MAS derived resistant line derived from Pusa Rohini | Susceptible plant of Pusa Rohini

Derived resistant line derived from Pusa Rohini through Marker Assisted Selection (MAS)

(s) was confirmed through linked molecular marker. Multiplex PCR-assays validated the genotypes of tomato breeding lines harboring resistant or susceptible alleles of *Ty-2*, *Ty-3* and *ty-5* loci in donor, susceptible varieties, F_1, and F_2 and advanced segregating populations. The promising MAS derived lines were evaluated under natural epiphytotic conditions as well as under controlled conditions for ToLCNDV resistance. Based on genotyping and phenotyping of parents, F_1s, and segregating populations, *Ty-3* gene was effective for ToLCNDV resistance. However, *Ty-3* is effective in homozygous condition (*Ty-3/Ty-3*) i.e. requires both resistance alleles.

The investigation indicates the recessive behavior of resistant allele (*Ty-3*) which has been reported dominant or partial dominant in earlier studies. The findings were validated on more than 100 F_1 combinations carrying *Ty-3* gene in heterozygous (*Ty-3/ty-3*) condition. As all F_1 combinations, the resistance breakdown was observed, although it was delayed compared to susceptible lines in which ToLCNDV symptoms appeared within a month of transplanting in field. Among other genes, *ty-5* and *ty-6* in pyramided combination (*ty-5+ty-6*) were effective in imparting resistance against ToLCNDV disease. *Ty-2* gene was not effective in imparting the resistance under North Indian plains during August-October season, as recorded.

Marker assisted selection (MAS) for *Ty-3* gene was done through closely linked molecular markers, P6-25 and SCAR-1. Both the markers were found useful in foreground selection of *Ty-3* gene in segregating breeding lines. Using these lines, hybrids have been developed noted resilient to ToLCNDV disease which is highly prevalent during autumn-winter season in plains of Northern as well as Eastern India. The study emphasizes the utilization of both alleles of *Ty-3* for durable resistance to ToLCNDV disease. Many resistant MAS derived lines in background of Pusa Ruby, Pusa *Rohini* and Pusa-120 will be useful in reviving these most adapted varieties which are preferred by consumers.

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Gobhi Sarson 'BN-2': a novel source for black rot resistance for cauliflower pre-breeding

Cauliflower cultivation has been expended across the seasons and regions but its production suffers from many biotic and abiotic stress factors resulting the yield and quality loss. Black rot disease (*Xanthomonas campestris* pv. *campestris* (Pam.) Dowson, *Xcc*) is one of the most devastating disease in vegetable *Brassicas* worldwide. Management of this disease is very difficult as the bacterium spreads within and between fields by water splashes, wind, insects, machinery and irrigation.

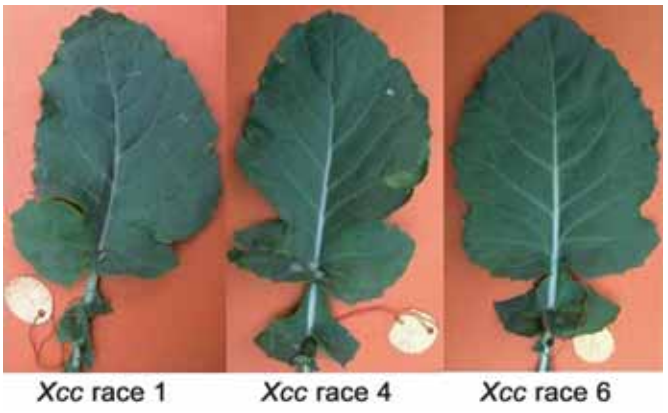
Since chemical control is being challenging and hazardous to health and environment. Its necessity to develop black rot resistant varieties/hybrids led to development of rot resistance genetic stock/variety. This has been done by transferring alien gene that provides better opportunity to minimize dependency of pesticides and also reduce input cost significantly. Since, there is a dearth of availability of resistance to black rot disease in *B. oleracea* (C genome), therefore exploring potential reservoirs for black rot resistance in A and B genomes becomes inevitable.

Brassica species are monophyletic in origin and could sexually be employed at any ploidy level for genetic introgression or alien genetic transfer. The chromosomes of genome A (irrespective of its source) have retained more chromosomal homology as compared with their homology to the chromosomes of genomes B and C. *Brassica napus* (AC genome) is more closer to *B. oleracea*, hence, 20 accessions of *Brassica napus* were used in study to search novel source of black rot resistance.

Black rot infected cauliflower plant

In total 20 accessions of *Brassica napus* were screened against *Xcc* race 1, 4 and during November to December 2017. The bacterial culture *Xcc* races 1, 4 and 6 were obtained from the Bacteriology Unit, Division of Plant Pathology, ICAR-IARI, New Delhi.

Inoculation of *Brassica napus* 'BN-2' plant



Inoculated leaves of *Brassica napus* 'BN-2' leaves (30 DAI)

The inoculation was carried out by standard 'dip and cut method' at 10 points per leaf on young leaves in three replications.

Our group, identified 'BN-2'inbred of *B. napus* as resistance (mean disease score: 0.3; mean disease incidence: 6.66 %) against all three prevalent *Xcc* races 1, 4 and 6 at 30 days after inoculation.

Exploring the new resistance sources in alien *Brassica* species and its introgression into *B. oleracea* group is one of the current priority areas to generate black rot resistance pre-breeding genetic stocks. But, genetic incompatibility often prevents effective crossing between two distantly related species. To overcome these barriers, *in vitro* isolated ovules culture in embryo rescue media appears as promising option. In cauliflower, already we could advance the pre-breeding materials using alien *Brassicas* to BC_{2-3} generations such as Cauliflower 'Pusa Sharad' × *B. carinata* 'NPC-9' and Cauliflower 'DC-401' × *B. juncea* 'Pusa Vijay' and Cauliflower 'DC-401' × *B. nigra* 'IC-56072' through *in vitro* embryo rescue. In the same line, we have attempted crosses Cauliflower 'Pusa Meghna' × *B. napus* 'BN-2' and got embryos germinated *in vitro* on embryo rescue media. Hence, introgression of durable resistance from *B. napus* to cauliflower using *in vitro* embryo rescue and or somatic hybridization will go a long way in developing pre-breeding black rot resistant genetic stocks in the cauliflower background. The stock will be useful for *Brassica* breeders to develop black rot resistant varieties / hybrids in vegetable *Brassicas*.

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Enhancing sugarcane yield per hectare through improved virus-free seed nursery programme

Varietal degeneration

Under Indian scenario, the serious viral diseases mosaic and YLD occur in all the sugarcane growing regions and the varieties under cultivation exhibit varying intensities of the diseases. *Sugarcane yellow leaf virus* (SCYLV) a phloem limited virus is associated with YLD, and the virus is primarily transmitted through infected setts and sugarcane aphid *Melanaphis sacchari* transmits the virus plant to plant in the field. Mosaic in sugarcane is caused by *Sugarcane mosaic virus* (SCMV) and *Sugarcane streak mosaic virus* (SCSMV) either alone or together under Indian conditions. Due to vegetative propagation these viral pathogens along with other non-fungal pathogens causing RSD and GSD gradually increase in their load in the canes over the generations. Such a high population of different pathogens inside the canes cause a decline in the performance i.e. loss in vigour of sugarcane varieties and this progressive decline in varietal performance, referred to as 'varietal degeneration'. Due to this, longevity of many elite sugarcane varieties was reduced in the past. Further, impact of these diseases was ignored in the past due to lack of precise diagnostic techniques and clarity in symptoms caused by different viral diseases in sugarcane.

Typical mid rib yellowing of leaves in the whorl in YLD affected cane

Combined infection of two or more viral/bacterial pathogens accelerates the damage to the crop in the field and this is due to infection of one pathogen which makes the plant more susceptible to another. In this way, a variety degenerates faster and its potential comes down over the years. Hence detailed studies were taken up at ICAR-SBI to assess the impact of SCYLV infection on different sugarcane varieties established that virus-infected varieties recorded significant reductions in growth/yield parameters, such as stalk height, stalk thickness and number of internodes in popular varieties. It is estimated that severe infection of the virus reduces cane yield by 30 to 50 % and juice yield by 34%. Since the loss caused by the disease is phenomenal in the field as well as in the mills, both the cane growers and millers suffer due to the disease.

Virus elimination

Of the different methods used for virus elimination, meristem tip culture is the most widely used method to eliminate the virus/phytoplasmas from the mother plants. Successful elimination of three RNA viruses infecting sugarcane SCYLV, SCMV and SCSMV and GSD phytoplasma from infected sugarcane has been established at the Institute and this cannot be guaranteed in tissue culture raised plants unless they are ensured free of the pathogens by molecular assays. At ICAR-SBI sensitive diagnostic techniques such as RT-PCR and PCR techniques were developed for the specific detection of the RNA viruses and phytoplasmas infecting sugarcane, respectively. These techniques have been applied to detect the pathogens in the tissue culture derived *in vitro* clones before rooting. Although the pathogen titre is expected to be very low, these techniques are highly sensitive to detect such low titre in young plantlets. When tissue culture derived seedlings are utilized for commercial planting without diagnosis for the designated pathogens, the process also facilitates spread of the diseases far and wide and this will have a catastrophic effect in the field on crop health. Hence production of disease-free plants through tissue culture should be indexed for the designated viruses and phytoplasmas. The Institute through Accredited test lab (ATL) for virus indexing of tissue culture raised sugarcane seedlings under NCS-TCP of DBT offered virus indexing services in the past to different sugarcane tissue culture production units across the country. Currently also, the service is being extended to various tissue culture production units in different states. By which, several hundreds of batch cultures or mother plants

Degenerated crop of the popular variety Co 86032 in the field due to severe YLD

Sugarcane seedlings raised from single bud setts of YLD-free canes

Healthy and vigorous growing Co 86032 free from YLD at the time of harvest

were indexed for sugarcane viruses / GSD phytoplasma and the labs were able to produce healthy planting materials free of these pathogens. In addition, the Institute also supplies virus indexed mother cultures of sugarcane varieties for the tissue culture production units for multiplication and production of virus-free planting materials.

Impact of virus-free planting materials on sugarcane production

The popular sugarcane variety Co 86032 is being cultivated in about one million hectares in the tropical region. The variety is in the field for nearly two decades and during the course of time it succumbed to YLD. Lack of healthy seed nursery programme led to severe degeneration in the field. Further, conventional heat therapy practiced in the sugar mills is ineffective against viral diseases. Hence we have recommended virus-free planting materials derived through tissue culture for the sugar industry to manage the disease and to achieve potential yield of the popular variety. This has been adopted in different districts of Tamil Nadu and sugar industry has realized the benefit of virus-free planting material in achieving higher yield. Since tissue culture derived plants cannot be directly planted for commercial cultivation the seedlings were used as breeder seed in the three tier seed nursery programme. Canes from this nursery were used to raise single bud settlings in protrays under shade-net and such healthy settlings were used for planting in the field either for commercial cultivation or subsequent multiplication. Large scale adoption of such nurseries in Erode and Namakkal Districts in Tamil Nadu resulted in significant jump in cane yield as compared to the conventional planting. Further, planting of these settlings under wide row has reduced seed cane requirement by one sixth of conventional planting of setts. Critical monitoring of YLD-free fields revealed that the disease-free fields always maintained a vigorous crop stand and the farmers realized an average increase of 37.5 tonnes/ha in cane yield in the region. Recently a farmer who planted the popular variety Co 86032 free from YLD recorded an yield of 250 tonnes/ha cane yield at Vellode village in Erode Dtwhich is more than 100% of the state average in cane productivity. This has amply demonstrated that achieving the potential yield of 250 t/ha is very much possible through improved nursery programme and this also helps to maintain varietal vigour in the field. Since the variety is cultivated in about one million ha in different states by large-scale adoption of the nursery programme would increase cane production to the tune of nearly 37.5 million tonnes in the same land area in the region. Ultimately this approach would increase land productivity, increase in farmer's income and sustaining sugarcane productivity.

Virus-free canes of Co 86032 show robust growth of more than 2 kg single cane weight at the time of harvest

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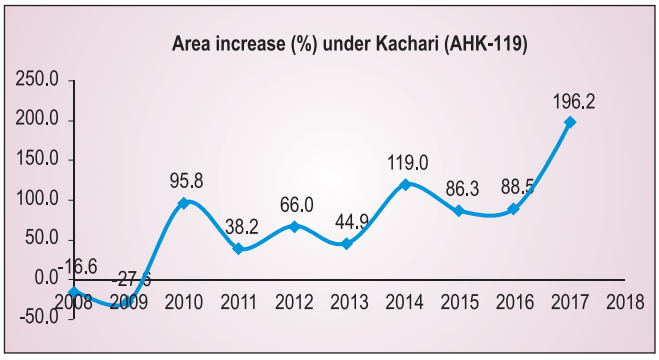
Quality evaluation of improved varieties of *kachri* (*Cucumis melo var. callosus*)

Kachri (*Cucumis melo var. callosus*), one of the most drought hardy and favourite cucurbitaceous vegetable of hot arid and semi- arid regions of India belongs to the family- *Cucurbitaceae,* genus-*Cucum*is, species- *melo* and *var. callosus/agrestis*. Commonly known as small gourd/wild musk melon (English), *kachari* (Gujarati), *kachari/kachariya*(Hindi), *chibdin* (Konkani), *chibbad* (Punjabi), *shinde* (Marathi), *gurmi* (Nepalese), etc., it is mainly grown during the rainy season under the mixed cropping system at large scale or as sole crop at small scale. Farmers who have irrigation facilities, grow the *kachri* as sole crop during the summer season also. It is a very good source of income, nutritious organic food stuff, value added products and source of traditional herbal medicine/ therapy also.



Trend in area (%) increased/decreased under improved varieties of kachri (AHK-119) in hot arid and semi-arid regions during 2008-2017 as compared to 2007

Development of an improved variety of *kachri:* ICAR-Central Institute for Arid Horticulture, Bikaner (Rajasthan) developed and released a unique variety of *kachri* known as "AHK 119" and disseminated widely to farmers' fields.Demand of the variety become very high and farmers adopted it on a very large area within a few years.

Improved variety of *kachri* "AHK-119"

Adoption, spread and production of the variety: The popularity of the variety increased very fast among the farming community and its unexpected demand hiked widely within 3-4 years of after it's releasing. The area and production of this variety increased tremendously year to year and continue to increase with increasing rate. In past, the farmers of the hot arid and semi-arid regions adopted AHK-119 very speedily to a large scale and spread over a large area within a few years with large production. A study was conducted in hot arid and semi-arid regions of the country (including- Rajasthan, part of Haryana, Punjab and Gujarat) to assess the impact of adoption of AHK-119. It was found that the total area under this variety of *kachri* was 2057 ha and production was 18.30 thousand tons in 2007 which

Year wise comparative gross and net return from improved as well as local variety of *kachri* under entire hot arid and semi-arid region of India

(Gross and net return in crores per year)

Years	Gross return under improved var. of kachri (AHK-119)*	Gross return under local variety of kachri**	Net return under improved var. AHK-119*	Net return under local variety**	Total net return from kachri crop
2007	28.19	18.44	20.74	11.58	32.33
2008	23.52	14.64	17.30	9.19	26.50
2009	20.41	11.42	15.02	7.18	22.19
2010	55.21	19.75	40.63	12.41	53.04
2011	38.96	15.72	28.67	9.87	38.55
2012	46.80	23.83	34.44	14.97	49.41
2013	40.86	15.86	30.07	9.96	40.03
2014	61.75	19.13	45.44	12.02	57.46
2015	52.52	15.67	38.65	9.84	48.49
2016	53.15	21.85	39.11	13.73	52.84
2017	83.51	22.34	61.45	14.03	75.48

* *Kharif* + summer season, ** *Kharif* season (as local variety is grown during *Kharif* season only)

Police is controlling the crowd of farmers at the Institute (ICAR-CIAH, Bikaner) during the seed distribution of improved variety (AHK-119) of kachri

increased to 6093 (196.2%) ha and 54.22 (196.28 %) thousand tones, respectively in the year of 2017 in hot arid and semi-arid regions.

Gross and net return: Studies showed that the gross return from AHK-119 in entire hot arid and semi-arid regions was ` 28.19 crores in 2007 which increased (three times) to ` 83.51 crores in 2017. Likewise the net return from *kachri* AHK-119 in these regions was ` 20.74 crores in 2007 which increased to ` 61.45 crores in 2017 which means, the net return from the improved variety of *kachri* AHK-119 in entire hot arid region also increased three times (196.28%) in 2017 in comparison to 2007. The net return from AHK-119 was 79.10 % and 337.99 % higher in comparison of local variety (local check) of *kachri* during 2007 and 2017, respectively.

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Identification of vegetable varieties for hot arid climate

The scanty and un-certain rains during monsoon, extremes of high temperature from March to October and low temperature from November to February, and all these factors together create an environment where very few vegetable crops and their genotype produce marketable yield. Varieties developed in favourable agro-climate did not perform well under abiotic stressed conditions of hot arid region, and therefore ICAR–CIAH, Bikaner has identified three varieties during 2018 for commercial cultivation under resource poor environment.

Palak – Thar Hariparna

Palak (*Beta vulgaris* var. *bengalensis* Roxb) variety *Thar Hariparna* is developed through selection and is an improvement over the native population. It is trait specific and produc excellent quality leaves and 7-9 pickings from October to March. It exhibited very good initial plant growth and first tender leaves harvesting start at 35–40 days with October sowing. Tender leaves at marketable stages are 9.81–12.54 cm length, 5.72–8.11 cm width, 1.748–1.838 g weight and 100 leaves are 174.8–183.8 g in weight. Light-green to dark-green colour and bigger sized leaves are glossy, smooth, thick, soft and juicy. Marketable fresh leaf yield potential is 128.48–235.84 q/ha.

Field view of *palak – Thar Hariparna*

Ivy gourd – *Thar Sundari*

Ivy gourd or *kundru* variety Thar Sundari has been developed through clonal selection from regional diversity. The gynoecious plants are moderate in growth habit, prolific in bearing of female flowers and parthinocarpic fruit development. Short-perennial plants respond to pruning and re-sprouted with on-set of spring and monsoon season, and after re-sprouting it took 50-55 days for first harvesting. For vegetable culinary, fruits are ready in 6.28–8.42 days from opening of female

Ivy gourd – *Thar Sundari*

Sponge gourd – *Thar Tapish*

flowers. Tender fruits of the highest marketable quality (A grade) are 5.83–6.48 cm length, 1.54–1.89 cm diameter and 11.76–13.54 g weight. The elongated-long shape tender fruits are light green-green-dark green in colour with non-clear white stripe and soft. The genotype recorded tender fruit yield of 2.85–3.48 kg/plant/season and yield potential is 248.2–351.7 q/ha with varying production situations.

Sponge gourd – *Thar Tapish*

Sponge gourd variety *Thar Tapish* is developed through hybridization (parentage AHSG-4 x AHSG-16). It is trait specific and first time bred through use of native germplasm for better marketable fruit yield and moderate plants 2.43–2.62 m under abiotic stressed conditions. It exhibited superiority for days to first harvesting of tender fruits (49.2–52.4 DAS), number of fruits/plant (9.74–12.47) and marketable fruit yield/plant (1.18–1.42 kg). Green–dark green colour tender fruits (A-grade) at marketable stages are 110–115 g weight, 20–22 cm length and 3.2–3.4 cm diameter. Fruit yield potential is 142.2–155.8q/ha with varying production situations.

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Micronutrients for spices

Micronutrients are those essential elements like copper, manganese, zinc, iron, boron, molybdenum etc, which are required by plants in very small amounts. The yield and quality of spices depends on the soils on which they are grown. Continuous exploitation of soil without replenishing the nutrients results in low yield, poor quality of the produce, besides making the crop susceptible to pests and diseases. Black pepper and cardamom are grown mainly in red and laterite soils of South India, Western Ghats and North Eastern states where soils are highly weathered and low in nutrient status. Besides, low pH, imbalance in the availability of major and secondary nutrients and application of inadequate quantities of organic manures have worsened the situation. At present about 48.1% of Indian soils are deficient in available zinc, 11.2% in iron, 7% in available copper and 5.1% in available manganese. Besides, deficiencies of boron and molybdenum have also been reported in soils. Soils with multi-

Products from few licensees available in the market

micronutrient deficiencies are also reported.

Ginger field of Mr Ajish Antony, Mananthavady, Waynad, Kerala sprayed with IISR ginger micronutrient special

Relatively excess/ indiscriminate and long term use of N and P straight fertilizers, which are generally free from micronutrients, ignoring potential soil amelioration with liming materials, has raised serious concern about preferential building up of P and imbalance of other nutrients, and created wide spread deficiencies of secondary and micronutrients especially Mg, B and Zn in major spice growing soils. These deficiencies/ limitations reduce yield significantly. Efforts to correct this imbalance have to be made through promotion of site-specific nutrient management taking into consideration the initial soil fertility status.

ICAR-Indian institute of Spices Research, Kozhikode, Kerala has developed crop specific, soil pH based micronutrient mixtures for foliar application in black pepper, cardamom, ginger, and turmeric crops which guarantees 15 to 25% increase in yield, besides enhancing quality. Bulk density (g/L) is one of the criteria for better quality of black pepper as it adds to the weight of the produce per unit volume. Users of black pepper micronutrient mixture recorded increase in bulk density of the produce due to its balanced nutrition. An innate advantage of these mixtures is that they can also be used in organic agriculture and therefore are environment friendly. Development is recommended to sustain the growth and production, split foliar application of nutrient mixtures evenly between stages of nutrient demand like new flush production and berry/ rhizome.

Evaluation trials conducted at farmer's field in Kerala, Karnataka and Tamil Nadu has given a clear yield advantage of 10-30% on various spices with significant increase in quality parameters like dry weight of berries and its bulk density in black pepper, boldness in cardamom, curcumin content in turmeric in sprayed fields as compared to control (non sprayed) fields.

Advantages

(i) Soil pH based, (ii) Crop-specific, (iii) Increases yield by 15-25%, (iv) Enhances quality of the crop produce, (v) Low cost, (vi) Easy application and (vii) Can be used in organic agriculture.

Novelty of the invention

a) These formulations are one of its kinds and have been developed for the first time for major spice crops like black pepper, cardamom, ginger, turmeric, b) The contents are so designed to fulfil the need of the crop based on the crop uptake pattern, c) Since the soil pH varies across spice growing states, the availability of micronutrient in soil also varies. Hence, the formulations especially for ginger and turmeric are pH based and meet the exact crop requirement vis-a-vis soil pH, d) It is given as foliar spray for easy and rapid absorption by the crop and for immediate alleviation of micronutrient deficiency, e) The formulations are cost effective with a

Mr Sailesh, Lakshmi Estate, G Hosahalli, Sakleshpur, Karnataka with black pepper sprayed with IISR pepper micronutrient

Turmeric field view of Mr Syed Nasir Ahmed, HD Kote, Karnataka sprayed with IISR turmeric special

cost: benefit ratio of 1:2.5. It not only enhances yield of crops (by 15-25%) but also increases the quality of the crop produce, f) The process for making these formulations is simple, g) Does not need special equipments or conditions to make these formulations and h) The ingredients used are the materials permitted (fully or in restricted quantities) under organic standards and hence it can be very well used under certified organic production of spices.

Method of application

Black pepper: Foliar spray at 5g per liter water should during spike initiation with the onset of monsoon and another after two months

Ginger: Foliar spray at 5g per liter water once during 60 days after planting and another 90 days after planting is recommended.

Turmeric: Foliar spray at 5g per liter water once during 60 days after planting and another 90 days after planting is recommended.

Cardamom: foliar spray at 5g per liter water should be given once during panicle initiation and another after three months.

Licensing and commercialization

Process patents for these formulations have been filed and non-exclusive licenses for each formulation have been issued. The Institute Technology Management and Business Planning and Development Unit (ITM-BPD Units) at IISR will help the entrepreneurs to prepare business plans for establishing manufacturing units. BPD unit will also provide consultancy services for commercial production. The mixtures are also available at ICAR-IISR Chelavoor campus.

Patents filed

- Patent Application No. 4745/CHE/2013 dated 21.10.2013 titled: "A Micronutrient Composition for black pepper and a process for its preparation".
- Patent Application No. 4754/CHE/2013 dated 22.10.2013 titled "A Micronutrient Composition for turmeric and a process for its preparation".
- Patent Application No. 3794/CHE/2013 dated 27.08.2013 titled: "A Micronutrient composition for ginger and a process for its preparation.
- Patent Application No. 4708/CHE/2013 dated 18.10.2013 titled: "A Micronutrient Composition for ginger and a process for its preparation".
- Patent Application No. 1681/CHE/2015 dated 31.4.2015 titled "A Micronutrient composition for cardamom and a process for its preparation".

Spread of technology in India

The technology has now spread to majority of the spice cultivating states like Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Telengana, Maharashtra, Madhya Pradesh, Gujarat and even NE states like, Nagaland, Assam, Tripura etc. covering 10% of the area and is expected to double by next 5 years.

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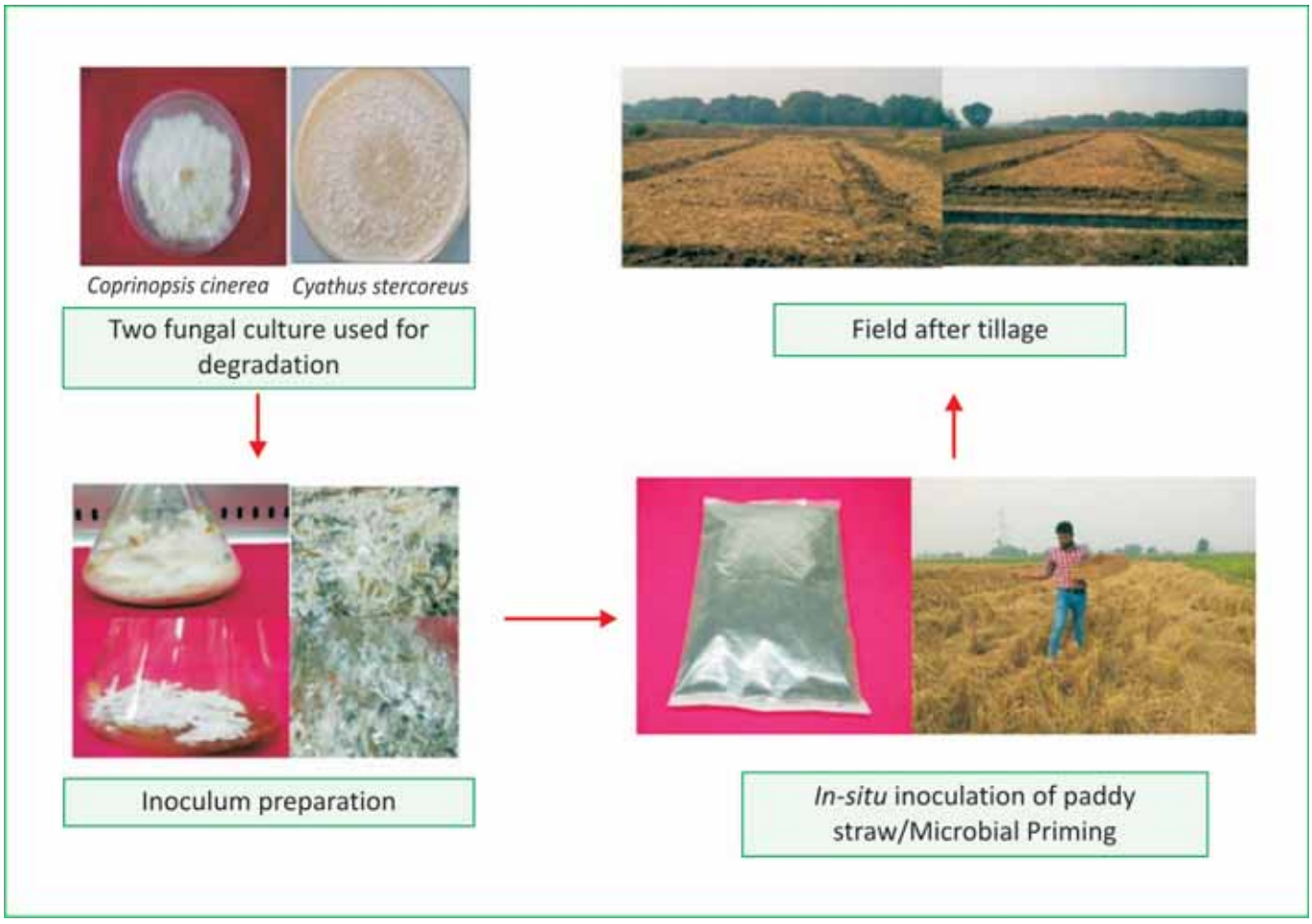
Microbial priming – alternative to straw burning

Indiscriminate residue burning of surplus residues of cereal crops accounting to about 82 Mt has become a major eyesore for environmentalists, scientists and policy makers. The high silica (11-15%), low protein content and poor digestibility of paddy straw makes it unfavorable for animal consumption. Farmers are forced to burn the left-over residue, primarily to clear the field for the next cropping cycle. In recent years, this residue burning has been confirmed through satellite images. The straw holds a good source of nutrients (0.5-0.8% N, 0.16-0.27% P_2O_5, 1.4-2.0% K_2O on dry matter basis) and has the potential to supply20 kg N, 6.5 kg P and 51 kg K per hectare. Hence the retention of these residues in soil is a better ecological option.

In long term experiments, *in-situ* straw retention of crop residues, remaining after combine harvesting in field, was found to be a feasible option but many reports documented a decrease in the yield of subsequent crop, due to N immobilization and phytotoxicity. Besides, incorporationof paddy straw increases CH_4 emission from field, which in turn adds to malice of global warming. An environment-friendly alternative can be the use of microorganisms (microbial priming) to degrade the residues *in-situ*. In nature, the bioconversion/degradation rate of paddy straw is slow due to its wide C: N ratio (H"80:1) and high lignin content. The natural microbiota that participates in degradation of this lignocellulosic biomass may not have the potential to produce sufficient extracellular enzymes to breakdown



this polysaccharide to simple monomers. Bioaugmentation with efficient microbes/ microbial consortium, comprising predominately cellulose and lignin degraders can be a suitable option for faster degradation.

Two lignocellulolytic indigenous fungi namely *Coprinopsiscineria* LA2 and *Cyathussterocoreus* ITCC 3745 were selected for the *in-situ* degradation of crop residues on the basis of colonization potential of these fungi on wheat/paddy straw under solid state. In-depth research using microbial consortium for the degradation potential of the paddy straw has been assessed in field. The compost based formulation of these fungi can readily decompose the residues in 20-25 days with N supplementation. These two fungi possess high levels of lignocellulolytic enzymes cumulatively which deconstruct both cellulose and hemicelluloses of the paddy straw efficiently. The cellulase activity was found to increase upto 60 days after inoculation and highest cellulase activity (4.61 IU/g soil/day) was observed in plots where straw was inoculated with fungal consortium. Similarly, xylanase (0.56 IU/g) and glucosidase activity (900.1 ug pNP/g soil) were observed to be maximum in the same treatment. Residue retention without microbial consortium resulted in 21% decrease in wheat yield but higher grain yield was recorded in the treatments with microbial priming. These inoculants seem to be very promising and not only help in recycling of the valuable nutrients, but also reduce the environmental pollution.

ICAR NEWS wishes all readers and contributors

A Very Happy New Year 2019

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ICAR Research Complex for Eastern Region, Patna

Developing the adoptable technologies relevant to the prevailing bio-physical and socio-economic environment of eastern region for sustainability and overall livelihood security of rural population

ICAR Research Complex for Eastern Region, Patna came into existence on 22nd February 2001 after merger of Directorate of Water Management Research, Patna with the complex. On the 1st April, Central Horticultural Experimental Station, Ranchi and Central Tobacco Research Station, Pusa were merged in the complex. The present form of the institute was dedicated to the Indian farming community on 16th October 2006 at its new complex in the sweet memory of Shri Babu Jagjivan Ram. ICAR-RCER, Patna would address the diverse issues related to resources management, crop husbandry, horticulture, aquatic crops, fishery, live-stock, poultry, processing and socio-economic aspects in a holistic manner for enhancing research capability and providing a backstopping for improvement in agricultural productivity and sustainability. The ICAR RCER is a multi-commodity and multi-disciplinary institutional framework to address the research issues. Geographically, the Institute is located at 25°35'30" N latitude, 85°05'03" E longitude, at an altitude 52 m above mean sea level.

MANDATE

- Strategic and adaptive research for efficient integrated management of natural resources to enhance productivity of agricultural production systems in eastern region.
- Transform low productivity-high potential eastern region into high productivity region for food, nutritional and livelihood security.
- Utilization of seasonally waterlogged and perennial water bodies for multiple uses of water.
- Promote network and consortia research in eastern region.

MISSION

- Transform "Low Productivity-High Potential" eastern region into high productivity region for food, nutritional and livelihoods security in a manner that is environmentally sustainable and socially acceptable.
- Tap unutilized potential of vast seasonally waterlogged and perennial water bodies for multiple uses of water and aquatic crops for social upliftment.
- Poverty alleviation, livelihood improvement and women empowerment through income and employment generation through on-farm and off-farm job opportunities.
- Promote network and consortia research in the eastern Region.

VISION

A broad based institutional framework to address diverse issues relating to land and water resources management, crop husbandry, horticulture, fishery, livestock and poultry, agro-processing, and socio-economic aspects in a holistic manner for enhancing research capability and providing a backstopping for improvement in agricultural productivity and sustainability in the eastern region

INFRASTRUCTURE

The complex has four divisions besides two research centres and two KVKs. The institute's main campus-cum-

laboratory building, guest house, residential complex and research farm is located at Patna and spread over 65 acre. It is situated near Patna Airport runway and about 12 km away from Patna Railway Station. Another two research farms 42.57 acre of farm land is located at Sabajpura which is 8 km away and 11 acre of farm land is located at WALMI, Phulwari Sharif which is 10 km away from the main campus. Besides main campus at Patna, the institute has 425.83 acre of farm land of Research Centre located at Plandu, Ranchi and 25 acre of farm of Research Centre for Makhana located at Basudeopur, Darbhanga. The institute also has two Krishi Vigyan Kendras at Buxar (25.64 acre) and Ramgarh (19.04 acre).

The Institute has nine well-equipped laboratories, viz. plant science laboratory, plant protection laboratory, crop improvement laboratory, soil science laboratory, soil processing laboratory, livestock production and reproduction laboratory, animal health laboratory, feed analytical and biochemical laboratory and fisheries laboratory with all the latest equipment for research activities. An engineering workshop also caters to the needs of the institute. In addition to these, meteorological observatory and pressurized irrigation system also exist at the research farm. The entire network administration of the computers, internet and website management is looked after by the ARIS cell. The ARIS cell also accommodates a fully developed Online Examination Centre. The Institute also has a well-established library, conference hall, committee room, training hall, guest house, PME Cell, etc. Institute has a cadre strength of 90 scientists, 61 technical, 35 administrative and 63 supporting staff. Presently the institute has 68 scientists and 22 administrative, 51 technical and 60 supporting staff and is an ISO 9001:2008 certified institute.

MAJOR ACHIEVEMENTS

The complex has developed number of resource conserving technologies for enhancing the agricultural production and ensuring the food and nutritional security in the eastern region. Some important technologies generated are as follow:

Integrated farming system mode of food production

- Half acre IFS model for small holders of middle Gangetic Plains of eastern India
- One acre IFS model for irrigated upland ecologies in Middle Gangetic Plains
- Two acre IFS model for low land irrigated ecosystem of Lower and Middle Gangetic Plains
- Tribal farming systems for eastern Hill & Plateau
- Rice-fish-vegetable farming system for low land ecosystems of EIGP
- Agroforestry land use including farming system model for water congested ecologies in EIGP
- *Makhana* based farming systems for Middle Gangetic Plains
- Raised and sunken bed integrated livestock-production system for EIGP

Area specific mineral mixture for Bihar

Based on analysis of blood samples of livestock, soil samples and fodder crops, it was observed that there was deficiency of P, Mn, Zn and Cu, which was supplemented through formulation of area specific mineral mixtures. In case of milch cattle, 50-100 g/day of mineral mixture need to be supplemented whereas non-milch animal need 30-50 g/day of mineral mixture.

Swarna Min

Mineral mixture formulation

Calcium (25.46%); Phosphorus (13.20%); Iron (0.16%); Copper (0.12%); Manganese (0.16%); Zinc (0.99%); Cobalt (0.02%); Iodine (0.04%) and Sulfur (1.04%).

The technology is suitable for eastern states wherever soils are deficient in above named minerals and thereby affecting adversely livestock health and productivity. This formulation has resulted into 5-10% high milk yield in cattle when compared with the milk productivity of those cattle which are fed with commercially available mineral mixture.

Low cost feed formulation based on locally available resources for dairy animals

The dairy animals are maintained on crop residues with supplementation of little concentrate mixtures (approximately 300-350 g/d/animal). Due to unbalanced feeding, the milk production of animal is low (2.0-3.0 kg/d/animal). To solve this problem, balanced concentrate mixture was prepared with available feed resources for dairy cow and buffalo. Two types of concentrate mixtures were prepared depending on the availability of resources. Concentrate mixture was prepared by mixing crushed maize/ broken rice/ wheat (30 kg), wheat bran/ rice bran (15 kg), deoiled rice bran (15 kg), mustard cake

(7 kg), linseed cake (12 kg), gram/ arhar/ lentil chunies (18 kg), mineral mixture (2 kg) and salt (1 kg). Similarly, other type of concentrate was prepared by mixing crushed maize/ broken rice/ wheat (20 kg), wheat bran/ rice bran (25 kg), deoiled rice bran (10 kg), mustard cake (16 kg), linseed cake (15 kg), gram/ arhar/ lentil chunies (11 kg), mineral mixture (2 kg) and salt (1 kg). The concentrate mixture may be fed at the rate of 2 kg for maintenance ration and 1 kg for every 2 kg of milk production for buffalo and 2 kg maintenance plus 1 kg for every 2.5 kg of milk production for dairy cow. The concentrate mixture is found as good as commercial balanced feed in respect of feed intake, milk yield and composition.

- Feed prepared with locally available resources cost ` 10/kg compared to ` 201/kg of commercially available feed.
- Cost of concentrate mixture was reduced by 30% by preparing home-made concentrate with available sources.
- Milk yield increased by 20-25% by feeding of homemade concentrate compared to feeding of unbalanced concentrate mixture.
- Cost of milk production reduced by 25-30%.

Makhana cultivation in cropping system mode

Makhana could be successfully cultivated in field conditions maintaining a water depth of 30 cm. *Makhana* is transplanted in the second week of April and harvested by the second week of August. Thereafter,

Makhana

either water chestnut or short duration varieties of rice could be cultivated in *makhana* growing fields. Thereafter, wheat or berseem is sown by mid of December. Hence, cultivation of three crops per year is possible in field method of cultivation. In general, the *Makhana* based different cropping system include: *Makhana*-Water chestnut; *Makhana*-Berseem; *Makhana*-Rice; and *Makhana*-Rice-Wheat. The technology is suitable for waterlogged and marshy areas and even to the areas where assured irrigation is possible. The technology has the potential to be adopted in more than 1.0 m ha area in eastern region of India.

The net monetary returns are depicted below:

Makhana, followed by water chestnut- `88,790/ha
Makhana, followed by berseem- `98,465/ha
Makhana, followed by rice, wheat- `1,22,570/ha

Integrated fish farming for increasing productivity

Feed costs often comprise 40-50% of the total production cost which is difficult to afford by marginal farmers.As a result, the fish productivity remained low (1.0-1.5 t/ha). Hence, an alternate method of fish farming was need of the hour so as to improve the productivity of composite fish culture.

(i) Fish-cum-cattle integration

Recycling of cowdung of five cattle on sustained basis can fertilize one hectare of fish pond. The composite fish culture (10000 nos. of yearlings/ha) productivity in fish-cattle integration has been accounted for 5.0 t/ha as compared to 1.0 t/ha productivity of fishery alone. Other components include milk (4320 ltr/yr) and cow urine (3.65 lakh ltr).

Cow-Fish

(ii) Fish-cum-poultry integration

Eight week old chicks (500 nos.) are required to fertilize one ha of pond. The fish productivity of this system is estimated to be 3.5-4.0 t/ha/yr besides 63,000-65,000 eggs and500kg of dressed chicken.

(iii) Fish-cum-duck integration

Five hundred ducklings could fertilize one ha of pond. The fish productivity has been recorded to be 3.8-4.1 t/ha besides 60,000-62,000 eggs/yr. Ducks could be slaughtered at 2 years' of age with 570-600 kg of dressed duck meat.

Duck-Fish

(iv) Fish-cum-pig integration

The stocking density of pigs has been standardized to be 40 nos. to fertilize one ha of pond. The fish productivity ranged 4.2-4.5 t/ha besides 1.6 t of pork.

Pig-Fish

(v) Fish-cum-goat integration

Fifty five nos. of goats can fertilize one ha of fish pond. The fish productivity was accounted for 3.5-4.0 t/ha besides 375 kg of mutton.

Goat-Fish

(vi) Fish-cum-buffalo integration

Buffalo-fish

Three buffalos are sufficient to fertilize one ha of fish pond with average productivity of 5.0 t/ha of fishes and 3600 ltrs of milk production.

Applicability: Area/ Situation

Eastern region has 0.66 m ha of pond and tanks. Integrating fish farming can increase the fish productivity by 3-4 folds as evidenced from above mentioned details.

Economics /Cost involved

Fish-cum-cattle	`4.26 lakh/ha
Fish-cum-poulty	`3.46 lakh/ha
Fish-cum-duck	`2.48 lakh/ha
Fish-cum-pig	`1.80 lakh/ha
Fish-cum-goat	`3.66 lakh/ha
Fish-cum-buffalo	`4.67 lakh/ha

Fruit based multitier cropping system for rainfed uplands

The technology on fruit based multitier cropping system has been standardized with a view to increase the profitability of fruit orchards with short gestation period under plateau conditions of eastern India by efficient

utilization of natural resources. The technology comprise of planting of fruit trees with large canopies (mango, litchi, *aonla*, jackfruit) at a spacing of 10 m x 10m as main crop, planting of precocious bearing fruit species with dwarf canopy (guava, custard apple, lime, lemon) at a spacing of 5 m x 5m between rows and between plants in the same field as filler crop and growing of intercrops in the interspaces. A productivity level of 12.0 t/ha of Rice Equivalent Yield (REY) can be obtained from 10 year old fruit based multitier system under the eastern plateau conditions.

Recommended domain

The technology was popularized through convergence with Wadi programme of NABARD, National Horticulture Mission and has been adopted in more than 10,000 ha area in different eastern states. The technology can be adopted in more than 1.0 lakh ha area in the rainfed uplands of eastern plateau and hill region which will result in more than 10 times increase in the productivity of rainfed uplands.

Economics

- Mango based multitier system - 2.40:1.0
- Litchi based multitier system - 4.06:1.06
- Aonla based multitier system - 2.51:1.0.

Rejuvenation of unproductive mango orchards

The old and senile orchards are mainly characterized by prevalence of long unfruitful branches with tip bearing habit, overcrowding of branches in the inner side of the canopy restricting the penetration of sunlight inside the canopy leading to a competition among the branches for light and fruiting confined in the outer periphery. Under these conditions, the farmer is generally left with the option of complete removal of plants and plantation of new orchard which takes 6 to 7 years for initiation of fruiting. The rejuvenation technique, however, provides an alternative for improving the productivity of these orchards within a

period of three years. The following steps are involved for rejuvenation of old mango plants:

- Selection and marking of limbs and pruning/cutting of limbs sharply (preferably tertiary branches) during December and removal of pruned woods from the vicinity of pruned plants,
- Pasting of cut ends to check infection, painting of trunk to avoid oozing of latex,
- Preparing ring near the trunk zone,
- Selecting 10-12 numbers of sprouts emerging from right position and removing all the unselected sprouts as and when they appear. In later years, 4-5 shoots per branch can be maintained,

- Management of selected sprouts to develop in to desired canopy,
- Grafting of scion of improved cultivars on the sprouts (in case of plants of inferior fruit quality),
- Control of trunk borer as and when noticed,
- Application of fertilizer at a rate of 800:300:1000 g NPK + 50 kg FYM per plant, and
- Cultivation of intercrops in the season.

By adoption of these steps, the plants can be brought to fruiting within three years. Optimum productivity of the plants can be attained after 6 years. In case of new plantation, the optimum productivity of plants can be attained only after 15 years. A total of ` 1500/tree will be required in a period of three years for rejuvenation. After 6 years of rejuvenation, 75-85 kg of mangoes/tree could be obtained as compared to 10-20 kg/tree in case of non-rejuvenated orchards.

Ultra high density planting in guava

Low productivity of guava under the hill and plateau region makes guava cultivation unprofitable. The technology on ultra high density planting in guava has been standardized for increasing the profitability of guava cultivation. Guava is planted at a spacing of 1 m x 2 m accommo-dating 5000 plants per ha. The emerged shoots are pruned thrice (March, June and October) to 50% of their total length. Under this system of planting, a yield level of 38t/ha is obtained during the third year as compared to 4.0 t/ha in case of traditional system of planting.

Guava

Recommended domain

The technology has been popularized in the region in collaboration with NABARD, National Horticulture Mission, NGOs and progressive farmers and has already been adopted in more than 100 ha area in different eastern states. Further, the technology can be adopted in more than 10000 ha area in the eastern plateau and hill region. This will result in production of additional 3.0 lakh tonnes of guava in the region.

For establishment of 1 ha of ultra high density guava orchard, an amount of ` 2.5 lakh will be needed and after four years of establishment, a net profit of ` 2.65 lakh/ha/yr can be obtained.

Rain water harvesting in plastic lined *Doba*

Unavailability of irrigation water is one of the major constraints for establishment of fruit plants under the rainfed uplands of plateau region. Low cost rainwater harvesting can provide effective solution for fulfilling the moisture requirement of newly planted saplings.

The technique on *Doba* has been standardized for storage of runoff water under upland conditions. The technology involves digging of pit of size 3.0m x 1.5m x 1.0m and lining the pits with UV-stabilized black polythene (250 micron). After collection of rainwater in the *Doba* in the rainy season, the pit has to be covered with thatch made out of locally available material. It has been estimated that one *Doba* is sufficient for storage of rainwater for providing lifesaving irrigation to 10 newly planted fruit saplings. The structure has a life span of 2 years. The structure can also be used for storage of water from seasonal streams for establishment of fruit trees.

The construction cost has been accounted `1200-1300 for each Doba. The technology has already been adopted in more than 20,000 ha area in different eastern states

Swarna Vaidehi – First ever variety of *Makhana*

The average yield of local cultivars of makhana ranged from 1.4-1.6 t/ha. There was need to develop suitable variety for improving *Makhana* productivity. Swarna Vaidehi has the productivity of more than 3.0 t/ha in farmers' field and thereby register 46% higher yield compared to local cultivars. It is rich in micro nutrients and essential amino acids. The variety is suitable for cultivation in perennial water bodies, waterlogged and marshy areas. As of now, *Makhana* is cultivated only in 11,000 ha area with a total productivity of 1000 t/yr. The varietal development has opened up the scope of *Makhana* cultivation in more than 6.0 lakh ha area in North Bihar alone. The technology has the potential for adoption in 1.0 million ha area in other Eastern states. Additional gain in net monetary return is estimated to be ` 30,000/ha with cultivation of *Swarna Vaidehi*.

Swarna Vaibhav – *Makhana*

with collaboration of NABARD and NGOs. Further, the technology can be adopted in more than 1.0 lakh ha area in the eastern plateau and hill region which will result in harvesting and effective utilization of 4.5 lakh m^3 of rainwater.

Swarna Shreya (IET 24003) for increasing rice productivity in rainfed agriculture

Water scarcity in rainfed areas is one of the major causes of low rice productivity. The rice productivity of rainfed areas is quite low (1.0-1.5 t/ha). In order to improve upon the productivity of rainfed/water deficit areas, the varietal development was necessary.

Swarna Shreya

Swarna Shreya was developed from the cross IR78877-208-B-1-1/IRRI 132 and found suitable for aerobic conditions. The variety is distinguishable through morphological features and long bold grains.It is highly resistant to leaf blast disease and moderately resistant to other diseases with average productivity of 4.0-4.3 t/ha in farmers' field. The variety showed high hulling recovery (77.5%), milling (69.2%), head rice recovery (56.2%), intermediate amylose content (21.87%) and alkali spreading value (ASV=4.0). IET 24003 has high GC (65.5 mm) with very occasionally chalky and long bold grain indicating good cooking quality.

AWARDS AND RECOGNITIONS

The Complex has been awarded with *"Ganesh Shankar Vidhyarthi Hindi Patrika Puruskar"* for the half yearly Hindi *Patrika* "*Akshay Kheti*".

LINKAGES AND COLLABORATION

Besides having linkages with leading ICAR institutions, SAUs and State Govt. of various eastern states, the Complex also has linkages with International institutions .

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Development of high temperature tolerant variety of longmelon

Longmelon (*Cucumis melo* var. *utilissimus*) popularly known as *Kakri* or *Tar Kakri* is an important warm season crop. It is used as salad, pickle and cooked as vegetable. Due to its cooling effect, it is very popular during summer. In hot arid region of Rajasthan, it is mainly sown in February-March. The flowering stage of February sown crop coincides with the prevailing high temperature and hot wind resulting in very low and poor-quality yield of longmelon.

Therefore a systematic breeding programme on longmelon was undertaken and *'Thar Sheetal'* variety was developed that is tolerant to high temperature (upto 42°C) during April-May months.

It is early in harvesting and takes 45-50 days in first harvesting from sowing. Fruits are 25.83-29.67 cm long, prolific bearer and a single plant produced 18.20-22.20 marketable fruits/plant. The fruits have desirable marketable attributes. They are tender, attractive, light green at edible stage and free from bitter principle which is highly accepted by the growers. It has yield potential of 132.00-142.50q/ ha under hot arid conditions which is 17.72-25.79% higher over check *i.e.* Punjab Longmelon-1. It produces an average yield of 165.52q/ ha in multi-location trials conducted at different KVKs during summer 2018 being maximum (180q/ ha) at KVK, Pali. During summer season of 2018 it recorded 17.04% higher yield over Punjab Longmelon-1 in an adaptive trial conducted at ATC, Jodhpur.

The cultivation of longmelon is very popular under tunnels to harvest 40-50 days early crop over open field conditions which fetches premium prices in the market. *'Thar Sheetal'* is best adapted to tunnel cultivation where the crop is sown during December-January and can be harvested in last week of February or first week of March.

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Diversity in muskmelon under hot arid region of Rajasthan

Muskmelon (*Cucumis melo* L.) is an economically important annual species cultivated all over the world. It belongs to the family *Cucurbitaceae*, genus *Cucumis*. The fruits are used as 'dessert' which contains 0.6% protein, 0.2% fat, 3.5% carbohydrates, 32 mg calcium, 14 mg phosphorus, 1.4 mg iron, 16 mg carotene and 26 mg vitamin C per 100 g fresh weight of fruit. Seed kernels are also edible, tasty and nutritious, since they are rich in oil and energy. Great morphological variation exits in fruit characteristics such as size, shape, colour and texture, taste and composition, and *C. melo* is therefore considered the most diverse species of the genus *Cucumis*. The species comprises of wild and cultivated varieties; the latter includes sweet 'dessert' melons, as well as non-sweet forms that are consumed raw, pickled or cooked. Persistence of large variability in muskmelon ensures better chances to select new genotypes for specific traits. Thus, collection, evaluation, maintenance and conservation of the variability are prerequisite in improvement programme.

Keeping in view a large number of diverse germplasm of muskmelon was collected and evaluated during 2012 to 2016 for different horticultural traits and observed wide genetic diversity. Days taken to 50% pistillate flowers, flesh

New brinjal varieties accepted

Four varieties of brinjal, resistant to bacterial wilt, have been accepted for release by State Seed Sub Committee for Agricultural and Horticultural crops, the state of Goa on 5th July 2018. *email:* ccari@icar.gov.in

Goa Brinjal-1 (262-4)

Wilt (%)	:	0.0
Yield (t/ha)	:	27.5
Fruit Colour	:	Purple
Fruit Shape	:	Oval
Fruit Size	:	8 x 5 cm
Fruit Wt. (g)	:	0.150
Fruit/plant	:	9-10

Goa Brinjal-2 (5-12-1)

Wilt (%)	:	0.0
Yield (t/ha)	:	20.5
Fruit Colour	:	Light Purple
Fruit Shape	:	Oblong
Fruit Size	:	7.7 x 5.4cm
Fruit Wt. (g)	:	0.136
Fruit/plant	:	10-11

Goa Brinjal-3 (262-4)

Wilt (%)	:	3.33
Yield (t/ha)	:	15.0
Fruit Colour	:	Purple
Fruit Shape	:	Oval
Fruit Size	:	6.4 x 5.2 cm
Fruit Wt. (g)	:	0.079
Fruit/plant	:	7-8

Goa Brinjal-4 (262-4)

Wilt (%)	:	3.33
Yield (t/ha)	:	25.0
Fruit Colour	:	Purple
Fruit Shape	:	Long
Fruit Size	:	10.7 x 4.2 cm
Fruit Wt. (g)	:	0.100
Fruit/plant	:	12-13

Genetic diversity in fruit traits of muskmelon

thickness, width of seed cavity, rind thickness, fruit diameter and fruit weight ranged from 44.00-52.33 days, 1.87-3.60 cm, 4.69-7.21 cm, 0.12-0.50 cm, 8.90-16.69 cm and 0.32-1.77 kg, respectively. The number of marketable fruits/ plant of muskmelon accessions varied from 2.67-5.33. Total soluble solids and flesh pH ranged from 8.07-13.90% and 4.64-6.57%, respectively. Sex expression is an important trait for breeding programmes of muskmelon. Andromonoecious is the most common and predominant sex forms however, monoecious form is observed only in IC-0599709. Fruit shape in longitudinal section varied from oval, elongated globe, round, flat globe, obovate to cylindrical. The flesh colour was observed as white, green and salmon orange. Slipable and non-slipable pattern of peduncle was observed at fruit maturity.

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WAY FORWARD

NANOBIOTECHNOLOGY, bionanotechnology and nanobiology are terms that refer to the intersection of nanotechnology and biology. Given that the subject is one that has only emerged very recently, the term serves as blanket term for various related technologies. Concepts that are enhanced through nanobiology include: nanodevices, nanoparticles, and nanoscale phenomena that occurs within the discipline of nanotechnology. This technical approach to biology allows scientists to imagine and create systems that can be used for biological research.

The most important objectives that are frequently found in nanobiology involve applying nano-tools to relevant biological problems and refining these applications. The imaging of native biomolecules, biological membranes, and tissues is also a major topic for the nanobiology researchers. Other topics concerning nanobiology include the use of cantilever array sensors and the application of nanophotonics for manipulating molecular processes in living cells. Recently, the use of microorganisms to synthesize functional nanoparticles has been of great interest. Microorganisms can change the oxidation state of metals. These microbial processes have opened up new opportunities for us to explore novel applications, for example, the biosynthesis of metal nanomaterials. In contrast to chemical and physical methods, microbial processes for synthesizing nanomaterials can be achieved in aqueous phase under gentle and environmentally benign conditions. This approach has become an attractive focus in current green bionanotechnology research towards sustainable development.

Nanomaterials display several unique properties like increased surface area, cation exchange capacity and ion adsorption. It has made an impact on several aspects of agriculture, from how a crop is grown to how it is harvested, packed and marketed. It could be beneficially used for developing applications for agriculture including fertilizers, agrochemicals, slow release of pesticides and fertilizers, nutrient management and better storage.

Development of nanonutrients, nanopesticides and nanoformulations will be required in small quantities resulting in economic uses, low cost and minimum pollution to the environment.It is also possible to control seed diseases and provide plant protection by treating the seed before planting. This can be done by coating seeds with fertilizers, pesticides, nutrients and growth regulators along with adhesive agents. The nanosensors monitor soil conditions and crop growth, and also detect animal and plant pathogens. They do enable delivery of growth hormones in a controlled fashion, while the nanoparticles help in delivery of DNA to plants i.e. in targeted genetic engineering.

In food processing front, the carbon nanotube is used to develop low cost sensors on surfaces such as the plastic film wrapping food, so that the sensor could detect spoiled food. Further, nanocapsules improve bioavailability of nutraceuticals in standard ingredients such as cooking oils, and enhance flavour. At the same time, nanoparticles selectively bind and remove chemicals or pathogens from food.

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

It is envisaged that the biodegradable nanosensors for temperature, moisture and time monitoring are to be developed. Further, the nanoclay and nanofilms act as barrier materials to prevent spoilage and prevent oxygen and moistureabsorption. This could reduce the possibility of food being spoiled or dried. Zinc oxide nanoparticles can be incorporated into plastic packaging to block UV rays and provide anti-bacterial protection, while improving the strength and stability of the packaging materials. Nanosensors are being developed that can detect bacteria and other contaminantes, such as *Salmonella,* at a packaging plant. This will allow for frequent testing at a much lower cost than sending samples to a lab for analysis. The engineered nanomaterials have elbowed their way into our ecosystem including soil, water and atmosphere. There are concerns about the risk posed by engineered nanomaterials, their potential to cause undesirable effects and environmental pollution. Regulatory mechanisms are however, required for the judicious use of nanomaterials in agriculture. Meanwhile, the OMICS (genomics, transcriptomics, proteomics and metabolomics) for understanding beneficial traits of microorganisms benefits researchers to develop biopesticides and biofertilizers for sustainable agriculture. It is also envisaged that computational chemistry will help in understanding the mechanistic aspects of cellular components such as enzymes and proteins at the molecular level.

Overall, the nanoscience is a high-end science that has the potential to revolutionize the future agriculture of the country. The Indian Council of Agricultural Research is focusing its nano-agriculture program with full wisdom to harness the fullest capacities of agricultural scientists to transform Indian agriculture towards sustainability vis-à-vis profitability.

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