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Sustainable sweetpotato **production** and **utilization** in Orissa, India

Sustainable sweetpotato production and utilization in Orissa, India

Edited by

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Abbreviations and **Acronyms**

AICRP	All India Coordinated Research Project
AVRDC	Asian Vegetable Research and Development Center
AOAC	Association of Analytical Communities
CIP	International Potato Center
CPAD	Communications and Public Awareness Department
CPSW	Council of Professional Social Workers
CTCRI	Central Tuber Crops Research Institute
DRWA	Directorate of Research on Women in Agriculture
FYM	Farm Yard Manure
IBPGR	International Board for Plant Genetic Resources
ICAR	Indian Council of Agricultural Research
IET	Initial Evaluation Trials
IPM	Integrated Pest Management
INM	Integrated Nutrient Management
INR	Indian Rupee
LAVS	Life Academy of Vocational Study
LSRB	Life Science Research Board
MLT	Multi-Location Trial
NABARD	National Bank for Agriculture and Rural Development
NGO	Non-Government Organization
NNMB	National Nutrition Monitoring Bureau
NRDC	National Research Development Organization
RDA	Recommended Dietary Allowance
OFSP	Orange-fleshed Sweetpotato
QPM	Quality Planting Material
SAU	State Agricultural University
SWCA	South, West and Central Asia
UP	Uttar Pradesh
URT	Uniform Regional Trials

Contents

Foreword

Over the past few years, sweetpotato production has undergone a fundamental transformation in Orissa, India. There has been a significant amount of interest in cultivating sweetpotato from farming sectors to commercial growers. The International Potato Center (CIP) through its liaison office in Bhubaneswar, Orissa has contributed to sweetpotato improvement in Orissa in both research and development, combining efforts with potential partners, including government and non-government agencies. Increased consumption of sweetpotato in the recent past has focused attention on improving value and production. But there has been a constant threat to and decline in sweetpotato area in Orissa; although production has marginally increased, productivity has remained at around 8.5 t / ha , lagging substantially behind the average productivity of other large sweetpotato growing states, including Uttar Pradesh and West Bengal. To improve productivity, several efforts are underway through crop improvement, crop management, and post-harvest utilization both by research organizations and extensions agencies. Keeping in view these current trends and interests, a workshop and training program was conducted on sweetpotato production and utilization at two Indian Council of Agricultural Research (ICAR) institutes, the Directorate of Research on Women in Agriculture (DRWA) and the Regional Centre of the Central Tuber Crops Research Institute (CTCRI), on 17-18 March 2010.

The workshop participants were mainly tribal women, accompanied by a few men from five districts in Orissa: Nuapada, Kandhamal, Koraput, Gajapati, and Kalahandi. These participants were encouraged to attend the program by local NGOs, including Suraksha, Antodaya, Samanwita, Life Academy of Vocational Study (LAVS), and the Council of Professional Social Workers (CPSW). The workshop and training program was titled "Knowledge fair on sweetpotato cultivation and utilization for tribal women in Orissa" (detailed program-Addendum A) and the two-day program was sponsored by the National Bank for Agriculture and Rural Development (NABARD).

The first day of the program included a workshop on sweetpotato utilization, which involved preparing indigenous sweetpotato recipes at DRWA. The activity was aimed at bringing together DRWA food scientists and tribal participants to learn together and improvise ways of incorporating sweetpotatoes with enhanced nutritional value into traditional recipes such that they maintained consumer appeal. Taste and acceptance tests were conducted to determine the most preferred recipe or sweetpotato product prepared on that day.

On the second day there was a technical training program on cultivation covering Integrated Pest Management (IPM), Integrated Nutrient Management (INM), varietal importance, and post harvest utilization. The participants visited the experimental and multiplication sites on the RC CTCRI campus to have first-hand experience of the varied tuber crops. CIP staff demonstrated the importance and role of vitamin A-rich, orange-fleshed sweetpotato varieties. Planting material (sweetpotato varieties /germplasm) from the campus and from CIP was distributed to participants for performance testing in their own fields.

One of the outcomes of the workshop and training on sweetpotato was an agenda for future sweetpotato production and post-harvest research and development in Orissa. The key research area is continued sweetpotato breeding for enhanced yields along with the introduction of nutrient-rich sweetpotato varieties with high beta-carotene levels for vitamin A. This goal is to increase consumption and cultivation in several districts of Orissa.

The topics in this book highlight the importance of sweetpotato in Orissa with technical insights for sustainable production and enhanced yields. Sections also focus on varietal importance and present some useful sweetpotato products in the Orissa context. Various authors outline and discuss critical issues concerning consumers and producers in Orissa, regarding ways in which sweetpotato and other root and tuber crops can improve livelihoods. The book also presents results from acceptability tests of different indigenous sweetpotato recipes conducted with the workshop/training participants. It includes multiple recipes for integrating beta-carotene rich, orange-fleshed sweetpotato, including as ice cream.

Sustainable production of sweetpotato and technology transfer for enhanced yields in Orissa

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INTRODUCTION

Sweetpotato (*Ipomoea batatas* (L.) Lam) is a starchy root crop grown in tropical and subtropical countries like China, USA, India, Japan, Indonesia, Philippines, Thailand, Vietnam, and Nigeria. In India it is cultivated in almost all the states. Sweetpotato is considered as a 'poor man's rich food' in many parts of India. In India, sweetpotato is largely grown in three states: Orissa, Uttar Pradesh, and West Bengal. In Orissa, sweetpotato is grown on an area of 50 700 hectares, with a production of 431 300 tons (indiastat.com 2010). The economy of most of the districts in the state of Orissa is rural and agrarian. Sweetpotato is grown both for consumption and as a subsidiary source of income. Sweetpotato is a vegetatively propagated crop, and it is rich in several essential macro and micronutrients. Considerable efforts have been made recently to promote sweetpotato and to create awareness among the farming communities, especially in the tribal population, on the usefulness of sweetpotato. As it is grown in most of the districts in Orissa (as shown in Table 1) farmers are aware of the traditional cultivation practices of sweetpotato. However, average productivity of sweetpotato in Orissa is only 8.5 t/ha compared to the Asian average of 15 t/ha (Campilan, 2009). Marginal farmers make up the largest group of farmers cultivating the crop in the major sweetpotato producing districts of Orissa.

Factors that influence sweetpotato production and some solutions for improved yields

Technical factors

Physical and biological

Varied climatic conditions, including frequent droughts and sporadic rainfall, affect the yields of sweetpotato as does poor soil. Enhancing crop productivity in poor and infertile soil is a major task and of primary concern. Sweetpotato is a reliable crop that could meet the requirements of the poor farming community in terms of nutrition and food security. Sweetpotato is grown with limited land, labor, and capital. Early maturing sweetpotato varieties provide higher edible energy per unit area per unit time than all other major food staples. Sweetpotato can perform well in fertile environments, far exceeding yields of cereal crops. However it cannot be stored for long periods of time and deteriorates quickly, especially in the low lands. Seed borne pests and diseases add to the difficulties of farming communities.

Cropping / seed systems

In Orissa, lack of efficient seed systems for multiplication, improper management of nurseries, lack of techniques for easy and rapid multiplication, and the lack of availability of improved varieties are just some of the causes for declined yields. Intercropping and mixed cropping of sweetpotato with other crops has resulted in increased yields. In the uplands, strip cropping of sweetpotato (ridge and furrow) and red gram (flat bed) (3:3 rows) have produced higher tuber equivalent yields under the rain fed conditions of Orissa. (Nedunchezhiyan et al. 2010).

Equal contribution by various authors for different topics (quoted in italics below) in this chapter:
Factors that influence sweetpotato production……..; Table 1 [1]Agronomist, International Potato Center, Bhubaneswar, Orissa
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Pest management… [5]Entomologist, Regional Centre of Central Tuber Crops Research Institute, Bhubaneswar, Orissa
Post harvest management….[6]Extensionist, Regional Centre of Central Tuber Crops Research Institute, Bhubaneswar,Orissa

Pests and diseases

Sweetpotato weevil (*Cylas formicarius*) is a major pest in most sweetpotato growing areas. Larvae and adult feed on the roots, causing extensive damage both in field and storage. Nematodes and insect pests attack the storage roots and vines. Meloidogyne spp. (root-knot) and Rotylenchulus reniformis are the major known nematode pests of sweetpotato in the tropics. They attack the fibers as well as fleshy roots, reducing yield and quality, and allowing other pathogens to penetrate through the wounds. In Orissa, diseases are observed in field conditions, but the severity is less than in other areas. Fungal diseases are not normally very serious in the tropics in field conditions. Virus diseases are not common and if found they do not cause drastic reduction in yields.

Socio-economic factors

There is a need and opportunity to improve sweetpotato yields in Orissa, as this crop has strong cultural and social attachments with the farming communities. Adaptive research could focus on developing and introducing improved crop management practices under Orissa's less-favorable growing conditions and low-external input systems. Efforts to promote the cultivation of sweetpotato could capitalize on its potentially superior agronomic traits over traditional varieties including shorter maturity, higher yield, and higher use-value and consumer demand. Equally important is the development of a support scheme to make available planting materials of sweetpotato through community-based systems for multiplication, maintenance, and distribution of sweetpotato planting materials. This is a critical measure in the absence of a functioning formal seed system for sweetpotato.

Unlike in other regions in Asia and Africa, where it is a staple crop, sweetpotato is primarily consumed in Orissa as a supplement to rice, as a snack item, or as a buffer food during crises. To better contribute to the goal of improved yields, it has to be integrated in a strategy with efficient crop management practices and improved seed systems. Inefficiency of local markets and limited access to higher value markets are the main reasons for low prices or price instability.

Institutional and policy factors

Sometimes sweetpotato cultivation is neglected as little investment is made for the sweetpotato production-processing-marketing chain. Inter-sectoral platforms among organizations – both public and private – working in agriculture, health, and education can help to boost the interests of sweetpotato growers. India's increased policy support for food-based nutrition interventions, helping hard-to-reach populations, provides a better enabling environment for the introduction of nutrient rich, orange-fleshed sweetpotato in Orissa. Research-for-development initiatives for sweetpotato directly support the Indian government's current plan for sustainable sweetpotato production. While only a small portion of sweetpotato roots are currently sold in most of the local markets, the potential for reaching target consumers through market chain development could be explored, especially in the urban setting and through proper policy.

Sweetpotato production techniques for improved yields

Sweetpotato is used as a subsidiary food after boiling or baking. The vines are a good source of green fodder for cattle. In some countries the vine tips are used as vegetables. The development of high dry matter, starch, carotene, and anthocyanin varieties has opened up new vistas in industrial applications for the crop apart from traditional usage as food and feed.

Planting materials

Nursery preparation

Primary nursery

Nursery preparation starts three months prior to planting in the main field. For planting one hectare of land, about 100 m^2 of primary area and about 100 kg of medium size weevil free seed roots (125-150 g each) are required. The roots are planted at spacing of 20 cm in ridges formed 60 cm apart. To ensure quick growth of vines they are top-dressed with 1.5 kg urea/100 m at 15 days after planting. The nursery is irrigated on every alternative day for the first 10 days and thrice in a week thereafter. On the 45th day the vines are cut to a length of 20-30 cm for further multiplication in the second nursery.

Secondary nursery

To produce enough planting material to plant one hectare of land, vines obtained from the primary nursery are further multiplied in the secondary nursery to an extent of 500 m^2. Farmyard manure (FYM) or compost of 500 kg is applied at the time of nursery preparation and ridges are formed at a spacing of 60 cm apart. Vines obtained from the primary nursery, or from freshly harvested crop, are planted in the secondary nursery at a spacing of 20 cm within ridges. To ensure enough vegetative growth, 5 kg of urea is applied in two splits at 15 and 30 days after planting. For the better establishment of vines in nursery, irrigations are provided every alternate day for the first 10 days and thrice in a week thereafter. The vines will be ready for planting in the manifold within 45 days.

Time of planting

In India, sweetpotato is grown throughout the country utilizing the monsoon rains during *kharif* (June-August) and with supplemental irrigation during rabi (October-January) in the uplands. Sweetpotato can also be grown as a summer season (February-May) crop with irrigation in the lowlands.

Method of planting

Mounds, ridges, and furrow and flat bed methods are being practiced in different locations. It is preferable to plant sweetpotato on mounds in areas experiencing drainage problems. Ridges formed across the slope are recommended in sloppy lands to reduce soil erosion. The cuttings are planted in the soil with both the ends exposed and the middle portion buried in the soil. Vines are also planted in an inclined position with half of its length buried in the soil. Horizontal planting has also resulted in higher plant survival and better development of the root system. There is no benefit in planting at depths where more than 3 nodes are below the soil surface, as it contributes little to tuber yield and produces small non-marketable grade tubers.

Farmers participatory planting in western Orissa

Spacing

A close spacing is generally recommended for sweetpotato to achieve maximum yield. CTCRI has recommended a general spacing of 60 x 20 cm for all types of sweetpotato.

Weeding

Sweetpotato plants are so aggressive in nature that they cover the soil surface quickly and suppress most weeds. However, weeds are a problem in the early stages of the crop. Inter-culturing and earthing up control weed growth, as well as improving the physical condition of the soil. In order to protect the crop from weeds, at least one weeding and earthing up has to be given between two and five weeks after planting, along with a top dressing of nitrogen.

Key components for sustainable sweetpotato production

Cultivating improved varieties

In Orissa, apart from the traditional/local sweetpotatoes, improved varieties are widely cultivated in most of the sweetpotato growing districts. In Orissa at least seven useful sweetpotato varieties that meet the requirements of the rural poor are available. These varieties are released by the Regional Center of CTCRI. Breeding for useful traits is a continuous process which requires evaluation of the germplasm and comparison with the existing local varieties. Identification of improved varieties with enhanced yields and also nutrition is therefore an important criterion. A case in this direction is the identification of the improved high yielding OFSP is various parts of Orissa.

Climatic adaptation and soil health

Sweetpotato is grown in tropical, subtropical, and warmer temperature regions, and from sea level up to 2000 m. Growth is restricted by cold weather and the plant is damaged by temperature below 100 C, so that in warm temperate areas there must be a minimum frost-free growing period of 4-5 months. Sweetpotato requires at least 500 mm rain during the growing season. It can tolerate considerable periods of drought, but yields are very much reduced if water shortage occurs between 10 and 30 days after planting when tuber initiation takes place. Sweetpotato grown under high rainfall frequently produces vigorous vine growth but poor tuber yield.

Sweetpotato can be grown on a wide variety of soils, but sandy loams, reasonably high in organic matter with permeable subsoil, are ideal. The vines are sensitive to saline and alkaline conditions and good drainage is essential. Heavy clays or soils very rich in humus generally result in good growth of shoots and leaves but normally result in low yields and poor quality tubers. Sweetpotato is an acid tolerant crop and yields are usually high in soils with a pH of 5.5 to 6.5

Nutrient management

The average productivity of sweetpotato at global level is 15.0 t ha^{-1} which is quite higher than the India's productivity of 9.02 t ha^{-1} and this yield gap represents an enormous potential for improving the tuber yields by adopting proper nutrient management programs. Orissa occupy highest cultivated area (47.9 thousand ha) with low productivity of 8.2 t ha^{-1}, according to the estimates of 2004-05.

Essential plant nutrients

Essential plant nutrients are inorganic or mineral elements, which are needed for crop growth and cannot be synthesized by the plant during normal metabolic processes. There are 17 elements needed for crop growth and classified as macro and micronutrients depending upon the quantity required. The macronutrients are again classified as primary nutrients {Nitrogen, Phosphorus and Potassium (K)} and secondary nutrients (Calcium, Magnesium and Sulphur) depending upon their importance. The micronutrients are equally important but their requirement is comparatively low in quantity and they include Iron, Manganese, Zinc, Copper (Cu), Boron (B), Molybdenum (Mo), Chlorine (Cl), and Sodium (Na).

Nutrient deficiency symptoms of some important elements in sweetpotato

Nutrients	Deficieny symptoms
Nitrogen	Symptoms are observed with chlorosis of leaves (older to younger), stunted plants and more pigmentation of young leaves
Phosphorous	Although stunted plants and leaf drop (older leaves) are typical symptoms, older leaves and stems becoming purple is also seen
Potassium	Interveinal chlorosis and chlorotic margins on older leaves are observed. Other symptoms of deficiency are browning of leaf margins and stunted plants
Calcium	More necrotic patches on young leaves and necrotic spots are seen on older leaves. Die-back of root tips and dropping of young leaves are other symptoms
Magnesium	Clear necrosis on older leaves and symptoms of interveinal cholorosis are observed
Sulphur	Stunted plants with chlorotic veins are observed. Stems become thin when deficiency is acute
Boron	Storage root deformation possessing brown spots and death of terminal buds are clear symptoms. Rosette formation of young leaves and leaf curl are other symptoms

Management of nutrient deficiencies

Macronutrients (Primary)

Integrated application of organic manure (FYM) @ 5 - 10 t ha^{-1} and NPK @ 75-50-75 kg ha^{-1} is found to be optimum for the sustainable production of sweetpotato. The nutrient requirement of the crop mostly depends on soil test values, prevailing agro-climatic conditions of the region, nutrient response efficiency of the cultivar, and time and method of application. Integrated use of *Azospirillum* and Arbuscular Mycorrhizal fungi and reduced doses of N and P fertilizers (75% and 50% of the recommended doses, respectively) could maintain soil health and high crop productivity. Deficiency of micro and secondary nutrients is being reported due to intensive cultivation of various agricultural crops and non replenishment of these nutrients has shown drastic reduction in crop yields as well as the occurrence of various diseases in humans and therefore, it is essential to apply recommended doses of secondary and micronutrients besides balanced doses of NPK. Incorporation of green manure has contributed to significant improvement of soil organic matter as well as retention and availability of essential plant nutrients to the crop, and the application of crop residues and locally available green manure crops helps to sustain the soil quality.

Macronutrients (secondary) and micronutrients

The measures to be followed for rectifying the secondary and micronutrient deficiencies encountered in sweetpotato are presented below

Nutrient	Control measures
Calcium	Addition of lime, single and triple super phosphate
Magnesium	Incorporation of dolomitic lime or Magnesium oxide in acid soils (Mg @ 20-50 kg ha^{-1}) or by band application of kieserite or fertilizer grade Magnesium sulphate (Mg @ 10-40 kg ha^{-1}).
Sulphur	Application of S containing fertilizers, gypsum or elemental S or Ammonium sulphate or Single super phosphate
Zinc	Soil application of $ZnSO_4$ @ 10 kg ha^{-1} or foliar spray of 1-2% $ZnSO_4$ $7H_2O$ or dipping of the vine cuttings in 2-4% $ZnSO_4$ for 15 minutes prior to planting
Iron	Foliar spray of chelated Fe or 1-2% Ammonium ferric sulphate solution
Manganese	Foliar spray of 0.1% $MnSO_4$ or Chelate or Mn @ 2-4 kg ha^{-1}, application of mulches and composts
Copper	Foliar spray of 0.1% $CuSO_4$.
Boron	Soil application of Borax or other borates @ 1.0-2.0 kg ha^{-1} before planting in sandy soils or up to 4.0-5.0 kg ha^{-1} in clayey, alkaline soils.
Molybdenum	Application of sodium molybdate or Ammonium molybdate @ 0.2-0.3 kg ha^{-1}, liming the soil to raise the soil pH above 5.5 can also alleviate Mo deficiency.

Nutrient management awareness for increased yields in sweetpotato

There is a wide gap between the actual and potential yields of tropical tuber crops in general and sweetpotato in particular at national and state levels. In most of the integrated farming systems, sweetpotato is being grown as a sole, inter, relay, or mixed crop and managed with low inputs of fertilizers and non adoption of improved technologies resulting in very low crop yields. Most of the harvested produce of sweetpotato in India as well as Orissa is used for domestic consumption and not meant for industrial processing. This causes reduction of net cultivated area and production. Due to lack of awareness in diagnosing the nutrient deficiency/ toxicity syndromes and diseases caused by plant pathogens and insects, the farming community is not advocating proper remedial measures for their control and to produce sustainable crop yields. Adoption of site-specific nutrient management practices and nutrient recommendations based on soil test values plays a vital role in boosting sweetpotato production. Sustainable crop production, including environmental safety and economic feasibility, depends on sound nutrient management programs. This involves both nutrient conservation and judicious application of fertilizers and organic manures, which ensures high yield and good quality. Enrichment of soil with macro and micronutrients assumes special relevance, as it not only enhances crop productivity but also increases the mineral content in plant foods, which may ultimately contribute to the nutritional quality of plant produce and thereby improve human nutrition and health.

Pest management in sweetpotato in Orissa

The production of sweetpotato has been going down in several parts of the country and is under constant pressure because of a lack of effective and implementable pest control measures. One of the constraints to the adoption of integrated pest management (IPM) technologies is the fact that sweetpotato producers in Orissa and its adjoining states are poor marginal farmers. Their resources for purchase of plant protection equipment or interventions are limited. In sweetpotato, the weevil *Cylas formicarius* is the most serious pest that damages the tubers; up to 90% if fields are left unprotected. Recent surveys in three tribal districts of Orissa (Kalahandi, Udayagiri and Keonjhar) revealed that farmers follow some cultural practices such as making ridges to prevent the sweetpotato weevil *C. formicarius* from entering into the base of the vine. In sweetpotato, even with good crop husbandry (excluding ridging) and a package of practices, the crop can suffer up to a 90% loss from weevils if suitable control measures are not adopted.

The best IPM strategy starts with development of host plant resistance (resistant varieties). The development of a pest-resistant variety involves several screenings before it can be released, and in some instances, the clones escape the channel or breeders release the varieties in a hurry.

Sweetpotato weevil

Sweetpotato weevil infested storage root

As sweetpotato farmers in states like Orissa, Chattisgarh, and Jharkhand do not use pesticides, alternate measures for weevil reduction are essential.

Though chemical pesticides are recommended to control the pest insects on sweetpotato, farmers in Orissa do not spray their crops as it is believed that the tubers which are eaten raw may absorb them. In some areas of north east, the vines are fed to pigs and in eastern and central states they are fed to goats. Hence, any IPM practice in sweetpotato that advocates use of pesticides needs to be re-evaluated. If pesticides are to be sprayed, their usage should be restricted to first 30-40 days of the crop, when weevil damage is observed. Educating farmers on proper IPM practices with on-farm trials where farmers participate in the evaluation of the IPM practices is more likely to lead to clean and pest free tubers for consumption and storage.

Post-harvest management

Sweepotato in Orissa is harvested manually by cutting the vines, digging out the storage roots. During harvest, care is taken to keep the storage roots free of surface wounds. Proper storage is essential to prevent post-harvest losses of the sweetpotatoes, which can be used for fresh consumption after a few days or weeks. Storage is done for consumption by the grower and customers, to add profit during off-season sales, and to preserve tubers for planting in the next season. Care is taken by the growers to minimize losses by deterioration in order to obtain a higher market price at a later stage. For marketing, the roots are graded initially based on the quality and size, and only marketable tubers are sold in local markets or otherwise exported to urban markets.

Research institutions' role in livelihood improvement

The Regional Center of CTCRI and CIP in Bhubaneswar, Orissa have been instrumental in advancing technologies to enhance crop yields and incomes of farming communities. Improved varieties, modern agronomic practices, plant protection, plant material distribution, value chain, and training are some important strengths and activities of these research institutions. Through partnerships and networks, some important technologies are rapidly reaching farmers. Government, Non-government, and development organizations are important agencies for technology transfer along with research institutions.

Table 1: Sweetpotato area and production in Orissa by district (2006-2007)

District	Area (hectare)	Production (MT)	District	Area (hectare)	Production (MT)
Balasore	120	992	Koraput	5500	49500
Bhadrak	103	856	Boudh	370	3049
Bolangir	3640	32760	Nabarangpur	125	1033
Sonepur	260	2195	Rayagada	1755	14677
Cuttack	630	5179	Phulbani	1970	17730
Jagatsinghgpur	190	1710	Mayurbhanj	3100	25197
Jaipur	125	1019	Malkangiri	1390	11865
Kendrapara	230	1871	Puri	42	341
Dhenkanal	3290	27741	Khurda	70	578
Angul	1782	14845	Nayagarh	264	2172
Ganjam	8500	71676	Sambalpur	1760	14626
Gajapati	2425	20200	Deogarh	630	5347
Keonjhar	2704	24336	Bargarh	1650	14850
Kalahandi	252	2107	Jharsuguda	26	218
Khariar	1040	8679	Sundargarh	3222	26521
Orissa (Total)	**47165 (hectares)**		**403870 (MT)**		

Source: Indiastat.com, 2010

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Sweetpotato varietal importance and its potential contribution to enhancing rural livelihoods in Orissa

Archana Mukherjee[1]

INTRODUCTION

Sweetpotato is grown in most of the states in India, but Orissa has the highest recorded area under production. Despite having a larger area under sweetpotato, productivity is low in Orissa compared to the national and international average. Hence, research and promotional activities are being conducted by CTCRI, India and its All India Coordinated Research Centers, as well as by international research organizations such as CIP and the Asian Vegetable Research and Development Center (AVRDC) Taiwan. Research is aimed at enhancing nutritional and green productivity of sweetpotato for the enhanced livelihood security of resource poor farmers.

In India, improved varieties of eco-friendly sweetpotato can play a pivotal role for a state like Orissa, which has a diverse range of agro-climatic conditions but is vulnerable to natural disasters in the form of frequent cyclones, floods, and droughts. Of the state's four million farm families, 84% belong to small and marginal categories. The majority of these underprivileged people lives in coastal, hilly, backward areas and can benefit by cultivating eco-friendly sweetpotato as a rescue crop.

Nutritional and industrial importance for livelihood security

Nutritional

Sweetpotato is not only a high energy crop, but also rich in nutrients (Table 1). It contains important amino acids while rice, the staple food crop, is deficient in lysine. Moreover, the orange-fleshed sweetpotato can provide twice the recommended daily requirement of vitamin A and more than one third of vitamin C. It is also a substantial source of dietary fiber. A regular intake of 100 g of orange-fleshed sweetpotato tubers per day provides the recommended daily amount of vitamin A for adults and children. The consumption of orange-fleshed sweetpotato improves vitamin A status. Additionally, purple-fleshed sweetpotato, being rich in anthocyanin (80-90 mg/100g), can provide good amounts of bio-available antioxidant to overcome oxidative stress. Sweetpotato is a short duration crop. Three to four crops can be raised in a year. Thus any productivity enhancement of orange or purple colored sweetpotato in the coastal, hilly backward areas will increase levels of beta-carotene and anthocyanin, as well as its availability throughout the year. Besides food and energy supplementation, nutrients like beta-carotene, ascorbic acid, Vitamin C, and Vitamin E can prevent coronary disorder and cancer.

Industrial

Sweetpotato is an important crop for food and feed and is a base material for processing industries. The dried chips made from sweetpotato tubers are used as raw materials for industrial products such as starch, alcohol, liquid glucose, high fructose syrup, maltose, citric acid, and monosodium glutamate. Fresh sweetpotato tubers, dry flour, or starch can also be used to make jam, jelly, noodles, etc. The animal feed industries use sweetpotato flour to prepare compound feeds for cattle and poultry. Besides tubers, other plant parts like leaves, vines, and roots can be fed to pigs either directly or in boiled form. Other products like wine, sweetpotato curd, and pickles can also be developed from tubers. However, the industrial utilization of sweetpotato is still in its infancy in India. As sweetpotato vines can withstand drought better than other common fodder crops, they can be used as fodder for cattle during off season.

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Table 1: Carotene, Vitamin C and Vitamin E content in sweetpotato tubers and other vegetables (100 g fresh weight basis).

Vegetable	Beta-carotene (mg)	Vitamin C (mg)	Vitamin E (mg)
Sweetpotato	1.8-16	23	4.56
Carrots	4-11	6	0.56
Onion	0.01	5	0.31
Tomatoes	0.64	17	1.22
Peppers (green)	0.27	120	0.80
Pumpkin	0.45	120	0.80
Soybean sprouts	0.04	7	ND

(**Source:** Naskar and Sivakumar, 2007)

Research institutions' role for varietal improvement in Orissa and its neighboring states

Since its inception, CTCRI, under the aegis of India's Council of Agricultural Research (ICAR), has been conducting and coordinating research and development activities for improved tuber crops technologies, including a varietal development program. CTCRI's laboratories located at Sreekariyam, Thiruvananthapuram, and Bhubaneswar (Regional Centre) and its All India Coordinated Research Project (AICRP) on tuber crops have been able to generate a large number of improved technologies in all tuber crops including sweetpotato.

The CTCRI has to its credit the release of nearly 16 varieties of sweetpotato (Abraham et al., 2006). AICRP has also released about 27 varieties. Therefore, a total stock of 33 improved sweetpotato varieties have been released for cultivation in Kerala, Andhra Pradesh, Maharashtra, Orissa, Jharkhand, Chattisgarh, Bihar, West Bengal, Karnataka, and Tamil Nadu. In eastern India, the major sweetpotato growing states are Orissa, Uttar Pradesh, West Bengal, and Bihar. Of the different states, Orissa has the maximum area under production, but productivity is lower than national and international averages. Hence, CTCRI, together with its AICRP Centers and CIP-SWCA, has put concerted efforts into sweetpotato development and promotional activities in these states, which have a higher percentage of underprivileged population or poverty status. Breeding for useful traits both by CTCRI and CIP in India is ongoing for developing sweetpotato varieties with high yield, high starch, and high beta-carotene (pre-cursor of vitamin A) content.

Sweetpotato crop improvement strategy in Orissa

In Orissa, the sweetpotato crop improvement program has mainly contributed to the release of some useful varieties needed to the farming communities. The crop improvement strategies are to essentially cover the main breeding thrust areas and which are mostly confined to:

1. Establishment of land races/ indigenous breeding population through germplasm collection, conservation, and evaluation
2. Introduce sweetpotato exotic collections
3. Selection and hybridization

Key activities related to sweetpotato breeding program

Collection

- Germplasm collection and its evaluation are the basics of any varietal improvement program.
- Indigenous collections have been made from different parts of the country including the North Eastern hills, coastal plains, hilly tribal areas of Orissa, and the tribal areas of Jharkhand and Chattisgarh.
- Exotic collections have been introduced from CIP, Lima, Peru in the form of botanical seeds as well as in vitro cultures.
- The in vitro cultures multiplied in Murashige and Skoog's medium (Murashige and Skoog, 1962) were hardened and established in field.

- At the regional center of CTCRI, a stock of 268 sweetpotato genetic resources are being maintained in field adopting row methods.
- Besides field maintenance, sweetpotato wild species I. trifida of 76 types are maintained as botanical seeds.
- 1620 cultures of 84 genetic stocks of released and exotic lines are also maintained in vitro in MS media by optimizing cultural conditions as explained by Mukherjee et al., (1994a), Mukherjee (2002).

Evaluation and Selection

- The maintained germplasm are evaluated with the specified objectives. Evaluated lines/ genotypes are either selected or being utilized for hybridization and further selection to isolate the superior one.
- Morphological characterization and evaluation studies have been carried out based on IBPGR descriptors. Germplasm are generally evaluated for various agronomic characters and pests and disease resistance apart from using for further breeding program or for direct selection.
- Selection is mainly done for choosing genotypes that have high yield potential, good physiological rhythm in crop development under adverse soil and climatic conditions, tolerance or resistance to major pests and diseases and ultimately preferable qualities

Hybridization technique

- The chief objective of hybridization is to create genetic variation. Today, hybridization is the most common method of crop improvement and some of the sweetpotato varieties have resulted from hybridization in India. Since the flowers are bisexual, emasculation is essential. Dehiscence of anthers occurs before the opening of the flower. Hence, emasculation is done on the previous evening and bagged with butter paper cover.
- The buds that would serve as male flowers are also covered with butter paper bags and protected. Pollination is done by dusting the stigma with pollen from the male flowers.
- The top of the paper cover is cut off to allow aeration for fruit setting on the third or fourth day after pollination.
- Despite self and cross incompatibility in sweetpotato, a good number of varieties have been developed through hybridization and released.
- Promising clones have also been developed as varieties from the progenies of open pollinated seeds viz. Sree Nandini (76-OP-217) and Sree Vardhini (76-OP-219) for commercial cultivation in Kerala state.

Sweetpotato varietal improvement and steps involved for release of a variety

Whether through evaluation of germplasm or hybridization, superior cultivars can be released as a variety considering yield and other quality parameters through AICRP recommended trials, such as Initial Evaluation Trials (IET), Uniform Regional Trials (URT) and Multi-location Trials (MLT) using the following steps.

- Entries/accessions /lines of germplasm selections or breeding lines are evaluated at institutional level for at least two years.
- Two years data with sufficient breeding materials are usually presented in respective AICRP meetings for recommendation of IET, URT and progressive trials.
- IET is conducted for two years at different AICRP/SAU Centers.
- Based on IET results, URT is recommended for two years at different AICRP/SAU Centers.
- Based on URT results, MLT is recommended for two years with location specific best performing entries along with standard check.
- Based on the results of all AICRP trials on yield performance and other quality parameters, the best performing entry/ entries are finally recommended for release.

Following the different breeding methods and AICRP recommended trials, the improved varieties developed and released from CTCRI are listed in table 2.

Table2. Improved sweetpotato varieties released from the Central Tuber Crops Research Institute (CTCRI), India.

Variety	Specific characters
Sankar	Red skin, creamy white flesh, medium duration (120 days), excellent cooking quality and with yield 14 t/ha. Suitable for irrigated and rainfed conditions. Released in 1998 for cultivation in Orissa state.
Gouri	Purple red skin, orange-fleshed variety with high beta-carotene content, medium duration (110-120 days), and with yield 19 t/ha. Can tolerate mid season moisture stress. Suitable for kharif and rabi season. Released in 1998 for cultivation in Orissa state.
Goutam	Clonal selection after polycross, medium duration (105-110 days) and with yield 18-20 t/ha. Ovate tubers, white skin, and creamy white flesh. Tolerant to sweetpotato weevil and mid season moisture stress. Suitable for rainfed as well as irrigated, medium to uplands and hilly areas. Released in 2005 for cultivation in Orissa state.
Sourin	Clonal selection after polycross, medium duration (105-110 days) and yield range is 16-22 t/ha. Round elliptic tubers with red skin and creamy white flesh. Suitable for rainfed as well as irrigated, medium to uplands in both kharif and rabi seasons. Released in 2005 for cultivation in Orissa state.
Kishan	Clonal selection after polycross, medium duration (110-120 days) and yield range is 16-26 t/ha. Long elliptic tubers with purple skin and white flesh. Suitable for rainfed as well as irrigated, medium to uplands and hilly areas. Released in 2005 for cultivation in Orissa state.
Kalinga	Open pollinated sweetpotato variety, suitable for rainfed and irrigated uplands, medium duration (105-110 days) and yield range is 25-28 t/ha.Purple red skinned tuber with creamy white flesh. Dual-purpose variety used for food and animal feed. Useful for starch extraction. Released in 2004 for commercial cultivation in Orissa, Jharkhand, Chattishgarh and West Bengal.
H- 41	Excellent cooking quality and with yield 20-25 t/ha. Reddish purple skin and white flesh.
H- 42	Excellent cooking quality and with yield 22-25 t/ha. Pink skin and creamy white flesh.
Varsha	Drought tolerant, recommended for Konkan region of Maharashtra. Yield range is 17-22 t/ha. Reddish purple skin and light yellow flesh.
Sree Nandini	Drought tolerant, early maturing (100-105 days) and with yield 20-25 t/ha. Creamy yellowish skin and white flesh.
Sree Vardhini	Early maturing (100-105 days), dual purpose variety with yield 20-25 t/ha. Purple skin and yellow flesh.
Sree Rethna	Early maturing (90-105 days) variety with yield 20-22 t/ha and excellent cooking quality. Purple skin and orange flesh.
Sree Bhadra	Early maturing (90 days) variety with yield 20-22 t/ha, excellent cooking quality and used as trap crop against root-knot nematode. Light pink skin and creamy white flesh.
Sree Arun	Early maturing (90 days) variety and with yield 20-28 t/ha. Pink skin and creamy white flesh.
Sree Varun	Early maturing (90 days) variety with yield 20-28 t/ha. Creamy yellowish skin and creamy white flesh.
Sree Kanaka	Short duration (75-85 days) hybrid, rich in beta-carotene (8.8 – 10 mg/100g fresh tuber) and with yield 12-15 t/ha. Reddish yellow skin and dark orange flesh.

Improved varieties released from RCCTCRI and popularized for food and nutrition security in Orissa and its neighboring states are presented in the following figures (Figs.1-6)

Fig. 1 | Sankar

Dry matter (%)	25.0
Total starch (%)	22.5-24.0
Total sugar (%)	2.8-3.4
Cooking quality	Excellent
Average yield	14 t ha^{-1}
Pedigree	Hybrid (H-219 x S- 73)
Areas of adoption	Orissa

Medium duration variety

Fig. 2 | Gouri

Dry matter (%)	22-27
Total starch (%)	16.5
Total sugar (%)	5.8
Carotene content (mg /100g)	4.5-5.5
Cooking quality	Fair, Non-mealy
Average yield	19 t ha^{-1}
Pedigree	Hybrid (H-219 x H- 42)
Areas of adoption	Orissa

Can tolerate mid season drought

Fig. 3 | Kalinga

Dry matter (%)	29.6
Total starch (%)	28
Total sugar (%)	2.5-3.3
Cooking quality	Excellent
Average yield	25-28 t ha^{-1}
Pedigree	Selection from open pollinated seed
Areas of adoption	Orissa, Chattisgarh, Jharkhand, West Bengal.

Medium duration variety
Suitable for food, fodder and starch extraction

Fig. 4 | Goutam

Dry matter (%)	29.9-31.0
Total starch (%)	24.0-25.5
Total sugar (%)	2.5-3.0
Cooking quality	Very good, soft, mealy, and very sweet
Average yield	19 t ha^{-1}
Pedigree	Poly cross, Dhenkanal local, a popular land race is one of the parents
Areas of adoption	All over the state of Orissa under both kharif and rabi season and suitable for rainfed, irrigated, medium to uplands and hilly areas.

Suitable for hilly and coastal areas

Fig. 5 | Sourin

Dry matter (%)	26.9-27.5
Total starch (%)	24.8-25.6
Total sugar (%)	2.8-3.5
Cooking quality	Good, slightly hard, sweet and intermediate to moist in texture
Average yield	19 t ha^{-1}
Pedigree	Poly cross, one of the parent accession No.1162
Areas of adoption	All over the state of Orissa

Tolerant to mid season drought

Fig. 6 | Kishan

Dry matter (%)	32.0-34.0
Total starch (%)	29.0-30.0
Total sugar (%)	3.0-3.5
Cooking quality	Good, sweet and mealy
Average yield	20 t ha^{-1}
Pedigree	Poly cross, one of the parent Accession 1016
Areas of adoption	All over the state of orissa (coastal, plains and hilly areas) under both kharif and rabi season.

Tolerant to mid season drought
Suitable for food, fodder and starch

Sweetpotato: A life saving crop in Orissa?

In recent years unfortunately, Orissa's vulnerability to natural disaster has been increasing. Frequent cyclones, floods, and droughts affect the livelihood of the majority (84%) resource poor farmers of the state. Although changing rainfall patterns and increased extreme weather events are causing adverse impact on agricultural productivity all over the globe, the impact of climate change is more visible in India, especially in the coastal states.

In general, agricultural productivity in coastal states is affected by water scarcity, soil salinity, soil erosion, and depleting biodiversity resources. Furthermore, states like Orissa, West Bengal, Andhra Pradesh, and Tamil Nadu are prone to cyclones, floods, and frequent droughts. All these factors are not only compounding wide spread poverty, but also account for malnutrition and a high infant mortality rate. Vitamin A deficiency is one of the major causes of child blindness especially in coastal states. About 40 000 children are affected every year. Being rich in beta-carotene and anthocyanin, orange and purple-fleshed sweetpotato are highly suitable as a biofortified crop to combat malnutrition in many developing nations. In this context, the development of biofortified sweetpotato tolerant to biotic and abiotic stresses would be a viable long-term food-based approach to achieve livelihood security among the underprivileged population living in backward coastal and hilly areas. Tuber crops are tribal friendly. Sweetpotato in particular is grown in most of the tribal dominated districts of Orissa. It is an important food supplement. Thus the state ranks first in area (39%) and production (33%) of sweetpotato. Of the 30 districts, Ganjam, Koraput, Bolangir, Dhenkanal, Sundergarh, and Mayurbhanj are the major sweetpotato growing districts of the state.

Sweetpotato is drought tolerant and can be grown successfully in drought prone districts like Kalahandi, Bolangir, Sonepur, Boudh, and Rayagada. It can also be grown under rainfed conditions on the state's marginal and sub marginal lands where traditional crops are not performing well and are subject to partial and total crop failure. Sweetpotato was found to be an important rescue crop when paddy and other vegetables failed to grow in the coastal regions of Orissa including Cuttack, Puri, and Jajpur districts that are prone to cyclones and floods. This crop survived against harsh environmental conditions and has made an impact as a food security crop among the affected farm families. Thus, the Bhubaneswar CTCRI Regional Centre, played a key role in the ICAR contingent action plan to rehabilitate cyclone affected farm families during 1999-2000, and also through a project during 2001-2005 for restoring the coastal agro ecosystem of Orissa affected by Super Cyclone. Under these programs, more than one million sweetpotato cuttings were distributed through demonstration trials, benefitting a total of 2400 farmers. Results of the trials revealed that sweetpotato could yield higher than other crops under harsh conditions. The varieties like Gouri, Sankar, Pusa Safed, and Sree Bhadra performed well in coastal regions. Kalinga, Goutam, Sourin, and Kishan were found suitable for Orissa's hilly and coastal regions.

Considerable progress has been made with those improved varieties towards food and nutrition security, but for livelihood security improved varieties with value addition and stress tolerance are essential. Until now, the major thrust of tuber crops research, including sweetpotato in India, was on improving yields. However, climate changes leading to frequent cyclone, flooding, and increased pests and diseases have led to reset the objectives for climate proof crops with a focus now on value addition and stress tolerance. Improved varieties for the future should be adapted for low water and chemical inputs for the benefits of resource-poor farmers. With these issues in mind, work has been redesigned to incorporate the following breeding thrusts. Progress made towards the development of salt tolerant and other promising breeding lines are summarized as follows.

Sweetpotato breeders efforts to meet crises in Orissa

- Collection, maintenance, and screening of genetic resources for high yield, dry matter, high starch, beta-carotene, and anthocyanin contents.
- Screening of genetic resources for tolerance to biotic (sweetpotato weevil) and abiotic stresses like salinity, drought, and water logging.
- Evaluation of selected genotypes for high response to low inputs especially potassium and phosphorus.
- Characterization of selected genotypes and dissemination of technologies through participatory approach, training, and demonstration.

Salt-tolerant sweetpotato

Soil salinity is the major problem affecting agriculture in coastal regions of Orissa. As sweetpotato can produce high energy per unit area per unit time, development of salt-tolerant orange and purple-fleshed sweetpotato can play a key role in the context of green productivity and nutrition security. To enhance the nutrient and green productivity of degraded coastal wet lands, a study was undertaken for biofortified salt-tolerant sweetpotato at RC CTCRI integrating conventional and non conventional hydroponic and *in vitro* culture methods (Mukherjee et al., 1994b; Mukherjee 2002; Mukherjee et al., 2009). Using these methods, six sweetpotato lines, ST 14, CIP SWA2, 420027, Gouri, ST 13 and SB 198/115 were identified as tolerant to salinity (6-8.0 dSm^{-1}). Several seedling progenies tolerant to salt stress (24.0 dSm^{-1}) were also developed.

Field screening and AICRP recommended trials for salinity tolerance indicated that the six salt-tolerant sweetpotato genotypes, and released varieties like Pusa Safed, can also give reasonably higher yield in the saline affected coastal areas of Orissa.

Improved sweetpotato variety for fodder

Of the different breeding lines and released varieties evaluated for fodder in multi-location trials in Orissa. The variety Sree Bhadra was found to have the maximum fodder yield of 19.44 t ha^{-1} to cater for the demand for animal feed.

Development of *in vitro* protocols

Developed *in vitro* protocols for the conservation and propagation of promising lines and released varieties and a stock of 1620 cultures are being maintained in an *in vitro* active storage gene bank (Fig. 7) in MS media by manipulating cultural conditions. Micropropagation through axillary shoot proliferation has been developed. Regeneration through callusing, organogenesis, somatic embryogenesis, and artificial seeds has also been achieved.

Fig. 7: *In vitro* storage of sweetpotato

Upcoming sweetpotato lines for varietal release and consumer use in Orissa

At CTCRI, research and development work resulted in the development of high yielding, high starch, high carotene-rich orange-fleshed and anthocyanin-rich purple-fleshed salt tolerant sweetpotato.

Evaluation of yield and biochemical parameters indicated salt tolerant traits in six genotypes. Of the six genotypes, the genotypes CIP-SWA 2, ST14, CIP-420027, SB 198/115, and Gouri are rich in beta-carotene (5-12 mg/100g) and ST13 is rich in anthocyanin (85-90 mg/100g).

Evaluation studies for high starch recommended ST1, ST10, ST12, ST 14, and ST13 exotic lines with high starch extractability (20-21%). In addition to high starch, ST14 which is packed with high carotene (14mg/100g) and ST13 with high anthocyanin (90 mg/100g) are suitable for food and industry.

Furthermore, based on the performance through AICRP-recommended trials during 2004-2008 the promising high starch line ST-10, orange-fleshed CIP lines 440127, and salt-tolerant line CIP-SWA-2 are in the pipe line for release. The salient characteristics of the promising high starch and beta-carotene rich lines are presented in Table 3 and figures 8 -13.

The identified high starch lines with 20-21% starch, orange-fleshed lines with beta-carotene 6-12mg/100g and 85-90 mg/100g anthocyanin rich purple-fleshed lines with salinity (6.0-8.0 dSm^{-1}) tolerance will reestablish poor man's sweetpotato as a high value industrial crop as well as a source for food security and economic sustainability.

The released variety 'Gouri' and other carotene rich breeding lines are now becoming popular in most of the backward areas of Orissa state. Popularization and mass education on the uses of orange-fleshed sweetpotato can eradicate vitamin A deficient diseases in coastal backward areas of the state.

Table3: Salient characteristics of promising sweetpotato lines under release / AICRP recommended trials at RC CTCRI.

Name of the clone	Yield (t/ha)	Duration (Days)	Salient characters
ST 10	16-17	110	• High starch variety (21.4% extractability) with good cooking quality.
ST 13	14-15	100	• High anthocyanin content (85-90 mg/100 gm)
ST 14	16-19	110	• High beta-carotene (14-16 mg/100gm)
CIP-SWA 2	21-22	110	• High beta-carotene (6-7 mg/100gm), high yield, salt tolerance
CIP-440127	23-24	100-110	• High beta-carotene (6-7 mg/100gm), high yield, salt tolerance
CIP-440038	14-16	100-110	• High beta-carotene (6-7 mg/100gm), high yield, salt tolerance

Fig. 8 | ST10

Dry matter (%)	27.4-29.7
Total starch (%)	Extractable starch 20.8-21.2
Total sugar (%)	3-3.7
Cooking quality	Excellent, soft and mealy
Average yield	23 t ha^{-1}
Parentage with details of its pedigree	Exotic, introduced from Japan
Breeding method	Clonal selection
Specific areas of its adoption	All over Orissa

Can tolerate mid season drought

Fig. 9 | ST13

Dry matter (%)	24-25.5
Total starch (%)	Extractable starch 16.5-17
Total sugar (%)	1.9-2.2
Anthocyanin content (mg/100g)	85-90
Cooking quality	Fair, non mealy
Average yield	18 t ha^{-1}
Parentage with details of its pedigree	Exotic, introduced from Japan
Breeding method	Clonal selection
Specific areas of its adoption	All over Orissa

Can tolerate salinity stress (6-8.0 dSm^{-1})

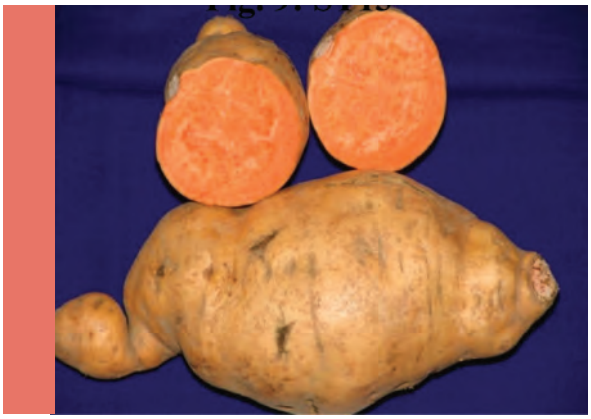

Fig. 10 | ST14

Dry matter (%)	27-29
Total starch (%)	Extractable starch 18.8-19.7
Total sugar (%)	2-2.4
Carotene content (mg /100g)	13.2-14.4
Cooking quality	Good and mealy
Average yield	19.8 t ha^{-1}
Parentage with details of its pedigree	Exotic, introduced from Japan
Specific areas of its adoption	All over Orissa

Can tolerate salinity stress (6-8.0 dSm^{-1})

Fig. 11 | CIP-SWA-2

Dry matter (%)	23.2-24.8
Total starch (%)	Total starch 16.6-17.2
Total sugar (%)	2.4-3.0
Carotene content (mg /100g)	6.5-7.2
Cooking quality	Good
Average yield	22 t ha^{-1}
Pedigree	Exotic, introduced from CIP, Lima, Peru
Breeding method	Clonal selection
Specific areas of its adoption	All over Orissa

Can tolerate salinity stress (6-8.0 dSm^{-1})

Fig. 12 | CIP-440127

Dry matter (%)	25-27
Total starch (%)	17.8-18.8
Total sugar (%)	2.5-2.8
Carotene content (mg/100g)	6.2-7.6
Cooking quality	Good and mealy
Average yield	23 t ha^{-1}
Parentage with details of its pedigree	Exotic, introduced from CIP, Lima, Peru
Breeding method	Clonal selection
Specific areas of its adoption	All over Orissa

Tolerant to mid season drought and salt stress.
Suitable for food and nutrition security

Fig. 13 | CIP-440038

Dry matter (%)	24-26
Total starch (%)	17-18
Total sugar (%)	2.0-3.0
Carotene content (mg /100g)	5.8-7.0
Cooking quality	Good
Average yield	14-16 t ha^{-1}
Parentage with details of its pedigree	Exotic, introduced from CIP, Lima, Peru
Specific areas of its adoption	All over Orissa

Can tolerate salinity stress (6-8.0 dSm^{-1})

The improved sweetpotato varieties already developed and released, and the promising lines under release for high energy (194 MJ/ha/day), nutritive value (high beta-carotene anthocyanin, minerals) coupled with high rates of productivity (> 15 t/ha) could be the right choice for livelihood security, especially for underprivileged people living in the hilly, coastal backward areas of Orissa.

NOTE: All the photographs from page 19 to 29 were contributed by Archana Mukherjee.

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Orange-fleshed sweetpotatoes for improved health and nutrition in Orissa

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Micronutrient malnutrition is increasingly recognized as a serious threat to health and productivity of people world-wide. In India, dietary micronutrient deficiency is widespread. About 80% of individuals consume diets that provide less than half of the RDA (Recommended Dietary Allowance) for iron and vitamin A (NNMB, 2000). Specifically, the intake of vitamin A is half of the RDA (600 micrograms of vitamin A) in the state of Uttar Pradesh and three-fourths of RDA in Orissa.

Vitamin A deficiency increases the risk of night blindness, Bitot spots, Xerophthalmia, and Keratomalacia. One possible solution for addressing vitamin A deficiency in these areas is through a food-based approach, using orange-fleshed sweetpotato as an inexpensive source of beta-carotene (the pre-cursor to vitamin A). Vitamin A is produced by the human body when it has sufficient quantities of its precursor beta-carotene. Vitamin A is produced only in animals; beta-carotene only in plants.

Orange-fleshed sweetpotato is attractive to children, who like its color and are especially susceptible to the negative health affects of vitamin A deficiency. Orange-fleshed sweetpotato also is more affordable than other carotene-rich foods, such as carrots or papayas.

Sweetpotato is grown and consumed in the Eastern region of India, but traditionally in its white-fleshed form, which does not offer the nutritionally benefit of the orange-fleshed varieties. There is a need to increase the availability of the beta-carotene rich orange-fleshed varieties in these regions. Recent studies in Orissa especially in Ganjam and Gajapathi districts suggest that orange-fleshed sweetpotato can be accepted and popularized in the region. In addition, the use of orange-fleshed sweetpotato genotypes possessing higher yields could improve the socio-economic conditions of farming community as well as their nutritional status.

A beta-carotene rich OFSP

White and Orange-fleshed sweetpotatoes

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Beta-carotene in sweetpotato

Depending on the beta-carotene content of the variety, the amount of orange-fleshed sweet potato root needed to meet the RDA for vitamin A in adults and children is about 100 grams per day. With yellow-fleshed varieties, the necessary amount is 100-120 grams per day. With deeper orange-fleshed sweetpotatoes, the amount needed is even less. Some of the varieties tested by CIP contain up to 8,000 micrograms of beta-carotene/100 grams, which is nearly 4-times the required amount.

Additional benefits

Orange-fleshed sweetpotato also provides calories, is rich in ascorbic acid (Vitamin C) and B vitamins, and contains helpful amounts of other micronutrients, such as iron (which is not found at very high levels in sweetpotato roots but is twice as high as the levels found in rice).

Relationship to Vitamin A Supplementation Programs

Supplementation programs have been enormously successful on a global basis over the past 10 years. However, they cannot easily reach poor farm families in remote areas of developing nations who are isolated by poor infrastructure and frequent weather events that make roads impassable and distribution ineffective. Using orange-fleshed sweetpotatoes to reach poor isolated communities, such as those in Orissa, can be an effective way to "supplement the supplement programs." In addition, the food-based approach is likely to be more sustainable. For example, mothers do not always see the need to continue supplementation when they cannot see the effects right away. Integrating orange-fleshed sweetpotato into regular diets promotes nutrition and food security more broadly. For example, orange-fleshed sweetpotato could be integrated in the diets of small children. CIP intends to work in Orissa with the health and nutrition sectors to maximize the potential of this approach.

Implications regarding orange-fleshed sweetpotato production

During the post-harvest period, taste tests and acceptability studies of orange-fleshed sweetpotato are being conducted for awareness and acceptability in many parts of Orissa. Demand for orange-fleshed sweetpotato is high in poverty stricken areas due to its nutritional and potential yield benefits. CIP, CTCRI, and NGO partners are making concerted efforts to provide and raise needed orange-fleshed sweetpotato planting material in the sweetpotato growing districts of Orissa.

Necessary participatory evaluation trials have been conducted in the past 2 years to introduce and assess the performance of orange-fleshed sweetpotatoes over white fleshed sweetpotatoes. The results are encouraging. Field studies indicate that the orange-fleshed sweetpotato performs well in different locations of Orissa, surpassing yield levels of the local white-

fleshed varieties. Access to planting material for orange-fleshed sweetpotato is a challenge for growers as its introduction is new to many parts of Orissa. There is a need for rapid multiplication methods and the establishment of community nurseries to meet the rising demand for orange-fleshed sweetpotato.

In order to achieve the nutrition security with respect to beta-carotene for the population at risk, sweetpotato crop production should be substantially increased. There is also a need to produce orange-fleshed sweetpotato with high dry matter. Productivity can be increased by increasing the knowledge and awareness among the farmers about the importance of carotene foods and ensuring supply of good quality seeds. Also important are training and practices to encourage correct crop management procedures regarding the application of chemical fertilizers and pesticides, and reducing the post harvest losses. Finally, small-scale farmers could benefit from a greater integration with the sweetpotato processing industry to better meet its needs and connect them more closely so that they can benefit from taking part in value market chains that could increase their incomes and improve livelihoods.

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Improved sweetpotato indigenous recipes: Overview of consumers' assessment

Sreekanth Attaluri[1], Abha Singh[2], and Rakesh Kumar Mohapatra[3]

INTRODUCTION

Sweetpotato recipes and products are generally liked by many consumers. This study presents an analysis that was organized based on the taste and preference tests for six sweetpotato recipes. The recipes were prepared with the involvement of food scientists and the participation of consumer groups, consisting of tribal people from the five districts in Orissa. The participants tasted and documented their opinions on individual recipes and products. This study provides in-depth information on the consumer appeal of various recipes.

Methodology

The participants (Addendum B) were provided with an evaluation sheet containing nine different attributes including appearance; color (intensity/uniformity); odor /smell /flavor; taste; sweetness; feel/texture; fiber, and "others". They also rated overall taste acceptability. The ranking/rating for the recipes was based on different attributes on a scale of 1 - 5. Univariate analysis was done to derive appropriate conclusions based on the organoleptic tests.

Sample evaluation sheet:

SWEETPOTATO RECIPE (Product) EVALUATION SHEET

Name of evaluator: _____ **Age:** _____ years **Sex** (M/F): _____

Village: _____ **District** _____ **Date:** _____ **Name of the recipe (English/Hindi/Oriya)** _____

Attribute	 1= Very Bad	 2= Bad	 3= Fair	 4= Good	 5= Very Good
Appearance					
Color (intensity/uniformity)					
Odor /Smell /Flavour					
Taste					
Sweetness					
Feel /Texture					
Fiber					
Others (specify)					
Overall Taste Acceptability					

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Recipes (products):

Product 1: Kandamula Khiri (Sweetpotato dessert)

A sweet dish featuring milk, sweetpotato, and sugar as the main ingredients. This recipe is used mainly as a dessert. However, it is also eaten as snack food any time during the day. This dish is especially appealing to children.

Product 2: Khandamula Khata (Sweetpotato Chutney)

This can be used as side dish for the main meal. Ingredients include sweetpotato, tomatoes, salt, chili powder or dry chilies, oil, and spices. This dish is mostly liked by adults and can be prepared easily by women.

Product 3: Kandamula Powder (Sweetpotato flour)

This is a sweetpotato flour which can be used in making Indian bread like chapatti, puri, etc. The flour also can be used in other forms to prepare snacks and other foods. Since this is a powdered form of sweetpotato it can be stored for a length of time.

Product 4: Kandamula Pakudi (Sweetpotato snack)

A sweetpotato snack that is eaten especially at evening time, both by adults and children. Ingredients include mashed sweetpotato, powdered pulses, salt, and oil. This snack can be prepared quickly and easily.

Product 5: Kandamula Puri (Sweetpotato snack/ bread)

This is an Indian bread mainly consumed for breakfast. Key ingredients are mashed sweetpotato, maida and oil. This is normally enjoyed by all age groups.

Product 6: Kandamula Achar (Sweetpotato pickle)

A sweetpotato pickle which is slightly spicy and hot. This is normally eaten during the main meal and sometimes for breakfast along with other food items. Generally it preferred by adults.

Results:

Two different comparisons were made based on the rankings given by the participants for the different attributes of six products, separately and individually. The comparisons are differentiated as 1. Intra comparison and 2. Inter comparison.

Intra comparison: This comparison is made within the same product by taking into consideration different attributes of the product and comparing them individually. The sums of all the rankings/ ratings given by different farmers were taken for a single product and for a particular attribute. By doing this, the strengths and the weaknesses of the attribute within a product could be identified and it could be improved upon. The following were the observations made:

PRODUCT	STRENGTH	WEAKNESS
PRODUCT-1	Texture	Others
PRODUCT-2	Taste	Appearance
PRODUCT-3	Sweetness	Odor, appearance and taste.
PRODUCT-4	Odor, taste and overall taste acceptability	Fiber
PRODUCT-5	Sweetness	Fiber
PRODUCT-6	Taste	Fiber

Inter Comparison: Here the comparison could be made between different products for a particular attribute. Different scores (percentage of responses) were obtained for each attribute and product. The scores were categorised into Very Good and Good. The scores reveal the superiority of products in relation to the attributes as well as gives information on the products for improvement over others to enhance marketability and demand. The following were observed:

Product	Appearance		Color		Odor		Taste		Sweetness		Texture		Fiber content		Overall Taste Acceptability	
	VG	G	VG	G	VG	G	VG	G	VG	G	VG	G	VG	G	VG	G
1	52	38	55	31	69	28	62	31	48	38	66	34	52	48	52	48
2	66	10	66	10	61	25	69	21	59	34	62	31	48	42	63	27
3	55	35	59	17	52	38	59	24	72	21	52	45	59	34	62	35
4	59	10	55	38	65	28	66	34	62	35	66	31	52	45	69	28
5	66	31	66	31	67	30	66	34	69	31	69	31	48	45	66	31
6	55	41	52	38	48	48	59	38	45	48	48	41	62	28	48	38

VG = Very Good | **G** = Good

By combining very good and good scores for each product we derive the top rated products as shown below:

Appearance - product 5

Color - product 5

Odor - product 1 and product 5

Taste product – 4 and product 5

Sweetness - product 5

Texture - product 5 and product 1

Fiber content - product 1

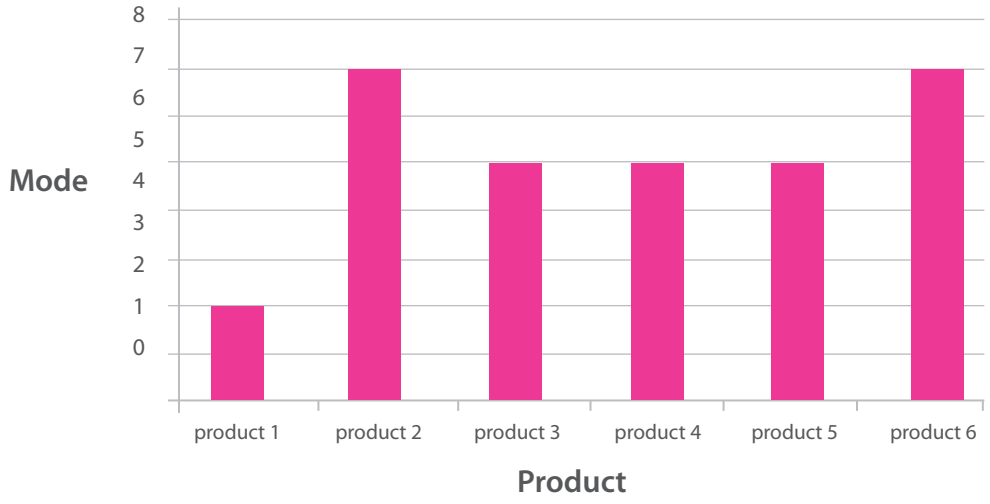
Overall taste acceptability - product 1

These findings may be helpful for improving the existing product or preparing new products, based on participants' preferences.

Farmers' preferences:

The products preferred by the participants/farmers were assessed using a holistic approach that took into consideration the method of preparation, preparation time, cost and availability of ingredients, taste, acceptability and, most importantly, whether the product is culturally/traditionally friendly to consumers.

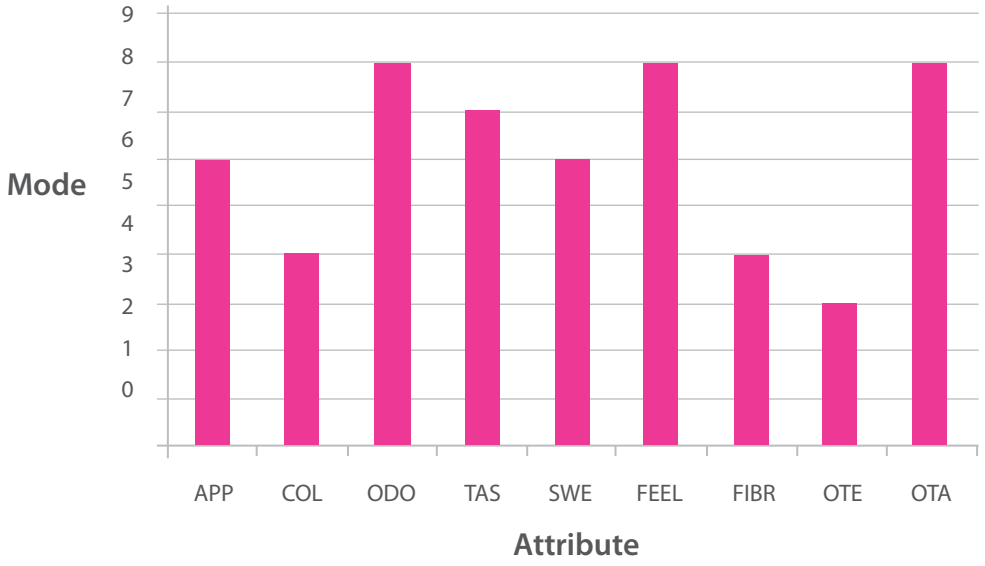
Taking all of these factors into consideration, the products preferred by 14 farmers were product 2 (Khandamula Khata) and product 6 (Khandamula Achar). Products 3, 4 and 5 were awarded high preference by 11 people, and product 1 was preferred by 7 people. By calculating the 'mode*' values , it was found that products 2 and 6 have the highest preference,whereas the least preferred product is product 1.



Attributes preferred by farmers

The mode was calculated for all the attributes on a scale of 5. The highly rated attributes are odor, texture and overall taste acceptability. Color and fiber were rated less, indicating scope for improvement of these attributes.

* Mode of data sample is the element that occurs most often in the collection.



APP-Appearance; COL-Color; ODO- Odor; TAS-Taste; SWE-Sweetness; TEX- Texture; FIBR-Fiber; OTE-Others; OTA-Overall Taste Acceptability

Conclusion:

The sweetpotato chutney and pickle were liked by most of the participants, although the other recipes were on a par in terms of taste and other preferred attributes. The tribal women and men were immensely encouraged by the food scientists' preparations, as the recipes were tasty, attractive and could be prepared at house hold level.

Acknowledgement:

The International Potato Center (CIP) duly acknowledges the inputs given by food scientists Mrs Abha Singh and Mrs Geeta Saha for their active involvement in preparing the recipes along with DRWA staff and participants. CIP would also like to acknowledge and thank Dr Krishna Srinath, Director, DRWA and Dr Suman Agarwal of DRWA for making the recipe preparations so successful, giving the participants an opportunity to use their traditional/local knowledge in improving the recipes along with the scientific staff.

All the photographs in this section are contributed by S Attaluri and D Campilan.

Selected sweetpotato based products for Orissa as developed by research institutions

By R.C. Ray G. Padmaja & P.S. Sivakumar

CTCRI, Thiruvananthapuram and its Regional Centre in Bhubaneswar have developed several food products from tuber crops for use by farmers, general consumers, processors, and traders in Orissa. Orissa is the largest producer of sweetpotato in India. However, sweetpotatoes are primarily eaten as a snack food in boiled or baked form. Sometimes peeled tubers are sliced and dried in the sun to produce chips, which are then ground into flour. No commercial products are available. CTCRI has developed the following products aimed at improving the marketability of sweetpotato in Orissa.

Sweetpotato jam

Tubers are washed, peeled, chopped and cooked. The cooked tuber is blended and sieved to obtain a fiber-free pulp. This is then mixed with fruit pulp from mango, banana, or apple. After adding the requisite quantity of sugar, the pulp mixture is cooked on a low heat for thickening. Food flavoring and coloring is added to the pulp along with citric acid and preservatives.

Gulab jamun mix

Gulab jamun is a popular sweet dessert of India, made traditionally from refined wheat flour and milk powder or 'khoa' (concentrated milk). The possibility of replacing part of the milk powder and refined wheat flour (RWF) with sweetpotato flour was investigated. It was found that 20% sweetpotato flour addition to milk powder: RWF mix (31: 29) gave an instant mix, which produced highly acceptable gulab jamuns. White- fleshed sweet potato varieties, having a soft texture on cooking are suited for making the instant mix.

Sweetpotato pickles

Sweet potato tubers are ideal for making pickles. The cleaned tubers after peeling are cut to ¼ inch cubes and put into diluted vinegar (1%) to prevent browning. After soaking for an hour, the cubes are taken, washed in water, drained, and made into pickles in the usual way. The product has a shelf life of two months.

Beta-carotene enriched ice cream from orange-fleshed sweetpotato

B.Vimala and Bala Nambisan

The major strategies to control vitamin A deficiency are: dietary diversification, food fortification and vitamin A supplementation. Dietary diversification includes the production and consumption of beta-carotene rich foods such as orange-fleshed sweetpotato. Sweetpotato roots are used for the preparation of various products like cakes, bread, pies, puddings, desserts, baby food, etc. The most common method of consumption of sweetpotato roots is in the form of snack food after boiling, baking, or roasting. The orange-fleshed sweetpotato can be utilized for preparing various value-added products. One such novel food product is orange-fleshed sweetpotato ice cream. In a Life Science Research Board (LSRB) funded project, about 40 orange-fleshed clones possessing different intensities of dark orange-flesh color were developed. The storage root of the clone (SV3-17) developed in the project is used for the present study.

Orange-fleshed sweetpotato ice cream

Ingredients:

Orange-fleshed sweetpotato small pieces (without skin)	400g
Milk	400ml
Cardamom	1or 2
Sugar	100g
Fresh milk cream	100g
Condensed milk (Milk maid)	400g (1 tin)
Vanilla essence	One tea spoon


S Attaluri


S Attaluri

Boil about 400g of dark orange-fleshed sweetpotato root pieces in 400 ml of milk along with 100g sugar and 1-2 small cardamom in a vessel till it cooks well. Allow to cool. Remove the cardamom and grind the mixture in a mixer. Add 100g of fresh milk cream, 500g of condensed milk, and one tea spoon of vanilla essence. Blend well with a wooden spoon or an electric egg beater and put the mixture in an air tight container. Cover with aluminium foil. Refrigerate thoroughly until completely chilled.

The total carotenoid of the fresh and the boiled roots were estimated as per the standard procedure given in AOAC (1995). The total weight of the ice cream prepared was 1000g (1kg). 1kg ice cream contains 400g boiled sweetpotato. A standard cup holds about 100g ice cream i.e, a total of 10 cups of ice cream can be made. The ice cream has an attractive bright orange color due to the gelatinization of starch. The taste and appearance is similar to other ice creams. However, the nutritional content is higher due to the presence of beta-carotene. The total carotenoid and beta-carotene in the fresh and boiled root was 15.34 and 13.23mg/100f.w. and in the cooked sweetpotato root it was 13.06 and 12.17 mg/100g.f.w. Out of 100g of ice cream, sweetpotato content was 40g. The beta-carotene content in each cup of ice cream was 4.87mg. This study showed that a high amount of beta-carotene (92%) is retained in the processed product compared to the fresh roots. Orange-fleshed sweetpotato ice cream has the potential of increasing vitamin A intake and hence contributes to health improvement.

Addendum A

Program details of the two day event at Bhubaneswar on March 17-18 2010

Title: Knowledge fair on sweetpotato cultivation and utilization for tribal women in Orissa

Date: 17-18 March 2010,

Venue: Directorate of Research on Women in Agriculture (DRWA), Regional Center - Central Tuber Crops Research Institute (RC CTCRI) and the International Potato Center (CIP) Bhubaneswar, Orissa

Topics

Day 1: Exhibition and demonstration of sweetpotato food utilization with emphasis on indigenous recipes contributing to nutrition security in tribal pockets of Orissa

Day 2: Technical training on sweetpotato cultivation and distribution of planting material for tribal women farmers

Schedule

Day 1

Time	Activity
09:30 -10.00	Introduction of participants
10:00 -10:15	Workshop overview – Dr Krishna Srinath, Director DRWA
10:15 -10:45	Sweetpotato for nutrition and livelihood security in Orissa-Dr Sreekanth,CIP
10:45 -11:00	Overview on sweet potato food preparation-Mrs Abha Singh, Scientist, DRWA
11:00 -13:00	Joint preparation of indigenous and improved sweet potato recipes by tribal women and DRWA staff led by Dr Krishna Srinath
13:00 -14:00	Lunch
14:00 -15:00	Organoleptic tests and consumer evaluation of the prepared sweetpotato food products
15:00 -16:30	Discussion on improving the recipes and promoting their use for nutrition and livelihood security among tribal farming households
16:30 -16:45	Summary of days proceedings and briefing on day two activity
16:45 -17:15	Viewing of DRWA exhibits and educational tour of campus

Time	Activity
09:30 -13:00	Field training on sweetpotato cultivation- CTRCI and CIP facilities
13:00 -14:00	Lunch
14:00 -15:30	Collection of sweetpotato planting materials by tribal women and NGO representatives and explaining do and don'ts in cultivation
15:30 -16:30	Discussion with tribal farmers and NGO representatives & planning on-farm learning activities for next cropping season
16:30 -17:00	Closing ceremony and valediction

Addendum B

List of Participants attended the workshop and training program on sweetpotato in Bhubaneswar.

S No	Participant	Village	District	Sponsoring NGO
1	Sudarsan Raith	Bettarsirg	Gajapati	Suraksha
2	Debendra B. Dalai	Mahulpada	Gajapati	Suraksha
3	Gangadhar Raith	Mahulpada	Gajapati	Suraksha
4	Kumudini Raith	Bettarsirg	Gajapati	Suraksha
5	Mandudhari B. Dalai	Bettarsirg	Gajapati	Suraksha
6	Sumitra B. Dalai	Bettarsirg	Gajapati	Suraksha
7	Kailash Chandra Pradhan	Patangi	Koraput	LAVS
8	Maliki Pangi	Turia	Koraput	LAVS
9	Siv Pangi	karanjaguda	Koraput	LAVS
10	Bhanumati Pangi	Kusuma	Koraput	LAVS
11	Lachi Pangi	Turia	Koraput	LAVS
12	Sundarma Hantal	Turia	Koraput	LAVS
13	Rabinarayan Singh	Randapada	Kalahandi	Antodaya
14	Laxman Majhi	Randapada	Kalahandi	Antodaya
15	Sukru Majhi	Taragaon	Kalahandi	Antodaya
16	Manmati Dei	Taragaon	Kalahandi	Antodaya
17	Suna Dei	Taragaon	Kalahandi	Antodaya
18	Sandharam Majhi	Babupalli	Nuapada	CPSW
19	Jagabandhu Sabar	Seekulmundi	Nuapada	CPSW
20	Mangalsingh Majhi	Mendhatad	Nuapada	CPSW
21	Ugresan Majhi	Danaghuda	Nuapada	CPSW
22	Mahesram sabang	Lalbhata	Nuapada	CPSW
23	Biswanath Mishra	Radkia	Kandhamal	Samanwita
24	Jakarias Pradhan	Mudelipanga	Kandhamal	Samanwita
25	Nabakishor Pradhan	Meakupenga	Kandhamal	Samanwita
26	Chandrakant Pradhan	Kandabada	Kandhamal	Samanwita
27	Balakrushna Pradhan	Gumamaha	Kandhamal	Samanwita
28	Minakshi Pradhan	Dalukamba	Kandhamal	Samanwita
29	Sanjukta Pradhan	Musumaha	Kandhamal	Samanwita

Other participants and resource persons: Mr Hembram (Asst. General Manager, NABARD Orissa Regional Office, Bhubaneswar), Dr Krishna Srinath (Director, DRWA), Dr R S Misra (Regional Centre of CTCRI), Dr Wayne Nelles (Head, Capacity Strengthening, Lima Peru). Others included scientists and staff from CIP, RC CTCRI and DRWA.

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