IBM – IORF

SUSTAINABILITY PROJECT

Adoption of a Cluster of Villages for Agricultural Sustainability and Food Security through Clean Food Program

PHASE- 3 PROJECT

MILESTONES

Validation of Quality Potentials of the Second Generation 'NET ZERO' Clean Paddy Seeds developed under Phase-II Project in Mandya District of Karnataka, in respect of Yield Improvement and Climate Resilience - in West Bengal Project Area.	:	**MILESTONE 1**
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Assessment of Quality Potentials of the First generation 'NET ZERO' Clean Vegetable Seeds produced under Phase-II Continuation Project in West Bengal, in respect of Yield Improvement and Climate resilience - in West Bengal Project Area.	:	**MILESTONE 7**
Development of 'NET ZERO' Clean Sugarcane Planting Material, in the Project area at Mandya District of Karnataka	:	**MILESTONE 8**

IBM - IORF SUSTAINABILITY PROJECT

Adoption of a Cluster of Villages for Agricultural Sustainability and Food Security through Clean Food Program

PHASE - III

MILESTONE 1

Validation of Quality Potentials of the **SECOND GENERATIONS 'NET ZERO' Clean Paddy Seed** developed under Phase-II Project in Mandya District of Karnataka, in respect of Yield improvement and climate resilience – in West Bengal Project

PROJECT SITE :

Block– Haringhata, **District-** Nadia , **State-** West Bengal, India

Challenges and Imperatives in Enhancing Seed Quality for Sustainable Agriculture

Seeds play a pivotal role in sustainable crop production, forming the basis for robust agricultural practices. Despite India's vast agricultural expanse of 90 million hectares dedicated to food crops, only 10-12% of this area is cultivated using quality-certified seeds. The importance of seed quality is evident as many crop diseases are seed-borne, highlighting the critical role of quality seeds in disease prevention.

In the Indian context, the limited availability of high-quality certified seeds is a significant constraint, with only 30% of seeds used by farmers being of certified or high quality. Quality seeds alone contribute around 15-20% to total production, a figure that could rise to 45% with efficient management of other inputs. Small and marginal farmers, comprising over 85% of Indian farmers, face challenges due to poor-quality seeds, leading to a potential 20% loss in crop potential, especially in rice cultivation.

Addressing the challenges associated with seed quality is crucial for unlocking India's full agricultural potential, ensuring food security, and promoting sustainable crop production practices. The shift towards sustainable agriculture is hindered by the dominance (80%) of High-Yielding Varieties (HYV) or hybrids designed for fertilizer sensitivity. These seeds lack essential traits like higher nutrient use efficiency, disease resistance, and resilience to changing climatic patterns, posing obstacles to sustaining crop yields. Overcoming these limitations is essential for advancing sustainable agriculture and ensuring long-term food security.

Climate-smart agriculture is crucial for mitigating the effects of climate change, starting with the use of quality-resilient seeds. Seeds developed under conventional farming are often fertilizer-responsive, lacking essential traits like higher nutrient use efficiency, disease resistance, and resilience to stress. Organic seeds, produced in an organic environment, offer a solution by imparting these traits, supporting better adaptability to climate change and sustainable agriculture.

Rice, as a staple grain in India, holds a significant position in the country's food supply. India boasts the largest area dedicated to rice cultivation. However, rice poses unique challenges as a C3 plant, being approximately 1/3rd less photosynthesis-efficient compared to C4 plants like maize and wheat. This makes rice highly susceptible to even minor fluctuations in weather conditions, impacting its overall performance.

The selection of rice for 'NET ZERO' Clean Seed production is driven by its pivotal role in the Indian food bowl and its designation as one of the most challenging crops concerning climate change mitigation. The challenges stem from the substantial water and nitrogen usage associated with rice cultivation, as well as its high greenhouse gas emission potential. Addressing these specific challenges in rice production becomes crucial in the broader context of achieving 'NET ZERO' Clean Seed production and implementing sustainable agricultural practices amid the changing climate.

Need of Climate Resilient Paddy Seeds

To sustained crop production under this climate change impact, we have to move towards climate resilient agriculture and organic farming which can increase the system resilience, can enable progression towards sustainable agriculture , enable significant reduction in GHG emission and offer long term sustainability and reduce the challenges towards food security; but "Climate-Resilient Seed" forms the prime requirement towards the objective.

In the present scenario 99% of the seeds are High Yielding Varieties (HYV), which are high fertilizer sensitive leading to limited response under any low input farming initiative. Moreover they lack the quality traits disease resistance and resilience against biotic and abiotic stress, that make them more vulnerable under the changing climatic patterns. In this context the seed produced under organic environment can help out in infusing such quality traits that can enable "Better Adaptability w.r.t. Climate Change and Support Safe and Sustainable Agriculture".

However, a significant impediment to the widespread adoption of organic seeds is the virtually non-existent availability of such seeds. This scarcity arises due to the substantial crop losses farmers typically incur, ranging from 30 to 70%, during the production of organic seeds. Addressing these challenges in organic seed production is essential to promote the adoption of sustainable agricultural practices and enhance the resilience of crops in the face of environmental changes.

Journey so far: Climate Resilient Paddy Seeds

'NET ZERO' Clean Paddy Seed i.e. Climate Resilient community Seed Development programme was taken under Phase-2 IBM-IORF Sustainability Project using Inhana Rational Farming (IRF) Technology. **The objective of the program was to undertake complete elimination of nitrogenous fertilizer, hormones and synthetic pesticides in order to produce quality- climate resilient seeds the prerequisite of climate resilient agriculture that will be responsive under low input production systems due to efficient resource utilization with the maintenance of the genetic diversity of food production.**

Clean Paddy Seed Programme has been initiated in July – October , 2022 with seed variety Satabdi Miniket (IET-4786) with conventional paddy seed sourced from market.

Outcomes: 1st generation Climate Resilient 'Net Zero' Clean Paddy Seeds

- Average yield of **4021 kg/ ha** obtained under **'NZ' Clean Paddy Seed program in comparison to convention paddy seed production (2850 kg/ ha),** exclusively demonstrated the relevance of **Inhana Plant Health Management** towards not only yield sustenance, rather yield improvement, especially significant, because this was obtained overcoming the extreme climatic events that occurred during the tillering and seed setting phase.

- The germination rate of the developed seeds was found to be **92% on an average, indicating a high seed viability.**
- Climate resilience of the seeds was evaluated through study of germination under water stress (GWS %), salt stress (GSS %), accelerated ageing (GAA%) and Electrolyte leakage (EC) and significantly higher value was obtained for 'NET ZERO' Clean Paddy Seed.
- Climate Resilience Index (CRI)" which was developed majorly as a function of seed germination under abiotic stress, **showed 35.5 % higher value as compared to conventional paddy seeds.**

The test results conclusively indicate **'NZ' Clean Paddy Seeds (1st Gen)** (*developed under IRF technology*), **as 'High Vigour' seeds, which indicates their potential to enhance the critical and yield-defining stage of crop establishment** - the primary objective of Safe & Sustainable Agriculture.

The 'NZ' Clean Paddy Seeds (1st Gen) was provided to the Project Farmers in about 10 ha. area for Boro Paddy Cultivation in Phase-II, IBM-IORF Sustainability Project at Nadia (West Bengal).

The 'NET ZERO' Clean Paddy Seeds, a breakthrough in sustainable agriculture, developed under West Bengal Project was provided to the Project Farmers of Phase-II, IBM-IORF Sustainability Project at Mandya (Karnataka).

This marks a significant milestone in Indian agriculture as it is the first instance where Safe & Sustainable 'Climate Resilient' Seeds have been employed for the cultivation of 'NET ZERO' Clean Paddy during the winter / Boro Paddy.

Notably, the innovation extends beyond the use of advanced seeds; it encompasses a holistic approach to sustainable farming. For the First Time in the Indian Agricultural Scenario that Safe & Sustainable 'Climate Resilient' Seeds has been used for Safe and Sustainable 'NET ZERO' Clean Paddy production (winter crop) at Mandya (Karnataka), through the utilization of Novcom Coir-pith Compost.

Climate Resilient 'NET ZERO' Clean Paddy Seeds *(1st Generation)* (Varity *:* Satabdi Miniket IET-4786), developed under IBM-IORF Sustainability Project at Nadia, West Bengal, India & distributed for Boro Paddy cultivation at Mandya, Karnataka (IBM-IORF Sustainability Project, Phase II) towards '**Net Zero' Clean Paddy Production in the farmers field (taken in 25.2 ha. Clean Food 'NET ZERO' (CFNZ) Model Development).**

OBJECTIVITY

Assessment of the efficacy of a high-quality paddy seed (Net Zero Clean Paddy Seed) in a distinct agro-climatic setting, particularly in less fertile soil conditions in terms of the adaptability and productivity of the seeds in these specific conditions.

The evaluation was conducted under same IRF Technology (Plant & Soil Health Management), with complete elimination of synthetic pesticides and fertilizers.

This study aims to determine how well the seed performs in challenging environmental conditions while adhering to sustainable and eco-friendly cultivation practices.

OUTCOMES: 2nd Generation CLIMATE RESILIENT 'NET ZERO' CLEAN PADDY SEEDS production under NET ZERO Clean Paddy Cultivation Programme (with in 25.2 ha. CFNZ Model) in Mandya, Karnataka

- Total area under Clean Paddy Net Zero: 1.8 ha.
- On- farm produced **Novcom Coir pith Compost** at 40 ton/ ha as well as various organic concoctions were used for **SOIL HEALTH MANAGEMENT** towards **elimination of Nitrate Fertilizers.** Elimination of N- fertilizers means **stoppage of N_20 Emission- another critical GHG**, while Restoration of Soil Biological productivity, through Novcom Compost application can initiate the regeneration process of **Soil-C Sequestration Potential-** a critical step towards GHG abatement .

- Adaptation to Climate Change was exhibited through the adoption of INHANA PLANT HEALTH MANAGEMENT (IPHM), driven by Inhana 'ENERGY SOLUTIONS'. IPHM has been adopted towards reactivation of Plant Physiology.

- The Dual approach of Soil & Plant Health Management was adopted in this program towards production of Clean Food 'NET ZERO'.

- The avg. productivity recorded 4335 kgs./ ha. under 'NET ZERO' CLEAN PADDY (about 7% higher productivity) compared to the avg. yield 4050 kg/ha. under conventional chemical practice of that region.

- GHG Footprint from 1.8 ha. '**Net Zero' Clean Paddy** under IRF Technology has been recorded **(-) 424.81 MT CO_2 eqv.** compared to **(+) 18.74 MT CO_2 eqv. Under same 1.8 ha. Conventional Chemical Farming Practice.**

- The quality parameters in terms of seed also has been studied for the 2nd Generation CLIMATE RESILIENT 'NET ZERO' CLEAN PADDY SEEDS production under NET ZERO Clean Paddy Cultivation Programme.

- **The germination % of the developed 'NET ZERO' CLEAN PADDY SEEDS (2nd Generation) was recorded 94.8%.**

- Climate resilience of the seeds was evaluated through study of germination under water stress (GWS %), salt stress (GSS %), accelerated ageing (GAA%) and Electrolyte leakage (EC) followed by "Climate Resilience Index (CRI)". **Seed viability test value for 'NZ' Clean Paddy Seeds was higher (95 % average) indicating their high quality as compared to conventional counterpart.**

The 2nd Generation 'NET ZERO' Clean Paddy Seeds, developed under Mandya, Karnataka Phase-II Project, IBM-IORF Sustainability Project were further taken for 'NET ZERO' Clean Paddy Seed Production in West Bengal, IBM-IORF Sustainability Project Phase – III (2023-24).

Objectivity:

Assessment of the Quality & Productivity Potential of the NZ Clean Paddy Seeds developed & passes two life cycles under the same IRF Technology in terms of Clean Paddy & NZ Clean Paddy Seed.

Net Zero Clean Paddy Production using 2nd generation Net Zero Clean Paddy Seed under IRF Technology

Introduction

Satabdi Miniket IET-4786 is a popular High Yielding Variety (HYV) majorly grown in winter months in West Bengal. Farmers retain a portion of their harvest to use as seed for the next season, is commonly known as farmer-saved seed or on-farm seed saving. It is considered in agriculture that using seeds saved over multiple generations may result in a loss of desirable traits and reduced overall productivity. This decline is often due to the natural genetic variability that occurs over time, leading to a less uniform and less productive crop. In modern agriculture, farmers often rely on certified seeds or seeds from reputable sources to ensure the quality and productivity of their crops.

Seed multiplication procedure is followed only for the certification of high yielding, hybrid varieties seeds which are notified under Seed Act 1966, to ensure genetic purity of high quality of notified varieties.

In this context, the focus is on evaluating the productivity potential and seed resiliency of second-generation paddy seeds. These seeds have been produced and managed using the same IRF Technology (under a complete Organic Plant and Soil Health Management) that was employed in the development of the initial seed generation. The assessment aims to understand how well these second-generation seeds perform in terms of productivity and resilience under the specified cultivation practices and technology.

This study contributes valuable insights into the sustainability and effectiveness of the IRF Technology in maintaining or enhancing the quality and performance of paddy seeds across generations.

Objectives

- Maintenance of HYV varieties under organic farming technology to reduce the chemical sensitivity of those varieties and to increase the resiliency of that variety.
- Development of organic quality seeds from organically propagated/maintained traditional and HYV varieties.
- Detailed comparative study of seed quality of source seed, organically propagated / maintained seed and organically developed quality seeds.

Clean Paddy Production using 2nd generation Net Zero Clean Paddy Seed under IRF Technology

A Program was undertaken by Inhana Organic Research Foundation (IORF), in Phase- III Project to develop Clean Paddy 'Complete Elimination of Pesticides and 100% Reduction of N-fertilizers' *(through Inhana Soil Health Management utilizing Novcom Compost)*

The program is driven by **Inhana Rational Farming (IRF) Technology** – a comprehensive Crop Technology for Safe & Sustainable Crop Production that undertakes the dual approach of Plant Health and Soil Health Management. **However, since conventional seeds were used for this program hence; a rigorous schedule of 'Plant Health Management' was undertaken to restore the inherent self- nourishment capability of the plant system.**

Soil Analysis Report

Soil quality was analyzed before main field preparation and post paddy harvest.

Sl. No.	Parameters	Before Initiation	Post Cultivation
1	Moisture %	31.31	24.66
2	pH	5.86	5.92
3	EC (1:5)	0.049	0.051
4	Av NO_3 (ppm)	33.60	28.34
5	Org. C %	0.95	0.98
6	Av-N (kg/ha.)	312.03	324.06
7	Av P_2O_5 (kg/ha.)	46.31	61.29
8	Av. K_2O (kg/ha.)	311.48	316.29
9	Av. SO_4 (kg/ha.)	28.56	19.46
10	MBC (microgram C/gm dry soil)	42.29	47.36
11	RESPIRATION (BR) (mg CO_2 /gm dry soil/day)	1.23	1.26
12	FDA (µg/gm dry soil)	20.65	23.29

Pre and post soil analysis in net zero clean paddy seed development program showed that there was slight improvement of soil quality in terms of soil available nutrient and soil microbial properties. However there was an incresing trend in soil microbial parameters which indicated that application of quality Novcom compost in the soil as part of soil nutrient management had an impact on soil health rejuvination.

Clean Paddy production using 2nd generation Net Zero Clean Paddy Seed under IRF Technology

Novcom Poultry Litter Compost made under Novcom Composting Technology of IORF. Compost Quality has been evaluated in terms of 18 different Physicochemical, Fertility, Microbiological and Stability, Maturity & Phytotoxicity Parameters.

Novcom Poultry Litter Compost Analysis Report

Test Parameters	Noncom Poultry litter Compost	Method
PHYSICOCHEMICAL PARAMETERS		
Moisture (%)	56.23	*Wolf & Wolf, 2003*
pH (H_2O)	6.58	*Black, 1965*
EC (dSm^{-1})	1.24	"
Organic carbon (%)	29.18	"
NUTRIENT & NUTRIENT DYNAMICS		
Total N (%)	1.79	"
Total P_2O_5 (%)	0.92	"
Total K_2O (%)	1.63	"
C:N	16:01	"
CMI	1.63	*Rekha et al, 2005*
BIOLOGICAL PARAMETERS		
Bacteria (c.f.u. per gm moist compost)	54×10^{16}	*Black, 1965*
Fungi (c.f.u. per gm moist compost)	39×10^{16}	"
Actinomycetes (c.f.u. per gm moist compost)	21×10^{16}	"
STABILITY		
CO_2 Evolution Rate ($mgCO_2$–C/g OC/day)	1.23	*Trautmann & Krasny, 1997*
MATURITY & PHYTOTOXICITY PARAMETERS		
Seedling Emergence (% Over Control)	99.66	*Trautmann & Krasny, 1997*
Root Elongation (% Over Control)	100.76	"
Germination Index (Phytotoxicity Bioassay)	1.00	"

All the compost samples appeared dark brown in colour with an earthy smell, deemed necessary for mature compost. Total NPK content was comparable to any good quality compost with C:N ratio around 16:1 indicated that all the compost samples were mature and suitable for soil application. The microbial population (in order of 10^{16} cfu in case of total bacteria, total fungi and total actinomycetes count) ensures speedy soil microbial rejuvination.

The different Stage of Operations towards Development of NET ZERO' Clean Paddy Seeds, Nadia, West Bengal, under IBM-IORF Sustainability Project Phase –III, 2023

Study Area: 1 bigha i.e. 0.13 ha.

Period: July – November, 2023

Seed Used: 2nd Generation NZ Clean Satabdi Miniket (IET-4786) paddy seed produced at Mandya, Karnataka under IRF Technology, was used for the program.

ORGANIC SEED BED PREPARATION: The Seed bed was prepared in 0.01 ha area. After 2 manual harrowing, **100 kg** Novcom Compost was applied in the seed bed. The land was kept for 7 days and after 3rd harrowing the bed was finally prepared.

MAIN FIELD PREPARATION: During the preparation of main field **Novcom Poultry litter Compost was applied @ 30 tons/ha**. at the time of 2nd ploughing and Seedling transplantation done about two weeks post compost application. CDS concoction was also applied @ 150 lit/ ha after 1st puddling and final puddling. Before transplanting in the main Field Leveling and Bund Construction was done.

SEED TREATMENT: Seeds were treated under IRF Technology. The seeds were soaked in water for 24 hrs. and then for 45 minutes in the water mixed with **Inhana Seed Treatment Solution (@ 1.5 ltr seed treatment solutions for the seeds of 1 ha). After 45 mins. all the seeds were put in a jute bag, the bag mouth was sealed and the bag was stored for 48 hours in a warm place.**

INHANA NURSERY MANAGEMENT PACKAGE: After the germination process, the Inhana Nursery Management Package was employed, involving the application of two distinct Energy Solutions**: NS-1 , NS-2 & NS -3 @200 ml solution in 0.01 ha. seed bed.** NS-1 was sprayed when the plants reached a height of around 3 to 4 inches. Following this, NS-2 was applied after a span of 7 to 10 days from the NS-1 application, and NS – 3 was applied after a span of 7 days from the NS-2.

The application of these energy solutions at specific growth stages contributes to the nurturing of the seedlings in the nursery.


Pic.: Nursery Bed (Ready for transplanting in the main field) (left); Application of Novcom compost before final land preparation (right) for cultivation of Climate Resilient 'NET ZERO' Clean Paddy Seeds under IBM-IORF Sustainability Project, Phase III, 2023.


Pic.: Land labeling before transplantation (left); uprooted Seedling Treatment (using Inhana Energy Solution) under IRF Technology before transplanting in the main field (right).

Pic : 25 days Seedling transplanting in the main field after seedling root deeping in Inhana seedling treatment solution

INHANA SEEDLING TREATMENT BEFORE TRANSPLANTATION IN THE MAIN FIELD:

Under IRF Technology Organic Seedling Treatment was done before the uprooted plants transplanting in the main field. 25 days seedling were taken out from the seed bed and made small bunches. Inhana Seed Solution II @ 200 ml. for seedling of 0.13 ha. was diluted in required quantity of water and the roots of the Paddy seedlings (of 0.13 ha.) were immersed properly. Then the seedlings were transplanted in the main field. The roots of the seedlings were soaked for 30 minutes and then air dried under shade before use.

Inhana Seed Solution II (for Seedling treatment) provides necessary stimulation towards, (i) Enhanced root growth for speedy establishment, (ii) Higher seedling vigor towards speedy growth and better tillering emergence, and (iii) Withstand transplanting shock and climatic stress.

TRANSPLANTATION : 25 days old seedlings with 4 – 5 leaf stages, after treatment were transplanted in the main land @ 3 – 4 Seedling in one bunch.

PLANT HEALTH MANAGEMENT IN MAIN FIELD

Different Inhana 'Energy' Solutions was applied on the paddy plants post Seedling Transplantation in the main field. Spraying was done at the different plant growth stages, in a scheduled manner.

9 Inhana Plant Health Management (IPHM) Spraying @ 200mL/ bigha, has been done as per Inhana Protocol at the different growth stages.

Objectivity: The objectives of this initiative encompass several key aspects. First and foremost, the aim is to eliminate the utilization of unwanted, unsustainable, and non-renewable energy sources. This aligns with the broader goal of fostering environmental sustainability.

Another focal point is the enhancement of plant physiological activity. This augmentation serves as a foundational pillar in ensuring robust and healthy plant growth. Moreover, IPHM acts as a catalyst for triggering the active host-defense mechanism within the plant system, further fortifying its resilience against potential threats.

Furthermore, IPHM seeks to bolster plant resilience against the backdrop of ever-changing climatic conditions. This resilience enhancement translates to increased resistance towards climatic fluctuations and the concurrent reduction of the toxicity burden on plants. No pesticides, growth promoters, hormones, micronutrients, was applied in this programme.

Pic.: Irrigation in the NZ Clean Paddy Plot (left); Inhana Plant Health Management Spraying (right) in 'NET ZERO' Clean Paddy Programme under IBM-IORF Sustainability Project, Phase III, 2023.

Pic.: Agronomic Data generation from field of 'NET ZERO' Clean Paddy Programme under IBM-IORF Sustainability Project, Phase III, 2023.

Pic.: Harvesting of paddy seedlings under Climate Resilient 'NET ZERO' Clean Paddy Production Program, Phase III, at Nadia, West Bengal, India.

INHANA PLANT HEALTH MANAGEMENT SPRAYING ON MAIN FIELD

Serial No.	Solutions sprayed	Dose of Application	Date
1	IB-7 + IB-13	1.8 ltr each / ha	5 Date after Transplanting (DAT)
2	IB-1 + IB-7	1.8 ltr each / ha	10 Date after Transplanting (DAT)
3	IB-2 + IB-7	1.8 ltr each / ha	15 Date after Transplanting (DAT)
4	IB - 3	1.8 ltr each / ha	20 Date after Transplanting (DAT)
5	IB-2 + IB-7	1.8 ltr each / ha	25 Date after Transplanting (DAT)
6	IB-6	1.8 ltr each / ha	30 Date after Transplanting (DAT)
7	SPL SOL-1	1.8 ltr each / ha	35 Date after Transplanting (DAT)
8	SPL SOL-2	1.8 ltr each / ha	42 Date after Transplanting (DAT)
9	SPL SOL-1	1.8 ltr each / ha	50 Date after Transplanting (DAT)

- *3 Rounds of Neem Oil Sprays have been done as alternative Pest Management along with Inhana Plant Health Management (IPHM) Package.*
- *No Inhana Spraying was done after fruit setting*

HARVESTING & YIELD RECORDING

- The harvesting was done in 2nd week of November, 2023 .
- Along with Net Zero Clean Paddy Plot Stage wise Agronomic Parameters, Yield, and End Product Quality have been recorded from Conventional Farming Practice of the same area.
- Both Pre & Post soil samples was collected & analyzed.

OUTCOMES OF THE NET ZERO CLEAN PADDY SEED PROJECT

- NO YIELD LOSS even, Higher Grain yield than conventional chemical farming Practice.
- Crop Sustainability through better plant resilience against adverse weather even when chemical practice reduced drastically.
- Sustainable Crop performance with consistent quality improvement in a same Miniket (IET- 4786) variety developed & maintained under the same Inhana Organic POP for two generations.

YIELD PARAMETERS OF PADDY CROP UNDER DIFFERENT MANAGEMENT

This year, the conventional miniket yield in the region has encountered a notable decline, with recorded yields ranging between 2700 and 2925 kg/ha. This decrease, amounting to 25% to 28% below the typical reference range of 3600 – 4050 kg/ha, can be attributed to several key factors.

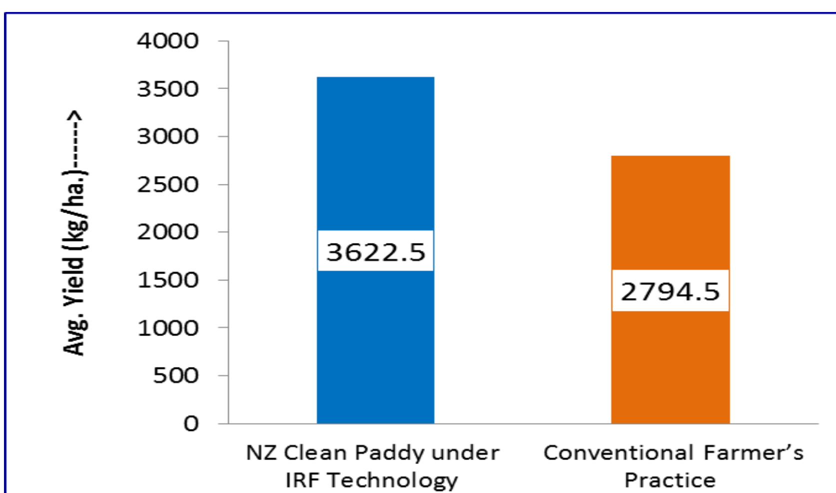
The primary challenges include inadequate and delayed rainfall, adversely affecting the crop's growth and development. Insufficient moisture during critical stages may have hampered germination, reduced tillering, and hindered overall plant health.

Furthermore, the comparatively higher incidence of pests and diseases has likely exacerbated the yield reduction. The increased prevalence of pests and diseases may have led to crop damage, affecting the plants' ability to photosynthesize and utilize nutrients efficiently.

Where as under NZ Clean Paddy Programme the achieved yield maintained the reference yield range 3622.5 kg/ha. probably due to the higher seed resiliency of the seeds developed & managed under organic environment for continuous two generations.

Whatever pest infestation occurred easily managed through alternative pest management (neem oils etc.) and Inhana Plant Health Management.

Avg. 29.63% higher Yield has been recorded under NZ Clean Paddy Programme compared to conventional farming practice, using the 2nd generation Paddy seed developed & managed under same IRF Technology.



Though Miniket Satabdi (IET - 4786) is HYV (high fertilizer responsive) shows significantly higher response compared to conventional farming practice even under 100% Fertilizer Reduction and Elimination of Chemical Pesticides.

The superior performance observed with the complete elimination of synthetic fertilizers and pesticides emphasizes the heightened resilience and improved adaptability of the 2nd Generation NZ Clean Paddy Seeds. Having successfully completed two life cycles under the same IRF Technology , these seeds exhibit a remarkable capacity to thrive in varying agro-climates.

This underscores their potential as a key component in promoting sustainable agricultural practices, showcasing their ability to respond positively to organic /sustainable farming practice.

The study provides valuable insights into the potential of IRF Technology towards development of a higher Quality Seed, when farmers opt out of using a conventional paddy seed for two consecutive years due to its lower yield potential under traditional farming practices. Inhana Plant Health Management plays a crucial role in enhancing the nutrient utilization efficiency of plants, resulting in improved responses under organic soil management done through the application of on-farm produced Novcom Compost.

Quality Analysis of 'NET ZERO' (NZ) Clean Paddy Seeds developed under IBM IORF Clean Seed Paddy Programme, Phase III 2023

Along with the Yield Assessment the Quality of the NZ Clean Paddy Seed was done in terms of its Physical & Climate Resiliency.

The paddy seeds were pure, free from any intermixed varieties, as indicated by the minimum presence of inert matter and absence of husk less and weed seeds .

Indian Seed Certification Standard vis- a- vis NZ Clean Paddy Seeds produced at Nadia, W.B.

Factor	Standards for each class		NZ Clean Paddy Seed developed using 2nd Generation NZ Clean Paddy Seed developed & maintained under IRF Technology
	Foundation	Certified	Miniket (IET-4786)
Pure seed (min.)	98.00%	98.00%	99.2%
Inert matter (max.)	2.00%	2.00%	0.08%
Huskless seeds (max.)	2.00%	2.00%	No
Other crop seeds (max.)	10/kg	20/kg	No
Total Weed seeds (max.)	10/kg	20/kg	No
Germination (min.)	80%	80%	94%
Moisture (max.)	13.00%	13.00%	9.82

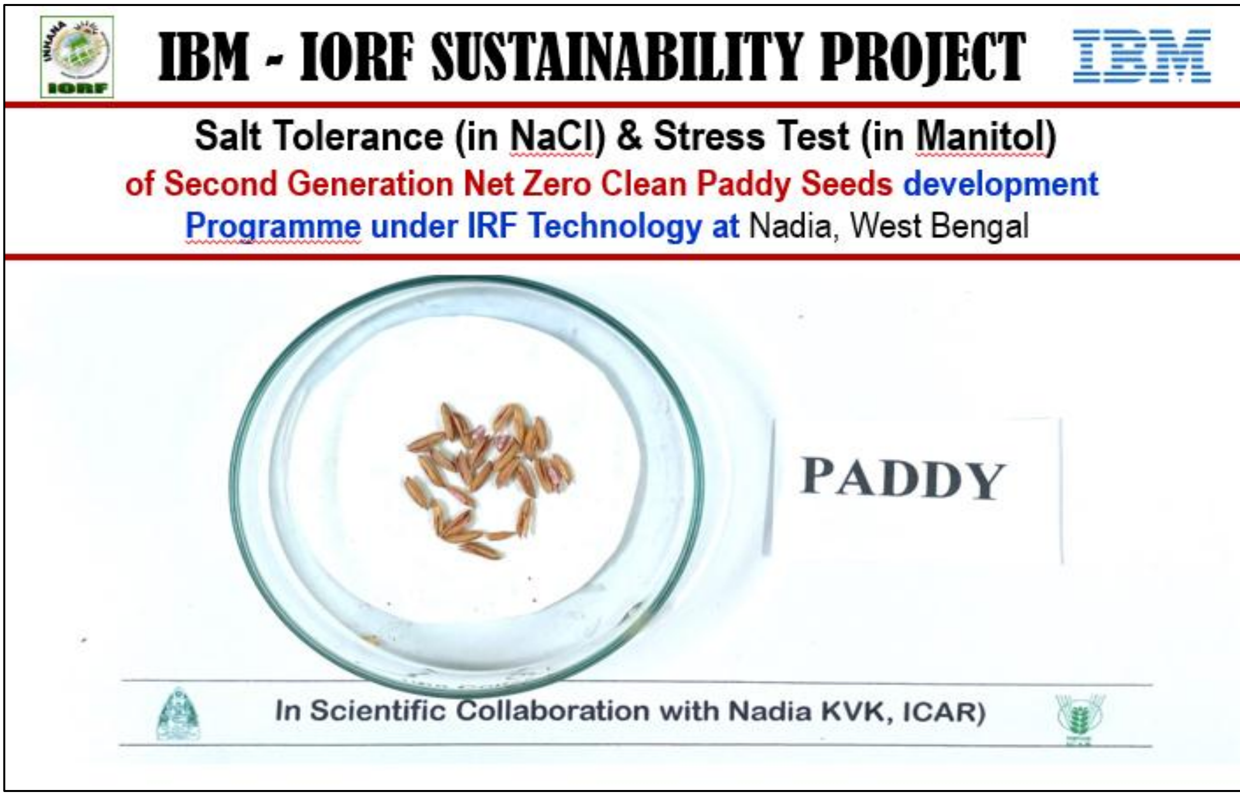
Proper seed moisture content is critical for seed storage and germination. Seeds with excessively high or low moisture content may lead to reduced viability, increased susceptibility to diseases, and poor storage stability. NZ Clean Paddy Seed produced under IBM-IORF Sustainability Project, Phase III is having the Moisture 9.82% compared to max. seed moisture as per Indian Standard is 13%.

Physical seed quality attributes are crucial factors that influence the performance of seeds in terms of germination, emergence, and establishment of plants. These attributes play a significant role in determining the success of crop production and are of utmost importance in sustainable agriculture.

Pic.: Physical Quality attributes study from 1000 Seeds (IET-4786) under Climate Resilient 'NET ZERO' Clean Paddy Production Program, Phase III, at Nadia, West Bengal, India.

Physical quality attributes of Net Zero Clean Paddy Seeds produced at Nadia, West Bengal.

Paddy Variety	Brown seeds %	Uneven seeds %	Unfilled grains %	Filling efficiency	Weight of 1000 grain(gm)	Fungi affected seeds %
Satabdi Miniket (IET-4786)	5.29	18.17	15	0.85	16.21	0.8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Salt Tolerance (in NaCl) & Stress Test (in Manitol)
of Second Generation Net Zero Clean Paddy Seeds development
Programme under IRF Technology at Nadia, West Bengal
PADDY
In Scientific Collaboration with Nadia KVK, ICAR)


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Salt Tolerance (in NaCl) & Stress Test (in Manitol)
of Second Generation Net Zero Clean Paddy Seeds development
Programme under IRF Technology at Nadia, West Bengal
11/9
Paddy
-0.3% NaCl
R1
In Scientific Collaboration with Nadia KVK, ICAR)

Comparative study of Seed Viability, Seed Vigor and Seed Resilience against Stress, of Clean Paddy Seed with intervention of IRF Organic Farming Technology.

Seed Quality parameters	Seed Viability		Seed Vigor			Seed Resilience against Stress			
	^{1}G %	^{2}SV %	^{3}GVI	^{4}SVI-I	^{5}SVI- II	$^{6}G_{WS}$ %	$^{7}G_{SS}$ %	$^{8}G_{AA}$ %	^{9}EC
Conventional Paddy Seeds (Farmers' Practice)	84	86.1	11.78	659.3	0.29	75	73.3	81.79	0.035
'Net Zero' Clean Paddy Seeds	96	99.12	14.96	780.3	0.32	79.3	76.2	84.41	0.027

Note : *^{1}G % : Germination %, ^{2}SV % : Seed Viability %, ^{3}GVI : Germination Velocity Index, ^{4}SVI-I : Seed Vigour Index-I, ^{5}SVI- II: : Seed Vigour Index-II, $^{6}G_{WS}$ % : Germination under water stress (-0.6 MPa induced osmotic potential); $^{7}G_{SS}$ % : Germination under Salt Stress (-0.6 MPa induced osmotic potential), $^{8}G_{AA}$% : Germination under Accelerated Ageing; ^{9}EC : Electrical Conductivity*

The Phase-II initiative of the 'NET ZERO' Clean Paddy Seeds development Programme, implemented as part of the IBM-IORF Sustainability Project under IRF Technology, is dedicated to elevating the quality and climate resilience of a widely used high-yielding variety (HYV) of Paddy Seeds in West Bengal. The primary goal is to achieve this enhancement through the adoption of organic/sustainable farming technology (IRF Technology), strategically aimed at mitigating the chemical sensitivity associated with these varieties. The program aligns with sustainable agricultural practices, prioritizing environmental and ecological well-being, with an overarching objective to foster a robust and resilient agricultural ecosystem in the region.

A groundbreaking development in Indian agriculture, the introduction of safe and sustainable 'Climate Resilient' seeds under IRF Technology under IBM-IORF Sustainability Project, marks a historic milestone.

First Time in the Indian Agricultural Scenario that Safe & Sustainable 'Climate Resilient' Seeds has been developed under IRF Technology and showed its potential towards Safe and Sustainable 'NET ZERO' Clean Paddy production (winter crop), through the utilization of Novcom Coir-pith Compost in a completely different Agro- climatic zone and further showed its prospect both in terms of its Productivity Potential & Climate Resiliency.

IBM - IORF SUSTAINABILITY PROJECT

MILESTONE 2

Development of 'NET ZERO' Clean Ginger Planting Material, in the project area at Mandya District of Karnataka

PHASE - III

SUMMARY

Development of ‘Clean Ginger Planting Material’ is an not very familiar in conventional farming system of ginger cultivation but deemed necessary in the backdrop of climate change impact specially changing rainfall pattern and increasing pest/disease in cultivation**. Moreover huge prevalence of seed and soil born disease** are the major challenges faced by the ginger **farmers**. At the same time, the technique involves raising transplants from single sprout seed rhizomes in the nursery and planted in the field after 60 days not only make the seedling disease free but less susceptible from soil born pathogens. The advantages of this technology are production of healthy planting materials, reduction in seed rhizome quantity, chemical fungicide and harbicide usage, requirement of irrigation and eventually reduced cost on seeds.

This objective of the present initiatives will focus on demonstrating a safe and sustainable pathway for ginger cultivation along with development of **Climate – Resilient, Disease free Clean Net Zero Ginger Cultivars – the primary tool for progression towards sustainable ginger cultivation t**hrough elimination of Chemical Pesticides and Reduction of N- fertilizers. **This Model perfectly aligns with the Indian Govt. Initiative ‘Bringing Innovative & Affordable Solution for Challenges Faced by the Farmers- Modern Technology to transform Agricultural practices’.**

Under IBM-IORF Sustainability Program we have initiated the program with organic cultivation of ginger to develop Climate resilient Net Zero Clean Ginger Seeds in the model farm at Mandya, Karnataka. More than 18 ton/ha productivity was achieved under IRF Package of Practice and the produced seeds were disease free and well above the conventional quality standard. This seeds were used for seedling developments in tubes as per the guiding protocol of IRF Technology.

Introduction

India is renowned throughout the world as "spice bowl" due to production and export of spices. The spices contribute 1.24 per cent to total export and 8.50 per cent to agriculture export (Karthick et al., 2015). Ginger is one important spice crop grown throughout the world. Ginger is botanically known as Zingiber officinale, belongs to family Zingiberaceae. It's an economically important cash crop grown for its aromatic underground rhizomes, which is used as a both spice and medicine purpose.

India is a leading producer of Ginger in the world. Ginger is cultivated in most of the states in India. Kerala, Karnataka, Meghalaya, Mizoram, Arunachal Pradesh, Sikkim, Nagaland etc., are major Ginger growing states in the country. During 2021 India ranked 1st in Ginger Production in the world with the production of 17.88 lakh MT. Ginger is cultivated in most of the states in India. The average productivity of ginger in India is around 10.72 tonnes/ha in 2021. In India, it is cultivated in all most all tropical and subtropical parts. Though grown all over India, five states Madhya Pradesh, Karnataka, Assam, West Bengal & Orissa contributes about 61.5% production share of the country.

World ranking based on Ginger Production: Year 2021

Rank	Country	Area (Hectares)	Production (tonnes)	Yield (hg/ha)	Share
	Top 10 countries	385,172	4,081,374	=	96.42%
1.	India	164,000	1,788,000	109,024	43.81%
2.	Nigeria	84,156	691,239	82,138	16.94%
3.	China	55,059	581,137	105,548	14.24%
4.	Nepal	22,132	297,512	134,426	7.29%
5.	Indonesia	8,077	174,380	215,897	4.27%

https://vtpc.karnataka.gov.in/storage/pdf-files/Ginger.pdf

Ginger production state-wise: India (2019-20)

Rank	State	Area (Hectares)	Production (tonnes)	Yield (Kgs/ha)	Share
	All India	172,040	1,843,530	10,716	=
1.	Madhya Pradesh	25,402	410,950	16,178	22.29%
2.	Karnataka	21,663	278,000	12,833	15.08%
3.	Assam	19,351	183,160	9,465	9.94%
4.	West Bengal	12,219	133,240	10,904	7.23%
5.	Orissa	16,573	128,000	7,723	6.94%

Source: https://numerical.co.in/

Ginger is one of the healthiest perennial herbs and considered one of the most important spices and an important cash crop of India. Globally, ginger is available in different forms such as raw ginger, dry ginger, bleached dry ginger, ginger powder, ginger oil, ginger oleoresin, ginger candy, etc. It is available in various forms depending upon its composition, agronomic conditions, curing methods, drying, and storage conditions. For over 5,000 years ginger has been recognized as the universal medicine by the ancient oriental of China and India. Today ginger remains a component of more than 50 per cent of the traditional herbal remedies. As per the research study, Global Ginger Industry is expected to grow with a CAGR of 3.13% from 2021 to 2027. (Source: TPCI -Trade Promotion Council of India.)

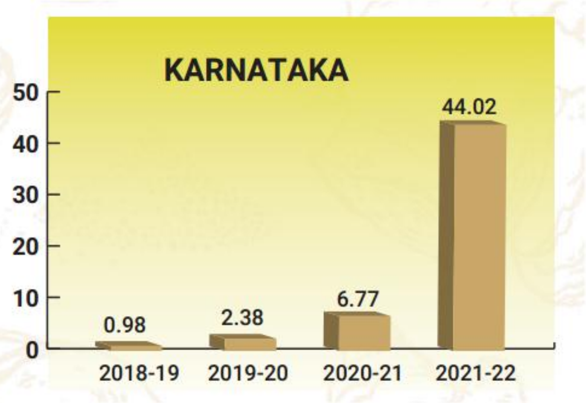
GINGER AS A VERY VALUE CASH CROP

The cultivation of the ginger crop is gradually increasing in Karnataka. Bhat et al. (2012) in their study stated that the higher profitability in ginger cultivation may have drawn many farmers to it. In 2017-18, the ginger crop area was 20,809 ha. Among the 30 districts in Karnataka, ginger crop area cultivation is the highest in Shivamogga and Hassan districts only.

Export Analysis of Ginger (Fresh or dried)

The global ginger & ginger processing market was valued worth of US$ 2.16 billion in 2018. This figure is expected to reach US$3.42 billion by 2023, proliferating at a CAGR of 6.6%. China is the largest exporter of ginger across the world, exporting over 50%, followed by Netherlands, Thailand, Peru and India.

Ginger Exports in India



Export of Ginger in India (Million USD)					
COUNTRY	2019	2020	2021	2022	CAGR, 2019-2022
Bangladesh	12.1	44.6	45.2	16.9	11.8%
Morocco	9.4	12.5	24.4	13.5	12.8%
United States	7.1	9.1	9.7	9.4	9.8%
United Arab Emirates	1.5	3.4	10.2	5.2	51.3%
Others	14.5	25.7	40.1	22.4	15.6%
Total	44.6	95.3	130	67.5	14.8%

India is a major producer of ginger, other than China, Nepal and Indonesia. Major export destinations of Indian ginger are Bangladesh, Saudi Arabia, UAE, Morocco, UK and US. As per the last year's trend, higher returns have prompted more farmers in Kerala, Karnataka and Maharashtra to substitute maize, cotton and tobacco with ginger.

Ginger Cultivation Challenges

Ginger is a highly succulent herb and its rhizomes are highly susceptible to different abiotic and biotic stresses. The soil-borne disease and nematode problems are high in ginger production. Among them major constraint in ginger production is rhizome rot complex disease. Rhizome rot or soft rot is the most destructive diseases of ginger worldwide caused by the association of fungi, bacterium and plant parasitic nematode (Dohroo, 2005). Rhizome rot or soft rot has been considered to be most destructive disease, causing huge economic losses in ginger growing areas (Stirling GR, 2009; Chattopadhya SB, 1997) is caused by the *Pythium spp.* (Le DP,2016; Lomavatu MF, 2009; Philip S,2005). Loss of ginger production by soft rot varies from place to place and ranged between 4- 100% (Stirling GR,2009; Nepali MB,2000). **The disease is both seed (**Thomas KM,1940; Park M,1941) **and soil borne; and survives between crops on infected seed rhizome.**

However this is not the only challenge. As ginger is prone to rhizome rot disease and the farmers do not want to risk crop failure, they use large quantities of chemicals—pesticides, herbicides, fungicides, insecticides and fertilizers—to prevent crop diseases and increase yield. Last year, a study conducted by the Centre for Ecological Sciences (CES) under the Indian Institute of Sciences, Bengaluru, found that indiscriminate use of chemicals has led to the loss of biodiversity and contamination of soil, rivers, lakes, streams and wetlands. “This has had adverse impacts on humans, cattle, flora, fauna and aquatic life,”

Objectivity of Development of Clean Net Zero Ginger Seedlings

Ginger cultivation in India specially in South India is presently facing several challenges due to changes of rainfall pattern, higher incident of seed and soil born diseases and depleting soil quality due to high usage of fertilizer and agro-chemicals. The situation was so complicated that it was advised to give at least 3 years gap after 1st year ginger cultivation to minimize risk of disease infestation. According to a report by DownToEarth 2015, farmers are ignoring is the harmful effect of ginger cultivation on the environment. Ginger is prone to rhizome rot viral disease. Since farmers do not want to risk crop failure, they use large quantities of chemicals—pesticides, herbicides, fungicides, insecticides and fertilizers—to prevent crop diseases and increase yield. Although a plot of land is leased for three to five years, farmers cultivate their crop for only a year and then move to newer pastures, leaving behind an infertile plot of land laced with pesticides.

In this background, under IBM-IORF Sustainability Project, Phase III the initiative was taken for the development of **Climate – Resilient, Disease free Clean Ginger Cultivars** – the primary tool for progression towards sustainable ginger cultivation through elimination of Chemical Pesticides and Reduction of N- fertilizers.

At the same time objectivity of development of disease – free – quality planting material was to eliminate risk of seed born disease , better resistance against soil born pathogens by healthy mature seedlings, reduce use of chemical pesticides, weedicides, irrigation and mandays resulting higher return potentials.

Analysis of Novcom Coirpith Compost

Coir pith is a recalcitrant agro-residue containing high amount of lignin and cellulose resisting decomposition by microorganisms under natural conditions. The management of deposited coir pith is becoming a critical issue as it is dumped as an agricultural waste for a long period of time.

The application of raw coir pith with wide C: N ratio can result in immobilization of plant nutrients. In addition, polyphenols and phenolics acids can be phytotoxic and inhibit plant growth. Due to the very high C:N ratio (100 : 1 or more) and very high lignin content (more than 40 %) in raw coir pith, the material is hard to degrade and the available composting techniques mostly do not provide the desired results.

Novcom Composting Method under IRF Technology has shown effectiveness in terms of enabling effective bio- conversion of coir pith into quality compost, supported by the detailed Compost Analysis Report and used for Soil Health Management in 'Net Zero' Ginger Cultivation in Mandya, Karnataka.

Large-scale Novcom coirpith compost prepared at Mandya, Karnataka under IBM-IORF Sustainability Project

The Compost are being evaluated as per Qualitative Parameters following National & International Stds. / 1

Test Parameters	Raw Coir pith	Novcom Coirpith Compost made using NOVCOM Technology under IBM-IORF Sustainability Project
PHYSICOCHEMICAL PARAMETERS		
Moisture (%)	**78.00**	72.17
pH (H_2O)	**5.90**	6.23
EC (dSm^{-1})	**3.21**	2.19
Ash Content (%)	**6.17**	52.26
Volatile Solids (%)	**93.83**	47.74
Organic carbon (%)	**52.13**	26.52
NUTRIENT & NUTRIENT DYNAMICS		
Total N (%)	**0.53**	1.09
Total P_2O_5 (%)	**0.08**	0.14
Total K_2O (%)	**1.31**	3.78
C:N	**98:1**	24:1
CMI	**-**	1.97

The Compost are being evaluated as per Qualitative Parameters following National & International Stds. / 2

Parameters	**Raw Coir pith**	Novcom Coirpith Compost made using NOVCOM Technology under IBM-IORF Sustainability Project
BIOLOGICAL PARAMETERS		
Bacteria (c.f.u. per gm moist compost)	-	$58X\ 10^{16}$
Fungi (c.f.u. per gm moist compost)	-	$21X\ 10^{14}$
Actinomycetes (c.f.u. per gm moist compost)	-	$31X10^{14}$
STABILITY, MATURITY & PHYTOTOXICITY PARAMETERS		
CO_2 Evolution Rate (mgCO_2–C/g OC/day)	-	1.85
Seedling Emergence (% Over Control)	-	87.50
Root Elongation (% Over Control)	-	98.32
Germination Index (Phytotoxicity Bioassay)	-	0.86
LIGNIN DEGRADATION STUDY		
Acid soluble lignin (ASL)%	**39.15**	0.74
Acid insoluble lignin (AIL)%	**0.65**	20.0
Total lignin %	**39.80**	20.74

Normal Raw Coirpith Nitrogen % approx. 0.5%, its optimum recovery or more specifically appreciation is utmost important for its quality. More than 100% Nitrogen appreciation from initial Raw Coir pith Sample found in the in Novcom Coir pith compost.

Lignin is the most abundant organic material; it decomposes very slowly due to complexity of its bonds and cross linkage. Coir pith is a recalcitrant agro-residue containing high amount of lignin (38.00 – 45.00%) and cellulose resisting decomposition by microorganisms under natural conditions. Lignin degradation, the major indicator of effective biodegradation specifically for Coirpith compost. Within 30 days the C:N ratio comes down to 24 :1 with about 76 % degradation & about 50% lignin degradation from raw coirpith value was recorded in Novcom Coir Pith Compost.

Microbiological count/population, the major strength of any Novcom Compost which is a critical component for any other coirpith composts. In the Novcom Coirpith Composts shows the values in the range of $X10^{14}$ - $X10^{15}$.

Demonstration of Novcom coirpith compost prepared at Mandya, Karnataka under IBM-IORF Sustainability Project

DEVELOPMENT OF NET ZERO CLEAN GINGER PLANTING MATERIAL UNDER IRF TECHNOLOGY

Under IBM-IORF Sustainability Project, Phase II ginger was taken under Coconut- based Net Zero intercropping Model. The model was developed with the adoption of Inhana Rational Farming Technology – a comprehensive organic package of practice. As part of soil health management, Novcom coir pith compost was applied @ 40 ton/ha towards complete elimination of chemical N- Fertilizers. Inhana Plant Health Management solutions were applied in a periodical manner towards development of healthy plants capable of withstanding biotic and abiotic stress. This helps elimination chemical pesticides and fungicides.

We have taken an exotic cultivar 'Rio - de - Janeiro' whish is also become very popular among cultivators. Carefully preserved seed rhizomes are cut into small pieces of 2.5 - 5.0 cm length weighing 20 - 25 g each having one or two good buds. The seed rate was about 1500 kg/ha. The seed rhizomes are treated with Inhana seed treatment solutions (10 ml/L of water) for 30 minutes, shade dried for 3 - 4 hours and planted at a spacing of 20 - 25 cm along the rows and 20 - 25 cm between the rows. The seed rhizome bits are placed in shallow pits prepared with a hand hoe and covered with well decomposed farm yard manure and a thin layer of soil and leveled. Sprinkler irrigation system was adopted for irrigation which reduces the requerement of irrigation water in comparison to conventional irrigation practice. In order to make the field free from weeds, we have done raw coirpith (mixed with fiber) mulching (8 tons/ha). It not only helps to control the weeds but also help to keep the soil moist and that results in comparatively longer irrigation round.

After 2 leaf stage, Inhana Plant Health management solutions were sprayed in periodical basis. Total 15 rounds of Inhana Plant health management solutions were used for plant health management of ginger. The recommended cultural practices and plant protection measures were adopted to raise a healthy crop

Organic Ginger seedling in the model farm at Mandya, Karnataka

Mulching of the soil with fibrous coirpith which helps to control weeds as well as preserve moisture

The Agronomic data were recorded from five randomly selected plants from each treatment in each replication and mean data was used for statistical analysis for thirteen diverse traits viz. plant height (cm), shoot diameter (cm), number of shoots, number of leaves, leaf length (cm), leaf breadth (cm), yield per plot (kg), yield per hectare (tonnes). The data was analyzed using the procedure of Panse & Sukhatme (1967).

Performance of ginger genotypes yield parameters under coconut ecosystem was recorded from Net Zero Ginger Cultivation Plot under IBM-IORF Sustainability Project, Phase II, Mandya, Karnataka.

No. Of Plots	Plant height (cm)	Shoot diameter (cm)	No. of shoots	No. of leaves	Leaf length (cm)	leaf width (cm)	Yield / plot (kg)	Yield (t/ha)
Plot/1	75.0	3.1	7.5	25	24.8	2.8	724	18.1
Plot/2	73.9	3.5	7.1	26	23.9	3.1	716	17.9
Plot/3	77.0	3.3	7.0	24	24.6	2.6	728	18.2
Plot/4	71.0	3.0	7.4	25	23.8	2.9	720	18.0
Plot/5	77.2	3.1	6.9	21	24.8	3.0	728	18.2
Avg.	74.82	3.2	7.18	24.2	24.38	2.88	723.2	18.08

Note : Agronomic parameters were recorded on 180 DAP

A significant 17.9 – 18.2 (avg. 18.08 tons/ ha.) tons/ha. yield was recorded under Coconut- based Net Zero intercropping Model (as Net Zero Clean Ginger Crop) that too demonstrated in the marginal soils (red gravelly soils with low soil fertility and microbial activity), deemed unfit especially for cultivation of nutrient sensitive short duration vegetable crops and that too with complete elimination of N- Fertilizers and chemical pesticides.

2 month old organic ginger seedling in the model farm at Mandya, Karnataka under IBM-IORF Sustainability Project

6 months old plantation for measuring agronomic data in the model farm at Mandya, Karnataka

Ginger flower and initiation of ginger rhizome in the ginger plots an model farm, Mandya, Karnataka under IBM-IORF Sustainability Project

Mature ginger rhizome in the ginger plots at model farm, Mandya, Karnataka under IBM-IORF Sustainability Project

Significant yield increase under the program was due to soil and plant health management under IRF Technology. High population of self generated native soil microflora not only help to established a dynamic soil-plant – nutrient relationship but at the same time eliminates the risk of any soil born disease infestation. On the other hand, plant health management under IRF technology helps towards developing efficient plant functioning resulted in higher immunity and better nutrient uptake and utilization efficiency.

Ginger rhizome from the project plots at Mandya, Karnataka under IBM-IORF Sustainability Project indicated larger size of rhizome is related to better soil and plant health management

NET ZERO CLEAN GINGER SEEDLING DEVELOPMENT

Ginger is conventionally propagated through seed rhizomes, which are carefully preserved and cut into small pieces of 2.5-5.0 cm length, each weighing 20-25 g and containing one or two good buds. The seed rate may vary by region. In Kerala, the seed rate varies from 1500 to 1800 kg/ha. At higher altitudes the seed rate may vary from 2000 to 2500 kg/ha *(ICAR-Indian Institute of Spices Research, Kozhikode, Kerala, 2015)*. These rhizome bits are then placed in shallow pits, prepared with a hand hoe, covered with a layer of soil, and leveled for optimal growth.

Though transplanting in ginger is not conventional, Inhana took the initiative for developing ginger seedling using single bud sprout to produce good quality planting material with reduced cost. **The objectivity of this initiative towards production of highly resilient, healthy planting materials and reduction in seed rhizome quantity and eventually reduced cost on planting material and at the same time reduced growing period & cultivation cost as farmers can easily plant of 50-60 days seedlings in the field.**

Experience of Net Zero Clean Ginger cultivation under IBM-IORF Sustainability Project was shared at a State-level workshop on ginger and turmeric crop organized by University of Horticultural Sciences, Karnataka.

Steps followed towards development of Net Zero Clean Ginger Seedling Development under IBM-IORF Sustainability Project at Mandya, Karnataka

Sourcing of Ginger Seeds locally from Mandya District, Karnataka

→ Selection of Healthy Ginger Rhizomes for seed purpose

→ Seeds were soaked in Inhana Seed Treatment Solutions for 30 mins., & dried under shades

→ seed rhizomes are cut into single buds with small piece of rhizomes weighing 8-10 g

→ Filling the plastic tubes of 6" X 8" with Soil & Novcom Coir pith Compost in 70: 30 ratio.

→ Planting the ginger buds sprouts in the tubes

→ IPHM PoP solution application initiated at 3" seedling height

→ Total 5 rounds of Inhana Plant Health Management Solutions were applied as per schedule.

→ Tubes are kept cleaned by manual weeding & Need based Irrigation was done.

→ Healthy Seedlings are ready by 60 days for Transplanting

Activity towards ginger seedling development under IRF package of Practice at model farm, Mandya, Karnataka under IBM-IORF Sustainability Project

Soil physical, physicochemical, fertility, biological properties and soil quality indices in the Pre & Post Net Zero Ginger Cultivation Plot, Mandya, Karnataka.

Physico Chemical & Fertility Parameters							
Parameters	pH (H2O)	ECe	Org. C	Av P2O5	Av. K2O	Av- SO4	Av NO3
		(dSm-1)	%	< ------------kg/ha------- >			ppm
Pre Ginger Cultivation Soil	6.01	0.48	0.46	28	827	800	33.74
Post Ginger Cultivation Soil	6.07	0.44	1.49	42	691	605	34.44

Physical Parameters								
Parameters	Sand %	Silt%	Clay%	Texture	Aggregates	Bulk Density	Soil Depth	Coarse Fragment
Pre Ginger Cultivation Soil	81.98	1.76	16.26	Sandy Loam	V Low	1.34	Strong limitation	V. Strong limitation
Post Ginger Cultivation Soil	84.14	1.60	14.26	Sandy Loam	medium	1.27	Strong limitation	Strong limitation

Biological Parameters						
Parameters	MBC	FDA	Microbial Quotient (qMBC)	Metabolic Quotient (qCO_2)	q FDA	Qr
Pre Ginger Cultivation Soil	12.01	4.62	0.26	1.88	0.100	0.017
Post Ginger Cultivation Soil	55.57	30.24	0.37	1.32	0.203	0.018

Soil Indices				
Parameters	FI	MAP	PI	SQI
Pre Ginger Cultivation Soil	10.86	3.03	6.6	0.12
Post Ginger Cultivation Soil	19.43	9.33	12.1	0.31

Class	Color Index
Very Poor	
Poor	
Moderate	
Moderately high	
High	
Very High	

Pre and Post Soil Quality Analysis of ginger plots

Soil samples were taken at the initiation of the study and at the last end of the harvesting stage to study the impact of soil health management under 'Net Zero' Ginger Cultivation program. The initial study confirms that the soil is very poor in terms of soil carbon and fertility status as well as soil microbial activity. Above all presence to small to medium size gravels in more than 50 % (by weight) make the soil practically unsuitable for any sensitive crop cultivation.

Evaluation of soil quality under 'Net Zero' Ginger Cultivation plot pre and post experimentation revealed no considerable changes in soil pH and EC. However, increase of organic carbon % have been observed **> 200** % which was mainly due to application of Novcom coir pith compost @ 40 ton/ha. Due to soil Health Management with the application of NOVCOM COIRPITH COMPOST & on-farm CDS Concoctions, made under IRF Technology of IORF, the % increase in the organic carbon status have been observed even in a very short cultivation period of 7-8 months, but most importantly it is much higher than a mere additive effect.

Soil micro-organisms play a crucial role in governing the dynamics of organic matter decomposition and the availability of plant nutrients. A higher value of soil microbial pollution, soil microbial biomass carbon (MBC), and its activity, as indicated by FDAH activity post soil analysis, suggests the positive impact of Novcom coir pith compost on the rejuvenation of soil microflora. This can be attributed to the exceptionally high microbial presence in Novcom coir pith compost, reaching one trillion billion microbes per ton of compost. Upon application, this compost facilitates the rapid regeneration of microbes in the soil. The overall reduction of synthetic fertilizers and pesticides also contributes to creating a toxicity-free environment, fostering conditions conducive to an increased microbial population. Overall development of soil represented by four indices viz Soil Fertility Index (FI), Microbial Activity Potential (MAP), Physical Index (PI) and overall Soil Quality Index (SQI) indicated that the effectivity of Inhana Soil Health Management under IRF Technology even within the very short period of 9-10 months.

Dr. P. Das Biswas, Founder Director, Inhana Organic Research Foundation (IORF), Kolkata sharing his experience from IBM-IORF Sustainability Project on the topic 'Attaining Sustainable Development Goals (SDGs) through Sustainable Agriculture : The best way to Instigate Climate Change Mitigation and Livelihood Regeneration' at TechForGood India Conclave, 2024 organized by Nascom Foundation at New Delhi

Dr. P. Das Biswas, sharing some points on Sustainable Agricultural Models developed under IBM-IORF Sustainability Project with Mrs Nidhi Bhasin, CEO, Nascom Foundation' at TechForGood India Conclave, 2024 organized by Nascom Foundation at New Delhi

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IBM - IORF SUSTAINABILITY PROJECT

MILESTONE 3

Development of 'NET ZERO' Clean Millet Seeds; for Food Security and Farmers' Welfare, aligning with the 'Indian Millet Initiative', in the Project area at Mandya District of Karnataka

PHASE - III

Summary

The significance of millets extends beyond mere sustenance; it embodies a harmonious relationship between nature, nutrition, and livelihoods. The Prime Minister's emphasis on India's Millet Mission naming it as Sri Anna, underscores a transformative initiative with far-reaching implications, extending beyond agriculture to impact millions of lives. This mission is poised to be a game-changer for the 2.5 crore millet-producing farmers in India, promising economic uplift ment and empowerment.

Ragi, a staple food in Karnataka and a crucial crop in the state, offers a promising solution to the perennial water distress the region faces, thanks to its drought-resistant nature. **In spite of several challenges, 'Net Zero' Clean Millet Programme under IBM-IORF Sustainability Project Phase – II, revealing more than 50% higher ragi productivity (2210 kg/ha.) compared to conventional yield of ragi crop in Mandya district. Moreover, the productivity surpassed the state average by 24%, emphasizing the success of sustainable practices in enhancing ragi cultivation, which holds significant potential for addressing water scarce agriculture and promoting agricultural resilience in Karnataka.**

Recognizing the pivotal role of seeds as the foundation for sustainable millet cultivation, it is imperative to strengthen and enhance the efficiency of millet seed systems for overall production improvement. The successful demonstration by IRF Technology highlights the effectiveness of Climate-Resilient Net-Zero Millet Seed (specifically Ragi/Finger Millet) production in boosting crop productivity, even with locally-adapted varieties in Mandya, Karnataka. **A significant 2289 kg/ ha. yield of Ragi was recorded under 'Net Zero' Clean Millet Seed production programme which was upto 24.8 % higher than conventional farmers practice.** The benefits in terms of higher return per unit area, can provide huge potential for quality & quantity as well as utilization in rainfed agriculture, involving the distribution of Net-Zero Clean Millet Seeds (Ragi/Finger Millet) along with the Inhana Plant & Soil Health Management Package to local farmers. This approach aims to not only improve millet production but also foster sustainability and resilience in agricultural practices.

BACKGROUND

According to World Food Programme Millets are considered traditional food for 1.2 billion people across Asia and Africa. It requires less water and other agricultural inputs than other similar and higher stress tolerant staples. Millets are important by the virtue of its mammoth potential to generate livelihoods, increase farmers' income and ensure food & nutritional security all over the world. **Millets were also known as "coarse cereals" or "cereals of the poor" but now rebranded as "Nutri Cereals"**. The relevance has multifolded when UN amend the 2023 as the International Year of Millets. Among the various benefits most prominent are Health Promoting Nutritious Crop, Superior Micronutrient Profile, Bioactive Flavonoids, low Glycemic Index & Gluten free. Millets could be key to ensuring food and nutrition security, resource sustainability, and economic empowerment. Thus, it is critical to create policies towards reversing the global trends of decreasing consumption and production of millets, and enhance consumer awareness of their nutritional and health benefits.

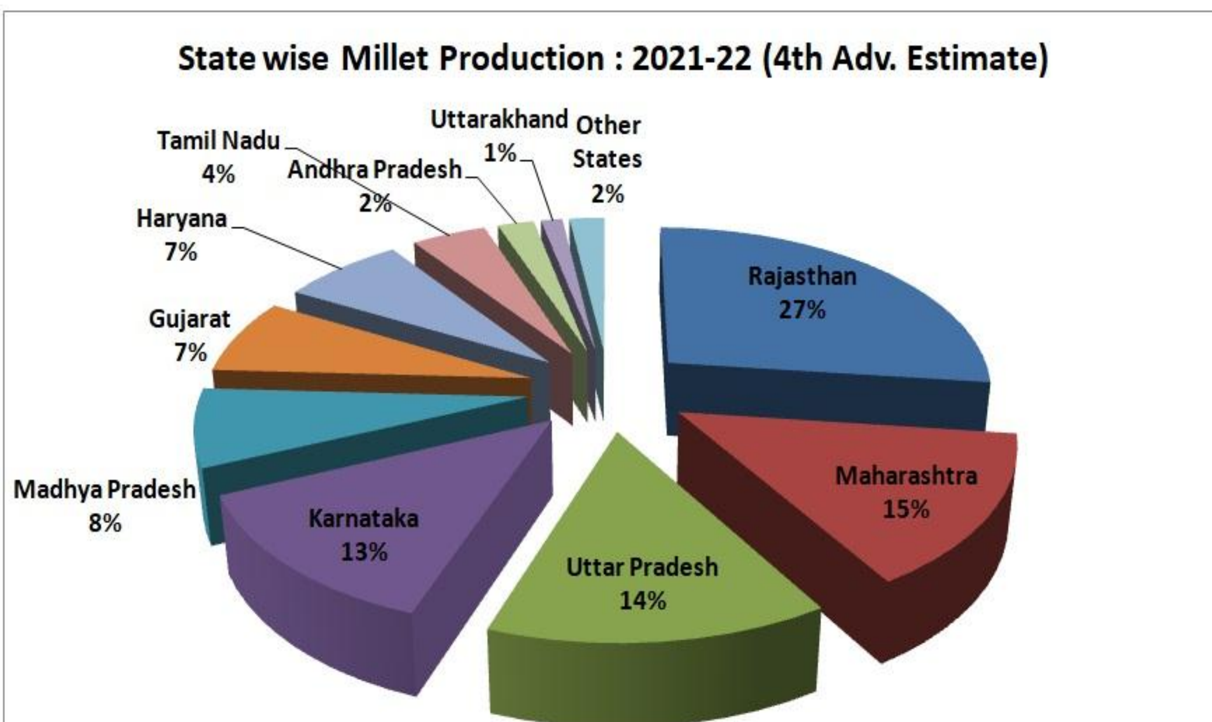
GLOBAL & INDIA'S MILLET SCENARIO

Millets are mainly grown in tropical, sub-tropical and slightly temperate regions of the world, with Asia and Africa accounting for major production and consumption centers. Global production of millet is about **97.75 million tonnes** from **78.43 million hectares** area. India is the leading producer of millets. Most of the states of India grow one or more millet crop species. A total of about **16.9 million tonnes of millets food grains are produced in India, about 17 percent of global production, from nearly 12.7 million ha area, which constitutes about 6% of the national food grain basket. (B Venkatesh Bhat, 2023).**

Millet consumption in India dropped post the Green Revolution when other staple grains underwent major genetic research to increase crop yields. Increasing crop yields and shifting consumer demand side-lined millets to the rural areas of India. The overdependence on rice and wheat has resulted in a decline in millet consumption over time. Therefore, millets are underused and neglected crops due to a lack of awareness among the general.

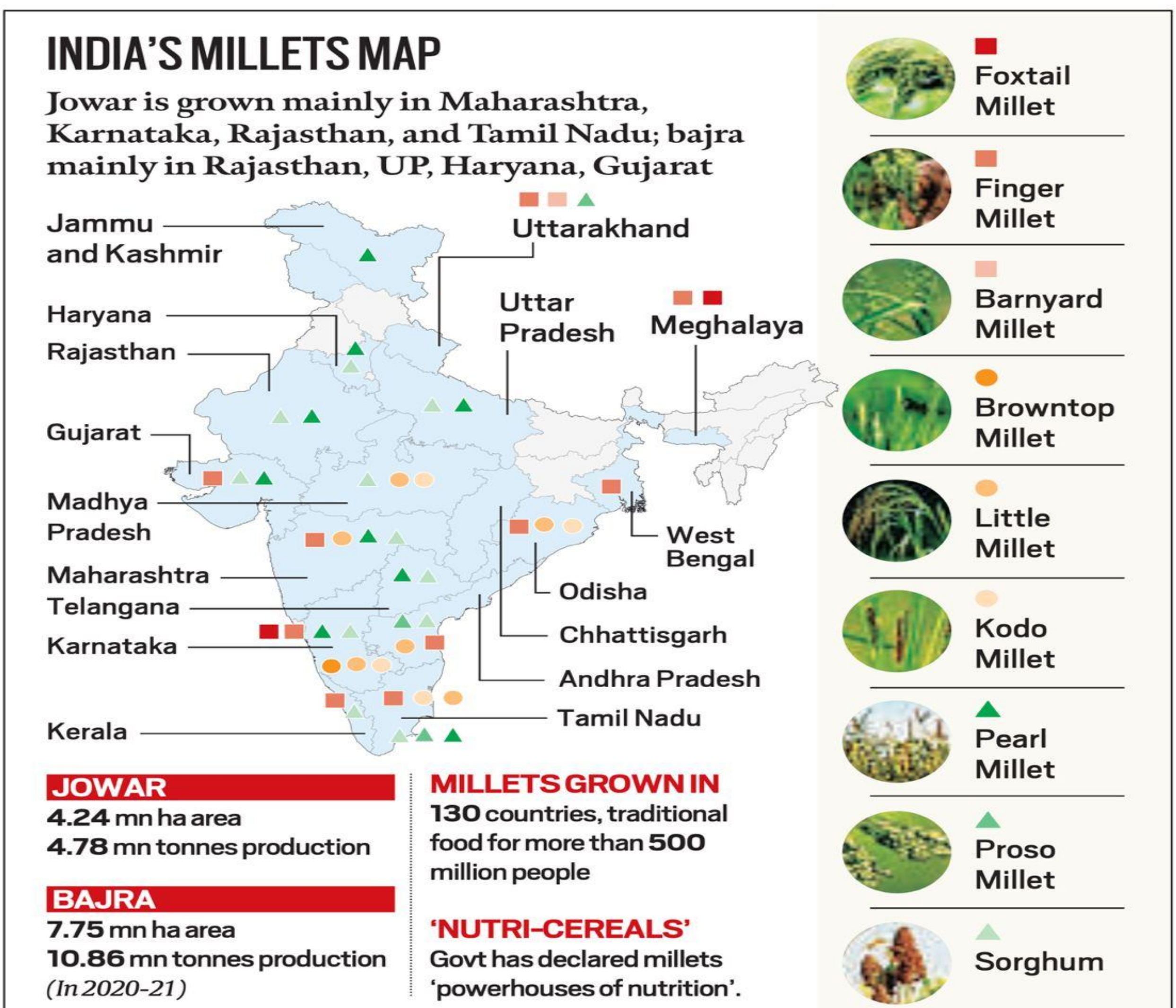
Rajasthan has the highest area under millets cultivation (29.05%) followed by Maharashtra (20.67%), Karnataka (13.46%), Uttar Pradesh (8.06%), Madhya Pradesh (6.11%), Gujarat (3.94%) and Tamil Nadu (3.74%). Ragi & Sorghum are two major millets grown over Karnataka.

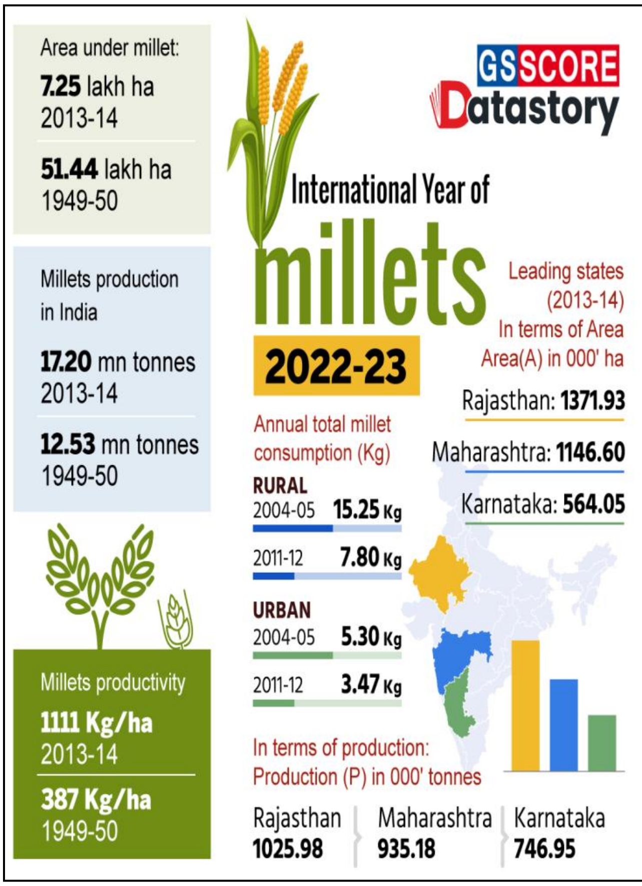
The highest yields 2021-22 were recorded in Andhra Pradesh (2626.58 kg/ha), Tamil Nadu (2153.22kg/ha), Haryana (1906.78 kg/ha), Gujarat (1762.05 kg/ha) and Madhya Pradesh (1729.70 kg/ha). The states like Gujarat and Andhra Pradesh have shown better productivity levels as compared to their counterparts (Ref. Millets, The Future Super Food for India, 2022. MOFPI, ASSOCHAM). The productivity of millet in Karnataka is 1255 kg/ha.



Source: https://apeda.gov.in/milletportal/Production.html

The Prime Minister highlighted the significance of India's Millet Mission, **"India's Millet Mission will prove to be a boon for 2.5 crore millet producing farmers of the country".** Based on India's proposal, the year 2023 was **declared the International Year of Millets (IYM) by the United Nations General Assembly (UNGA). In line with the Prime Minister's vision to make the celebrations of IYM 2023 a 'people's movement' and position India as the 'global hub for millets' all central government ministries/departments, states/UTs, farmers, start-ups, exporters, retail businesses and other stakeholders are being engaged to promote and spread awareness about the benefits of millets (Shree Anna) for the cultivator, consumer and climate.** *(ref. https://pib.gov.in/PressReleasePage.aspx?PRID=1908322).* 'Sri Anna' means the best among all the food grains.





Karnataka Millet Production Scenario 2021-22*			
Millet 2021-22*	Area (lakh ha)	Production (lakh tonns)	Productivity (kg/ha)
JOWAR	6.23	9.04	1204
BAJRA	1.47	1.71	1161
RAGI	8.49	11.33	1334
SMALL MILLETS	0.27	0.29	789

**4th Advanced Estimate Source: Directorate of Millets development, Jaipur*

Millets : A Healthier Option.

FAO, UN: Rich in heritage and full of potential, millets are a sustainable, nutritious and under-valued food source.

- Millets, being a short-duration and climate-resilient crop that can be grown even in harsh, hot (up to 50°C), and dry environments and respond well to available nutrients.
- Compared with commonly known cereals, millets can grow under drought and non-irrigated conditions as they have a low water footprint hence, the most secure crops to small farmers.

- The ability of millets to grow in poor, degraded soils can also provide land cover in arid areas, reducing soil degradation and supporting biodiversity.
- Higher efficiency to absorb and use carbon dioxide - as **C4 crops, millets have higher efficiency in absorbing and utilizing carbon dioxide.**
- Millet production requires comparatively a low initial capital investment.
- The global Millets market was valued at US$ 9.95 billion in 2020 and is projected to reach US$ 14.14 Billion in 2028, growing at a CAGR of 5% from 2021 to 2028 .
- They are rich sources of nutrients, such as carbohydrates, protein, fibre, and good-quality fats, and contain significantly higher amounts of minerals, such as calcium, potassium, magnesium, iron, manganese, zinc, and B-complex vitamins. Millets are an excellent source of slow digestive starch and fibre.
- The high carbon content of the crop residues also helps maintain and increase soil carbon and provide forage for livestock.

Limitations Millet Production

- Millet cultivation dropped from 35 million hectare in 1960 to less than 15 million hectare in 2021.Major reasons for decline;
- Compared to wheat, rice and maize, millets have lower productivity in the country. This is attributed to farmers cultivation in marginal lands in rainfed farming , non availability of quality seeds/ cultivars and non-adoption of any sustainable technology.
- Lack of access to quality seeds.
- Lack of commercialization.
- Lower shelf-life of millet grains & flours.
- Poor Farmers awareness on benefits of millet cultivation, including its high nutritional value and resilience to drought.
- Govt. Policies favoring irrigated crops viz. Rice, wheat etc. with input subsidies.

- Most unorganized, farmers grow millets primarily to feed their families rather than for commercial sale, less focus on maximizing yields or adopting advanced agricultural practices.

- Lower profitability and lack of commercialization leading to millets being less remunerative crops due to lower yields coupled with declining prices due to vulnerable quality to environmental factors (e.g., as in the case of Kharif Sorghum).

- No focused policies / technologies towards yield growth and area expansion.

- Inadequate support to research efforts for improving the millets cultivation: While aligning more resources for the improvement of fine cereals, millets were not given adequate importance in research and development on improved varieties, productivity, diversification of processing technologies and marketing.

Millet cultivation in the project area, Mandya, Karnataka under IBM-IORF Sustainability Project

Net Zero Clean Millet Seed Development at Mandya, Karnataka

Background

Ragi is one of the prominent crop of Karnataka. **In 2019-20, ragi was sown in 6.74 lakh hectares with the production of 11.32 Lakh tonns, average productivity 1769 kg/ha.** In the state, Ragi is grown in Bengaluru Rural, Bengaluru Urban, Chikkaballapur, Chitradurga, Chikkamagaluru, Hassan, Kolar, Mandya, Ramanagara, Tumkur, Ballari and Davangere districts. In 2019-20 Ragi cultivation in Mandya Dist. Was done in about 48,000 hectare (7% area of the state) area with the production of 65,000 tonns (5.7% production share of the state), avg. productivity 1427 kg/ha (20% less productivity of the state).

Under IBM-IORF Sustainability Project, Phase II Ragi was taken in 4 ha. area under Net Zero Clean Food 25.2 ha. Model. The model was developed with the adoption of Inhana Rational Farming Technology – a comprehensive organic package of practice.

In the net zero clean food production system under IRF technology, the seeds of finger millet were treated with Inhana seed management solutions before sowing. As part of soil health management, Novcom coir pith compost was applied @ 40 ton/ha was applied as the basal dose at the time of sowing during both the years. Inhana Plant Health Management solutions were applied in a periodical manner towards development of healthy plants capable of withstanding biotic and abiotic stress. This helps complete elimination of chemical pesticides.

The avg. productivity achieved under Net Zero Ragi Production under IBM-IORF Sustainability Project Phase – II , 2210 kg/ha. even after using the locally available conventional Ragi seeds.

More than 50% higher Ragi Productivity achieved under IBM-IORF Sustainability Project Phase – II under 'Net Zero' Clean Millet Programme (2210 kg/ha.) compared to conventional ragi productivity of Mandya district and even 24% higher productivity achieved compared to the State's productivity.

Development of 'NET ZERO' Clean Millet Seeds in IBM-IORF Sustainability Project Phase-III; aligning with the 'Indian Millet Initiative'- India's Millet Revolution is driven by growing awareness in respect of both human health and the environment, to revive traditional agricultural practices and promote sustainable agriculture and support small-scale farmers.

About 48% of the total cultivated area in the Mandya district is under millets, out of which <10% area under Ragi cultivation, lack of quality seeds forms the major challenge for the millet farmers. Availability of Climate- Resilient Quality seeds forms the baseline for all of the above and this particular initiative will focus to bring forth a safe and sustainable pathway to produce that. The initiative of developing et Zero Clean Millet Seed has been taken assuming that this climate resilient quality Net Zero Ragi Seed is having the potential for further productivity enhancement under IRF Technology.

Net Zero Clean Millet Seed Development under IRF Technology (IBM-IORF Sustainability Project, Phase –III, 2023-24)

SEED SOURCE: Seeds used for Net Zero Clean Millet Seed Production were sourced from the Net Zero Clean Ragi Production programme of Phase –II.

SOIL HEALTH MANAGEMENT: On- farm produced **Novcom Coir pith Compost at 40 ton/ ha** as well as various organic concoctions (CDS & P5 etc.) were used for SOIL HEALTH MANAGEMENT towards elimination of Nitrate Fertilizers. Bioconversion of coir pith to a quality compost through Novcom composting Technology and application of this compost for sustainable soil management and removal of synthetic chemical fertilizers are the keys towards attending Clean Food 'Net Zero' objectives.

Novcom coirpith compost was prepared for soil health management in the project area, Mandya, Karnataka under IBM-IORF Sustainability Project

Analysis of Novcom Compost Quality

The compost developed with Novcom Technology provides the energized environment for regeneration of soil fauna. Hence, application of even a small quantity of the compost brings about a noticeable change in the soil in the shortest possible time. Final Novcom coir pith compost (30th day) were evaluated for 19 different quality parameters as per National and International standards. The samples were analyzed for physicochemical properties, microbial population, maturity and phytotoxicity parameters.

Effective degradation of organic matter as demonstrated by the rapid decline of C:N ratio from 102:1 to < 27:1, appreciation of total nitrogen by >100 percent and 44 % degradation of lignin within a 30 days' time period. And the values are corroborated by the respective very high **(in the order of 10^{16} c.f.u. per gm or One Trillion Billion Microflora per ton compost)** population of bacteria, fungi and actinomycetes.

Pic. Large scale Novcom coir pith composting at Mandya, Karnataka for Clean Food 'Net Zero' program

Physicochemical properties, fertility parameters and lignin content of 30 days Novcom coir pith compost utilizing Novcom Composting Technology.

Test Parameters	Raw Coir pith	Novcom Coirpith Compost made using NOVCOM Technology under IBM-IORF Sustainability Project
PHYSICOCHEMICAL PARAMETERS		
Moisture (%)	78.00	70.95
pH (H_2O)	5.90	6.68
EC (dSm^{-1})	3.21	2.23
Ash Content (%)	6.80	50.50
Volatile Solids (%)	93.20	49.50
Organic carbon (%)	51.78	27.50
NUTRIENT & NUTRIENT DYNAMICS		
Total N (%)	0.51	1.03
Total P_2O_5 (%)	0.08	0.16
Total K_2O (%)	1.36	3.59
C:N	102:1	27:1
CMI	-	1.84
BIOLOGICAL PARAMETERS		
Bacteria (c.f.u. per gm moist compost)	-	78×10^{16}
Fungi (c.f.u. per gm moist compost)	-	21×10^{16}
Actinomycetes (c.f.u. per gm moist compost)	-	11×10^{16}
STABILITY, MATURITY & PHYTOTOXICITY PARAMETERS		
CO_2 Evolution Rate ($mgCO_2$–C/g OC/day)	-	1.63
Seedling Emergence (% Over Control)	-	97.50
Root Elongation (% Over Control)	-	98.45
Germination Index (Phytotoxicity Bioassay)	-	0.96
LIGNIN DEGRADATION STUDY		
Acid soluble lignin (ASL)%	40.15	0.89
Acid insoluble lignin (AIL)%	0.65	21.85
Total lignin %	40.80	22.74

INHANA PLANT HEALTH MANAGEMENT (IPHM) UNDER IRF TECHNOLOGY

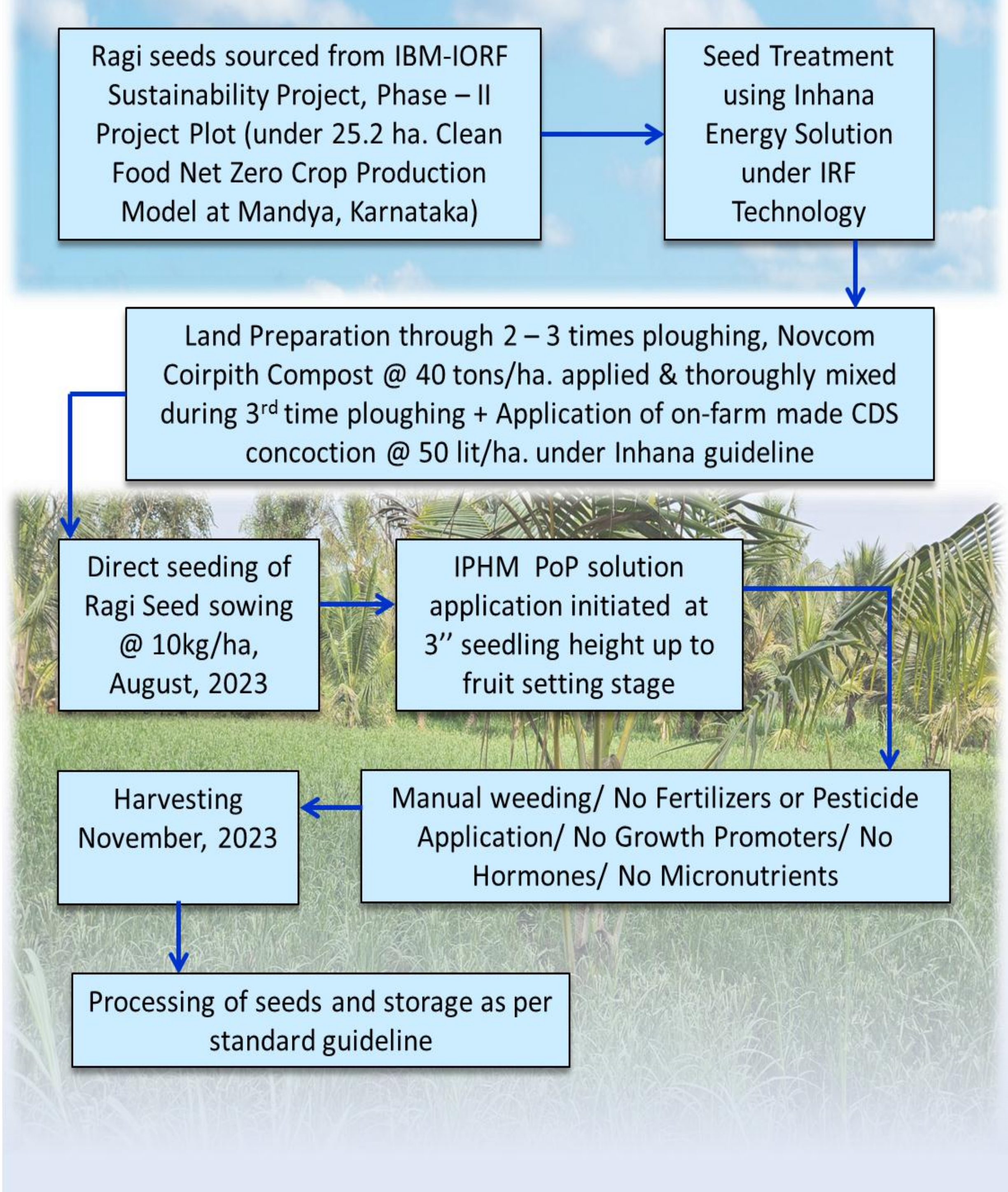
IRF Technology places a spotlight on PLANT HEALTH MANAGEMENT a pivotal yet often overlooked element in Sustainable Agriculture. Its primary objective is to invigorate, stimulate, and rejuvenate the physiological, metabolic, and biochemical functions of plants. This process is crucial for enhancing agronomic efficiency and bolstering the immunity and defense mechanisms of plants against pests and diseases. By doing so, it plays a key role in reducing or eliminating the reliance on chemical pesticides and fertilizers. This approach not only fosters crop sustainability but also proves resilient in the face of the impacts of climate change.

Moreover, IPHM works towards Curtailing the Accumulation of Ready Food Source for Pests, in Plants' Cell Sap & Enhancement of Host- Defense of Plants to Discourage Disease and Pest Incidence leading to the ELIMINATION OF PESTICIDE. No growth promoters/ hormones/ micronutrients were sprayed.

The Dual approach of Inhana Soil & Plant Health Management in this program demonstrated the pathway towards production of Clean Food 'NET ZERO'.
Plant Health Management under IRF Technology is attended through the scheduled application of 'INHANA ENERGY SOLUTIONS'. These solutions are the potentised and energized botanical extracts developed under Element-Energy-Activation (E.E.A) Principle.

- IPHM Schedule started with Organic Seed Treatment to promote a healthy Crop Cycle.
- Post seed germination and once the Saplings attained a 3-4 leaf stage the Inhana Nursery Solutions (IB AG-1, IB AG-2 & IB AG-3) were applied in a synchronized manner to enable Higher survival and a healthy growth phase thereafter.
- 6 rounds of IPHM Schedule was followed post nursery stage till fruit setting stage.

Flow Diagram of - Net Zero Clean Millet Seed Development under IRF Technology (IBM-IORF Sustainability Project, Phase –III, 2023-24)



Final Mature stage (Ragi) from the ‘Net Zero’ Clean Millet Seed project plots at Mandya, Karnataka under IBM-IORF Sustainability Project, phase - III

Ragi Harvesting from the ‘Net Zero’ Clean Millet Seed project plots at Mandya, Karnataka under IBM-IORF Sustainability Project, phase - III

Crop performance of Ragi (Finger Millet) from 'Net Zero' Clean Millet Seed project plot under IBM-IORF Sustainability program at Mandya, Karnataka

Crop productivity of Ragi (Finger Millet) under IBM-IORF Sustainability program at Mandya, Karnataka was increased with adoption of IRF Technology. A significant 2289 kg/ ha. yield of Ragi was recorded under 'Net Zero' Clean Millet Seed production programme which was upto 24.8 % higher than conventional farmers practice.

The yielding ability of a crop is the reflection of yield attributing characters like more number of productive tillers plant^{-1} , number of fingers earhead^{-1} , earhead length, finger length, grain yield plant^{-1} , 1000 grain weight. Plant growth is also dependent on the rate of accumulation of dry matter. As vegetative parts of the plant serve as a source where as grains are the sink.

Higher level of biomass accumulation and efficient translocation to the reproductive parts due to IRF plant health management which activates plant physiological functioning resulting better nutrient uptake and assimilation for better crop productivity.

Pic. Ragi (Finger Millet) seed developed at Mandya, Karnataka for Clean Food 'Net Zero' Millet Seed Production program, Phase – III.

Comparative crop performance of finger millet under Clean Food net Zero Program at Mandya, Karnataka

Plots	Plant height (cm)	Productive tillers m^{-2}	Above ground biomass ($gplant^{-1}$)	No. of ears m^{-2}	Fingers ear $head^{-1}$	1,000-grain weight (g)	Grain yield ($kg\ ha^{-1}$)	Stover yield ($kg\ ha^{-1}$)	Biological **y**ield ($kg\ ha^{-1}$)	Productivity per day ($kg\ ha^{-1}$)	Harvest Index (%)
Finger Millet Productivity under Conventional Farming Practice											
CFP -1	108.6	76	22.8	189	6	1.80	2012	4416	6428	16.23	0.31
CFP -2	109.5	70	23.9	175	5.9	1.79	1978	4334	6312	15.95	0.31
CFP -3	112.3	68	24.4	183	5.8	1.79	1952	4287	6239	15.74	0.31
Mean Value	**110.1**	**71.3**	**23.7**	**182.3**	**5.90**	**1.79**	**1981**	**4346**	**6326**	**15.97**	**0.31**
Finger Millet Productivity under Clean Food Net Zero Program under IBM-IORF Sustainability Project											
Project farmer - 1	106.5	78	21.2	211	6.2	1.81	2313	4826	7139	18.65	0.32
Project farmer - 2	110.3	82	23.1	226	6.0	1.82	2436	5214	7650	19.65	0.32
Project farmer - 3	108.7	69	22.3	189	6.4	1.81	2154	4687	6841	17.37	0.31
Project farmer - 4	108.6	72	22.8	201	6.4	1.8	2259	4811	7070	18.22	0.32
Project farmer - 5	109.5	75	23.1	206	6.2	1.82	2284	4864	7148	18.42	0.32
Mean Value	**108.72**	**75.2**	**22.5**	**206.6**	**6.24**	**1.812**	**2289.2**	**4880.4**	**7169.6**	**18.46**	**0.32**

Note : CFP: Conventional Farmers Practice

Quality Analysis of 'NET ZERO' (NZ) Clean Ragi/ Finger Millet Seed developed under IBM IORF Net Zero Clean Millet Seed Programme, Phase III 2023-24

Along with the Yield Assessment the Quality of the NZ Clean Ragi/ Finger Millet Seed was done in terms of its Physical & Climate Resiliency.

The seeds were pure, free from any intermixed varieties, as indicated by the minimum presence of inert matter and absence of weed seeds .

IBM-IORF Sustainability Project (Phase III), Moisture of Net Zero Clean Ragi (Finger Millet) Seed is 8.36% compared to max. seed moisture as per Indian Standard is 13%. Physical seed quality attributes are crucial factors that influence the performance of seeds in terms of germination, emergence, and establishment of plants. These attributes play a significant role in determining the success of crop production and are of utmost importance in sustainable agriculture. Germination percentage of Net Zero Clean Ragi (Finger Millet) Seed achieved 91% compared to min. seed germination as per Indian Seed Standard 80%. The study of seed resilience against stress also indicated that Net Zero Clean Ragi (Finger Millet) Seed had better capacity to withstand abiotic stress due to climate change impact

Comparative study of Seed Viability, Seed Vigor and Seed Resilience against Stress, of NZ Clean Ragi/ Finger Millet Seed with intervention of IRF Technology.

Seed Quality parameters	Seed Viability		Seed Vigor			Seed Resilience against Stress			
	[1]G %	[2]SV %	[3]GVI	[4]SVI-I	[5]SVI- II	[6]G_{WS} %	[7]G_{SS} %	[8]G_{AA} %	[9]EC
Conventional Ragi / Finger Millet Seeds (Farmers' Practice)	86	89.1	12.80	670.0	0.31	78.0	65.0	84.79	0.028
'Net Zero' Clean Ragi / Finger Millet Seeds	92	94.62	16.16	789.0	0.43	84.2	68.5	89.40	0.025

Note : *[1]G % : Germination %, [2]SV % : Seed Viability %, [3]GVI : Germination Velocity Index, [4]SVI-I : Seed Vigour Index-I, [5]SVI- II: : Seed Vigour Index-II, [6]G_{WS} % : Germination under water stress (-0.6 MPa induced osmotic potential); [7]G_{SS} % : Germination under Salt Stress (-0.3 MPa induced osmotic potential), [8]G_{AA}% : Germination under Accelerated Ageing; [9]EC : Electrical Conductivity*

Analysis of Soil Quality

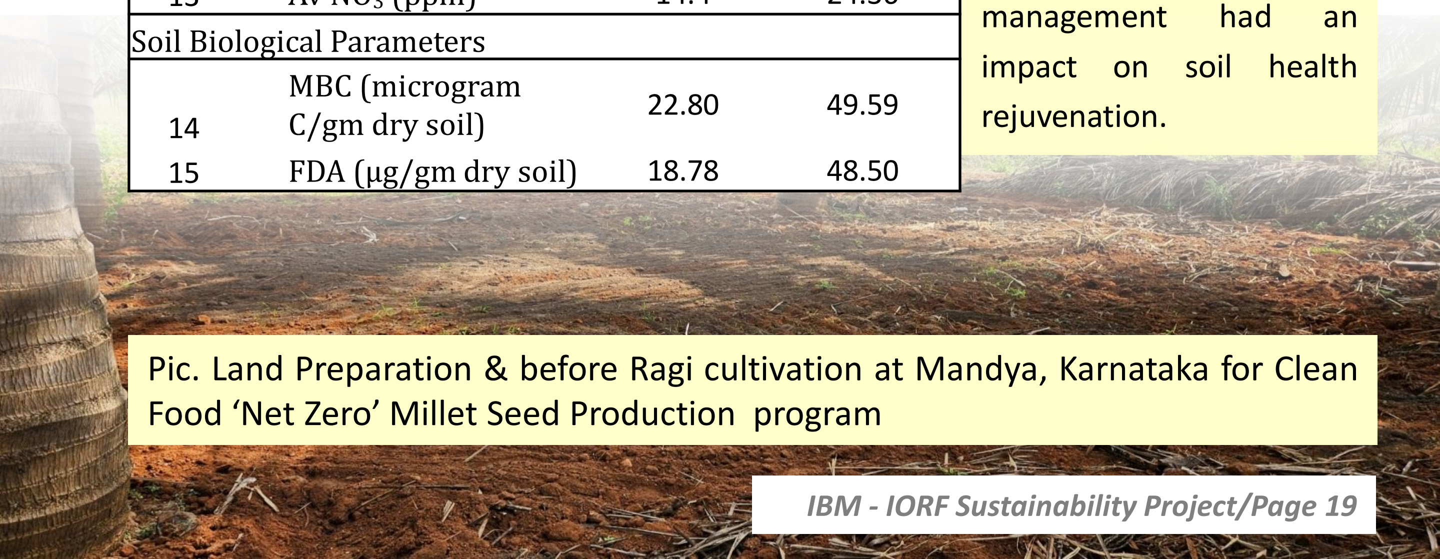
Soil samples were taken at the initiation & after completion of the study. The initial study confirms that the soil is very poor in terms of soil carbon and fertility status as well as soil microbial activity. Above all presence to small to medium size gravels is close to 60 % (by weight) make the soil practically unsuitable for any sensitive crop cultivation.

Soil physical, physicochemical, fertility, biological properties in the Pre & Post Ragi Cultivation Plot, Mandya, Karnataka.

Sl. No.	Parameters	Pre Cultivation Soil	Post Cultivation Soil
Soil Physical Parameters			
1	Soil Gravels %	58.99	-
2	Sand %	71.92	-
3	Silt%	16.26	-
4	Clay%	11.82	-
5	Texture	Sandy Loam	-
Soil Physico-chemical Parameters			
6	pH	5.50	6.10
7	EC (1:5) dSm-1	0.066	0.072
8	Org. C%	0.39	0.71
9	Av-N (kg/ha.)	292	315
10	Av P_2O_5 (kg/ha.)	45	49
11	Av. K_2O (kg/ha.)	678	579
12	Av- SO_4 (kg/ha.)	722	612
13	Av NO_3 (ppm)	14.4	24.36
Soil Biological Parameters			
14	MBC (microgram C/gm dry soil)	22.80	49.59
15	FDA (µg/gm dry soil)	18.78	48.50

Pre and post soil analysis in net zero clean ragi seed development program showed that there was slight improvement of soil quality in terms of soil organic carbon% and soil biological properties.

However there was an increasing trend in soil microbial parameters which indicated that application of quality Novcom compost in the soil as part of soil nutrient management had an impact on soil health rejuvenation.



Pic. Land Preparation & before Ragi cultivation at Mandya, Karnataka for Clean Food 'Net Zero' Millet Seed Production program

CONCLUSION

Nutritional quality and drought-resistant properties of millets have increased focus to improve the millet varieties and to enhance their use in processed food products. In order to improve production of millets and nurture a sustainable seed production system, strengthening and improving the overall efficiency of the millet seed systems is essential. Like all other agricultural crops seeds are the primary input for sustainable millet cultivation.

IRF Technology successfully demonstrated the effectivity of Climate resilient – quality Net – Zero Millet Seed (Ragi / Finger Millet) production in terms of crop productivity enhancement even with locally-adapted variety of Mandya, Karnataka.

An extension activities for creating awareness and demonstration of rain-fed agriculture, these Net Zero Clean Millet Seed (Ragi/ Finger Millet) along with Inhana Plant & Soil Health Management Package can be distributed to the local farmers.

Millet as a gluten free cereal with protein, mineral and various micronutrients are also relatively higher stress tolerant crop. However, for large scale production and optimum nutritional quality along with maximum/higher crop production that too carbon sequestrated manner - Seed becomes an important criteria for the accomplishment of the desired objectives. The central point is the productivity and quality of the crop production also confirms the potential of such seed with these potentials. This is extremely relevant if such important Nutritive Crop is to be propagated at a large scale. IBM-IORF Sustainability Project Phase II demonstrated the effectivity of NOVCOM Coirpith compost and Inhana Plant Health Management under IRF Technology of IORF towards 'Net Zero' Clean Millet (Ragi) production. Phase III Project also successfully established the effectivity of IRF Technology towards Net Zero Clean Millet (Ragi) Seed production.

This indeed is a unique milestone towards the Govt's initiative for the promotion of millet as Shree Anna and establishment of a Center for Excellence for R & D for providing pathway for community based Climate Resilient Net Zero Clean Millet seed production and use of this technology for developing quality seed development and propagation for all the important varieties of millet.

IBM - IORF SUSTAINABILITY PROJECT

MILESTONE 4

Development of Coconut based Circular Economy (CE) Model, in the Project area at Mandya District of Karnataka

PHASE - III

Development of Coconut based Circular Economy (CE) Model, in the Project area at Mandya District of Karnataka

Introduction

One of the principal challenges faced by humankind is feeding a constantly growing population. Specifically, it is estimated that we will need to increase food production by 5.1 billion tonnes before 2050 (FAO, 2017). This will generate huge pressure on the agricultural ecosystems, given that they are the principal food providers. Furthermore, this could cause negative impacts on the natural environment as agricultural system the main food supplier in the world requires a large amount of water (about 70%) and about 30% of total global energy consumption and at same time Agricultural and land-use changes account for around 31 per cent of global greenhouse gas emissions, making the sector a major contributor to climate change. The environmental, social, and economic costs of the “linear” nature of the modern food production system are significant. Food-related CO2 emissions could double by 2050 without changes to the current unsustainable food systems and consumption patterns (UN, 2021).

Towards sustainability and circular economy

The industrial revolution spurred the rise of economic models, but also brought challenges like resource scarcity, inefficient utilization, and environmental degradation. These issues have catalyzed discussions around new models to replace the linear economy. The Sustainable Development Goals (SDGs) have become focal points for sustainability efforts, with concepts like the green economy, circular economy, and bioeconomy gaining prominence in macro-level sustainability discussions of the policymakers.

Circular agriculture focuses on using minimal amounts of external inputs, closing nutrients loops, regenerating soils, and minimizing the impact on the environment. If practiced on a wide scale, circular agriculture can reduce resource requirements and the ecological footprint of agriculture. It can also help ensure a reduction in land-use, chemical fertilizers and waste, which makes it possible to reduce global CO_2 emissions (UN 2021).

Development of Coconut based Circular Bio-economy

A circular bio-economy offers the opportunity to transform our land, food, health and industrial systems and it could create new sustainable income opportunities. This transition will bring with it opportunities for decarbonization, and contribute to managing and rebuilding ecosystems and landscapes that desperately need it. Adoption of this new economic growth model, which aims at decoupling environmental growth from fossil fuel dependence and providing biomass-based feedstock for consumption. Thus, bioeconomy adds value to biomass resources, and analysis of the economic benefits of a particular resource can be performed via a “value web” (Nagarajan *et al*, 2021). Thus the resource efficiency or replacement of fossil fuel-derived feedstock and innovations in the biotechnological perspective are the two great pillars in bio-economy (Nagarajan *et al*, 2021) which requires introduction of new sustainable technology to drive. This is because, circular bio-economy requires low-carbon energy inputs and promising disruptive conversion technologies for the sustainable transformation of renewable bioresources to high-value bio-based products (Tan and Lamers, 2021). The bio-based circular carbon economy, in particular, stresses capturing atmospheric carbon via photosynthesis and it sits at the intersection between the circular economy and the bioeconomy concept, resulting in a framework that focuses on closing the carbon cycle and stressing the opportunity to create an additional carbon sink capability in the technosphere by utilizing biogenic carbon for products and materials that are circulated in same or improved use cycles (Tan and Lamers, 2021).

Now specially looking at South India's vast arid and semiarid land scape with limited choice of crop, poor soil quality, coconut as natural vegetation and problems of recycling of coirpith –a agro waste generated from coir industry – a concept of circular bio-economy can be perfectly fit if a suitable technology can relates / binds all the factors in a single thread. This idea motivates to drive an agricultural sustainability initiatives with adoption of Inhana Rational Farming (IRF) Technology under IBM-IORF sustainability project to established an Coconut-based Circular Bio-economy Model for improvement of crop productivity, soil quality and farm economics. With Adoption of IRF technology, coir pith was utilized to make quality Novcom compost for organic soil management followed by IRF Plant Health Management package of practice for crop sustainability with the objectivity of efficient resource recycling, soil quality development, crop sustainability and finally enhance farm income.

Coconut – maize intercropping as part of coconut based circular bio-economy model at Mandya, Karnataka

Program undertaken at Mandya towards development of coconut based circular economy (CE) models

Coconut is a major crop in Mandya, but in the last 10 Years its yield has drastically reduced and is now about 30% lower than the national average and about 50% Lower than Tamil Nadu- the highest coconut producing state.

Coconut plantations are highly suited for intercropping. Multispecies cropping under coconut can ensure higher resource utilization and additional income per unit area of soil. But to achieve the desired benefits in the already declining soil quality, adoption of Sustainable Practice will be crucial. Intercropping with sustainable practice results in improvement of soil properties and improves biological activities in the root region. At the same time coconut based intercropping system can produces adequate returns from land and labor within the constraints of unpredictable climatic conditions and limited inputs.

Under IBM-IORF Sustainability Project, an effort was generated to introduce Coconut- based Circular Economy Model to open up the scope for improving crop diversity as well as farm productivity especially concerning the marginal soil, especially on reuse and recycling of coirpith waste.

The model was developed with the adoption of Inhana Rational Farming Technology – a comprehensive organic package of practice. Under this technology, coir pith- a waste generated from coir industry and a source for soil and water pollution and methane generation was utilized for soil health management; post effective bioconversion under Novcom Composting Technology. Novcom Composting Technology enables bioconversion of coir pith waste into a safe, stable and mature compost within 30 days and the end product is rich in self generated native microflora; which can help out in speedy regeneration of soil microbial population. Novcom coir pith compost was applied @ 40 ton/ha.

3 different cropping model were cultivated as intercrop within the coconut plantation. The significance was that this intercropping model was primarily demonstrated in the marginal soils (red gravelly soils with low soil fertility and

microbial activity), deemed unfit especially for cultivation of nutrient sensitive short duration vegetable crops and that too with complete elimination of N-Fertilizers and chemical pesticides.

Circular economy models were analyzed with a focus on their impact on yield, nutrient utilization, soil health, energy usage, greenhouse gas (GHG) emissions, and cost-benefit ratio, all of which play crucial roles in influencing the livelihoods of resource-poor farmers. These models aim to optimize resource efficiency, minimize waste, and promote sustainability throughout the agricultural value chain. By emphasizing practices such as recycling, reusing, and regenerating resources, circular economy approaches strive to enhance productivity while reducing environmental impacts.

Under IBM-IORF Sustainability Project it was aimed to showcase how the circular economy principles can be integrated into agricultural systems through scientific technological intervention (IRF Technology) to improve the well-being and economic prospects of farmers facing resource constraints.

Management adopted in coconut based circular economy (CE) models

For **Soil Health Management** in the coconut plantation, 40 ton of Novcom Coir pith compost was applied per hectare. Also about 250 ltr. of Cow dung slurry was applied in the soil for enhancement of microbial activity, post application of Novcom Coir pith compost.

After transplanting/sowing of different crops, **Inhana Plant Health Management** solutions were sprayed in a periodical manner as per the recommended schedule. This management practice not only helped towards balanced growth, at the same time improved plant immunity and defense mechanism against pest and disease leading to natural elimination in the requirement of pesticides.

Physicochemical properties, fertility parameters and lignin content of 30 days Novcom coir pith compost utilizing Novcom Composting Technology.

Test Parameters	Novcom Coirpith Compost made using NOVCOM Technology under IBM-IORF Sustainability Project
PHYSICOCHEMICAL PARAMETERS	
Moisture (%)	68.4 – 74.2
pH (H_2O)	6.26 – 6.67
EC (dSm^{-1})	2.04 – 2.44
Ash Content (%)	44.22 – 47.29
Volatile Solids (%)	52.71 - 55.78
Organic carbon (%)	27.67 – 30.24
NUTRIENT & NUTRIENT DYNAMICS	
Total N (%)	0.96 – 1.07
Total P_2O_5 (%)	0.16 – 0.19
Total K_2O (%)	3.14 – 3.44
C:N	27: 1 - 30:1
CMI	1.49 – 1.57
BIOLOGICAL PARAMETERS	
Bacteria (c.f.u. per gm moist compost)	(37 – 49) X 10^{16}
Fungi (c.f.u. per gm moist compost)	(11 – 27) X 10^{16}
Actinomycetes (c.f.u. per gm moist compost)	12 X10^{16}
STABILITY, MATURITY & PHYTOTOXICITY PARAMETERS	
CO_2 Evolution Rate (mgCO_2–C/g OC/day)	1.41 -1.78
Seedling Emergence (% Over Control)	103.7 – 108.7
Root Elongation (% Over Control)	107.1 – 112.5
Germination Index (Phytotoxicity Bioassay)	0.97 – 1.24
LIGNIN DEGRADATION STUDY	
Acid soluble lignin (ASL)%	0.79 – 0.91
Acid insoluble lignin (AIL)%	22.65 – 22.91
Total lignin %	23.64 = 23.84

Novcom coir pith compost was produced within a period of 30 days with 2 turnings of the compost heap on 10th & 20th day. Physicochemical and fertility status of compost resembled the standard set by different international composting councils, while its total nitrogen (0.96 – 1.03 %) content was much higher than coir pith compost produced using other composting processes. The high value of nitrogen might be due to intense biodegradation process, which lowered the potential for N loss and favourably influenced atmospheric- N fixation through naturally generated autotrophic microflora within compost heap. The finding was corroborated by the high population of microbes (10^{14} to 10^{16} c.f.u. per gm moist compost) within compost, which were generated naturally during the composting process. Maturity and phytotoxicity bioassay tests confirmed that Novcom coir pith compost was mature and free from phytotoxic effect. The study concluded that Novcom composting method could be an effective and economical process for speedy conversion of coir pith into a valuable input for organic soil management.

Novcom Coirpith Compost prepared under IBM-IORF Sustainability Project at Mandya, Karnataka

Crop performance under coconut based circular economy (CE) models

Crop productivity of coconut based intercropping under different bio circular economy model adopted in Mandya, Karnataka was compared with conventional coconut based intercropping practice. Under IBM-IORF Sustainability project, 3 major coconut based intercropping viz (i) CE 1 : Coconut -Millet – Vegetable (Cabbage), (ii) CE 2: Coconut based Maize – Vegetable (Brinjal) and CE 3: Coconut – Ginger was taken under study.

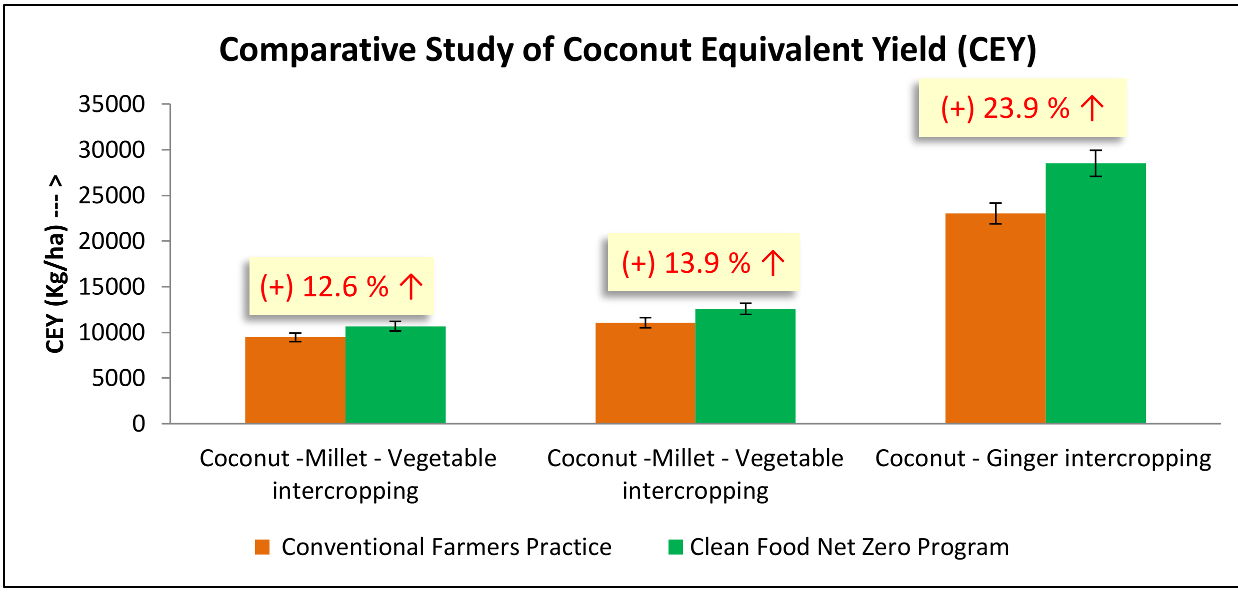
Comparative crop performance under different coconut based intercropping practice under IBM-IORF Sustainability Project at Mandya, Karnataka

Management Practice	Crop Productivity			Coconut Equivalent Yield (Kg/ha)	System Productivity (Nuts/ha)
	Coconut (Nuts/ha)	Millet (Kg/ha)	Vegetable (Kg/ha)		
CE 1 : Coconut -Millet - Vegetable intercropping plot					
Conventional Farmers Practice	7200	1986	24400	9473	14555
Clean Food Net Zero Program	7900	2256	28260	10666	16387
CE 2: Coconut - Maize - Vegetable intercropping plot					
Management Practice	Crop Productivity			Coconut Equivalent Yield (Kg/ha)	System productivity (Nuts/ha)
	Coconut (Nuts/ha)	Maize (Kg/ha)	Vegetable (Kg/ha)		
Conventional Farmers Practice	7350	3120	22300	11044	16991
Clean Food Net Zero Program	8120	3440	26220	12574	19345

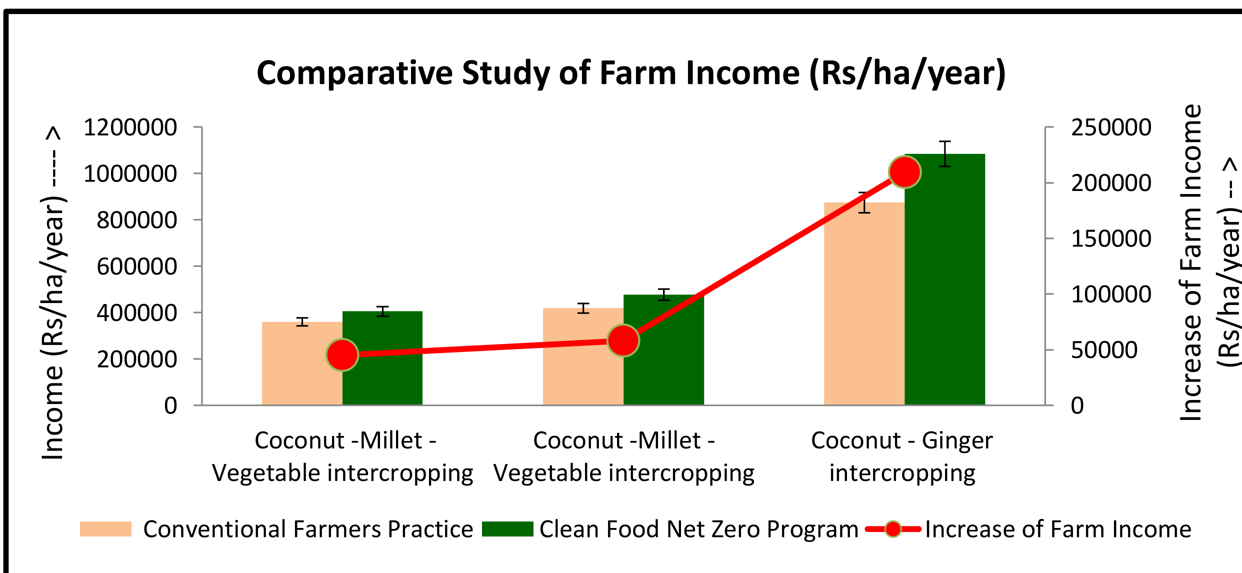
CE 3: Coconut - Ginger intercropping plot

Management Practice	Crop Productivity		Coconut Equivalent Yield (Kg/ha)	System productivity (Nuts/ha)
	Coconut (Nuts/ha)	Ginger (Kg/ha)		
Conventional Farmers Practice	7440	14400	23025	35424
Clean Food Net Zero Program	8240	18350	28535	43900

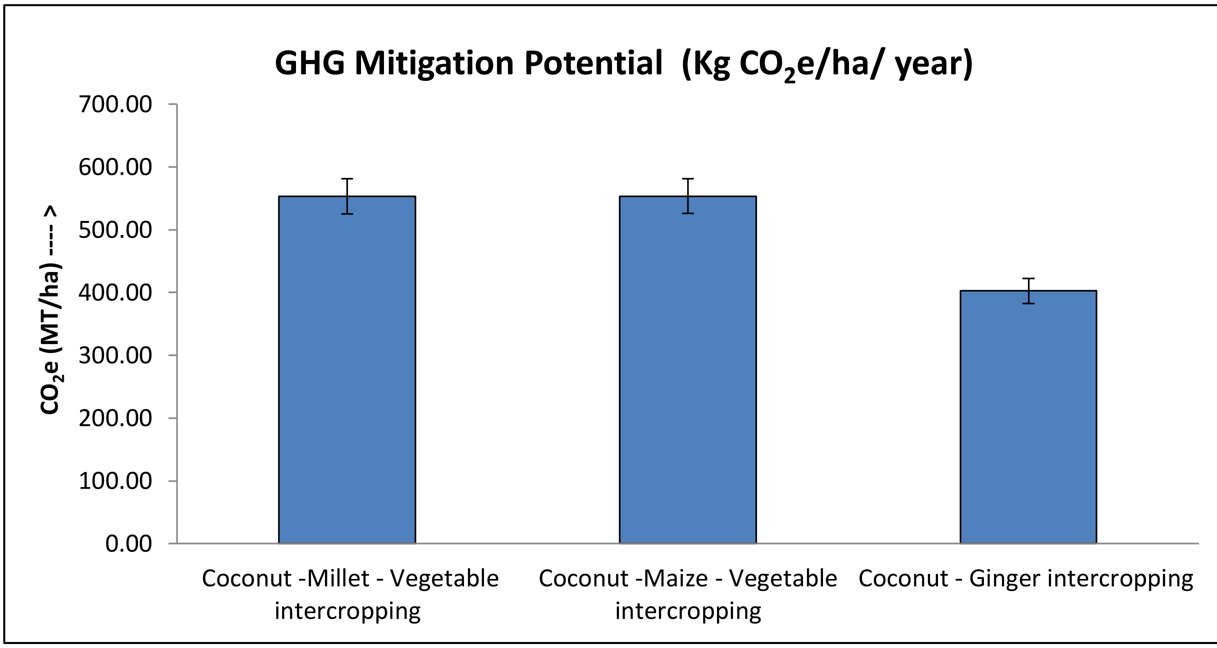
Note : Approx 60 % area was utilized under other crop in coconut intercropping



Comparative study of coconut equivalent yield (CEY) showed that there was highest increase (23.9 %) of CEY (kg/ha) was in case of coconut – ginger inter-cropping practice with adoption of Clean Food Net Zero program. However in other two model also showed significant increment of CEY under the program which might be due to adoption of Inhana Rational Farming (IRF) Technology as experienced under different crop under IBM-IORF sustainability program irrespective of Agro-ecological zone.



Comparative study of farm income showed that it was highest under coconut – ginger inter-cropping practice (Increase of farm income was Rs 209360 /ha/year) with adoption of Clean Food Net Zero program.



Comparative study of GHG mitigation potential under Clean Food Net Zero program in comparison to conventional farmers practice revealed that highest GHG mitigation potential was under coconut –maize –vegetable intercropping (553.49 MT CO_2e / ha/year). The study reveled that adoption of Clean Food Net Zero program have the potential for meaningful contribution towards climate change mitigation.

Coconut – millet intercropping as part of coconut based circular bio-economy model at Mandya, Karnataka

Impact of coconut based circular economy (CE) models on Soil Quality

In the study focused on soil health management within coconut-based circular economy (CE) models, soil samples were collected both at the outset of the research and at the conclusion of the harvesting phase to assess the impact of the initiative. Despite the somewhat rushed nature of the endeavor to draw definitive conclusions, the aim was to glean insights from the program. Initial findings revealed significant deficiencies in soil carbon levels, fertility status, and microbial activity. Moreover, the presence of small to medium-sized gravel particles exceeding 50% of the soil's weight rendered it largely unsuitable for cultivating sensitive crops. These observations underscore the pressing need for interventions to address soil health issues within the context of circular economy models in coconut based intercropping.

Soil Physical Quality Evaluation of Coconut based Circular Economy (CE) Model, in the Project area at Mandya ,Karnataka

Sl. No.	Land Use	Soil Gravels %	Sand %	Silt%	Clay%	Texture
1	CE 1 : Coconut based Millet - Vegetable intercropping plot	57.89	72.00	16.00	12.00	Loamy Sand
2	CE 2: Coconut based Maize - Vegetable intercropping plot	63.29	82.00	5.00	13.00	Loamy Sand
3	CE 3: Coconut based Ginger intercropping plot	59.55	74.00	15.00	11.00	Loamy Sand

Novcom Coirpith Compost at Mandya, Karnataka

Soil Physico-chemical Parameters Evaluation of Coconut based Circular Economy (CE) Model, in the Project area at Mandya ,Karnataka under IBM-IORF Sustainability Project, Phase III

Sl. No.	Major Land Use	pH	EC (1:5) dSm^{-1}	Org. C%	Av NO_3 (ppm)	Av-N (kg/ha.)	Av P_2O_5 (kg/ha.)	Av. K_2O (kg/ha.)	Av- SO_4 (kg/ha.)
1	CE 1 : (Pre Management Soils)	6.06	0.054	0.55	22.00	163.64	61.14	603.12	410.32
	CE 1 : (Post Management Soils)	6.12	0.051	0.71	20.00	210.26	72.19	627.29	350.23
2	CE 2: (Pre Management Soils)	6.23	0.049	0.59	34.30	181.26	11.92	539.27	391.22
	CE 2: (Post Management Soils)	6.27	0.044	0.77	24.29	203.12	13.46	538.29	383.17
3	CE 3: (Pre Management Soils)	6.19	0.056	0.36	31.26	159.23	24.22	460.39	472.19
	CE 3: (Post Management Soils)	6.29	0.048	0.46	28.26	196.37	31.27	471.23	453.22

Coconut – vegetable intercropping as part of coconut based circular bio-economy model at Mandya, Karnataka

Soil microbial properties Evaluation of Coconut based Circular Economy (CE) Model, in the Project area at Mandya ,Karnataka under IBM-IORF Sustainability Project, Phase III

Sl. No.	Major Land Use	**MBC (microgram C/gm soil)**	**FDA (µg/g dry soil)**	**Bacteria X 10^4**	**Fungi X 10^3**	**Actinomycetes X 10^3**
1	CE 1 : (Pre Management Soils)	30.12	17.61	62	27	12
	CE 1 : (Post Management Soils)	50.72	21.22	72	20	11
2	CE 2: (Pre Management Soils)	28.37	13.67	41	19	10
	CE 2: (Post Management Soils)	47.29	18.19	76	37	14
3	CE 3: (Pre Management Soils)	21.62	12.11	21	18	12
	CE 3: (Post Management Soils)	42.46	17.62	29	42	42

Note: Soil MBC : *Soil Microbial Biomass (µg.CO_2.C/gm dry soil);* ***FDAH :*** *Fluorescein di-acetate hydrolyzing activity (FDAH) (µg/gm dry soil)*

Evaluation of soil quality under Coconut based 'Net Zero' Intercropping pre and post experimentation revealed no considerable changes in soil pH and EC. However, slight increase (28% - 30%) in organic carbon was noted which was mainly due to application of Novcom coir pith compost @ 40 ton/ha. Available N, P, K showed increasing trend though the difference is not significant.

Soil micro-organisms play a significant role in regulating the dynamics of organic matter decomposition and availability of plant nutrients.. Comparatively higher value of soil microbial pollution, soil MBC and its activity (indicated by FDAH activity) etc. post soil analysis indicated the favourable role of Novcom coir pith compost towards soil micro flora rejuvenation. This was probably due to very high (one trillion billion microbes / ton compost) self generated microbial presence in Novcom coir pith compost, which post application helps to regenerate microbes in soil in speediest manner. Overall offsetting of synthetic fertilizers and pesticides also helps to create a toxicity free favourable condition for increasing microbial population.

In summary, the study found that implementing coconut-based intercropping systems within the CFNZ program, alongside adopting IRF Technology, enhances soil properties and productivity. This is achieved by maintaining a dynamic equilibrium among biotic and abiotic components of the soil, sustaining biochemical processes, and rejuvenating soil microflora. Diverse species under coconut trees contribute to continuous nutrient replenishment through recycling and addition, leading to improved crop productivity compared to conventional farming practices.

Red loamy soils of Mandya, Karnataka

Preparation of different organic concoctions towards rejuvenation of soil microbes at Mandya, Karnataka

Conclusion

A circular, bio-based economy is the most comprehensive pathway towards a sustainable future as it safeguarding and regenerating the health of our (agro)ecosystems, avoiding non-essential products and the waste of essential ones, prioritizing biomass streams for basic human needs, utilizing and recycling by-products of (agro)ecosystems and using renewable energy while minimizing overall energy use.

Under IBM-IORF Sustainability project at Mandya, Karnataka we have developed coconut based circular bio economy model with adoption of IRF technology which not only help to enhance crop productivity and thereby increase overall farm income but at the same time help to improve soil health and mitigation of green house gases.

Development of Coconut based Circular Economy (CE) Model could be a benchmark study for formulating any sustainable agricultural program specially looking at climate change mitigation.

IBM - IORF SUSTAINABILITY PROJECT

MILESTONE 5

Development of ‘Clean Millet’ encompassing different important varieties for improvement of Crop Productivity and Quality, in the Project area at Mandya District of Karnataka

PHASE - III

Development of 'Clean Millet' encompassing different important varieties for improvement of Crop Productivity and Quality, in the Project area at Mandya District of Karnataka

INTRODUCTION

Millets, hailed as the ancient sustenance of humanity, hold a venerable position in the annals of agricultural history. These small yet hardy grains, cultivated since time immemorial, thrive in arid climates as rain-fed crops, defying the odds of meager soil fertility and scarce moisture. Beyond their tenacity, millets boast a remarkable trait: a swift growing season, making them indispensable in regions with unpredictable weather patterns. India, blessed with a rich agricultural heritage, is home to a diverse array of millets, including Sorghum (Great millet), Bajra (Pearl millet), Ragi (Finger millet) and small millets viz., Korra (Foxtail millet), Little millet, Kodo millet, Proso millet and Barnyard millet. Recognizing their nutritional potency, the Government of India has rightfully designated them as "Nutricereals," a testament to their exceptional dietary value. India is the largest producer and 7th largest exporter of millets now calls **"Shree Anna"** as of 2021. The Indian government has launched various schemes and programs to promote millet cultivation, including the National Food Security Mission and the Millets Mission. These initiatives aim to increase millet production, improve market linkages, and raise consumer awareness.

A total of about **16.9 million tonnes of millets food grains are produced in India, about 17 percent of global production, from nearly 12.7 million ha area, which constitutes about 6% of the national food grain basket. (B Venkatesh Bhat, 2023).** Other than Shorghum India is the topmost producer of Barnyard (99.9%), Finger (53.3%), Kodo (100%), Little millet (100%) and pearl millet (44.5%), producing about 12.46 million metric tonnes from an area of 8.87 million ha.

Millets and the Nutritional & Health benefits

Millet grains are rich sources of nutrients like carbohydrate, protein, dietary fibre, good-quality fat and have substantially higher amounts of minerals like calcium, potassium, magnesium, iron, manganese, zinc, and B complex vitamins, making them a preferable choice over the cereal grains.

1. Millets are rich in phytochemicals like tannins, phytosterols, polyphenols and antioxidants.
2. Health-promoting nutritious crop: Compared to other cereals they have superior micronutrient profile and bioactive flavonoids.
3. Millets are an excellent source of slow digestive starch and fibres which are good for the gut cohabited with trillions of bacteria, namely Lactobacillus acidophilus, rhamnosus GG, Actinobacteria and Bifido species. The non-starch polysaccharides found in millets form a major part of dietary fibre which produce short-chain fatty acids by fermentation of resistant starch and serve as excellent Prebiotics.
4. Millets have lower glycemic properties owing to higher fibre content.
5. They are good source of minerals like iron, zinc, and calcium.
6. Millets are Anti acidic, Gluten-free, Detoxify body.
7. Millets help lowering cholesterol, reduce blood pressure, prevents cancer and many other diseases, optimize kidney, liver and immune system health and reduces risk of gastrointestinal conditions etc.

Nutritional profile of millets in comparison with cereals (per 100 g).

Grains	Energy (kcal)	Protein (g)	Carbohydrate (g)	Starch (g)	Fat(g)	Dietary Fiber (g)	Minerals (g)	Ca (mg)	P (mg)
Sorghum	334	10.4	67.6	59	1.9	10.2	1.6	27	222
Pearl millet	363	11.6	61.7	55	5	11.4	2.3	27	296
Finger millet	320	7.3	66.8	62	1.3	11.1	2.7	364	283
Proso millet	341	12.5	70.0	-	1.1	-	1.9	14	206
Foxtail millet	331	12.3	60.0	-	4.3	-	3.3	31	290
Kodo millet	353	8.3	66.1	64	1.4	6.3	2.6	15	188
Little millet	329	8.7	65.5	56	5.3	6.3	1.7	17	220
Barnyard millet	307	11.6	65.5	-	5.8	-	4.7	14	121
Maize	334	11.5	64.7	59	3.6	12.2	1.5	8.9	348
Wheat	321	11.8	64.7	56	1.5	11.2	1.5	39	306
Rice	353	6.8	74.8	71	0.5	4.4	0.6	10	160

IIMR . Nutritional and Health Benefits of Millets. Indian Institute of Millets Research; Hyderabad, India: ICAR; New Delhi, India: 2017.

Millet Scenario in India

India is the largest producer of millets in the world. In India, Millets are grown in about 21 States. There is a major impetus in Rajasthan, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Kerala, Telangana, Uttarakhand, Jharkhand, Madhya Pradesh, Haryana and Gujarat.

Rajasthan, Maharashtra and Karnataka are the topmost states in millets cultivation in India with a share of 35%, 23% and 14% to total millets area. Maharashtra and Karnataka have the maximum area under sorghum while Rajasthan, Gujarat, Uttar Pradesh and Maharashtra have more area under pearl millet. Ragi has the maximum area in Karnataka, Tamil Nadu and Uttarakhand. Small millets area is maximum in Madhya Pradesh, Uttarakhand and Chhattisgarh.

Nutri/Coarse Cereals : Area, Production and Yield during 2019-20 and 2020-21 in major Producing States

Area - Million Hectares
Production - Million Tonnes
Yield - Kg./Hectare

State	2020-21#					2019-20				
	Area	% to All-India	Production	% to All-India	Yield	Area	% to All-India	Production	% to All-India	Yield
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Rajasthan	6.15	25.81	8.33	16.30	1355	6.13	25.56	7.33	15.36	1196
Karnataka	3.45	14.47	7.73	15.11	2243	3.26	13.60	6.81	14.27	2088
Maharashtra	3.89	16.33	6.00	11.72	1540	4.22	17.61	4.39	9.20	1040
Madhya Pradesh	2.01	8.42	4.63	9.06	2309	1.92	8.01	5.03	10.53	2617
Uttar Pradesh	2.02	8.49	4.59	8.97	2266	1.99	8.29	4.39	9.19	2206
Tamil Nadu	0.99	4.14	3.67	7.17	3721	0.96	4.01	3.49	7.32	3633
West Bengal	0.37	1.57	2.46	4.81	6563	0.31	1.30	2.02	4.23	6478
Andhra Pradesh	0.51	2.14	2.45	4.78	4805	0.54	2.24	2.53	5.30	4714
Bihar	0.67	2.80	2.25	4.39	3367	0.69	2.87	2.02	4.23	2932
Telangana	0.37	1.57	1.95	3.81	5212	0.66	2.76	3.14	6.57	4749
Gujarat	0.91	3.80	1.73	3.38	1906	0.93	3.90	1.79	3.74	1912
Haryana	0.62	2.59	1.42	2.77	2300	0.54	2.25	1.10	2.30	2031
Others	1.88	7.87	3.95	7.73	2108	1.82	7.60	3.70	7.76	2032
All India	**23.83**	100.00	**51.15**	100.00	2146	**23.99**	100.00	**47.75**	100.00	1991

Source: Directorate of Economics & Statistics, DA&FW
Note: States have been arranged in descending order of percentage share of production during 2020-21.
Fourth Advance Estimates.

Agricultural Statistics at a Glance, 2021

Sorghum and Pearl millet are the major millet crops grown, constituting above 90% of the world millets production followed by Finger millet, Foxtail millet, Proso millet, Barnyard, Little millet and Kodo millet. Furthermore, Foxtail millet predominates all millets in terms of productivity, yielding about 2166 kg/ha followed by Finger millet (1623 kg/ha), Proso millet (1535 kg/ha), Sorghum (1426 kg/ha), Barnyard millet (1034 kg/ha), Pearl millet (850 kg/ha), Little millet (469 kg/ha) and Kodo millet (419 kg/ha) *(Ref. Millet, the future super food for India, 2022, ASSOCHAM).*

Sorghum is the major millet grown globally constituting 65% of total millets. During 2010–2020, the Sorghum area is near stable between 42.16 million hectares to 40.98 million hectares while production between 60.18 million metric tonnes to 58.70 million metric tonnes. During the same decade, the area under other millets showed a declining trend from 36 million hectares during 2010 to33.02 million hectares during 2020, while production decreased from 32.79 million metric tons in 2010 to 30.46 million metric tonnes in 2020 *(Ref. Millet, the future super food for India, 2022, ASSOCHAM).*

Karnataka Millet Scenario

With the second-largest area of dry land in the country after Rajasthan, Karnataka has the highest proportion of drought-prone area among all major states in the country. The land resources of Karnataka, especially its dry, drought-prone lands that comprise more than 79% of the total arable area, have been poorly managed by resource-poor farmers. The total irrigation potential from all sources, including inter-basin transfers, is estimated at around 50% of the total cropped area of 10.5 million hectares by the Karnataka state land use.

Millets are climate-resilient crops. They can even survive delayed rains, unlike paddy which has its disadvantages, including being water intensive in a state which has declared droughts for last several years. Crops like ragi (finger millet), jowar (sorghum) and bajra (pearl millet), consumed and produced in large quantities in Karnataka. The minor millets include Foxtail millet, Little millet, Kodo millet, Proso millet, Barnyard millet and Browntop millet.

Ragi is a staple food in several parts of Karnataka, especially the southern region whereas jowar and bajra are considered a staple in the north-western parts of Karnataka. However, changes, accentuated by policy and demand, has seen the state move towards paddy and sugarcane, resulting in total loss in area of over 7.5 lakh hectares.

Table 1: Region wise area and production of millets (2019)			
Region	**Area (m ha)**	**Production (m ton)**	**Yield(kg/ha)**
Africa	48.9	42.3	865
USA	5.3	19.3	3642
Asia	16.2	21.5	1327
Europe	0.8	2.00	2500
Australia & New Zealand	0.6	1.20	2000
India	**13.8**	**17.3**	1254
World	**71.8**	**86.3**	1202
Source: FAO Stat, 2021			

Millets are grown in 131 countries and comprise traditional food for 59 crore people in Asia & Africa. The global production of millets is 89.17 m t from an area of 74 m hac (FAO, 2020). India is the biggest producer of millets in the world, accounting for 80% of Asia's & 20% of global production.

However, when we are evaluating the average productivity of millets, it showed that India's productivity was only higher than Africa but far lower than that of USA, Europe Australia and New Zealand. Even it was lower than average productivity of Asia. It implies that we arte still to achieve the optimum productivity though there was improvement of productivity of millets from last decades with increasing attention in millet cultivation.

Yield gaps and improvement strategies

In order to develop a suitable strategy to improve the productivity levels of millets, it is imperative to assess the potential yield and yield gaps between potential and actual yields. Many field trials are conducted every year at research stations and these yields reported in these trials can be used for determining production potential at various management levels. However, there are hiccups as the yields reported in these trials conducted over locations and seasons are sometimes confounded because of inadequate considerations to genotype, climatic factors and their variability and agronomic management.

OBJECTIVITY

Post green revolution During the period major emphasis were on increasing food grain production to feed the people which led to ignorance towards the indigenous nutri-rich crops like millets. These are traditionally cultivated on marginal lands with least agri-inputs and having low productivity.

Thus improvement of millet productivity is one of the most important objectivity to the agriculturist to attend the growing food demand and meet nutritional security. So **it is the right time to relook towards the promotion of millets cultivation through introduction of improved agro-technologies for productivity enhancement, value addition and marketing to improve farmers' livelihood**.

To improve crop productivity of Millets, Sustainable Management Program with adoption of an effective nature friendly technology which can ensure increase in crop productivity while maintaining the fine balance of our ecosystem and contribute to climate change mitigation is the major focus of our study under the IBM-IORF Sustainability Program.

Millet cultivation under IBM-IORF Sustainability Project at Mandya, Karnataka

Net Zero Clean Millet Development encompassing different important varieties at Mandya, Karnataka under IBM-IORF Sustainability Project Phase III, 2023-24

Karnataka has a long history of growing millets. Karnataka's push for global recognition of millets got a big boost with the United Nations General Assembly adopting a resolution - initiated by India and other countries -- to declare 2023 as the International Year of Millets. In Mandya district also it was a staple food, but was replaced due to the invasion of rice and wheat in the last three to four decades.

Increasingly erratic rainfall patterns and crop losses due to climate change factors has forced farmers who were following to conventional agriculture are forced to abandon irrigation-intensive crops like rice, sugarcane or maize. In the project area of Mandya district Ragi (Finger millet) is being cultivated in a large area in rainfed season. Under IBM-IORF Sustainability Project, Phase II, Ragi was also taken in 4 ha. area under Net Zero Clean Food 25.2 ha. Model.

Under the IBM-IORF Sustainability Project's Phase III, a concerted effort is underway to promote sustainable agriculture through the cultivation of five distinct millet varieties. These include small millets such as Proso and Kodo Millet, as well as sorghum, pearl millet, and finger millet. Recognized for their resilience to environmental stresses, these millet varieties are being cultivated using IRF Technology under Net Zero Clean Millet Development. The aim is to demonstrate the potential of sustainable agricultural practices in enhancing farmers' livelihoods while ensuring assured productivity and mitigating the adverse impacts of climate change within the project area.

The model was developed with the adoption of Inhana Rational Farming Technology – a comprehensive organic package of practice. In the net zero clean food production system under IRF Technology, the seeds of all 5 millets were treated with Inhana seed management solutions before sowing. As part of soil health management, Novcom coir pith compost was applied @ 40 ton/ha was applied in soil at the time of final soil preparation. Inhana Plant Health Management solutions were applied in a periodical manner towards development of healthy plants capable of withstanding biotic and abiotic stress. This helps complete elimination of chemical pesticides.

Novcom coir pith compost

Compost application in soil

Germination of millets in the farmers field at Mandya, Karnataka

SOIL HEALTH MANAGEMENT UNDER IRF TECHNOLOGY

Soil health plays an important role in agricultural productivity, food quality, environmental resilience, and ecosystem sustainability as HEALTHY SOILS PRODUCE HEALTHY CROPS that in turn nourish life on earth.

In regions like Mandya, millet cultivation follows a minimal intervention approach. Farmers prepare the soil and sow seeds before the arrival of rains, without any specific interventions for nutrient management, irrigation, or crop protection. This lack of focused intervention often leads to compromised productivity, and millet is perceived as a low-income potential crop by farmers.

In 2023-24, as part of the IBM-IORF Sustainability Project Phase-III, Inhana aimed to assess the potential of indigenous climate-resilient crops in terms of productivity and their impact on farmers' livelihoods. This assessment focused on utilizing the IRF Technology, a sustainable crop production approach. A comprehensive plant and soil health management strategy were implemented to achieve Net Zero Clean Millet Cultivation across five different varieties. Through this initiative, the aim was to promote environmentally friendly farming practices while enhancing millet productivity and improving the economic prospects of local farmers.

Novcom Coirpith Compost @ 40 tons./ha. as well as various organic concoctions (CDS & P5 etc.) was applied as a Safe and Quality Compost in Soil. The application of this compost not only enhances soil quality but also facilitates the elimination of synthetic chemical fertilizers. By adopting such practices, the agricultural sector can progress towards achieving Clean Food 'Net Zero' objectives, promoting sustainability and environmental responsibility in food production.

Physicochemical properties, fertility parameters and lignin content of 30 days Novcom coir pith compost utilizing Novcom Composting Technology.

Test Parameters	Raw Coir pith	Novcom Coirpith Compost made using NOVCOM Technology under IBM-IORF Sustainability Project
PHYSICOCHEMICAL PARAMETERS		
Moisture (%)	**78.00**	70.95
pH (H_2O)	**5.90**	6.68
EC (dSm^{-1})	**3.21**	2.23
Ash Content (%)	**6.80**	50.50
Volatile Solids (%)	**93.20**	49.50
Organic carbon (%)	**51.78**	27.50
NUTRIENT & NUTRIENT DYNAMICS		
Total N (%)	**0.51**	1.03
Total P_2O_5 (%)	**0.08**	0.16
Total K_2O (%)	**1.36**	3.59
C:N	**102:1**	27:1
CMI	**-**	1.84
BIOLOGICAL PARAMETERS		
Bacteria (c.f.u. per gm moist compost)	-	78×10^{16}
Fungi (c.f.u. per gm moist compost)	-	21×10^{16}
Actinomycetes (c.f.u. per gm moist compost)	-	11×10^{16}
STABILITY, MATURITY & PHYTOTOXICITY PARAMETERS		
CO_2 Evolution Rate ($mgCO_2$–C/g OC/day)	-	1.63
Seedling Emergence (% Over Control)	-	97.50
Root Elongation (% Over Control)	-	98.45
Germination Index (Phytotoxicity Bioassay)	-	0.96
LIGNIN DEGRADATION STUDY		
Acid soluble lignin (ASL)%	**40.15**	0.89
Acid insoluble lignin (AIL)%	**0.65**	21.85
Total lignin %	**40.80**	22.74

QUALITY ANALYSIS OF NOVCOM COIR PITH COMPOST

Due to high lignin content and high C:N ratio, coir pith when left untreated can take decades to decompose, which not only leads to environmental pollution but most importantly methane emission, thereby contributing to climate change. However, once composted, coir pith can transform into an effective soil rejuvenator, considering its utility towards amelioration of especially marginal/ agriculturally degraded soil and improvement of soil productivity.

Periodical study of Novcom coir pith compost samples on 0, 10, 20 and 30 days confirmed effective degradation as demonstrated by the rapid decline of C:N ratio from 100:1 to < 30:1, appreciation of total nitrogen by 98 % and 60 % degradation of lignin within a 30 days' time period. The facts are corroborated by the respective very high (in the order of 10^{16} c.f.u. per gm or one Trillion Billion microflora per ton compost) population of bacteria, fungi and actinomycetes. Phytotoxicity Bioassay test values confirmed not only the absence of phytotoxic elements in compost, but also indicated that this compost can actually accelerate seed germination and root growth process.

Novcom coir pith compost at Mandya, Karnataka under IBM-IORF Sustainability Project

Millet Productivity under Clean Food Net Zero Program with adoption of IRF Technology

Support Millet cultivation is not just popularization of a neglected and underutilized crop but also an effort to achieve the sustainable development goals (SDGs) – mainly SDG 2 (zero hunger), SDG 3 (good health and well-being), SDG 12 (sustainable consumption and production), and SDG 13 (climate action). In the search for climate resilient solutions, millets could be a crucial link in sustaining the food supply chain especially for the less privileged people.

We have taken objectivity of improving millet productivity through introduction of improved agro-technology (Inhana Rational Farming Technology) which not only helps to improve crop productivity but also helps to value addition for better marketability towards improvement of farmer's livelihood.

Millet cultivation under IBM-IORF Sustainability Project at Mandya, Karnataka.

Comparative study of Millet productivity

Millets	World Productivity	India's Productivity	Farmers Experience	Productivity Under Clean Food Net Zero Program
Finger Millet (Eleusine coracana)	600 kg/ha	1591 kg/ha	1360 - 1960 kg/ha	2289 kg/ha
Kudo Millet (Paspalum scrobiculatum L.)	-	429 kg/ha.	850 - 1600 kg/ha	1860 kg/ha
Proso Millet (Panicum miliaceum)	-	531 kg/ha.	1200 - 1500 kg/ha	1940 kg/ha
Pearl Millet (Pennisetum glaucum)	500 kg/ha	1130 kg/ha	1500 - 2100 kg/ha	2650 kg/ha
Sourgam (Sorghum bicolor L. Moench)	1408 kg/ha	883 kg/ha	960 -1120 kg/ha	1650 kg/ha

There was a huge variation in millet productivity as it was mostly cultivated in poor soil with minimum management effort. However with due management effort and introduction of agro-technology can improve the productivity dramatically. It was demonstrated under IBM-IORF sustainability project with adoption of IRF technology. Application of Novcom compost @ 40 ton/ha for organic soil management followed by spraying of energized and potentized energy solutions for crop health management helps to improve significant crop productivity. At the same time IRF Technology helps towards GHG mitigation with negative carbon footprint per kg millet which help towards value added marketing towards livelihood support for local farmers

Soil physical, physicochemical, fertility, biological properties in the Pre & Post Millet Cultivation Plots, Mandya, Karnataka.

Millets Plots	Soil Details	Soil Gravels %	Sand %	Silt%	Clay%	Texture	pH	EC (1:5) dSm-1	Org. C%	Av-N (kg/ha.)	Av P2O5 (kg/ha.)	Av. K2O (kg/ha.)	Av- SO4 (kg/ha.)	Av NO3 (ppm)	MBC (microgram C/gm dry soil)	FDA (µg/gm dry soil)
Finger Millet	Pre Cultivation Soil	46.29	54.66	34.88	10.46	Sandy Loam	5.91	0.039	0.41	287	43.26	609	588	19.46	21.24	18.86
	Post Cultivation Soil						6.23	0.047	0.63	291	46.24	587	537	20.72	43.29	38.24
Proso Millet	Pre Cultivation Soil	60.22	65.24	23.47	11.29	Sandy Loam	6.76	0.061	0.37	278	53.37	578	612	18.24	20.44	25.46
	Post Cultivation Soil						6.09	0.072	0.51	301	54.31	519	590	21.22	41.22	50.22
Kodo Millet	Pre Cultivation Soil	50.23	60.19	24.17	15.64	Sandy Loam	5.79	0.059	0.38	237	29.38	628	637	14.64	17.44	19.28
	Post Cultivation Soil						6.13	0.068	0.43	269	31.22	601	501	17.22	23.16	27.44
Pearl Millet	Pre Cultivation Soil	50.14	62.46	22.25	15.24	Sandy Loam	6.08	0.078	0.47	248	19.46	596	512	14.32	19.29	12.46
	Post Cultivation Soil						6.17	0.089	0.59	281	27.22	525	490	16.14	27.44	26.22
Shorghum	Pre Cultivation Soil	48.23	63.49	22.29	14.22	Sandy Loam	6.24	0.069	0.49	256	21.34	487	612	17.92	20.14	8.24
	Post Cultivation Soil						6.39	0.082	0.57	267	33.12	438	601	18.24	32.46	22.22

SOIL QUALITY ANALYSIS

Soil samples were taken at the initiation & after completion of the study. The initial study confirms that the soil is very poor in terms of soil carbon and fertility status as well as soil microbial activity. Organic carbon content tends to increase post-cultivation across all millet plots, indicating the addition of organic matter through plant residues and other agricultural practices, contributing to soil fertility and health. Overall, the soil data suggests that cultivation of millets with adoption of Inhana Soil Health Management under IRF Technology has led to improvements in soil fertility, with increased organic matter content and nutrient availability.

CONCLUSION

Millets are one of the oldest food grain crops and are generally grown in traditional agricultural systems with low inputs by resource poor farmers. But importance of millets towards mitigating food and nutritional security was emphasizes in recent years and Millets are designated as SHREE ANN on the occasion of International year of Millets-2023 in light of their nutritional values and suitability for climate resilience.

Under IBM-IORF sustainability project at Mandya District of Karnataka an initiative was undertaken for development of pesticide free ‘Clean Millet’. **towards the promotion of millets cultivation through introduction of improved agro-technologies for productivity enhancement, value addition for better marketability to improve farmer’s livelihood**.

There was considerable yield improvement was noticed under Clean Food Net Zero program with adoption of IRF Technology irrespective of millet variety. This clearly indicated that adoption of effective agro-technology like IRF Technology have the potential to change India’s Millet cultivation scenario.

IBM - IORF SUSTAINABILITY PROJECT

MILESTONE 6

Development of 'NET ZERO' Clean Coconut Planting Material, in the Project area at Mandya District of Karnataka

PHASE - III

Development of 'NET ZERO' Clean Coconut Planting Material, in the Project area at Mandya District of Karnataka

India is the largest coconut-producing country in the world and accounted for about 31.45% of the world's total production during 2021-22, with a production of 19,247 million nuts. The crop contributes around Rs. 30,795.6 crore (US$ 3.72 billion) to the country's gross domestic product (GDP) during 2022-23. The 4 states Kerala, Karnataka, Tami Nadu and Andhra Pradesh, accounting for 89.13% of the coconut area and 90.77% of the coconut production in the country during 2021-22. *(www.ibef.org/exports/coconut-industry-india).*

Karnataka state holds second highest area (604.23 thousand Ha.) after Kerala (756.44 thousand ha.) during 2021-22 (GoI). In Karnataka state almost all districts are cultivating coconut crop. **The Coconut productivity of Karnataka (8,569 nut/ha.) is 25% lower than Tamilnadu (11,400 nut/ha.) and even 5% lower than the National productivity (8,966 nut/ha.) (GoI).**

All India Area and Production of Coconut 2021-22

(https://coconutboard.gov.in/Statistics.aspx)

Sl No.	States /Union Territories	AREA (''000 Hectares)	Production (Million nuts)	Productivity (Nuts/ha)
1	Andhra Pradesh	105.80	1,689.09	15,964
2	Arunachal Pradesh	0.07	0.30	4,615
3	Assam	21.03	156.52	7,444
4	Bihar	12.16	78.39	6,449
5	Chhatisgarh	1.66	14.74	8,890
6	Gujarat	25.60	212.62	8,307
7	Karnataka	604.23	5,177.63	8,569
8	Kerala	765.44	5,522.66	7,215
9	Maharashtra	30.32	238.45	7,863
10	Mizoram	0.03	0.15	4,412
11	Nagaland	1.07	9.34	8,762
12	Odisha	52.82	397.57	7,527
13	Others	49.13	292.06	5,945
14	Tamil Nadu	446.15	5,091.83	11,413
15	Telangana	0.90	9.48	10,487
16	Tripura	4.71	12.97	2,753
17	West Bengal	32.63	406.10	12,447
	Total	2,153.74	19,309.90	8,966

Source: Ministry of Agriculture and Farmers Welfare, Government of India.

In terms of production of coconut in Karnataka, the major districts are Tumkur , Hassan , Chitradurga, Mandya, Chikkamagalur, Dakshin Kannada, Mysore etc.. Coconut forms a major crop in the IBM-IORF Sustainability Project area at Mandya, and when grown as a monoculture, often leads to farmers distress mainly due to crop loss associated with the pest and disease incidences and market price fluctuations.

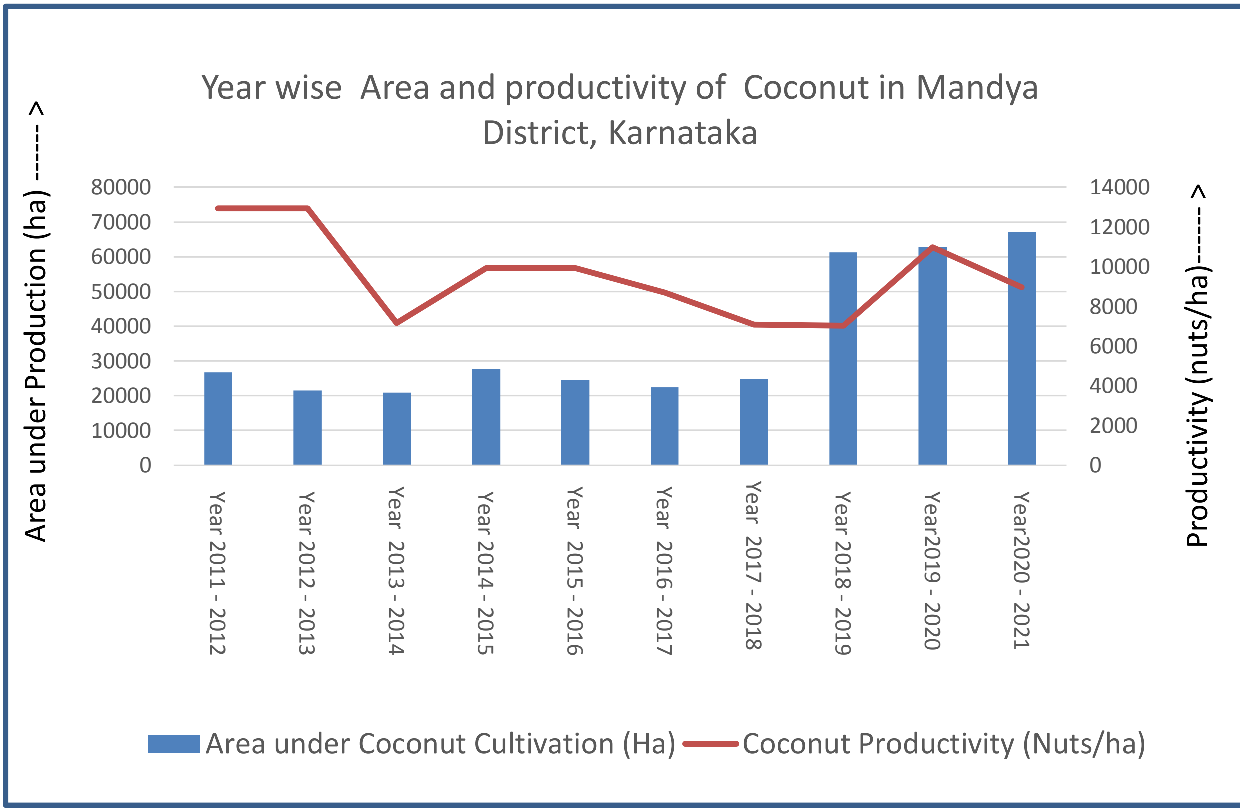


Fig. 1 : Year wise area under coconut cultivation and coconut productivity in Mandya District, Karnataka, India

According to the data available from Coconut Development Board, Ministry of Agriculture, Government of India, presently about **67106 ha area** is under coconut cultivation in Mandya and the average productivity is **8,955 nuts per ha**. Mandya is the 3rd largest district in Karnataka as far as area under coconut cultivation is concerned,2019-20. **Nearly 11% of area under coconut cultivation and 11.6 % of coconut production in Karnataka is from this district, 2019-20 (DIRECTORATE OF ECONOMICS AND STATISTICS, BENGALURU).** However comparing the data of last 10 years, it was found that though the production increased by about 151% **but the productivity sunk by about 31 %;** primarily due to climatic fluctuations, occurrence of higher pest and diseases and poor soil conditions

Quality Seedlings : Major Problem Encountered by the Coconut Growers

Coconut cultivation and its associated products have played a significant role in the socio-economic development of India for centuries. However, despite the promising prospects, the coconut products industry also faces several challenges that hinder its growth and potential. Though coconut provides livelihood for more than ten million farm families in the country, productivity of coconut plantations are found to be low. Prevalence of old and senile unproductive palms, poor genetic base of the existing palms under cultivation are some of the important reasons for low productivity.

During last two decades, the coconut growers have been facing many problems, which has ultimately resulted in declining the production and profits from their estates. Inadequacy of technical knowledge, planting materials and absentee landlordism are among the main problems faced by the growers. Recent study reveals that growers' were confronted with four critical problems. **The most critical problem was lack of quality seedlings**, followed by pest damage, farm gate nut price and access to technology. A recent survey said that the most critical problem was the lack of good seedlings as almost all the growers (89%) mentioned that they do not have a place to buy certified seedlings. **Since lack of seedlings is a severe problem, and it cannot be overcome within a short period of time, a well planned seedling production program is vital.**

Objectivity:

The quality of planting material determines the ultimate returns from arable crops, particularly from tree crops like coconut. The seedling vigour is highly correlated with adult palm characters such as early flowering, nut yield and copra production. Coconut, being a perennial crop, needs much attention in the selection of planting materials during establishments of an orchard or even for homestead garden.

Due to selection of the inappropriate mother palm, wrong planting technique, pest or disease attack during seedling/ nursery stage etc. ultimately impact on the coconut seedling quality. This reflected in terms of poor establishment, growth, yield and quality resulting a significant economic loss . In this background Net Zero Clean Coconut Seedling Development programme has been taken under IBM-IORF Sustainability Project, Phase III at Mandya, Karnataka.

The major objective taken under the IBM-IORF Sustainability Project was **production and distribution of high-quality planting material to enhance productivity.**

This involves development of Clean, Resilient, Disease free and Healthy Coconut Planting Material through adoption of Inhana Rational Farming (IRF) Technology. Specially plant health management practice under IRF technology help to energized the plant system towards healthy seedling development .

Flow Diagram of - Net Zero Clean Coconut Seedling Development under IRF Technology (IBM-IORF Sustainability Project, Phase –III, 2023-24)

Collected & selection of Coconut seed nuts from Model Farm area under IBM-IORF Sustainability Project, at Mandya, Karnataka). (Seed nuts were allowed to drop naturally, not harvested from palm.)

→

Seed nuts were soaked in Inhana Seed Treatment Solution for 48 hrs. **under IRF Technology**

↓

Filling the plastic tubes of 1.5 ft X 2 ft with Soil & Novcom Coir pith Compost* in 80: 20 ratio under IRF Technology

←

Planting of Seed Nuts in the Tubes

←

IPHM PoP solution application initiated at 5-6 inches height post germination

↓ →

Total 10 rounds of Inhana Plant Health Management Solutions were applied as per schedule.

→

Tubes are kept cleaned by manual weeding & Need based Irrigation was done.

The initial and most crucial step is the selection of mother palms. Specifically, mother palms aged between 25-30 years with an average annual yield of 120 over the last 5 years are chosen for seed nut collection.

Inhana Rational Farming (IRF) Technology

Inhana Rational Farming Technology (IRF) developed by Indian Scientist Dr. P. Das Biswas, is a comprehensive organic POP aiming at restoration of soil and plant health that simultaneously deflates pest pressure due to alleviation factors responsible for pest – parasite interactions. The package works towards (i) energization of soil system i.e., enabling the soil to function naturally as an effective growth medium for plants and (ii) energization of plant system i.e., enabling higher nutrient use efficiency alongside better bio-chemical functions that leads to activation of the plants' host defense mechanism.

Soil energization aimed at rejuvenation of soil microflora, is primarily attended by application of on-farm produced Novcom compost (that contains rich population of self-generated micro flora); different types of herbal concoctions and adoption of cultural practices. However, the technology emphasizes plant management as a precursor for resilient plant system that can ensure sustainability even under changing climatic patterns.

Plant management under this technology is a systemic approach that utilizes a set of potentized and energized botanical solutions developed on Element Energy Activation (EEA) Principle. According to EEA Principle, radiant solar energy is stored in plants and the bound or stored energy components from energy rich plants are extracted on specific day, time, by specific extraction procedure and subsequently potentized so that energy components can be effectively received by plant system for activation of various metabolic functions.

Each solution has one or more defined functions, but work in an integrated manner when applied in a schedule, for bringing about harmonized plant growth with ensured aggregation of biological compounds responsible for flavour, nutrition and medicinal properties.

Novcom Coir pith Composting

Under IBM-IORF Sustainability project (2022-23) at Mandya, Karnataka, an effort was initiated utilizing Novcom Composting Technology, towards bioconversion of coir pith into safe, mature and qualitative compost for sustainable soil management, especially looking at the stony red soils of the area which are erosion prone, and have a poor productive potential. Periodical study of Novcom coir pith compost samples on 0, 10, 20 and 30 days confirmed effective degradation as demonstrated by the rapid decline of C:N ratio from 1:100 to < 1:25, appreciation of total nitrogen by 98 percent and 60 % degradation of lignin within a 30 days' time period.

The facts are corroborated by the respective very high (in the order of 10^{16} c.f.u. per gm or one Trillion Billion microflora per ton compost) population of bacteria, fungi and actinomycetes. Phytotoxicity Bioassay test values confirmed not only the absence of phytotoxic elements in compost, but also indicated that this compost can actually accelerate seed germination and root growth process.

Estimation of methane mitigation potential under this technology utilizing the carbon assessment tool - Agriculture Carbon Footprint Assessor (ACFA, version: 1.0) indicated that Novcom Composting Technology can enable methane mitigation of about 6000 ton CO_2 equivalent per 1000 ton waste, directly from the source point.

Novcom coir pith compost

Coconut seedling quality under management of IRF Technology

Under IBM-IORF Sustainability Project, good quality clean coconut seedlings having average collar girth of 16 -18 cm, 8 -9 fronds and 145 - 175 cm height was obtained within 11th month. The majority (92.5%) of the nuts germinated within 90 days and recovery of good quality seedlings was to the tune of 89.5 per cent.

Table 1 : The temporal change in seedling height, girth at collar zone and total number of leaves at Monthly intervals after seed nut laying in response to IRF package of Practice

Months	6	7	8	9	10	11
Seedling Height (cm)	72.8	90.2	103.3	123.5	145.5	162.5
Girth at Collar (cm)	8.4	9.3	12.2	14.3	15.6	17.4
Total No of leaves	2.6	3.4	4.9	6.2	6.9	8.6

From the above study it can be concluded that adoption of Inhana Rational farming technology and addition of Novcom compost in the nursery tube helps towards healthy and vigorous growth of coconut seedlings. This this study cloud be a benchmark for development of quality coconut seedlings which is a major constraint in India

When the general recovery percent of quality coconut seedling is about 60 – 65 %, under IRF Package of Practice the recovery percent increased over 90 % under IBM-IORF Sustainability Project

Conclusion

India is the largest coconut-producing country in the world and accounted for about 31.45% of the world's total production. The major objective taken under the IBM-IORF Sustainability Project was production and distribution of high-quality planting material to enhance productivity. This involved development of Clean, Resilient, Disease free and Healthy Coconut Planting Material through adoption of Inhana Rational Farming (IRF) Technology. Specially plant health management practice under IRF technology helped to energize the plant system towards healthy seedling development .

The study showed that adoption of Inhana Rational farming technology and addition of Novcom compost in the nursery tube helps towards healthy and vigorous growth of coconut seedlings.

Mature coconut seedlings at Mandya under IBM-IORF Sustainable Project

IBM - IORF SUSTAINABILITY PROJECT

MILESTONE 7

Assessment of Quality Potentials of the First generation 'NET ZERO' Clean Vegetable Seeds produced under Phase-II Continuation Project in West Bengal, in respect of Yield Improvement and Climate resilience

PHASE - III

Introduction

Organic or sustainable crop production is the need of the day for agricultural sustainability as well as to mitigate the increasing risk of food chain contamination due to synthetic pesticides. The risk increases under the climate change impact and conventional farming has practically no answer towards meeting the safe and sustainable objectives. However shifting over from the conventional farming practice to nature friendly, sustainable crop production is not easy. It needs a great effort starting from suitable technological intervention to efficient resource utilization along with market support. However, the most important thing to start with is 'Quality Seeds' which can perform under low input environment and show resilience towards biotic and abiotic stress factors. Furthermore, adaptation is the key for achieving resilience in our food and agricultural system. Adapting seed to changing climates, resource availability, and environmental conditions is one way to mitigate risks for farmers and the food supply they serve.

It is estimated that more than 95% of organic/ low input agriculture is dependent on seeds varieties that were bred for the conventional high input sector. Recent findings have sown that such varieties lack important traits required under organic and low –input production system, which have major importance towards climate change mitigation strategies. A range of breeding goal desired for the climate resilient agriculture such as reduce reliance on inorganic N-inputs, higher nutrient use efficiency, greater resistance against diseases as well as other biotic and abiotic stress; are severely compromised under the conventional high input dependent seed development program. Especially the vegetable crops are highly sensitive to climatic vagaries, where sudden rise in temperature or irregular precipitation at any phase of crop cycle can affect growth, flowering, pollination and fruit development, which may subsequently lower the crop yield. To mitigate the adverse impact of climate change on the productivity and quality of vegetable crops there is need to develop sound adaptation strategies.

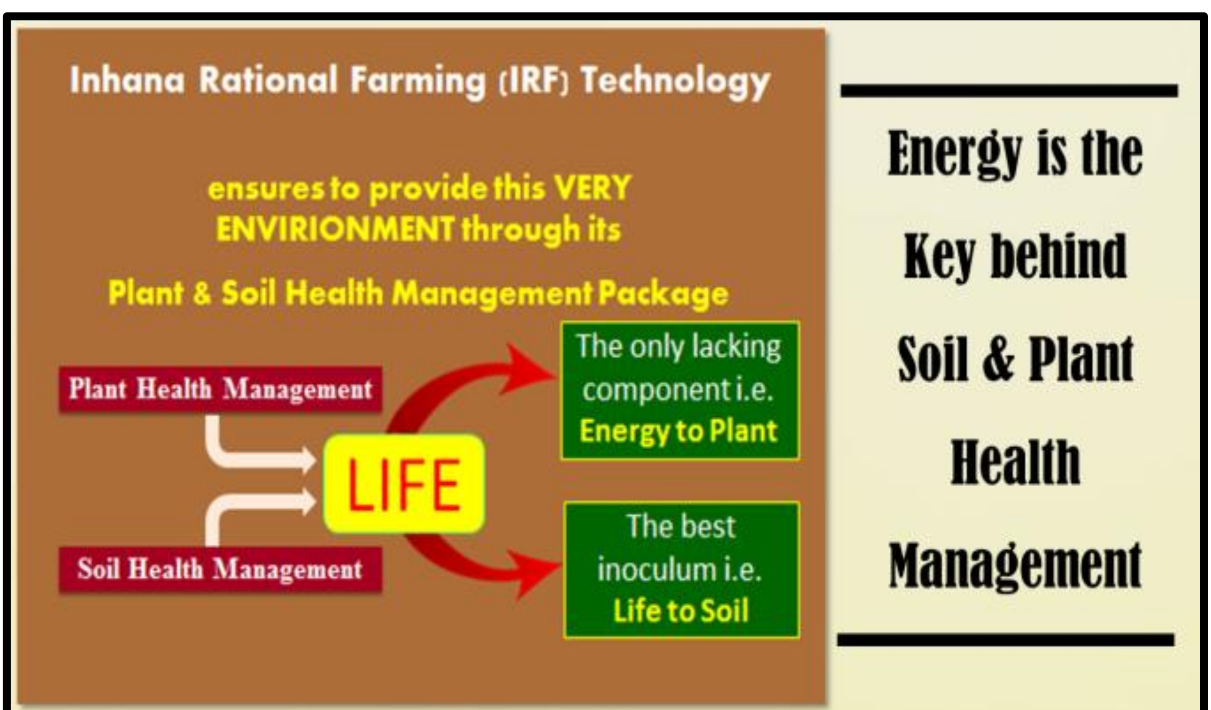
At the same time, organic/Net Zero Clean Seed development can reduce agriculture’s reliance on a seed industry based on proprietary control and chemical-intensive farms leading to . Organic seed systems – when viewed as an alternative to the dominant seed system – can help address bigger problems in agriculture. Expanding organic seed systems can also increase economic opportunities for farmers who successfully produce organic seed on their farm. The economic benefits include selling organic seed commercially, becoming more seed self-sufficient and reducing input costs, and reducing financial risks by having seed that’s better adapted to their farm. Farmer involvement decentralizes how organic seed is bred, produced, and distributed, and expands the diversity of seed grown and available.

In this background, we have taken a initiative to study the Assessment of Quality Potentials of the First generation 'NET ZERO' Clean Vegetable Seeds produced under Phase-II Continuation Project in West Bengal, in respect of Yield Improvement and Climate resilience . At the same time we also tried to develop second generation net zero clean seed development under the same study

The roads towards assessment of Net Zero Clean Seed

Net Zero Clean vegetable seed development program was initiated in the farmers field at Satyapole village, one of the 5 project village under IBM-IORF Sustainability project. It was second year continuation of seed development project . The study area falls under the New Alluvial and old Alluvial Agro-climate zone of West Bengal. Soils here are moderately well drained, deep and medium textured, pH varies from 6.5 - 7.5 with a good base saturation. Annual rainfall in the area varies from 1,401-1,671 mm; maximum and minimum temperature ranges between 25.2 - 37.9°C and 9.8 - 26.7°C respectively.

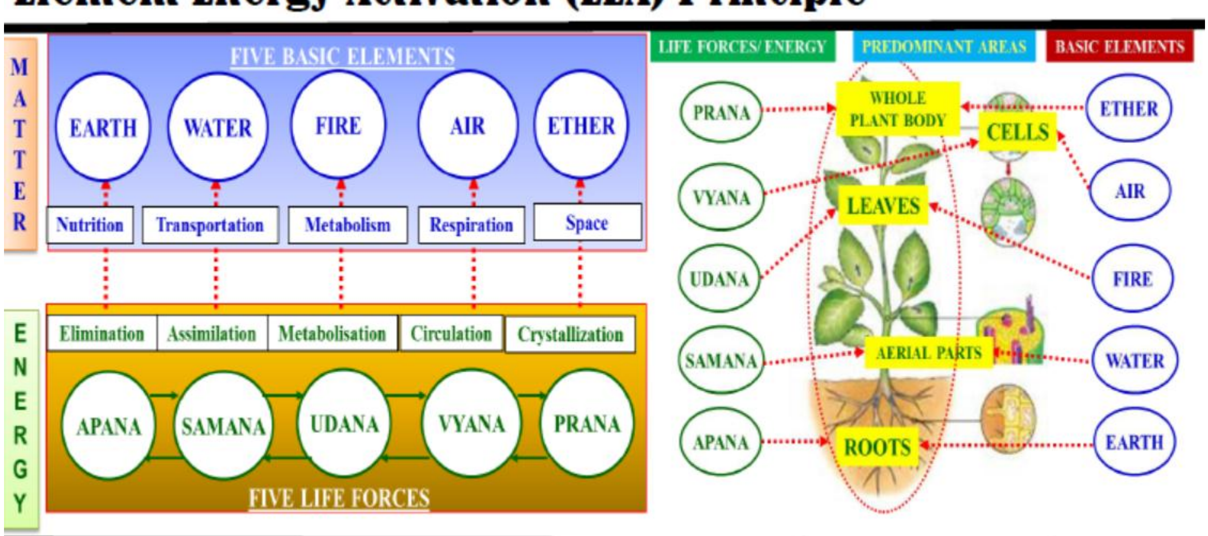
Inhana Rational Farming (IRF) Technology : Inhana Organic Farming Technology developed by the Indian scientist, Dr. P. Das Biswas, is a comprehensive organic approach towards Ecologically and Economically Sustainable Crop Production. Inhana Organic Farming focuses on Energy Infusion or Energization of the two critical influential components of crop production i.e., Soil and Plant System. The approach is aimed to restore the population and functional abilities of the native soil microflora and to reactivate the two lost qualities of the plant kingdom i.e., Sense of Self- Nourishment and Sense of Self- Protection.



Energization of Soil System aims to reactivate the soil- plant- microflora dynamics by providing an ideal environment and food source for natural regeneration of the population and functional abilities of the native soil microflora. This is primarily done through application of on-farm produced Novcom Compost as well as Soil Energizers prepared on- farm from cow based and locally available organic inputs. Along with this different cultural practices viz. mulching, in-situ composting, green manuring, cover cropping, etc. are also recommended as per specific requirement.

Energization of Plant System aims to energize, stimulate and reactivate the plants' physiological, metabolic and biochemical functions, through the scheduled application of '**Inhana Energy Solutions'. These solutions are the potentized and energized botanical extracts developed under Element-Energy-Activation (E.E.A) Principle.**

Element Energy Activation (EEA) Principle



Energy specific plants which store the radiant solar energy or the basic life force in differential forms can serve as a potential medium of energy components, which when released at the right time and in the right proportion can make matter (hereby the plant physiological functions) functional at the desired level and to restore/ bring equilibrium.

Cultivation Practice :

Eight different crop varieties were selected for the study *viz*. Brinjal (*Solanum melongena; variety* Tara BWX, DEB - 721), Chilli (*Capsicum frutescens* L.; varity Bullet, DEB - 1301), Okra (*Abelmoschus esculentus; varity Deb Swarna, DEB - 411*), Amaranthus Red (*Amaranthus cruentus, varity : Lal Kanaka, DEB - 2603*), Tomato (*Solanum lycopersicum, varity :*Kashi Aman, DEB- 2929), Spinach (*Spinacia oleracea; varity :* Pusa Bharati, DEB - 1905), mustard (*Brassica nigra, variety : local*) and Potato (*Solanum tuberosum, variety*).

Organic Soil Management

Organic soil management was done primarily with application of Novcom poultry compost @ 40 ton/ha followed by application of enriched cow dung slurry prepared as per the guideline of IRF Technology. Seeds were treated with IRF seed treatment solutions before sowing. Standard cultivation guideline along with IRF Plant Health Management was followed strictly from seed sowing to harvesting.

Development of Novcom poultry compost heap at the project area under IBM-IORF Sustainability Project

Quality of Novcom poultry compost

Compost samples were analysed for different quality parameters as per National and international standards. Unpleasant smell and flies around the raw poultry litter disappeared 3 to 4 days after the compost heap prepared, which may be due to the rise of temperature within the compost heap due to initiation of prolific microbial activity. High temperature generated within the heap compost (> 62.8^0C) for more than 3 continuous day confirm destruction of pathogens within the compost heap. The final compost appeared blackish brown in colour with earthy smell which was an essential criteria for mature compost.

Organic carbon content in Novcom poultry compost ranged between 22.92 and 24.93 percent, total nitrogen content in the Novcom poultry compost samples ranged between 1.69 and 2.14 percent, which was well above the reference range (1.0 to 2.0 percent) and C/N ratio varied from 13:1 to 14:1 indicating that all the compost samples were mature and suitable for soil application.

Microbial population (in the order of 10^{16} c.f.u to 10^{14} c.f.u in case of total bacteria, total fungi and total actinomycetes count) in Novcom compost was significantly higher (at least 10^3 to 10^6 c.f.u times) than the population obtained in case of other compost samples.

Sl No	Parameter	Range value	Mean Value	Std. E
1.	Moisture percent (%)	59.21 – 64.12	62.14	± 1.10
2.	pH (H2O)	6.77 – 7.81	7.58	± 0.12
3.	Organic Carbon (%)	22.91 – 24.79	23.91	± 1.03
4.	Total NPK (%)	3.96 – 4.71	4.35	± 0.10
5.	C:N Ratio	13 : 1 – 14 : 1	13 : 1	± 0.15
6.	Total Microbial population	21×10^{16} – 43×10^{16}	31×10^{16}	$\pm 2.1 \times 10^{16}$
7.	Compost Quality Index (CQI)	4.68 – 5.81	4.76	± 0.36

Productivity of the vegetables under IRF package of practice

Productivity of vegetables grown under the Clean Food 'NET ZERO' (CFNZ) Program in the Project Area Model Farm was compared with the productivity range of the respective vegetables under conventional farmers' practice in this zone.

Productivity of almost all the vegetables under IRF package of practice was higher than the average productivity of the same under conventional farmers practice. The findings indicated that adoption of IRF technology as an effective nature friendly package of practice for increasing crop productivity. This initiative could be a benchmark study for sustainable management of vegetables and the technological advancement can be transfer to farmers field for facilitates sustainable crop production specially when excessive use of fertilizer and pesticides enhance the risk of deterioration of soil health as well surrounding ecology.

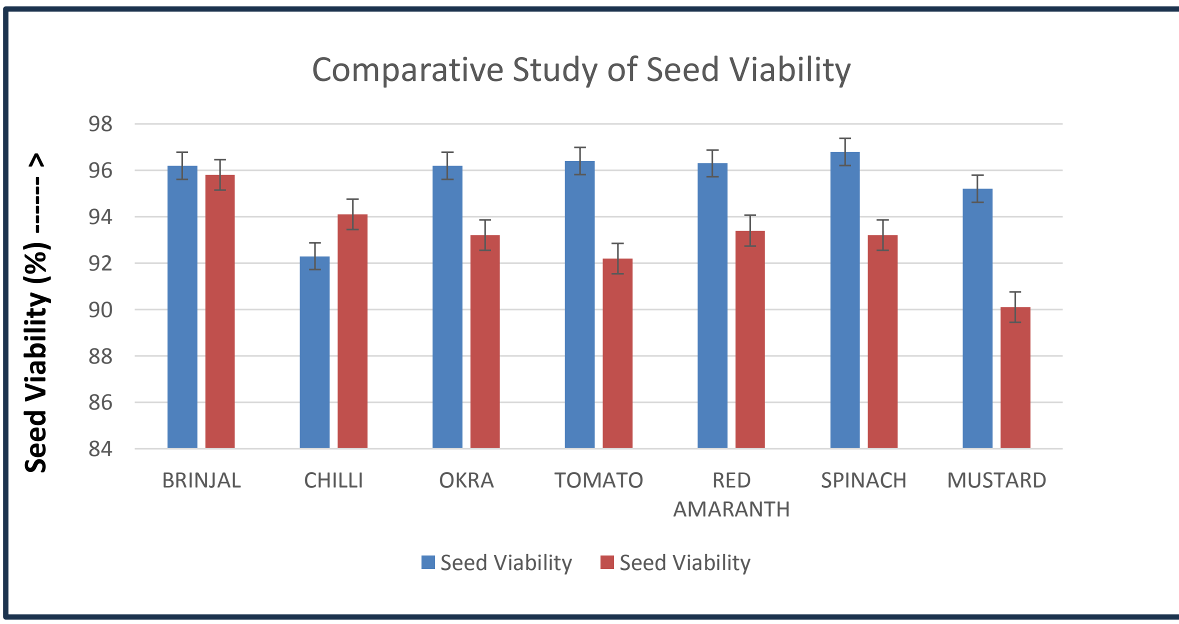
Productivity of Vegetables & Oilseed under Clean Food 'NET ZERO' Program

Crop		Clean Food 'NET ZERO' Yield (Tonne/ ha)	Conventional Farmers Yield (Tonne/ha)	'NET ZERO' Clean Seed Yield (Tonne/ ha)
BRINJAL	:	32.14	26.2 – 30.4	0.290
CHILLI	:	18.96	14.6 – 18.2	0.310
OKRA	:	19.41	13.4 – 16.6	1.340
TOMATO	:	33.20	24.5 – 30.7	0.242
RED AMARANTH	:	17.21	12.04 – 15.8	1.780
SPINACH	:	37.10	28.4 – 32.2	3.740
MUSTARD	:	0.558	0.46 – 0.50	0.558
POTATO	:	34.12	27.68	21.12

Evaluation of Seed Quality

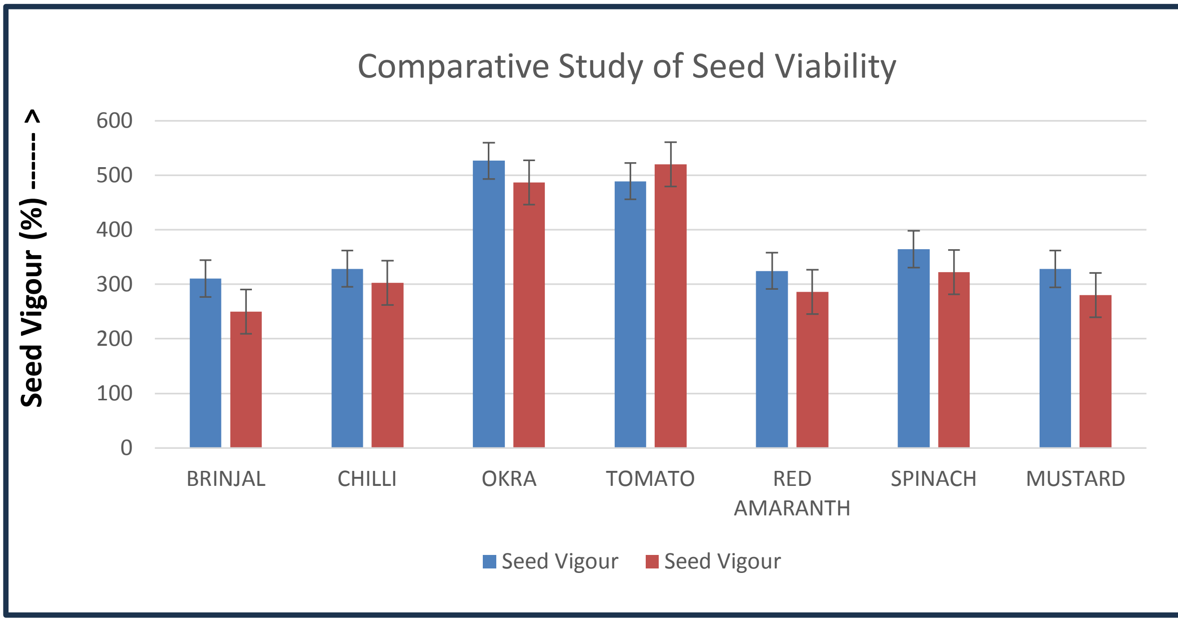
Seed quality is the key to successful crop production and food security. Crop yield and resource use efficiency depend on successful plant establishment in the field, and it is the vigour of seeds that defines their ability to germinate and establish seedlings rapidly, uniformly, and robustly across diverse environmental conditions. Improving vigour to enhance the critical and yield-defining stage of crop establishment remains a primary objective of the farmers to develop their own seed in their field.

Comparative study of Seed Viability between Conventional and Net Zero Clean Seeds.



Seed viability was tested through Tetrazolium test to study the degree of activity of the dehydrogenase enzyme system closely related to seed respiration and viability. Seed viability test showed value high score (ranged between 92.3 and 96.8) irrespective of the vegetable varieties indicating high quality of the organically developed seeds .

Comparative study of Seed Vigor between Conventional and Net Zero Clean Seeds.



Seed Vigour (SV-II) : Seed vigour is the combination of characteristics that determine the potential for high performance after sowing. The basic objective of seed vigour testing is to provide a precise identification of important differences in physiological potential among seed lots of commercial value, aiming to identify lots of higher probability to perform well after sowing and/or during storage. In fact, seed vigour is an interaction of characteristics that could be considered as independent attributes of physiological potential such as speed of germination, seedling growth and ability to germinate under abiotic stresses. Therefore two seeds might have similar germination percent but when subjected to the more stressful conditions experienced in the field, they might show vastly contrasting abilities to establish plants due to differences in their vigour. Seed vigour test showed significantly higher value in the case of Net Zero Clean Seed irrespective of seed varieties as compared to conventional seeds. The values clearly indicated superiority of Net Zero Clean Seed over the conventional ones.

Net Zero Clean Seed production under IBM-IORF Sustainability Project

Field validation of Net zero clean seed in farmer's field under IBM-IORF Sustainability Project

Conclusion

Seed forms the foundation for sustainable agriculture and more than 40 % of crop loss can attributed alone to poor seed quality. More than 70% farmers of our country do not have the access to authenticated quality seeds (both availability and/ or economic strength). On top that the hybrid/high yielding seeds have gradually captured more than 80% of the seed market and we are gradually losing out our seed diversity.

The ‘Net Zero Clean Seed’ development program done under IBM-IORF Sustainability Project has come forth as a benchmark study towards economically viable net zero clean seed production through the adoption of a comprehensive organic technology namely Inhana Rational Farming in the farmers’ field.

The findings have indicated the qualitative superiority of the seeds over conventional seeds in terms of seed vigour and seed germination. These qualitative changes in the seeds produced might have been influenced by the completely new approach of ‘Plant Health Development’ under IRF Technology; that was adopted for the programme. The approach helped in activating the plant physiology, which in turn led to the production of quality, climate resilient seeds.

In the case of IRF management, yield of the vegetables and the related economics were found to be much better as compared to the average productivity and the cost of vegetable production in the Nadia District of West Bengal. But most importantly, if this program can be transferred to the farmers’ field, the farmers can produce quality seeds to fulfill their own requirements at less than 10% expenses in relation to the market rates of quality seeds and to get higher yield which in turn help to sustained their livelihood,

IBM - IORF SUSTAINABILITY PROJECT

MILESTONE 8

Development of 'NET ZERO' Clean Sugarcane Planting Material, in the Project area at Mandya District of Karnataka

PHASE - III

Introduction

As the global population continues to rise, the demand for food and natural resources like land and water is escalating. Meeting the needs of this expanding population poses a significant challenge for the agricultural sector. With agriculture requiring more land and water to produce sufficient food grains, the strain on natural resources is becoming increasingly apparent. In India, sugarcane stands as a pivotal cash crop with diverse applications, including sugar production and renewable energy through ethanol. However, ensuring an adequate supply of sugarcane amidst diminishing natural resources has become more daunting than ever before.

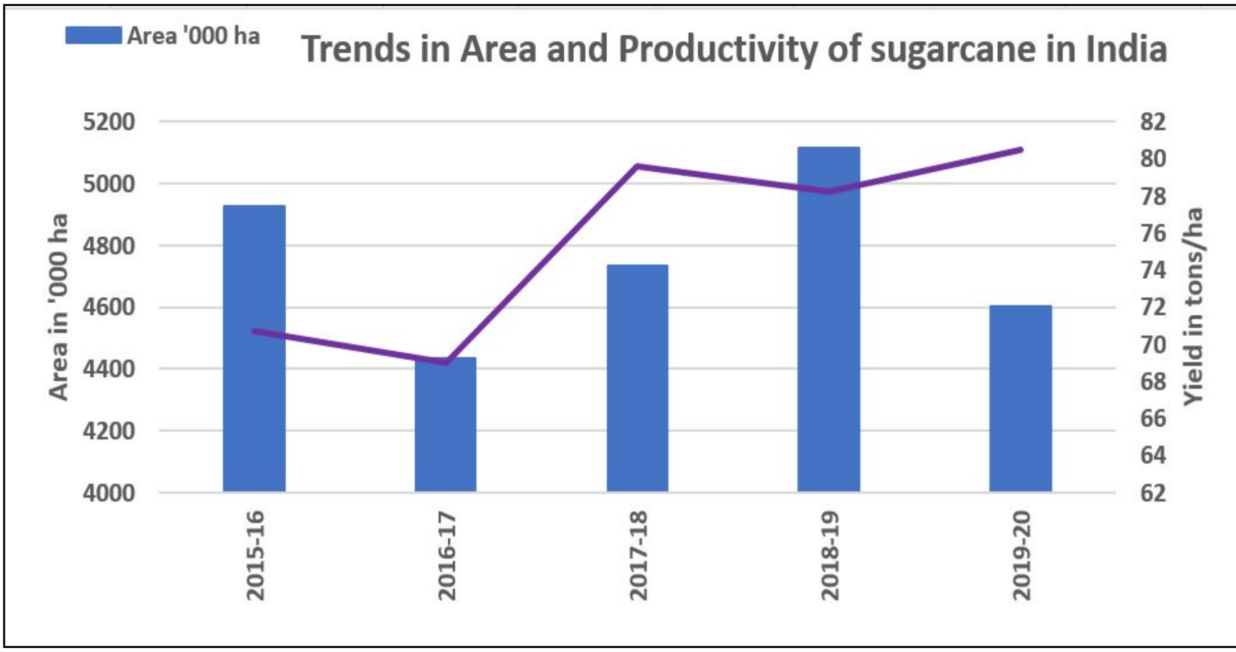
Sugarcane is the main source of sugar (80%) globally and holds a prominent position as a cash crop. Sugarcane and sugar play significant role in economy of India, trade and livelihood. Sugar is country's second largest agro-based industry, next to cotton. Sugarcane and sugar industry together impact the livelihood of over 5 crore farmers and their dependents involved in cultivating sugarcane in an area of almost 50 lakh hectares. India is the largest consumer and the second-largest producer of sugar in the world *(Ref.: https://www.niti.gov.in)*.

India is the second-highest producer of sugarcane in the world after Brazil. There are two distinct agro-climatic regions of sugarcane cultivation in India, viz., tropical and subtropical. Tropical region has about 45% area and contributes 55% of the total sugarcane production in the country *(Ref. AICRP (S) Technical Bulletin - No. 1, ICAR-Sugarcane, 2017).*

Area, Production and Productivity of sugarcane in India

Year	Area ('000 h)	Production ('000 tons)	Productivity (tonnes /h)
2016-17	4436	306070	69.0
2017-18	4732	376905	79.66
2018-19	5114	400157	78.25
2019-20	4603	370500	80.50

https://sugarcane.icar.gov.in/index.php/sugarcane-statistics/



https://sugarcane.icar.gov.in/index.php/sugarcane-statistics/

The largest producer of sugarcane in India is Maharashtra, which produced over 138 lakh tonnes of sugarcane in 2022-23. Uttar Pradesh, Karnataka, and Maharashtra together contribute to 80% of the total sugarcane production in India.

Sugarcane-producing states in India in 2021:

No	States / UT	2018-19	2019-20	2020-21*	Average (2015-16 to 2019-20)	% to total production	Rank
1	Maharashtra	89.77	69.31	101.59	73.6	20.33	1st
2	Uttar Pradesh	179.71	179.54	177.67	164.37	45.4	2nd
3	Karnataka	42.41	38.18	42.09	35.39	9.77	3rd
4	Tamil Nadu	17.14	14.12	12.8	18.58	5.13	4th
5	Bihar	20.12	13.58	10.71	14.64	4.04	5th
6	Gujarat	11.33	11.57	15.85	11.61	3.21	6th
7	Haryana	8.51	7.73	8.53	8.16	2.25	7th
8	Andhra Pradesh	8.09	6.72	4.12	7.96	2.2	8th
9	Punjab	7.77	7.3	7.49	7.37	2.04	9th
10	Uttarakhand	6.33	6.94	6.96	6.38	1.76	10th
11	Madhya Pradesh	5.28	7.43	5.88	5.63	1.56	11th
12	Telangana	3.18	2.01	1.36	2.45	0.68	12th
13	West Bengal	1.34	1.53	1.56	1.52	0.42	13th
14	Others	4.45	4.53	2.64	4.41	1.22	
	All India	**405.42**	**370.5**	**399.25**	**362.07**	**100**	

**4th Adv. Est ICAR-2020-21*

Area Under Sugarcane, Production and Yield in Karnataka

Karnataka stands 3rd in Sugarcane production next to Uttar Pradesh in India and Maharashtra 2nd with respect to sugar recovery after Maharashtra. Sugarcane is grown in 16 districts of the state. Belgaum, Bagalkot, Bijapur, Mandya, Mysore, Chamrajnagar and Bidar are the major sugarcane producing districts.

KARNATAKA	2016-17	2017-18	2018-19	2019-20	2020-21*
Area ('000 ha)	397	350	506	429	428
Production ('000 Tonnes)	27378	28263	42006	38181	41088
Productivity (Tonnes/ha)	69.0	80.8	83.0	89.0	96.0

https://sugarcane.icar.gov.in/wp-content/uploads/2023/02/ss_6.jpg

Mandya Sugarcane Scenario

Sugarcane is important commercial crop of Karnataka. Sugarcane plays a vital role for the overall socio-economic development of farming community in Karnataka State and Mandya District. Mandya district is one of largest producer of sugarcane in Karnataka. The district ranks fourth in Sugarcane production from an area of 34.67 thousand hectares and production of about 3.72 million tonnes during 2018-19 *(Madegowda Mand Dr. Mahesha M , IJSSER 2022).*

Sugarcane producing farmers are facing issues like low productivity in this district and the average sugar recovery rate is lower than the key sugar producing nations. The growth of area under Sugarcane in Mandya district from 1997-98 to 2018-19 shows negative growth of 0.17 percent. At the same time production of Sugarcane reduced to 37,18,282 tonnes 2018-19 from 42,63,661 tonnes during *2001-02 (Madegowda Mand Dr. Mahesha M , IJSSER 2022).* Though sugarcane productivity of Mandya district is 107 ton/ha. which is 30% higher than the national productivity about 80.5 tons/ha. but the major limitations in the sugar recovery percentage. *Madegowda M and Dr. Mahesha M, 2022* concluded in their study that the value of output of Sugar in Karnataka has positive growth of 15.87 percent over the study period of 2001-02 to 2018-19. **But in Mandya district the production of Sugar has negative growth by 3.86 percent.**

Background of developing Quality Sugarcane Planting Material

For commercial cultivation, sugarcane is propagated vegetative and requires a considerable amount of seeds. Good planting material (seed) contributes to higher yields; therefore, the supply of healthy seed cane is the main prerequisite for improving the productivity of the sugarcane crop. Availability of disease-free and quality planting material is essential for achieving a high yield of sugarcane cultivation. As sugarcane is propagated vegetatively, it favours the accumulation of pathogens (Vishwanathan, 2016). Hence along with seed canes, there are possibilities of introduction of disease-causing pathogens into the new areas.

At the same time conventional sugarcane cultivation requires more nutrients and water because of production of higher biomass and nutrient removal. Sugarcane crop is attacked by large number of insect–pests and diseases (Yadav et al. 2009a, b). The application of chemical fertilizers for supplying nutrients and pesticide to control insect pest in sugarcane is increasing day by day to achieve the target yields.

The prolonged indiscriminate use of chemicals particularly in the soils like Mandya District, with very poor organic matter content has, however, resulted in further soil health hazards along with environmental pollution.

In this background under IBM-IORF Sustainability Project Phase III, 2023-24 IORF took the initiative for the towards development of Climate resilient – quality planting material through adoption of IRF Technology , the primary solution for the above challenges.

Development of ‘Net Zero Clean Sugarcane Planting material’ will serve as the foundation for cultivation of ‘Clean Sugarcane’ and finally Clean Sugarcane ‘Net Zero’. ‘Net Zero Clean Sugarcane Planting material’ not only safeguard the environment (soil, water and air) and improve sustainability ultimately can provide a safe and sustainable pathway towards improved sugarcane yield (even within the same variety) and sugar recovery besides enhancing farmer’s income and sustainability.

In essence, by reorienting our efforts towards the development and adoption of 'Net Zero Clean Sugarcane Planting Material,' we can create a safer and more sustainable pathway for sugarcane cultivation, benefiting both the environment and the livelihoods of farmers in Mandya district, Karnataka.

Relevance of Sugarcane Seedling Quality

Sugarcane being a vegetative propagated crop, 12 to 14% of total cane production is used annually as seed material. A huge quantity of good quality seed cane is required for improving the productivity. Seed constitute the most vital input for successful and profitable agriculture. Thus quality seed production is an important activity to sustain the yield levels of current varieties and also to obtain maximum benefits from the newly identified varieties. The major objective of sugarcane seed production is to control diseases transmitted through seed cane.

As many sugar factories do not have a healthy seed nursery programme, farmers have no choice except to use their own seed material. Many of the diseases are seed borne and hence, poor seed quality leads to varietal degeneration. Therefore, the importance of quality seed cane in sugarcane cultivation cannot be overlooked. The diseases are considered to be an important limiting factor for sugar production and difficult to their control hence, production of healthy seed cane is necessary to ensure profitability.

A good seed in sugarcane is defined as the sett obtained from a healthy crop. It should be free from pests and diseases and should have a good germination rate of more than 85%. Healthy seed material, free from pests and disease like red rot, wild, smut, ratoon stunting etc., should be selected for seed purpose. For best results separate crop nurseries should be raised especially for producing seed-canes under good crop management.

The seed borne diseases viz., Red Rot, Smut, wilt, Grassy Shoot Disease (GSD) Ratoon Stunting Disease (RSD), Leaf scald, Mosaic and Chlorotic streak are to be controlled before planting through seed treatment

Quality of sugarcane seedlings

Good quality planting materials of Sugarcane through Single Bud raised seedling is gaining popularity and is the major answer to increasing yield and minimising cost of cultivation little portion of stem with one Eyebud are used to raise seedling in nursery. They result in producing a good crop when transplanted in main field. The principle advantage of Single Eye Bud plant is substantial saving in seed material and free from diseases Seed requirement is reduced to less than one ton per ha.

Advantage of Seedling of Single Eye Bud

- The Seedlings are free from diseases at the time of supply
- The Seedlings are ready to plant in the field and don't require any gap filling
- Quicker stem development and less time to harvest
- Reduction in cost of irrigation and less cost in farming practices as planting of established seedlings in the field
- Increase in sugarcane yield and sugar recovery
- Helpful in implementing season and varietal planting and harvesting program in sugar factory.

Flow Diagram of - Net Zero Clean Sugarcane Seedling Development under IRF Technology (IBM-IORF Sustainability Project, Phase –III, 2023-24)

Collected & selection of canes of 8-10 months old from Model Project area under IBM-IORF Sustainability Project, at Mandya, Karnataka).

→

Seed nuts were soaked in Inhana Seed Treatment Solution for 48 hrs. **under IRF Technology**

↓

Filling the plastic tubes of 1.5 ft X 2 ft with Soil & Novcom Coir pith Compost* in 80: 20 ratio under IRF Technology

→

Planting of Seed Nuts in the Tubes

→

IPHM PoP solution application initiated at 5-6 inches height post germination

→

Total 10 rounds of Inhana Plant Health Management Solutions were applied as per schedule.

→

Tubes are kept cleaned by manual weeding & Need based Irrigation was done.

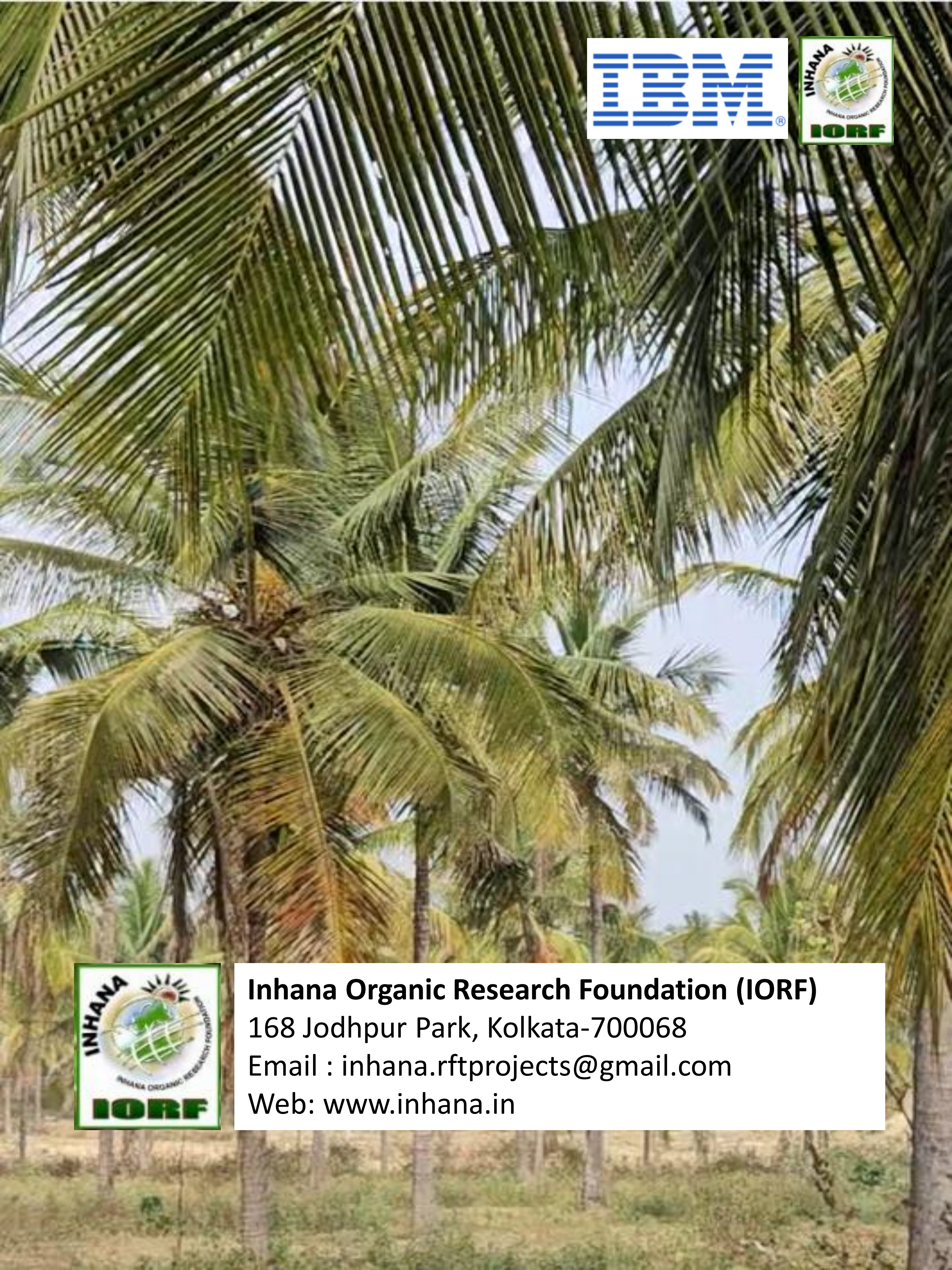
Development of Novcom coirpith compost under IBM-IORF Sustainability project at Mandya, Karnataka

Sugarcane plantation under Clean Food Net Zero program in IBM-IORF Sustainability project at Mandya, Karnataka

Future potential of the initiative taken

In the backdrop of climate change impact, development of sugarcane seedling using polythene bags or tray culture not only save the seed cost, but also reduce risk of crop failure. Specially looking at the cultivation scenario of Karnataka where there was scarcity of irrigation and people are mostly depends on rain. Now with disruption of natural rainfall pattern, development of sugarcane seedling using tray save water, prevent spreading of seed born diseases, reduce mandays, irrigation and other related cultivation cost. Now under IBM-IORF sustainability project, the initiative of development of 'NET ZERO' Clean Sugarcane Planting Material helps the farmers in the locality towards

(i) Development of quality seedling in their own farmyard
(ii) Selection of disease free seedlings
(iii) Reduce crop standing time in field
(iv) Reduce irrigation cost
(v) Reduce pest/disease management cost
(vi) Reduce weed management cost
(vii) Avoid risk of crop failure due to rainfall irregularity
(viii) Enhance crop productivity
(ix) Reduce carbon footprint
(x) Enhance farm income to support livelihood.



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