

Scientific Journey for Bio fortified salt tolerant sweet potato, taro and other tropical tubers – The Food in need is the Food indeed

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Abstract: I wished the papers of Kalbach and Satell in 2012, 2013 respectively would have been published much earlier prior to my professional journey- “Before you Innovate, Ask the Right Questions”. It is applicable to all streams of subjects. I got thrilled when I had read it. At the same time I felt myself fortunate that what they have suggested, nature had taught me in October 1999. In fact, our higher qualifications, knowledge, innovations, have no value when “Nature” becomes furious. I was quite happy after joining ICAR-CTCRI through Agricultural Research Service (ARS) examination in the year 05.02.1986 in Thiruvananthapuram, Kerala. With the back ground of plant biotechnology, I have started working on Micro propagation, meristem tip culture to generate healthy propagules of different tuber crops. In December 1994, I got transfer to Regional Center of ICAR-CTCRI located in Bhubaneswar, Odisha, India. I was quite happy as my native place is just overnight journey but got disappointed as there were no proper facilities to work. I could not imagine to work again on biotechnology. I got upset for sometime and then went for my Ph.D. Studies in CSIR- IMMT, Bhubaneswar with CSIR – SRF fellowship. I had persuaded my doctoral study under Late Dr. B.K. Debata and S.K. Naskar. After three years, I joined back Regional Centre but situation was almost the same. With guidance of my senior Dr. S.K. Naskar, I had accepted the field research and started working with him.

Then the turning point had come in October 1999 through “Super Cyclone”. It taught all of us a lot, especially our higher qualifications have no value when there is vagaries of nature. During such situation only commonsense works. I was suggested to take care of affected farm families of Kendrapada under contingent action plan of ICAR. I distributed them different tuber crops of different varieties. It was observed that very few could sustain under the ingress of saline water. That mooted me to think ‘why so?’ I started working rigorously with two of my Ph.D. students viz. M.R. Sahoo and M. Dasgupta. We worked hard to establish biotech laboratory with externally funded projects. We could come out with good results on salinity tolerant sweet potato and taro. Subsequently we strengthened the irrigation source and drip irrigation facility in our farm. Our first salt tolerant purple flesh sweet potato variety “Bhu Krishna (anthocyanin 90mg/100g, starch 22-23%)” and delicious salt tolerant orange flesh “Bhu Sona (beta carotene 14mg/100g, starch-20-22%)” have attracted not only the farmers but the Agro experts of the state, Nation and across. An overview of my scientific professional journey especially on sweet potato and taro is projected. The work plan I proposed as Director and had executed in strengthening R&D of Regional Centre, Head quarter as well as enhancing visibility of tropical tubers in and across Nation are also highlighted.

Keywords: *Scientific Journey, Bio fortified, Salt tolerant, Sweet potato, Taro, Food in need*

INTRODUCTION

Me (Dr. Archana Mukherjee) would like to take all the readers of the article back in 5th Feb. 1986. I joined as Scientist in ICAR-CTCRI, Thiruvananthapuram through ARS examination. The day I joined the Institute, regular Director Dr. S.P Ghosh was out of station. Dr. N G Pillai Sir was acting. After joining I started feeling for my six month old baby girl whom I left first time under baby sitter. I started weeping, Pillai Sir asked me the reason and consoled that I have to take the pain only for three years till the baby attains to go nursery. If I leave the job, I may have to repent later. After two days, our regular Director came back and asked me about tuber crops. I started telling about beet root, radish etc. He could not digest, told me to follow him and showed me the pictures of all tropical tuber crops.

'Have you seen'?- Yes Sir. He asked where? ; I replied all these are being used as cattle feed in our house. He became furious and told me go to the Library and study there. These crops provide food to millions of people across the globe. Next day he attached me with all stalwart seniors of different divisions to have thorough knowledge both in theory and in practical. I first got attached with M. Unnikrishnan Sir, he took me to a plot which was far below down the Institute. I was not able to keep pace with his walking speed. But I felt fortunate that I could learnt about taro – the ancient crop of the World. Then I joined Dr. P.G. Rajendran – who was working in elephant foot yam. He had showed me seeds of elephant foot yam and I was astonished to see its polyembryonic nature. Later, I was asked to join Dr. B. Vimala to do pollination in sweet potato. She took me in yearly morning 4 am and told to complete hybridization work by 5 pm. Subsequently I joined with Dr. S.G Nair, Dr. R.B. Nair, Dr. K. Abraham, Dr. Vasudevan to know different tuber crops and their improvement programme.

After two weeks orientation course with different scientists I was asked by the then Director to select a field to work. During my M.Sc. thesis, I had worked with Prof. Dr. K.B. Datta, Head Cytogenetic and plant breeding section, Kalyani University, West Bengal.

I gathered experience to work on cytological changes under *in vivo* and *in vitro* in *Allium cepa* and *Allium sativum*. Dr. Ghosh advised me to work on haploid breeding in sweet potato and cassava through *in vitro*. As we were not having tissue culture lab in crop improvement division, he had attached me with Dr. N. G .Nair Sir. I will never forget the kind gesture of Dr. N.G Nair and Dr. M. Thankappan Sir. They had accommodated me well in their laboratory. In my crop improvement division all senior lady colleagues like Smt. Easwari Amma, Smt. Thankamma Pillai, Dr. Sreekumari, Dr. V. Shanta were used to take due care of me. Senior colleagues of other divisions like Dr. T. Ramanujam, Dr. C. Balagopalan, Dr. K.S. Pillai, Dr. M.S. Palaniswami, Dr. C. Mohankumar, Dr. B. Mohankumar, Dr. Muralidharan, Dr. Sundaresan, Dr. Bala Nambisan, Dr. Padmaja, Dr. Lila, Dr. K.R. Lakshmi, Dr. Rajamma, Dr. Ramanathan, Dr. Anantharaman, Dr. C.S Ravindran, Dr. P. Indira, Dr. Kabeerthumma, Dr. Radhakrishnan, Dr. Govindankutty and Smt. Rajama, Librarian all were found to be very accommodative and cooperative.

All our technical and administrative staff were very punctual and helpful. I still remember the support of Dr. R. G. Nair, Shree Asokan Nambiar for their affectionate support to a new comer. I also got boosted from Dr. J.S. Jose, Head of division of crop improvement. He became too much satisfied when I had sectioned the immature embryos of cassava and sweet potato. Despite such assistance to Head Sir and other Senior Sirs they told me that they cannot include my name in their papers but they will acknowledge my contributions. With this kind of gestures, I was quite happy and not expecting more. In those days, we felt,

good wishes of seniors are more valuable than my name in the papers. Yes, I had learnt a lot from all my seniors.

After sometime, we got Internationally renowned Dr. N.M. Nayar Sir as our Director for six-seven months. All colleagues were scared and started telling me that I have to be careful. He was a man of science and literature. Punctuality and discipline were the motto in his dictionary. Initially I too scared but one day he called me and asked some basic questions of genetics and plant breeding. I felt happy that I could satisfy him. After few days he called me, Dr. N.G Nair and advised to stop our regular projects and give our hundred percent to clean CMD disease of lucrative cultivars of cassava. We had started doing so through apical meristem culture followed by thermotherapy. He consoled us that our projects are important but "Farmers' need is our Priority" - "Farmers' first emerged out".

During his regim he had reformed ICAR-CTCRI in every sphere including AICRP-TC. He used to spare 20- hours a day for the improvement of Institute. All our publication got new dimensions with excellent harmony of Science and literature along with future directions. After him the successors mostly followed the same publications only with new cover page and new names. I still feel proud of our Dr. N.M. Nayar Sir. After N.M Nayar Sir, we got Dr. G.T. Kurup Sir, as our Director. He was nice, sober having due respect to Dr. N.M. Nayar Sir. During Kurup Sir's regime I got chance to come to our Regional Centre ICAR-CTCRI, Bhubaneswar, Odisha.

I bow down to Dr. Kurup Sir. In his time, I faced personal problems and requested him to transfer me to Bhubaneswar. Sir, gave me patient hearing and advised to wait as he wanted to transfer me with public interest. He frankly told me that scientists of HQ will not move, under such prevailing situation "You deserve transfer with public interest". He did so. I joined Regional Centre in December 1994 during Dr. T.K. Pal's Headship. Afterwards

I had worked with Dr. S.P. Verma. I had started working on sweet potato and taro plant breeding totally based on field research as there were no basic amenities for tissue culture work. One thing I must admit whether HQ or RC we were used to work like a family, no enviousness, no competition no score card based selfishness. Overall, we all were happy. Meanwhile I got CSIR-SRF for pursuing my Ph.D during 1996 to 1998. I had submitted my thesis on time in 1999 January.

Then in October 1999 we all faced 'Super Cyclone'. I got moved with the papers of Satell 2013 and Kalbach 2012 "Before you Innovate, Ask the Right Questions"- as quoted by them is very logical. I think the youngsters especially score card obsessed Scientists must read the said papers. They are day by day becoming scientist by "designation" far beyond from "reality of science".

Real science will haunt you, 'Am I right? Am I doing the justice to science and the society' etc.?

I wished I should have Read those papers much earlier. In October 1999 'Super Cyclone' exposed us before the farming community. What we did for them? Why they were starving ? Why the crops failed owing to ingress of saline water. All these questions were haunting me. I with two small kids became very emotional. Meanwhile, all the ICAR Institutions of Bhubaneswar and Cuttack got directions to rehabilitate the affected farm families with our respective commodities.

I fortunately or unfortunately got the furthest affected zones like Kendrapada-Mahakalapada Block affected areas of Odisha, India. Supplied them different varieties of sweet potato and other tuber crops. On periodical monitoring, I found few varieties thrived well despite salinity and that was the mooted question to me- why few not all? I had started to work more and more and had proposed two projects to ICAR. One on sweet potato and another on taro for their tolerance to salinity. We got both the projects one under

AP-Cess and other under NATP-CGP with support of the then ADG, Dr. Dhankar. We started working rigorously both in laboratory and field with support of two of my good students Dr. M.R. Sahoo and Dr. M. Dasgupta. We got lots of support from sister Institutions to use their lab equipments. Thereafter we didn't look back or stop to develop salt tolerant bio fortified sweet potato and taro. The food and nutrition for all. These would not have been possible without the support of senior breeders like Dr. S.K. Naskar, Dr. B. Vimala. We all the breeders bow down to Bharat Ratna Prof. Dr. M.S. Swaminathan Sir, as well as our former Director Dr. N. M. Nayar Sir for their constant encouragement in our endeavours. We are grateful the then Director General Dr. T. Mohapatra Sir, who is our pathfinder to carry forward the lab products at the site of "Hunger Vulnerable" areas through system based cluster approach. In this communication I would like to shed more light in my scientific journey with tuber crops especially on sweet potato and taro.

PROPELLING OF MY SCIENTIFIC JOURNEY FROM *IN VITRO* TECHNOLOGY TO CLIMATE RESILIENT BIO-FORTIFIED FIELD PRODUCTS OF DIFFERENT TUBER CROPS

The agro science journey was undertaken since joining the ARS in 1986 under aegis of ICAR with following major initiatives of inter and multidisciplinary research, development and dissemination of developed technologies. Such initiatives were mooted especially by SWOT analysis of the mandate crops like tropical tuber crops (cassava, sweet potato, taro & yams) and their consumers such as small, marginal, tribal, backward farmers and the natural calamities. Such scenario not only prevailing in India but also across the globe. While doing the SWOT, the strength observed that tropical tuber crops are adaptive to wide agro - ecological conditions. They are efficient

transformer of solar energy [[cassava (250×10^3 kcal/ha), sweet potato (240×10^3 kcal/ha) as compared to rice (76×10^3 kcal/ha), wheat (110×10^3 kcal/ha) and maize (200×10^3 kcal/ha)] and provide food to more than 500 millions.

Even such adaptive and hardy crops are vulnerable to disease and pests due to continuous vegetative mode of propagation resulting in sexual degeneracy, asynchrony in flowering, heterozygosity and protogynous nature threatening their allelic diversity (Mukherjee *et al* 2011 a & b; Mukherjee *et al* 2015 a & b; Chairl *et al* 2016). Despite high calorie, nutritional values such robust groups of crops had not received due attention for their scientific technological advancement due to low status of their consumers like poor marginal farmers, the tribal, mostly the needy populace. Importance of these group of crops regained in the context of climatic change. Taro and sweet potato were grown as rescue crops during post Super cyclone (October 1999 - March 2000), Tsunami (2004). This led to rethink the researchers to tap the untapped potentials of sweet potato and taro. As a whole, to redesign the tropical tuber crops especially for adaptive food, nutritional security and livelihood improvement under adversities. With these facts, R & D as well as promotional activities was conceptualized to develop high value climate resilient tuber crops with special mission to address the food insecurity, malnutrition and livelihood improvement.

The Scientific professional journey had began with my M.Sc. thesis on basic innovation focused on Cytological changes of chromosomes of two important food items- onion (*Allium cepa*) and garlic (*Allium sativum*) under the guidance of Late Prof. K.B. Datta, the then Head, Botany Department, Kalyani University. I was thrilled to study in depth of Cytogenetical changes along with Prof. M.L. Chakraborty, my UG teacher and doctoral student of Prof. K.B. Datta. I gained basic knowledge on plant tissue culture, cytogenetics and plant breeding from

them. Thereafter, I had joined as Junior Research Fellow of CSIR based on JRF examination. I had started my doctoral programme under the guidance of Dr. A.G. Mathew, the then, Director of present CSIR-NIIST. My research study was on histo chemistry and histology in palms. Simultaneously I got selected in ARS, ICAR in the stream of 'Genetics and Cytogenetic'. Based on that, I had switched over to my scientific professional career as scientist in ICAR-CTCRI, Thiruvananthapuram, Kerala on 05.02.1986. With background of plant tissue culture, I was guided by Dr. S.P. Ghosh, the then Director, ICAR-CTCRI to work on haploid breeding through tissue culture. Along with pollen culture, I was also suggested to develop in vitro propagation techniques for all tuber crops. When Dr. N.M. Nayar became Director, he guided all the tissue culture experts to clean Cassava Mosaic disease of popular cultivars through meristem tip culture and propagate them for the urgent need of the Farmers. During that journey we could do so successfully and could developed the in vitro techniques to recover desirable hybrids in sweet potato, pollen cultures in cassava (Mukherjee *et al* 1991; Mukherjee *et al* 1994; Mukherjee 1999; Mukherjee and Vimala 1994).

In 1994, December I got transfer to our Regional Centre (RC) in Bhubaneswar, Odisha with support of Dr. G.T. Kurup, the then Director. One year I had worked with Senior crop breeders Dr. S.K. Naskar in the field as we were not having proper facilities for intensive lab or biotechnological work. I got selected for CSIR –SRF and joined for Ph.D. at CSIR-IMMT under the guidance of Late Dr. B.K. Debata and Dr. S.K. Naskar as Co-guide. During my doctoral study I could again work on plant biotechnology with Dr. Debata in IMMT laboratory and could validate the products in field at RC under supervision of Dr. Naskar. During Ph.D, I could study thoroughly sweet potato, some medicinal crop species and taro. Best on the Ph.D. work on sweet potato we

have published the work on reputed National and International Journals (Mukherjee *et al* 1998 a & b; Mukherjee 2001 & 2002; Mukherjee *et al* 2001; Mukherjee 2002).

I have been awarded Jawaharlal Nehru Gold Medal of ICAR for best PG work on Horticulture. My work on sweet potato got further recognition as Best Poster Award in "International Conference 'New Horizons in Biotechnology- the year 2010 and beyond'. In Food Biotechnology section.

After completion of Ph.D. I had joined back to Regional Centre, but facilities were not improved by that time. I started working in field. Then the "Turning point" came in my career. 'The Super Cyclone' in Odisha, in October, 1999. The miseries of cyclone victim farmers mooted my mind. While I was working under 'ICAR- Contingent Action' plan in post cyclone period I felt ashamed to give them meagre amount of money and our produce. Anyway I kept on monitoring their situation in the areas of Kendrapada, Jagatsinghpur, Odisha. Helped them with medicine, drinking water, clothes and supplying ready to use food. 2-3 weeks later I had supplied them our different varieties of different tuber crops (Fig. 1).

Guided them to grow as they were the growers of cabbage and brinjal. With periodical interactions, I came to know few varieties had thrived well and rest could not grow owing to ingress of saline water in their fields. It started haunting me 'why few survived? Not all.' I had collected those survived samples and analysed. I have observed in sweet potato the variety Gouri (orange flesh) and variety Kishan (white flesh) grown well despite salinity in soil. Survival rate of Gouri was more compared to Kishan. Gouri is having beta carotene 5-6mg/100g to overcome the oxidative stress. Kishan is having high dry matter and starch 20-21%. These features enabled those crops to survive compared to other white flesh varieties with less starch, dry matter etc. Based on those



Training and planting materials distribution at Kanaguli, Jagatsingpur, Ramakrishna Mission rehabilitation centre

**Fig. 1 : Training to rehabilitate cyclone affected farm families, contingent action plan
ICAR during October 1999- March 2000**

analysis me with Dr. Naskar proposed two externally aided projects – One on salt tolerant coloured flesh sweet potato (ICAR, AP-Cess) and another on biotic and abiotic stress tolerant taro (ICAR, NATP-CGP) through integrated breeding approaches. We got students Sri M.R.

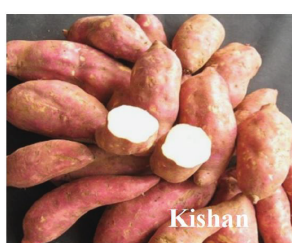
Sahoo and M. Dasgupta under those schemes. We all worked rigorously and established basic biotech facilities with externally aided projects and Institutional support from the then Director, Dr. S. Edison. Since the projects were time bound , we had worked and developed

the salt tolerant, weevil resistant, purple flesh- Bhu Krishna with 90-95mg/100g anthocyanin. Salt tolerant orange flesh sweet potato, Bhu Sona with beta carotene 14-16mg/100g; Bhu Kanti with beta carotene 7-8mg/100g; Bhu Ja with beta carotene 6-7mg/100g. We also developed Bhu Swami, white flesh sweet

potato tolerant to mid season drought with highest extractable starch of 23%. We also have developed salt tolerant, blight resistant (taro) Bhu Kripa; Bhu Sree; short duration greater yam 'Bhu Swar' and hybrid yam bean (8x9) [Figs. 2 & 3]. The specific attributes of the improved varieties have been well explained



Kalinga
 Dry matter (%) : 29.6
 Extractable Starch (%) : 16
 Total sugar (%) : 2.5-3.3
 Cooking quality : Excellent
 Average Yield : 18 tha^{-1}
 Suitable for food, fodder



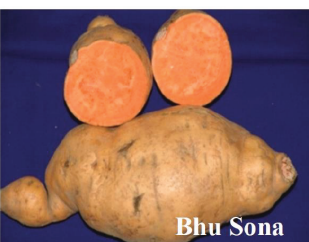
Kishan
 Dry matter (%) : 32.0-34.0
 Extractable Starch (%) : 17.5
 Total sugar (%) : 3.0-3.5
 Cooking quality : Excellent
 Average Yield : 19 tha^{-1}
 Suitable for food & processing



Bhu Swami
 Dry matter (%) : 27.4-29.7
 Extractable Starch (%) : 21
 Total sugar (%) : 3-3.7
 Cooking quality : Excellent
 Average Yield : 20 tha^{-1}
 Suitable for food & processing



Sree Kanaka
 Dry matter (%) : 23.8
 Starch (%) : 15
 Total sugar (%) : 1.8
 β -carotene (mg/100g) : 9
 Cooking quality : Good
 Average Yield: 14-15 tha^{-1}
 Matures within 85 days



Bhu Sona
 Dry matter (%) : 27-29
 Starch (%) : 20
 Total sugar (%) : 2-2.4
 β -carotene (mg/100g) : 14
 Cooking quality : Good
 Average Yield : 19.8 tha^{-1}
 Tolerant to salt stress (6-8.0 dSm^{-1})



Bhu Kanti
 Dry matter (%) : 24-25.5
 Starch (%) : 16
 Total sugar (%) : 1.9-2.2
 β -carotene (mg/100g) : 6.5
 Cooking quality : Good
 Average Yield: 20 tha^{-1}
 Tolerant to salt stress (6-8.0 dSm^{-1})



Bhu Krishna
 Dry matter (%) : 24-25.5
 Extractable Starch (%) : 19.5
 Total sugar (%) : 1.9-2.2
 Anthocyanin content (mg/100g) : 85-90
 Cooking quality : Fair and non mealy
 Average Yield: 18 tha^{-1}
 Can tolerate salinity stress (6-8.0 dSm^{-1})

Fig. 2: Improved varieties of sweet potato for food, feed and industrial uses



Yield : 15-20 t/ha
 Dry matter (%) : 23.5 to 24.6
 Starch (%) : 12.3 – 14.2
 Total sugar (%) : 1.3 – 1.7
 Cooking quality : Good



Yield : 15-20 t/ha
 Dry matter (%) : 23.5
 Starch (%) : 17.8
 Total sugar (%) : 2.0
 Cooking quality : Excellent



Yield : 15-18 t/ha
 Dry matter (%) : 23
 Starch (%) : 12
 Total sugar (%) : 3.3
 Cooking quality : Good



Yield : 13 t/ha
 Dry matter (%) : 22.6
 Starch (%) : 13.5
 Total sugar (%) : 2.8
 Cooking quality : Good

Developed high yielding short duration greater yam & yam bean



Yield : 20-25 t/ha
 Dry matter (%) : 32-33
 Starch (%) : 18-20
 Total sugar (%) : 1-1.5
 Cooking quality : Excellent



Yield : 40-45 t/ha
 Smooth surface
 Tuber skin : Cream
 Flesh is white

Fig. 3: Developed taro varieties resistant to leaf blight, tolerant to drought, salt, submergence

(Sahoo *et al* 2007, 2009 & 2010; Mukherjee 2010; Moorthy *et al* 2010; Mukherjee 2013, Mukherjee 2016, Mukherjee and Naskar 2012, Mukherjee 2024, Mukherjee *et al* 2024a).

We further analysed the micro elements contents of those varieties. Considering the desirable attributes of those varieties, we started recurrent breeding and evaluation using those improved varieties as parents. Meanwhile we strengthened the farm facilities as water availability for irrigation was constant problem. Me along with support of Seniors viz. Dr. Naskar, Dr. Abraham could

extend farm facilities like bore well, pump house and drip irrigation system under PPV & FRA, New Delhi sponsored DUS projects. We had further strengthened the drip irrigation coverage for our farm under International Network Projects for Edible Aroids- taro (INEA, taro). Both with lab and farm facilities we had worked intensively to generate hybrids of coloured flesh sweet potato as well as hybrids of exotic dasheen and indigenous eddo taro. We have developed the hybrids in both the crops with nutritional attributes (Tables 1&2).

Table 1: Nutrient composition of high yielding purple (a), orange (b) and white flesh (c) clonal lines of F1 (Hybrids)

Table 1(a): Purple flesh

Sl. No.	Breeding Lines*	Total Yield (t/ha)	Total Starch (%)	Total Carotene	Ca	Fe	Zn
				(mg/100g)			
1	KS-22	21.37	20.4	6.4	25.3	0.52	0.52
2	KS-12	20.95	20.8	5.8	24.8	0.74	0.58
3	ST10-19	22.45	23.4	2.2	20.4	1.23	0.72
4	KS-27	21.33	21.8	4.4	24.2	0.8	0.65

*All these four lines recorded anthocyanine (65-85mg/100g)

Table 1(b): Orange flesh

Sl. No.	Breeding Lines	Total Yield (t/ha)	Total Starch (%)	Total Carotene	Ca	Fe	Zn
				(mg/100g)			
1	ST14-34	21.84	23.6	13.8	37.6	0.72	0.62
2	SV-22	21.57	22.8	9.4	34.8	0.56	0.48
3	ST14-16	21.15	23.5	14.2	36.9	0.68	0.66
4	CO350-23	20.93	22.4	8.4	34.2	0.52	0.54

Table 1(c): White flesh

Sl. No.	Breeding Lines	Total Yield (t/ha)	Total Starch (%)
1	ST-11	23.3	23.5
2	CO3 4-8	25.3	22.8
3	IGSP-10-17	23.49	22.6
4	CO3 4-9	24.75	23.4

Source: Mukherjee *et al* 2024b

Table 2 : The Salient characteristics of Indigenous, exotic and hybrid taros

Varieties	Total Yield (t/ha)	Plant Type	Resistance to Blight (R)	Tuber type	Ca	Zn	Fe
					(mg/100g)		
Muktakeshi	14-16	80-100cm (Medium)	R	Eddoe	31.3 – 34.2	0.75-0.81	0.58-0.63
Bhu Kripa	15-18	40-50cm (Dwarf)	R	Eddoe	30.5 – 32.7	0.77-0.81	0.64-0.68
Bhu Sree	15-16	40-50cm (Dwarf)	R	Eddoe	24.2-26.5	0.87-0.92	0.72- 0.75
Exotics	20-22	120-150cm (Tall)	R	Dashen	22.5-25.3	0.71-0.74	0.48-0.56
Hybrids	18-20	80-120cm (Medium)	R	Inter mediate	26.4-28.2	0.82-0.85	0.64-0.71

Source: Mukherjee *et al* 2024c

Simultaneously we have developed *in vitro* techniques for faster production of healthy propagules of all improved tuber crops. We also developed cryo preservation tool to overcome pollination barrier in taro (Fig. 4),

[Mukherjee *et al* 2016; Lebot and Aradhya 1991 & 1992; Dasgupta *et al* 2008; Mukherjee *et al* 2004, Mukherjee *et al* 2009a&b, Mukherjee *et al* 2011].

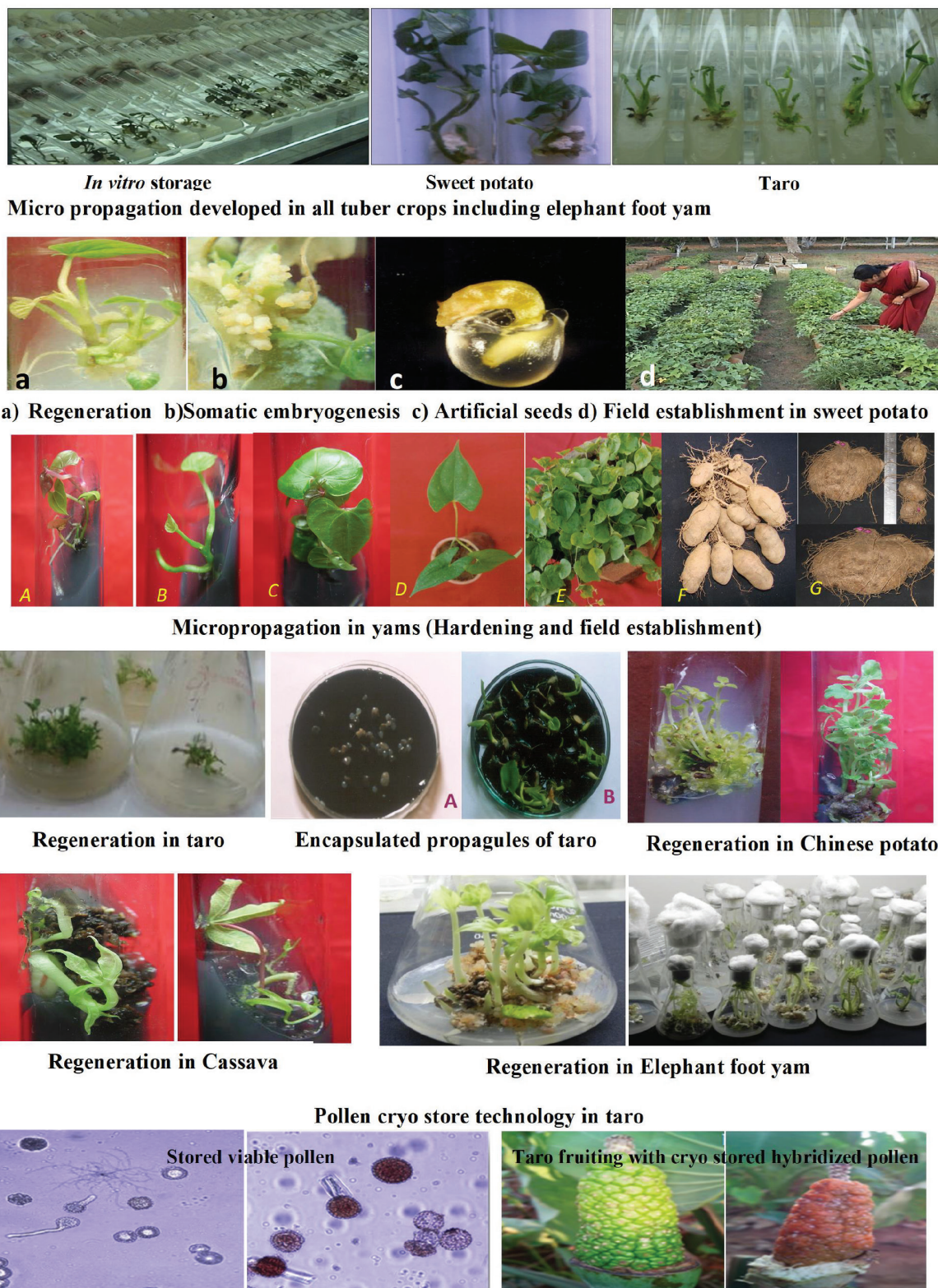


Fig. 4 : *In vitro* techniques developed

Dissemination of products in vulnerable areas in and across the country

Dissemination of those released improved varieties were being carried out tribal dominated district of Odisha, Kerala through Rashtriya Krishi Vikas Yojana (RKVY) with support from Sri. M. Ahuja, Sri S. Prusty; Odisha; Advocate Sunilkumar ; Kerala, Dr. S.K. Malhotra, New Delhi. Those improved varieties were also disseminated in different parts of the country through various schemes as well as in collaboration with sister Institutions, Line departments through “System Based Approach” focusing the ‘Clusters of Nutrition Vulnerable areas’ as guided by Dr. Trilochan Mohapatra, the then DG, ICAR and Secretary DARE, New Delhi. Bharat Ratna Prof. M. S Swaminathan, and Dr. N.M. Nayar, former Director, ICAR-CTCRI had encouraged and showered their blessings in developing colourful, nutritionally enriched stress tolerant products.

Outreach programme for food-nutrition security through (Local, National & International)

The improved tropical tuber crops varieties are gaining popularity since their development through various outreach programme especially in tribal districts of the country.

- Local - (KVKs, SAUs, SHGs, NGOs, Line depts.)
- National - (AICRP, DUS, TSP, SC-ST-P, NEH & Institutional)
- International - (INEA), LANSa, FSN of MSSRF

The improved varieties released and under release are distributed to strengthen food-nutrition and livelihood of small, marginal, tribal farmers and farm women. The mode of dissemination was through Institutional and linkages with line departments in and across Odisha and other States. Those are also distributed nationally in other tribal

dominated states and fragile zones through ICAR – TSP, ICAR – NEH, National Agril. Innovative Pro. (NAIP), Protection of Plant Varieties and Farmers’ Rights Authority (PPV & FRA) programme, SC-ST plan and on site participatory evaluation programme.

International Outreach Programme

Our Institute is having international linkages with other international tuber crops organizations like IITA, Nigeria; CIAT, Colombia; CIRAD, France; CIP, Lima Peru. The ongoing taro project entitled “Adapting clonally propagated crops for climatic and commercial changes” under International Network for Edible Aroids (INEA) has enriched CTCRI with 50 exotic taro genetic resources from 7 different countries through SPC, Fiji. Those received in culture forms have multiplied and distributed among the farmers of Odisha for participatory breeding and evaluation to enhance allelic diversity to adapt climate changes (disease, pest outbreaks) and also to satisfy the market needs. Developed Blight resistant, early maturing taros were distributed to taro growers. Biofortified especially β carotene rich orange flesh and anthocyanin rich purple flesh sweet potato also distributed through FOODSTART, FSN, LANSa programme.

Such interventions like distribution of high yielding, stress tolerant lines of elephant foot yam, taro, yam, cassava and sweet potato; Training on pre-harvest techniques & post-harvest utilizations (Fig. 5) have directly benefitted more than 2700 farm families over three years.

Livelihood Improvement

Sweet potato varieties viz. BhuSona (Orange flesh), BhuKrishna (Purple Flesh) and Kishan (White flesh) spread in backward coastal and hilly areas of Odisha. Those are also spreading across the country viz. North East, West Bengal, AP, Jharkhand, Chhattisgarh. Progressive



Training and participatory nutrie farming in Malkangiri, Odisha



Introduction of orange flesh sweet potato at PAU, Ludhiana



Dessimination of biofortified sweet potato through FSN, LANSa of MSSRF



Participatory breeding & dissemination of improved taro through INEA

Fig. 5: Dissemination of technologies across the country and beyond

vertical & horizontal dissemination of improved technologies are stepping ahead towards livelihood improvement of needy mass. Few such success related incidents are briefed below.

Success Stories

During post super cyclone period after 29th – 30th October 1999 in Odisha, ICAR contingent action programme was taken up to rehabilitate the cyclone affected farm families of Mahakalpada block of Kendrapara & Erssama block of Jagatsinghpur, Odisha (Table

3). Improved sweet potato varieties with all inputs were distributed among the super cyclone affected farmers, who lost all other vegetables due to ingress of sea water. The farmers of villages Kajolpatia could make a profit of rupees 5000/- by growing sweet potato in hundred sq.m. followed by the farmers Kanaguli Erssama who made profit of rupees 3000/- . Further the farmers could get additional 25 % more income by using sweet potato vines as fodder to goats. When vines were used, goats milking rate was 800 ml as compared to 500 ml with other fodder.

Table 3: Sweet potato improved varieties distributed to super cyclone affected farmers of Odisha, India through KVK and other line departments during (1999-2000)

District	Block	Village	Crops	Area (Sq.m)	No. of Farmers	Planting materials
Kendrapara	Mahakalpada	Khariansi	SP	100	2	1000 cuttings
		Kajalpatia	SP	100	2	1000 cuttings
		Jambu	SP	300	5	3000 cuttings
Jajpur	Jaraka	Duba gadia	Sp	200	2	2000 cuttings
		Mangalapur	SP	600	5	5000 cuttings
Jagatsingpur	Erasama	Karnaguli	SP	200	10	2000 cuttings

Kajalpatia, Kendrapara farmers got a profit of Rs. 5000/ 100 Sq.m.

Kharinasi, Kendrapara farmers got a profit of Rs. 3000/ 100 Sq.m.

Milking rate was enhanced in goat by 25% using sweet potato vines, as fodder (milk ~ 800 ml) compared to (500ml) with other fodder.

Livelihood improvement through tuber crops based integrated farming system

Under ICAR-TSP programme of CTCRI, tuber crops based integrated farming in Kandhamal (Odisha), Ranchi (Jharkhand) revealed higher net income approx 2.7 times more in addition to house hold food- nutrition security. Such success is now getting horizontal spread among farmers besides the adopted farmers. Farmers of 11 adopted villages under MGMG programme in Odisha are now growing tuber crops with other vegetables to have food during January to June. New initiative taken to combat malnutrition of Nabarangpur villages of Odisha have aroused interest among paddy growers to get required nutrition by growing nutrition rich sweet potato and other tuber crops for food and income generation during lean period (January – June, Fig. 6).

Food under Socio-climatic turmoil

The improved tuber crops technologies identified and developed biofortified stress tolerant tuber crops are gaining popularity as alternative source of food nutrition and livelihood improvement. The energy content and nutritional values reveal the fact of importance of these tuber crops to readdress the issues like “food insecurity” and “malnutrition” especially in the context of climate change. The turbulence of agro climate across the world is evident day by day with frequent drought, flood, and cyclone. In this context, the said group of tuber crops and its valued processed products can play pivotal role not only towards adaptive food, nutrition security but also to support sustainable livelihood as always under socio-climatic turmoil (Fig. 7).



Fig. 6 : Our intervention in Nabarangapur, Odisha was the 1st time in agriculture.



Fig. 7 : Climate resilient tuber crops with valued traits.

Mechanization and diversification are the need

The adaptability of tuber crops to marginal environments, their contribution to household food security as well as flexibility in mixed farming systems make them important components for improving the inclusive growth of the rural poor. However, continuous generation and diffusion of improved

production and postharvest technology is essential in achieving this. The cassava processing industries are facing threat from import of starch from countries like Thailand and Indonesia, due to the high domestic production cost. In India, mechanization of cassava cultivation, availability of high quality disease free planting material, product diversification, etc. are the bottleneck for its industrial growth. The problems like cassava

mosaic disease, sweet potato weevil menace, taro leaf blight, poor shelf life of tubers and lack of diversified products from tuber crops also affecting their commercial visibility.

To overcome those, greater thrust is necessary in tuber crops research, by spreading their cultivation to non-traditional areas, for food and nutritional security, augmenting the utilization prospects by developing value added food, feed and industrial products. Exploring new market options like developing herbal products with medicinal effects, bio-insecticides, natural food colourants, etc. The effective dissemination of the technological advancements on tuber crops can help in a big way to unravel the utilization prospects of these crops for the benefit of rural and needy population.

Genomic database, *in silico*- *in vivo* molecular path ways and nano technology are the ‘Gate Way’ to resurgent tuber crops

Wide adaptive Root and tuber crops can be redesigned further with advanced biotechnology, genomics, phenomics *in silico*- *in vivo* and nano-technology. Use of biotechnology especially silencing the gene

responsible for post-harvest deterioration in cassava could help to extend the shelf life of tubers, the essential keeping quality to process. Developing acyanogenic cassava through RNA interference will reduce the risk of cyanogens mediated, toxin, pollution.

The genomic database in cassava, sweet potato and other tuber crops could help in identifying biotic and abiotic resistance related genes and their molecular pathways *in silico* & *in vivo*. It will facilitate better understanding of the crop to redesign genotype in a desirable manner. Application of nanotechnology for developing tuber starch based novel products can help in developing safe drug delivery systems. It can also be applied in encapsulation of bioactive compounds for multiple uses.

The work plan proposed and had executed as Director, ICAR-CTCRI

The work plan I proposed as Director considering holistically the prevailing lacunae of R&D of the crops, its current status and future prospects. Hence a SWOT analysis was essential prior to laying out the ‘Road Map’ of R&D, its execution and expansion.

‘Way forward’ demands ‘SWOT’ analysis for both the ‘Commodity’ & the ‘Institute’

	<i>Crop</i>	<i>ICAR-CTCRI</i>
Strength (S)	1. Third most important food crop. 2. Wide adaptive, symbol of self sufficiency and most are of GI crops of the country. 3. Environment, farmer, tribal and women friendly crops-highly responsive to organic farming.	1. Ideal locations for linkages and extension work especially to cater the need of greater Eastern, North Eastern and Southern India with effective coordination and support between HQ & RC. 2. Amidst of ICAR Institutes, Universities, other R & D Institutions research & educational hubs. 3. Good land bank available for farm studies.
Weakness (W)	1. Low commercial visibility of Present cultivars. 2. Poor keeping and processing Qualities. 3. Low productivity in India.	1. Locations encompassed with coastal saline & hilly backward areas with vulnerability to higher GHI. 2. Lack of collective approach, team spirit, organizational belongingness & infrastructure especially at RC for advanced research.
Opportunities (O)	1. Wide adaptive tuber crops can be made more resilient to sustain natural vagaries by development of climate proof varieties with valued traits to enhance commercial visibility. 2. These crops with high productivity (20-50 t/ha) & nutritional values can address the issues of food & nutrition 3. Technology mission for value chain & awareness programme can boost up per capita consumption.	1. Ample scope to work as intra and inter institutional teams with other sister concerns, other Institutes, Universities, line depts., KVKs (33 +14) for hilly, coastal and tribal dominated districts. 2. To intervene & strengthen the livelihood of weaker sections of backward areas-‘The foundation of the Nation’. 3. Scope to improve commercial traits, production, protection, processing technologies and their visibility through collective approach.
Threats (T)	1. Biotic and abiotic stresses. Least priority crops. 2. Non-collective approach in solving the problems. 3. Protection of valued gene sources	1. Second line (new generation) expertise for multidisciplinary system approach. 2. Water resources in the farm, poor soil health. 3. Value chain from production to marketing.

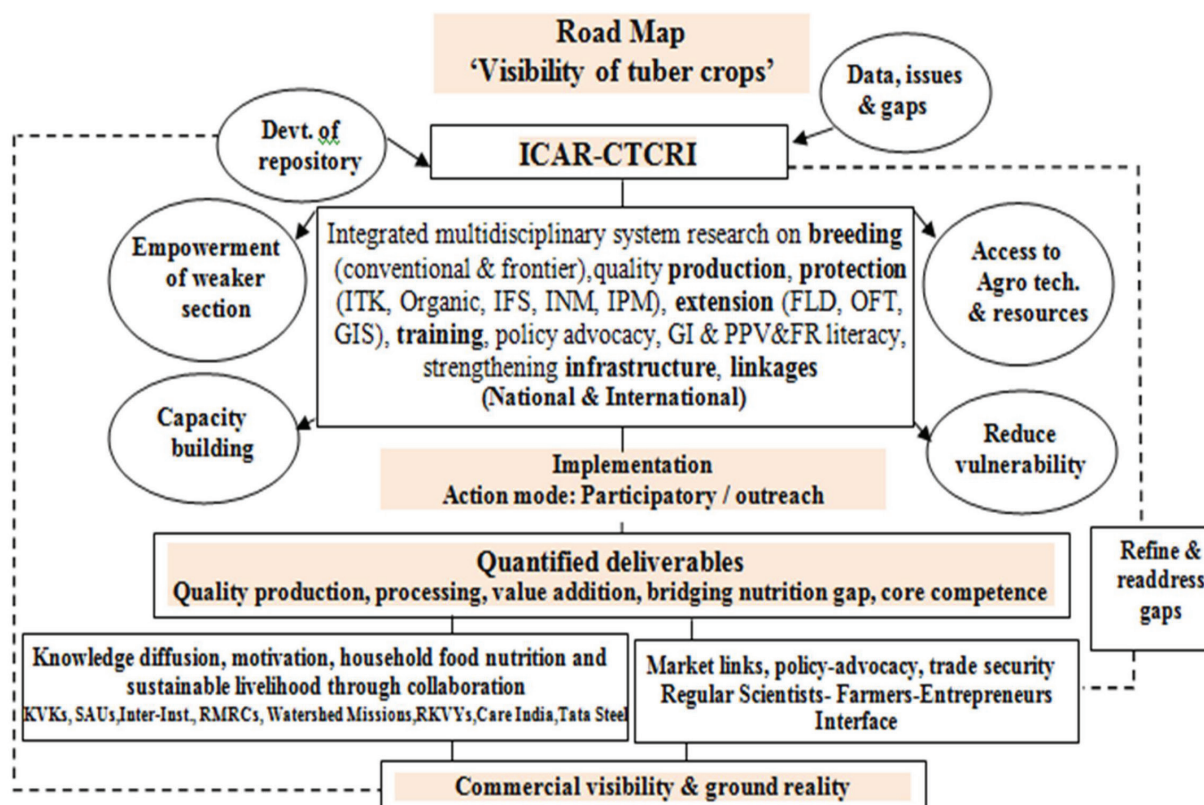
National & International threats vs Tuber Crops

India's position in GHI is alarming. Climate Change compounds with consequences of frequent flood, cyclone, drought and affecting the productivity of major food crops like rice, wheat, pulses (flowering types). Hence the 3rd world crops like tropical tuber crops propagated vegetatively have the potential to face the challenges of food and nutritional demands.

This group of crops regained its importance during post Super cyclone (October 1999 - March 2000) and Tsunami (2004) in India. Such instances led to rethink the researchers to tap the untapped potentials of tropical tuber crops.

Tuber crops research in India was initially focused on improving yields. Recently a paradigm shift has taken place for climate resilient crops with valued traits. Wide adaptive (Fig. 7) nutritionally enriched tuber crops are unique of its kind especially under awakening threats of global warming. A number of studies

covering developed and developing countries have shown greater concerns about the loss of genetic diversity of such climate resilient valued tuber crops genotypes. Some popular cassava varieties observed to have drought tolerant traits and can grow in drought prone areas. Such high value clonally propagated crops are going to play pivotal role in coming years when cereal and pulses are attaining yield stability and are depended on climate for flowering and seeding. To facilitate research, development, promotion and utilization of tropical tuber crops in the country, the ICAR - Central Tuber Crops Research Institute at Thiruvananthapuram spearheading with its Regional Centre at Bhubaneswar and All India Coordinated Research Project on Tuber Crops with twenty two Centres across the country. The developmental work on root and tuber crops has been redesigned with the 'Road Map' to attain the 'expected deliverables' with following 'major objectives'.



Work through multidisciplinary system approach on proposed directions will contribute more & more in bridging food and nutrition gap of 1.4 billion Indians towards the vision of "Glorious Bharat"

Expected deliverables with milestone and impact

Sl. No.	Deliverables	Year	Impact
1.	Enrichment of food, nutritional values, enhanced storability and processing qualities of the crops.	1 st to 3 rd year	Affordable food, nutritional & livelihood sources for low, marginal farmers & vulnerable sections of the society as well as healthy functional food for all.
2.	Development of biotic & abiotic stress tolerant / resistant lines. Especially resilient to CMD, TLB & sweet potato weevil pest.	1 st to 3 rd year	Revenue generation through recovery of yield loss due to CMD in cassava, leaf blight in taro & weevil pest in sweet potato.
3.	Development of short duration tuber crops.	1 st to 3 rd yr	To adapt changing climate, easy acceptability as intercrop, crop diversification, profit maximization.
4.	Development of sustainable production, protection technologies fitting to fragile ecosystems and production of quality planting materials through seed villages.	1 st to 3 rd year	Easy acceptability by farmers, judicious management of scarce water, soil, resources to maintain soil health & other macro-micro flora for sustainable farming in fragile zones & to supply quality propagules.
5.	Processing of high valued products like functional foods, ecofriendly polymers, composites, hydrogels.	1 st to 3 rd year	To address holistically food, health & environmental issues.
6.	Vertical & Horizontal dissemination of improved nutritious varieties in vulnerable areas across the country & beyond like South Asia through LANSAs, INEA (Oceania & Africa).	1 st to 3 rd year	‘To lessen hunger, malnutrition and to improve livelihood’ in hunger- malnourished hot spot areas.
7.	DUS guidelines for registration / protection of valued traits & licensing of products.	1 st to 3 rd yr	Commercial visibility with trade security.
8.	To generate data base of high valued qualitative & quantitative attributes, sustainable production, protection and appropriate mode of dissemination technologies.	2 nd to 3 rd year	To address the national & international gaps, issues related to commercial traits, sustainable productivity, PRA, PPP appraisal etc. for competitive farming & products.
9.	Overall deliverables (1-7).	2 nd to 3 rd year	Strengthening value chain of these crops to enhance commercial visibility.

MAJOR OBJECTIVES

- ‘Multidisciplinary breeding for valued traits to enhance commercial visibility
- Integrated approach for sustainable production and protection of improved varieties especially for fragile hilly & coastal ecosystems
- Farm mechanization, processing of functional foods & high value products for bioprospecting
- ‘Vertical, Horizontal dissemination’ of integrated technologies “to lessen hunger-malnutrition” in Vulnerable / hunger-malnourished areas of the country, hunger hot spot areas across country
- Protection of valued gene sources of our custodian crops
- To enhance commercial visibility for food, Nutrition and processed products
- Improvisation of existing infrastructure for lab, field research & streamlining Admn. activities

To accomplish the targeted goal, conventional and nonconventional biotechnological approaches and sustainable production, protection technologies were developed to evolve improved varieties, to conserve, utilize and disseminate improved technologies (Figs. 8 & 9). Technologies are being disseminated across the country and beyond through various outreach programme of National like NATP- Jay Vigyan, ICAR-TSP, ICAR-NEH, NAIP, AICRP, DUS, KVKs and International like INEA(International Network for Edible Aroids) Farming System Nutrition

(FSN) of MSSRF, Inter Institute collaborations and PPP mode etc. (Mukherjee *et al* 2019a, b, c & d)

Glimpse of achievements are briefed objective wise as follows

1. 'Multidisciplinary participatory breeding and evaluation for valued traits to enhance socio-commercial visibility

- We have already taken up intensive breeding, conventionally and non-conventionally in tuber crops to enrich '**gene pool**' with '**high value targeted traits**' like -
- High dry matter, starch, β -carotene, anthocyanin, Fe, Zn contents, response to low K& P and enhanced storability for food, nutrition and processing, generated such high valued varieties.
- Short duration (sweet potato: 80-90 days; taro: 140-150 days) have been developed.
- Resistance to biotic (cassava mosaic, taro leaf blight, collar rot in elephant foot yam & sweet potato weevil) & tolerance to abiotic (salt, drought, water logging) stresses. Evolved stress tolerant varieties.

2. Integrated approach for sustainable production and protection of improved tuber crops varieties especially for fragile hilly & coastal ecosystems

- Suitable agronomic practices like intercrop models, integrated farming, drip fertigation, zero tillage & seed village concepts are being inducted.
- Integrated nutrient management (NM), site specific NM & organic farming are operational.
- Disease diagnostics, integrated disease & pest management, use of bio control agents, ITKs are being followed vibrantly.

3. Farm mechanization, processing of functional foods & high value products for bio-prospecting

- Establishment of mechanized model farms for cassava are in progressive trials.
- Functional foods and eco-friendly biodegradable thermoplastic starch, biopolymers, hydro gels have been developed and are getting validated in practical fields.

4. 'Vertical, Horizontal dissemination' of improved technologies "to lessen hunger-malnutrition"

A. Vulnerable / hunger-malnourished areas of the country

- We have been contributing in mission of "Mal nutrition free India" through dissemination of bio-fortified tuber crops like high beta carotene and anthocyanine rich sweet potato; Fe, Zn rich taro across the country through various Institutional (FLD, OFT, AICRP, NEH, TSP), collaborative SAUs, KVKs, ICAR- CIWA & other programme like 'Farming System for Nutrition (FSN)' of MSSRF, RK Missions & allied sectors. Those have been strengthened through watershed Missions & RKVY projects

B. Hunger hot spot areas as targeted sites

- Besides vertical dissemination, horizontal dissemination across the country is also on wheel with our improved bio-fortified varieties through LANSAs of MSSRF & International Network (INEA)
- Intervention continued in '**hunger hot spots through integrated multidisciplinary system approach including GIS, DSS etc**'.
- Adoption of 60 needy villages under '**Mera Gaon and Mera Gaurav**' programme (Kerala-49, Odisha-11) are

operational with improved varieties and integrated technologies.

5. **Protection of valued gene sources of our custodian crops**

- Established CTCRI as Nodal DUS Centre. Developed DUS guidelines in taro, elephant foot yam, sweet potato, cassava, greater yam and yam bean for registration
- High valued sweet potato registered in NBPGR and also submitted for registration in PPV&FRA. Licensing of products are done and strengthened
- Established "Farmers Incubation Centre " especially for tarining and incubation starting from 'production to value chain management' for overall growth of farmers

6. **To enhance commercial visibility for food, Nutrition and processed products with wide adaptive nutrient rich improved varieties through women, farmers friendly participatory action mode**

- Popularized β -carotene, anthocyanin, resistant starch rich sweet potato & Fe, Zn rich taro as source of healthy dietary food for all **"including patients in hospital"**
- PPP mode is encouraged to enhance the usages of improved crops for food/ allied industries for processing.

7. **Improvisation of existing infrastructure for lab, field research and streamlining e-Admn. activities**

- Expanded drip irrigation facility, renovated storage sheds, rooms, established modern storage hub under Odisha RKVY
- Expanded lab, equipped for research for post harvest and advance molecular marker techniques
- Streamlined e-mediated administrative & other accessory activities

Propelling of science in any field necessitates SWOT analysis to proceed in right directions. Though I started my scientific professional journey in the field of plant biotechnology but equipped myself in field research. Such expertise was the demand to address the gaps of root and tuber crop research vibrantly through integrated approach (Mukherjee 2024 a, b & c; Sahoo *et al* 2018; Vishnu *et al* 2019).

The overall onlooker as Director of the Institute within a span of 2 years 7 months

It is not that SWOT analysis, Action plan executions have been done only during directorship. The seed of SWOT and to address it has actually been started in the beginning of my career with tuber crops. However, it has become more vibrant after Super Cyclone. Those have further escalated during Headship of Regional Centre as well as Directorship of ICAR-CTCRI.

Besides those deliverables, I feel contented that i could complete certain due assignments of the Institute like –

- Documents for Institute (ICAR-CTCRI), performance rank
- Monetization of ICAR-CTCRI Institute
- Performance review reports, QRT documents (Institute & AICRP-TC)
- Satisfactory response to the pending Parliamentary questions
- Registered with GeM portal, compliant GST, ERP-HRM, PFMS within time during July 2017 to March 2018.
- Connecting school children with tuber crops Science first time through 'National Science Day' and youtube programme (Produce Tuber Reduce Hunger: Video on Technologies of ICAR-CTCRI, ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala. [https:// www. youtube.com / watch?v=7tg9dkvqIJI](https://www.youtube.com/watch?v=7tg9dkvqIJI)).

- Wide visibility of the Institute and its activities with magnified National exhibitions, entrepreneurship programme.
- I could organized successfully “National Conclave on Tuber Crops Technologies” with support of my colleagues and encouragement of our Director General- Dr. T. Mohapatra and Dr. Farnandez, Director, KSIDC.
- Organized Asia sweet potato Breeders and seed system meeting 2018.
- Conducted successfully live web cast of “Hon’ble Prime Minister’s interaction with Kerala Farmers” during the PM-KISAN Launch through Video Conference at ICAR-CTCRI, 24 February 2019.
- Organized Regional workshop for Kerala and Karnataka farmers on ‘Enriching custodian farmers with PPV&FR Act to safeguard valued plant genetic resources towards green prosperity’ on 10-11 October 2019.
- We could bring out first time the “In flight- Magazine, Shubh Yatra, Air India” with support of my colleague Dr. T. Srinivas and Sri. Akhtar Max, Air India.
- We could set up “Farmers’ Incubation Centre” with financial support of IPTMU Cell, New Delhi and my colleagues Dr. Immanuel, Dr. J. Sreekumar and Dr. P.S. Sivakumar.
- We could make the ‘New Guest house’ functional which was inaugurated prior to my joining as Director but was not fully functional owing to various gaps. I could address the gaps with financial support of Sri Debendrakumar, Director Finance, ICAR, New Delhi. We could beautify it with constant support of Dr. J. Sreekumar and his team.
- I have invited and we could get the foot prints of the Honourable Governor of Kerala and the Chancellor Sri. B.N. Suresh, of IIST at CTCRI campus. Further, I am thankful to Dr. T. Mohapatra DG, ICAR and Secretary DARE for his immense support and visits both in HQ and RC. We could also get Sri Loknath Behera, DGP, Kerala Police and other Stalwarts of different subjects in our campus are my greatest satisfaction.
- I am grateful to the Almighty God, the Institute when I joined as Director was having negative balance of lacs of rupees but with grace of God, situation improved after my rigorous efforts. When I superannuated it was surplus of Rs. Crores. I could do this collectively with support of hierarchical people viz. Sri Ahuja, VSSunilkumar, Dr. Malhotra, Dr. Sanjeev (IPTMU, New Delhi), Sri Debendrakumar (Finance, ICAR-New Delhi) and also with support of my colleagues Dr. Sreekumar, Dr. Sivakumar, Smt. Saribai and Sri. Krishnakumar.

One incident which pains me till now was that I could not organize the “National Southern Regional Farmers’ Fair” owing to haste decision of Dr. T. Janakiram, the then ADG, Hort. ICAR.

In fact ICAR-CTCRI got that opportunity for the first time during my tenure of Directorship.

CONCLUSION

My Scientific journey started in 05.02.1986 in ICAR-CTCRI, Thiruvananthapuram, Kerala. However, I had my real scientific test in October, 1999 in Odisha. I gathered experience in plant biotechnology prior to my scientific-professional career but real professionalism acid test I had to perform when I had faced

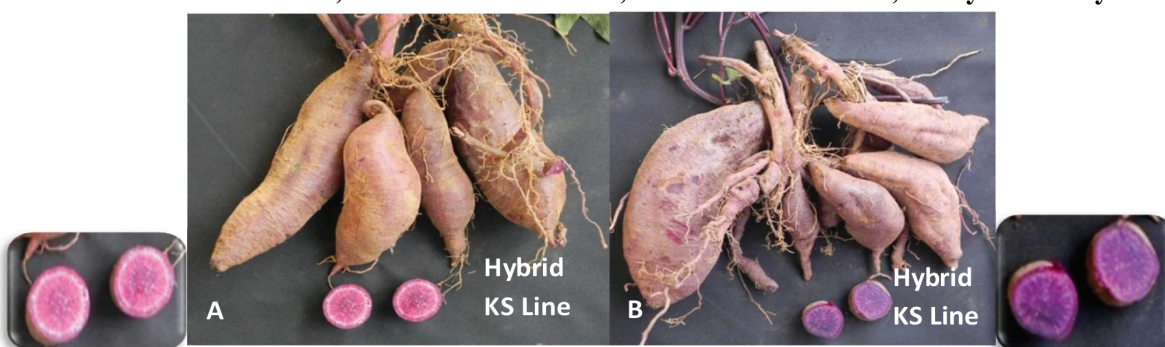
2015- 2020

Targets

- Yield- (>17 t/ha), Starch (>18%),
- β -carotene (>14mg/100g),
- Anthocyanin (>100mg/100g)
- Reduced crop growth cycle (75-90 days)
- Weevil resistance (infestation less than 10%)

Progress

Purple flesh sweet potato (A & B)- yield 19-20 t/ha, anthocyanin 0.9g-1.2g/100g, starch 18-20.5%, weevil infestation <5%, tolerant to salt stress, 90 days maturity



Orange flesh sweet potato (C-E)-yield 20-21 t/ha, β -carotene 14-16mg/100g, starch 16-18.5%, weevil infestation <10%, tolerant to salt stress, 90 days maturity



White flesh sweet potato (F&G)-yield 22-23t/ha, high starch 18-20.8%, weevil infestation < 7%, tolerant to salt stress, 90 days maturity

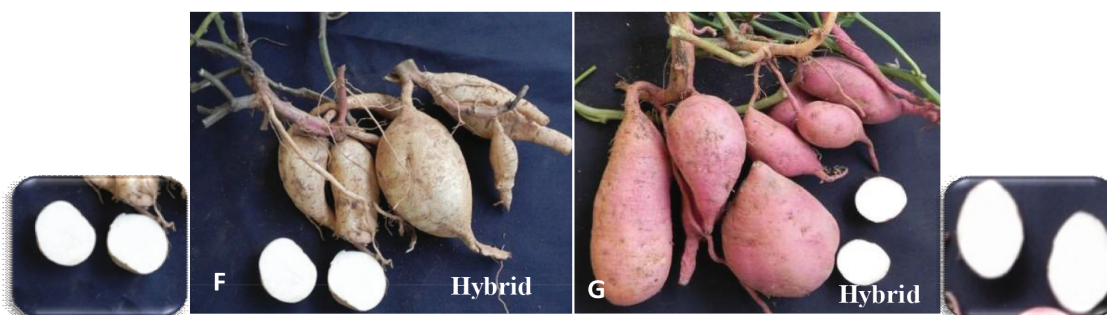


Fig. 8 : Generation of hybrid sweet potato for valued traits

Farmers- Researchers Participatory breeding & evaluation for quality taro



- To adapt climate changes
- To satisfy consumer demands



Exotic dasheen



Flower

X



Flower



Eddoe



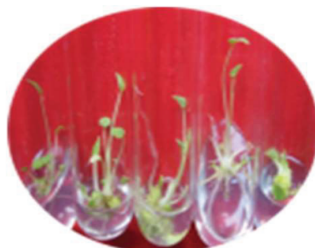
Fruits



Seeds



Berry



Seed germination



Hardening



Evaluation

- Early maturity
- Whole parts edibility
- Blight resistance
- High Fe, Zn, Ca contents

Fig. 9: ICAR- CTCRI RC- INEA International Network for Edible Aroids Taro project, April 2011 -Dec. 2015

the super cyclone affected farm families of Jagatsinghpur and Kendrapada. I found my educational qualification is a 'Big Zero' before the miseries of cyclone affected victims. I was given the farthest points to work in cyclone affected areas under "ICAR Contingent Action Plan" in Kendrapada. Officially I got to give hundred rupees along with produce of different tuber crops to each affected family. On reaching the site, I felt ashamed to offer them such meagre amount as they were not in need of produce, they were in urgent need of medicine, good drinking water and "Ready to eat Food". During the next visit I could not bear and had carried medicine, bread, cloths of my own and distributed to them. They were so honest told that they would not accept things free from me. They gave me immature cabbage and brinjal which were started rotting owing to ingress of sea water, I learnt a lot from them. Their attitude started haunting me- "What a mental stability they got even in utter despair". I prayed to Lord Jagannath to save them. Two weeks later, I have distributed and guided them to grow different varieties of tuber crops. They had learnt and had grown. After two months I asked their feedback. They showed that some were growing but some could not. I had inspected those and found among the different tuber crops, few varieties of sweet potato and taro had thrived well. I brought those samples in the laboratory and started analysing their characteristics and found orange colour sweet potato Gouri, white coloured Kishan and taro viz. Muktakeshi, Bhu Kripa, Bhu Shree are having special characteristics to overcome the stress.

At that time we were not having basic laboratory facilities to work. We proposed for ICAR AP-Cess Fund project for salt tolerant coloured flesh sweet potato. We also proposed ICAR, NATP-CGP grant for improved taro. We got the projects and could create the basic biotechnological facilities at our Regional Center of ICAR-CTCRI, Bhubaneswar. We got

very good assistance by our Ph.D students' viz. Sri Manas Ranjan Sahoo and M. Dasgupta to help us in our hard endeavours. Though Regional Centre started in 1976 but irrigation was its constant constrain. Such situation mooted me and Dr. S.K. Naskar to strengthen the farm facilities as lab work alone would not help to test the validity of the produce. Me with senior breeders like Dr. S.K Naskar, Dr. K. Abraham had proposed "DUS Projects" to PPV & FRA incorporating the facilities like bore well, Pump house along with drip irrigation for all the tuber crops. Later, Dr. Naskar and me had become partners of International Network for Edible Aroids (INEA) project- Taro. We had further strengthened the drip irrigation layout of our farm. In fact, both of our efforts had enabled to cover approx 35 acres of land with drip irrigation. As the AP-Cess, CGP projects were time bound- me, Dr. Naskar, M.R Sahoo, M. Dasgupta, Dr. K. Rajasekhar Rao worked rigorously to develop the coloured flesh sweet potato and nutrient enriched taro with resistance to biotic (sweet potato weevil, taro leaf blight) and abiotic stresses like salinity, drought etc.

We could collectively do so and could released the Nations' first purple flesh "Bhu Krishna" (containing anthocyanine 90mg/100g) followed by new generation orange flesh "Bhu Sona" with highest beta carotene 14mg/100g and starch (22%).

We also have released other "Bhu Series" varieties of different tuber crops including greater yam. Root and tubers are major food components in tribal dominated districts of Odisha, India. Shri M. Ahuja, the then Principal Secretary, Dept. Of Agril. and Farmers empowerment, Odisha, India and S. Prusty the then Director, Dir. Hort. , Odisha (2016-17) encouraged us to disseminate the produce among the needy mass of the Odisha state through a RKVY (Rashtriya Krishi Vikas Yojana) project entitled "Popularization of climate resilient and nutritionally rich varieties

of tuber crops for economic development and nutritional security of farmers of Odisha" (2017-2022) with a budget of Rs. 4.56 crores. Those were implemented and operational in Odisha. For such projects, Shri Ahuja had given special training to me and Dr. Korada. We and Odisha Agri. Farmers' Empowerment Department sincerely wanted that technological fruits must reach to the needy farming communities across the 8 tribal dominated districts. It supposes to cover 730 ha within three years, so that farmers could be self reliant. They need not to depend on the Institute for seed materials as "Seed villages" had also proposed for the targeted areas.

Dr. Trilochan Mohapatra, the then Director General, ICAR and Secretary DARE, India encouraged us to collaborate with ICAR-CIWA to intervene Nabarangapur, Odisha district specially the 'hunger- mal nutritional vulnerable areas'. We have started doing so as per his suggestion through the "System based" approach involving all the line departments, KVKs etc. in "Cluster" wise manner. During that journey I got selected as Director ICAR-CTCRI, Thiruvananthapuram and the other PI, Dr. Korada had to move to ICAR-NRRI.

Under that situation, we had handed over our dream project RKVY entitled "Popularization of climate resilient and nutritionally rich varieties of tuber crops for economic development and nutritional security of farmers of Odisha" worth Rs. 4.56 Crores to Head In-charge and rest of the colleagues of the Regional Centre anticipating that they would do justice to Science and the Community. If the project has been carried out as per the objectives then there should not be dearth of planting materials (seed). Project was well equipped with all farm implements including 'Modern Seed Storage Facility'. We had kept provision for modern storage facility to store the vegetative propagules healthy, to supply the farmers' as and when they need planting materials besides the seed villages.

Similar RKVY project with Rs. 3.57 Crores we got sanctioned for tribal dominated three districts of Kerala with support from Advocate, Sri V.S. Sunil Kumar the then Agriculture Minister of Kerala and Dr. S.K. Malhotra, Agri. Commissioner, New Delhi.

Besides vertical, horizontal dissemination, as Director of the Institute I tried to escalate visibility and the utility of these food crops connecting school children and other Food-Health, allied Institutions.

"We should try to understand that we all will be vanishing from this planet". Each one of us should try to do well to others especially for those who seek our help. "Jay Jagannath"

ACKNOWLEDGEMENT

I surrender to Lord Jagannath and my beloved parents, parents in law, my all ancestors for their blessings. I express my gratefulness to all my teachers, mentors starting from primary to doctoral studies. I am indebted to my family members.

I express my heart and soul prayers to my Ph.D. guide late Dr. B.K. Debata. My profomed gratitude to Govt. of India for National Scholarship, UGC, India for merit scholarship and CSIR, India for Junior Research as well as Senior Research Fellowships. I extend my gratitude to DSE-ZEL, Germany for International Fellowship in refining my outlook.

I am grateful to ICAR, India for selecting me as Scientist based on ARS examination. I extend gratitude to ICAR for Jawaharlal Nehru Gold medal for best PG work as well as Punjabrao Deshmukh Award for Outstanding Woman Scientist.

I am also grateful to National and International Concerns bestowing on me awards for my work. I express my immense gratitude to Dr. Trilochan Mohapatra, Director General ICAR, India who has inspired and encouraged me in propelling of Science and its percolation among the needy communities. I am grateful to Dr. K. Krishnakumar, DDG, Hort. ICAR who encouraged me to comeback in Scientific World after the recovery from severe attack of Cancer in 2014.

I express my heart and soul gratitude to Bharat Ratna Prof. M.S. Swaminathan and Dr. N. M. Nayar (Former Director, ICAR-CTCRI), for their constant encouragement in my scientific endeavours.

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