are most notorious. Owing to parasitic nature, it was not possible to culture them in laboratory, and hence, forward genetic and biochemical approaches could not be applied. RNA interference (RNAi) technology is a promising reverse genetic tool that has the potential to specifically down-regulate gene expression in the organism. Oesophageal gland secretory proteins are arsenal of RKNs for entry into the root zone. Double stranded RNAi constructs were designed against salivary/oesophageal gland gene (*AF531160*), and effectivity of the gene in controlling nematodes was demonstrated. **Fieldpea** lines have been developed using *Agrobacterium tumefaciens* mediated genetic transformation of a susceptible fieldpea cultivar, HUDP15, using double stranded RNAi construct (AF531160). Nematode bioassay (*Meloidogyne javanica*) of homozygous transgenic fieldpea lines (T3) indicated significant reduction in gall formation and subsequent egg mass.

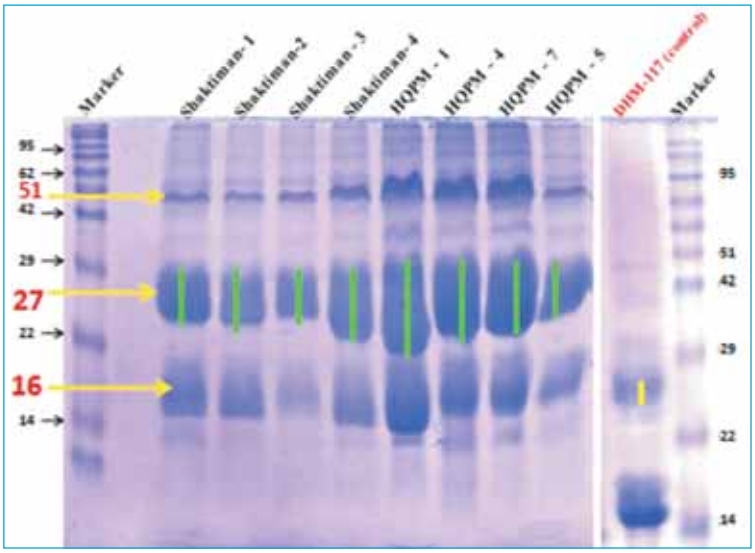
Genetic improvement in pulses would complement conventional breeding approaches for ensuring nutritional security of the country.

K.R. Soren, Alok Das, S.K. Chaturvedi and **N.P. Singh**
ICAR-Indian Institute of Pulses Research
Kanpur (Uttar Pradesh) 208 024
e-mail: npsingh.iipr@gmail.com

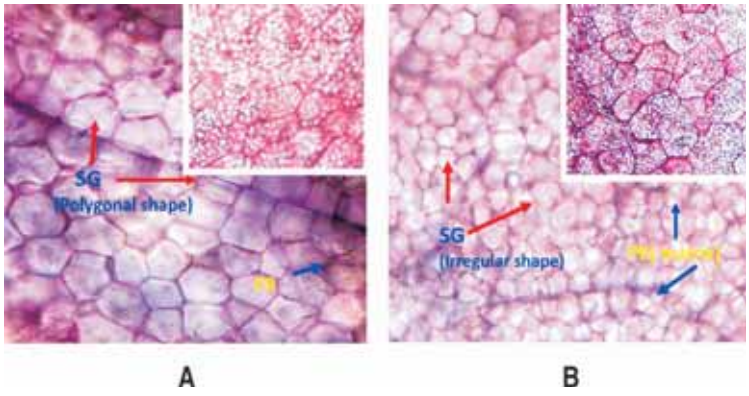
27-kDa gamma zein role in vitreousness of Quality Protein Maize kernels

Maize, being robust and extremely adaptable to varying agroclimates, is a favourite crop of farmers. Especially for rural poor, maize also constitutes the main bulk of daily diet. But the concern is insufficient protein quality and quantity in maize-grain, leading to malnutrition. Its nutritional value is limited by low levels of essential amino acids, particularly lysine and tryptophan.

With the discovery of tryptophan and lysine-rich maize mutant *opaque-2* (*o2*) in 1961, the quest began to improve nutrient quality of indigenous maize varieties by producing variants of opaque-2 cultivars. Soft kernels of *o2* cultivars are prone to damage by pests; thus opaqueness appears as the biggest hurdle in acceptance of *o2* variants by farmers. To override this, Quality Protein Maize (QPM) varieties with hard, translucent (vitreous) kernels, high lysine content and improved amino- acid composition have been developed. In general, kernel hardness is influenced by storage proteins, which in turn, are responsible for the association between starch granules and endosperm matrix proteins. The composition and arrangement of storage proteins alter texture, and consequently physical structure of endosperm. But the basis of modified kernel texture in Quality Protein Maize (QPM) was still not clear.



Gamma zein accumulation in QPM and non-QPM genotypes, extracted from mature seeds and assayed using SDS-PAGE. Based on equal amount of endosperm flour, QPM hybrids revealed enhanced level of 27 k-Da γ zein as compared to non-QPM DHM 117



Light microscopy analysis of starch granules in mature endosperm of non-QPM and QPM hybrids: **A.** DHM 117 (non-QPM) kernel contains polygonal starch-grains embedded in a proteinaceous matrix containing protein bodies; **B.** HQPM 1 kernel has polygonal to round starch grains with loose matrix

The microscopic study on eight QPM hybrids and one normal hybrid, DHM117, released for cultivation in India, has shown that non-QPM cultivar (DHM 117) has well-defined wall of the endosperm cell and its starch granules are in perfect polygonal format. In contrast, starch granules in kernels of QPM hybrids are irregular in shape but their inter-granular spaces are filled, and there are interconnections among many adjacent starch granules, leading to vitreous phenotype. In QPM hybrids, restoration of vitreousness may be due to the presence of abundant and organized protein bodies, which apparently allow greater adherence and better distribution of starch granules in the endosperm, and consequently greater physical resistance of grains. Proteomic analysis of QPM lines indicated increased non-zein protein fraction and decreased levels of zein/ storage proteins. On the contrary, there was an elevated accumulation, approximately twice as much of 27-kDa γ-zeins and reduction of 22-kDa and 19-kDa α-zeins and 15- kDa β - zein. Correlation between physical properties, zein content and kernel structure in QPM hybrids has shown positive correlation between vitreousness and density (r=0.263) and negative correlation between vitreousness and floatation index (r = – 0.869*). This shows that

densely packed structure has high density and low floatation index as well as higher hardness value than loosely packed structure. High positive correlation (r=0.667) between vitreousness and 27-kDa gamma zein content justifies hypothesis of 27- kDa gamma zein role in kernel vitreousness. Unraveling of the missing information on improved protein quality and modified kernel texture in QPM may accelerate development of Quality Protein Maize in countries where it can impact human nutrition.

Nirupma Singh
ICAR-Indian Institute of Maize Research
Pusa Campus, New Delhi 110 012
e-mail: nirupmasingh@rediffmail.com

Whole genome and transcriptome analysis of *Colletotrichum falcatum* to decipher specific adaptation as an intriguing stalk pathogen

Red-rot of sugarcane, caused by fungal pathogen *Colletotrichum falcatum*, is a major challenge in sugarcane cultivation. Although tropical region of India remained free from the rot for many decades in the past century; from 1970s, the disease has caused extensive losses to cane cultivation in Tamil Nadu, Andhra Pradesh, Gujarat and Odisha. Onslaught of red-rot continues in both subtropical and tropical states, excepting Maharashtra and Karnataka. Affected canes are unfit for milling owing to inversion of sucrose into reducing sugars. Emergence of new variants of the pathogen

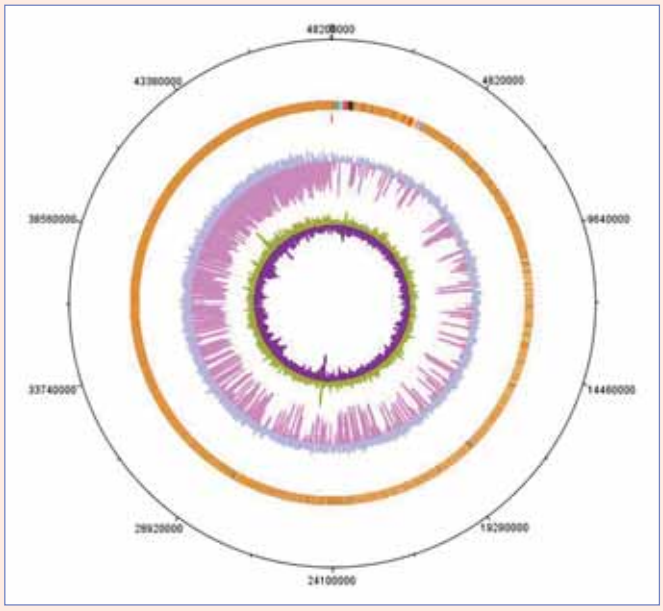
Severe devastation on sugarcane-crop in the recent red-rot epidemics in the east coast region of the country

causes frequent breakdown of varieties in the field. Overall, pathogen exhibited enormous variation in virulence, which was not clearly understood. Although about 11 pathotypes of the pathogen have been identified through differential host interaction, but the pathogenicity mechanism could not be properly established.

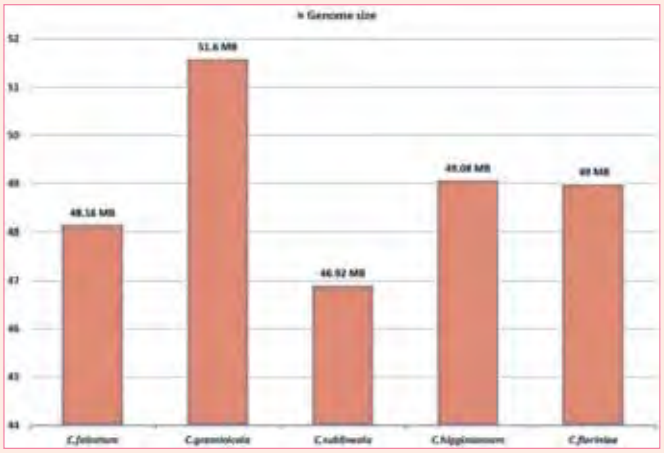
Lately, a few genes such as chitin synthase and those involved in melanin biosynthesis involved in pathogenicity were characterized. But the complete information on genome / transcriptome was required to understand pathogen biology and its molecular signatures governing virulence / host adaptation

C. falcatum pathotype CF06 (isolated from sugarcane cv CoC 671; MTCC accession number 12142) was sequenced using HiSeq 2000 platform (Genotypic solutions, Bengaluru) and assembled into contigs and scaffolds based on the pair-end library using Velvet assembler and contig extension/ scaffolding done by SSPACE.

Genome of *C. falcatum* is 48.2 MB with predicted 12,270 genes at 150×coverage (Bio Project ID-272959, Accession number - PRJNA272959). This sequenced genome of *C. falcatum* is found comparable in size to the recently reported *Colletotrichum* spp. The arsenal of *C. falcatum* genes involved in hemibiotrophic lifestyle is found similar



Colletotrichum falcatum genome: The genome map constructed using ARTEMIS software - first circle denotes the size of genome (48.16 MB); second orange yellow frame consists of full length scaffolds; pink and blue colour circles denote presence of GC content and purple and green colour circles denote AT content.



Genome size of *C. falcatum* and other *Colletotrichum* spp.

to *C. graminicola* and *C. sublineola,* infecting related hosts maize and sorghum, respectively. The *falcatum* genome has revealed presence of plant cell-wall degrading enzymes (PCW), candidate secretory effectors (CSEPs), transposable elements, primary and secondary metabolites, membrane transporters, signaling molecules, CAZy, mating proteins, involved in the development, and sclerotic management proteins. Analysis of such genes revealed that *C. falcatum* has adopted a hemibiotrophic lifestyle with the expansion of secondary metabolites, membrane transporters and with the crucial role of plant cell-wall degrading proteins in establishing infection strategy with uniqueness.

Further, sequencing of expressed transcripts of the fungal pathogen using Illumina Hi-Seq technology generated a total of 53,410,513 reads (50 bp read length), specific to *C. falcatum*. The sequences were assembled into 24,732 transcripts, representing 23,136 predicted coding regions. GO analyses suggested prevalence of genes associated with cellular components like cell envelope, and extracellular, macromolecules and membrane enclosed organelles and among the transcripts, genes associated in majority with molecular functions like antioxidant, binding, catalytic activities, electron carrier, enzyme regulator and transcription regulator. Genes associated with biological processes were categorized into anatomical structure formation, growth, pigmentation, establishment of localization and response to stimulus. KEGG pathway analysis suggested prevalence of genes encoding carbohydrates, lipids, glycans, cofactors, vitamins, terpenoids, polyketides kinases, proteases, glycoside hydrolases, cutinases, cytochrome P450 and transcription factors in transcriptome.

The transcriptome analysis has identified several putative pathogenicity determinants, candidate effectors and transition specific metabolites. Interestingly, large number of transcripts encoding biotrophy-necrotrophy transition and membrane transporters were identified, and gene enrichment analysis revealed that numbers of transporters encoded by *C. falcatum* are significantly more compared to other *Colletotrichum* species.

Exploration of genome and transcriptome has paved a way in understanding biology of red- rot pathogen, and this has identified several unique putative genes/functions required for its pathogenesis in sugarcane. This work lays the foundation for facilitating future research towards understanding this intriguing host-pathogen interaction.

R. Viswanathan, C. Naveen Prasanth, P. Malathi and **A. Ramesh Sundar**
ICAR-Sugarcane Breeding Institute
Coimbatore (Tamil Nadu) 641 007
e-mail: r.viswanathan@icar.gov.in

Transcriptional changes in immunoglobulin isotypes of rohu in response to *Argulus siamensis* infection

A challenge experiment with an ectoparasite *Argulus siamensis* was conducted to evaluate changes in adaptive immune response in skin, head-kidney and mucus of infected rohu(*Labeo rohita)* by quantitation of expression of Ig heavy chains by real-time PCR. IgM level reached its peak 30 d post-infection in head -kidney tissue, while IgM transcripts were below detectable range in skin and mucus. IgZ and IgD levels up-regulated significantly post-infection in all the three tissue samples. Early up-regulation of IgD was observed in skin and mucus, compared to head-kidney. This study has shown that parasitic invasion can trigger varied expressions of immunoglobulin type to provide systemic as well as local protection in the host. Appearance of high level of expression of IgZ and IgD in skin and mucus, in particular, would pave the way for vaccine development against *A. siamensis,* which feeds on tissues.

ICAR-Central Institute of Freshwater Aquaculture
Kausalyaganga
Bhubaneswar (Odisha) 751 002
e-mail: director.cifa@icar.gov.in

New host-plants for Kusumi lac cultivation in Karnataka

For the first time, an experiment was conducted in Dharwad, Karnataka, to study performance of Kusumi strain of *Kerria lacca* Kerr. (Tachardiidae: Homoptera) on thirty-four different host-plants. Of the various host-plants screened, lac was cultivated successfully on nine plants — *Flemingia semialata, Calliandra calothyrsus, Schleichera oleosa, Ziziphus mauritiana, Albizia saman, Prosopis juliflora, Cajanus cajan, Albizia lebbeck* and *Eriolaena candollei*. Performance on *C. calothyrsus* and *P. juliflora* was promising, especially in view of the natural abundance of these in Uttarkannada and North Karnataka districts, respectively. Kusumi strain of lac has been recorded for the first time on these two plants from Karnataka. The brood lac was inoculated during 7-9 February 2015 (summer crop) and 13-14 July 2015 (rainy crop). About 100 g of brood lac was inoculated per plant on each of the host-plant and observations were made. In view of the multi utility value and the availability of both the host-plants naturally, there is a huge potential to exploit them for commercial lac cultivation during rainy season as well as in summer in Uttarkannada and several districts of North Karnataka. Large-scale field trials are in progress to exploit both, *C. calothyrsus* and *P. juliflora,* for commercial lac cultivation in farmers' fields.

Potential new host-plants

Initial settlement on *P. juliflora* (25th day of inoculation)

Filamentous growth on *P. juliflora* (90th day of inoculation)

Harvesting time (160th day)

Initial settlement on *C. calothyrsus* (25th day of inoculation)

Filamentous growth on *C. calothyrsus* (90th day of inoculation)

Harvesting time (160th day)

Host-plants/ Season	*P. juliflora*		*C. calothyrsus*	
	Summer	Rainy	Summer	Rainy
Brood lac used for inoculation (g)/plant	100	85	100	85
No. of crawlers settled/0.5 cm^2	54.05	45.66	83.00	87.66
Average diameter of lac encrustation (mm)	6.16	4.76	8.30	6.10
Brood lac yield (g)/100g	84.28	*	325.95	*

* To be harvested

R.R. Patil, Beerappa R. Pujar, Hasansab A. Nadaf and **A.K. Jaiswal**[1]
Department of Agricultural Entomology
College of Agriculture, UAS
Dharwad (Karnataka) 580 005
[1]ICAR-Indian Institute of Natural Resins and Gums
Namkum, Ranchi (Jharkhand) 834 010
e-mail: patilrr6@gmail.com

Rice landraces from West Bengal

Rice is cultivated in over 65% area of West Bengal state, called as a 'bowl *of rice*'. The state has a rich diversity — over 500 rice landraces have been reported.

An exploration was undertaken during *kharif* (November 2015) in which 40 germplasm accessions, comprising 37 distinct rice landraces and three wild rice (*O. nivara*), were collected from parts of Nadia, Hooghly, North-24 Parganas and South-24 Parganas districts.

Variability in grain shape, size and colour of rice from parts of Nadia, Hooghly, North- 24 Parganas and South-24 Parganas districts of West Bengal

Kalo Moto and *Madi Sail* are the most common traditional rice landraces, accounting for more than four accessions of the germplasm from this region. Husk of 27 accessions is grey-orange and grey-yellow. Landraces pericarp colour varies from white to black, and brown, golden yellow, light brown and red. Out of the 37 landraces, aroma has been recorded in 19; 31 are awnless and only six have awns of different lengths. Maximum kernel weight (1,000 kernel) was recorded in *Suraj Patnai* (30.26 g) and minimum in *Kala Jeera* (9.55 g). Kernel length was from 4.24 mm (*Begun Bichi*) to 10.48 mm (*Suraj Patnai*)

Variability in different landraces of West Bengal

Sl No	Landrace	Kernel length with husk (mm)	Kernel breadth with husk (mm)	1,000 kernel wt (g)
1	Begun Bichi	4.24	2.70	13.15
2	Roop Sail	8.28	3.08	21.41
3	Suraj Patnai	10.48	2.88	30.26
4	Nuna Khitesh	7.04	3.26	26.47
5	Chini Kamini	5.42	2.48	13.07
6	Kamini	5.66	2.62	16.33
7	Kalo Moto	7.74	3.48	24.14
8	Minikhet	8.82	2.06	16.00
9	Kalo Moto	7.56	2.76	24.69
10	Patnai	10.42	3.06	26.71
11	Madi Sail	5.81	3.28	19.91
12	Dudheswar	6.86	1.92	17.19
13	Madisal	6.50	3.11	16.61
14	Gobindo Bhog	5.51	2.06	11.44
15	Ranjaut	6.00	2.68	22.97
16	Harkul	7.48	4.24	26.92
17	Lokhi Purnai	6.3	2.66	24.08
18	Amulya	6.92	2.70	19.21
19	Haladi Guri	6.30	3.10	22.78
20	Inderbhog	4.86	2.46	11.32
21	Lakhi Bilas	8.00	2.88	23.21
22	Radhuni Pagal	5.22	2.48	10.51
23	Kalazira	4.92	2.28	9.55
24	Kali Khosa	4.82	2.66	11.09
25	Kallo Bhog	6.94	2.92	15.72
26	Agniban	6.68	2.38	30.07
27	Balam	7.50	2.84	21.16
28	Jangli Jatta	6.30	2.74	22.86
29	Jhinga Sail	8.12	2.76	28.61
30	Murki Balam	7.34	2.82	15.55
31	Kamini	6.08	2.26	10.51
32	Tulai Panji	6.90	2.72	15.35
33	Katari Bhog	6.92	2.76	15.09
34	Sita Bhog	5.50	2.86	9.95
35	Badshah Bhog	5.46	3.34	11.00
36	Khejur Chadi	6.51	3.50	22.63
37	Dudheswar	8.28	3.04	17.90
	Min.	**4.24**	**1.92**	**9.55**
	Max.	**10.48**	**4.24**	**30.26**

Landraces and their utilization

Kalo Moto (very good taste, black husk, aromatic rice) is the most popular landrace among the local people; especially conserved and grown for food and medicinal use. *Tulai Panji* (soft-kernel aromatic rice with good digestibility) landrace is used in *annaprasan* (when infant is offered food for the first time) in Hooghly district. Like-wise landraces *Dudheswar* (taste-like milk) and *Sita-Bhog* (small size rice) are also used for religious ceremonies in Palbadi area of South-24 Parganas district. Generally, aromatic rice, *Kali Khosa* is preferred for preparation of dessert (*kheer*-sweet meal) and used in traditional ceremonies in Mohanpur, Nadia and adjoining areas. *Madi Sail*, mainly grown in South-24 Parganas, is mostly used in *mudi* preparation (local sweet/*laddoo*) during *Sagar puja* (for worship of Goddess Ganga). A distinct landrace – *Kala Jeera* (black scented, small size rice, looks like cumin) – is also used in sweet-meal preparation by local people in Nadia district, particularly in Mohapur, Chakdaha villages.

and kernel breadth from 1.92 mm (*Dudheswar*) to 4.24 mm (*Harkul*). Cluster analysis, performed on grain size and weight, grouped all accessions collected into two clusters (I, II). Cluster-I includes *Begun Bichi, Badshah Bhog, Chini Kamini, Katari Bhog, Kamini, Kallo Bhog, Kala Jeera, Madi Sail, Gobindo Bhog, Ranjaut, Inderbhog, Radhuni Pagal* and *Sita Bhog,* which are mostly aromatic with small grains. Cluster-II includes *Agniban, Amulya, Balam, Dudheswar, Harkul, Haladi Guri, Jhinga Sail, Kalo Moto, Khejur Chadi, Lakhi Bilas, Minikhet, Jangli Jatta, Jhinga Sail, Murki Balam, Kali Khosa, Nuna Khitesh, Patnai, Roop Sail, Tulai Panji* and *Suraj Patnai* based on the similarity in kernel size and 100-kernel weight.

Shrinkage in the cultivated area of these landraces is an alarming situation. It is important to collect, evaluate and identify desirable traits in these landraces to contribute to rice genetic improvement.

D.P. Semwal, O.P. Dhariwal and **S.P. Ahlawat**
Division of Plant Exploration and Germplasm Collection
ICAR-National Bureau of Plant Genetic Resources
New Delhi 110 012
e-mail: dinusem@rediffmail.com

Phenolic compounds for resistance to post-flowering stalk-rot disease of maize

Post-flowering stalk-rot (PFSR) of maize is one of the most important diseases in India, which is caused by more than one pathogen — *Fusarium verticillioides*, *Macrophomina phaseolina* and *Harpophora maydis*. The potential grain yield losses owing to the disease have been estimated up to 42.9%, and can be as high as 100% in areas where susceptible genotypes are grown. Stalk-rot causes internal decay and discolouration of stalk tissue, thus reduces yield by blocking translocation of water and nutrients, and leads to death and lodging of plants also. It cannot be entirely controlled, but damage can be reduced through integrated management programme (Sanitation and removal of previously infected crop debris. Crop rotation with non-host crop like vegetable crops; Applying potash @ 80 kg/ha in endemic areas; Use of *Trichoderma* formulation after mixing with FYM @ 10 g/kg and incubating for 10 days in furrows at the time of sowing). Cultivation of resistant hybrids is one of the measures, and keeping this in view, resistant inbred lines/genotypes were developed from germplasm of different genetic backgrounds — from PFSR resistant pools and from NE purple and yellow maize.

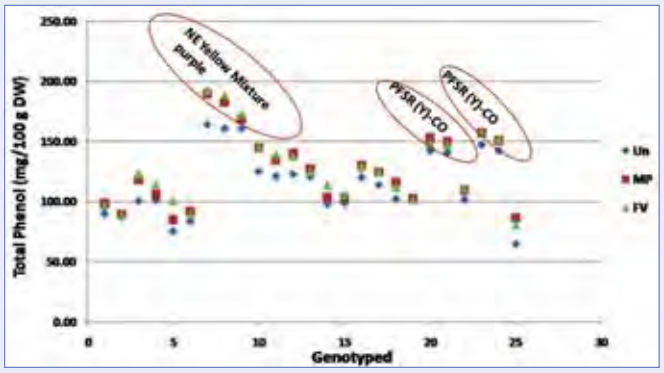
Plant phenolics are secondary metabolites needed for pigmentation, growth and reproduction, and for developing resistance to pathogens as well. Purple Corn is an important source of anthocyanins and other

Best genotypes of maize with total phenols content

Sl No.	Best genotypes	Total phenols (mg/100 g dwt)	
		Inoculated	Uninoculated
1.	Mixture Purple-1	189.27	160.40
2.	Mixture Purple-2	169.13	157.52
3.	Mixture Purple-3	167.85	157.52
4.	PFSR (Y)-C1-B ⊗-1-1-1	156.11	139.64
5.	PFSR (Y)-C0-1-⊗-4-1⊗-1-1-1-3⊗-1-1-1-1	159.22	149.29
6.	PFSR (Y)-C0-1-⊗-4-1⊗-1-1-1-3⊗-1-1-1	152.83	134.95

PFSR (Y)-C0 line

NE (Yellow purple) mixture-line



Twenty-four genotypes with different concentrations of total phenolic compounds in inoculated and uninoculated conditions (Mp: *Macrophomina phaseolina;* FV: *Fusarium verticilliodes;* Un: Uninoculated)

polyphenols, which are distributed throughout the plant. To determine content of total phenolic compounds (TPC) of resistant lines developed from different genetic background, biochemical analysis was done.

Overall, highest TPC (189.27 and 178.83 mg/100g dry weight) was observed in mixture purple genotype (3 lines), obtained from the North East at after flowering/ pollination stage, when inoculated with *M. phaseolina* and *F. verticilloides,* respectively, and in uninoculated condition, it was 160.75mg/100g dry weight, followed by PFSR (Y)-C0 line (4 lines), derived from pools. Hence, these developed lines produced more phenolic compounds as compared to 24 others tested for resistance when challenged with fungal pathogens and represent means of protection. The lines can be used by breeders for development of resistant hybrids.

Meena Shekhar
ICAR-Indian Institute of Maize Research
Pusa Campus, New Delhi 110 012
e-mail: shekhar.meena@gmail.com

Co 0238 – Wonder sugarcane variety

Co 0238 (Karan 4) is a high-yielding and high-sugar sugarcane variety, derived from a cross of CoLk 8102 × Co 775. This variety was released by the Central sub-committee on Crop Standards, Notification and Release of Varieties in 2009 as an early-maturing variety for commercial cultivation in the North West Zone, comprising Haryana, Punjab, western and central Uttar Pradesh, Uttarakhand and Rajasthan.

Co 0238 is a medium-thick cane variety with cylindrical internodes, round to pentagonal buds, deltoid auricles, shallow bud grooves and yellow-green to grey-orange internodes. Its leaf-sheath colour is green and often has brown/red blotches. The variety is free from hairiness on the leaf-sheath and splits on the internodes. During summer, leaf-tip drying (up to ¾ of leaf length) is common in this variety. Its jaggery is of A_1 quality with light-yellow colour. Co 0238 is moderately resistant to prevalent races of red-rot pathogen in the North West Zone (NWZ).

In comparison to CoJ 64, it showed 19.96%, 15.83% and 0.50% improvement in cane yield, sugar yield and sucrose%, respectively.

Comparison of Co 0238 with standards in trials conducted in the NWZ

Particulars	Co 0238	CoJ 64	CoPant 84211
Cane yield (tonnes/ha)	81.08	67.59	66.84
% increase over standards		19.96	21.30
Sugar yield (tonnes/ha)	9.95	8.59	8.28
% increase over standards		15.83	20.17
Sucrose %	17.99	17.90	17.65
% increase over standards		0.50	1.93

Co 0238 was better than all the standards at all the test locations for cane yield (27–37% improvement over the standards) and pol % in cane, excepting in central Uttar Pradesh, where it showed 0.03% less pol% in cane (–0.24– 6.78% improvement over CoJ 64).

Ratoonability during winter: Co 0238 is suitable for taking up to 2nd ratoon under subtropical conditions. It sprouts well even if harvested during peak winter — during last week of December to first week of January. The reduction in cane yield of Co 0238, when harvested during winter, was just 4.66% in comparison to cane yield of spring harvested ratoon; this reduction in CoJ 64 was observed to be 41.29%.

The variety combines both high cane yield and better juice quality, and hence is being preferred by both farmers and sugar industry. Since 2009-10, the area under Co 0238 has been increasing at a faster rate in all the five major sugarcane- growing states. This has also crossed boundaries of the zone to eastern Uttar Pradesh, Bihar, Madhya Pradesh and Odisha. During 2014-15, about 9.8% of the total cane area (2,764,547 ha) in North India was occupied by Co 0238 (272,128 ha). Punjab had the maximum coverage (52% area), followed by Haryana

(19%), Uttar Pradesh (8.3%), Bihar (5.5%) and Uttarakhand (3.7%).

Impact of Co 0238 on cane yield and sugar recovery

Fourty-four districts of Uttar Pradesh were divided into 2 categories on the basis of negligible area (<500 ha) and sizable area (>500 ha) under Co 0238. In 24 districts, with negligible area, decreasing trend in both cane yield and sugar recovery % was observed during 2014-15 over 2013-14. The average cane yield of these districts was 58.07 tonnes/ha and 57.96 tonnes/ha whereas sugar recovery was 8.99% and 8.92% during 2013-14 and 2014-15, respectively. These minor variations in cane yield and sugar recovery between 2years indicated negligible role of environmental factors on cane yield and sugar recovery.

On the contrary in 20 districts, with sizable area, average cane yield increased from 63.4 tonnes/ha during 2013-14 to 66.1 tonnes/ha during 2014-15, i.e. 2.7 tonnes/ha higher cane yield during 2014-15. Higher cane yield and sugar recovery % was due to increased area of Co 0238 from 72,623 ha (3.1%) during 2013-14 to 176,763 ha (8.3%) in 2014-15. The higher cane yield and sugar recovery % with sizable area of Co 0238 in comparison with negligible area was due to more area (72,623 ha) under Co 0238 during 2013-14. It is thus concluded that improvement in cane yield and sugar recovery was due to increased area (about 1.04 lakh ha).

Co 0238 in 17,170 ha in **Bihar** or 5.5% of state's cane area

Co 0238 in 36,459 ha in **Haryana** or 29% of state's cane area

Co 0238 in 52,075 ha in **Punjab** or 52% of state's cane area

Co 0238 in 4.03 lakh ha in **Uttar Pradesh** or 19.6% of state's cane area

Co 0238 has also spread to tropical state like **Odisha**

Co 0238 in 8,281 ha in **Uttarakhand** or 8.4% of state's cane area

As already stated above, environmental factors are not important for variations in cane yield and sugar recovery. A survey of sugar recovery recorded on 21 December 2015 by different sugar mills was conducted. All these mills have a sizable area of Co 0238 in their factory region. High sugar recovery has been recorded for the first time in the history of sugar industry in the subtropical India.

Performance (mean of 2 plants and 1 ratoon) of Co 0238 in Indian Sugar Mills Association (ISMA) trials

State/Region	No. of sugar mills	Variety/ Standard	Cane yield (tonnes/ha)	% improvement over standard	Pol % in cane	% improvement over standard
Western Uttar Pradesh	5	Co 0238	90.55	37.61	13.06	0.93
		CoJ 64	65.80	-	12.94	-
Central Uttar Pradesh	7	Co 0238	93.65	30.61	12.60	-0.24
		CoJ 64	71.70	-	12.63	-
Eastern Uttar Pradesh	4	Co 0238	68.81	27.31	12.61	1.86
		CoJ 64	54.05	-	12.38	-
Mean (Uttar Pradesh)	16	Co 0238	84.34	32.09	12.76	0.87
		CoJ 64	63.85	-	12.65	-
Uttarakhand	1	Co 0118	-	-	12.39	4.73
		CoJ 64	-	-	11.83	-
Bihar	4	Co 0238	82.60	30.70	12.60	6.78
		BO 130	63.20	-	11.80	-

Spread of Co 0238 in subtropical states

State	2012-13	2013-14	2014-15	2015-16
Punjab		26,683 (27.8)*	52,075 (52.0)	
Haryana	3,866 (3.7)	13,831 (12.6)	22,503 (19.0)	36,459 (29.0)
Uttarakhand	612	1,574 (1.4)	3,617 (3.7)	8,281 (8.4)
Uttar Pradesh		72,628 (3.1)	1,76,763 (8.3)	4,02,719 (19.6)
Bihar	1,795 (0.7)		17,170 (5.5)	
Total area under Co 0238	6,273 (0.2)	114,716 (4.3)	272,128 (9.8)	447,459 (20.5)
Total area under sugarcane	**2,996,734**	**2,676,008**	**2,764,547**	**21,77802**

*Figures in parentheses indicates area of Co 0238 in percentage of the total sugarcane area

Sugar industry was passing through a distress situation since 3 to 4 years because of lower sugar prices prevailing in the country. The feedback received from farmers and sugar industry indicates that in the prevailing situation, Co 0238, the wonder variety of sugarcane, is the only hope for them. With the spread of this news of historic impact of Co 0238 on sugar recovery in Uttar Pradesh, demand for its seeds from Maharashtra, Tamil Nadu and Andhra Pradesh is showing an increase. This is a reverse trend, i.e. demand of a subtropical sugarcane variety in tropical India.

Bakshi Ram, N.V. Nair, G. Hemaprabha, B.K. Sahi, Narendra Singh, R. Viswanathan, and **M. Balamuralikrishnan**
ICAR-Sugarcane Breeding Institute
Coimbatore (Tamil Nadu) 641 007

Bagging litchi-fruit bunches for harvesting quality fruits

During litchi fruit development, mainly fruit borer (*Conopomorpha* spp.), birds and bats affect fruit quality and yield. In North-eastern India, growth and development of litchi- fruit takes place during April-May, which often synchronizes with high temperature and low humidity, resulting in localized light-brown blotches on the fruit-skin and fruit cracks also. These all cause considerable losses in yield as well as in quality of litchi-fruits.

In India, fruit bagging, being practised mainly in pomegranate, guava, apple, peach and papaya since a century for protection against fruit-fly, butterfly and moth infestation at the kitchen-garden level, has shown effectiveness in litchi also in improving fruit quality, reducing pest damage, sun-burning and cracking. Bagging of litchi-fruits improved physical quality of fruits.

Physico-chemical characteristics of bagged and unbagged litchi-fruits

Sl No.	Attributes	Results		Performance of bagged fruits
		Unbagged fruits	Bagged fruits	
1.	Sunburn and cracked fruits (%)	25-36	5-15	80.0-58.33%↓
2.	Fruit-borer infested fruits (%)	7-26	2-6	71.43-76.92↓
3.	Marketable fruits (%)	68-32	95-79	39.70-146.88%↑
4.	Fruit weight (g)	17.60	20.85	18.50%↑
5.	Total anthocyanin content (mg/100 g)	25.55-32.86	42.74-48.61	67.28-47.93%↑

Benefits of bagging the bunches

- Deterrence to birds, animals and many insects and pests (Pest control)
- Reduction or elimination of pesticide use
- Improvement in overall fruit colour
- Reduced culling time of damaged fruit
- Reduced number of damaged fruits and 2nd grade fruits
- Increased yield (fruit retention, delayed harvesting and pack-out)
- Uniform ripening/control ripening time
- No need to individually harvest ripe fruits
- Consumers prefer appearance of bagged fruits over unbagged fruits
- Potential increased for higher net return

Unbagged (*right*) fruit bunch and bagged (*left)* fruit bunch

The litchi-fruit bunch of cv. Shahi was bagged at 40 days after bloom (40 DAB), which was during 3rd fortnight of April, when the average fruit weight was approximately 3 - 5 g. The white butter paper bag/ Non woven PP bags (30 GSM) 500-550 mm × 350-400 mm (L × W) should be used. The bags should be removed 2-3 days before harvesting. Generally cost for bagging one tree (15-20 years old) is nearly ₹200-250 with B: C ratio of 1:3.

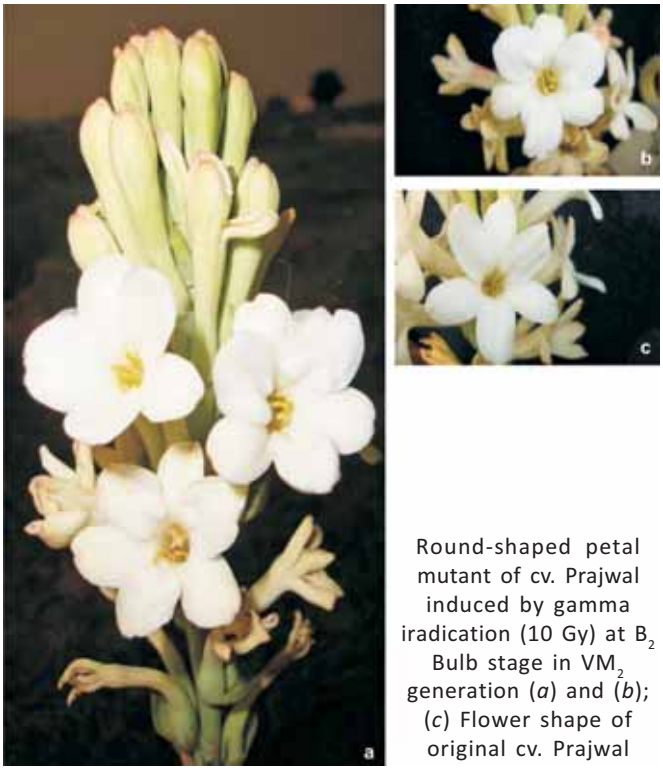
Bagging is a simple, cost-effective and eco-friendly technology. Management of tree canopy and plant stature is the essential requirement for efficient adoption of bagging technique.

S.K. Purbey, Amrendra Kumar, Alemwati Pongener and **Vishal Nath**
ICAR-National Research Centre on Litchi
Mushari, Muzaffarpur, Bihar
e-mail: skpurbey_nrcl@yahoo.com

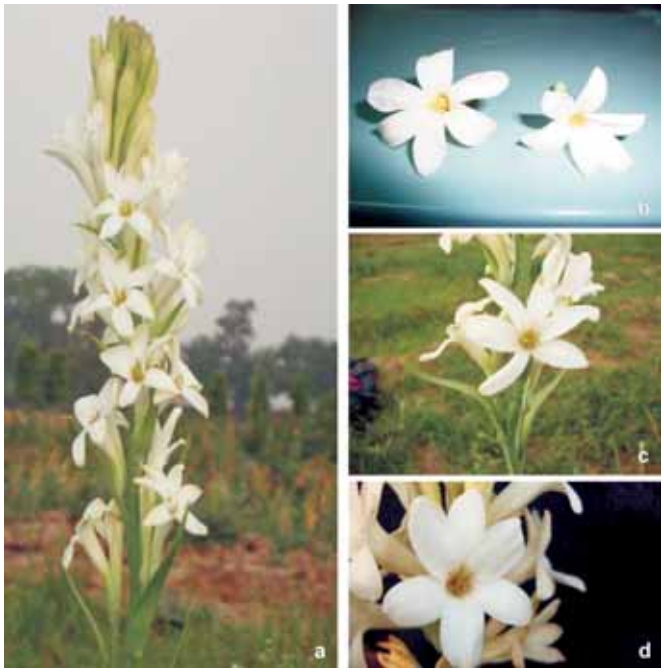
Novel mutants of tuberose using gamma irradiation

Tuberose (*Polianthes tuberosa*) is one of the most important bulbous flowering plants of tropical and sub-tropical areas. It's all species are wild with the exception of *P.tuberosa,* which has been found under cultivation. The serene beauty of the plant is because of its tall and straight spikes; which bear bright-white florets, loosely arranged on the spikes; and may attain a height of 3-4 feet. Tuberose cultivars derive their name from the number of tepal rows each flower possesses: Single – cultivar with a single row of tepals; Double — the one that bears more than three rows of tepals; and Semi-double — bears flowers with two to three rows of tepals. Genetic variability in tuberose is very limited; it has a narrow genetic base.

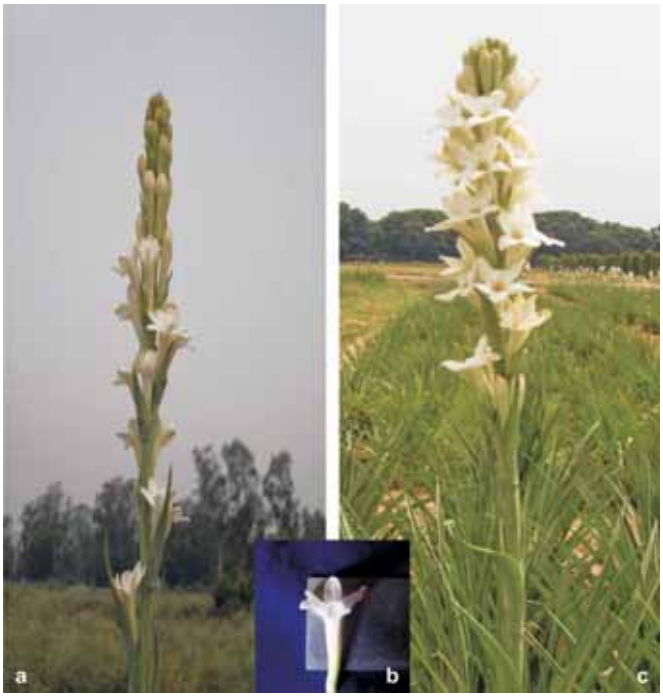
In conventional breeding of tuberose, non-availability of genetic variability has become a major constraint. Seed set is also observed only a few Single-type cultivars that too with limited seed set and poor germination. To achieve rapid evolution, needed by the plant breeders, for the changing needs, faster generation of new forms is required. This can only be met with induced mutations as supplements to natural genetic resource. Compared to chemical mutagens, physical mutagens (gamma radiations) have yielded many useful mutants, and are still showing an elevated potential for improving vegetatively propagated plants. The present



Round-shaped petal mutant of cv. Prajwal induced by gamma iradication (10 Gy) at B_2 Bulb stage in VM_2 generation (*a*) and (*b*); (*c*) Flower shape of original cv. Prajwal



Individual large size and long petal length mutant of cv. Prajwal at B_1 bulb stage by 2.5 Gy gamma irradiation *(a,b* and *c); (d)* Floret of original cv. Prajwal



Mutant spike with florets arranged at equally spaced nodes with very small sized florets in cultivar Prajwal at B_0 bulb stage by 10 Gy in VM_2 generation *(a, b)*; *(c)* Original spike of cv. Prajwal

Tall mutant of cv. Phule Rajani at B_0 bulb stage by 7.5 Gy gamma irradiation in VM_2 generation

investigation has been carried out to induce novel mutants using gamma irradiations in tuberose, and then select novel types based on the important traits and to check inheritance and stability of characters expressed in M_1 and in M_2 generations.

To evaluate sensitivity, proper bulb stage and optimal gamma irradiation dosage to induce desirable mutants in tuberose field experiments were conducted in 2008, 2009, 2010 and 2011. Cultivars Prajwal and Phule Rajani with three different bulb stages — freshly harvested bulb (B_0), three weeks after uprooting (B_1) and six weeks after uprooting (B_2) were irradiated with 2.5Gy, 5.0Gy, 7.5Gy, 10.0Gy and 15.0 Gy of gamma rays. Probable LD_{50} dose of gamma irradiation was between 10.0 Gy and 12.0 Gy for freshly harvested bulbs and bulbs after six weeks after uprooting in cv. Prajwal and in all bulb stages of cv. Phule Rajani. Probable LD_{50} dose for bulbs after three weeks after uprooting was 3.25 Gy in cv. Prajwal and 10.25 Gy was in cv. Phule Rajani. Non-sprouting of Prajwal bulbs at B_1 stage beyond 2.5 Gy was supported by histological results. In general, sprouting and all vegetative parameters decreased with increased irradiation levels. Out of the three bulb stages tested, freshly harvested bulbs (B_0) responded comparably to high gamma irradiation doses, followed by bulbs after six weeks of uprooting (B_2) in both the cultivars. The study indicated that gamma irradiation dose 7.5 Gy and 11.5 Gy yielded attractive and useful mutants. With increase in doses of gamma irradiation treatment, gradual reduction in number of spikes, flower number, number of bulbs, weight bulb diameter was observed. In some cases, lower dose was found stimulative, while higher dose was inhibitory on morphological variations. Various macro-mutations were scored for uniform flowering, reduced number of bulbs and spike number in M_1 population. Mutants of VM_1 generation were not found stable in VM_2 generation. But some more mutants were obtained from maintained gamma-irradiated population of VM_1 generation related to changed flower shape.

In general, freshly harvested tuberose bulbs of Prajwal and Phuel Rajani responded more to gamma irradiations. Gamma irradiations at 7.5Gy and 10.0Gy have been found optimal for mutation induction in these two tuberose cultivars.

[1]Jyothi R. and **[2]Krishan P. Singh**
[1]KVK, Koppal, Karnataka
[2]ICAR-Directorate of Floricultural Research
Pune (Maharashtra) 411 015

Directorate of Onion and Garlic Research, Pune

Onion and garlic are two most important vegetable commodities used in culinary preparations. India is the second largest producer of onion and garlic after China, and second largest exporter of onion in the world, next to Netherlands, contributing 12% to the global market.

Realizing the importance of onion and garlic in the country, the Indian Council of Agricultural Research (ICAR) established a National Research Centre for Onion and Garlic in VIII Plan at Nasik in 1994. Later, it shifted to Rajgurunagar, Pune, on 16 June 1998. And it was upgraded to the Directorate of Onion and Garlic Research (DOGR) in December 2008. It has All-India Network Research Project on Onion and Garlic (AINROG) with 11 main centres and 14 voluntary centres across the country.

The institute disseminates its varieties by producing and distributing breeder and quality seeds of onion and garlic. During the past 10 years, about 200 quintals of onion seeds and 300 quintals of garlic cloves have been distributed to state-seed agencies, seed companies, KVKs and farmers.

MANDATE

- To act as a repository of genetic resource and scientific information on onion and garlic.
- To undertake basic and applied research for enhancing production and productivity of onion and garlic.
- To undertake strategic research for technology development and production of quality seeds of onion and garlic.
- To promote utilization and development of value-added products through processing and post-harvest management.
- To disseminate technology, provide advisory and consultancy services and promote entrepreneurship.
- To develop linkages with national, international and private organizations in the network mode for collaborative research programmes.

INFRASTRUCTURE

Farms: The institute has 55 acres of research farm at Rajgurunagar, 55 acres at Kalus and 10 acres at Manjri with perennial irrigation facilities.

Laboratories: The DOGR has well-equipped laboratories for Biotechnology, Soil Science, Plant Protection, Post-harvest Technology and Seed Technology.

Agricultural Knowledge Management Unit (AKMU): The AKMU is well developed with 43 computers interlinked with LAN and two servers for high speed broadband internet connectivity with firewall protection. It has most advanced research software like SAS, data management system, application packages and word-processing software.

The logo symbolizes 'onion and garlic'. The large petal in red colour represents 'onion' and small petal represents 'garlic'. Bottom arch indicates earth and green colour of the arch indicates Agriculture. Green background with text प्या ल अनु नि represents the name of the institute in Hindi.

Onion and garlic under Tribal Sub-Plan

Onion and garlic are important commercial crops, which can improve livelihood of farmers. The tribal belt of Nandurbar in Maharashtra has congenial climatic conditions for production of onion and garlic at the commercial level. But cultivation of these crops was limited to the kitchen garden before the initiation of Tribal Sub-Plan (TSP). The scheme was initiated in this area in April 2013. About 350 tribal farmers were selected from 35 farmers' groups. Each group undertook demonstrations on onion and garlic cultivation in one acre of land in Navapur, Akkalkua and Dhadgoan talukas of Nandurbar district.

In total, 49 demonstrations on newly improved varieties of onion and garlic and production technology were undertaken. Demonstrations on *kharif* onion production were carried out in Navapur taluka of Nandurbar district.

More than one thousand tribal farmers were trained. Fifteen tribal villages have been benefited with the commercial cultivation of onion and garlic. Farmers earned a net income of ₹ 80,000-100,000 per acre by production of about 120 q bulbs of onion Bhima Shakti during *rabi* and almost same income by production of about 80 q bulbs of Bhima Super in *kharif*. Cultivation of garlic at the commercial level has also been introduced in this belt. An amount of ₹ 80,000-90,000 per acre was earned through production of about 30 q bulbs per acre of Bhima Purple.

Nandurbar also has favourable climate for onion-seed production. Farmers earned a net income of ₹ 100,000-120,000 per acre through production of 250 kg seeds per acre of variety Bhima Kiran.

Library: It has online access to premier journals (Hort. Database 1972-2013).

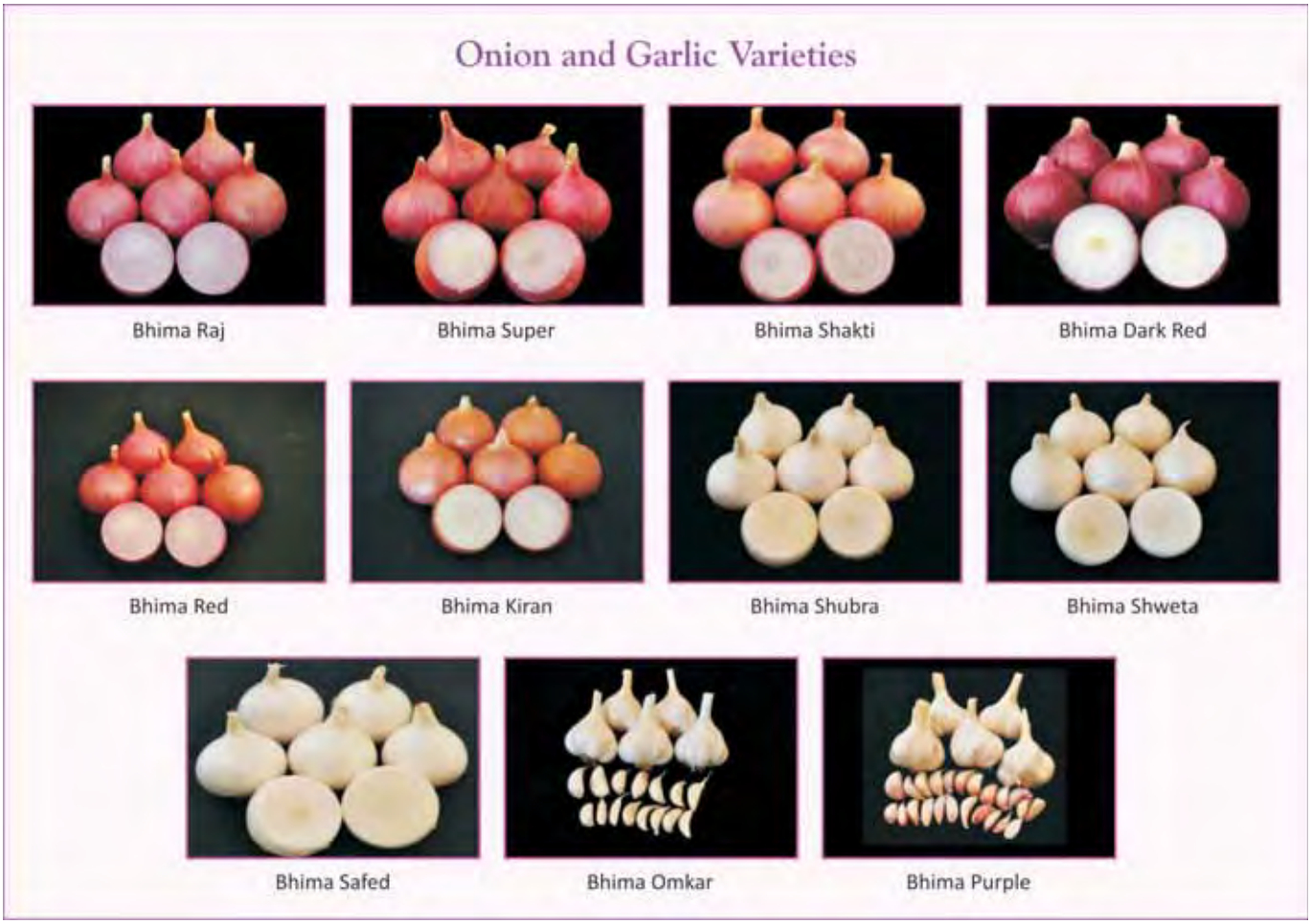
RESEARCH ACHIEVEMENTS

Crop Improvement

- Six red and three white onion varieties, and two garlic varieties have been developed. Varieties Bhima Super and Bhima Red have been licensed, respectively, for seed production and marketing.
- The institute is the national active germplasm site for onion and garlic germplasm and holds more than 1,700 accessions, including 25 *Allium* species.
- Early-maturing elite line "DOGR 1203 DR" has been registered with the NBPGR, New Delhi, with national identity, IC0598327, and Registration No. INGR 14057.
- Molecular markers (RAPD, ISSR and SSR) for estimating genetic diversity in onion, garlic and related wild Alliums have been identified.
- Meristem-tip culture and multiple shoot/bulbil production protocols for garlic have been developed for virus-free seed production.

Externally Funded Projects

- Mega Seed Project "Seed production of agricultural crops and fisheries".
- Outreach Research Programme on sucking pests
- Development of hybrids of onion: A joint venture with Beejo-Sheetal
- Formulation, validation and promotion of adaptable IPM technology for bulb (onion) vegetable crops
- Studies on male sterility systems to increase efficiency of F_1 hybrids in horticultural crops
- National Innovation on Climate Resilient Agriculture (NICRA)
- CRP on Agrobiodiversity
- Intellectual Property Management and Transfer/Commercialization of Agricultural Technology Scheme (IPMT-CATS), ICAR
- DUS testing through ICAR-SAU's system



- Developed haploids through gynogenesis.
- Double haploids have been developed for production of inbred lines and their possible use in hybrid breeding.

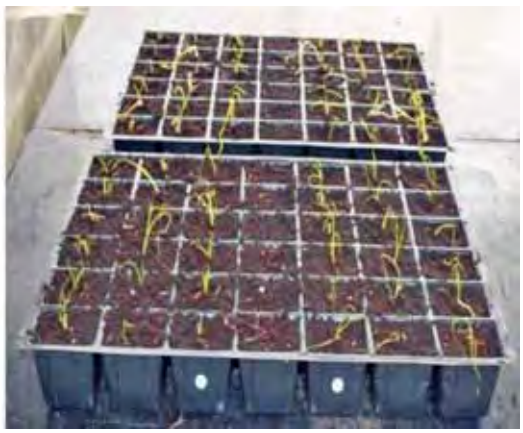
Crop Protection

- Developed IPM and IDM modules for management of pests and diseases.
- Highly sensitive serological- and nucleic- acid-based diagnostic system has been developed to detect major onion and garlic viruses.
- Forecasting model for thrips prediction has been developed

Crop Production

- *Kharif* onion-production technology has been standardized.
- Micro-irrigation like drip and sprinkler for closely spaced onion and garlic crops has been developed successfully; 30% water saving was observed in drip irrigation system as compared to surface system.
- Fertigation for higher input-use efficiency has been developed. It saved water by 40%, fertilizers by 30%, labour by 30% and increased yield by 15-20%.
- Developed Integrated Nutrient Management (INM) for sustainable *Rabi* onion production.

Garlic mericlones



Mericlones in seedling trays

Kharif-onion production in Vidarbha in excess rainfall

Kharif-onion production is not a tradition in Vidarbha region; farmers of Vidarbha generally cultivate *rabi* onion. But owing to shortage of water, irregular electric supply, high temperature, *rabi* onion production is also becoming less profitable. Keeping these constraints in view, Shri Namdeorao Adhau, a progressive farmer of Deulgaon village of Vidarbha, decided to cultivate *kharif* onion. On advice from the institute, he first planned for 4 acres and used variety Bhima Super and raised nursery on raised beds with sprinkler irrigation and transplanted seedlings on broad based furrows with sprinkler irrigation in the first week of August. He followed fertilizer doses and plant protection recommendations as per the DOGR guidelines, and earned a net profit of ₹2.60 lakh per acre. Paradoxically, in *kharif*, in Maharashtra, there were yield losses to the tune of 30-60 %. Yield level was 2-4 tonnes/acre when planted on flat beds while raised-bed planted crop recorded higher yield of 10 tonnes/acre.

- Legume-based cropping sequences like soybean in *kharif,* followed by onion or garlic in *rabi* for higher bulb yield and improved soil health have been recommended.

Nursery raising in *kharif*

Drip irrigation in onion

- A method for onion-sugarcane intercropping has been developed with paired-row planting of sugarcane (November-December planting) under drip irrigation system.

Post-harvest Management

- Hand-operated grader and motorized onion grader have been developed. They have increased efficiency by 5 and 20 times, respectively, over manual sorting. The precision achieved by graders is 98% as against 50% with manual grading.
- Low-cost storage model of 5- to 10- tonne capacity and high cost model of 25- to 50- tonne capacity with bottom and side ventilation have been designed and tested and have become popular among farmers.

Bhima Shubhra — a white onion variety has been found suitable for Vidarbha region of Maharashtra, where white onion is preferred over red. It matures in about 110-115 days after transplanting during *kharif* and 120-130 days after transplanting in late *kharif.* Impressed by the performance of this variety, a group of about 300 farmers from twelve villages was formed. Most of the members are often earning a net profit of more than ₹1.0 lakh/acre

Bhima Purple — a high-yielding garlic variety has been found suitable for Maharashtra and adjoining states. It matures in 135-140 days after planting and has light purple bulbs with good storability. It is also field tolerant to thrips and foliar diseases. Most of the farmers are often earning a net profit of more than ₹1.0 lakh/acre

Hand-operated onion grader

Motorized onion grader

Low-volume low-cost onion storage structure

High-volume onion storage structure (storage model with bottom and side ventilation)

FUTURE THRUST AREAS

For Onion R&D

- Augmentation and characterization of onion and garlic germplasm
- Development of varieties /F_1 hybrids in short-day onions for different seasons (a) *kharif* (b) late *kharif* (*rangda*) (c) *rabi* for domestic as well as export markets.
- Development of yellow onion varieties for export to European markets.
- Development of high T.S.S. white onion varieties for processing.
- Sustenance of productivity through
  (a) Integrated nutrient and water management
  (b) Integrated disease and pest management
- Improvement in storage quality of late *kharif* and *rabi* onion through
  (a) Genetic manipulations
  (b) Cultural practices
  (c) Modifications in storage environment
- Mechanization for direct seeding and transplanting.

For Garlic R&D

- Development of big cloved garlic varieties, which can respond to short winter of peninsular India
- Generation of genetic variability in garlic through somaclones
- Sustenance of productivity through integrated nutrient managment, water management and disease-pest management
- Production of virus-free planting material
- *In-vitro* conservation of garlic germplasm.

Urgent Attention of Contributors

For high quality presentation, designing and print quality of the ***ICAR News***, We request all our contributors to make sure that following points are taken care of before sending the articles:

- Text matter with photographs and captions may be provided in **MS Word**; no PDF files please.
- Good quality photographs **in original form** *i.e.* **high resolution jpeg files** without any effects, need to be given separately also.

– Editor

Jai Gopal
ICAR-Directorate of Onion and Garlic Research
Rajgurunagar
Pune (Maharashtra) 410 505
e-mail: director.dogr@icar.gov.in

Management of lenticel browning in mango

Lenticels are macroscopic porous openings consisting of cells with large intercellular spaces in periderm of the secondarily thickened organs, especially fruits of mango. These openings play a significant role in transpiration and exchange of gases. Lenticels act as a necessary evil as they are required for several physiological functions of the plant; but their discolouration leads to loss of fruit quality, and thus is considered as one of the main problems in post-harvest mango management. Several efforts have been made to reduce causal factors, which affect quality, appearance and ultimately export of mango-fruits. Lenticel browning has also limited mango export to a great extent as it affects appearance of mango-fruits. It is one of the main reasons of quality loss in mango-fruits; predominant both in indigenous and exotic varieties grown in India and abroad. Lenticel browning decreases shelf-life of the fruits and also affects their appearance.

Lenticels on harvested mango-fruits

Lenticel browning in ripened mango-fruits

Advantages of the technique

- Lenticel browning reduces 90-95% during storage.
- The appeal of the fruits improves significantly.
- This treatment helps reduce fruit decay considerably.
- It is a cost-effective technique, involves merely ₹0.50/ kg fruits.
- Incidence of storage diseases like anthracnose or stem-end rot also lowers.

An attempt has been made for the first time in India to manage this problem using farmer-friendly technique

Mango orchard

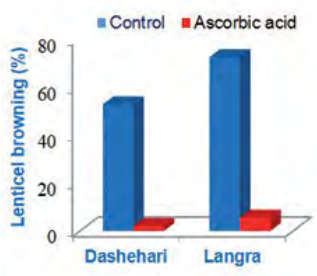
Harvesting of fruits

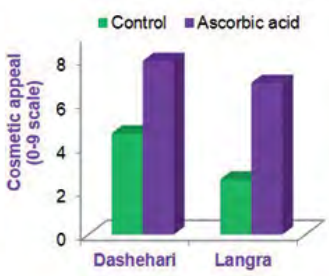
Desapping of fruits

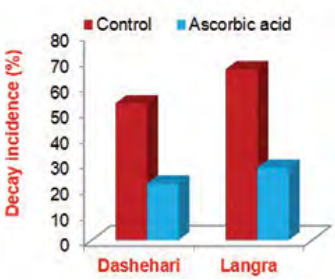
Packaging of fruits

Drying of fruits

Dipping in ascorbic acid







in famous north Indian varieties (Langra and Dashehari); worst affected by this.

Mango-fruits are harvested at full maturity. They are de-sapped using standard technique and then dipped into 150 ppm solution of ascorbic acid for 5-10 minutes. After lifting off from the solution, fruits are dried under fan and then packed in corrugated fibre-board boxes for transport, marketing or storage.

K. Prasad and **R.R. Sharma**
Division of Food Science and Postharvest Technology
ICAR-Indian Agricultural Research Institute
New Delhi 110 012. *e-mail:* rrs_fht@rediffmail.com

Pineapple production in Manipur — Energy requirement and cost economics

Pineapple is the major fruit produced in Manipur; planted in a total of 12,100 ha with an annual production of 103,500 tonnes. Average weight of a single pineapple is generally 1.5 kg, but the weight of pineapple in Manipur ranges from 1 to 3 kg. Locally known as 'lengthei', pineapple is cultivated in all 9 districts of Manipur. Churachandpur District, with over 284ha of land in cultivation, is recorded to have the most extensive cultivation. The markets of Imphal, Churachandpur, Thoubal, Moirang are hubs for hard-to-resist yellowish fruits during July and August.

Yield of the main crop of pineapple after 17 months: 60 tonnes/ha

Value return from the main crop: ₹6 lakh/ha

Net return from the main crop after 17 months: ₹4.175 lakh/ha

Weeding and harvesting cost for the first ratoon crop of pineapple: ₹35,000/ha

Total weeding and harvesting cost for three ratoon crops of after main crop: ₹1.05 lakh/ha

Cost of production of pineapple crops as three ratoon crops: ₹1.05 lakh /ha

Yield of single ratoon crop: 55 tonnes/ha

Net return from three ratoon crops after main crop for 165 tonnes/ha production: ₹16.5 –1.05 lakh/ha

Net return from three ratoon crops after the main crop: ₹15.45 lakh/ha

Net benefit considering main crop and three ratoons crops of pineapple (225 tonnes/ha): ₹19.625 lakh/ha

Benefit-Cost ratio of main pineapple crop of 17 months: 2.28 : 1

Benefit-Cost ratio of three successive ratoons crops: 14.7 : 1

Productivity of pineapple-crop depends upon the energy inputs consumed during various farm operations. The sources of energy include material inputs such as seeds, fertilizers, manures, insecticides and mechanical energy along with human and bullock labour hours used in crop production. Considerable variations in the form and extent of energy use and its efficiency exist in the production of pineapple-crop in different districts of Manipur.

Standard energy coefficients are considered in working out energy consumption for pineapple production in Manipur. The total input energy required for pineapple cultivation is 53,673.62 MJ/ha, which includes indirect energy, forming part of the input energy of 41,166.02 MJ/ha, and equipment energy of 355.60 MJ/ha in different unit operations. The output energy value is 612,000 MJ/ha, and ratio of output energy and input energy comes to 11.40. Energy productivity and specific energy values are 4.192 kg/MJ and 0.238 MJ/kg, respectively.

Energy consumption in pineapple (Kew) production in Manipur

Unit operation	Direct energy Time of operation, h/ha	Energy equivalent, MJ/ha	Indirect energy (MJ/ha) equipment energy (MJ/ha)	Inputs energy equivalent (MJ/ha)	Total energy (MJ/ha)
Seebed preparation	560	1097.60	103.60	-	1,201.20
Shredding of lower leaves of suckers	240	470.40	12	-	482.40
Planting of suckers	280	548.80	-	-	548.80
Fertilizers and FYM application	320	627.20		-	627.20
Weeding (4 times) with Khurpa/narrow spade	800	1568	40	-	1608
Main crop harvesting	400	784	20	-	804
Ratoon crop weeding for next three years	2,400	4,704	120	-	4,824
Ratoon crop harvesting for next three years (local Sickle/Knife)	1,200	2,352	60	-	2,412
Farm Yard Manure (25tonnes/ha)			-	7,500	7,500
Fertilizers					
Urea (740 kg/ha, N-46%)			-	22,514.05	
SSP (770 kg/ha, P_2O_5 - 16%)				1,532.60	
MOP (1225 kg/ha, K_2O -50%)				6,829.37	30,876.02
Pineapple suckers (Average weight : 300g)			-	2,790	2,790
Total	**6,200**	**12,152**	**355.60**	**41,166.02**	**53,673.62**

Economics for cost of production of pineapple (Kew) in Manipur

Parameter	Labour requirement, Man-h/ha	Cost, ₹/ha
Unit operations		
Seedbed preparation using traditional plough and narrow spade	560	11,200
Shredding of lower leaves of suckers	240	4,800
Planting	280	5,600
Fertilizer and farmyard manure application	320	6,400
Weeding (Manual *khurpa*)	800	16,000
Harvesting of pineapple	400	8,000
Sub-Total (A)		**52,000**
Inputs cost		
Suckers as planting Material (Average sucker weight : 300 g)	-	62,000
Farmyard Manure (25 t/ha)	-	35,000
Chemical fertilizersUrea (740 kg/ha), SSP (770 kg/ha,), MOP (1225 kg/ha)	-	34,000
Sub Total (B)		**130,500**
Grand Total		**182,500**

The net energy gain during pineapple production is 558,326.38 MJ/ha. Formulae used in working out energy consumptions are as follows:

Output-Input Ratio = Output Energy (MJ/ha)/ Input Energy (MJ/ha)

Energy Productivity (kg/MJ) = Pineapple Yield(kg/ha) including Ratoon/Energy Input (MJ/ha)

Net Energy Gain (MJ/ha) = Energy Output (MJ/ha) – Energy Input (MJ/ha)

Specific Energy (MJ/kg) = Input Energy (MJ/ha)/ Pineapple Production (kg/ha)

The transport cost for pineapple production @20% of total cost of production resulted in net profit of 15.7 lakh/ha. When average post harvest losses during transport and storage-houses were taken @20% of total production cost, profit margin was reduced to the tune of 11.775 lakh/ha. The production cost has a scope for reduction (approximate 30-35%) through savings on inputs, time of unit operations and labour by mechanizing different unit operations when rotavator, post hole diggers, power weeder, power sprayers, urea super granule applicator, sucker transplanter and mechanized harvesting units are promoted in the region.

R.K. Tiwari[1], Jekendra Yumnam[2] and S.K. Chauhan[3]
[1]CAEPHT, Ranipool (Sikkim)
[2]Department of Agricultural Engg.
College of Agriculture, Manipur
[3]AICRP on UAE, CAEPHT
Ranipool (Sikkim)
e-mail: rk96tiwari@gmail.com

Micronutrient formulations for major spices

Designer formulations of micronutrients have been developed for major spices like ginger, turmeric, black pepper and cardamom. These micronutrient mixtures are applied as foliar sprays, and guarantee 15 -25% increase in yield.

For black pepper, foliar spray at 5g per litre water should be done once during spike initiation with the onset of monsoon and another after two months. For cardamom, spray at 5g per litre water should be given during panicle initiation and after three months. For ginger and turmeric foliar spray at 5g be given at 60 days after planting and then at 90 days after planting.An important point to be kept in mind is that these mixtures should never be mixed with any other chemical pesticides during application.

An innate advantage of these mixtures is that they can be used in organic agriculture, and therefore are benign and environment friendly. While organic manures enhance soil microbial activity and therefore nutrient

transformation/ mobilization, these mixtures guarantee to enhance yield and quality of the crop produce. Patents have been filed for these formulations, and the technology has been transferred to private agencies through non-exclusive licensing.

M. Anandaraj
ICAR-Indian Institute of Spices Research
P. O. Box 1701, Marikunnu P.O.
Calicut (Kerala) 673012
e-mail: arajiisr@gmail.com; anandaraj@spices.res.in

Adoption of conservation agriculture-based technologies in Jabalpur

Crop production in Jabalpur is dominated by rice, soybean, maize and sugarcane in *kharif*, followed by wheat, chickpea, lentil, peas and mustard in *rabi*. Most of the region has deep- black cotton soils, belonging to vertisols. On-farm research trials were undertaken from 2012 onwards in six localities. In each locality, 2-3 villages and 5-8 farmers from each village were identified and selected. Resource- conservation technologies such as direct-seeding of rice, brown manuring with *Sesbania*, zero-till sowing of crops, residue retention on soil surface,

Locality	Villages	Crops/cropping system	Major interventions
A- Jabalpur District			
1- Majholi	Pola, Dhora, Hinota, Gathora	Soybean-chickpea	Line /zero till sowing, recommended seed rate and fertilizer, improved weed management
2- Bankhedi	Amna, Dhanwahi	Rice-wheat	Line /zero till sowing in wheat, recommended seed rate and fertilizer, improved weed management
3- Panagar	Mahagawa, Kariwah, Chanti, Beher, Bharda, Padaria	Rice-wheat-greengram	Resource-conservation technologies, improved weed management, recommended seed rate
4- Shahpura	Bhamki, Kisrod, Magarmuha, Noni	Rice-wheat/ chickpea	Resource-conservation technologies, improved weed and fertilizer management, recommended seed rate
5- Gosalpur	Podi-nindora, Bhadam, Khajari	Rice-wheat	Resource-conservation technologies, improved weed and fertilizer management, recommended seed rate
6- Kundam	Khukham, Padariya, Ranipur, Kalyanpur	Maize-wheat	Line sowing, recommended seed rate and fertilizer, improved weed management
B - Other Districts			
1- Katni	KVK	Wheat	Resource-conservation technologies, improved weed and fertilizer management, recommended seed rate
2- Narsinghpur	KVK	Wheat, summer greengram	Resource-conservation technologies, improved weed and fertilizer management, recommended seed rate
3- Damoh	KVK	Wheat	Resource-conservation technologies, improved weed and fertilizer management, recommended seed rate



growing of summer legumes like greengram or *Sesbania* in crop rotation, and integrated weed management technologies were demonstrated in diversified cropping systems And nearly 100 such on-farm research trials were conducted.

The following are the main observations:

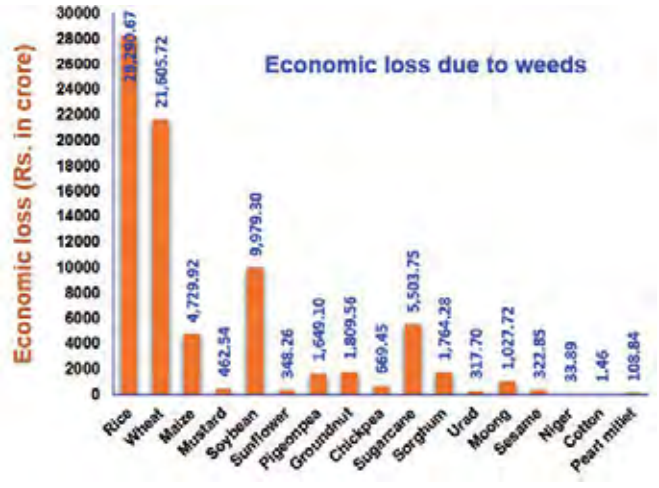
- Direct-seeding of rice by mid-June was most suitable to replace transplanting to get an assured crop, reducing cost of cultivation (by ₹ 2500 /ha) besides fetching higher income (by 15-20%).
- Weeds in direct-seeded rice can be effectively controlled through a sequential application of pre-emergence herbicides (pendimethalin/pretilachlor), followed by post-emergence herbicides (bispyribac-Na/ Fenoxaprop *fb* 2, 4-D /metsulfuron + chlorimuron). A light manual weeding can be recommended in specific situations for ensuring weed-free condition.
- Zero-till sowing of wheat with residues of previous rice-crop with a happy seeder showed outstanding performance and yielded 15-20% more at reduced cost (₹ 4,500/ ha). The zero-till sown crop did not lodge under adverse conditions. Successful weed control was achieved with a single post-emergence application of herbicides like sulfosulfuron, clodinafop, or herbicide mixtures like sulfosulfuron +metsulfuron , mesosulfuron + iodosulfuron and clodinafop+metsulfuron based on the nature of weed flora.
- Sowing greengram during mid-April immediately after wheat harvesting yielded 1.3-1.5 tonnes/ha in 65 days. Single application of post- emergence herbicide like quizalofop/imazethapyr at 25 DAS controlled weeds in greengram.
- Growing zero-till greengram or *Sesbania* in summer was apparantly beneficial for controlling weedy rice, which is a major emerging problem in *kharif* rice. This involved zero-till greengram or *Sesbania,* followed by running a grass cutter at harvest, application of glyphosate for killing of emerged weedy rice-plants, and sowing of following rice under zero-till.

Zero-till cultivation of crops with residue of the previous crop improved weed management, and this technology has spread in more than 1,000 ha.

A. R. Sharma, P K Singh and **Yogita Gharde**
ICAR-Directorate of Weed Research
Jabalpur(Madhya Pradesh) 482 004
email: sharma.ar@rediffmail.com,
drsinghpk@gmail.com

Economic yield losses due to weeds

In general, losses caused by weeds exceed losses caused by any other agricultural pests like insects, diseases, rodents and nematodes. The yield losses owing to weeds are mostly by assemblage of different weed species. Practically, it is difficult to estimate yield losses due to a single weed species; therefore, collective yield losses by weeds are estimated. In the past, no studies were conducted to estimate economic losses due to weeds. Therefore, information on yield losses in different crops was generated using data from different weed management trials. Data on percentage yield losses in farmer's practice were compiled from trials conducted during2003-04 to 2014-15. To calculate economic losses caused by weeds, normal estimates of the production of different crops (average of 2008-09 to 2013-14) in different states and Minimum Support Price of the crops (except fair and remunerative price for sugarcane) for the crop year 2014-15 were considered. Economic loss in a particular crop was calculated using yield loss data of different states with a following formula.



Crops and states considered for calculation of economic losses owing to weeds

Crop	States
Rice	AP, Bihar, Chhattisgarh, Haryana, HP, Jharkhand, Karnataka, Kerala, MP, Odisha, Punjab, UP, Uttarakhand, WB
Wheat	Gujarat, Haryana, Maharashtra, Rajasthan, Jharkhand, MP, Punjab, UP, Uttarakhand, WB
Maize	Andhra Pradesh, Gujarat, HP, Jharkhand, Karnataka, MP, Punjab, Rajasthan, Tamil Nadu
Mustard	Gujarat, Jharkhand, WB
Soybean	HP, Jharkhand, Karnataka, MP, Maharashtra, Uttarakhand
Sunflower	Jharkhand, Karnataka, Maharashtra
Pigeonpea	Jharkhand, Karnataka, MP, Maharashtra
Ragi	Jharkhand, MP
Groundnut	Karnataka, MP, Maharashtra, Punjab
Chickpea	Karnataka
Sugarcane	Karnataka, Punjab, Tamil Nadu, Uttarakhand
Sorghum	Karnataka, MP, Maharashtra
Urd	MP
Mung	MP, Maharashtra, Rajasthan
Sesame	MP, WB
Niger	MP
Cotton	Maharashtra, Punjab, Tamil Nadu
Pearl millet	MP

AP-Andhra Pradesh, HP-Himachal Pradesh, MP-Madhya Pradesh, UP-Uttar Pradesh, WB-West Bengal

Economic loss owing to weeds
= Normal estimates of production

$$* \left(\frac{\text{\% yield loss due to weeds}}{100} \right) * \text{MSP}$$

Economic yield loss was calculated for major crops of a particular state. Altogether, combined information was generated for 18 crops; yield losses along with estimated economic losses were also calculated.

It is evident from the data that average percentage yield loss is more in pulses and oilseed crops as compared to major cereal crops. As far as economic loss is concerned, it is highest as 36% ((₹28,290.67 crore) of the total loss in the case of rice, followed by wheat ((₹21,605.72 crore), soybean ((₹9,979.30 crore) and sugarcane (₹5,503.75 crore) respectively. In rice, 14% average yield loss was in transplanted rice and 21% was in direct seeded rice; due to high production its economic loss is more compared to other crops. Yield loss up to 65% was observed in rice when weeds were not controlled. Many weed management methods were used at farmer's level to control weeds in rice and wheat. Foodgrains (cereals, pulses and millets) experienced more economic losses owing to weeds (76.5%), followed by oilseed crops (16.5%) and cash crops (sugarcane and cotton). All together total economic losses in these major crops owing to weeds alone were estimated at ₹78,630.30 crore.

Yield losses and estimated economic losses owing to weeds

Crop	Yield loss (%)±SD	Range of % yield loss	Economic losses due to weeds (₹ in crore)
Transplanted rice	14±9.4	3.4-30	28290.67
Direct seeded rice	21±13.1	5.6-49.7	
Wheat	19±11.0	7.5-43	21605.72
Maize	25±12.9	8.6-51	4729.92
Mustard	21±14.8	9.6-38	462.54
Soybean	31±9.5	20.2-47.7	9979.30
Sunflower	32±8.3	25-41	348.26
Pigeonpea	24±15.4	5.1-42	1649.10
Ragi	42±4.9	38-45	5.32
Groundnut	36±11.3	25-50.7	1809.56
Chickpea	35±0.0	35	669.45
Sugarcane	22±16.3	6.6-43.2	5503.75
Sorghum	25±2.0	23.5-27.4	1764.28
Blackgram	31±0.0	30.7	317.70
Greengram	31±15.8	13-43.3	1027.72
Sesame	24±13.1	14.4-32.9	322.85
Niger	38±0.0	37.5	33.89
Cotton	18±5.7	13.9-4.4	1.46
Pearl millet	28±0.0	27.6	108.84

P.K. Singh and **Yogita Gharde**
ICAR-Directorate of Weed Research
Jabalpur (Madhya Pradesh) 482 004
e-mail: drsinghpk@gmail.com

Induced breeding in *Osteobrama cotio cotio*

Osteobrama cotio cotio, commonly known as 'rohitee', is a small indigenous minnow belonging to family Cyprinidae. Captive production of its seeds for promoting its culture is necessary, and attempts have been made to develop its breeding protocol.

A total of 300 juveniles (25-50 g), collected from the natural source, were maintained in a 0.04 ha earthen-pond with suitable feeding and pond-management protocol. Groups each of four females were given a single injection of Ovatide at 0.2. 0.3, 0.4 and 0.5 mg/kg body weight and were released in 1,000 litre FRP tanks filled- up to 1 m with pond -water. Similarly, four females each injected at 0.4 and 0.5 mg/kg were released in egg-incubation tanks of Chinese eco-hatchery; circular water movement was ensured after 3 hours of injection. Males injected with Ovatide at half of the doses of the females were released simultaneously in all tanks. Pairing

activity started in all the groups within 3-4 hours of injection, and spawning started approximately after 14-15 hours. Females injected with 0.3 mg/kg showed partial spawning, while complete spawning was observed in those injected at 0.4 mg/kg in both FRP tanks and incubation tanks with flowing water. The study has indicated that Ovatide at 0.4 mg/kg is ideal for induced breeding of *Osteobrama cotio cotio,* and water circulation facilitates egg spawning, fertilization, hatching as well as subsequent larval survival.

ICAR-Central Institute of Freshwater Aquaculture
Kausalyaganga, Bhubaneswar (Odisha) 751 002
e-mail: director.cifa@icar.gov.in

Modified mobile fish vending unit

The fish vending trolley carriage has been redesigned and fabricated. Fibre Reinforced Plastic (FRP) is the base material for the carriage. It is of 4'×2'9"×2'6" dimension. The specialty of the carriage is its unibody design; all the facilities and equipments are integrated into it. An ice-box of 2'×2'9" ×2'6" dimension is integrated in the carriage-box and packed with 1" thick Rigid Polyurethane Foam to be an insulator. The cutting tool is removable and more than one type of cutting tools can be used. There is also a water-storage tank of around 20-litre capacity and a waste-collection crate chamber. Tool box is also provided for keeping cutting tools, money-box and other items required during marketing. According to an estimate carriage can hold 100 kg of fish in ice for marketing.

Modified mobile fish vending unit

ICAR-Central Institute of
Freshwater Aquaculture
Kausalyaganga
Bhubaneswar (Odisha) 751 002
e-mail: director.cifa@icar.gov.in

Seed production and culture technology of *Mystus gulio*

Mystus gulio, commonly known as long-whiskered catfish, is a euryhaline catfish occurring mostly in freshwater. It has also been found to thrive in backwaters of low salinity. It has good consumer preference and market demand due to taste and high nutrient profile, and it fetches ₹250-350/kg.

During July 2015, captive stocks of *M. gulio* were successfully induced bred by injecting commercially available inducing agent, gonadotropin. Fishes of 25 – 82 g were selected for induced breeding. The eggs were adhesive, demersal (when not attached to any substrate) and transparent,and they hatched out in 23-26 h at 26-27°C. In an experiment conducted in glass tank, early fry of 15 days old (mean weight 0.05 g) attained size of 0.5 to 1.2 g in weight and 3.4 to 4.4 cm in length in 30 days of rearing. Their survival percentage ranged between 80 and 100%. A total of around 0.18 lakh fingerlings (2 months old) could be produced.

ICAR-Central Institute of Freshwater Aquaculture
Kausalyaganga, Bhubaneswar (Odisha) 751 002
e-mail: director.cifa@icar.gov.in

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Conceptualization and Editing : **Shashi A. Verma** ***Design & Production :*** **Dr V.K. Bharti and Punit Bhasin**

WAY FORWARD

INDIA accounts for 35% of global area and 27% of global pulses production. About 87% of pulses cultivation in India is rainfed; grown mostly in poor and marginal lands with minimal inputs and very little mechanization. The current pulses production of the country has fallen short of the domestic requirement of processed *dal* by 2.5–4.0 million tonnes. In 2007-08, the country imported pulses to the tune of 2.94 million tonnes; that rose to 4.54 million tonnes in 2014-15. It is an interesting observation that per capita consumption of pulses as the source of proteins decreased between 1988 and 2009 across the country; percentage share of pulses in the total protein uptake in the rural households decreased from 10.8 to 7.3%, and to 7.4% from 12.9% of the urban households.

Yield of pulses has gradually declined due to their low productivity and poor spread of improved varieties and technologies, abrupt climatic changes, complex disease-pest syndrome, emergence of new biotypes and races of key pests and pathogens and reduced total productivity and area under pulses. The primary production constraint in maintaining or increasing pulses production in the semi-arid regions has been the shortage of water every year for 7.5 to 10 months along with the widespread nutrient deficiencies in the soils.

With the Government of India's renewed focus on Pulses Revolution, the ICAR is fast-tracking its contribution through the strategic research and through the development of high-yielding varieties along with the package of practices for enhancing pulses productivity. During 2001-15, 280 high-yielding varieties of different pulses, including 61 of chickpea, 50 of mungbean, 35 of pigeonpea, 34 of urdbean, 27 of fieldpea, 23 of lentil, 18 of cowpea, eight each of guar and rajmash, seven each of horsegram and mothbean and two varieties of *Lathyrus* have been notified for cultivation. Availability of the breeder seed is crucial for quality seed production. Against a total indent of 75,870q of breeder seeds for different pulse crops placed by the DAC&FW during the last six years (2009-10 to 2014-15), 82,546q of breeder seeds were produced and supplied to different seed-producing agencies for further multiplication and distribution of seeds to farmers.

To ensure self-sufficiency in pulses, a road map to achieve 21 million tonnes of pulses production in 2017-18 and 24 million tonnes in 2020-21 as against 17.2 million tonnes production in 2014-15 has been proposed; for which ICAR and DAC&FW have jointly

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

submitted a comprehensive action plan. On these lines, allocation under the National Food Security Mission in 2016-17 has been increased by ₹400 crore compared to the last year. In addition, a new sub-scheme under the RKVY, to specially focus on rice-fallow areas in the eastern India, with a total allocation of ₹200 crore, comprising central share of ₹130 crore, has also been drawn by the DAC&FW.

To enhance overall production of pulses, there is an urgent need to bring in 3-4 million hectares of additional area under pulses. This can be achieved by increasing area under pulses in rice fallows, by intercropping them with sugarcane, cotton, millets, groundnut, sorghum and other crops, and by growing pulses in short-season spring/summer windows in the northern states. Mungbean can be promoted in Punjab, Haryana, western Uttar Pradesh and parts of Rajasthan during summer after the harvest of wheat, potato and rapeseed-mustard. Likewise, lentil and chickpea can be promoted in the rice fallows of eastern Uttar Pradesh, Bihar, Jharkhand, Odisha, Chhattisgarh, West Bengal, and mungbean/urdbean in rice fallows of Andhra Pradesh, Tamil Nadu, Odisha and Karnataka. There is also ample scope of increasing area under fieldpea in Punjab, Haryana, Uttar Pradesh and Bihar, and it is anticipated that with active policy and research support, 50-60 thousand hectares additional area can be brought under pulses cultivation. Further, with increased minimum support price, as has been announced during 2015-16, it is time for farmers to come forward and grow more pulses to meet growing demand of pulses and for ensuring nutritional security!

(T. Mohapatra)
e-mail: dg.icar@nic.in