Training Manual

Model Training Course on

Root and tuber crops based integrated farming system: A way forward to address climate change and livelihood improvement

(19-26 September, 2016)

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Dr. M. Nedunchezhiyan

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Mr. V.V. Bansode
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Sponsored by
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Department of Agriculture, Cooperation and Farmers Welfare
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ICAR- Central Tuber Crops Research Institute, Regional Centre
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FOREWORD

Food security is achieved when it is ensured that all people at all times have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life. It has been reported that 7 out of 10 young children are anaemic. Similarly, almost half of Indian women aged 15-49 years and 43% of Indian men aged 15-49 have one of the problems of abnormal thinness or overweight. It is not only the food security, nutrition, health, environment and livelihood securities are equally important and will need enhanced focus in near future. During last 3 decades diversification in agriculture was mainly governed by economic gains and issues of sustainability, ecology and environment got less emphasis. Further, climate change has been a cause of concern to the world agriculture over the past decade. Yield decline due to climate change in various regions are reported. One of the major challenges facing humankind is to provide an equitable standard of living for present and future generations' viz., adequate food, water, energy, safe shelter and a healthy environment. Vulnerability to climate change is closely related to poverty, as the poor have fewer resources and depend on climate sensitive sector such as agriculture. Many reports emphasized that Asia-Pacific regions are likely to face the worst impacts of climate change on cereal crops. However, many studies showed that tropical tuber crops can perform well under harsher climatic conditions. The FAO has identified cassava and yams as climate resilient crops. These tropical tuber crops are adapting in to any farming system due to their flexibility in planting and harvesting time.

In this backdrop, this Model Training Course entitled "**Root and tuber crops based integrated farming system: A way forward to address climate change and livelihood improvement**" has been organized at ICAR-CTCRI, Regional Centre, Bhubaneswar from 19-26 September, 2016. I appreciate the efforts of the course team for bringing out this Training Manual, which will be an useful reference material for the extension functionaries of State Development Departments, Krishi Vigyan Kendras, researchers and other related stakeholders.

17/9/16

Date: 17-09-2016 **(James George)**
Place: Bhubaneswar **Director (Acting)**

CONTENTS

Role of tuber crops in food security and farm income

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Introduction

As per FAO definition of food security 'food security is achieved when it is ensured that all people at all times have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life'. The food production in India is 260 million t presently and the rate of increase in food production outpacing the rate of population increase. Yet 20% of the Indian population would go undernourished as per the estimate of Indian Planning Commission in 2012 (Nayar, 2014). Further it has been reported that 7 out of 10 young children are anaemic. Similarly, almost half of Indian women aged 15-49 years and 43% of Indian men aged 15-49 have one of the problems of abnormal thinness or overweight. It is not only the food security, nutrition, health, environment and livelihood securities are equally important and will need enhanced focus in near future. During last 3 decades diversification in agriculture was mainly governed by economic gains and issues of sustainability, ecology and environment got less emphasis. No doubt, it helped the country to achieve food security but at the cost of degradation of natural resources (Singh, 2015).

There are two fundamental issues in food security, particularly in the Indian context – availability of food especially in remote areas, and difficulties in accessing food, because of lack of purchasing power.

Importance of tuber crops

Food security

Tropical tuber crops are important group of crop species which produce tubers that are used for human food and animal feed. These crops rank third in terms of their contribution to food after cereals and legumes. The popular tropical tuber crops include cassava (*Manihot esculenta*), sweet potato (*Ipomeas batatus*), greater yam (*Dioscorea alata*), white yam (*D. rotundata*), lesser yam (*D. esculenta*), taro (*Colocasia esculenta*), tannia (*Xanthosoma sagittifolium*), elephant foot yam (*Amorphophallus paeniifolius*), yam bean (*Pachyrrhizus erosus*), coleus *(Solenostemon rotundifolius*) etc. The root and tuber crops continue to play important roles in feeding large number of population in developing countries. They contribute substantial amount of cheap energy coupled with high quality nutrition for more than 2 million people living in developing countries. These crops are primary/ secondary staple food of million in the temperate zones and in the vast areas of the tropics and sub-tropics of Africa, Asia, Latin America and Pacific where a large number of world's under nourished people live.

Tropical tuber crops are rich source of energy and carbohydrates although each of them also provides other important nutrients as well. They contribute 3.9% (cassava 1.9%, sweet potato 1.5% and yams and other root and tuber crops 0.3%) energy requirement of world population. Tropical tuber crops supply food 28.5 kg/head/year and 75 kcal energy/head/day (Nayar, 2014). They produce large quantities of energy (carbohydrate) in relatively less time than other crops. They are most efficient in converting solar energy, for example cassava producing $250x10^3$ kcal/ ha and sweet potato $240x10^3$ kcal/ha as compared to on $76x10^3$ kcal/ha for rice, $110x10^3$ kcal/ha by wheat and $200x10^3$ kcal/ha for maize. Tuber crops grow well in marginal soil with fewer inputs where other crops usually fail to grow. They are tolerant to drought and some of them grow fast and provide a wide soil cover to prevent erosion. These crops have great flexibility in mixed cropping systems to generate additional employment and income. Crops like yam and elephant foot yam grow as intercrops in horticultural and plantation crops.

Nutritional security

Tuber crops are rich in essential vitamins or minerals but poor in protein. On an average cooked yams have about 2% protein, Cassava and sweet potato provide ascorbic acid (Vitamin C) whereas cereal based foods have none. Sweet potato also contains important amino acids while rice is deficient in lysine. The orange and yellow-fleshed sweet potato roots and green tops are good source of Vitamin A, which can prevent night blindness and malnutrition prevalent in many parts of the country. So a regular intake (100 g/day) of orange or yellow fleshed sweet potato having moderate concentration of Vitamin A (3 mg/100 g) or greens or/of mixture of both to provide 100% of Recommended Daily Allowance (RDA) of Vitamin A for children. Besides, sweet potato is rich in anti-oxidant, nutrients like β-carotene, ascorbic acid (Vitamin C) tocoferol (Vitamin E), which can prevent coronary disorder and cancer.

Table 1. Concentrations of β-carotene, Vitamin C and Vitamin E in sweet potato roots and other vegetables (Per 100 g fresh)

Vegetable	β-carotene (mg)	Vitamin C (mg)	Vitamin E (mg)
Sweet potato	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

Table 2. Comparative proximate composition of tuber crops

Tuber crops	Grams per 100 g on dry weight basis					
	Protein	Fat	Minerals	Fibre	Carbohydrates	Calories
Potato	7.3	0.4	2.4	1.6	89.0	382
Sweet potato	3.8	0.9	3.1	2.5	88.5	377
Cassava	1.7	4.9	2.5	1.5	84.9	386
Yam	4.7	0.3	5.3	3.3	86.6	370
Colocasia	11.6	0.4	6.3	3.7	78.5	361
Elephant foot yam	5.6	0.5	3.8	3.8	86.3	371
Rice	7.8	0.8	0.7	0.2	89.9	397
Wheat	13.5	1.7	1.7	1.4	81.2	393
Colocasia leaves (black types)	31.9	9.4	11.8	8.5	38.0	362
Colocasia leave (green types)	22.6	8.7	12.8	16.8	39.4	325
Cabbage	22.2	1.2	7.4	12.3	56.6	332

Economic security

Tuber Crops, besides providing food and nutritional security, contribute to the economy security of the farmers with an array of value added products. Cassava is an established commercial crop as its roots are utilized into array of products for human food as fresh or processed roots, starch and flour for food and industry, and animal feed. In China cassava meets basic needs both of food security and income generation, while animal feed in Vietnam. The starch of cassava is utilized in Thailand for manufacturing monosodium glutamate and plywood. Cassava starch finds application in array of industrial products in India- textiles corrugation box, paper conversion, liquid gum for domestic sector, paper industry etc. Besides food, sago industry is the major one. A number of stable and marketable food product as well as less stable snack food can be made from tuber crops. Cassava rawa of semolina and fried cassava chips are successful stable products that can be made from cassava tubers. Besides, cassava flour fortified with cereals or legumes flours can be used for making extruded fried foods which also have good post product self life.

Sweet potato is an important crop for food, feed and raw material industries. For industrial processing, starch and dry chips of sweet potato have been used as raw materials in the manufacture of products such as deep processing starch, alcohol, liquid glucose, high fructose syrup, maltose, citric acid, monosodium glutamate and for food processing fresh roots dry flour or starch can be used for noodles fried chips, canned flakes and candid pal production. In feed processing the main product is sweet potato flour used by the compound feed industry. Besides stored roots other parts like leaves, vines, pencil roots even residues after starch processing can also be dehydrated and powdered and can used as supplement to cereal flour. The industrial utilization of sweet potato is rudimentary in India. Sweet potato roots and leaves are used in fattening the pig. Starch of colocasia is very fine and it is used in cosmetic industries and also as filler for biodegradable plastic. The corms and cormels are good source of pig feed.

Production scenario

As per FAOSTAT (2012), cassava is produced in 20.4 million ha with production of 262.6 million t and productivity of 12.8 t/ha. Sweet potato is produced in 8.1 million ha with production of 104.5 million t and productivity of 12.9 t/ha. Yams are produced in 5 million ha with production of 58.8 million t and productivity of 10.7 t/ha. Taro is produced in 1.3 million ha with production of 9.6 million t and productivity of 7.8 t/ha. Cocoyam is produced in 0.04 million ha with production of 0.4 million t and productivity of 8.4 t/ha. In terms of percentage contribution of World production as follows: cassava (60.2%), sweet potato (24.0%), yams (13.5%) and taro (2.2%) and cocoyams (0.1%). Cassava is mostly produced in Africa, Asia and South America while sweet potatoes are heavily concentrated in Asia. Africa dominates the production of yams and taro. Consumption pattern of tuber crops in major growing regions differ significantly. The consumption of cassava (150 kg/head/year) is maximum in Africa followed by South Africa while in Asia sweet potato (39 kg/head/year) is consumed maximum. The yams (39 kg/head/year) are mostly consumed in Africa and taro (10 kg/head/year) is consumed mostly in Oceania.

In India, cassava and sweet potato are grown in almost all the states except temperate climatic zones.

Research developments in tuber crops

The Central Tuber Crops Research Institute, formed under the auspices of Indian Council of Agriculrtural Research, is the premier institute in India working exclusively on research and development of tuber crops. There are 15 different tuber producing crop species which form the mandatory crops of the Central Tuber Crops Research Institute, India are two major crops Cassava (*Manihot esculenta*) and Sweet potato (*Ipomeas batatus*) , three Yam species (*Dioscorea alata, D. esculenta* and *D. rotundata)*, five Aroids species (*Colocasia esculenta, Xanthosoma sagittifolium, Amorphophallus paeniifolius, Alocasia macrorrhiza, Cyrtosperma chamissionis*) and five minor tuber crops *(Solenostemon rotundifolius, Pachyrrhizus erosus, Maranta arundiacea, Psophocarpus tetragonolobus, Canna edulis*).

Since inception in 1963, CTCRI has contributed enormously to the research and development of tuber crops and is presently an internationally recognized Premier Institution, dedicated solely to tropical tuber crops research. About four decades of research have led to several innovations such as improved high yielding/ early maturing varieties, cropping systems for various agro-ecological zones, integrated pest and disease management packages for better production, technologies to reduce post harvest losses and enhance the prospects of utilization in the food, feed and industrial sectors etc.

Cassava

Among the tuber crops, cassava is the most important industrial crop in developing countries including India. Its production, processing and marketing has contributed tremendously in social and economic development in Asia. It is emerging as a fully commercial crop entering diversified markets. Roots are utilized into array of products human food as fresh or processed roots, starch and flour for food and industry and animal feed. In China, cassava meets basic needs both of food security and income generation while animal feed in Vietnam. The starch of cassava is utilized in Thailand for manufacturing monosodium glutamate and plywood.

In India, cassava is mostly grown as irrigated as well as rainfed crop. In Tamil Nadu, and Andhra Pradesh, it is commercially grown under irrigated conditions mainly for raw materials for industries as starch. Cassava comes up well in all types of soils, except saline, alkaline, heavy and ill-drained soils. Besides, it is also cultivated by tribal and disadvantaged people in all the states, which form an important secondary staple in their diet.

The research conducted at CTCRI has yielded 16 improved cassava varieties, which are suitable for a wide-range of farming systems in India. Besides, a rapid propagation technique for cassava using three node cassava mini-setts was standardized to increase the planting material production. Research also revealed that soil loss and run off in cassava fields could be controlled by growing multiple crops like banana and coconut. Cassava mosaic virus (CMV) caused by a Gemini virus is the serious problem affecting plant growth and tuber yield in all cassava growing areas. Sree Padhmanabha, a cassava mosaic resistant variety, is being released shortly.

Cassava is also raw material for sago and starch industries and a component of animal, fish and poultry feeds. Cassava starch is more pure than potato or maize starch, as the tubers are practically free from non-starchy constituents like protein and lipids and hence the extraction is easier and direct. Cassava starch find application in array of industries in India – textiles, corrugation box, paper conversion, liquid gums for domestic sector, paper industry etc. besides food and sago industry are the major ones. Environmentally degradable plastic product incorporating cassava starch has been developed and commercialized in India through NRDC and transferred to four manufacturers in Haryana, Himachal Pradesh, Delhi and Karnataka. Technology for economic production of alcohol from cassava tubers is also perfected.

Bio-pesticides from cassava are formulated. A pilot plant to scale up production of biopesticide and biofumigant from cassava-leaf and tuber-rind has been designed and fabricated. The formulation of Menma is very effective against borer pests – pseudostem weevil and rhizome weevil in banana; red palm weevil in coconut etc. sucking pests such as mealy-bug, thrips, scale insects, mites etc. in horticultural crops can be very effectively controlled by formulation Nanma. Waxy coating around mealy bug gives it protection from insecticide application, but Shreya can dissolve mealy substance and kill it. Biofumigants isolated from cassava-leaves are effective against stored product pests.

Sweet potato

Sweet potato is an important crop for food, feed and raw materials for industries. The crop can be grown in marginal soil with less input. It is eco-friendly in the sense that it is fast growing and covers soil rapidly to prevent soil erosion. Its roots and leaves are highly nutritious besides providing high dry matter. The orange or yellow flesh root and green tops are good source of vitamin A, which can prevent night blindness and malnutrition prevalent in many parts of the country. So, a regular intake (100 g/day) of orange or yellow flesh sweet potato having moderate concentration of vitamin A (3 mg/100 g) or greens or of mixture of both could provide 100 percent of Recommended Daily Allowance (RDA) of vitamin A for children. Besides, sweet potato is rich in antioxidant nutrients like β-carotene, ascorbic acid (vitamin C) and tocopherol (Vitamin E) which can prevent coronary disorder and cancer.

Since inception, the CTCRI has released 16 sweet potato varieties with variety of attributes, which could contribute to food and nutritional security besides having flexibility to adapt existing farming systems. Short duration sweet potato varieties identified for respective states are as follows: CO-3 and CO-CIP – 1 in Tamil Nadu; Samrat and Kiran in Andhra Pradesh; Varsha and Konkan Ashwini in Maharashtra; Bidan Jagannath in West Bengal etc. Sweet potato varieties Sree Nandini, Sree Vardhini and Sree Bhadra with high yield and quality are ideal for North Kerala. The Regional Centre of CTCRI has identified high β-carotene variety ST14 (14 mg/100 g fresh tuber) and high anthocyanin variety ST 13 (85 mg/100 g fresh tuber) suitable for all India.

In the Coastal regions of Orissa including Cuttack, Puri and Jajpur districts that are prone to cyclones, sweet potato is an important crop. Blessed with abilities to survive in harsh environmental conditions, this crop could save people during the adverse climatic conditions. In this view, the Regional Centre of CTCRI, Bhubaneswar has taken a project for restoring coastal agro-ecosystem of Orissa affected by Super Cyclone during 2001-2005. Under this project, 16,00,000 sweet potato cuttings, colocasia 44 quintal, elephant foot yam 36 quintal, yam 41 quintal, yam bean 12 kg and cassava setts 10750 were distributed free of cost to the resource poor farmers. A total of 2400 farmers were benefited. Demonstration trials revealed that sweet potato could yield higher than other crops under these conditions. Besides the varieties like Gouri, Sankar, Pusa Safed and Sree Bhadra, Kalinga, Gautam and Sourin were found suitable for hilly and coastal regions of Orissa. *In vitro* techniques for propagation and storage of sweet potato (through artificial/ synthetic seeds) and taro have been developed. Methodologies have been standardized for *in vitro* selection of salt tolerant lines of sweet potato.

Sweet potato is grown as rainfed crop during rainy (*kharif*) or autumn (*rabi*) seasons and as irrigated crop during other periods. For sweet potato production, vine dipping in 2 kg of *Azospirillum* per hectare and soil application @ 10 kg per hectare recorded maximum sweet potato tuber yield.

Sweet potato weevil is the most important pest causing damage to vines and tubers. An Integrated Pest Management Strategy using healthy vines, dipping vines before planting in 0.05% fenthion or fenitrothion for 10 minutes, spraying the crop with pesticides 3-4 times, controlling sweet potato weevil population using pheromone traps and adopting crop rotation with rice is recommended. Very effective sex pheromone, [(2)-3- dodecenol- 1 – ol (E)- 2 – butenoate] and kairomone, boehmeryl acetate have been developed, which provide a safe way of managing the weevil.

For industrial processing, starch and dry chips of sweet potato have been used as raw materials in the manufacture of products such as deep processing starch, alcohol, liquid glucose, high fructose syrup, maltose citric acid and monosodium glutamate and for food processing, fresh roots dry flour or starch can be used for noodles, fried chips, canned flakes and candid pulp production. In feed processing, the main product is sweet potato flour used by the compound feed industry. Other products like wine, sweet potato curd, pickles are also developed. Besides store roots, other parts like leaves, vines, pencil roots, even residues after starch processing can also be dehydrated and powdered and used as supplement to cereal flour. The industrial utilization of sweet potato is rudimentary in India. Sweet potato roots and leaves can be used in fattening the pig. In North Eastern India, most of people eat meat of pig, beef, poultry, yak and mithun etc. In China and Vietnam, the large percentage of sweet potato is used to feed animal particularly pig. As its vines can withstand drought better than other common fodder crops, the vines can be used as fodder for cattle during off season.

Yams

In India, yams are grown as rainfed crops and the tubers are mainly consumed as vegetables. They are also useful for processed products like fries and chips. Yam starch resembles sweet potato starch in many chemical qualities. The greater yam is cultivated all over the Orissa in Homestead, and also grown in commercial scale in Ganjam district. It is a common vegetable in various Oriya food preparations like *Dalma*, chat and various curries.

Extensive research at CTCRI has produced 12 yam varieties including greater yam (7), lesser yam (2), white yam (3). Among yam varieties, Sree Dhanya is a highly promising dwarf yam, which eliminates the cost of staking. Sree Shilpa is the first hybrid in greater yam with high yield. Production technology of greater yam has been standardized with a fertilizer dose of 80:60:80 Kg N, P_2O_5 and K_2O along with 10 t FYM per hectare is recommended for profitable yield. Nematode pests of yams and Chinese potato can be controlled by growing sweet potato variety Sree Bhadra as a trap crop.

Taro

Taro is native to North East region and is an important vegetable in many homes. The corms and cormels, also used as pig feed. Starch of taro is very fine and it is used in cosmetic industry and also as filler material for biodegradable plastic. The corms and cormels are good source of pig feed. Taro is well grown in humid environment and it flourish in shaded conditions. The corms are baked or cooked and eaten like potato. It has longer shelf life than cassava and sweet potato. However, it's industrial utilization is very limited in India.

Six taro varieties were released for the farmers of various states of India. *Phytophthora* leaf blight is a common disease-affecting taro in Odisha. This yield loss is estimated to the extent of 20 % to 90% in severe cases. The variety Muktakeshi is found tolerant to leaf blight and which have high yield potential and have good scope for improving the taro productivity level in coastal states.

Elephant foot yam

It is an important vegetable and commercially grown in many parts of India. Though it is long duration crop, the importance of the crop as inter crop with coconut and banana is well recognized. Among the edible tuber crops, elephant foot yam can be stored for a longer period or can be harvested at any time after attaining required size. So, during off season when other vegetable can not be found in market, this crop can be sold at a higher price. So, it provides remunerative income o the farmers than other vegetables.

The CTCRI has released two elephant foot yam varieties namely Sree Padma and Sree Athira. Varieties like Gajendra, Sree Padma, Bidan Kusum and NDA-9 are important elephant foot yam varieties identified for various states. Among them Gajendra with an yield potential of 50 to 80 t/ha at 180-200 days duration is popular all over India.

Constraints to growth of root and tuber crops in India

Low productivity for most of root and tuber crops except cassava has been observed in India which may be attributed due to the following reasons.

a) Inadequate ability of high yielding and quality planting materials
b) Use of indigenous land races with low productivity
c) Grown as subsidiary crop without proper scientific management
d) Competition from other remunerative crops
e) Decrease in demand for tuber crops due to the availability of cereals and vegetables in plenty
f) Change in dietary habits
g) Weak extension system
h) Incidence of pests and diseases
i) Lack of commercialization of these crops for utilization in industries

Conclusion

The role of tuber crops in the future is bright in India. With the capacity to survive in wide range of environments, ability to provide staple food to disadvantaged population, nutritious animal feed, and ability provide various farm, home and industrial products, the tuber crops can consistently cater to the food and nutritional security of the people. However, the problems like non availability of quality planting materials, lack of knowledge and skills on improved technologies, lack of enthusiasm among the potential entrepreneurs to start processing units, marketing problems, inadequate storage facilities, and stiff competition from other crops affect tuber crops technology transfer in the state. The socio-economic strategies like popularisation of tuber crops as alternate crops, integrated product development, production and distribution of quality planting materials, participatory technology development, capacity building and market regulation with government policy support will improve tuber crops scenario in the state. So it is high time for various actors involving in the development of the state, to understand, accept the promote tuber crops among the farming community.

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Concept, scope and components of integrated farming system

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Introduction

Integrated farming system is a multidisciplinary whole farm approach, which enables the farmers to identify opportunities and threats and act accordingly. It is a dynamic approach which can be applied to any farming system around the world. It is very effective in solving the problems of small and marginal farmers. The approach aims at increasing income and employment from small-holding by integrating various farm enterprises and recycling crop residues and byproducts within the farm itself. It involves attention to detail and continuous improvement in all areas of a farming business through informed management processes. Integrated farming combines the best of modern tools and technologies with traditional practices available at a given location and situation. Preserving and enhancing soil fertility, maintaining and improving a diverse environment and the adherence to ethical and social criteria are indispensable basic elements of integrated farming systems.

Concept and Definitions

'Farming' is a process of harnessing solar energy in the form of economic plant and animal products. 'System' implies a set of interrelated practices and processes organised into functional entity, i.e. an arrangement of components or parts that interact according to some process and transforms inputs into outputs (Fresco and Westphal, 1988).

Integrated farming system (IFS) is a commonly and broadly used word to explain a more integrated approach to farming as compared to monoculture approaches. In this system an inter-related set of enterprises are maintained and by-products or wastes from one production system becomes an input for another production system, which reduces cost and improves production and/or income. Thus, IFS works as a system of systems (Soni *et al.*, 2014). FAO (1977) stated that 'there is no waste', and 'waste is only a misplaced resource which can become a valuable material for another product' in IFS. For example, paddy straw, by-product from rice crop can be used as a valuable input for mushroom cultivation or dry fodder for dairy animals. Similarly spent of mushroom cultivation (used straw) can be used as a raw material in compost or vermicompost pits and by-products from dairy unit like dung can be used as fish feed or raw material for vermicompost unit. The farming system is essentially cyclic, organic resources - livestock - land - crops. Therefore, management decisions related to one component may affect the others. Combining ecological sustainability and economic viability, the integrated livestock-farming system maintains and improves agricultural productivity while also reducing negative environmental impacts.

Different scientists have defined a farming system differently. However, many definitions, in general, convey the same meaning that it is the strategy to achieve profitable and sustained agricultural production to meet the diversified needs of farming community through efficient use of farm resources without degrading the natural resource base and environmental quality. Farming system is a decision making unit comprising the farm household, cropping and livestock system that transform land, capital and labour into useful products that can be consumed or sold (Fresco and Westphal, 1988).

Lal and Miller (1990) defined farming system as a resource management strategy to achieve economic and sustained agricultural production to meet diverse requirements of farm livelihood while preserving resource base and maintaining a high level of environment quality. On the other hand, a farming system is the result of complex interactions among a number of inter-dependent components, where an individual farmer allocates certain quantities and qualities of four factors of production, viz. land, labour, capital and equipments to which he has access (Mahapatra, 1994).

Mixed farming system consists of components such as crops and livestock that coexist independently from each other. In this farming, integrating crops and livestock serves primarily to minimise the risk and not to recycle resources. But in IFS, crops and livestock interact to create a synergy, with recycling allowing the maximum use of available resources (Sasikala *et al*., 2015). Crop residues can be used for animal feed, while livestock and livestock by-product production and processing can enhance agricultural productivity by intensifying nutrients that improve soil fertility, reducing the use of chemical fertilizers. Thus, IFS is an integrated set of elements / components and activities that farmers perform in their farms under their resources and circumstances to maximize the productivity and net farm income on a sustainable basis (Singh and Ratan, 2009). The integration is made in such a way that the product i.e. output of one enterprise / component should be the input for the other enterprises with high degree of complementary effects. The rationale of IFS is to minimize the wastes from the various subsystems on the farm and thus it improves employment opportunities, nutritional security and income of the rural people (Panke *et al*., 2010).

Scope of IFS

Farming enterprises include crop, livestock, poultry, fish, tree crops, plantation crops, etc. A combination of one or more enterprises with cropping, when carefully chosen, planned and executed, gives greater dividends than a single enterprise, especially for small and marginal farmers. Farm as a unit is to be considered and planned for effective integration of the enterprises to be combined with crop production activity (CARDI, 2010). Integration of farm enterprises to be combined on many factors such as

1. Soil and climatic features of the selected area.
2. Availability of resources, land, labour and capital.
3. Present level of utilization of resources.
4. Economics of proposed integrated farming system.
5. Managerial skill of the farmer

There are a number of situations and conditions that can be alleviated by an integrated farming System. The following situations are ideal for the introduction of IFS (CARDI, 2010).

1. The farmer wishes to improve the soil quality
2. The farm household is struggling to buy food or below the poverty line
3. Water is stored on-farm in ponds or river-charged overflow areas
4. Fertilizers are expensive or the recommended blend is unavailable
5. Soil salinity has increased as a result of inorganic fertilizer use
6. The farmer is seeking to maximize profits on existing holding
7. The farm is being eroded by wind or water
8. The farmer is looking to reduce chemical control methods
9. The farmer wants to reduce pollution or waste disposal costs

In agriculture, crop production is the main activity. The income obtained from crops may hardly be sufficient to sustain the farm family throughout the year. Assured regular cash flow is possible when the crop is combined with other enterprises. Judicious combination of enterprises, keeping in view of the environmental conditions of a locality will pay greater dividends. At the same time, it will also promote effective recycling of residues/wastes. A grower can use IFS to

1. Improve productivity
2. Regulate nutrient and material flows
3. Increase on-farm biodiversity
4. Limit disease
5. Reduce the smell of some livestock operations.

Integrated farming system gives insurance against recurrent natural disasters, creates employment opportunity for rural youth and ensures nutritional security particularly for children and women.

Objectives of IFS

The overall objective of integrated farming systems is to evolve technically feasible and economically viable farming system models by integrating cropping with allied enterprises for irrigated, rainfed, hilly and coastal areas with a view to generate income and employment from the farm. The major objectives of integrated farming systems can be listed as below (CARDI, 2010; Behera, 2013).

1. Maximisation of yield of all component enterprises to provide steady and stable income at higher levels.
2. Rejuvenation/amelioration of system's productivity and achieve agro-ecological equilibrium.
3. Control the buildup of insect-pests, diseases and weed population through natural cropping system management and keep them at low level of intensity.
4. Reduction in the use of chemical fertilizers and other harmful agro-chemicals and pesticides to provide pollution free, healthy produce and environment to the society at large.
5. Utilization and conservation of available resources and effective recycling of farm residues within system and to maintain sustainable production system without damaging resources/environment.

Components of IFS

Farmers make decisions about what to grow, what animals to keep, the level and type of inputs and the methods they will use. Their decisions are based upon a range of social, economic and environmental/climatic factors. The farmers' preferences, attitudes and level of knowledge and skill are also important. However, the selection of enterprises must be based on cardinal principle of minimising the competition and maximising the complementarities between the enterprises (Annadurai *et. al*., 1994).

Farming system is an integrated resource management strategy for obtaining economic and sustained crop and livestock production and preserving the resource base with high environmental quality. The entire philosophy of farming system revolves around better utilization of time, money, resources and family labour. Integrated farming system is focused around a few selected, inter-dependent, inter-related and often inter-linking production systems based on few crops, animal and related subsidiary enterprises. It involves the utilization of primary and/ or secondary produce of one system as raw material for other system, thus making the entire system mutually interdependent as one whole unit. There is a need for effective linkages and complementarities of various components to develop holistic farming system. Important components of the farming system include field crops, vegetable crops, fruit crops, floriculture, livestock (cow, buffalo, sheep, goat, pig, rabbit, etc.), pisciculture, poultry, duckery, agroforestry, bee keeping, mushroom cultivation, bio-gas, vermicompost, etc.

The crop activities in the IFS consist of grain crops (rice, wheat, maize, sorghum, pulses, soybeans), oilseeds (groundnut, sesame, rapeseed and mustard, linseed, niger, sunflower, castor), vegetable crops, plantation crops (coconut, arecanut), short duration fruit crops (papaya, banana, citrus, pineapple), root crops (cassava, sweet potato), sugarcane, tree crops (moringa, mulberry, teak, acacia, sissoo) and fodder crops. The selection of crops is dependent on preferences based on family consumption, market, soil type, and rainfall and type of animals raised.

Integrated farming system comprising crop and livestock has been sustainable over the centuries. In this system animals are raised on agricultural wastes and animal power is used for agricultural operations and animal excreta are used as manure and fuel. In coastal areas, the rice + fish system can stabilise the productivity and profitability in rice production areas. Cereal based crops in combination with livestock (poultry, dairy, sheep and goat) systems can improve the profitability of the farmers along with the sustenance of natural resources.

The livestock activities in IFS consist of cows, goat, sheep, poultry, ducks, pigs and small ruminants. The selection of livestock is also dependent on preference based on family consumption, potential market and availability of resources. Livestock and livelihoods are intimately related and the ownership of livestock is more egalitarian than that of land (Swaminathan, 2010). The livestock component acts as a stabilising factor in the system, thus needs strengthening of the crop and livestock linkage to enhance the economic viability and sustainability of the farming systems (Baishya *et al*., 2007).

Crop livestock integration involved the natural resources (crops, animals, land and water) in which these subsystems and their synergetic interactions have a significant positive and the greater total effect than the sum of their individual efforts. These systems increase crop yields and soil fertility and improve the livelihoods with promotion of stable households and increased economic output. The livestock farming systems can be grouped into small holder livestock production with little and low land and commercial livestock production dominating with poultry and dairy. The livestock production in IFS should conserve the natural resource base and raise the productivity through efficient utilization, optimised allocation and rational management of available of resources.

Agroforestry systems like agri-silvicultural, silvi-pastoral, horti-silvicultural, horti-silvi-pastoral, agri-horti-silvipastoral, aquaforestry, etc. can be integrated to farming systems. Besides timber and fuel wood agroforestry systems offer lot of other products like gum, resin, fibre, oils, medicines and other non-forest timber products depending upon the tree/shrub species covered in the system. The suitable species for hedgerow planting are *Cassia siamea*, *Leucaena leucocephala*, *Glyricidia sepium*, *Calliandra calothyrsus*, *Sesbania sesban*, *Acacia mangium*, *Gmelina arborea*, *Albizia* spp., *Cajanus* spp., *Chamaecytisus* spp., *Desmodium* spp., *Erythrina* spp., *Flemingia* spp., *Inga* spp. and *Tephrosia* spp (Patra, 2013). In the agri-horti-silvicultural system, suitable arable crops are grown in inter-spaces of perennial fruit or multipurpose tree rows. In between two trees one fruit crop like mango, guava or pomegranate may be planted. When annual crop yield is substantially reduced due to canopy closure the system is converted to a horti-silvicultural system. With appropriate management practices this practice can give a sustainable production system. In silvi-pastoral and horti-pastoral systems, suitable fodder grasses like guinea (*Panicum maximum*), dinanath grass (*Pennisetum pedicellatum*), napier grass (*Pennisetum purpureum*), thin napier (*Panicum polystachion*), anjan grass (*Cenchrus ciliaris*) and fodder legumes like stylo (*Stylosanthes hamata* and *Stylosanthes scabra*), cowpea (*Vigna sinensis*) are grown in inter-spaces of perennial fruit or multipurpose tree rows. These systems are very effective to control soil erosion as the grasses give a permanent soil cover.

The aquaforestry system comprises composite fish culture in farm ponds, and various trees and shrubs, leaves of which are preferred by fish (Ex. *Leucaena leucocephala*, *Morus alba*, *Gliricidia sepium*, *Moringa olifera*, etc.) are planted on the boundary and around fish ponds. Leaves of these trees are used as feed for fish. Inland fish such as catla, rohu, mrigal, common carp, silver carp and grass carp can be grown in the ponds. In the coastal regions farmers are cultivating fish and prawn in saline water and growing coconut and other trees on bunds of ponds. Now fish culture in the mangroves is also advocated, which form a rich source of nutrition to the aquatic life and breeding ground for juvenile fish, prawn and mussels. Other terms that have been used for this practice are silvipisciculture, agrisilviaquaculture and aquasilviculture. In paddy field, fish can easily be reared by planting trees on field bunds or boundary. This system can be practised in high rainfall areas. Coconut plants can also be successfully planted on raised paddy field bunds with an alley space of 5 m width depression which is utilized for pisiculture purpose (Patra, *et. al*., 2008).

Mushroom cultivation can also be integrated to farming system to augment the overall household income. Besides some of the homestead vocations like *khali*/*patravali* making, bamboo/cane work, chalk/candle making, tailoring, embroidery, food processing, doll making, carpentry, hand paper, packaging, paper packet, spice making, *papad* making, composting, marketing agricultural produce, etc can be considered in the farming system.

Integrated farming systems are often less risky and, if managed efficiently, benefits from synergisms among enterprises, diversity in produce, and environmental soundness (Mahapatra, 2010). On this basis, IFS models have been suggested by several workers for the development of small and marginal farms across the country (Behera and Mahapatra, 1999; Singh *et al*., 2006). Dominant farming systems of the different agroclimatic regions are presented in the following table.

Table 1. Dominant farming systems in different agroclimatic regions of the country

Agroclimatic region	States	Most dominate farming systems in the region
Western Himalayas	J & K, Himachal Pradesh, Uttarakhand	Crops + Dairy Agri-horti system
Eastern Himalayas	Assam, Meghalaya	Crops + Fish + Cattle + Piggery Monocropping of rice and maize + Piggery + Backyard poultry + 2-3 cows
Trans Gangetic Plain	Punjab, Haryana	Crops + Dairy
Upper Gangetic Plain	Uttar Pradesh	Crops + Dairy
Middle Gangetic Plain	Uttar Pradesh, Bihar	Crops + Dairy Crops + Fishery
Lower Gangetic Plain	West Bengal	Crops + Dairy Crops + Dairy + Poultry + Duckery
Easter Plateau & Hills	Chhattisgarh, Jharkhand	Crops + Dairy Crops + Backyard Poultry + Fish
Central Plateau & Hills	Madhya Pradesh	Crops + Dairy
Western Plateau & Hills	Maharashtra	Crops + Dairy Crops + Goatery Crops + Horticulture
Southern Plateau & Hills	Andhra Pradesh, Telengana, Tamilnadu, Karnataka	Crops + Dairy Crops + Horticulture Crops + Horticulture + Dairy
East Coast Plain & Hills	Odisha	Crops + Dairy Crops + Dairy + Fish
West Coast Plain & Hills	Maharashtra, Goa, Kerala	Crops + Dairy Coconut based homestead farming Rice based farming systems
Western Dry Region	Rajasthan	Crops + Dairy
Gujarat Plain & Hills	Gujarat	Crops + Dairy
Islands	Andaman & Nicobar	Plantation crops + Piggery 2. Crops + Cattle + Fish

Source: Singh, 2010

The overall objective of integrated farming systems is to evolve technically feasible and economically viable farming system models by integrating cropping with allied enterprises for irrigated, rainfed, hilly and coastal areas with a view to generate income and employment from the farm. Integrated farming system involves the utilization of primary and/ or secondary produce of one system as raw material for other system, thus making the entire system mutually interdependent as one whole unit. The productivity of farming system depends upon natural resources climate and soil, available technology, besides latest information of market technology and human resources.

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Tropical tuber crops an alternative for food, nutrition and livelihood improvement

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Introduction

India harbors 833.10 million people in 6, 40, 867 villages including hilly, backwards and coastal areas. The tropical tuber crops like Cassava (*Manihot esculenta*), Sweet potato (*Ipomoea batatas*), Taro (*Colocasia esculenta* (L.) Schott) and yam especially Greater yam (*Dioscorea alata*) and Elephant foot yam (*Amorphophallus paeoniifolius*) are the food crops of planet Earth since inception across the world. These group of crops thrived in all agro climatic conditions including harsh climate with its resilient wide adaptive nature. In a word we can say "Tropical tuber crops are the demand of the day" in the context of climate change vs. food, nutrition and sustainable livelihood.

At ICAR-CTCRI, Thiruvanthapuram and its Regional Centre at Bhubaneswar, breeders have developed improved tubers crops varieties rich in energy, nutrients and are tolerant to biotic and abiotic stresses. Such valued traits widened the acceptability of tuber crops as an option not only for calorie, nutritional values but also for their sustenance in harsh climate. These were very much evident during post super cyclone (1999), Tsunami (2004) in coastal belts as well as in hilly backward areas (Mukherjee et al 2015), (Pradhan et al 2015). ICAR-CTCRI with its improved tuber crops technologies progressing ahead to address the issues of "food insecurity", "mal nutrition" & "livelihood improvement" especially in rural, tribal and backward areas.

Ascent to food and nutrition

The improved varieties of tuber crops which are resilient to climate with other valued traits are presented as follows:

1. Nutritionally enriched salt tolerant sweet potato

Dry matter (%) : 29.7-32.4
Total Starch (%) : 22.9-28.1
Cooking quality : Excellent soft & mealy
Average yield : 23 t ha^{-1}

<u>Tolerate mid season drought</u>

Dry matter (%) : 27.4-32.5
Total Starch (%) : 20.8-23.9
Cooking quality : Fair
Average Yield : 18 t ha^{-1}
Anthocyanin: 95mg/100g

<u>Tolerate salt stress (6-8 dsm^{-1})</u>

Dry matter (%) : 27-29
Total Starch (%) : 21.4-23.8
Cooking quality : Good & mealy
Average Yield : 19.8 t ha^{-1}
β- carotene : 14mg/100g

Tolerate salt stress (6-8 dsm^{-1})

Sweet potato leaves contain 'Lutein'

- Sweet potato leaves & vine tops are also nutritionally rich
- Sweet potato leaves are one of the richest sources of anthocyanin (15 types)
- Contain higher level of 'Lutein' (0.38-0.58 mg/g fwb) more than

2. Submergence tolerant –Taro & Sweet potato

Experiments under induced flooding and *in situ* water logged coastal and flood prone areas resulted in identifying two taro genotypes Panisaru-1 & Panisaru-2. Similar studies in sweet potato resulted in identifying submergence tolerant three genotypes (cv. Kalinga, Pusa safed and Samrat)

Taro

Dry matter (%): 26
Total Starch (%):12
Total sugar (%): 3.3
Cooking quality: Good
Average yield: 15.7 t ha^{-1}

Dry matter (%): 32
Total Starch (%):17
Total sugar (%): 2.8
Cooking quality: Good
Average yield: 13 t ha^{-1}

Sweet Potato

Dry matter (%): 29.6
Total Starch (%):28
Total sugar (%): 2.5-3.3
Cooking quality: Excellent
Average yield: 17-18 t ha^{-1}

3. Biotic and abiotic stress tolerant taro

Developed taro varieties (Muktakeshi, Jhankri & Sonajuli) tolerant to both biotic (blight) and abiotic stresses (drought and salinity)

Yield : 15-20 t ha^{-1}
Dry matter (%): 23
Starch (%) :17.8
Total sugar (%): 2.0
Cooking quality: Excellent

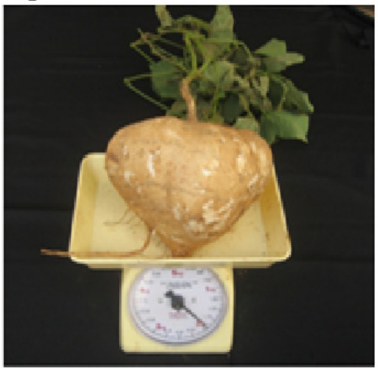
Yield : 15-20 t ha^{-1}
Dry matter (%): 23.5-24.6
Starch (%) :12.3-14.2
Total sugar (%): 1.3-1.7
Cooking quality: Good

Yield : 15-20 t ha^{-1}
Dry matter (%): 23.0-24.8
Starch (%) :15.6-17.3
Total sugar (%): 1.2-1.5
Cooking quality: Good

Taro rich in Zn & Fe

- Taro tubers good source of Zn & Fe
- 100g of taro fresh leaves can supplement 4825 IU or 161% of RDA of Vit. A
- 100g tubers provide 11% daily requirement of dietary fibre
- Purple and orange flesh provides additional antioxidants

4. Early maturing Yam bean & Yam



Yam bean

- 8 × 9 Hybrid yam bean,
- Average yield 35-40 t/ha,
- Matures within 4 - 5 months
  Suitable as dietary food, eaten as raw.

Greater Yams

Yield : 20-25 t ha^{-1}
Dry matter (%): 28.3
Starch (%) :20.1
Total sugar (%): 3.8
Cooking quality: Excellent

Yield : 20-25 t ha^{-1}
Dry matter (%): 32-33
Starch (%) :20-22.5
Total sugar (%): 1-1.5
Cooking quality: Excellent

Both are short duration (6-7 months) greater yams

Greater yams rich in estrogenic compounds

- Greater yams rich in antioxidants (phenolics, anthocyanin, flavonoids & vitamins)
- Rich in estrogenic compounds
- Antihypertensive, bone protective, immune-stimulatory

5. Improved cassava

- Early maturing variety (6-7 months)
- A rotation crop in low land
- Excellent cooking quality
- Yield 25-28 t ha^{-1}

Cassava rich in ascorbic acid and B-vitamins.

- Cassava tubers are rich sources of ascorbic acid and B-vitamins.
- Cultivars with yellow flesh colour contain good levels of β-carotene.
- Calcium and phosphorous are the important minerals present in the tubers.

6. Elephant foot yam

cv. Gajendra

- **Maturity (8-9 months)**
- **Remunerative intercrop**
- **Yield: 35-45 t/ha**
- **Non acrid**
- **Good cooking quality**

Elephant foot yam contain Omega-3 fatty acid

- **Elephant foot yam rich in natural antioxidants**
- **Rich in Zn (2-2.3mg /100g) against RD intake of 0.15mg (WHO, 2001)**
- **Zn essential for synthesis and catabolism, also for immunity**
- **It also contain omega-3 fatty acid**

The following table (Table 1) reflects comparative proximate composition of different tuber crops. The data indicate the energy contents are on par with major food crops like rice and wheat. In fact all the tuber crops are having more minerals and fibre contents as compared to rice and wheat. Such values and the specific crop wise nutritional values reveal tuber crops are better option as functional food. Further, sweet potato is reported to have a low glycaemic index of <55 which makes it an ideal food for diabetics. The tubers are considered as a highly functional, low calorie food, with antidiabetic effects.

Table 1. Comparative proximate composition of different tuber crops

Tuber crops	Grams per 100 g on dry weight basis					
	Protein	Fat	Minerals	Fibre	Carbohydrates	Calories
Potato	7.3	0.4	2.4	1.6	89.0	382
Sweet potato	3.8	0.9	3.1	2.5	88.5	377
Cassava	1.7	4.9	2.5	1.5	84.9	386
Yam	4.7	0.3	5.3	3.3	86.6	370
Taro	11.6	0.4	6.3	3.7	78.5	361
Elephant foot yam	5.6	0.5	3.8	3.8	86.3	371
Rice	7.8	0.8	0.7	0.2	89.9	397
Wheat	13.5	1.7	1.7	1.4	81.2	393

Those improved tropical tuber crops varieties gaining popularity through various outreach programmes especially in tribal districts of the country. Glimpse of which are as follows:

Outreach programme

- Local - (KVKs, SAUs, SHGs, NGOs, Line depts.)
- National – (AICRP, DUS, TSP, NEH & Institutional)
- International - (*INEA*), LANSA

A. Outreach and technology transfer : North eastern India

The NEH region (Manipur, Meghalaya, Nagaland and Tripura) having rainy, tropical climate with poor agro-economic conditions. Fringe farming, shifting cultivation with minimal use of technology. Aroids are popular there but not as a cash crop. After following interventions with improved technologies, scenario is changing with increase in demands of improved tuber crops.

ICAR-CTCRI intervention

- Distributed fortifying, high yielding and climate resilient varieties of cassava, EFY, Taro and sweet potato
- Pre & post harvest technologies imparted through training
- Post harvest tools of cassava slicer, chipping machine, grater are distributed
- Around 986 farmer families directly benefitted

B. Outreach and technology transfer : Odisha, India

Odisha having fragile agro-climatic conditions, poor food & nutritional status in tribal districts. Under Tribal Sub Plan (TSP) and AICRP (TSP) programme improved tuber crops technologies are disseminated at Koraput and Kandhamal districts. Such interventions are briefed below. Besides, taro based nutrie farming found quite promising in Puri; (Fig.1), Bramhagiri of Odisha.

ICAR-CTCRI intervention

- Distributed high yielding, tolerant lines of elephant foot yam, taro, yam, cassava and sweet potato.
- Imparted pre-harvest techniques & post-harvest utilizations.
- 655 farmer families benefitted directly over three years
- Horizontal dissemination has further benefitted other neighboring villages

Fig.1 Taro based nutrie farming in Puri, Odisha

Livelihood Improvement

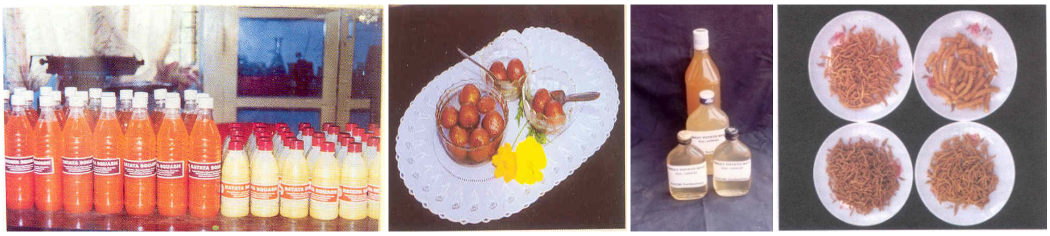
I. Tuber crops as cash crops for sustainable livelihood

Fresh produce cannot be stored hence processed products are developed for household food, nutrition and livelihood improvement. Such efforts would help to facilitate visibility in non-traditional areas. Tuber crop based starch factories and food processing units are steadily gaining popularity in urban areas of following states in India.

- Cassava and EFY in Andhra Pradesh
- Yams, Sweet potato in Maharashtra
- Sweet potato, Taro and EFY in UP, WB and Bihar
- Sweet potato, taro and yam in Karnataka
- Sweet potato and yam in Goa

Following tuber crops products are gaining popularity across India.

Cassava – Starch, sago, chips, wafers, industrial alcohol, silage, fish feed, bio- degradable plastic etc.
Sweet potato – Starch, Industrial alcohol, pro-biotic curd, pickle, wine, jam, jelly, squash etc.
Yams – Starch, chips
Taro – Starch, chips
Arrowroot – Starch, biscuits



Starch based industrial products

Superabsorbent Gel from cassava starch

Drug in cassava Starch

Biofilm from starch nanomatrix

Animal feed

II. ICAR-CTCRI adding value to tuber crops for wellness and commercial prospects

- Developing therapeutic & prophylactic applications from tuber crops for wellness
- Inclusion of tuber crops extruded products in mid-day meal scheme
- Development of bio-colorants, animal feed and biofuel
- Commodity chemicals, pigments, enzymes, yeast ,flavours etc. from microbial bio-technology
- Ethanol production from cassava & sweet potato, nano-composites, degradable plastics from tuber starch
- Developing pre and post-harvest mechanization to reduce costing

Conclusion

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. These groups of crops supporting sustenance of life since inception of Planet Earth. 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 can play pivotal role not only towards food, nutrition security but also to support sustainable livelihood as always under climatic turmoil.

100g of orange fleshed sweet potato per day can supplement RDA of Vit.A for children 100g of taro fresh leaves can supplement 4825 IU or 161% of RDA of Vit. A 100g elephant foot yam rich in Zn (2-2.3mg /100g) against RD intake of 0.15mg (WHO, 2001)

Livelihood improvement through tuber crops based integrated farming system

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Introduction

ICAR 2050 vision document emphasizes raising of agricultural income and employment opportunities (ICAR, 2015). Per capita availability of land has been declining continuously in India. It has declined from 0.5 ha in the year 1950 to 0.15 ha during 2000 A.D (Mahapatra, 2008). It is expected to reach 0.08 ha by 2021. Hence, income through arable farming alone is insufficient for small and marginal farmers. Activities such as piggery, dairy, poultry, pisci-culture, sericulture, biogas, agro-forestry, agro-horticulture *etc*. assume critical importance in supplementing farm income. It fits well with farm level infrastructure and ensures fuller utilization of byproducts such as poultry manure as fish feed in poultry-fish farming system. The only alternative left for the small and marginal farmers is Farming System Approach (FSA). Etienne (2011) writes that the next stage of green revolution may be more complex and knowledge based. He also highlighted the importance of availability of energy and connectivity.

Farming system approach

Definition

The term 'farming system' can also mean different things to different people. To avoid ambiguity and confusion, both terms 'farming' and 'system' should be clearly understood. Farming is the process of harnessing solar energy in the form of economic plant and animal products and the system implies a set of inter related practices/processes organized into a functional entity.

Farming System therefore defined as '*a set of agricultural activities organized while preserving land productivity, environmental quality and maintaining desirable level of biological diversity and ecological stability'*.

The emphasis is more on a system rather than on gross output. In other words, farming system is a resource management strategy to achieve economic and sustained agricultural production to meet diverse requirements of the farm household while preserving the resource base and maintaining high environmental quality. The farming system in its real sense will help in productivity, profitability, potentiality/sustainability, balanced food, recycling resources and employment generation to lift the economy of Indian agriculture and standard of living of the farmers of the country as a whole.

Basic principles of FSA

FSA is based on the following basic principles:

Make the farm household self sufficient; make the farm free from being vulnerable to external forces. Enterprise diversification aims to increase income, minimizes the spread risks, enhance natural resources and the environment and improve the diet of farm families.

Farming system seems to be the answer to the problem of increasing food production, for increasing income and for improving nutrition of the small-scale farmers with limited resources without any adverse effect on environment and agro-ecosystem.

Advantages of farming system

Farming system aims at maximum utilization of on-farm inputs and minimum of purchased inputs for higher productivity. Byproducts of one enterprise (i.e. poultry manures) are used as input (i.e. fish feed) into other enterprises, which can reduce the cost of production.

Productivity

Farming system provides an opportunity to increases economic yield per unit area per unit time by virtue of intensification of crop and allied enterprises. Time concept by crop intensification, space contact by building of vertical dimension through crop and allied enterprises are the ways to increase the productivity indicated above.

Profitability

The system as a whole provides opportunity to make use of the produce /waste material of one component to another component at the minimal cost. Thus the cost of production is reduced in the components and the profitability per rupee invested is enhanced by eliminating the interference of middle man in most of the input use. While working out the net income for the farm as a whole, the benefit cost ratio increases.

Potentiality

Of late, within enthusiasm to produce more and more food from the land area available to meet the requirement of population increase of 2.2% per year (Srinivasulu Reddy and Nedunchezhiyan, 2008), huge quantity of inorganic fertilizers, pesticide and herbicide are applied. Thus soil and environment are becoming increasingly polluted. Once when we loose large land areas by such degradation the productivity of the soil gets drastically reduced in course of time. In farming system organic supplementation through effective utilization of byproducts of linked components is done thus providing an opportunity to sustain the potentiality of production base for much longer periods.

Balanced food

In the farming system, components of varied nature are linked to produce different sources of nutrition viz. protein, carbohydrates, fat, minerals, vitamins etc. from the same unit area. This will provide an opportunity to solve the malnutrition problem that exists in the diet of the average Indian.

Recycling

Farming system establishes its stability due to effective recycling of produces/waste materials of any one of the components as input to the other component linked in the programme. Thus by way of recycling his/her own material at the farm level, the farmers could reduce the cost of production and increase the net income of the farm as a whole.

Nutrient management

In farming system the nutrients requirement of the crop is met through the use of on-farm available resources. Further in farming system nutrients are applied considering whole cropping patterns and cropping sequences. Hence nutrient losses through various farms are minimized in farming systems.

Soil microbial productivity

Intercropping stimulates horizontal transfer of beneficial rhizospheric microorganisms such as non-symbiotic N_2 fixing bacteria (*Azospirillum* spp.), phosphorus solubilizing bacteria, sulphur oxidizing bacteria etc. among the component crops rhizosphere (Ghai and Thomas, 1989; Schnurer et al., 1986). It ensures enhancement in microbial numbers and biomass dynamics in the cropping system and is influenced by seasonal changes.

Employment generation

Combining crop with livestock enterprises would increase the labour requirement significantly and would help in reducing the problem of under employment to a great extent. Farming system provides enough scope to employ family labour round the year.

Various enterprises that could be included in the farming system are crops, dairy, poultry, goat rearing, fishing, sericulture, agro-forestry, horticulture, mushroom cultivation etc.; thus, it deals with whole farm approach to minimize risk and increase the production and profit with better utilization of wastes and residues. It may be possible to reach the same level of yield with proportionately less input in the farming system and the yield would be more sustainable because the waste of one enterprise becomes the input for another, leaving almost no waste to pollute the environment or to degrade the resource base (soil and water). To put this concept into practice efficiently it is necessary to study the linkage and complementarities of different enterprises in various farming systems.

Climate changes

Over 80% of our farms are less than 1 ha in size and mostly mono cropped. It will be extremely difficult for small and marginal farmers to face individually the adverse impact of climate change leading to higher frequency of drought and flood. Under such situations the immediate need is introduction of multitier cropping system which can confer on farmers with small holding the power and economy.

Farming system classification

Predominant farming systems classified based on the net returns which are more than 50% derived from single enterprise. Horticultural farming was identified as the pre-dominant farming system in the western zone of Tamil Nadu and it was practiced by 46.2% of total farmers followed by agriculture farming (17.2%) and livestock farming system (9.0%) (Saravanakumar et al., 2012). Diversified farming was the major farming system being practiced by all categories of farmers where the income derived from cereals, vegetables and livestock sources (Saravanakumar et al., 2012).

Labour scarcity, high input cost, non-availability of time sensitive critical inputs and low price of outputs were the major constrains faced by the farmers under various farming systems which was also reported by Saravanakumar and Jain (2008).

Tropical tuber crops

Tropical tuber crops are the most important food crop after cereals and grain legumes. They are known as energy banks of nature serving either as primary or secondary staple to one fifth of world's population. Tuber crops have myriad and complex roles to play in the food and nutritional security as well as hunger reduction. They are used for food, medicine, animal feed and raw material for starch based industries. International Food Policy Research Institute (IFPRI), Washington has predicted that there is likelihood of shortfall of 41% in food production in India by 2020 and need to produce 300 m t of food by 2010. To meet out food requirement, Indian agriculture has to go for horizontal as well as vertical increase in crop production. As the cultivable area is decreasing year after year, increasing cropping intensity by multiple cropping has little scope; however, the vertical increase in production has tremendous potential. Further, most of the crops have reached its genetic potential and achieved yield maxima. Tuber crops are however yet to exploit its genetic potential with sustainable production technologies. The commonly cultivated tropical tuber crops are: Cassava (*Manihot esculenta*), Sweet potato (*Ipomoea batatas*), Elephant foot yam (*Amorphophallus paeoniifolius*), Taro (*Colocasia esculenta* var. *anticorum*), Bunda (*Colocasia esculenta* var. *esculenta*), Swamp taro (*Colocasia esculenta* var. *stoloniferum*), Tannia (*Xanthosoma sagittifolium*), Lesser yam (*Dioscorea esculenta*), Greater yam (*Dioscorea alata*), White yam (*Dioscorea rotundata*), Aerial yam (*Dioscorea bulbifera*), Yam bean (*Pachyrhizus erosus*), Chinese potato (*Solenostemon rotundifolius*), Arrowroot (*Maranta arundinacea*) etc.
Tuber crops are capable to utilize available resources more efficiently especially in partial sunlight and residual moisture (Nedunchezhiyan and Laxminarayana, 2006). Great flexibility in planting and harvesting are additional characters of these crops which are optly suitable to include in any farming systems.

Tuber crops based farming system includes growing tuber crops with other seasonal, horticultural and silvi-cultural crops either mixed/intercropping or sequential cropping; utilization of tubers and leaves in animal production either in fresh or processed form. Further byproducts of tuber crops such as cassava bagasse are utilizing in allied activities.

Cassava

Cassava is a popular crop among all the tropical tuber crops. It is grown in Asia, Africa, South America and Latin America. In India, cassava is being cultivated on an area of 0.24 m ha with a production of 6.7 m t (FAOSTAT, 2005). Cassava is an important crop in South India (Kerala, Tamil Nadu and Andhra Pradesh) and is slowly spreading to Western (Maharastra) as well as Eastern (Orissa) and Northeastern (Assam, Meghalaya and Tripura) India.

Cassava tubers are utilized primarily as human food after boiling, frying, baking or steaming. They are used in a variety of food products like sago, noodles, wafers, rava, jam, chips, flakes, puddings and other confectionary items. Leaves and tubers also form an important component of animal feed and are extensively used in feed for cattle, poultry and swine. The other uses of cassava are in industry where it is used for production of starch, liquid glucose, dextrin, high fructose syrup, alcohol and preparation of biodegradable plastics.

The biochemical constituents in cassava tuber on fresh weight basis are as follows: dry matter 40%; starch 32.5%; total sugars 0.5%; protein 0.8%; fibre 0.5%; fat 0.2%; ash 1%; calcium 0.05%; phosphorus 0.04%; vitamin C 0.025%; cyanoglucoside 25-400 µg cyanide/g of tuber. The biochemical constituents in cassava leaf on fresh weight basis are as follows: dry mater 22%; starch 8%; protein 8%; fibre 2%; fat 1.7%; ash 1.5%; calcium 0.125%; phosphorus 0.08%; vitamin C 0.25% and cyanoglucoside 350-600 µg cyanide/g (Kay, 1987; Bradbury and Holloway, 1988). Some cassava genotypes are rich in β-carotene. The rind of the tubers and seed extract are found to have biopesticidal properties especially for nematodes and insect pests.

Cassava and livestock production

Farmers' part of their cassava produce can be fed to livestock by properly storing and processing. This will reduce the purchase of feed from out side sources. Cassava dried chips are fed to livestock and poultry in India, China, USA and South East Asian countries. Cassava foliage made into silage is fed to livestock in Brazil. In animal feed, both fresh and dried cassava tubers in different forms such as sliced, chopped, grounded and pelleted are used. In the European countries large quantities of cassava chips, pellets and meals are being imported for animal feeding. Inclusion of cassava up to 65% in pellet form had not affected health, carcass quality or overall performance of pigs. Feed formulae for cattle wherein cassava chips form ingredients from 24 to 43% has been recommended in Kerala, India (KAU, 2001). As cassava tubers contain low amount of protein (1-2%), its use as animal feed for monogastric animals is limited. However, it is found that cassava meal could be included in poultry rations up to 40% without any detrimental nutritional effect, provided nutrient content of ration meet the poultry requirements (Kompiang *et al*., 1994). Raw chopped cassava tubers supply major source of energy for growing finishing pigs if properly supplemented with protein, minerals and vitamins. Pigs given chopped raw tubers with a protein supplement gained less weight but feed conversion ratio (FCR) was similar when compared to maize-soybean (*Glysine max*) meal ration (Ly *et al*., 2008). Under humid conditions, it is difficult to dry cassava tubers and hence, root silage can be processed. The silage feeding had similar performance for growing and finishing pigs as those were given with fresh cassava tubers (Buitrago *et al*., 1978). One of the major factors for restricted use of cassava tuber in swine diets is the presence of cyanogenic glucosides and linamarin. Various processing methods like boiling, chopping, crushing followed by sun drying remove cyanogenic glucosides (Maner, 1973; Tewe, 1992). The low cyanogenic glucosides varieties can be used in feed preparations.

In Central Vietnam, cassava roots are preserved by making silage under village conditions for feeding pigs. After harvesting, the roots are cleaned, grated and mixed with 0.5% salt. The mixture is put into large plastic bags of 20-30 kg, the wet mass is compacted to expel inside air and the bags are tied. The roots are left to ferment naturally. The mixture can be ready in 2-3 weeks after ensiling and is stored for 6-8 months (Ly *et al*., 2008).

Cassava meal is prepared by chopping whole tuber followed by drying. Cassava meal can substitute maize about 16% crude protein (CP) diets (Sankaran *et al*., 2008). A slight decrease in ADF was noticed as the level of cassava meal is increased. But intake was similar indicating that palatability is not a problem in cassava meal based diets. A level of 680-770 g ADF could be reduced using cassava meal based ration. Piglets from weaning to 20-25 kg body weight (BW), given diets containing 20-25% cassava meal showed similar performance as those given with maize-soybean meal ration (Sankaran *et al*., 2008). Cassava bagasse, a byproduct of starch extraction from cassava tubers can be successfully used as feed for growing and lactating cows which possesses 2.0% digestible crude protein (DCP) and 64% total digestible nutrients (TDN) (Ranjan, 1980).

The crude protein content (dry basis) of cassava tubers can be increased by solid state fermentation with *Aspergillus niger* from 3 to 18-42%. The product is named as protein enriched cassava or 'Cassapro", brand name which is quite popular in Indonesia (Kompiang *et al*., 1994). The dried fermented cassava tubers may be fed directly to ruminants or may be grounded to a 1.0 mm mesh before feeding to monogastrics.

Cassava leaf yield is ranged from 2-8 t of dry matter /ha/year depending up on variety and soil fertility. The leaves are high in crude fibre (CF) and crude protein as compared to tubers. Cassava leaf meal is deficient in methionine but rich in lysine. Ensiling of cassava leaves is an appropriate way to conserve them. Nutritional value of cassava leaves may be increased by fermentation with *A. niger* using a similar process as for cassava tubers. Other advantages obtained through this process are that the toxic content of cyanogenic glucosides in leaves may be significantly reduced and fermented product may be stored for an extended period as they are in the form of powder and easily transported to other places if required. The bioprocess technology using *A. niger* to cassava leaf meals increased protein content and digestibility of dry matter and protein (Darma, 1994, 1995). As cassava leaf meal is an important source of β-carotene, it has great potential as feed for poultry and fish.

Ensiling cassava leaves with either rice bran or cassava root meal at 5 or 10% or with fresh grated cassava roots at levels of 20-50% (on fresh weight basis) produced good quality silage that could be stored for up to five months (Ly *et al*., 2008). Under village conditions using 20-60% ensiled cassava roots in the diets (as DM) of growing pigs increased the live weight gain, decreased the feed conversion ratio and reduced feed cost by 7.3-18.3% (Ly *et al*., 2008). Using a 13-15% of DM inclusion of ensiled cassava leaves in the pig ration containing 30% ensiled cassava roots (as DM) as replacement for sweet potato vines and partial replacement of fish meal in diets of growing pigs did not significantly affect the growth rate but reduced feed cost/kg gain by 12-26% (Ly *et al*., 2008). Supplementation with 0.1% methionine in diets containing 30% ensiled cassava roots and 15% ensiled cassava leaves of growing pigs improved the performance of these pigs (Ly *et al*., 2008). Ensiled cassava leaves can also be used as a supplemental source for feeding pigs (Ly et al., 2008). In Hue province of Vietnam, ensiled cassava roots and leaves were used for pig feeding. In 2003, there were 1172 households used this technology for feeding 2910 pigs and obtained gross income of 185.060 million VND over three years (Ngoan, 2008).

During harvesting season cassava stems are available in plenty which have many uses in rural areas. Dried stems after removal of bark are used as fuel and the stem scrapping are fed to cattle. Tender stems are used for feeding livestock after crushing into pieces.

Cassava and fish production

Starch is one of the important ingredients in fish feeds. It is the source of energy as well as excellent binder. Cassava is being utilized as fish feed ingredient in several parts of the world. In fact all parts of cassava are useful in fish culture. Cassava leaf is an excellent fodder rich in protein and can be utilized for feeding fishes like grass carp and *Barbus gonionotus* (Sankaran *et al*., 2008). Cassava stem is an excellent material for periphyton development and fishes like tilapia, rohu, and mrigal browse the partially decomposed skin with periphyton (Sankaran *et al.*, 2008). Dried and powdered tubers are utilized as a starch source as well as a binder to have good quality pelleted feed.

Falayi *et al.* (2001) evaluated the economic losses due to leaching of feed nutrients in fish farming at Nigeria and reported that cassava tuber was the most efficient ingredient tested in terms of nutrient retention, higher growth, feed utilization and economic evaluation indices as compared to all other binders tested. Adebayo *et al.* (2003) reported that cassava meal can be used at 2% level to reduce nutritional loss in fish feed. Boscolo *et al.* (2002) reported that cassava meal can be incorporated up to 24% in the feed of Nile Tilapia for reducing feed cost without any adverse effect on its growth and performance. El-Baki *et al.* (1999) reported that the cassava root meal can be incorporated upto 50% replacement of corn meal without affecting performance of Nile tilapia in Egypt.

Oresegun and Alegbeley (2002) reported that 30% of the starch ingredient can be replaced by cassava peel with an addition of 0.4% methionine in pelleted feeds to maintain the serum and tissue thiocyanate concentration for tilapia. Akegbejo-Samsons (1999) reported that cassava flour can replace the yellow maize totally in the fish feed for African catfish. Cassava flour can be used for replacement of starch source without any noticeable change in fish production in common pond fish culture in Tripura, India (Santhosh *et al.*, 2006). Cassava is the second most commonly used fodder for integrated fish culture in Malaysia (Ahmad, 2003). The palatability tests conducted using grass carp in Tripura, India also showed that cassava leaves are preferred by grass carps than other plant materials tested. Better growth rate of grass carp fingerlings were observed when green cassava leaves were fed compared to five commonly used grasses in laboratory level experiments (Santhosh, 2006).

Cassava stem with its soft coating easily disintegrates in pond water and forms a thick mass of periphyton that fishes prefer to browse upon. It is popularly advised to small farmers to go for cassava cultivation around the ponds and feed the fishes with the green fodder produced out of it. Even in lean season, cassava produces good vegetation and can be used for feeding fishes. The varieties which are having luxuriant foliage are ideal for this purpose.

Cassava bagasse can be utilized for phytase production after addition of a nitrogen source and mineral salts (Hong *et al.*, 2001). Rajeshwarisivaraj *et al.* (2001) found that activated carbons prepared from waste cassava peel are efficient as adsorbents for dyes and metal ions.

Sweet potato

Sweet potato is ranked seventh in food crops and next to cassava among the root and tuber crops grown in the world. It is cultivated through out the tropics, subtropics and warmer temperate regions. In India, sweet potato is cultivated in 0.112 million ha with the production of 1.09 million tonnes (NHB, 2013). Odisha ranks first in area (43,460 ha) and production (4,10,100 tonnes) (NHB, 2013). Sweet potato roots and tops are highly nutritious, which can be used to combate nutritional deficiencies in many parts of the developing world. The roots are primarily used as human food after boiling, frying, steaming and baking. Apart from source of energy, roots also contain significant quantities of water soluble vitamins *i.e.,* ascorbic acid, thiamin, riboflavin and niacin. The contents of pyridoxine, folic acid and pantothenic acid may be relatively high. Raw leaves and tender tips are also excellent sources of ascorbic acid and some of the B-vitamins especially riboflavin which is deficient in many Asian diets. However, high percentages of water soluble vitamins are lost on cooking (Woolfe, 1992).

The biochemical constituent of sweet potato tubers are energy 490 kJ/ 100 g; water 65-81%, protein 0.95-2.4%; fat 0.4-6.4%; carbohydrate 25-32%; fibre 0.9%; ash 0.9-1.4%; calcium 30-34 mg/ 100 g; iron 0.8-1.0 mg/ 100 g; magnesium 24 mg/ 100 g; phosphorus 49 mg/ 100 g; potassium 373 mg/ 100 g; sodium 13 mg/ 100 g; carotene trace to 12 mg/ 100 g; thiamine 0.1 mg/ 100 g; riboflavin 0.05-0.06 mg/ 100 g; niacin 0.6-0.9 mg/ 100 g; ascorbic acid 23-25 mg/ 100 g (Kay, 1987; Bradbury and Holloway, 1988; Wheatley *et al.*, 1995).

Sweet potato and livestock production

Culled and damaged tubers as well as green tops are used for feeding livestock (Nedunchezhiyan and Ray, 2010). Sweet potato is the common feed crop for livestock in many countries including China, India, Philippines, Vietnam, Taiwan, Uganda, Papua New Guinea and Indonesia (Naskar *et al.*, 2008). In India unmarketable roots and vines after harvest are fed to pig and other livestock. Both root and foliage provides energy and protein respectively which can be used fresh, boiled, dried or fermented into silage (Woolfe, 1992; Ray and Tomlins, 2010). The chemical composition of the tuber shows 17-23% dry matter contents and DM digestibility above 70% (Nedunzhiyan, 2001).

In China which is the leading sweet potato producing country in the world, half of the produce goes to feed pigs (Scott, 1991). It is hoped that higher global prices for corn and strong demand for animal meat will further escalate sweet potato demand as animal feed. Massey *et al.* (1976) reported that increased vitamin A content in milk and increased milk production up to 0.75 kg/cow/day were observed when sweet potato roots were fed. In a pig ration feeding substitution trial, Naskar *et al.* (2008) reported that boiled sweet potato tubers could be fed to the level of 40% of total dry matter intake to the weaned piglet for higher growth rate and nutrient utilization whereas up to 60% of total dry matter intake to grower pig along with good quality protein supplement for better growth performance.

Sweet potato vines can be fed to pigs either in fresh form or after drying. Nedunzhiyan *et al.* (2000) reported supplementary application of sweet potato fresh vines improved the digestibility of the pigs. Vines can be dried and grounded into a meal. Sweet potato vine meal can be used in compounded pig rations, but only at low levels. It should not be used more than 5% level in pig rations.

Sweet potato meal can also be included in poultry ration. In rations of young birds that are less than eight weeks old, sweet potato can be used up to 20%. As the birds grow bigger, it can be increased gradually and in rations of laying chickens it can be used up to 30%. Fresh green leaves of sweet potato can be chopped and given to birds in addition to mash to the tune of 3%.

Dried and powdered sweet potato can be utilized for fish feed along with other ingredients. Sweet potato leaves can be used as a fish feed for grass carp. Mokolensang (2003) reported that sweet potato distillery byproduct increased growth of common carp more than conventional feed in experimental conditions.

Pig manure produced in the farm is decomposed and applied to sweet potato field in China and Northeastern states of India. Pig manure application reduces cost of cultivation of sweet potato (Nedunchezhiyan and Srinivasulu Reddy, 2002). Application of pig manures in sweet field helps to rebuild the fertility status of the soil (Nedunchezhiyan and Srinivasulu Reddy, 2004). The pig-sweet potato system generates additional employment and improves the living standards' of the farmers (Srinivasulu Reddy and Nedunchezhiyan, 2008).

A fast growing sweet potato variety can be used as cover crop in pond slopes. The foliage can check siltation of the pond sand prevent shallowing the fish culture ponds. Thus it serves dual purpose, providing fodder to fish and strengthen the slopes/bunds of the ponds (Palaniswami and Peter, 2008). Harvesting of these cover crops should be restricted because it may loosen the soil.

Yam

Yam is grown throughout the tropics and sub-tropics, where rainfall is sufficient for their growth. In India, though yam is cultivated in all most all the state in homestead gardens. Yam is commercially cultivated in certain specific locations in Andhra Pradesh, Bihar, Gujarat, Kerala, Orissa, Madhya Pradesh, Tamil Nadu and Rajasthan. However no statistical data is available.
Yams are basically carbohydrate foods with relatively high protein and ascorbic acid contents. The edible portion of fresh tuber contains energy 439 kJ/ 100 g; water 72.4%; protein 2.4%; fat 0.2%; carbohydrate 42.1%; fibre 0.6%; calcium 22 mg/100 g; iron 0.8 mg/100 g; thiamine 0.09 mg/100 g;

riboflavin 0.03 mg/100 g; niacin 0.5 mg/100 g; ascorbic acid 10 mg/100 g (Kay, 1987). In general avitominosis C (scurvy) is rare in yam growing countries.

Elephant foot yam

Elephant foot yam (*Amorphophallus paeoniifoilus*) is cultivated for its edible corms in India, phillipines and Malaysia. In India, it is grown in Andhra Pradesh, Tamil Nadu, Kerala, Orissa, Bihar, West Bengal, Uttar Pradesh, Maharastra and Gujarat.

The biochemical composition of elephant foot yam corms on fresh weight basis are energy 330 kJ/100 g; water 72-79%; protein 1.7-5.1%; fat 0.2-0.4%; carbohydrate 18-24%; fibre 0.6-0.8%; ash 0.7-1.3%; calcium 50-56 mg/100 g; iron 0.6-1.4 mg/100 g; phosphorus 20-53 mg/100 g; vitamin A 434 IU/100 g; thiamine 0.04-0.06 mg/100 g; riboflavin 0.05-0.08 mg/100 g; niacin 0.7-0.75 mg/100 g; ascorbic acid trace-3 mg/100 g. The most of the carbohydrate is starch (75-80%); the starch granules vary in shape and size (5.5-19 microns) (Kay, 1987).

Taro

Taro otherwise known as cocoyam is grown throughout the tropical and sub-tropical countries. Nigeria leads in area (0.735 m ha) and production (4.027 m t) in the world and it is followed by Ghana (0.270 m ha; 1.8 m t) (FAOSTAT, 2005). The highest productivity is reported from Egypt (FAOSTAT, 2005). In India, it is grown in all most all the states, but commercially cultivated in Andhra Pradesh, Tamil Nadu, Kerala, Orissa, Uttar Pradesh, Maharastra and Gujarat. However the area and production statistical data is not available.

Corms and cormels are rich in starch; the flesh is mealy to smooth and usually has a somewhat nutty flavor. The composition of the edible portion of the fresh corms has the following: energy 373-406 kJ/100 g; water 73-78%; dry matter 24-26%; carbohydrate 19-21%; starch 15.5-18.0%; total sugars 1.75-1.90%; protein 1.4-3.2%; fat 0.1-1.5%; fibre 0.4-2.9%; ash 0.6-1.3%; calcium 32-44 mg/100 g; iron 0.8-5.27 mg/100 g; phosphorus 64-135 mg/100 g; manganese 0.19-0.26 mg/100 g; potassium 514-575 mg/100 g; sodium 7-9 mg/100 g; carotene trace-67 IU/100 g; thiamine 0.09-0.18 mg/100 g; riboflavin 0.03-0.04 mg/100 g; niacin 0.4-0.9 mg/100 g; ascorbic acid 0.10 mg/100 g (Kay, 1987).

Farming system involving tuber crops

Pond based farming system involving tuber crops

Kandhamal district in Odisha state is a hilly terrain dominated by Kandha tribes. They are resource poor small and marginal farmers. Tribal farmers cultivate extensively but harvest minimum because of their low resource use capabilities. They grow rice and ragi in uplands by direct seeding and low lands by transplanting. Being rainfed ecosystem, they cultivate during rainy season and land remains fallow during post rainy season. Food insecurity is regular feature in their life. Diversification into farming system mode in small holder farming appears promising to secure future and nutritional security at the grass root level (Singh, 2012). Farming system is integrating existing sub systems on a farm to harness maximum efficiencies and develop sustainable resource use systems which will optimize their use, minimize degradation with consideration to regenerative capacity and increase income and employment for farm families and promote quality of life and environment.
During the year 2013-14, four community pond based farming system involving tuber crops study was conducted at Gadragoan village according to the farmers conditions, resources and needs. The major objective was to develop an appropriate integration of crops, livestock and fish for round the year employment, income and sufficient food to farm family on the farm. Gadragoan was a typical tribal village in Chahali GP, Chakapad Block, Kandhamal District, Odisha state under Tribal Sub Plan programme by the ICAR-Central Tuber Crops Research Institute, Regional Centre, Bhubaneswar. The village was having uplands, medium lands and lowlands. The village was also having four farm ponds and 31 farm families. All the four farm ponds were renovated and able to collect run off water during rainy season. Each farm pond size was approximately 400 m^2. Four community pond based tuber

crops involving farming system research was conducted with the components of rice, tuber crops, fish, vegetables, poultry and goat (Table 1). The area and components of all the four community pond based farming system involving tuber crops was same. Each farming system study was 2.5 ha with the total area of 10 ha. Seven to eight tribal families involved in each community pond based tuber crops involving farming system covering 31 farm families. The Goat and poultry manures collected from the sheds were composted and then applied to crops and fish ponds. Sweet potato vines after harvest, and culled and damaged tubers were fed to goats. Broken rice and maize kernels and surplus grains were fed to poultry birds. However, during day time goats were taken for grazing in near by forest and poultry were scavenging in backyards.

Shortage of water was observed for drinking and cleaning of livestock and shed, domestic use of farm family, irrigation to plantation crop during dry months in rainfed farming areas. Therefore for sustaining water availability in the farm, a farm pond and shallow dug well are the essential components of rainfed farming system that helps for life saving irrigation, rabi vegetable production and household domestic needs. A diversified farming with a farm pond received sufficient water to fulfill the water requirement for optimal productivity under limited water supply.

Yields of crops, goat, fish and poultry for the four community pond based farming system involving tuber crops were collected; averaged it and presented in the Table 1. In community pond based tuber crops involving farming system, apart from rice, tuber crops, vegetables etc. were produced along with goat, fish and poultry. The community pond based tuber crops involving farming system produced 19,479 kg of rice equivalent yield and net return of Rs 2,27,980/2.5 ha. Whereas cultivation of rice alone produced 8,960 kg of rice and net return of Rs 91,700/2.5 ha. Part of the yields of grains, pulses, tuber crops, vegetables, egg, meat and fish were sold for cash income. By marketing of vegetable, fruit, flower, and livestock product (milk and meat) a farmer is able to earn sufficient money to meet out daily needs. The cash income from each community pond based farming system involving tuber crops was distributed to the respective numbers of farm families which would be helpful in covering up major expenditures like festivals, ceremonies etc. Further availability of tubers for household consumption for long period due to high storability along with other vegetables, rice, fish, egg and meat enhanced food and nutritional security of the household. The cash income improved the livelihoods of the farm families.

Table 1. Community pond based tuber crops involving farming system components, yield and economics (Mean of four)

Sl. No.	Crop/animal	Area (ha)	Yield (kg)	Rice equivalent yield (kg)	Gross Income (Rs)	Expenditure (Rs)	Net income (Rs)	Employment generation (man-days)
1	Rice (Gangabali)	1.2	4300	4300	86000	42000	44000	264
2	Sweet potato (Kishan & ST 14)	0.4	4225	1690	33800	16000	17800	60
3	Yam bean (RM-1)	0.4	7540	3770	75400	22000	53400	56
4	Greater yam (Orissa Elite)	0.1	2400	2400	48000	18000	30000	26
5	Elephant foot yam (Gajendra)	0.1	2225	2225	44500	20000	24500	25
6	Taro (Muktakeshi)	0.1	1850	1850	37000	18000	19000	22
7	Cassava (Vellayani Hraswa)	0.1	1895	474	9480	4200	5280	22
8	Fish (pond) (Rogu, Catla, Mrigal)	0.04	150	600	12000	5000	7000	20

9	Vegetables (*Amaranthus*, bhendi, brinjal, beans, potato etc.)	0.02	1800	900	18000	5000	13000	30
10	Poultry (Vanaraja): 20 Nos.	0.02	70	420	8400	1400	7000	10
11	Goat (Ganjam local): 5 Nos.		42.5	850	17000	10000	7000	25
Total		2.5	-	19479	389580	161600	227980	560

Check/Control

Sl. No.	Crop	Area (ha)	Yield (kg)	Gross Income (Rs)	Expenditure (Rs)	Net income (Rs)	Employment generation (man-days)
1	Rice (Gangabali)	2.5	8960	179200	87500	91700	550

Rice: Rs 20/kg; Sweet potato Rs 8/kg; Yam bean Rs 10/kg; greater yam Rs 20/kg; elephant foot yam Rs 20/kg; Taro Rs 20/kg; cassava Rs 5/kg; Fish Rs 80/kg; vegetables Rs 10/kg; poultry Rs 120/kg; goat meat Rs 400/kg

There is no additional employment generated in community pond based tuber crops involving farming system compared to monoculture of rice. This was due to inclusion of tuber crops cultivation. Tuber crops though long duration, cultivation was less labour intensive. But employment was distributed through out the year in community pond based tuber crops involving farming system. Whereas in monoculture rice, the total employment generated was spread within seven months (June-December) only. Thus dependency on out side family labours was much less in community pond based tuber crops involving farming system. Pali et al. (2012) also reported generation of additional 12 days employment in 0.4 ha pond based integrated farming system.

Farming system involving tuber crops (0.4 ha)

During the year 2014-15, participatory research on farming system involving tuber crops (0.4 ha model) under rainfed ecology was conducted in Khanjuguda (village), Chakapada (Block), Kandhamal (District), Odisha state. Farming system involving tuber crops (0.4 ha) was laid out in 52 tribal researcher fields. Sole rice cultivation 0.4 ha was laid out in four tribal researcher fields as a check. The components of farming system and their area of cultivation were given in the Table 2. The results revealed that farming system involving tuber crops produced 1739.1 kg of rice equivalent yield and net return of Rs 34770/0.4 ha. Whereas rice alone produced 800 kg of rice and net return of Rs 13000/0.4 ha. Farming system involving tuber crops generated 18 man days additional employment. Further the employment was spread throughout the year. Pali et al. (2012) also reported generation of additional 12 days employment in 0.4 ha pond based integrated farming system.

Table 2. Integrated farming system components yield and economics (0.4 ha)

Sl. No.	Crop/animal	Area (ha)	Yield (kg)	Rice equivalent yield (kg)	Gross Income (Rs)	Expenditure (Rs)	Net income (Rs)	Employment generation (man-days)
1	Rice	0.20	381	381.0	11430	5500	5930	44
2	Maize	0.03	62	31.0	930	350	580	3
3	Ragi	0.02	25	16.7	500	250	250	2
4	Redgram	0.02	14	23.3	700	250	450	2
5	Sweet potato	0.04	516	172.0	5160	1400	3760	6
6	Yam bean	0.03	514	257.0	7710	1200	6510	6

7	Greater yam	0.02	376	250.7	7520	2000	5520	10
8	Colocasia	0.02	305	203.3	6100	1400	4700	6
9	Elephant foot yam	0.008	115	76.7	2300	700	1600	3
10	Cassava	0.002	38	12.7	380	250	130	2
11	Vegetable (*Amaranthus*, Bhendi, bitter gourd, ridge gourd etc.)	0.01	237	158.0	4740	1500	3240	12
12	Backyard poultry	20 (nos.)	47	156.7	4700	2000	2700	10
Total		0.4	2630	1739.1	52170	17400	34770	106

Check/Control

Sl. No.	Crop/animal	Area (ha)	Yield (kg)	Gross Income (Rs)	Expenditure (Rs)	Net income (Rs)	Employment generation (man-days)
1	Rice	0.4	800	24000	11000	13000	88

Rice Rs 30/kg; Maize Rs 15/kg; Ragi Rs 20/kg; Redgram Rs 50/kg; Sweet potato Rs 10/kg; Yam bean Rs 15/kg; Greater yam Rs 20/kg; Colocasia Rs 20/kg; Elephant foot yam Rs 20/kg; Cassava Rs 10/kg, Vegetables Rs 20/kg; Poultry live bird Rs 100/kg

Conclusion

Wider adoptability and greater flexibility in planting and harvesting of tuber crops makes them fit into any cropping/farming systems. Partial shade tolerance of yams and aroids was found highly suitable to intercrop in grown up orchards and plantation crops. High dry matter production potential/ unit area/ unit time coupled with cheap source of energy encourages farmers to use tuber crops in livestock feeding. Tuber crops products can be used in fresh form or dried form or ensiled form in animal feeding, which is the uniqueness of tuber crops. In small holder farming systems growing tuber crops along with seasonal, horticultural and silvicultural crops, feeding green tops and excess/culled tubers either fresh or processed form to animals decreases the purchased inputs and increase the farm net income. In the changing climate, tuber crops are indispensable in small holder farming systems along with cereals, livestock and fisheries. Thus, food and nutritional security can be achieved through tuber crops based sustainable farming systems.

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Optimizing water productivity through integrated farming system models

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Introduction

The International Organisation of Biological Control (IOBC) describes Integrated Farming as a farming system where high quality food, feed, fibre and renewable energy are produced by using resources such as soil, water, air and nature as well as regulating factors to farm sustainably and with as little polluting inputs as possible.The integrated farming system approach introduces a change in the farming techniques for maximum production in the cropping pattern and takes care of optimal utilization of resources. The farm wastes are better recycled for productive purposes in the integrated system. A judicious mix of agricultural enterprises like dairy, poultry, piggery, fishery, sericulture etc. suited to the given agro-climatic conditions and socio-economic status of the farmers would bring prosperity in the farming.

Components of Integrated Farming System

- Crops, livestock, birds and trees are the major components of any IFS.
- Crop may have subsystem like monocrop, mixed/intercrop, multi-tier crops of cereals, legumes (pulses), oilseeds, forage etc.
- Livestock components may be milch cow, goat, sheep, poultry, bees.
- Tree components may include timer, fuel, fodder and fruit trees.

What is water productivity?

It is the physical mass of production or the economic value of production measured against gross inflows, net inflow, depleted water, process depleted water, or available water.

WP= Agricultural benefit/ water use

It is normal to represent WP in units of kg/m^3. If production is measured in kg/ha, water use is estimated as mm of water applied or received as rainfall, convertible simply to m^3/ha (1mm = 10m^3/ha). Alternative notations include food (kcal/m^3) or monetary value (Rupees/m^3).

Crop water productivity is defined in either physical or monetary terms as the ratio of the product (usually measured in kg) over the amount of water depleted (usually limited to crop evapotranspiration, measured in m^3).

In case of **irrigation water productivity** the denominator refers to irrigation water only, not to rainfall. Obviously, values of irrigation-water productivity cannot be compared with water productivity with depleted water in the denominator.

Economic productivity is the gross or net present value of the product divided by the value of the water diverted or depleted, which can be defined in terms of its opportunity cost in the highest alternative use.

In an agro-ecosystem context, **fisheries water productivity (FWP)** may be defined as the ratio of beneficial fisheries goods and services produced in an agricultural system to the amount of water depleted in producing them.

We define **livestock-water productivity** (LWP) as the amount of water depleted to produce livestock and livestock products and services, including farm power or as the ratio of beneficial livestock goods and services generated in an agricultural system to the amount of water depleted in producing them.

Basin water productivity takes into consideration beneficial depletion for multiple uses of water, including not only crop production but also uses by the non-agricultural sector, including the environment.

Water productivity definition is scale-dependent. For a farmer, it means getting more crop per drop of irrigation water. But, for society as a whole, concerned with a basin or country's water resource, this means getting more value per unit of water resource used. Increasing water productivity is then the business of several actors working in harmony at plant, field, irrigation-system and river-basin levels.

Why integrated farming system for optimizing water productivity?

The agriculture is of fundamental importance in India's economy contributes about 20-21% of gross domestic product (GDP) and generates two third of employment. Total food grain production, which was only about 51 million tons at the time of 1st five year plan, has gone up to 213.45 million tons in 2003-04. But in spite of all these impressive achievements, net sown area in the country remained at about 141.1 M ha and per capita availability of land is decreasing. Water sustains life and is primarily used for growing crops, household uses, as input to industries, power generation, recreations and for sustaining earth's ecosystems. Presently, this essential natural resource is under threat as evident from the following facts. India covers 2.42% of the total land area of the world and supports 16.8% population of world with only 4.2% of water resources. Though India gets about 400 M ha m of water due to an average annual rainfall of 1194 mm, but it varies from 150 mm at Jaisalmer to 11690 mm at Mawsynram near Cherrapunji. About 60% of the area is rainfed and we are also unable to store desirable quantity of water in uplands of the country for agricultural use. Also per capita water availability is continuously declining from 5176 m^3 in 1951 to 2209 m^3 in 1991, 1820 m^3 in 2001 and 1703.6 m^3 in 2005. In order to meet the challenge of feeding ever increasing population of our country, there is an urgent need to produce more food from less water. This could be only possible by enhancing the water productivity through integrated farming systems.

In recent years, country is frequently experiencing natural calamities like floods, droughts, cyclone, etc. In India, by the year 2025, high rate of population growth is likely to result in about 1333 millions people while the low growth projections place the number at nearly 1286 millions. The projected food grain demand for 2025 would be 320 M tones (high demand scenario) and 308 M tones (low demand scenario). The quantum of water used for irrigation by the last century was of the order of 31.8 M ha of surface water and 20.6 M ha of groundwater, total 52.4 M ha. The estimates indicate that by the year 2025, the water requirement for irrigation (both surface and groundwater) would be 56.1 M ha for low demand scenario and 61.1 M ha for high demand scenario. A reduction in share of water for agriculture from present level of 83% to 72% by 2025 is expected due to competing demand of water for industries, municipalities and environmental needs. A large coastal tract of India has either saline water ingress or at many places a thin layer of fresh water floats over saline water. Also poor and degraded quality waters pose a challenge for effective utilization in non-consumptive domestic and production system through IFS technology. In order to meet the challenge of feeding ever increasing population of our country, there is an urgent need to produce more food from less water. This could be only possible by enhancing the water productivity through IFS.

Principles for improving water productivity

The key principles for improving water productivity are:
(i) to increase the marketable yield of the crop per each unit of water transpired;
(ii) to reduce all out flows (e.g.: drainage, seepage and percolation, including evaporation outflows, other than the crop stomatal transpiration), and
(iii) to increase the effective use of rainfall, stored water and water of marginal quality.

The three principles apply at all scales, from plant to field and agro-ecological levels. However, option and practices associated with these principles require approaches and technologies at different spatial scales.

IFS for enhancing water productivity

Integrated farming system for waterlogged area management

A study was conducted for development of pond based integrated farming system for management of waterlogged area in Khurda district. There was a patch of 3 ha area under severe waterlogging. Continuous waterlogging has converted that land to wasteland. No crop was possible to be grown in those fields and it was remaining fallow in almost all years. The soil pH observed ranged from 3.5 to 6.5; soil texture is sandy clay loam; soil organic carbon was low (< 0.5%); soil available nitrogen was low (< 280 kg ha^{-1}); soil available potassium was medium (50-170 mg/kg of soil); soil available phosphorous was medium (5-10 mg/kg of soil); iron toxicity was present. Depth of groundwater table was ranging from 20-40 cm as minimum and 50-150 cm as maximum from ground surface during December to June. During monsoon it is above ground surface. The yield of shallow aquifer is low. The land was unsuitable for ploughing except during the months of May and early June, and was left fallow in almost all years.

For determining the design and dimensions of the ponds, collection and analysis of climatic data (rainfall, pan evaporation etc.) for the period 1975-2003 for Bhubaneswar was done. The climatic parameter analysis and water balance study resulted the design dimensions of the experimental ponds which were 27 m x 27 m, 30 m x 30 m, and 34 m x 34 m at the top with 2 m depth and side slope 1:1 in experimental plot 1, 2 and 3 respectively. The excavated soils were spread around the pond to elevate the surrounding area so as to keep the water table below 2 m from ground surface. Hume pipes of 30 cm diameter and 4 m length were used as inlet and emergency outlet of the pond. Since the objective of the study was to store excess water for reclamation of waterlogged area, the area of the ponds are kept within 20 to 25% of the total area considering the water balance component of the study area.

Design and construction of three micro water resources covering water surface area of 625 (P_1), 785 (P_2) and 1025m^2 (P_3) was completed by March 2006. Treatment implementation and stocking of fish fingerling (*Magur*, 12.2g MBW) was done as the first crop. Population density was maintained at 1200, 2100 and 1700 for P_1, P_2 and P_3 respectively. The recorded mean minimum and maximum values of various water quality parameters were: water temperature 27.9 - 32.3 ^{0}C; water pH 6.7 - 8.7; dissolved oxygen 3.6 - 9.1 ppm; total alkalinity 78 - 127 ppm; dissolved organic matter 1.4 - 6.4 ppm; nitrite –N 0.006 - 0.077 ppm; nitrate-N 0.06 - 0.57 ppm; ammonia 0.01 - 0.34 ppm; transparency 39$\pm$3 – 52$\pm$4; total suspended solid 169 - 367 ppm and total plankton count 14.9x 10^3 to 19.8 x 10^4 nos/liter. Average primary production in the first month of rearing ranged between 121.4-149 mg C m^{-3} h^{-1}, which improved further (533$\pm$41.3 mg C m^{-3} h^{-1}) with the advancement of rearing period. TSS and DO concentration showed a decreasing trend with the advancement of rearing period while, gradual increase in nitrite, nitrate, ammonia were attributed by intermittent fertilization, increased level of metabolites and decomposition of unutilized feed. At any given point of time, other water quality parameters did not register any specific trend. In this experiment, average growth performance of *Magur* was highest inpond-1 (P_1)(163.5g) followed by pond-3, (P_3) (141.0g) and pond-2 (P_2)(130.5g). In this experiment, reductions in growth did not appear to be due to poor water quality, as water quality did not differ significantly among various treatments, may be due to behavioral interaction or physiological response to density itself. Relatively moderate survival rate (61-64.75%) was mainly due to cannibalism at the initial stage of rearing. In this, crop yield of fish ranged between 1632-1710kg/ha/ 200days, survival rate (SR%- 61-64.75), feed conversion ratio (FCR)- 1.39-1.47, per day increment (PDI) was 0.595-0.623 g/day.

Indian major carps (IMC) were taken as subsequent crops in coming years and were released during 4th week of August. All growth parameters were undertaken regularly. The catla has recorded a maximum growth in comparison to rohu and mrigal. As age of the pond increased the quality of water improved as the sides of the bunds have been stabilized, hence IMC was undertaken in place of magur to reduce the input cost and preference in market.

Under on-dyke horticulture activities, there were 114 papaya, 89 banana, and 16 coconut plants around 1st pond, 69 banana, 9 papaya and 4 coconut plants around 2nd pond and 70 banana plants were planted around the 3^{rd} pond (Plate 1). Besides another 90 banana plants were planted in adjacent area. The different varieties of tissue culture banana planted are *G-9, Bantal, and Robosta*. Papaya variety was *"farm selection"*.

In the first year under on-dyke horticulture activities vegetable such as bottle gourd in 386 m^2 area (7.8 t/ha), tomato in 252 m^2 area (2 t/ha) and brinjal on 66 m^2 (1.52 t/ha) were taken up. Different varieties of paddy such as *Khandagiri, Swarna, CR-1009 and Surendra* were grown in four different plots showed average yield of 2.72 t/ha.

In subsequent years on an average 220 bunches of banana were harvested. Different varieties of paddy such as *Khandagiri, Swarna, CR-1009 and Surendra* were grown in four different plots. During *kharif* the yield of Khandagiri was 2.1 t/ha, Surendra gave 3.2 t/ha and Swarna showed average yield of 2.7 t/ha. During *rabi* Khandagiri paddy gave a yield of 2.3 t/ha. Different vegetable were taken as on-dyke horticultural activities as well as intercrops such as brinjal (6.25 t/ha), cowpea (1.5 t/ha), Bean (2 t/ha), ladies finger (4.9 t/ha) and 200 kg of bottle gourd was also obtained.

Integrated farming system with aquaculture in the pond such rearing magur in the first year followed by Indian major carps in subsequent years is highly profitable and helps in improving the livelihood options of poor farmers. On-dyke horticulture such as banana, papaya and other vegetables as intercrop is possible in the system and helps in crop diversification and rural livelihood option.

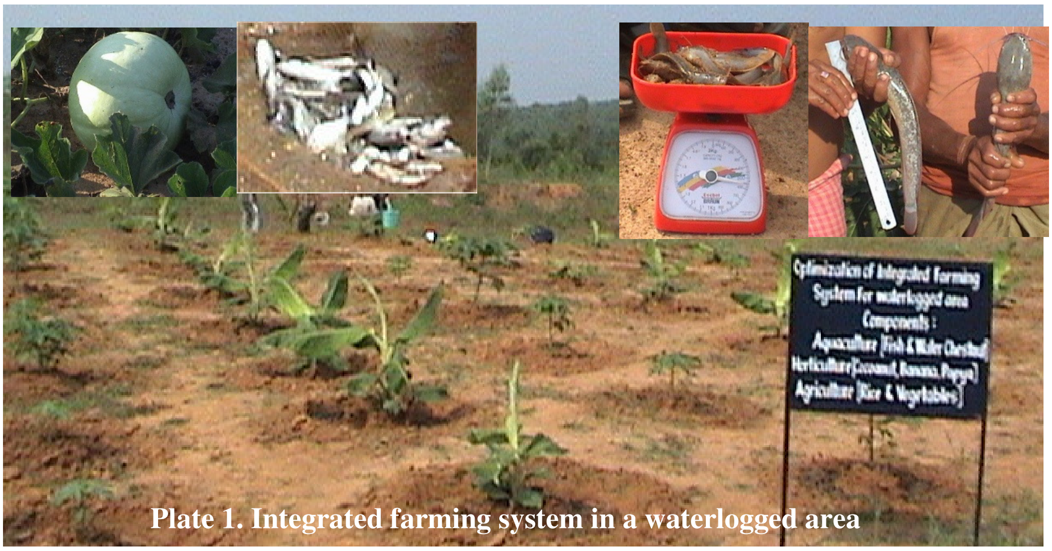

Plate 1. Integrated farming system in a waterlogged area

Integrated farming system in Mahanadi delta

Where nothing is feasible i.e. drainage measures/alternate waterlogged resistant paddy crop, etc., there pond drainage with integrated farming system is recommended. The entire waterlogged area is converted into an integrated resource management unit where fishery, duck rearing, poultry or birds go together with horticulture, forest and other economic crops in bunds and vegetables in between.

One such unit was developed in Khentalo village of Barmania Pat (waterlogged area) where water logging was up to 2 m depth. Out of 2.47 ha waterlogged area of the farmer, 1.64 ha was converted into grow-out pond for fish and prawn culture while vegetable, flower and fruits were grown on 0.83 ha of raised embankment all around the pond since 1989. Poultry sheds were also constructed for rearing 4000 birds in such a way that their droppings could fall into pond as organic manure and feed for fish. The average productivity of low land high yielding paddy was 3.5 t ha^{-1} as compared to 9.4 t ha^{-1} per annum fish equivalent (fish + prawn). Gross and net returns from fish and prawn culture alone during 2002 were Rs. 6,17,160 (Rs. 3,76,317 per ha) and Rs. 3,31,065 (Rs. 2,01,868 per ha) respectively. This accounted to Rs. 14.00 per m^3 of water productivity in the pond system alone. Whereas the gross and net returns from the whole system of 2.47 ha during the year 2002 were Rs. 6,51,110 (Rs. 2,63,607 per ha) and Rs. 3,62,515 (Rs. 1,46, 767 per ha) respectively. The farmer initially invested Rs. 1,23,910 in 1988 towards construction of the pond plus infrastructure and earned a net return of Rs. 40,554 per ha of whole system in 1989, which gradually increased up to Rs. 1,32,894 per ha in 1997. He again invested Rs. 1,30,000 towards stone pitching in 1998 and Rs. 3,20,000 towards poultry shed and the net return (after adjusting investment) was Rs. 2,17,600 (Rs. 88,097 per ha) during 1998 and a net loss of Rs. 1,16,900 during super cyclone year in 1999. The net returns per ha again increased steadily after cyclone from Rs. 27,465 in 2000 to Rs. 1,37,894 in 2001 reaching up to Rs. 1,46,767 (35 times higher of the paddy cropping) in 2002.

Adjacent to the developed integrated farming system, the farmer is cultivating 2.4 ha waterlogged paddy field giving net return of Rs. 4,166 per ha only (2.8% of the integrated farming system). IIWM has designed a deep water high density rice-fish integrated system of 1.2 ha out of the 2.4 ha waterlogged paddy field system and it is estimated that it will give net return of Rs. 1.5 to 1.6 lakh per ha per year. Revival of poultry component and addition of milch cattle in the system is going to make it more profitable and more sustainable utilizing surface and ground water of the waterlogged area. This is going to be a replicable integrated farming model for the coastal Orissa. It may also be replicated in irrigated alluvial land of other regions.

IFS in cyclone affected coastal Odisha

IFS around sub surface water harvesting structure was implemented in participatory basis for 22 locations in coastal waterlogged ecosystem devastated by 1999 super cyclone where saline aquifer exists beyond 3-7 m below ground level, and fresh water aquifer floats over it. This fresh water was harvested by constructing sub surface water harvesting structures up to a depth of 3 m and the stored water was utilized for aquaculture and irrigation of the crops grown on the bund and in surrounding area. Introduction of integrated farming system approach (aquaculture, water chest nut, on dyke horticulture and vegetables in the pond command area) in those structures resulted in gross water productivity of Rs. 12.93 to Rs. 47.20 per m^3 of water used. The impact of this technology resulted in construction of 135 such new structures (SSWHS) by farmers in the coastal tract of Erasama. Consequently, significant increase in crop production (3-4 fold), water productivity (Rs. 12.93-Rs. 47.20 per m^3) and cropping intensity (103-230%) has led to the socio-economic upliftment of the resource-poor farmers with diversified livelihood options. The findings can be replicable in different waterlogged eco-systems of India.

Integrated farming system in deep water condition

In a farmer's field at Khentalo of Cuttack district, 2 ha waterlogged area was converted into two units of deep water rice-fish system with another 1 ha land exclusively for deep-water rice. Periodic observation of water quality, soil quality, fish and prawn growth parameters, yield and yield components, hydrological and water balance related studies were carried out at regular intervals at the experimental site. In the first year the water level went up to as high as 65 cm above ground surface in 34th standard week and remained above the surface during 25th to 48th week. During driest period the water table went down to 167 cm below ground level. This was a precarious water logging condition prohibiting growing of any other crop than paddy with very low return. Under this scenario, construction of refuge that acts as a drainage system and helps in lowering the water table was adopted for rice-fish culture in reclaiming waterlogged degraded area. Comparison of weekly rainfall and evaporation revealed that the rainfall is higher than the evaporation during 24th to 43rd week causing water congestion. Hence excess water was stored in the rice-fish culture field for aquaculture and for irrigating rabi crop. During 3rd year of the study the water level went up to as high as 32 cm above ground surface in the 1st week of October. There was no visible difference in water table from mid-October till December. However during summer, water table went as deep as 3.3 m below ground level indicating lowering of water table.

The yield of deep water paddy was 2.97 and 2.42 t/ha in rice-fish system and control respectively. Average post paddy second crop (black gram) yield was 0.75 t/ha, yield from on-dyke horticulture was 463 and 495 kg for brinjal and ladies finger respectively. Net water productivity for only deep water rice was Rs. 0.46/m^3 where as it was Rs. 7.46/m^3 for only fish & prawn culture.

Conclusions/ Recommendations

Integrated farming system with aquaculture in the pond such as rearing magur in the first year followed by Indian major carps in subsequent years was highly profitable and helps in improving the livelihood options of poor farmers. On-dyke horticulture such as banana, papaya and other vegetables as intercrop was possible in the system and helps in crop diversification and rural livelihood option. IFS around sub surface water harvesting structure are very advantageous and profitable in cyclone affected areas of coastal area.Deep water rice-fish system in deep waterlogged area is very much profitable.

The different advantages of Integrated Farming System are

- Higher food production to equate the demand of the exploding population of our nation
- Increased farm income through proper residue recycling and allied components
- Sustainable soil fertility and productivity through organic waste recycling
- Integration of allied activities will result in the availability of nutritious food enriched with protein, carbohydrate, fat, minerals and vitamins
- Integrated farming will help in environmental protection through effective recycling of waste from animal activities like piggery, poultry and pigeon rearing
- Reduced production cost of components through input recycling from the byproducts of allied enterprises
- Regular stable income through the products like egg, milk, mushroom, vegetables, honey and silkworm cocoons from the linked activities in integrated farming
- Inclusion of biogas & agro forestry in integrated farming system will solve the prognosticated energy crisis
- Cultivation of fodder crops as intercropping and as border cropping will result in the availability of adequate nutritious fodder for animal components like milch cow, goat / sheep, pig and rabbit
- Firewood and construction wood requirements could be met from the agroforestry system without affecting the natural forest
- Avoidance of soil loss through erosion by agro-forestry and proper cultivation of each part of land by integrated farming
- Generation of regular employment for the farm family members of small and marginal farmers.

Low cost protected cultivation of vegetable crops for sustainable farm income

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Introduction

Vegetables are recognized as health food globally and play an important role in food, nutrition and livelihood security. Vegetable growing is becoming an industry in the country because of its increasing demand and per capita requirement. The Indian scenario has changed tremendously during the last decade because of change in the life style and food habits. The people are becoming more aware to eat healthy foods but due to several biotic and abiotic stresses productivity and quality of vegetables decreased under open field cultivation more specifically during rainy and post rainy season. The increasing demand of off-season and high quality vegetables in various markets of the county has gotten the attention of the vegetable growers for diversification from traditional way of vegetable cultivation to modern methods of vegetables cultivation in an agri-business model. Protected cultivation, which in the past was considered only as a means of production only for affluent western countries having unfavorable environments, is now very much needed under Indian conditions to improve the productivity and quality of the vegetables. After the green revolution more emphasis has been laid on the quality along with quantity of the produce to meet the ever-growing food requirements. Both these demands can be met when the growing environment for the plant is suitably modified. The need to protect the crops and to sustain production even under unfavorable climates led to the development of protected cultivation. Cultivation of high value vegetables under protected conditions in India is gaining more importance.

During winter season under north Indian conditions, it is extremely difficult to grow tomato capsicum, cucurbits, French bean, amaranth etc. in open field condition. Similarly, in several parts of the country pests and diseases are more prominent during rainy and post rainy season, does not allow successful production of vegetables like tomato, chilli, okra, sweet pepper etc. in open field condition. As a result of various biotic stresses most of these vegetables are severely damaged. In hilly areas specially Leh and Laddak, cold desert conditions prevails where the temperature is extremely low (-100C to -300 C) during winter season and most of the hilly region cut off from rest part of the country from November to March due to very heavy snowfall and it is very difficult to cultivate and supply vegetables in these areas. The low cost Polyhouse is economical for small and marginal farmers, who cannot afford huge cost of high-tech poly house. The temperature inside the poly house is 6-10 0C higher than outsides during winter. The cold waves during winter season (December to February) do not enter inside the poly house and inside environment becomes conducive for quick germination of seed and growth of seedlings. Many times farmers produce good amount of cucumber, capsicum and tomatoes during main season, which eventually leads to the market glut and fall in price. On the other hand, due to weather extremes during winter, it is difficult to grow high value vegetables like tomato, capsicum, cucumber, gherkin etc. in open condition. Therefore, poly-house technology allows producing year round high quality vegetable, raising disease free seedlings and hybrid seed production of high value vegetable crops.

Present status and national scenarios

India first exposure to truly hi-tech protected farming of vegetables and other high-value horticultural produce came through the Indo-Israel project on greenhouse cultivation, initiated at the New Delhi-based Indian Agricultural Research Institute (IARI) in 1998, shortly after the establishment of diplomatic ties with that country. However, the Israeli experts left India in 2003 at the end of this five-year project, IARI continued to maintain the facility, calling it the Centre for Protected Cultivation Technology (CPCT). It has, in the past 10 years, managed to refine and upscale the system to reduce costs, besides designing greenhouse structures to suit local conditions. The area under greenhouse cultivation, reported by the end of 20th century was about 110 ha in India and world over 275,000 hectare (Mishra, et al 2010). During last decade this area must have increased by 10 per cent if not more. The states that have consistently expanded the area under protected cultivation for the period of 2007-2012 are Andhra Pradesh, Gujarat, Maharashtra, Haryana, Punjab, Tamil Nadu and West Bengal. Maharashtra and Gujarat had a cumulative area of 5,730.23 hectares and 4,720.72 hectares respectively under the protected cultivation till 2012.

Prospects of protected vegetable production

In temperate areas, vegetable growers can increase their income by raising early crops in protected structures mainly in low-cost greenhouses. Raising of vegetable nursery in protected structures has many fold benefits such as easy management, early nursery, and protection from biotic and abiotic stresses. This technology is highly productive, amenable to automation, conserve water and land. In 21^{st} century, protected vegetable production is likely to be common commercial practice not only because of it potential but out of sheer necessity.

Different types of structures used for vegetable cultivation:

1. Plastic low tunnel technology for off season vegetable cultivation

Plastic low tunnel technology is a simple and profitable technology for off season cultivation of cucurbits during the winter season in northern plains of our country. Crops like summer squash can be grown as a complete off-season crop, whereas other cucurbits like muskmelon, round melon, bottle gourd, cucumber, bitter gourd, watermelon can be advanced by 30-40 days over their normal growing season. Plastic low tunnels are flexible transparent coverings that are installed over single or multiple rows of vegetables to enhance the plant growth by warming the air around the plants in the open field during winter season when the temperature is below 8°c. Plastic low tunnels are often used to promote the growth of plants during the period of winter season. Low tunnels are supported above the plants by using hoops of GI wire and a clear or transparent plastic of 20-30 micron is covered/ stretched over the hoops and the sides are secured by placing in soil. The plastic is vented or slitted during the growing season as the temperature increase within the tunnels. The farmers can grow different varieties of summer squash (round fruited, long fruited) which is a emerging crop along with cultivation of netted muskmelon varieties in place of traditional varieties. Bitter gourd and round melon are two other crops with increasing demand and which usually fetches very high price during off-season and can be grown successfully by using the plastic low tunnel technology. This technology is highly suitable and profitable for the farmers living in northern plains of India.

2. Vegetable cultivation under shade net houses:

Shade nets are perforated plastic materials used to cut down the solar radiation and prevent scorching or wilting of leaves caused by marked temperature increases within the leaf tissue from strong sunlight. These nets are available in different shading intensities ranging from 25% to 75%. Leafy vegetables and ornamental greens are recommended to be grown under shade nets whose growth rates are significantly enhanced compared to un-shaded plants when sunlight is strong. The basic objective of shade net is to reduce radiation and temperature up to some extent during critical summer months (May-Sept.). Black colour shade nets are most efficient in reduction of temperature compared to other colours like green, white or silver etc. as the black colour in the maximum absorbent of heat. Mostly leafy vegetables like beet leaf and green coriander are preferred to be grown under shade nets, but it is also suitable for growing early cauliflower and radish cultivation during June to September months.

3. Off season vegetable cultivation under walk in tunnels:

Walk in tunnels are the temporary structures erected by using G.I. pipes & transparent plastic. Walk in tunnels are used for complete off season cultivation of vegetables like bottle gourd~ summer squash~ cucumber etc. during winter season (Dec. - mid February) the basic objective & utility of walk in tunnels is to fetch high price of the complete off season produce to earn more profit per unit area. The ideal size of a walk in tunnel can be of 4.0 m width and 30m length (120m2) and total cost of fabrication may be Rs.12000-14000/.

4. Vegetable cultivation under rain shelters

This is naturally ventilated low cost green house to protect plants from direct rain. Rain shelters are the most suited protection structures in high rainfall states like Assam and Kerala. It is provided with roof claddings of UV stabilized low density poly-ethylene film and sides are fully open. Mostly even span structure is used for construction of rain shelters

5. Use of insect proof net house technology for safe vegetable cultivation:

During rainy season farmers are growing their vegetable like tomato, chilli, sweet pepper, okra etc. under open field condition but it is very difficult to grow these crops successfully due viruses. Viruses are spread by insect vectors like whiteflies, aphids, thrips, jassids and sometimes also by hoppers. The population of white fly after on start of monsoons is very high and it remains in the open environment up to end of October depending upon the temperature. The fanners are using several insecticides for several sprays to control these vectors, even they could not control these vectors and their tomatoes, chilli or okra crops are highly infected with viruses. The second most common and most severe problem in tomato, brinjal and okra is the fruit borer against which the growers are using huge amount of insecticide even they are unable to control this insect. The only way to control the virus and fruit borer is to put a mechanical barrier between the crops and open environment and this is possible with the use of insect proof net of 40 or 50 meshes in form of net houses or insect proof net covered walk in tunnels. By 'this way the growers can directly reduce the use of insecticides and they can grow virus free crops of tomato, chilli, sweet pepper and okra during rainy or post rainy season. But for growing these crops under insect proof net houses, it is pre-requisite to raise virus free healthy seedlings of these crops either in the greenhouse or by covering the nursery beds with insect proof net. The farmers can erect these insect proof net houses by using half inch size GI pipes after bending them in half circle shape. Other insect proof net houses can also be made by covering all sides and top with insect proof net of 40 or 50 meshes, but the net should be UV stabilized. Under these net house crops like sweet pepper, tomato, chilli or okra can be grown successfully without infestation of viruses or other insects like fruit borer etc. and the growers can save the huge amount spent on pesticides. Insect proof net houses can also be fabricated in greenhouse design for maximum utilization of the space through vertical growing of high value vegetables. These structures can be fabricated with a cost of Rs.250- 300/m^2. Such structures can be covered with 40-50% shading nets during critical summer months (April-June) and with plastic during critical winter months (Dec- Feb) with transparent plastic under arid and semi-arid climatic conditions. High value vegetables like tomato, cherry tomato (crop duration 7- 8months), two crops of parthenocarpic cucumber (summer and post rainy season) and capsicum (crop duration 7-8 months). The basic objective of Insect proof net house vegetable cultivation is to minimize the use of pesticides in fresh vegetable cultivation for producing safe vegetables.

Table 1:- Crops for nursery raising under insect proof net house

S. No.	Crop	Planting time	Objective of nursery raising
1	Tomato	June 15-July 15	Production of virus free healthy nursery
2	Chilli	June 15-July 15	Production of virus free healthy nursery
3	Capsicum	August 15-September 15	Production of virus free healthy
4	Early cauliflower	May 20 - June 20 (By using 40% black shade net)	Production of healthy nursery by reducing soil born problems
5	Tomato, Chilli, Brinjal	15-30 December	Production of healthy nursery by protecting against frost in winters
6	Cucurbits	December 25- January 10	Off-season production of nursery by using plug tray technology

6. Zero energy naturally ventilated greenhouses for cultivation of high value vegetables:

The protected structures, where no heating or cooling devices are provided for climate control is called zero energy naturally ventilated greenhouses. These are simple and medium cost greenhouses which can be erected with a cost of Rs.650-700 sq. meter and these greenhouses can be used successfully and efficiently for growing year round parthenocarpic slicing cucumber, off season muskmelon, tomato and sweet pepper crops for 8-9 months duration. These structures are having a manually operated cross ventilation system as and when required. Looking to the year round, increasing demand of high quality parthenocarpic slicing cucumber in up markets of the metro and other big cities of the country, this is one of the most suitable and profitable crop for cultivation under naturally ventilated green houses in peri-urban areas of the country. Three successful crops of cucumber can be grown in a naturally ventilated greenhouse in a period of one year. Muskmelon is the second crop, which can be successfully cultivated for its complete off-season availability, which can fetch very high price of the off-season produce in the up markets of the metro and' other big cities of the northern parts of the country. Similarly high' value vegetables like standard tomatoes, cherry tomatoes and coloured peppers are can be grown for long duration (8-10 months period) under naturally ventilated greenhouse conditions.

7. Climate and semi-climate controlled greenhouses for production of high value vegetables:

Climate greenhouse provided with fibreglass covering with full climate control devices. Temperature, humidity, light, day length and winds are automatically controlled using computers. Sensors and data loggers are provided in glass house to detect variation and to record climatic factors. The structures are also provided with fully automatic fertigation system, sprinklers, misting system and fumigation devices. But in case of semi-climate controlled greenhouse, all four sides are completely covered and temperature inside is controlled by "Fan and pad cooling system", shade nets and micro-sprinklers. During winter, hot air blowers are necessary to maintain higher temperature. It has a single layer covering of ultraviolet stabilized polythene of 800 gauge thickness on GI pipes of 15 mm bore.
Three crops of value vegetables like tomatoes, cherry tomatoes slicing cucumber and coloured peppers can be grown for long duration (10-12 months period) under climate control greenhouse. Although the initial and running cost of the climate controlled greenhouse is very high, which restrict the adoption of this technology. But now the time has come when the vegetable growers around metro cities can use the green house technology for cultivation of high value vegetables for higher profits. High value vegetables produced under climate and semi-climate controlled greenhouses can also be exported to the other countries.

Type of protected structures and their economics for cultivation of vegetable crops:

The economics of the protected cultivation largely depends upon the initial cost of fabrication of the protected structures, running and maintenance cost of the structures, available market for the product produced under a particular protected structure. Economics of some vegetable crop cultivation under different kind of greenhouses and low cost protected structures have been worked out at Indo-Israel Project of IARI, New Delhi have been given in table 2.

Table2. Comparison of cost of production of vegetables under different protected structures

S. No.	Kind of protected structures	Cost (Rs./m^2)	Suitable crops	Duration crops (days)	Yield (t/1000m^2)	Cost (Rs./kg)
1	Climate controlled greenhouse	3200-3500	Tomato	320	25.0	22-25
			Sweet pepper	300	6.0	45-50
			Cucumber	360(4 crops)	18.0	20-25
2	Semi-climate controlled greenhouse	1400-1500	Tomato	290	20.0	15-18
			Sweet pepper	260	5.0	35-40
			Cucumber	280 (3 crops)	15.0	15-18

3	Naturally ventilated greenhouse	500-600	Tomato Sweet pepper Cucumber	270 240 280	16.0 4.0 15.0	8-9 18-20 7-8
4	Insect proof net-house	80-100	Sweet pepper	200-240	3.5-4.0	15-16
5	Plastic low tunnels	5-6	Summer squash Musk melon Bitter gourd Bottle gourd	90-95 110-120 110-120 80-90	5.0-6.0 2.0-3.0 1.0-1.5 2.0-3.0	1.5-2.0 3.0-4.0 4.0-5.0 3.0-4.0

Advantages of protected vegetable cultivation:

i. Vegetables can be produced year round regardless of season. Adverse climate for production of vegetables can be overcome by different systems of protected production.
ii. Multiple cropping on the same piece of land is possible.
iii. Off season production of vegetables to get better return to growers is feasible.
iv. It allows production of high quality and healthy seedlings of vegetables for transplanting in open field supporting early crop, strong and resistant crop stands.
v. Protective structures provide protection to high value crops from unfavorable weather conditions, pests and diseases.
vi. Use of protected vegetable cultivation can increase production by more than five folds and increase productivity per unit of land, water, energy and labour.
vii. Protected cultivation supports the production of high quality and clean products.
viii. It makes cultivation of vegetables possible in areas where it is not possible in open conditions such as high altitudes deserts.
ix. It makes vertical cultivation of vegetables possible using technologies like hydroponics, aeroponics etc and use of vertical beds for production.
x. Disease free seed production of costly vegetables becomes easy under protected structures.

Limitations:

i. Manual or hand pollination in cross pollinated vegetables like cucurbits or development of their parthenocarpic hybrids/ varieties.
ii. Uninterrupted and regular power supply is required for operating cooling and heating system of the greenhouse, which is not available almost in all parts of the country.
iii. Expensive, short life and non-availability of cladding materials.
iv. Lack of appropriate tools and machinery.
v. Structure cost initially looks unaffordable. Farmers with zero risk affordability do not come forward to adopt it.
vi. Inadequate support from planners and scientists- suitable varieties/hybrids and their production packages for protected production systems are either not available or very few. Protected structures in use are not scientifically designed; hence potentials of structure are not fully exploited.

Conclusion

Cultivation of high value off-season vegetables under low cost protected structures was found a viable technology for growing vegetables successfully. The produce from protected structures was off-season and hence fetched higher prices in the market. Low cost protected technology like plastic low tunnels or walk in tunnels, shade net houses can be used for off season vegetable cultivation for getting high returns from off season produce. Similarly insect proof net houses can be used on a large scale for safe vegetable cultivation by way of minimizing the use of pesticides in vegetable cultivation and virus seedling production. Therefore to enhance income and to ensure nutritional security of the small and marginal farmers off season vegetables cultivation under low cost poly houses is found to be economical and profitable enterprise

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Tuber crop varieties for integrated farming system

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Introduction

A farming system is the result of complex interactions among a number of inter-dependent enterprises/components, where an individual farmer allocates certain quantities and qualities of four factors of production, namely land, labour, capital and management to which he has access (Mahapatra, 1994). Farming system approach is a powerful tool for natural and human resource management in developing countries such as India. It is a multidisciplinary whole-farm approach and can be effectively employed in solving the problems of small and marginal farmers. The approach aims at increasing employment and income from small-holdings by integrating various farm enterprises and recycling crop residues and by-products within the farm itself (Behera and Mahapatra, 1999; Singh et al., 2006).The crop and cropping system based perspective of research needs to make way for farming systems based research conducted in a holistic manner for the sound management of available resources by small farmers (Jha, 2003). Under the gradual shrinking of land holding, it is necessary to integrate land based enterprises like fishery, poultry, duckery, apiary, field and horticultural crops, etc. within the bio-physical and socio-economic environment of the farmers to make farming more profitable and dependable (Behera et al., 2004). No single farm enterprise is likely to be able to sustain the small and marginal farmers without resorting to integrated farming systems (IFS) for the generation of adequate income and gainful employment year round (Mahapatra, 1992; 1994).

The crops and the variety to be grown should be selected based on their adaptability to the prevailing conditions in the farm. Furthermore, it is an advantage to have access to lists of different crops under the various plant classification based on natural adaptation or habitat. Root and Tuber Crops are the most important food crops after cereals and very important group for food security and income generation. All these crops are rich in starch and good source of energy. These crops are adapted to the wide range of agro-climatic conditions and give good performance even under marginal growing conditions. Tuber crops are hardy crops and fit well in various cropping systems. They have the highest rate of dry matter production per day and are major calorie contributors. Tuber crops not only enrich the diet of the people but also possess medicinal properties to cure many ailments or check their incidence.

Varieties

Cassava (*Manihot esculenta* Crantz)

H-97
Tubers are conical medium sized with 27-31 percent starch content. Duration 10months, average yield 25-35 t/ha
H-165
A short duration variety and field tolerant to CMD. High starch content. Easy harvest ability. Suitable for rotation cropping. A popular industrial variety. Average yield 33-38 t/ha.
H-226
Most popular industrial variety in Tamil Nadu. Duration 9-10 months. High starch content 28-30%. Average yield 30-35 t/ha.
Sree Visakham
It is good for culinary purpose. Duration 10 months. Starch content 25-27percent. Average yield 35-38 t/ha.
Sree Prakash
Tubers are medium sized, contain 29-31 percent starch. Early maturing 7 months duration. Average yield 30-35 t/ha.
Sree Harsha

Tubers have light brown skin, white flesh contain 38-41 percent starch. Duration 10 months. Average yield 35-40 t/ha.

Sree Jaya

Early maturing variety (6-7 month). A rotation crop. Excellent cooking qualitywith 24-27 percent starch content. Average yield 26-30 t/ha.

Sree Vijaya

Early maturing variety (6-7 month). A rotation crop in low land. Excellent cooking quality with 27-30 percent starch content.Yield 25-28 t/ha.

Sree Rekha

High yielder. Excellent cooking quality with 28-30 percent starch content. Suitable for upland and low land cultivation. Duration 8-10 months. Average yield 45-48 t/ha.

Sree Prabha

High yielder. Excellent cooking quality. Suitable for upland and low land cultivation. Duration 8-10 months.Average yield 40-45 t/ha.

Sree Padmanabha

First CMD resistant variety. Suitable for Irrigated and rainfed areas. Silvery white skin colour. 25-28%extractablestarchcontent. Average yield 38 t/ ha

5-3

Triploid variety shows robust growth, higher yield, high starch content, early maturity, shade adaptability and tolerance to mealy bug attack. High extractable starch (28-30%). Average yield 38 t/ha.

Sweet Potato (*Ipomoea batatas* L.)

Sankar

Red skin, creamy white flesh, medium duration (120 days), excellent cooking quality.Suitable for irrigated and rainfed conditions. Yield 14 t/ha

Gouri

Purple red skin, orange-fleshed variety with high beta-carotene content, medium duration (110-120 days). Can tolerate mid-season moisture stress. Suitable for kharif and rabi season. Yield 19 t/ha.

Goutam

Clonal selection after poly cross, medium duration (105-110 days) 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. Yield 18-20 t/ha.

Sourin

Clonal selection after poly cross, medium duration (105-110 days) tubers with red skin and creamy white flesh. Suitable for rainfed as well as irrigated, medium to uplands in both kharif and rabi seasons. Yield range 16-22 t/ha.

Kishan

Clonal selection after poly cross, medium duration (110-120 days).Purple skin and white flesh. Suitable for rainfed as well as irrigated, medium to uplands and hilly areas.Yield range 16-26 t/ha

Kalinga

Open pollinated sweetpotato variety, suitable for rainfed and irrigated uplands, medium duration (105-110 days).Purple red skinned tuber with creamy white flesh. Dual-purpose variety used for food and animal feed. Yield range is 25-28 t/ha

Sree Nandini

Drought tolerant, early maturing (100-105 days).Creamy yellowish skin and white flesh.Yield range 20-25 t/ha.

Sree Rethna

Early maturing (90-105 days) variety withpurple skin and orange flesh. Excellent cooking quality. Yield range 20-22 t/ha

Sree Bhadra

Early maturing (90 days) variety, excellent cooking quality and used as trap crop against root-knot nematode. Light pink skin and creamy white flesh. Yield 20-22 t/ha.The variety was found to have the maximum fodder yield of 19.44 t/ ha to cater for the demand for animal feed.

Sree Arun

Early maturing (90 days) variety. Pink skin and creamy white flesh. Yield range 20-28 t/ha

SreeVarun
Early maturing (90 days) variety. Creamy yellowish skin and creamy white flesh.Yield range 20-28 t/ha.
Sree Kanaka
Short duration (75-85 days) variety, rich in beta-carotene (8.8 – 10 mg/100g fresh tuber) Reddish yellow skin and dark orange flesh.Yield range 12-15 t/ ha.

Taro (*Colocasia esculenta*)

Sree Pallavi
Corms are comparatively bigger in size and cormels are small. Cormels are having good cooking quality and contain 24-25 percent starch. Duration 7 months. Average yield 15-18 t/ha.
Sree Rashmi
The corms are big and cylindrical and cormels are medium sized and having good cooking quality. It contains 15-15 % starch. Duration 7months. Average yield 15-20 t/ha.
Muktakesi
Excellent cooking quality. It contains 23 % day matter, Starch 16-18 % and 2 % total sugar.Tolerant to *phytophthora* blight. Duration 5-6 months. Average yield 20 t/ha.
Pani Saru – 1
Clonal selection. Suitable for water-logged/ submerged conditions of Orissa and also be grown under upland conditions. Brown skinned tuber with white flesh. Duration: 6-7 months.Yield – 15.74 t ha^{-1}
Pani Saru –2
Clonal selection. Suitable for water-logged/ submerged conditions of Orissa and also be grown under upland conditions. Brown skinned tuberwith white flesh. Duration: 6-7 months.Yield – 12.83 t ha^{-1}

Elephant foot Yam (*Amarphophalus paeoniifolius*)

Gajendra
The cooking quality is very good and free from acridity. Produce smooth corm of white flesh, free from daughter corms. Perform well in eastern and southern India. Average Yield 50-60 t/ha.
Sree Padma
The tubers are non acrid and generally have one mother corm and a few cormels. Duration 8-9 months. Starch content 12-13% and average yield 42 t/ha.

Greater Yam *(Dioscorea alata)*

Orissa Elite
Suitable for rainfed/ irrigated conditions of Orissa. Maturity 180 days, Resistant to yam virus. White flesh with good cooking quality with 20 % starch. Average yield – 22-25 t/ ha
Da-25
Excellent cooking quality. It contains 32-33% dry matter, 18-20 % starch and 1-1.5 % total sugar. Average yield 20-25 t/ha.
Sree Keerthi
Good cooking quality. It contains 20-22 % starch. Duration 9-10 months. Average yield 25-30 t/ha.
Sree Roopa
Excellent culinary properties. It contains 16-18 percent starch. Duration 9-10 months. Average yield 25-30 t/ha.
Sree Shilpa
Excellent cooking quality. It contains 17-19 percent starch. Duration 8 months. Average yield 28 t /ha.

White Yam (*D. rotundata*)

Sree Priya
Tubers are cylindrical with brown skin and white flesh. It has good taste and contains 19-21 percent starch. Duration 9-10 months. Average Yield 35-40 t/ha.

Sree Subhra
Brown skin with white flesh tuber. Good cooking quality. It contains 21-22 % starch. Duration 9-10 months. Average yield 35-40 t/ha.
Sree Dhanya
Brown skin and white fleshtuber. Duration 9 months. It contains 22-24 % starch. Average yield 20-25 t/ha.

Lesser yam(D*. esculenta*)

Sree Latha
Duration 8 months. Contains 18-19 % starch. Average yield 25-30 t/ ha.
Sree Kala
Excellent culinary qualities. Duration 7-8 months. Contains 23-25 % starch. Yield 20 t/ha.

Yam Bean (*Pachyrhizus erosus*)

Rajendra Mishrikand 1 (RM-1)
Sweeter,comparatively free from cracking with smooth surface. Cream coloured tuber skin with white flesh. Duration 110-140 days. Individual tuber weighs 0.6 – 0.7 kg.Average tuber yield 40 – 55 t /ha

Conclusion:

Tuber crops are nutritionally rich mainly of essential vitamins and minerals which make human diet complete and help human being physically fit and mentally more sound. To make the family members' diet nutritionally rich and bring prosperity, tuber crops was considered more appropriate to integrate in integrated farming system. It will provide opportunity to mitigate malnutrition problem of the farmers.

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Integrated disease management in tuber crops

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Introduction

Like other crops, tuber crops are also prone to diseases caused by virus, fungus and bacteria. Among these virus diseases are very serious because it is present in the tubers and stems which are the propagating material generally. Identification is an essential component for formulating management strategies. Now-a-days apart from symptomology, molecular techniques like ELISA and PCR based techniques are used for detecting the pathogen rapidly. Since we have to move the planting materials from one country to another for our research and development, we should have knowledge on diseases infecting tuber crops in view of quarantine to avoid spreading of new diseases. Since tuber crops are vegetatively propagated, planting materials are the major mode of transmitting the diseases. Disease-free planting material/seed is essential for successful cultivation of any crop. The diseases and integrated management for major diseases are discussed here.

Diseases of sweet potato

Fungal diseases

Fungal diseases are not severe in sweet potato. The chlorotic distortion caused by *Fusarium* sp. cause distortion and chlorosis symptom in the young leaves. The fungus will grow as a powdery coat on the leaf surface. The leaf spots caused by *Cercospora* sp. produce brown coloured spots surrounded by yellow halo.

Viral diseases

In sweet potato**,** viral diseases are important ones. The symptoms of sweet potato feathery mottle disease (SPFMD) on many cultivars can be mild, transient, or may not appear at all on sweet potato foliage. Many cultivars do not exhibit foliar symptoms of SPFMD, but do induce SPFMV symptoms on *I. setosa* after grafting. Plant age, light intensity, temperature, and leaf pigment have been shown to have an effect on SPFMV symptom expression in sweet potato. Several types of symptoms expression of SPFMD in sweet potato have been reported from different parts of the world which includes ring spot, feathering, chlorotic specks, leaf curl / leaf roll, yellow netting, mosaic, witches' broom. Most of these symptoms were best observed during the early growth period and they were generally mild and transient which is similar to that of as described by earlier workers. The most distinctive symptom of the virus, irrespective of strain, present is the chlorotic feathering of the leaf midrib and in some genotypes, the expression of chlorotic spots with purple rings. Symptoms of sweet potato leaf curl include leaf curl and leaf cupping or inward rolling of leaf margin. Symptoms associated with SPVD are variable and depend on the sweet potato genotypes. The most characteristic symptoms include vein clearing, severe stunting, chlorosis, leaf strapping, excessive branching, short internodes, indistinct vein banding and indefinite mosaic, mottling, and purpling on lower leaves in some varieties.

Diseases of yams

Yam anthracnose disease
Anthracnose disease of yam has had a considerable impact on yam production worldwide. All the above cultivated species are infected by the diseases but *D. alata* is highly susceptible.
Causal organism
This is caused by *Colletotrichum gloeosporioides*. IITA reported that *Glomerella cingulata* is the perfect stage of *C. gloeosporioides*, the form that is usually found causing field anthracnose disease.
Symptoms

On susceptible yam cultivars, symptoms appeared as small dark brown or black lesion on leaves, petioles and stems. The lesion is often surrounded by a chlorotic halo enlarged and coalesces, resulting in extensive necrosis of the leaves and die-back of the stem.

Management

- Use of crop rotation, fallowing, removal of debris and ploughing immediately after harvest also helps to reduce the inoculam,
- Planting of healthy material and destruction of infected cultivars.
- Spraying Dithane M-45 (0.2%) and Bavistin (0.25%)

Leaf spot disease

Dioscorea alata is infected by many leaf spot diseases whereas other species are not much affected.

Cercospora leaf spots

Next to anthracnose, leaf spots caused by Cercospora spp are important. It is caused by different species, viz., C. carbonaceae, C. dioscoreae, Pseudocercospora contraria and C. golaghatii. Among these, leaf spot caused by P. contraria is causing severe leaf spot. It starts as small chlorotic leaf spot which enlarges and finally turns necrotic. In each leaf large number of spots could be seen which will coalesce in the latter stage.

Black spot

The black spot/ leaf blight caused by *Sclerotium rolfsii* showed black, circular, concentric spots 5–10 mm in diameter in the middle and bottom portion of the vines. As the disease advanced, the central portion of the leaf spots dried and fell out, resulting in shot-hole symptoms. When the leaves are wet, abundant fluffy white mycelia emerged from the leaf spots.

Management

- Field sanitation by removal of debris after harvest
- Spraying Dithane-M-45 (0.2 %) or Bavistin (0. 2%) when the symptom initiates and three sprays at weekly intervals

Viral diseases

Seven different viruses are reported to infect *D. alata* plants. The infected plants show mosaic, green banding, chlorosis, leaf distortion etc. In India not much work has been done on viral diseases of yams except some preliminary studies at CTCRI. The studies revealed the wide prevalence of *Dioscorea alata potyvirus* (DAPV), *Yam mosaic virus* (YMV) belonging to the genus *Potyvirus*, Cucumber mosaic virus belonging to Cucumovirus and a *Badna Virus, Dioscorea alata badnavirus* (DABV).)

Dioscorea alata virus

This virus infects all the three edible species of *Dioscorea*. This is single stranded RNA poty virus with flexuous rod shape about 12 x 750 nm size. In *D. rotundata* it causes mild mosaic and leaf distortion. In *Dioscorea alata* also mosaic, mottling, leaf distortion and cupping. In *D. esculenta* severe mosaic, leaf distortion and puckering is observed. It is not transmitted mechanically but is transmitted by *Aphis craccivora* to certain cultivars of cowpea. From that it can be mechanically transmitted to *D. alata*. It could be detected using ELISA methods and RT-PCR using DAV specific primers.

Yam mosaic virus

YMV is the most important virus known to cause yield loss of about 27% on *D.alata* in Ivory Coast (Thouvenel and Dumont, 1990). This is found in *D. alata* and *D. rotundata* which cause mild mosaic in *D. rotundata* and *D. alata*. This is also single stranded RNA poty virus almost similar to DAV in size. It is non persistently transmitted by *Aphis gossypii* and mechanically transmitted to *Nicotiana benthamiana.* This could also be detected through ELISA and RT-PCR methods.

Cucumber mosaic virus

The infected leaves shows chlorosis and mosaic. This is found in *D. esculenta* and *D. rotundata* along with other viruses.

Dioscorea alata Badnavirus
Single stranded DNA virus which causes mosaic as well as leaf distortion in *D. alata*. This has not been observed in other species. This could be detected using ELISA and PCR methods using universal Badna primers.

Mixed infection
The mixed infection of DAV,and CMV is found in *D. rotundata and D. esculenta. DAV and DABV in D. alata.*
Management
Since yams are propagated through tubers and since the viruses are present in the tubers it is difficult to manage after planting. So, Selection of healthy planting materials is an important criterion. Tubers should be selected from healthy plants. Meristem culture can also be utilized to get disease free material as mother stocks. In CTCRI as well as other countries resistant lines are available in germplasm which can be utilized for developing resistant cultivars.

Minor diseases
Leaf spots caused by *Curvularia lunata var. aeria* and *Pestalotiopsis* s. and were also isolated from India which is not causing much damage to the crops.

Diseases of cassava

Cassava mosaic disease (CMD)
A severe mosaic disease was recognized as a serious threat to cassava cultivation in India as early as 1942. African cassava mosaic disease reported by Walburg in 1984 occurs in African countries and West Pacific islands. There are six different viruses recorded causing mosaic symptoms on cassava.
Symptomatology
The first symptom appears on young leaves as chlorotic speck. Gradually they enlarge and intermix with green tissue to provide a mosaic pattern. The pale discoloration may be intensified to yellow colour depending on the varieties
Causal organism
Cassava mosaic disease is caused by a single stranded DNA virus belongs to Gemini group. The Indian Cassava mosaic virus (ICMV) is serologically different from African Cassava Mosaic Virus (ACMV). Two biotypes of ICMV, viz., Indian strain and Srilankan strain are recorded.

Yield loss
Tuber yield of diseased plants vary with different varieties as well as time of infection. Up to 80% crop loss has been recorded in highly susceptible varieties as against 18% in field tolerant varieties. Crop loss will be maximum when the disease appear at the time of planting .No reduction in yield has been recorded when the disease occurred after 5 months of planting.

CMD can be effectively managed though the adoption of the following practices as follows

- Use of disease free planting materials
- Use of field tolerant cultivars-viz., H-165, Sree Vijaya, 4-2,5-3, MNga-1,MVD-1, CO-3,CO-4 etc
- Timely rouging of infected plants
- Use of trap crop viz., red gram, maize etc
- Use of meristem derived plants
- Use of true seed plants
- Nursery techniques
- Transgenic

Varietal reaction
Though all available cassava varieties take up CMD infection, symptom expression vary with different varieties several highly susceptible local varieties viz., Kalikala, Arimaniyan etc. are totally extinct due to heavy infection. The hybrid varieties from CTCRI viz., H-165 H-226 etc. though susceptible to ICMV provide sufficient tuber yield Tripoids 4-2 and 5-3 show good field tolerance to ICMV. Recently introduced cassava line from IITA Nigeria MNga-1 (Sree Padmanabha) has high degree of field tolerance to ICMV.

Transgenic plants
Resistant cassava plants could be produced against African cassava mosaic virus through coat protein mediated resistant genes (CPMR). Similar attempts are made at CTCRI against ICMV. The resistant gene could be successfully introduced into cassava genome through bacterial vectors.

Nursery technique
Growing single node cuttings in nurseries and transplanting only the healthy plants to main field will avoid the primary infection and thus reduce the loss to some extent.

Tissue culture
Generally meristem tip is free from the viruses .Hence meristem tip culture is an efficient tool for the elimination of CMD and regeneration of disease free planting material. The synthetic Murashige & Skoog Medium is very efficient for the successful cassava meristem culture. Trials showed that meristem derived plants gave higher tuber yield than normal plants.

Cassava tuber rot
This disease has been reported in Africa and Tropical America causing yield loss up to 80%. Three species of *Phytophthora* viz. *P. drechsleri, P. erythroseptica* and *P. cryptogea* are recorded as primary pathogen in these countries. In India, cassava tuber rot was recorded during 1995 from cassava plantations around Salem district in Tamil Nadu. The causal agent has been identified as *Phytophthora palmivora.*

The causal organisum
The fungus *Phytophthora* is constantly associated with cassava tuber rot disease. The pathogen was identified as *Phytophthora palmivora.*

Symptoms
There will be no external symptom on the plant. Dark round to irregular water soaked lesions appears on mature tubers. White mycelial mats of the pathogen develop around these lesions. The lesions enlarge causing internal browning oozing of internal fluids and shrivelling of the tubers. The infected tubers emit characteristic foul smell and rot with in 5-7 days. With the available information about pathogen, predisposing factors and role of biocontrol organisms a field management trial conducted at Salem for consecutive years in a heavily infected garden gave promising results. Most successful treatment included deep ploughing (up to 24 inches), planting the sets on top of ridges, controlled irrigation, application of neem cake (250 kg/ha) and incorporation of *Trichoderma viride.*

All rotten tubers were removed as part of hygienic cultivation. The above treatment gave a tuber yield of 45.50 t/ha with 11.5% disease incidence as againt 25.0 t yield and 100% infection in the control plot (farmers practice). The above package being very affective is well adapted by the Salem farmers for the management of cassava tuber rot disease.

Biological control
Among the biocontrol organisms tested, species of *Trichoderma* viz., *T. viride* and *T. harzianum* gave good antagonistic activity against the pathogen under laboratory condition. The bacterium *Pseudomonas florescens* also gave good suppression of the pathogen. A native strain of *Trichoderma viride* isolated form heavily infected field at Salem which gave good antagomistic activity as well as survival ability In Salem soils were multiplied in sorghum grains and used for the management trials.

Cassava bacterial blight
It is a serious disease in South American countries *viz.,* Brazil, Columbia and Venezuela as well as in certain African countries. The disease cause complete crop loss. The disease is characterized by leaf spotting, blight, wilting, die back, gum exudation and vascular necrosis. *Xanthomonas manihots* is identified as the primary causal organism of the disease. The bacterium spreads through soil, infected tools, rain splashing and infected planting materials. Use of disease free planting materials and resistant varieties suggested.

Die-back/ Anthracnose
Anthracnose caused by *C. gloeosporioides fsp manihotis* leads to die-back or white tip symptoms killing the terminal shoots under favourable conditions. The disease is observed only during prolonged

rainy period. Wider spacing, balanced fertilizer application, destroying the inoculum source and use of tolerant cultivars like H-97, Sree Visakam and Sree Sahaya help in avoiding the yield losses.

The disease is caused by *Colletotrichum manihotis(Glomeralla cingulata*). Spraying with 0.2 % Dithane -M-45 or 0.1 %. Bavistin gives good control of the disease. Association of *Phyllosticta s*p./ *Phoma sp.* are also recorded from dieback infected cassava shoots.

Diseases of taro

Taro leaf blight

Leaf blight of taro, caused by *Phytophthora colocasiae* Raciborski, is the most destructive disease of colocasia. Butler and Kulkarni reported this disease in 1913 for the first time in India. This disease is reported to have destroyed taro plantings all the taro growing countries. In addition to leaf blight, *P. colocasiae* Rac. causes a serious post harvest decay of corms.

Symptoms

Phytophthora blight of colocasia appears as small, water soaked spots that increase in circumference and also spread to healthy plants. Yield losses of 25-50% are common due to this disease.

Causal organism

Raciborski first described the causal organism of leaf blight of taro as *Phytophthora colocasiae* in 1890 from Indonesia.

Management

Several methods for the management of leaf blight of colocasia have been recommended but the use of tolerant cultivars seems to be the most ideal and economical method. Many cultivars of taro tolerant to leaf blight have been reported from India. Two cultivars, "Muktakeshi" and "Jankhri" have shown high degree of field tolerance to blight. The variety "Muktakeshi" has been released for all India cultivation due to its high yield potential, excellent cooking quality and resistance to leaf blight.

Recently the glucan elicitors have been isolated from the *P. colocasiae* isolates. The PC-glucan elicitor could induce hypersensitive reaction in the field tolerant cultivars like Muktakeshi and Jankheri while the induction of hypersensitive reaction was not induced or delayed in the susceptible variety (Telia). A technique for *in vitro* screening of the colocasia varieties for leaf blight resistance using PC-glucan elicitor has also been standardized.

Copper fungicides have proved very effective in successfully controlling the disease in many places. Mancozeb, Metalaxyl, Captafol and Chloroneb were also found to be effective in controlling *Phytophthora colocasia*e under *in vitro* and *in vivo* conditions.

Planting time can be shifted in such a way that crucial stage of plant growth and optimum climatic conditions for disease development do not coincide with each other. May planting with short duration variety gave highest tuber yield and escaped much of the damage caused by blight.

Removal and destruction of infected leaves and use of healthy corms and crop rotation have been recommended as control measures. Mulching with paddy straw and taro cultivation as intercrop with non-host crops gives better yield, good weed control and lowers disease severity. Since the disease has been reported in many countries, strict quarantine measures should be observed to prevent further spread of this disease and movement of taro between countries should be limited to sterile, pathogen tested plantlets growing in tissue culture medium.

A farmer's friendly IDM package for the management of the taro blight has been developed at CTCRI. The package includes growing resistant variety like "Muktakeshi", short-duration variety with early planting, one protective spray with mancozeb (0.2%) at 45 days after planting followed by one more spray with Metalaxyl (0.05%) at 60 days after planting in susceptible cultivars, intercropping with non-host crops, use of disease free seed tubers and seed tuber treatment with *Trichoderma viride*.

Dasheen mosaic

This disease is caused by virus and is widely spread and observed in the entire region. However, the incidence of this disease is generally less than 2% and all the leaves of mosaic-infected plants do not show the symptoms. The disease is characterized by interveinal yellowing along the major veins and vein lets. In severely infected plants leaf distortion symptoms like cupping, curling and shoestring appearance are observed. This disease is sap transmissible. From economic point of view, this disease is not considered to be significant. However, use of seed tubers from mosaic-infected plants should be invariably avoided.

Corm rot

The corm rot caused by *P. colocasiae* is commonly found. The symptoms in young plants may be confined to small spots, which later cause severe stunting or death of the plant. In older plants, chlorosis, stunting and wilting followed by collapse of the whole plant are seen. Dipping planting material in fungicides and soil drenches have been suggested. Dasheen type of taro is affected by the *Pythium* rot. *P. myriotylum* causes serious root rot disease in taro under high soil moisture (60%) and high temperature (25 - 30%). *Sclerotium rolfsii* causes soft rot, which is easily recognized by the presence of white mycelial growth with distinct Sclerotia on the infected parts. *Fusaium* spp., like *F. solani* and *F. coeruleum* cause dry rot of the tubers. The infected tubers are brown, black, dried and shrunken with deposition of dry powder like fungal growth. Dry rot caused by *Fusarium* spp. casuses major loss of taro tuber in storage.

Diseases of *Amorphophallus*

Mosaic

Amorphophallus mosaic affects several cultivated species including *A. paeoniifolius* and *A. konjac*. In a survey of *Amorphophallus paeoniifolius* growing areas, up to 5% mosaic infected plants were found in different states of India. Generally, the mosaic symptoms were present in second or third leaves while the first leaf remained symptom-free. In such cases where the first leaf showed mosaic symptoms, the plants remained very weak and all the new leaves also showed severe symptoms. The mosaic-infected plants are generally dwarfed and chlorotic in appearance and exhibit mosaic mottling which is more pronounced in young leaves.

Using planting material from mosaic-free plants is the best way to avoid the disease. Hot air treatment of mosaic-infected tubers at 45° C for 10 min. before planting followed by two sprayings with Monocrotophos (0.05%) or any other broad-based insecticide at 60 and 90 days after planting significantly reduced *Amorphophallus* mosaic incidence and there was a corresponding increase in tuber yield. Mosaic-free plants are produced using micropropagation techniques in several crops. Shoot tips of *Amorphophallus konjac* induced protocorm-like calluses (PLC) on medium containing NAA, and the continuous division of PLC yielded plantlets in large quantities. DMPV (dasheen mosaic potyvirus) and KMV (konjac mosaic virus) were eliminated at a high rate when shoot tips were cut off at 0.3-0.5 mm.

Collar rot

Collar rot is the most common disease, and prevalent in all *Amorphophallus* growing areas. This disease occurs in serious form if the clay content is more in the soil and drainage facilities are not proper. It is caused by *Sclerotium rolfsii* Sacc. This disease is generally observed in the later part of crop growth but the pathogen is capable of infecting the plants at any stage. The disease is more destructive during the rainy season followed by warm dry weather. The pathogen is soil borne and passive type. Injury to the collar region during intercultural operations acts as a predisposing factor for infection by *S. rolfsii*. As a result of invasion by the pathogen in the collar region, water-soaked lesions appear on the stem just above the soil surface and the leaf starts turning yellow from the tip. Yellowing gradually spreads downwards leading to the complete yellowing of the plant. Finally the petiole (pseudostem) shrinks and the plant collapses due to rotting of the collar region causing heavy yield loss. A thick, white mycelial mat with globular dark brown mustard-seed like structures called sclerotia, the fruiting bodies of the pathogen, can be seen all around the affected tissues. The pathogen survives through these sclerotia during the off-season. Repeated cultivation of *Amorphophallus* in the same field leads to increased incidence of the disease. There are large numbers of alternate hosts for the pathogen. Heavy rains, warm and humid weather, heavy soils, high organic matter, poor drainage and injuries caused by insects, fertilizers and implements act as predisposing factors for disease incidence.

Cultural practices like removal of infected plant debris and crop residue and proper drainage minimize the disease incidence. Thick mulching with paddy straw or other organic waste reduces the frequency of weeding and other intercultural operations, thereby avoiding injury to the plants. *Trichoderma* spp. has been found very effective against collar rot.
Leaf blight / Leaf rot

Leaf blight/leaf rot is more common in highly humid and warm areas. Leaf blight is caused by *Phytophthora colocasiae* Racib. Symptoms of leaf blight are generally observed in lower leaves. Small water-soaked lesions develop on the leaflets. These spots coalesce, enlarge and give rise to a blighted appearance. The secondary spread is through sporangia and zoospores, which are carried by rain droplets. Inoculum may also come from taro field infected with *P. colocasiae*. However, compared to taro leaf blight, *Amorphophallus* leaf blight is less serious.

Leaf blight of *Amorphophallus* is also caused by bacteria, viz., *Pseudomonas pseudoalcaligens* sub sp. *konjaci* and *Erwinia carotovora* sub sp. c*arotovora*. A bacterial leaf spot disease caused by *Xanthomonas amorphophalli* on *Amorphophallus has also been* reported from India.

Leaf rot caused by *Corynespora cassicola* appears as minute, oval to sub circular, reddish brown spots on the leaves. These spots gradually enlarge and become irregular in shape and are prominently visible as light brown necrotic areas, encircled by reddish brown margin. The centre of the spots dry and becomes brittle, break and fall off leaving shot holes.

Post harvest diseases of *Amorphophallus*

Tuber rot could be a serious problem in *Amorphophallus* if the planting material used for raising the crop is infected. Injuries during harvest and transport further aggravate the problem of tuber rot. Infestation of the roots and tubers by *Meloidogyne incognita* acts as a predisposing factor for infection by a large number of fungi.

Six major pathogens that cause post-harvest rotting of elephant foot yam tubers have been reported. Of the six pathogens, five fungal pathogens viz., *Botryodiplodia theobromae, Sclerotium rolfsii, Fusarium* spp*., Phytophthora colocasiae* and *Rhizopus* spp. caused considerable damage to tubers. One bacterial pathogen, *Erwinia carotovora* was found to cause serious damage to tubers stored at higher temperature with poor ventilation.

Collar rot
Cultural practices like removal of infected plant debris and crop residue and proper drainage minimize the disease incidence. Thick mulching with paddy straw or other organic waste reduces the frequency of weeding and other intercultural operations, thereby avoiding injury to the plants. *Trichoderma* spp. has been found very effective against collar rot.

Storage rot
To avoid storage rot, tubers free from mechanical injury, infection and field soil should be used for storing. However, if it is essential to use infected tubers for planting purpose, the infected portions should be removed with a sharp knife in such a way that no infected portion is left on the tubers. While removing the infected portion, even the healthy tissues adjoining infected portions should be removed. Cuts tubers should be immediately treated with Mancozeb (0.2%) and stored in a single layer before planting. Storage of seed tubers of *Amorphophallus* in a cool and ventilated place followed by periodic removal of damaged tubers has been found good.
Management of field and storage diseases of *Amorphophallus*

Amorphophallus diseases cause serious yield losses. The following integrated disease management evolved at CTCRI has been found very effective for managing the major field diseases of *Amorphophallus*.

- Use of healthy planting material with no symptoms of tuber rot and obtained from mosaic-free plants.
- Mulching with dry paddy straw/plant leaves or black polyethylene sheets.

- Tuber treatment with Cowdung slurry mixed with *Trichoderma* before planting.
- Application of *Trichoderma* enriched compost in pits before planting**.**
- Two preventive sprayings with Mancozeb (0.2%) + Monocrotophos (0.05%) at 30 and 60 days after planting.

Xanthosoma and *Alocasia* crops are generally free from major diseases. While, *Xanthosoma* is affected by minor leaf spot and tuber rot diseases, *Alocasia* is affected by leaf blight caused by *P. colocasiae*, but the disease severity is generally very low and the disease is not of much economic significance

Conclusion

It has been seen in the last ten years, plant viruses are becoming more widespread and there are real threats of new virus epidemics. It is therefore essential that the movement of viruses around the world be documented and quarantine restrictions put in place where necessary. Among the methods of detection outlined above, arrays capable of detecting a wide range of viruses show the most promise of accurately identifying new viruses as they move to new geographical areas and to new hosts. At present, however, the costs and technical difficulties of designing, constructing and utilizing microarrays limit its use. Hopefully, costs will reduce as chips become available commercially and as economies of scale are realized. In the meantime, organizations ideally should utilize more than one diagnostic technique, and they should screen for high-risk pathogens even where they are not known to exist in the region. ELISA with polyclonal or monoclonal antiserum may be used for large scale testing of plant materials. NASH or PCR based techniques may be utilized to confirm the identity of new pathogen or for double confirmation in case of quarantine pests or high risk pathogens.

Climate smart IFS for sustainable production and farm income

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Introduction

Climate smart agriculture is based on certain principles viz. specificity(S) of objectives, measurable (M) quantity emission reduction, achievable(A) plan, realistic(R) approach and tangible(T) gain. As per deliberations at the Second Global Conference on Agriculture, Food Security and Climate Change in Hanoi in 2012, the Climate Smart Agriculture emphasizes on benefiting primarily smallholder farmers and vulnerable people in developing countries. Climate-smart agriculture, forestry and fisheries (CSA), as defined and presented by FAO at the Hague Conference on Agriculture, Food Security and Climate Change in 2010, contributes to the achievement of sustainable development goals. It integrates the three dimensions of sustainable development (economic, social and environmental) by jointly addressing food security and climate challenges. It is based on the following three main pillars.

1. Reduction and/or removal of greenhouse gases emissions where possible
2. Adaptation and building resilience to climate change
3. Sustainable increase in agricultural productivity and incomes

Reduction and/or removal of greenhouse gases emissions where possible

Global warming is basically a change in the climatic conditions of the Earth, brought about by a considerable rise in the near-surface temperature of the planet. Earth's surface and the troposphere become warmer due to absorption of infrared radiation emitted by the Earth's surface by Greenhouse gases. The important green house gases include carbon dioxide(CO_2), methane(CH_4), nitrous oxide(N_2O), chloro-fluoro-carbons(CFCs), ozone(O_3) and water vapours(H_2O). Relative contribution of GHG's viz. carbon dioxide, methane, nitrous oxide, chloro-fluoro-carbons and ozone to global warming is 50, 1. 7. 23 and 9 %, respectively**.** The GHG emission sectors viz. electric power plants, agriculture, residential / commercial houses, industry and transport contributes 35.7, 7.1, 6.0, 36.8 and 14.4 % of total emission, respectively. Fuel sources like coal, oil and natural gas account for 70.3, 27.5 and 2.2 % of total emission.

Carbon Dioxide comes from fossil fuel, deforestation and failing sinks. Methane is released from cattle and low land rice fields, the arctic tundra and clathrates. Nitrogen Oxides is generated from faulty agricultural practices**.** The role of ocean as carbon sink is steadily diminishing. The oceans are no longer able to store carbon as they have in the past. The ocean is a huge carbon sink, holding about 50 times as much carbon as the atmosphere. The increased thermal stratification of the oceans has caused substantial reductions in levels of phytoplankton, which store CO2. As carbon sinks fail, the amount of carbon in the atmosphere climb. Methane has Huge Impact on global warming. Per unit of volume, it is twenty times more potent than carbon dioxide when its impact is measured over the course of a century. When one considers its effects within a single decade, methane is 100 times as powerful as carbon dioxide as a GHG.

Carbon levels in the atmosphere are about 385 parts per million (ppm) currently, whereas methane is only about 1.8 ppm. But because methane is so powerful, it has the potential to have significant impacts on the future of global warming.

Methane is created when bacteria break down organic matter under oxygen-starved conditions. This occurs when organic matter is trapped underwater, as in low land rice fields. It also takes place in the intestines of herbivorous animals, such as cows, sheep, and goats. Landfills and leakage from natural gas fields (methane is a component of natural gas) are also significant sources of methane. Clathrates are a hidden source of Methane. Clathrates are frozen chunks of ice and methane that rest at the bottom of the world's oceans. As the water warms, the ice melts, and the methane is released.

If the current global warming, which is caused by humans, were to cause changes in the Earth's ocean currents, then a rapid melting of clathrates would be possible. This too would create a positive feedback loop that would cause further global warming. It is believed that some of the warming cycles in the Earth's history have been caused by the sudden thawing of clathrates.

Agriculture is responsible for 7.1% of the total GHG emission by different sectors. This sector contributes carbon dioxide, methane and nitrous oxide to atmosphere. Farming practices should be designed to check emission of these gases.

Adapting and building resilience to climate change/natural disasters

Abnormal weather events/natural disasters are becoming common as a consequence of climate change. A natural disaster is a major adverse event resulting from natural processes of the Earth. Natural disasters include floods, volcanic eruptions, earthquakes, cyclones, tsunamis, and other geologic processes. A natural disaster can cause loss of life or property damage, and typically leaves some economic damage The severity of a natural disaster depends on the affected population's resilience, or ability to recover. Among natural disasters, floods and cyclones are very common in Odisha. Farming practices should be resilient to the weather adversities.

Sustainably increasing agricultural productivity and incomes

Climate-smart agriculture addresses the impacts of a changing climate on agriculture and presents solutions to both mitigate the contribution of agriculture to greenhouse gas emissions and to feed an ever-increasing global population. Farming practices, such as incorporating perennial trees into farms, rain water capture technologies, mixed/inter-cropping, integrated crop-tree-livestock systems, increase resilience to climatic stress, building soil organic matter, and sequestering carbon. Agriculture is considered to be "climate-smart " when it contributes to increasing food security, adaptation and mitigation in a sustainable way. Any agricultural practice that improves productivity or the efficient use of scarce resources can be considered climate-smart, because of the potential benefits with regard to food security, even if no direct measures are taken to counter detrimental climate effects. In addition, virtually any agricultural practice that reduces exposure, sensitivity or vulnerability to climate variability or change like water harvesting, terracing, mulching, drought-tolerant crops, community activities are also climate-smart because they enhance farmers ' ability to cope with weather extremes. Likewise, agricultural practices that sequester carbon from the atmosphere (for example, agroforestry, minimum tillage), reduce agricultural emissions (for example, manure management, biogas plants, reduced conversion of forests and rangeland) or improve resource use efficiency (for example, crop varieties and livestock breeds with higher productivity, improved crop management and animal husbandry) can all be considered climate-smart because they contribute to slowing the rate of climate change.

Categorization of farmers as per size of landholdings

As per the recommendation of FAO Programme for the World Census of Agriculture, the holdings have been classified into 18 size classes in terms of the 'operated area'. The classification is given in Table 1.

Table 1. Recommendations of FAO on size classes for tabulation of data from agriculture census and their application in India

FAO recommendations	Classifications used in India	
Size of holdings	For statistical purposes	For policy purposes
Less than 0.1 ha	Less than 0.02 ha	Marginal Farmers (below 1 Ha)
0.1– 0.19ha	0.02- 0.5	

0.2– 0.49ha		
0.5 –0.99ha		
1 – 1.99 ha	1-2 ha	Small Farmers (1-2 ha)
2 – 2.99 ha	2-3 ha	Semi-medium Farmers (2-4 ha)
3 – 3.99 ha	2-4 ha	
4 – 4.99 ha	4-5 ha	Médium Farmers (4-10 Ha)
5 – 9.99 ha	5-7.5 ha	
	7.5-10 .0 ha	
10 – 19.99 ha	10-20.0 ha	Large Farmers (over 10 ha)
20 – 49.99 ha	20.0 ha and above	
50 – 99 ha		
100 – 199 ha		
200 – 499 ha		
500 – 999 ha		
1,000 – 2,499ha		
2,500 ha and over		

Diversification of rice farms in Odisha through farming system approach

Marginal and small farmers depend mainly on production of agricultural crops for livelihood. This enterprise is usually subjected to high degree of risk and uncertainty and provides only seasonal, irregular, uncertain and low income and employment. Rice is the staple food crop in the state and rice-based cropping systems are predominant. In different rice growing ecologies, productivity is declining due to several bio-physical, edaphological, socio-economic, technological and institutional constraints. Average land holding and present level of productivity from rice based cropping systems cannot sustain a 6-member rural farm family in the state. Besides, decline in crop productivity has led to food and nutritional insecurity. It is the need of the hour to integrate crop and other allied enterprises in a harmonious manner to obtain appreciable net return (Behera *et al*., 2010). Various enterprises, viz. crops, tree, livestock and ancillary enterprises are to be integrated in Integrated Farming System (IFS) for better and sustainable livelihood. Harvesting of surplus rain water during rainy season by constructing farm ponds in 10% area of the farm enhances opportunity for diversification in space and time dimension. Ghosh *et al.* (2009) observed enhancement in cropping intensity, employment generation and farm income due to rain water harvesting and its efficient recycling.

A farming system is defined as the population of individual farm units that have broadly similar, resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate. Farming system involving crop-tree-animal integration has become essential for small and marginal farmers due to shrinkage in area under cropping and need for meeting household requirement from limited holding, small and fragmented land holdings, seasonal nature of income and employment in rainfed belt and out-migration and deterioration of resource base.

Principles and practices of integrating enterprises in rice based IFS

1. Maximisation of productivity of component enterprises and system productivity to provide steady and stable income at higher level.
2. Farm house hold self sufficiency with focus on food and nutritional security.
3. Creating opportunities for gainful employment round the year for ensuring higher standard of living and checking migration
4. Efficient management of resources with due emphasis on *in-situ* recycling of organic residues. Primary/secondary produces/wastes of one component should be utilized as input for other component.

5. The components should be interlinked and interacting for complementarity.
6. Enterprise dimension is decided by size of holding.
7. Enhancement of factor productivity i.e. soil, water, fertiliser, energy, labour and time and decrease in cost of cultivation.
8. Continuous spread/flow of income round the year.
9. Maintaining/enhancing quality of environment with due emphasis on biological diversity &ecological stability.

Experimental findings

Field experiments were conducted at five cluster of villages located in five different blocks viz. Khajuripada of Kandhamal district, Dhenkanal Sadar and Odapada of Dhenkanal district, Golamunda and Narla of Kalahandi district of Odisha under rainfed medium land situations during 01 April 2010 to 31 March 2013. The experiments aimed at comparing performance of pond based integrated farming system model comprising rice-onion sequence cropping system, multilayer pisciculture, poultry and mushroom with conventional cropping system of rice-green gram in 0.8 and 1.6 ha size farm. The following four enterprises were integrated in IFS models(Behera *et al.*, 2015).

a) Cropping

Rice cv. Lalat in *kharif was* followed by onion in *rabi* in an area of 0.7110 ha and 1.4310 ha under 0.8 and 1.6 ha models, respectively under pond conditions. Performance of the IFS models was compared with rice- greengram cropping grown under rainfed conditions.

b). Pisciculture

Composite fish culture was followed with *catla, rohu* and *mrigal* @ 5000 fingerlings/ha in 3:4:3 ratio. Pond dykes were utilised for planting horticultural crops viz. papaya, banana and drumstick.

c). Poultry

Most of the farmers reared local birds. For high return, broiler farming was introduced.

d). Mushroom

Three tier system mushroom unit of size 7.5 m X 3.6 m to produce paddy straw mushroom during March- October(8 batches) and oyster from November- February(2 batches) were integrated with cropping to utilize rice straw**.**

Productivity

The 0.8 ha IFS model(Table 2) gave 3.0 t grain of rice, 15.3 t onion, 213 kg fish, 1570 kg fruit of papaya, 843 kg banana, 525 kg drumstick, 852 kg poultry meat, 901 kg paddy straw and 714 kg oyster mushroom and recyclable wastes of 3.3 t paddy straw, 0.9 t onion leaves, 3 t pond silt, 2 t poultry excreta and 13 t mushroom spent for recycling in the system(Sahoo *et al*, 2015a and Sahoo *et al*, 2015b).

The 1.6 ha IFS model gave 5.5 t of grain, 29.8 t of onion, 444 kg fish, 1983 kg papaya, 1083 kg banana, 642 kg drumstick, 852 kg poultry meat, 901 kg paddy straw mushroom and 714 kg oyster mushroom and 5.9 t paddy straw, 1.7 t onion leaves, 5t pond silt, 2 t poultry excreta and 13 t mushroom spent for recycling in the system.

Model size of 0.8 ha gave rice equivalent yield of 31.92 t as compared to 3.78 t from Conventional Cropping System(CCS) of rice-green gram and 1.6 ha IFS model gave rice equivalent yield of 44.93 t compared to 6.70 t in conventional cropping.

Profitability from IFS model

The mean gross return and net return from 0.8 ha IFS model (Table 1) was ₹ 3,56,196 and ₹ 1,61,148 with B: C 1.83 as compared to ₹ 41,952 and ₹ 11,631 with B:C 1.38 in conventional rice-greengram cropping system. The mean gross and net return was ₹ 5,01,523 and ₹ 2,27,521 with B:C 1.83 for 1.6 ha IFS model (Table 2) as compared to ₹ 74,429 and ₹ 15,235 with B:C 1.26 in conventional rice-greengram cropping system. Rangasamy *et al.*(1995) demonstrated superiority of the integration of crops with fish, poultry and mushroom in low lands of Tamil Nadu over conventional system of cropping.

Employment opportunities

Labour requirement for conventional rice-greengram cropping system was 204 and 400 in 0.8 and 1.6 ha models. The IFS model with 0.8 ha size required a total labour of 588 human days per annum constituting 60.0, 24.0, 9.9 and 6.1 percent in crop, mushroom, poultry and fish, respectively. In case of 1.6 ha model the total employment opportunities was 942 human days with share of 71.8, 15.0, 6.1 and 7.1 percent for respective enterprises. Shekinah and Sankaran(2007) also report6ed higher employment opportunity for family labour compared with conventional cropping alone in integrated farming systems provided.

Nutritional security

The models ensured production of rice, vegetables, fish, mushroom and meat and ensured food and nutritional security of farm family.

Table 1. Yield, economics and labour employment in small holder IFS models and Conventional cropping system

Productivity and economic indicators	0.8 ha farm	1.6 ha farm
Farming system approach(IFS models)		
Rice equivalent yield (t)	31.92	44.93
Cost of cultivation (₹)	195048	274000
Gross return (₹)	356196	501523
Net return(₹)	161148	227521
B: C	1.83	1.83
Labour employment (man days)	588	942
Conventional cropping system(Rice-green gram)		
Rice equivalent yield (t)	3.78	6.70
Cost of cultivation (₹)	30321	59194
Gross return (₹)	41952	74429
Net return (₹)	11631	15235
B: C	1.38	1.26
Labour employment (man days)	204	400

Role of IFS in achieving goals of climate smart agriculture

1) Reduction in GHG emission – All the recyclable waste materials including animal excreta, crop residues aare properly utilized and recycled in IFS models. Paddy straw is utilized for mushroom production. Spent mushroom substrate ids utilized for vermicomposting. Cow dung is utilized for biogas(methane gas) production. In farming system approach, the use of external inputs like chemical fertilizers, pesticides are restricted. Due to adoption of organic farming practices, the release of GHGs is reduced.

2) Resilience to climate change/natural disasters
On farm water harvesting structures in IFS models help in protecting crops and animals during drought during the cropping season. Surplus rain water vis stored in the pond and a part of

siored water is subjected to infiktration which helps in ground water recharge. Capture of run off water in large number of on farm storage structures will minimize the flood menace. Multi purpose trees/perennial fruit trees around the boundary reduce speed of wind and protect the crops and structures from wind/cyclone damage.

3) Sustainable increase in agricultural productivity and incomes

Diversification from cropping to multi enterprise farming system models increases farm productivity many times. Cropping activity in rainfed areas is restricted to four months. Often it is subjected to vagariues of adverse weather. Due to diversification, the farming activity is spread round the year. Family labour including women is efficiently used due to integration of farm and home. Efficient utilization of resources leads to increase in productivity. Cost of production is reduced due to reduced dependence on external inputs, efficient use of family labour and easy protection from theft. Ultimately farm profitability increases due to decrease in cost of cultivation and better price to commodities grown organically. The farming system approach provides cash and livelihood security to smallholder farmers.

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Nutrient management in tuber crops based integrated farming system

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Introduction

India harbours 17% of global population in only 2.3 % land mass supported by 4 % of fresh water resources (Sen, 2009). The advent of high yielding, fertilizer responsive and photo-insensitive crops and crop varieties led to a record food grain production of 211 Mt in 2001-02 with a sizeable buffer stock of about 60 Mt (Yadav, 2003) and the production increased to 255.36 Mt in 2012-13. The quantum jump in food grain production is not matching the proportionate increase in fertilizer consumption from 0.07 Mt to 19.3 Mt (about 275 times), in net irrigated area from 18 Mha to 59 Mha (about 3.3 times), in cultivated area under food grains from 97 Mha to 122 Mha (< 1.3 times), and in gross area under high yielding varieties from none to 76.4 Mha during 1951-52 to 2001-02. The per capita arable land in India decreased from 0.34 ha in 1950-51 to 0.15 ha in 2000-01 and is expected to shrink to 0.08 ha in 2025. No possibility of further horizontal expansion in the cultivated area besides the galloping population from 361 million in 1951 to over 1.28 billions at present, with further projections of 1.4 and 1.8 billions by 2025 and 2050, respectively, the scarce soil resources are under heavy pressure.

Fertilizer scenario

Even though India is the second largest fertilizer user followed by China, the average rate of nutrient application in India is 128.34 kg ha^{-1} (84.54 + 33.44 + 10.36 kg N, P_2O_5 & K_2O/ha), highest in Punjab 250.19 kg ha^{-1} (188.47 + 58.67 + 3.05 kg N, P_2O_5 & K_2O/ha) (2012-13). The National Academy of Agricultural Sciences projected that 30 to 35 Mt of fertilizer nutrients would be required to meet the food grain demand by 2020. Therefore, demand will stretch by almost 15 Mt if requirements of horticultural, plantation, sugarcane, potato, cotton, etc are included, thus making a total requirement of 45 Mt. Emphasis on application of major nutrients has triggered widespread deficiencies of secondary and micronutrients like Sulphur (41%), Zinc (49%), Boron (33%), Fe (12%), Mn (5%) and Cu (3%) (Singh, 2009). It has been estimated that hardly 270-300 Mt of organic manures of different kinds contributing around 4 to 6 Mt of NPK are available in the country.

Fertilizer consumption in India (Mt)

Year	N	P_2O_5	K_2O	Total
2009-10	15.58	7.27	3.63	26.49
2010-11	16.56	8.05	3.51	28.12
2011-12	17.30	7.91	2.68	27.79
2012-13	18.04	5.96	1.81	25.80
2013-14	16.53	5.46	1.98	23.96

All India demand forecast of fertilizer products (thousand tonnes)

Year	Urea	DAP	NP/NPKs	SSP	MOP
2014-15	32029	12002	10861	5091	4492
2015-16	32858	12212	11142	5513	4643
2016-17	33677	12413	11420	5948	4793
2017-18	33754	12764	11841	6476	4934

The area under food grains in Odisha has declined from 5.428 M ha in 2008-09 to 5.03 M ha in 2012-13. The food grain production in Odisha was 8.36 Mt in 2013-14 as compared to 10.21 Mt in 2012-13 and 6.32 Mt in 2011-12. Cropping intensity in the state was 167% in 2013-14. The red, laterite and lateritic group soils constituting more than 75% of the total land area in the state having the productivity constraints like low pH & cation exchange capacity, deficiencies of Ca, Mg, S, Zn, B & Mo, toxicity of Fe, Al & Mn, low organic matter and low status of available N, P & K. Average Fertilizer consumption in Odisha was 90.29 kg/ha (58.03 + 22.88 + 9.39 kg N, P_2O_5 and K_2O/ha) (2012-13). Fertilizer consumption in Odisha reduced from 0.490 Mt in 2012-13 to 0.487 Mt during 2013-14 with a NPK ratio changed from 6.2:2.4:1 (2012-13) to 5.5:2.1:1 (2013-14). More than 50% of soils are deficient in Zn, and 33% in B.

Integrated nutrient management

The integrated nutrient supply includes the conjunctive use of chemical fertilizers with organic sources like green manure, Farmyard manure (FYM), crop residues, biofertilizers etc. helps not only in bridging the existing wide gap between the nutrient removal and addition but also in ensuring balanced nutrient proportion, in enhancing nutrient response efficiency, and in maximizing crop productivity of desired quality. Balanced fertilization ensures that fertilizers are applied in adequate amounts, and correct ratios for optimum plant growth and sustenance of soil and crop productivity. It should take into account the crop removal of nutrients, the economics of fertilizers and profitability, farmer's investment ability, agro techniques, soil moisture regime, weed control, plant protection, seed rate, sowing/planting time, soil salinity/alkalinity, physical environment, microbiological condition of the soils, soil status of available nutrients, cropping sequence, etc. The ultimate objective is to facilitate the development of nutrient efficient, stress tolerant and high quality crop varieties that will contribute to the agricultural sustainability, food security and environmental safety. Knowledge on nutrient removal under intensive cropping systems is important for developing future nutrient management strategies.

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 the normal metabolic processes. There are 19 elements needed for crop growth and classified as macro and micro nutrients depending upon the quantity required. Of these 19, all except carbon, hydrogen, and oxygen are derived from the soil. When the soil cannot supply the level of nutrient required for adequate growth, supplemental fertilizer applications become necessary.
The macro nutrients are again classified as primary {Nitrogen (N), Phosphorus (P) & Potassium (K)} and secondary {Calcium (Ca), Magnesium (Mg) & Sulphur (S)} nutrients depending upon their importance. The micronutrients are equally important but their requirement is comparatively low in quantity and they include Iron (Fe), Manganese (Mn), Zinc (Zn), Copper (Cu), Boron (B), Molybdenum (Mo), Chlorine (Cl), Sodium (Na), Nickel (Ni) and Silicon (Si).

Nitrogen

Functions: Nitrogen conc. in healthy plants varies from 1 - 5 %. It is an essential component of amino acids, proteins, nucleic acids, flavins, enzymes, alkaloids and chlorophyll. N is responsible for the transfer of genetic code to the off-springs as being a constituent of RNA and DNA. N fertilization improves protein quality by enhancing the proportion of different amino acids.

Deficiency symptoms: Plants having < 1.0 % N content are usually deficient in N. Symptoms first appear on older leaves due to its high mobility. Stunted growth, chlorosis of leaves, reduction in flowering, and low protein content associated with N deficiency. Chlorotic tissues later become necrotic resulting in drying and death of the plant. Increased anthocyanin pigmentation of the young leaves especially the leaf veins is a noticeable symptom. Excessive consumption makes succulence of the plant and more susceptible to insect pests and diseases.

Phosphorus

Functions: In healthy plants, P varies from 0.1 to 0.4% by weight. It is a constituent of nucleic acids (RNA & DNA), phospho-proteins, phospholipids, sugar phosphates, enzymes and energy rich adenosine triphosphate (ATP) and Adenosine diphosphate (ADP). Major processes involving ATP are generation of membrane electric potentials, respiration, biosynthesis of cellulose, hemicellulose, pectins, lignins, proteins, lipids, phospholipids and nucleic acids. P is involved in energy transfer, photosysnthesis, transformation of sugars and starch, nutrient movement within the plant and transfer of genetic characteristics from one generation to the next.

Deficiency symptoms: In general, plants having < 0.1% or 1000 mg kg^{-1} P are designated as P-deficient. Due to its faster mobility in plants, P gets easily translocated from older leaves to the meristematic tissues and deficiency symptoms appear first on the older leaves. Under severe P deficiency, plants develop dark yellow or orange coloured lower leaves, which later become necrotic and shed. Premature senescence of older leaves with purple discolouration due to the production of anthocyanin pigments. Young to mature leaves remain dark green at all levels of severity. Symptoms on older leaves are associated with severe stunting. When necrosis is not preceded by yellowing, the symptoms resemble K deficiency.

Potassium

Functions: Potassium concentration in healthy plant tissues varies from 1-5 %. It regulates the opening and closing of stomata, which are essential for photosynthesis. It plays major role in transport of water and nutrients throughout the plant in xylem. It increases root growth and improves drought tolerance. It activates a large number of enzymes (> 60). K is responsible for activation and synthesis of protein forming nitrate reductase enzyme. Reduces lodging of crops and enhances their winter hardiness. It imparts disease resistance to crops.

Deficiency symptoms: Deficiency symptoms develop first on older leaves gradually progressing to the upper leaves. The leaf margins turn yellow towards the midrib and the leaf tip and margins become dry and necrotic. Necrotic leaves are dark in colour and the necrotic areas become dry and brittle. Potassium deficient crops tend to produce small, thin storage roots of poor quality. Symptoms of water stress are indicative of poor K nutrition.

Calcium

Functions: Calcium in plants ranges from 0.2 - 1.0 %. It is a constituent of calcium pectate in the cell wall. It is important for the growth of meristems and functioning of the root tips. Plays a role in mitosis and helps to maintain the chromosome structure. It activates phospholipase, arginine kinase, amylase and adenosine triphosphatase enzymes.

Deficiency symptoms: Plants having < 0.1% Ca considered as deficient. It is immobile in the plant and cannot be readily translocated from older to the new leaves and hence deficiency symptoms appear on younger leaves. Leaves become cup shaped and crinkled, desiccation of terminal buds and weakening of the stem structure. Deficiency of Ca affects the root system. Excess lime in the field may lead to induction of deficiency of Fe, K, Mg, Mn or Cu. Upward cupping or incomplete unrolling or a puckered or corrugated leaf surface. Interveinal tissue is initially necrotic, petiole tends to curve downward, new leaves do not uncurl or expand. Root growth is reduced and necrosis of root tip occurs in severe cases.

Magnesium

Functions: Magnesium concentration in healthy plants varies from 0.1 - 0.4 %. Mg is a constituent of chlorophyll as Mg-porphyrin with one atom of Mg bound to four pyrrole rings. Mg being a constituent of chlorophyll, is indispensable in the reaction of photosynthesis. It is an activator of many enzymes involved in carbohydrate metabolism and synthesis of nucleic acids.

Deficiency symptoms: Deficient plants usually had < 0.1 % Mg. It is a mobile element and deficiency symptoms appear on older leaves. Interveinal chlorosis with marginal necrosis is the characteristic symptom. Chlorosis appears on older leaves accompanied by upward or downward curling of leaf margins or a wilty drooping of leaf lamina. In severe cases of Mg deficiency, root growth will be inhibited and root tips may die back. The interveinal areas dry up towards the tip.

Sulphur

Functions: The conc. of S in healthy plants ranges from 0.1-0.4 %. It is an essential constituent of S containing amino acids, viz., cysteine, cystine and methionine. It is a constituent of ferrodoxin- containing nitrogenase, which takes part in biological N fixation and other electron transfer reactions. It is involved in the metabolic activities of vitamins, biotin, thiamine and coenzyme A.

Deficiency Symptoms: Plants having < 0.1 - 0.2 % sulphur suffer from its deficiency. Deficiency symptoms first appear on younger leaves as it is immobile in the plants. Crops having N : S ratios more than 16:1 also can be suspected to be deficient in S. Pale green to yellow symptoms are similar to N deficient leaves except that they appear on upper leaves, but later extend over the whole plant and leaves remain small. Purple or red brown pigmentation may develop on both young and old leaves.

Iron

Functions: Fe conc. in matured leaf tissue ranged from 100 - 500 mg kg^{-1}. It is a transition metal, exhibits two oxidation states – Fe (II) and Fe (III) in plants and forms complexes with organic ligands. It is a constituent of 2 groups of proteins, a) Heme proteins containing Fe porphyrin complex as cytochrome oxidase, catalase, peroxidase, leghaemoglobin, and b) Fe-S proteins like cysteine, Ferrodoxin. It activates a number of enzymes. It plays an essential role in the nucleic acid metabolism. It is necessary for synthesis and maintenance of chlorophyll in plants.

Deficiency Symptoms: Plants having < 50 mg kg^{-1} of Fe usually considered as deficient. Interveinal chlorosis appears first on younger leaves with leaf margins and veins remain green. Initially yellow interveinal chlorosis develops which is characterized by a sharply contrasting green network of veins. Under severe deficiency, the chlorotic areas turn white, veins may loose their green colour and growth cessation occurs with the whole plant turning necrotic. Necrosis usually spreads from the tip and margins to the interveinal zones.

Manganese

Functions: Healthy mature plants contain 20-300 mg kg^{-1} of Mn. It is an integral component with photosystem II. It is a constituent of superoxide dismutase (present in mitochondria, peroxisomes & glyoxisomes) protects cells against deleterious effect of superoxide free radicals.

Deficiency Symptoms: Mn deficient plants contain < 25 mg kg^{-1} Mn. Deficiency symptoms are more severe on middle leaves than younger ones. Distinct interveinal chlorosis symptoms are usually seen on fully expanded leaves throughout the plant. Chlorosis accompanied by drooping of the leaves, slight puckering of the upper leaf surface or downward curling of the leaf margins. Mn deficient plants produce small thin tubers which have brownish streaks in the flesh.

Zinc

Functions: Zinc sufficient plants contain 27-150 mg kg^{-1} Zn in mature tissues. It is a constituent of enzymes *viz.*, Carbonic anhydrase (localized in cytoplasm and chloroplasts for photosynthetic CO_2 fixation), Alcoholic dehydrogenase (plays imp. role in anaerobic root respiration in waterlogged cond.), Superoxide dismutase (protects lipids and proteins of the membranes against oxidation). Zn plays important role in the stabilization and structural orientation of the membrane proteins.

Deficiency Symptoms: Plants containing < 15 mg kg^{-1} are regarded as deficient in Zn. Interveinal chlorosis first appear on younger leaves, reduction in leaf size, clustered or borne very closely, bronzing, and purple, violet reddish brown coloration of foliage. The leaves are thickened but not distorted. Shortening of inter nodes (rosetting) in dicotyledons. Leaf tips turn necrotic under severe cond. Internodes get shortened. Interveinal chlorosis of young leaves, narrow leaf lamina, brown discolouration of flesh of the tubers.

Copper

Functions: Conc. of Cu in healthy plants varies from 5-30 mg kg^{-1} and its toxicity occurs at 20-100 mg kg^{-1}. Cu is a constituent of various enzymes, *viz.*, Plastocyanin (component of electron system of photosystem II), Diamine oxidase (located in apoplasts of epidermis and xylem for peroxidase activity in lignification), Ascorbic oxidase (Occurring in cell walls & cytoplasm, catalyses the oxidation of ascorbic acid to dehydroascorbic acid), Polyphenol oxidase (involved in lignin biosynthesis), Superoxide dismutase (located in cytoplasm, mitochondria and chloroplasts, involved in detoxification of superoxide radicals generated during photosynthesis).

Deficiency Symptoms: Plants having < 5 mg kg^{-1} Cu are regarded as Cu deficient. Chlorosis, wilting and drooping of mature leaves is the first visible symptom of Cu deficiency. Young leaves turn to yellow and show a stunted and cup shaped appearance. The chlorosis is interveinal with a gradual fading of green colour. Leaf tip become necrotic, leaves are either cupped upwards or curled downwards. Plants die back from stem apices and bushy appearance. Reduced root development causes susceptible to water stress.

Boron

Functions: Boron sufficient plants contain 10 - 200 mg kg^{-1} of B. It is responsible for cell wall formation and stabilization, lignification and xylem differentiation. It imparts drought tolerance. It plays a role in pollen germination and pollen tube growth. It facilitates ion uptake and transport of K in guard cells and stomatal opening.

Deficiency Symptoms: Plants having 5 - 30 mg kg^{-1} are suspected to be B-deficient. The typical deficiency symptom is cessation of growth of terminal bud which becomes short and bunchy in appearance. In acute deficiency, plant growth ceases and the tips start wilting and drying. B deficiency affects growing tissues, both the shoots and roots. Plants become shorter with few roots. Internodes may be shortened, producing a compact habit around the apex. In severe deficiency of B, death of the growing points occurs. There was no tuber formation and only roots are noticed. The tuber skin may be rough and wrinkle towards the ends. The flesh may be mottled or corky in some places.

Management of nutrient deficiencies

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 showed drastic reduction in crop yields as well as occurrence of various diseases to human beings and therefore, it is essential to apply recommended doses of secondary and micro nutrients besides balanced doses of NPK.

Incorporation of lime is customary in acid soils and high rainfall areas for not only to enhance the crop productivity and quality but also to improve the soil fertility. 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 hence application of crop residues and locally available green manure crops is much advantageous to sustain the soil quality. The decomposition of organic manures is accompanied by the release of appreciable quantities of CO_2, which dissolved in water forms carbonic acid, which is capable of decomposition of certain primary minerals and release of appreciable amount of plant nutrients to the soil, which could contribute higher crop yields (Naphade *et al*., 1993). The difference in release of nutrients from the organics is also related to the amount and composition of manure, C/N ratio, lignin content of plants and management practices (Mubarik Ali, 1999).

Use of VAM has shown promise in solubilization and transport of immobile micronutrient cations *viz*., Fe, Zn, Cu and Mn besides P and hence, it can be effectively utilized for enhancing crop productivity and to maintain soil health. Fungal inoculation with *Glomus microcarpum* enhanced the root volume and release of organic acids facilitates mineralization of organic P and solubilization of insoluble inorganic P fractions which ultimately contributed higher absorption of P including Fe, Cu, Mn & Zn. These results are in concurrent with the findings of Pushpakumari and Geethakumari (1999).

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

Nutrient	Control measures
1. Calcium	Addition of lime, single and triple super phosphate
2. Magnesium	Incorporation of dolomitic lime or Magnesium oxide in acid soils (Mg @ 20-50 kg ha^{-1}) or Magnesium sulphate (Mg @ 10-40 kg ha^{-1}).
3. Sulphur	Application of S containing fertilizers, gypsum or elemental S or Ammonium sulphate or Single super phosphate
4. Zinc	Soil application of $ZnSO_4$ @ 10 kg ha^{-1} or foliar spray of 1-2% $ZnSO_4$ $7H_2O$.
5. Iron	Foliar spray of chelated Fe or 1-2% Ammonium ferric sulphate solution
6. Manganese	Foliar spray of 0.1% $MnSO_4$ or Chelate or Mn @ 2-4 kg ha^{-1}.
7. Copper	Foliar spray of 0.1% $CuSO_4$.
8. 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.
9. 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 Toxicity Disorders

Boron: Boron toxicity causes conspicuous necrotic lesions in the interveinal areas of older leaves leading to premature senescence and shedding of the leaves. B toxicity also causes root damage with severe stunting and poor survival of the plants. Boron toxicity symptoms resemble salinity induced symptoms. Interveinal chlorosis may develop well in advance of necrotic lesions. Early symptoms of B toxicity resemble Mg deficiency, but the appearance of discrete necrotic spots on older leaves distinguish B toxicity from Mg deficiency. Root tips appear to be curled, laterals are very short, and necrosis of tips and lateral roots.

Aluminium: High concentration of Al affects roots development, height and vigour of plants thereby affecting nutrient and water absorption. Roots appear short and thickened, with short laterals, and may be discoloured to yellow or brown colour. Downward extension of the roots may be restricted, resulting in a very shallow root system and poor root development. Plants show yellow lower leaves with brown or black spots along the veins and these leaves may later fall off. Al in the soil solution inhibits the uptake of Ca & Mg by roots, symptoms of Ca and Mg deficiency may develop. In addition, the solubility of P is reduced in the high concentration of Al, so that P deficiency is often associated with Al toxicity. Tubers become narrow but more tubers produced.

Manganese: Manganese toxicity also causes necrotic spots which appear on the older leaves due to accumulation of Mn in the tissue over a period of time. Mn toxicity also causes chlorosis, most severe on the younger leaves due to an induced Fe deficiency. Mn toxicity causes chlorosis on younger leaves due to an induced Fe deficiency. Unlike B toxicity or salinity these spots do not usually form a regular alignment but remain scattered within the interveinal tissue. In severe cases, root growth is severely inhibited. It can be corrected by improving soil drainage and lime application.

Zinc: Zinc toxicity in sweet potato causes severe growth reduction, even prevent the establishment of transplanted vine cuttings. Dark pigmented spots or blotches appear on older leaves, or red pigmentation was observed throughout the vine in severe cases of Zn toxicity. Severe damage to the roots at high Zn concentration in soil can cause general chlorosis and wilting. High levels of Zn inhibit the uptake of Fe, causes severe Fe deficiency.

Conclusions

There is a wide gap between the actual and potential yields of tropical tuber crops at national and state level. In most of the integrated farming systems, tuber crops are being grown as a sole crop or inter crop or relay crop or mixed crop and managed with low inputs of fertilizers and non adoption of improved technologies resulting very low crop yields. 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 very vital role to boost up the production of tuber crops. Sustainable crop production, including environmental safety and economic feasibility depends on sound nutrient management programmes. 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 only enhances crop productivity but also increases the mineral content in plant foods which may ultimately contribute to nutritional quality of plant produce, thereby improving human nutrition and health.

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Tropical tuber crops: Potential future crops under the changing climatic scenario

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Introduction

Climate of a region represents the long term (more than thirty years) average of weather. It is a resultant of an extremely complex system consisting of different meteorological variables which vary with time. Climate may be defined as average weather or more as the statistical description in terms of mean and variability of relevant weather variable over a period of time.

Climate change refers to a statistically significant change in either the mean state of the climate or its statistical properties (such as standard deviations, the occurrence of extremes etc.), persisting for an extended period particularly decades or longer. Climate change is not only a major global environmental problem, but also an issue of great worry to a country like India.

Causes of climate change

Climate change can take place due to forcing that may be external to earth or internal. Two external forcing are important. Earth's orbit and tilt of its rotational axis are changing slowly caused by gravitational forces of other planets and orbit of solar system about the centre of Galaxy. Milankovitch Cycles is the collective name for cycles in earth's movement. Changes in these cycles cause very slow and long term climate change. Three types of orbital variations are identified. Tilt of earth's axis with respect to plane of orbit varies between 22.1 to 24.5° in about 41,000 years. The tilt does not impact total solar radiation received but the space and time distribution changes. Next, axial precession is the gradual shift in orientation of earth's axis of rotation relative to fixed stars in a cycle of 26000 years. When this axis is aligned to point towards sun during perihelion, one polar hemisphere will have a greater difference between seasons while the other will have milder seasons. Finally, eccentricity of earth's orbit around the sun controls shape of earth's orbit around Sun and the radiation received.

Internal forcing mechanisms of Climate change operate within the climate system. Great volcanic eruptions release huge amount of gases, ash and aerosols and impact climate by reducing solar radiation reaching Earth. GHG emissions due to combustion of fossil fuels to generate electricity, heating and transport account for =70% of total emissions and are the main cause of global warming. Movement of tectonic plates has a direct connection between uplift, atmospheric circulation and hydrologic cycle.

Greenhouse effect: Short wave radiation from the sun passes through the earth's atmosphere which contains different gases. A part of this radiation is reflected back into space, a part is absorbed by the atmosphere and the remainder reaches the earth's surface where it is either reflected or absorbed. In particular, the earth's surface emits long wave radiation towards space. Some of the gases in the atmosphere absorb a part of the long wave radiation emitted by the earth's surface and reradiate it back to the earth forcing it to warm. These gases help modify the heat balance of the earth by retaining long wave radiation that would otherwise be dispersed through the earths atmosphere to space. This effect is known as the green house effect and the gases causing this are called greenhouse gases (GHGs). The principle greenhouse gases present in the atmosphere include carbon dioxide (CO_2), nitrous oxide (NO_2), methane (CH_4), water vapour, chlorofluorocarbons (CFCs) and ozone (O_3).

GHGs have an important role in controlling the temperature of the earth and keeping it sufficiently warm for life to survive but excess of these gases is having harmful consequences. An increase in the levels of GHGs would lead to greater warming which could have major impact on the world's climate, leading to Climate change. Global atmospheric concentration of CO2, methane, and nitrous oxide have increased from 280 – 399 ppm (parts per million), 722-1834 ppb (parts per billion) and 270-328 ppb respectively, between pre-industrial period (1750) and 2015. In addition, presence of excess quantities of CFCs adversely affects the protective ozone layer which deflects the harmful short wave rays.

Evidence of climate change

The fifth assessment report of IPCC (2015) has produced many evidences which clearly show that global warming is indeed happening. Observed thermometer data at many places on earth are available back to 1850. Record high average global surface temperatures have been observed in recent decades. Earth's surface in each of the last three decades has been successively warmer compared to any preceding decade since 1850. IPCC (2014) notes that the period from 1983 to 2012 was likely the warmest 30 year period of the last 1400 years in the Northern Hemisphere. The globally averaged combined land and ocean surface temperature data as calculated by a linear trend shows a warming of 0.85 (0.65-1.06)°C over the period 1880 to 2012, when multiple independently produced datasets were used.

Climate change: adaptation and mitigation

According to IPCC, adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Adaptation can be of different types. Anticipatory or proactive adaptation that is not in response to climatic inputs but is triggered by changes in natural systems and by market or welfare changes in human systems is called as autonomous or spontaneous adaptation.

IPCC defines mitigation is any action taken to permanently eliminate or reduce the long term risk and hazards of climate change to human life and property. Mitigation of climate change is a global responsibility. Agriculture and forestry have significant potential for GHG mitigation. While mitigation tackles the causes of climate change, adaptation tackles its effects. The potential to adjust to minimise negative impact and maximize any benefits from changes in climate is known as adaptive capacity.

In general more the mitigation, the less will be the impacts to which the society will have to adjust and the less the risks for which people will have to be prepared. Conversely the greater the adaptation, lesser will be the impacts associated with any given level of Climate change. Adaptation should be viewed as an active adjustment in response to expected changes. Less mitigation means greater climatic change, require more adaptation. This is the basis for the urgency surrounding reductions in emission of GHGs. Climate mitigation and adaptation should not be seen as a combined set of actions in an overall strategy to reduce GHG emissions.

The climate change would reduce food production in most of the lowland tropical and sub tropical farm lands, but it may increase it in the high lands and the traditional very cold temperature areas of the world, such as Siberia and Canada. These will have a profoundly destabilizing effect on global food production (Foley et al., 2011; Nature, 2013).

Reducing carbon emissions by larger use of new technologies such as renewabale energy (wind power), drip irrigation etc. Farmers should diversify enterprises apart from agriculture, such as dairy farming, fish cultivation, animal husbandry, fruit preservation etc. In agriculture, farmers should adopt crop diversification to ensure sustainable production and income.

Tropical Tuber crops

Tropical tuber crops supply 28.5 kg food annually and 75 kcals energy/head/day. This amounts to 3.9% of total energy consumed by a person in a day. Tropical tuber crops include cassava (*Manihot esculenta*), sweet potato (*Ipomeas batatus*), greater yam (*Dioscorea alata*), white yam (*D. rotundata*), lesser yam (*D. esculenta*), taro (*Colocasia esculenta*), tannia (*Xanthosoma sagittifolium*), elephant foot yam (*Amorphophallus paeniifolius*), yam bean (*Pachyrrhizus erosus*), coleus

(*Solenostemon rotundifolius*) etc. The area under tropical tuber crops increased by only about a third during the period 1961-2011, the production increased by as much as two and half times (Nayar, 2014). The reasons are (i) in all the crops productivity has increased by about 60%; (ii) in cassava and yams, both the area and production have been steadily increasing in recent years, though they have not been making the kind of dramatic increases being shown by the two major cereal crops, wheat and rice (Nayar, 2014). However, the recent increases in cassava and yams production may be attributable to the greater resilence of these two crops to climate changes in sub-Saharan Africa. Incidentally, The FAO has identified so far cassava and yams as the most climate resilient crops.

Several countries in middle Africa, such as Uganda, Rwanda and Barundi have taken up sweet potato cultivation in big way. The two aroid crops, taro and cocoyam have made moderate increase in area and production in recent past (Nayar, 2014). These indicate, tropical tuber crops have bright future under changing climate and will be the future food crop.

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Organic production of tropical tuber crops

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Introduction

India witnessed a remarkable growth in the agricultural front due to the technological revolution termed as "green revolution" (since mid 1960s) wherein high input farming practices using high yielding varieties combined with chemical fertilizers, pesticides, fungicides and herbicides as well as intensive irrigation could enhance the food grain production from 50.80 million tonnes during 1950 to 108 million tonnes during 1970-71 and 253 million tonnes during 2015-16. India rose from the level of begging bowl to the status of self sufficiency. However, the consequences of high input conventional agriculture, which envisages large chemical inputs and few carbon additions, on long term profitability and resource use, often referred to as post-green revolution problems or second generation problems were undesirable in certain locations: wide spread soil erosion, salinisation, decline in soil quality due to reduction in soil organic matter content, poor soil fertility, poor surface water quality, reduced water infiltration rates and unfavourable soil tilth all leading to ill health of soil, pesticide pollution, desertification, loss of biodiversity and adverse effects on human health. Besides, chemical based intensive agriculture resulted in prosperity of rich farmers especially in the irrigated tracts, neglecting the marginal and resource poor farmers in dry land areas and enhancing rural poverty. Hence presently there is a growing interest to practice alternative agricultural systems like organic farming for sustainable and safe food production, healthy life and pollution free-environment.

Debate: Organic vs Conventional Agriculture

The simple question that is posed time and again when it comes to debating alternatives to current agriculture: Can organic agriculture feed the world? The right question to ask ourselves in order to nourish a more fruitful debate is then: Why does conventional agriculture fail to feed the world? (Titonell, 2013).

Why does conventional agriculture fail to feed the world?

Unequal access to resources and diverging productivity worldwide

While world average yields of major food crops increased by a factor two in the last 50 years, the total amount of external N brought in through fertilisers increased seven times in the same period, the amount of P three times and the amount of water used for irrigation doubled (Foley et al., 2005). The most realistic estimates of food demand by 2050, considering changes in diets and population growth indicate that daily caloric requirements will increase from 19 to 33 kcal per day, worldwide. Or, a 70% increase. Looking at the future, can we envisage replicating the green revolution as it happened in the past? (Titonell, 2013).

Energy crises

Since the onset of the green revolution, energy inputs in agriculture increased 50 times compared to traditional agriculture. Feeding an average person in the developed world costs about 1500 l of oil equivalents per year. More than 30% of this energy is used in the manufacture of chemical fertilisers, 19% for the operation of field machinery and 16% for transport. Production of one kg of N contained in fertiliser requires the equivalent energy contained in 1.4 to 1.8 l of diesel fuel. In other words, producing food for 9 billion people with conventional agriculture will need close to 8% of the total world oil reserve, which will exhaust our global oil reserves in about 12years. On average, energy use by organic agriculture is about one third as compared to conventional agriculture due to higher efficiency in biological N fixation.

Hidden costs

Conventional agriculture incurs hidden costs by way of subsidies, costs in public health by the use of pesticides, cost of cleaning the ground water from excess nitrates associated with fertiliser use, costs incurred through biodiversity loss when pesticides are applied. If we take a systems perspective and internalise all the above-mentioned costs in the calculation of food prices, the price difference between conventional and organic food will narrow down, disappear or, in some cases, become more favourable for organic food.

Obesity outweighs hunger

The State of Food Insecurity report of 2012 estimated that of the 870 million people suffering from chronic undernourishment in 2010-2012 the vast majority of them (852 million) live in developing countries. Yet, for the first time in human history, obesity outweighs hunger. The current number of overweight people in the world is estimated at 1300 million (WHO Global InfoBase, 2012). About 65% of the world population lives in countries where overweight and obesity kill more people that underweight. These trends reveal not just problems in the distribution of resources or inequity in access to food worldwide, but also the effect of current patterns of food consumption worldwide, notably the increasing intake of energy-dense foods that are high in fat, salt and sugars but low in vitamins, minerals and other micronutrients (WHO Global InfoBase, 2012).

Waste causes hunger

Due to poor practices in harvesting, storage and transportation, as well as market and consumer wastage, it is estimated that 30 to 50% (or 1.2 – 2 billion tonnes) of all food produced never reaches the human stomach (Gustavsson et al., 2011; IMECHE, 2013). Wastes may occur post harvesting, post processing and post consumption. In SE Asia, for example, postharvest losses of rice can range from 40 to 80%.

Environmental externalities

The critical report commissioned by the top secretariat of the Consultative Group on International Agricultural Research (CGIAR) more than a decade ago (Marediaand Pingalli, 2001) provided quantitative estimates of the negative externalities of productivity-enhancing crop technologies in terms of loss of genetic diversity, salinity and water logging (45 million ha worldwide), changes in the level of water table, loss of soil fertility/erosion, water pollution, air pollution, food contamination, impacts on human and animal health and effects on pest population. The manufacture and use of N fertilizers represent 6% of the country total anthropogenic emissions of greenhouse gases (GHG).

All these indicate that we need alternatives.

Organic agriculture as an alternative

Presently world agriculture needs knowledge-intensive management systems to increase yields and access to food and incomes in the South, and knowledge-intensive design to reduce the dependence on external (fossil fuel) inputs in the North. The strategy should be intensify in the South, 'extensify' in the North, detoxify everywhere (Titonell, 2013). Organic farming creates opportunities for synergies between food production and ecosystem services. Most importantly, this can contribute to detoxify our food and environment.

Hence presently there is a growing interest to practice alternative agricultural systems that are less exploitative, less dependent on nonrenewable fossil fuels like fertilizers, pesticides etc., which can conserve the precious soil and water resources and protect the environment and human health. The National Organic Standards Boards (NOSB) defines Organic Agriculture as an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity. Organic farming is therefore an alternate farming strategy that focuses on soil health, environmental protection and human health by largely excluding the use of synthetic chemicals and with minimum use of off-farm inputs. Though the use of chemical inputs cannot be altogether avoided, their use in agriculture needs to be reduced.

Organic agriculture, an innovative adaptation to climate change

Globally, organic agriculture could significantly reduce global agriculture emissions of green house gases: 20% from avoided mineral fertilizer production and enhanced nutrient efficiency and 40-72%

from soil C sequestration (Scialabba, 2010). Organic agriculture reduces farmer's vulnerability by encouraging highly diverse farming systems, thus improving income diversity. Results show that organic agriculture has positive impacts on MDG goals 1, 7 and 8, focusing on income and food security (Setboonsarng, 2009).

Is Organic farming feasible in India ?

In India, about 62%of cropped area is rainfed, where there is little or no use of fertilizers and other agro-chemicals due to poor resources with small holder farmers. Thus promotion of organic farming in India is advocated initially in these rainfed areas particularly in the hilly areas of northern and north-eastern regions and dry land areas of the country. The Fertilizer Association of India has identified altogether about 50 districts in the states of Orissa, Jharkhand, Uttranchal, Himachal Pradesh, Jammu & Kashmir, Rajasthan, Gujarat, Madhya Pradesh and Chhattisgarh as low fertilizer consuming districts with fertilizer consumption ranging from 1.79 kg $ha^{-1}$to 19.80 kg ha^{-1} as against the national average of 90.2 kg ha^{-1} (Das and Biswas, 2002). This means that there is immense scope for organic farming in these selected areas and for selected cropsin India, like pulses, oilseeds, tuber crops etc., for which conventionally little or no fertilizers and agro-chemicals are used. On the other hand, some areas under tea, coffee, cashew, nuts and spices may be easily brought under organic farming with a thrust on export of organic produce. In other words, rather than promoting organic farming *en masse*, it would be appropriate to carefully delineate areas or crops where fertilizer use is nil or nominal or demarcate export oriented crops that can give reasonable yield of high quality produce without the use of chemicals. *It is worthy to mention that tuber crops hold great promise in this regard.*

Tuber crops: Underground crops with hidden treasures

Tropical tuber crops, including cassava, yams (greater yam, white yam and lesser yam), sweet potato and aroids like elephant foot yam, taro and tannia form the most important staple or subsidiary food to about 500 million global population. Tuber crops are the third most important food crops of man after cereals and grain legumes. These crops possess high photosynthetic ability, capacity to yield under poor and marginal soils and tolerate adverse weather conditions. They are also recognized as the most efficient in converting solar energy, cassava producing 250 x 10^3 kcal ha^{-1} and sweet potato 240 x 10^3 kcal ha^{-1}, as compared to 176 x 10^3 kcal $ha^{-1}$for rice, 110 x 10^3 kcal $ha^{-1}$for wheat and 200 x 10^3 kcal ha^{-1} for maize; hence the tropical root crops are known to supply cheap source of energy. They can serve as substitute for cereals due to higher carbohydrate and calorie content. The higher biological efficiency and the highest rate of dry matter production per unit area per unit time make tuber crops inevitable components of our food security systems. Besides they have potential as sources of alcohol, starch, sago, liquid glucose, vitamin C and as raw materials for many other industrial products and animal feed. In times of famine, tuber crops have come in handy to overcome catastrophes and provide relief from hunger.

Tuber crops are cultivated in India mainly as rainfed in the southern, eastern and north-eastern states. These crops form a source of livelihood to small and marginal farmers and tribal population in these areas. Cassava production is mainly from the states of Kerala, Tamil Nadu, Andhra Pradesh and NEH regions. Sweet potato is cultivated mainly in the states of Orissa, Bihar, Jharkhand, Eastern Uttar Pradesh, West Bengal, Madhya Pradesh, Maharashtra and Karnataka. Other tuber crops like yams (greater yam, white yam and lesser yam) and aroids (elephant foot yam, taro and tannia), popular as vegetables, are not yet commercially cultivated, being confined only to the home gardens in almost all the States (except elephant foot yam which is cultivated on a commercial scale in Andhra Pradesh).

Prospects of organic farming in tropical tubers

Organic farming is a viable strategy targeting on sustainable production and soil, environmental and human health hand in hand. Conventional agriculture using chemical inputs results in higher yield, but it is ecologically unfriendly as it has some negative impacts on food, soil, water and environmental quality. Indiscriminate use of chemical fertilizers for decades has lowered the organic carbon status of our soils to less than one per cent. Moreover pesticide residues cause concern over the safety of food. Organic farming helps to promote biodiversity and soil biological activity and strongly advocates the use of on-farm generated resources. Reduced energy use and CO_2 emissions are the other benefits of organic farming. It offers opportunities for employment generation, waste recycling and export promotion. The clean and safe organic foods fetch a higher premium price in world markets.

Most of the tuber crops are grown by small and marginal farmers in rainfed areas and tribal pockets and hence use of chemical fertilizers and insecticides are limited except in the case of cassava in the industrial production areas of Tamil Nadu (Salem, Dharmapuri, Namakkal, South Arcot districts) and Andhra Pradesh (Rajahmundry district). Tuber crops in general and aroids in particular, like elephant foot yam do respond well to organic manures and there is considerable scope for organic production in these crops. Further the tropical tuber crops are well adapted to low input agriculture. They are less prone to pest and disease infestations. Research work done in India and elsewhere had shown that the use of chemical fertilizers are beneficial in maximizing production of these group of crops. An eperimental evidence clearly shows that satisfactory productivity can be obtained even in the absence of chemical fertilizers by the proper supplementation of nutrients through organic sources. Moreover presently there is a great demand for organically produced ethnic vegetables, particularly aroids and yams, among affluent Asians and Africans living in developed nations (Europe, United States of America and Middle East).

Issues in organic tuber production

Many methods and techniques of organic agriculture have originated from various traditional farming systems all over the world, where there is the non use of chemical inputs. To the maximum extent possible organic production systems rely on crop rotations, crop residues, animal manures, legumes, green manures, farm wastes, mineral bearing rocks and aspects of biological pest control to maintain soil productivity, to supply plant nutrients and to control pests, diseases and weeds. Being highly responsive to organic manures and having fewer pests and disease problems as compared to cereals and vegetables, the main issue in organic production of tuber crops is the proper scientific use of a wide variety of cheaper and easily available organic sources of plant nutrients (Suja, 2008).

Strategies for organic tuber production

Building up of soil fertility of the land

Before the establishment of an organic management system, the fertility status of the land must be improved by growing green manure crops like cowpea twice or thrice during a year and incorporation of the green leaf matter at the appropriate pre-flowering stage. This will help to re-establish the balance of the eco-system and offset the yield decline, if any, during the initial period of organic conversion, as tuber crops are highly nutrient depleting crops (Suja et al., 2009). Virgin land or barren land, if available, also will be highly suitable for organic farming of tubers.

Use of planting materials produced by organic management

Varieties cultivated should be adapted to the soil and climatic conditions and as far as possible resistant to pests and diseases. Local market preference also should be taken into account. The planting materials should be produced by adopting organic management practices.

Meeting nutrient needs in organic tuber production

The potential organic sources of plant nutrients for tropical tuber crops are farmyard manure, poultry manure, composts like vermicompost, coir pith compost, mushroom spent compost, saw dust compost, press mud compost, green manures, crop residues, ash, oil cakes like neem cake etc. Table 1. indicates the average nutrient contents in these organic sources.

Vermicompost, produced by chemical disintegration of organic matter by earthworms, is an ideal blend of plant nutrients with the worm enzyme and probiotics to boost the crop performance. It contains higher amount of nutrients, hormones and enzymes and has stimulatory effect on plant growth. If farmers can produce vermicompost utilizing on-farm wastes, organic farming of tuber crops becomes profitable.

Coir pith, a by product of the coir industry, an organic waste obtained during the process of separation of fibre from coconut husk, is normally resistant to bio-degradationdue to its high content of lignin and accumulates to act as an environmental pollutant. Extraction of 1 kg of coconut fibre generates 2 kg of coir pith, and in India, an estimated 5,00,000 MT of coir pith is produced per annum. The Coir Board in collaboration with TNAU has developed the technology for converting coir pith into organic manure using PITHPLUS, a spawn of edible mushroom, *Pleurotus sajor caju*. Coir pith compost developed from coir waste is a good organic manure and a soil conditioner and can be applied to tuber crops.

Table 1. Average nutrient contents of some organic manures

Organic manures	N (%)	P_2O_5 (%)	K_2O (%)
Farmyard manure	0.50	0.20	0.40
Poultry manure	1.2-1.5	1.4-1.8	0.8-0.9
Vermi compost	1.50	0.40	1.80
Coir pith compost	1.36	0.06	1.10
Press mud compost	1.30	2.20	0.50
Mushroom spent compost	1.84	0.69	1.19
Sawdust compost	1.00	0.50	0.50
Biogas slurry	1.41	0.92	0.84
Neem cake	5.00	1.00	1.50
Bone meal	3.50	21.00	-
Municipal compost	1.20	0.036	0.90

The practice of green manuring for improving soil fertility and supplying a part of N requirement of crops is age old. About 15-20 t ha^{-1} of green matter can be obtained from green manure crops like cowpea when grown in systems involving tuber crops. Nitrogen contribution by green manure crops varies from 60-280 kg ha^{-1}.

Biofertilizers offer a cheap and easily available source of nutrients, especially N and P, besides enhancing the efficiency of native and applied nutrients in the soil. The commonly used N biofertilizer for tuber crops is theN fixing bacterium, *Azospirillum lipoferum*, which can partially meet the N demand of the crop. Powdered neem cakes also serve as an organic N source. These organic N supplements unlike the fertilizer N do not suffer much loss in the fields and enhances the N recovery. Phosphorus-solubilizing and mobilizing organisms such as phosphobacterium and mycorrhizae are helpful in augmenting P availability of the soil. Besides, natural reserves of rock phosphate are permitted for use as P fertilizer. Potassium for these crops can be supplied by using K rich organic amendments such as wood ash, rice straw and composted coir pith. K solubilizers can also be used for enhancing the K availability and meeting the K requirements. Harnessing the above mentioned easily available organic sources of plant nutrients conjointly and judiciously to meet the nutrient needs of highly nutrient exhausting crops like tropical tubers will definitely help to maintain/promote productivity in organic farming in the absence of chemical inputs.

Pest, disease and weed management

When compared to cereals and vegetables, tuber crops have fewer pest and disease problems. Barring a few major ones, like cassava mosaic disease (CMD), cassava tuber rot, sweet potato weevil (SPW), *Phytophthora* leaf blight in taro, collar rot in elephant foot yam, the others are of minor significance. In general for the management of pests and diseases, non-chemical measures or preventive cultural techniques can be resorted to. This includes use of tolerant/ resistant varieties, use of healthy and disease free planting materials, strict field sanitation (against almost all), deep ploughing (eg. tuber rot), rogueing the field (eg. CMD), use of pheromone traps (eg. SPW), use of trap crops (eg. SPW, root knot nematodes), adapted crop rotations, use of neem cake (collar rot, tuber rot), use of bio-control agents like *Trichoderma, Pseudomonas* (collar rot, leaf blight) etc. Normally two hand weedings are advocated in tuber crops for efficient weed management. Since most of the tuber crops (except sweet potato) take about 75-90 days for sufficient canopy coverage, raising a short duration intercrop (like green manure/ vegetable/grain cowpea, vegetables, groundnut etc in cassava, cowpea in yams and aroids) can also help to a great extent to reduce weed problem. Mulching the crop using any locally available plant materials (green leaves, dried leaves etc.) immediately after planting (in yams and aroids) will help to conserve moisture and regulate temperature, apart from weed control.

A decade of research on organic farming of tuber crops

Seven separate field experiments were conducted at the ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, India, for more than a decade (2004-2016) to compare organic vs conventional farming in cassava, elephant foot yam, taro, yams and Chinese potato in an acid Ultisol (pH: 4.3-5.0). In cassava, the experiment was laid out in split plot design with three varieties, H-165 (industrial variety), Sree Vijaya and Vellayani Hraswa (domestic varieties) in main plots and five production systems, traditional, conventional, integrated and two types of organic in sub plots. The impact of conventional, traditional, organic and biofertilizer farming was evaluated in RBD in elephant foot yam. Comparative response of five varieties of elephant foot yam (Gajendra, Sree Padma, Sree Athira and two locals) under organic and conventional farming was also evaluated in another experiment. Like wise, the response of three varieties of taro (Sree Kiran, Sree Rashmi and local) to the various production systems was studied. All the three trailing genotypes of edible *Dioscorea* (white yam: *D. rotundata* (var. SreePriya), greateryam: *D. alata* (var. SreeKeerthi) and lesseryam: *D. esculenta* (var. Sree Latha)) were evaluated under conventional, traditional and organic systems in split plot design. The dwarf genotype of white yam (var. Sree Dhanya) as well as Chinese potato (var. Sree Dhara) were also evaluated in two separate experiments under conventional, traditional, organic and integrated systems in RBD. The field experiment on organic production of arrowroot (with the same treatments) is underway. The on-station developed organic farming technologies for cassava, elephant foot yam, yams and taro were on-farm validated. Varietal response, tuber yield, economics, tuber quality, soil physico-chemical and biological properties were evaluated.

Chemical inputs were not used for an year prior to the start of the investigations. In "conventional plots" farmyard manure (FYM) + NPK fertilizers were applied. Farmers practice of using FYM and ash was followed in "traditional plots". In "organic farming plots", FYM, green manure, crop residues, ash, neem cake and/or biofertilizers were applied to substitute chemical fertilizers. In "biofertilizer farming", FYM, mycorrhiza, *Azospirillum* and phosphobacterium were applied. In "integrated farming", FYM, chemical fertilizers and biofertilizers were used. Organically produced planting materials was used for the study.

Field experiment on organic production of elephant foot yam

Field experiment on organic production of yams

Field experiment on organic production of taro

Field experiment on organic production of dwarf white yam

On-farm validation of taro and yams

On-farm validation of elephant foot yam

Field experiment on organic production of Chinese potato

Field experiment on organic production of arrowroot

Validation trials on organic farming of yams at ICAR-CPCRI, Kasaragod

Pooled analysis of yield data of 5 years was done. Proximate analyses of tubers for dry matter, starch, total sugar, reducing sugar, crude protein, oxalates and total phenols, mineral composition of corms viz., P, K, Ca, Mg, Cu, Zn, Mn and Fe contents, chemical parameters of soil viz., soil organic matter (SOM), pH, available N, P, K, Ca, Mg, Cu, Zn, Mn and Fe status, physical characters of the soil such as bulk density, particle density, water holding capacity and porosity, plate count of soil microbes viz., bacteria, fungi, actinomycetes, N fixers, P solubilizers and the activity of dehydrogenase enzyme were determined by standard procedures. Economic analysis was done.The analysis of variance of data was done using SAS(2008) by applying analysis of variance technique.

Insights from tuber crops

Response of varieties to organic management

The industrial as well as edible varieties of cassava, the elite and local varieties of elephant foot yam and taro and all the three species of *Dioscorea*responded similarly to both the systems (Suja et al., 2012a; 2013b). However, the industrial variety of cassava, Gajendra variety of elephant foot yam and the trailing genotypes of *Dioscorea*yielded more under organic farming than conventional practice.

Yield and economics

Organic farming resulted in 10-20% higher yield in cassava, elephant foot yam, white yam, greater yam, lesser yam, dwarf white yam and Chinese potato ie., 8, 20, 9, 11, 7%, 9 and 10.5% respectively (Fig.1) (Suja et al., 2012b; Suja and Sreekumar, 2014). This is contrary to some of the reportsthat crop yields under organic management are 20–40%lower than for comparable conventional systems (de Pontiet al., 2012; Seufertet al., 2012).

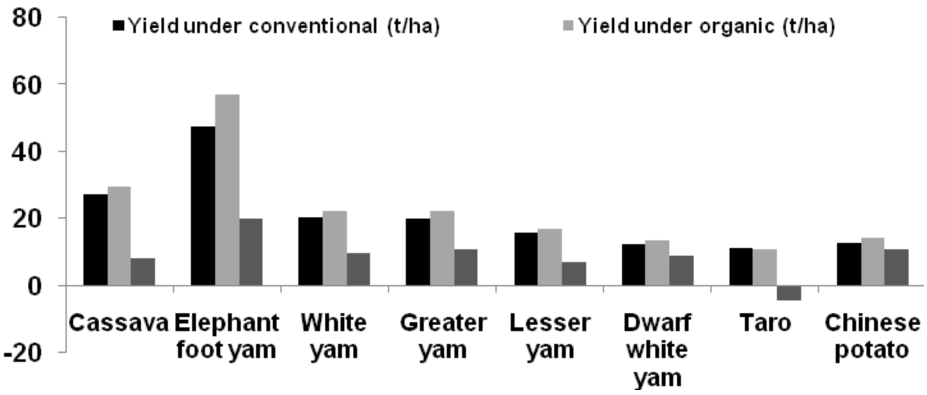

Fig.1. Organic vs conventional farming in tuber crops: tuber yield

Yield trend over 5 years and pooled analysis indicated the significantly superior performance of organic farming in elephant foot yam (Suja et al., 2012b). In yams, up to third year, organic farming proved superior, thereafter it was on par or slightly lower than conventional practice. Pooled analysis indicated that organic farming was on par with conventional practice, but with slightly higher yield. Taro preferred chemical based farming as slight yield reduction was noticed under organic farming (5%). This was because taro leaf blight could not be controlled by organic measures. Cost-benefit analysis indicated that the net profit under organic farming was 20-40% higher over chemical farming (Suja et al., 2016).

Tuber quality

In general, the tuber quality was improved in these crops under organic management with higher dry matter, starch, crude protein, K, Ca and Mg contents. The anti-nutritional factors, oxalate content in elephant foot yam and cyanogenic glucoside content in cassava were lowered by 21 and 12.4% respectively under organic farming (Suja, 2013; Suja et al., 2014).

Soil quality indicators

The water holding capacity was significantly higher under organic management in elephant foot yam (14 gcm^{-3}) and yams and higher in taro over conventional practice (11-12 gcm^{-3}). There was significant improvement in pH in organic farming (1.0, 0.77, 0.46, 1.20 and 0.65 unit increase over conventional system) in cassava, elephant foot yam, yams, taro and Chinese potato. The SOM increased by 10-20% in organic plots over conventional plots in these crops. In elephant foot yam, exchangeable Mg, available Cu, Mn and Fe contents were significantly higher in organic plots. Organic plots showed significantly higher available K (by 34%) in yams and available P in taro.

The population of bacteria was considerably higher in organic plots than in conventional plots; 41% and 23% higher in elephant foot yam and yams respectively. Organic farming also favoured the fungal population by 17-20%. While the N fixers showed an upper hand in organically managed soils by 10% over conventional management under elephant foot yam, P solubilizers remained more conspicuous under organic management of yams (22% higher than conventional management). The count of actinomycetes was favoured by 13.5% in taro. The dehydrogenase enzyme activity was higher by 23% and 14% in organic plots in elephant foot yam and yams (Sujaet al., 2015).In elephant foot yam the organic system scored significantly higher soil quality index (SQI) (1.930), closely followed by the traditional system (1.913). SQI of conventional (1.456) and biofertilizer systems (1.580) were significantly lower (Fig. 2) (Suja et al., 2012a). The SQI was driven by water holding capacity, pH and available Zn followed by SOM (Suja et al., 2013a).

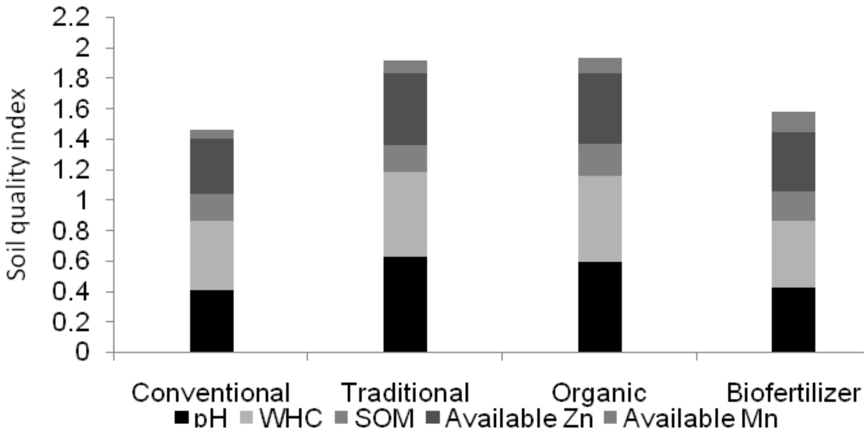

Fig. 2. Soil quality index: Organic vs conventional in elephant foot yam

The Package

Use of organically produced seed materials, seed treatment in cow-dung, neem cake, bio-inoculant slurry, farmyard manure incubated with bio-inoculants, green manuring, use of neem cake, bio-fertilizers and ash formed the strategies for organic production (Fig. 3). The organic farming package for elephant foot yam is included in the Package of Practices Recommendations for crops by Kerala Agricultural University (KAU, 2011) and for yams and taro approved for including in POP Crops (2015) of KAU.

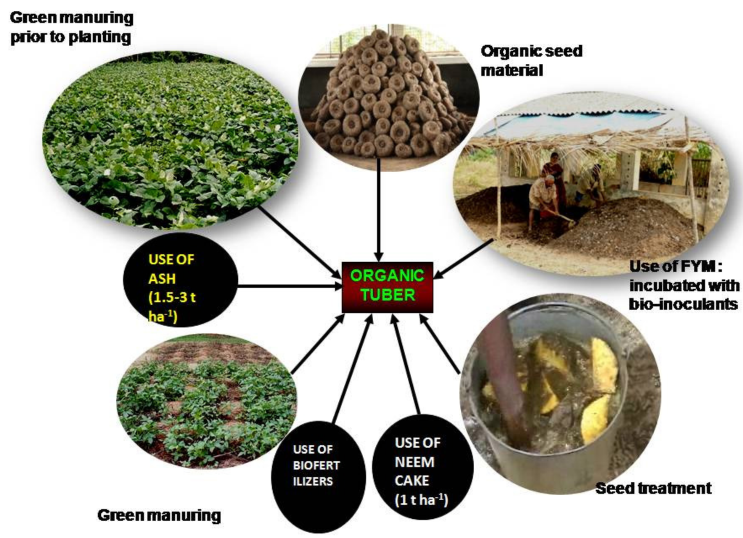

Fig. 3. Essential components of organic tuber production

Table 1. Technologies for organic production of tuber crops

Crops	Conventional practice		Organic practice
	FYM (t ha^{-1})	NPK (kg ha^{-1})	
Cassava	12.5	100:50:100	FYM @ 12.5 t ha^{-1}, *in situ* green manuring (green matter @ 15-20 t ha^{-1}), crop residue incorporation (generates dry biomass @ 3 t ha^{-1}), *Azospirillum* @ 3 kg ha^{-1}, phosphobacteria @ 3 kg ha^{-1} and K solubilizer @ 3 kg ha^{-1}
Elephant foot yam	25	100:50:150	Seed treatment in FYM + neem cake + *Trichoderma* slurry. Application of FYM @ 36 t ha^{-1} (FYM: neem cake mixture (10:1 ratio) incubated with *Trichoderma harzianum*), *in situ* green manuring with cowpea (green matter @ 20-25 t ha^{-1}), neem cake @ 1 t ha^{-1}, ash @ 3 t ha^{-1}
Taro	12.5	80:25:100	FYM @ 15 t ha^{-1}, *in situ* green manuring with cowpea (green matter @ 15-20 t ha^{-1}), neem cake @ 1 t ha^{-1}, ash @ 2 t ha^{-1}, *Azospirillum*@ 3 kg ha^{-1}, mycorrhiza @ 5 kg $ha^{-1}$and phosphobacteria @ 3 kg ha^{-1}
Tannia	12.5	80:50:100	FYM @ 20 t ha^{-1}, *in situ* green manuring with cowpea (green matter @ 15-20 t ha^{-1}), neem cake @ 1 t ha^{-1}, ash @ 2 t ha^{-1}
Yams (Trailing)	10	80:60:80	FYM @ 15 t ha^{-1}, *in situ* green manuring (green matter @ 15-20 t ha^{-1}), neem cake @ 1 t ha^{-1}, ash @ 1.5 t ha^{-1}, *Azospirillum*@ 3 kg ha^{-1}, mycorrhiza @ 5 kg ha^{-1} and phospho bacteria @ 3 kg ha^{-1}
Dwarf white yam	10	80:60:80	FYM @ 15 t ha^{-1}, *in situ* green manuring with cowpea (green matter @ 15-20 t ha^{-1}), neem cake @ 1 t ha^{-1}, ash @ 1.5 t ha^{-1}, *Azospirillum* @ 3 kg ha^{-1} and mycorrhiza @ 5 kg ha^{-1}
Chinese potato	10	60:60:100	FYM @ 10 t ha^{-1}, green manure @ 15-20 t ha^{-1}), neem cake @ 1 t ha^{-1}, biofertilizers (*Azospirillum*, P solubilizer and K solubilizer @ 3 kg ha^{-1} each)

Conclusion

Organic agriculture system is an alternative viable option for sustainable production of safe food with less environmental pollution. Tuber crops, especially elephant foot yam and yams can be considered to be highly prospective for organic farming. Organic production of tuber crops will be successful if sufficient biomass can be generated in and around the farms. Development of biogas plants/biogas technology and agro-forestry for providing alternate sources of fuel, addition of crop residues, green manuring, recycling of on-farm and off-farm wastes and enhancing nutrient value of manures through proper composting, adoption of crop rotations involving legumes etc., are some of the strategies that will definitely help to promote organic farming of tuber crops in tribal and rainfed areas. Integration of tropical tuber crops with diverse crops/enterprises will help to develop sustainable cropping/farming systems models for safe food production, environment and livelihood security. These policies and practices will go a long way in supplementing inorganic fertilizers, whose use cannot be totally eliminated in Indian Agriculture. The benefits accrued through organic farming like yield security, premium price for organic produce, safe food, high soil quality, reduced energy consumption and pollution will further help to promote this alternative farming strategy on a large scale.

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Secondary horticulture: A potential sector for entrepreneurship development

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Introduction

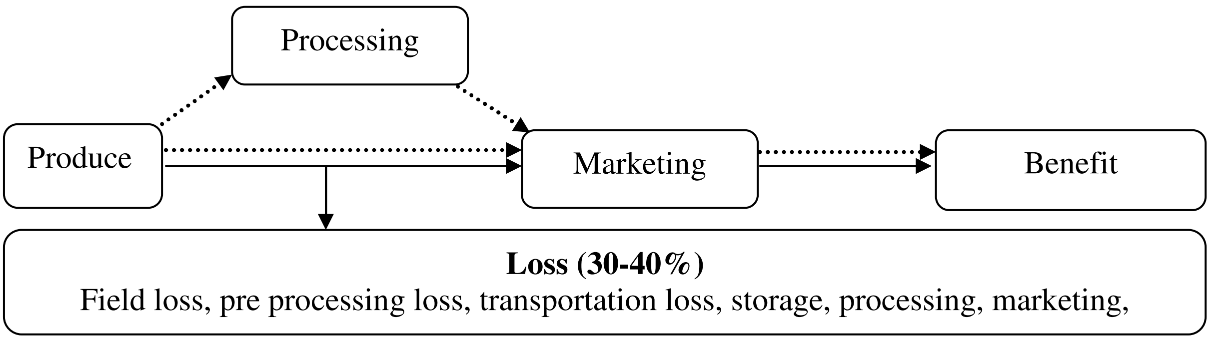
Agriculture is the mainstay of Indian economy which supports the livelihood of about 2/3rd of population. In order to achieve self sufficiency, India has adopted various institutional interventions, technology, crop diversification programme, natural resource management, human resource development, skill upgradation and policies as the key drivers to guide the agriculture sector. On the one hand we have fluctuating agricultural growth and on the other we have distress in farm sector. The reducing farm size, dwindling profitability, resultant indebtedness and farmers' suicides are a matter of concern. The farmers most often complain that they are not properly rewarded for their production efforts. We produce various crops but the supply chain for most agricultural commodities is highly fragmented with multiple intermediaries contributing to the inefficient handling and high transaction costs. The supply chain is characterised by lack of sufficient and efficient facilities like processing, product-specific transport models, grading, certification and packing.

The secondary agriculture provides value addition to agricultural products, creating facilities for primary processing and stress management in agriculture and adds value to the basic agro commodities to allow farmers to get better returns from their harvest. It also creates a new job in the rural sector to grow rural economy which is entirely based on agriculture. Moreover, secondary agriculture has potential to add two to three-fold value to primary agriculture. ICAR is going to shift its focus from primary to secondary agriculture in the 12th five year plan (2012-17). Secondary horticulture can be employed primarily in horticultural produce viz. processed products from fruits and vegetables, essential oil, medicinal and herbal products, etc. Value addition to agriculture produce can easily be promoted and established at village level which will prepare products of local importance for sale in the local markets. It can increase farm income up to 40 per cent and will create additional job opportunities and will also improve nutritional status of the people. The export of processed food has also increased from US$ 16,312 million in 2008–09 to US$ 36,212 million in 2012–13. This sector provides employment to about 8.53 million people in India along with a wide range of contributions to revenue.

India's horticulture production has crossed all time high of over 282 million tonnes (NHB, 2015). Horticulture occupies 8.5% of the cropped area only however it contributes over 30% to the gross agricultural output. Among horticultural crops, fruits and vegetables have the lion's share of more than 90% (256 million tonnes) of production; however they also experience high PHT losses (30-40%). Considering whooping post harvest loss the actual production of fruits and vegetables is 170 million tones and consequently the per capita availability of fruits and vegetables reduced to less than the ICMR recommendation of 120 g/day and 300 g/day fruits and vegetables, respectively. The economic growth and changes in dietary patterns have made both the production and consumption of fruit and vegetables increasingly important. The fruit and vegetable sector has a vital role in farm income enhancement, poverty alleviation, food security, and sustainable agriculture, especially in developing countries. This sector, however, suffers greatly from postharvest losses. Some estimates suggest that about 30–40% of fruit and vegetables are lost or abandoned after leaving the farm gate. Secondary horticulture has the potential to address the problem of post harvest loss.

Importance of secondary agriculture (Post-harvest technology) lies in the fact that it has the capability to meet food requirement of growing population by eliminating losses making more nutritive food items from raw commodities by proper processing and fortification. Importantly, Post-harvest technology has potential to create rural industries which can be a great asset for Indian economy as 80 percent people live in the villages and 70 per cent of them depend on agriculture. Industrialization in urban areas has resulted in capital drain from rural to urban areas, decreased employment opportunities in the rural areas balance trade in favour of urban sector and mismatched growth in economy and standard of living between rural and urban people. It is possible to evolve appropriate technologies which can establish agricultural based rural industries. The farmer whose role has been reduced to producer can be transformed into producer cum processor and thus getting more dividends for hard labour, input, kind of risk taken and generating resource for socio-economic advancement keeping pace with the modern times.

The key role played in the past by women in agriculture including horticulture was largely unacknowledged in government statistics and decision-making even though they possess first-hand knowledge and insights into such things. This situation has changed over the last two or three decades, and much has been achieved in giving recognition to the importance of women in the agricultural sector. The empowerment of women engaged in farming is gathering pace in many parts of the developing world. Gender mainstreaming, as a strategy, has developed out of a major shift in the focus of efforts to promote gender equality and equity in recent years. The gender mainstreaming strategy focuses on the fact that men and women should be benefitted equally. The concept of mainstreaming recognizes that the empowerment of women can only be achieved by taking into account the relationships between women and men. The advantage of a gender mainstreaming approach is that it allows for the advancement of gender equality and equity regardless of whether it is women or men who are disadvantaged and whose position needs to be addressed. The secondary horticulture will have better say of women since they are more proficient in carrying out different activities of processing and value addition. The role of women is likely to be more critical and there are immediate opportunities for community-led ventures to be successful in rapidly developing markets. Given the extensive participation of women in all aspects of agricultural production, the mainstreaming of gender into the horticulture sector is a key strategy not only for the promotion of equality between men and women, but also for sustainable agricultural and rural development. However the major constraints of processing sector in India are poor infrastructure, technical knowhow, and Poor market linkages and poor coordination between the R&D institutes and processing units. Secondary agriculture is complex, as it involves old as well as new technologies, capital investments, improvements in rural infrastructure, marketing and some critical changes in Government regulations. However, this sector has potential to bring women in the mainstream of development by improving their livelihoods. The supply chain can be made more economically viable with the processing of fruits and vegetables which more prone to wastage.



Post harvest management, processing, storage and utilization of horticultural produce are generally the domain of women at home scale. The rural and tribal women have obtained expertise in the traditional foods and formulations through inherited knowledge. The commercial utilization of these formulations and products by small scale enterprises may be helpful in the income enhancement and additional employment of women. Further the new products and changing preferences of the consumers are opening new avenues for the small and medium scale enterprises in post harvest handling and value addition. The post harvest and value addition industry are expanding to utilize new opportunities. Since women are traditionally engaged in this sector more women need to be trained on the new technologies and policies in the post harvest handling and processing of various horticultural crops to fulfill the growing needs of the sector. Women are involved in the small scale marketing especially in the informal marketing of vegetables in most part of the country**.** In some areas the women comprise 60 to 80 per cent of the workforce in trading of fruits and vegetables. The expertise and the knowledge about the local market practices may be helpful and they can easily be partner in the larger chain of supply of these produces.

Levels of post harvest management

Important sectors in agro processing industries are: fruit and vegetable processing, grain processing, fish processing, milk processing, meat and poultry processing, packaged/ convenience foods and soft drinks etc. As much as 42 per cent of the food industry is in the organized sector and 33 per cent in the small scale, tiny and cottage sectors.

There are three stages of processing.
Primary processing: Purification of produce (fruits, vegetables, spices, cereals, etc) by removing foreign matter, immature grain and then making the raw material eligible for processing by grading in different lots or conversion of raw material into the form suitable for secondary processing.
Secondary processing: Processing of primary processed raw material into product which is suitable for food uses or consumption after cooking, roasting, frying etc. Packaged food like cornflakes, oat, etc is prepared by secondary processing.
Tertiary processing: Conversion of secondary processed material into ready to eat form.
Food items are marketed in different forms as raw, primary processed, secondary processed and tertiary processed. Processed products like jam, jelly, pickle, etc are the outcome of tertiary processing.

Value added products
Many value added products are prepared from horticultural crops. However, fruits and vegetables are most commonly used.
Pickle - Pickles are one of the important consumer products. The important pickles are mango, mixed, chilli, garlic, ginger, etc. Fully matured fresh vegetables or fruits are washed and cut into required sizes and treated with brine water (15%) for 30 minutes. The partially dried materials are addes with spices, salt, and oil and other ingredients in required quantity. The prepared fresh pickles are cured for a week and packed in different sizes for market.
Squash – Squash contains about 25 per cent fruit juice and 40-50 per cent total soluble solids (TSS) apart from 1.0 per cent acid and 350 ppm sulphur dioxide or 600 ppm sodium benzoate. It is diluted twice or thrice before serving. Orange, mango and pineapple are used for squash. It can also be prepared from lemon, bael, papaya, etc. using potassium metabisulphite (KMS) as preservative or from jamun, passion-fruit, peach, plum, raspberry, strawberry, grapefruit, etc. with sodium benzoate as preservative.
Ready- to - Drink (RTD) – RTD is very common as it is most liked by the consumer. It contains at least 10 per cent fruit juice and 10 per cent total soluble solids besides about 0.3 per cent acid. It is not diluted before taking. Mango, litchi, apple, pineapple, guava, berry, etc. are commonly used for RTS preparation.
Cordial - It is a sparkling, clear, sweetened fruit juice from which pulp and other insoluble substances have been completely removed. It contains at least 25 per cent juice and has 30 per cent TSS. It also contains about 1.5 per cent acid and 350 ppm of sulphur dioxide. Lime and lemon are suitable for cordial. This is very suitable for blending with wines.

Nectar - This type of fruit beverage contains at least 20 per cent fruit juice / pulp and 15 per cent total soluble solids and also about 0.3 per cent acid. It is not diluted before serving.
JAM - Jam is a thick consistent product made by boiling fruit pulps with sufficient amount of sugar to a reasonably firm enough to hold the fruit tissues in position. Apple, papaya, plum, sapota, peach, strawberry, raspberry, mango, grapes and muskmelon are used for preparation of jams. It can be prepared from one fruit or more than one fruit (mixed).
Jelly - Jelly is a transparent semi solid product prepared by boiling a clear, strained juice of pectin-containing fruit, with sugar and acid. A perfect jelly should be well-set, but not too stiff, and should have the original flavour of the fruit. It should be of attractive colour and keep its shape. Guava, plum, karonda, loquat, papaya and goose-berry are generally used for preparation of jelly. Apricot, pineapple, strawberry, raspberry, etc. can be used but only after addition of pectin powder, because these fruits have low pectin content.
Marmalade - This is a type of fruit jelly in which slices of the fruit or its peel are suspended. The term is generally used for products made from citrus fruits like oranges and lemons in which shredded peel is used as the suspended material. For preparation sweet orange and sour orange are used in the ratio of 2:1 and the shreds of sweet orange peel are used.
Candy – Candy is prepared from whole fruit / vegetable or its pieces impregnated with sugar syrup, and subsequently drained free of syrup and dried. The most suitable fruits for candying are ash gourd, aonla, karonda, pineapple, cherry, papaya, apple, peach, and peels of orange, lemon, grapefruit and citron, ginger, etc. Covering of candied fruits / vegetables with a thin transparent coating of sugar, which imparts them a glossy appearance, is known as glazing or glazed candy.
Preserve - A mature fruit / vegetable or its pieces impregnated with heavy sugar syrup till it becomes tender and transparent is known as a preserve. Aonla, bael, apple, pear, mango, cherry, karonda, strawberry, pineapple, papaya, etc. can be used for making preserves.

These products could be easily prepared by rural women with requisite skill. However, rural infrastructure is required to initiate the secondary agriculture at the place of production.

The secondary horticulture is critical to India’s development as it establishes a vital linkage and synergy between the Industry and horticulture. India is the world’s second largest producer of fruits and vegetables and holds the potential to acquire the driver’s sit with sustained efforts. The enormous growth potential of this sector can be understood from the fact that food production in the country is expected to double in the next 10 years, while the consumption of value-added food products will also grow accordingly. The growth of processing industry will bring immense benefits to the women and in turn the economy by creating employment and improving livelihood of rural farm women areas. Moreover, round the year availability of raw materials, social acceptability and vast domestic market further increase the scope of processing industry. However, emphasis should be put on the establishment of new agro-industrial plants in the production catchments to minimize transport cost, create employment opportunity in the rural sector and utilize process waste and by-products for manure and animals. It is evident that the viable way to cope with the present situation is to give a massive thrust on reduction of post harvest losses in order to make available more food from the existing level of production.

Insect pest management in tuber crops based integrated farming system

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Introduction

Root and tuber crops are important crops mainly for the arid and semi-arid tropics and many of the farmers cultivating these crops are either poor or marginal. Being cultivated in dry lands and other water-scarce areas and soils, these crops suffer severe losses to many insect pests and some time they cause economic damage. Integrated Management of pests includes many types of control measures, which include prophylactic and preventive measures. For the poor farmers, prophylactic measures do useful, where as for the commercial ones; both types of interventions are needed. Here, the information on the IPM of various tuber crops is furnished, but many times the IPM what we do on our farms depend on many other parameters like availability of planting materials, availability of bio agents, pheromones and further the pesticides. Without having these inputs, realistic goal of achieving IPM may not sound enough.

Cassava

Few serious pests and diseases affect cassava. Spider mites occur during dry season from January to May, feed on leaf sap, causing blotching, curling and leaf shedding. Spray dimethoate 0.05% at monthly intervals starting from January whenever infestation occurs. Spraying water at runoff level on the foliage at 10 days interval is also effective.

Scale insects infest the stems when stacked and occasionally in the field causing drying. Store stems in vertical position in shade to prevent multiplication of scale insects. As prophylactic measures, spay the stems with 0.05% dimethoate during storage.

Cassava mosaic disease is caused by Indian Cassava mosaic geminivirus. Chlorotic areas intermixing with normal green tissue gives mosaic pattern. In severe cases leaves reduced in size, twisted and distorted, reducing chlorophyll content and photosynthetic area. It causes 25-80% yield reduction. Use disease free planting material. Grow field tolerant varieties like H 97, H 165, SreeVisakham and SreeSahya. Rogue-out infected plants and follow strict field sanitation. Keep the field free of self sown cassava plants which may serve as a source of inoculum and help the spread of disease. Prompt disposal of cassava residue is essential.

Tuber rot is caused by *Phytophthoradrechsleri*. Infected tubers show brown discoloration of internal tissues, rotten and emit foul smell and unfit for consumption or marketing, causing heavy yield losses. Improve drainage and remove infected tubers from field and incorporate *Trichoderma viridae* in the soil.

Sweet Potato

Sweet Potato weevil is the most important pest causing very severe damage to the crop. Adult weevil makes puncturing on vines and tubers. The grubs bore and feed by making tunnels. Even the slightly damaged tubers are unsuitable for consumption due to bitterness. Yield loss may go up to 100 % in severe cases. On an average, 20-55% tuber loss occurs.

- Dip the vine cuttings in chlorpyriphos 0.02% solution for 10 minutes before planting.
- Keep sex pheromone traps @ 1 trap/1000 m^2(i.e. 10 traps/ha) area to collect and kill the male weevils.
- Destroy the crop residues after harvest by burning.

Among the 12 virus symptoms recorded, **feathery mottle** (SPFMV) is widely occurring. The primary spread is through planting material. The disease causes upto 50% crop loss. The disease can be managed through field tolerant varieties viz. SreeVardhini, use of virus free planting materials as well as meristem derived plants.

Yams

Yam scale found to occur on the tubers both under field and storage conditions. As a prophylactic measure, dip the planting material in chlorpyriphos0.02%. Use scale free seed tuber for planting.

Elephant Foot Yam

Collar rot is a problem caused by soil borne fungus *Sclerotiumrolfsii*. Water logging, poor drainage and mechanical injury at collar region favour the disease incidence. Brownish lesions first occur on collar regions which spread to the entire pseudostem and cause complete yellowing of the plant. In severe cases, the plant collapses leading to complete crop loss. The disease can be managed by using disease free planting material, removal of infected plant materials, improving drainage conditions, incorporation of organic amendments like neem cake, use of biocontrol agents *Trichoderma harzianum*, drenching the soil with 0.2% captan.

Taro

Aphids and worms are important pests attacking the leaves. The other pests include spider mites, thrips, grasshoppers, scale insects and mealy bugs. Using quinalphos or dimethoate 0.05% spray can control these. Mealy bugs and scale insects damage cormels and corms and hence select cormels free of these pests for planting. If infested, the seed cormels should be dipped in the above-mentioned chemical solution for 10 minutes before planting.

The fungus *Phytophthora colocasiae* causes taro leaf blight. Oval or irregular purplish or brownish necrotic lesions with water-soaking periphery appear on leaves. In severe cases, the entire leaf lamina and the petiole are affected giving a blighted appearance and collapse of the plant. The disease can be managed by use of field resistant varieties viz. Mukthkeshi and Jankhri, early planting to avoid heavy monsoon rains, use healthy planting materials, removal of self grownColocasia plants, spraying with fungicides viz. mancozeb (0.2%), metalaxyl (0.05%). Treat the seed tubers with biocontrol agents viz. *Trichoderma viridae*.

Rice based integrated farming system for livelihood of farm families

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Introduction

Rice being the staple food is grown in the country in around 43.5 million (m) ha under various ecologies of which about 50 % area is rainfed. More than 80% of the rice farmers belong to small and marginal groups and the average per capita land holding in India is only about 0.17 ha. In view of the population growth, competition of land with industrialization and urbanization, declining farm holding size and the dietary nutrition requirement of the farm families, it is necessary to look for the optimum use of resources through shift from conventional rice farming to integrated farming systems. Rice based farming system involving rice, other field and horticultural crops, agro-forestry, fish birds livestock and further income generating enterprises will be the right approach in this respect. However, this will be more relevant in the risk prone *rainfed* ecologies which are mostly located in the eastern part of the country. Rice based integrated farming systems can provide household food, nutrition, income and employment without degrading the environment.

Farming family in tropical India is mainly dependent on *rainfed* farming with high risk of weather uncertainty. In a constant struggle to survive, the small and marginal farmers over the years have evolved techniques which have benefited them immensely. But without knowing the scientific basis of such integration they have been practicing the system for a long time. In India, traditionally, farming has been family based and majority of them are smallholders. The success of farming family lies not in 'specialization' but in practicing farming to meet diverse household needs rather than market opportunities alone. Hence, income from seasonal field crops alone in small and marginal farms is hardly sufficient to sustain the farming family. As such agriculture in India is facing the challenge to achieve sustainable food security with shrinking land resources by producing an additional 50 million tonnes of food to meet the requirement of prognosticated population of 1000 million in the country. Because of declining per capita availability of land in India, there is hardly any scope for horizontal expansion of land for food production. Hence, intelligent management of available resources including optimum allocation of resources is important to alleviate the risk related land sustainability.

Integrated farming system- a promising approach

Integrated farming system is the potential approach and powerful tool for management of vast natural and human resources in developing countries, including India to meet the multiple objectives of poverty reduction, food security, competitiveness and sustainability of small and marginal farmers. The approach aims at increasing income and employment from small-holding integrating various farm enterprises and recycling crop residues and by-products within the farm itself (Behera and Mahapatra, 1999; Singh *et al.*, 2006). Under the gradual shrinking of land holding, it is necessary to integrate land-based enterprises such as dairy, fishery, poultry, duckery, apiary, field crops, vegetable crops and fruit crops within the bio-physical and socio-economic environment of the farmers to make farming more profitable and dependable (Behera *et al.*,2004). Integrated farming systems are often less risky, because if managed efficiently, they benefit from synergisms among the enterprises, leading to diversity in produce and environmental soundness (Lightfoot, 1998; Pullin, 1998).

The Traditional Rice based farming System in India

In irrigated rice ecology, carp fingerlings of natural stock are collected by traps in the inlet/outlets from rice fields irrigated from Godavari river in East Godavari district of Andhra Pradesh with fish yield of 3 kg/ ha. In rainfed lowlands and deepwater rice ecologies capture fisheries are mainly followed realizing around 3 to 300 kg of fish /ha during and after rice growing period in the rice field seeded/planted with mostly traditional rice varieties yielding around 1.0 to 3.0 t grain / ha (Dehadrai, 1988, Ghosh, 1992). The productivity of fish and prawn in coastal saline areas ranges from 100 to 2000 kg/ha/yr (Ghosh, 1992). In Meghalaya rice-fish farming as flow through system in the terraces and also in valleys/ plains. Trap-sum method is followed in *few* areas in the coastal part of Orissa (brackish water areas). In flood prone areas of Brahmaputra valley, rice-fish farming is extensively practiced. In West Bengal Rice-fish farming is practiced by the farmers mostly in rainfed and some irrigated areas mainly in Midnapore and 24 Parganas districts The field design includes one pond refuge of about 1.5 to 2 m deep covering around 8-10% of the area and raised bunds all around. Mostly Eucalyptus trees are planted 3 to 4ft apart since this plant is preferred because of fast growing and a cash crop, in demand for construction and fuel purpose. In this type of farming, a crop after rice (mostly Jaya cross in Midnapore district) taken in *rainfed* condition during *kharif*. Capture fisheries of mostly catfish, perch and murrel types are trapped in the pond along with the water and later harvested after drying of the field. Around Rs. 1,500/- to 2,000/- are obtained by the farmers from fish in one acre unit.

Improved rice based integrated farming system

Rice –fish farming system:

Eastern India, in particular with about 5.6 m ha irrigated area and 14.6m ha rainfed lowlands of the total 26.58 m ha rice area, offers high potential for rice-fish farming system, especially in view of the resources, food habits and socio-economic needs of the people. Rice-fish farming system with higher water and land productivity and employment opportunities can ensure food, nutrition and livelihood security for the farming communities, particularly for the largest groups of small and marginal farmers. Rice-fish culture systems can be mixed or concurrent, sequential or rotational. However, the techniques differ based on the physical, biological and socio-economic profiles of the target agro-ecosystem.

Rice –fish diversified farming system for rainfed lowland areas

In order to improve and stabilize farm productivity and income from rainfed water logged lowland areas, national Rice Research Institute, Cuttack has developed an adoptable technology of rice-fish diversified farming system. Farm size may vary from minimum of about one acre to one hectare or more. Field design includes wide bunds (Dykes) all around, a pond refuge connected with trenches on two sides(water harvesting come fish refuge system) and guarded outlet. The approximate area allotments will be, 20 % for bunds, 13 % for pond refuge and trenches and rest 67 % for main field. The pond refuge measures 10 m wideand 1.75m deep constructed in the lower end of the field. The two side trenches of 3 m width and average 1 m depth have gentle(0.5%) bed slope towards the towards the pond refuge. Small low cost (Thatched/asbestos top)duck house and poultry unit are constructed on bunds with a floor space of about 1.5 sq.ft. for each duck and 1 sq.ft. for each poultry bird. Poultry unit maybe projected upto 50 % over the water in the pond refuge to utilize the dropping as fish food and manure in the system. In such case birds can be housed in cage of made of wire net. A small goat house is made on the bund with floor space of about 2 sq.ft for each animal.

Production Technology

Production Technology broadly involves growing of improved photo-period sensitive semi tall and tall wet season rice varieties with field tolerance to major insect pest and diseases. The suitable rice varieties are Gayatri, Sarala, CR Dhan 500, CR Dhan 505, Jalmani, Varshadhan for Orissa, Sabita, Jogen, Hanseswari for West Bengal, Sudha for Bihar, Madhukar and Jalpriya for eastern uttar Pradesh and Ranjit, Durga and sabita for Assam. Management of insect pest in rice crop is done with the use of sex pheromen traps, light traps and botanicals (Netherin/ Nimbicidin spray at 1%). Indian major carps(Catla, Rohu , Mrigal) *Puntius sarana*, exoctic carps (common carp, silver carp silver barb) and fresh water giant prawn (*macrobrachium rosenbergii*) are grown along with the rice crop and later in the refuge after the rice crop is harvested. Fish fingerlings of 3-4" size and prawn juveniles of 2-3" size are released in a ratio of 75 % and 25 %, respectively at 10,000 per hectare of water area after sufficient water accumulation in the refuge and in the field. Fish and prawn are regularly fed at 2% of total biomass with mixture containing 95 % of oil cake +rice bran (1:!) and 5 % of fish meal. After ric, various crops like watermelon, mung sunflower, groundnut, sesame and vegetables are grown in the field with limited irrigations from the harvested rainwater. On bunds different seasonal vegetables are cultivated round the year including creepers on the raised platform, spices and pineapples are grown in shades. The fruit crops on bunds include varieties of dwarf papaya, banana T x D coconut and arecanut. Flowers like tuberose marigold etc. are also cultivated on the bunds. Both straw and oyster mushroom cultivation are done in the thatched or polythene enclose. Bee rearing is practice in 2-3 bee boxes on bunds. Agro-forestry component on the bund include short term plantation of mainly *Accacia* spp. (*A. mangium, A. auriculiformes).* Animal component constitutes improved breeds of duck, poultry birds and goats. Ducks are raised in the rice field upto the beginning of flowering stage and later in an enclose in pond refuge till the harvest of rice crop. Live *Azolla* is released @0.5 - 1.0 t /ha and is maintained to supplement duck feed and also to some extent fish feed, besides nutrition to the rice crop. Fresh water pearl culture is integrated in the system using the host mussel (*Lamellidens marginalis)* which is normally available in the lowland rice ecology. Components can however, be included in the system based on location –specific requirements.

Productivity and economics

The rice fish farming system can annually produce around 16 to 18 t of food crops, 0.6t of fish and prawn, 0.55 t of meat, 8000-12,000 eggs besides flowers, fuel wood and animal feed as rice straw and other crop residues from one hectare of farm. The net income in the system is about Rs. 76,000 in the first year. Subsequently this increases to around 1, 30,000 in the sixth year. This system thus increases farm productivity by about fifteen times and net income by 20 folds over the traditional rice farming in rainfed lowlands. The rice fish system also generates additional farm employment of around 250 – 300 man-days/hectare/year.

Rice-Fish-prawn-horticulture-agro-forestry based farming system for deep water

With the aim of enhancing farm productivity in deep water areas (5—100 cm water depth), a multi-tier rice-fish –prawn horticulture crops-agro-forestry based farming system model has also been developed in 0.06 hectares area at NRRI, Cuttack. The design of the system includes land shaping in the form of uplands(Tier I and tier II) covering about 15 % of field area followed by rice field area of 40% as *rainfed* lowland (tier III) and deep water (tier IV). This rice field is connected to a micro water shed cum fish refuge (pond) of 20 % area for growing of fish and prawn with the rice crop. Raised and wide bunds are made all around using 25 % of the farm area. The production technology includes growing of high yielding varieties of *rainfed* lowland rice (Gayatri, Sarala)in teir III and deep water rice (Durga and Varshadhan) in tier IV along with the fish and prawn during wet season. Dry season crops like sweet potato, mung, sunflower, groundnut, vegetables are grown after lowland rice in tier III. Dry season rice is cultivated after the deep water rice is harvested in their IV. Harvested rain water in the pond refuge is used for irrigation of the dry season crops. Improved varieties of perennial (mango, guava, sapota) and seasonal fruit crops (Papaya, Banana, Pineapple) are grown in upland (tier I). Round the year different seasonal vegetables and tuber crops (sweet potato, elephant foot yam, yam bean, colocasia and greater yam) are cultivated in tier II(Upland). Agro-forestry (*Acacia mangium*) and plantation crops (Coconut and areca nut) are planted on the northern side of the bunds. Greater yam is grown with the support of trunk of agro forestry tree. The productivity of the system is about 8 t of rice crop/hectare, one tone of fish and prawn per hectare, 20-25 t of vegetables/ha and 8.5 to 51.7 t of tuber crops/ha. The cropping intensity in this system greatly increases to 170 % in field and 360 % in the upland.

Rice-ornamental fish culture

In order to utilize the rice ecology for value added aquaculture, the technique of breeding and culture of ornamental fishes in irrigated waterlogged rice field has been developed at NRRI, Cuttack. The rice field is renovated to make a pond refuge and raise bunds all around. Ornamental fishes like Blue gourami, Red gourami, Pearl gourami, Guppies are bred and cultured with rice (lowland varieties) crop during wet season. During the dry season, rice (Naveen) crop is grown along with ornamental fishes with irrigation. About 25,000- 6, 00000 ornamental fish/ha can be produced in the system, in addition to 3.5t and 5.0t of rice grain during wet and dry season, respectively. Such farming can be taken up by women farmers including Self Help Groups.

Rice based farming system under irrigated condition

With the objective of improvement of livelihood of small and marginal farmers, rice based integrated farming system model for irrigated areas has been developed at NRRI, Cuttack

Production Methodology

Site selection and layout : About an acre of integrated farm area is required for the farming system. 30% of the area is converted to two rice fish fields of 600 sq.m area each with a refuge of 15 % area and another 30 % area is developed into two nursery fish ponds of equal size of fingerlings rearing. The remaining 40% (1500 m2) area is utilized as bunds for growing vegetables, horticultural crops and agro-forestry. Three rice crops are grown in the sequence of kharif rice (var.,sarla/Durga) followed by rabi rice (naveen/Satabdi) and then summer rice(vandana/ Sidhant). Yellow stem borer pest is controlled by using sex pheromone traps or by applying1 % Nethrin/Nimbecidine. Fish culture is taken up with catla, rohu and mrigal species. The fish fingerlings are reared in the two nursery ponds and are used for culture with rice crop in the system. The excess fingerlings are sold out. On the bunds agro-forestry plants like teak, Accacia, sisoo, neem, aonla and bamboo are planted on the northern and southern bunds. Horticultural crops such as banana, papaya and arecanut are grown on the bunds. Pineapple and spices are cultivated in the shade.

Flowers like marigold. Hibiscus and Jasmine are also cultivated in the western bund in 50m^2 area. Two plants of lemon and each of guava, jackfruit, mango and litchi are also planted on the southern bund near the farm house to meet the household requirement. One poultry and one duckery unit are integrated in the system in which 40 poultry birds are raised during the dry seasons.(October to April) and 20 ducks are reared during the wet season (July to December).

Productivity and economics

Three crop of rice yields 800 to 1000 kg of grain per year. Entire produce is sufficient to cater the need of the small farm family. The straw is used for the cattle feed, mushroom base and roof of the farm house. Rest of the straw is sold to earn Rs. 500-1000 per year. Afetr two – three months of rearing, fish fry worth of Rs. 4000- 5000 is sold to the other farmers. Fish are harvested according to the need after the size becomes 250-300 g after 6 months or 0.5-1.0 kg after a year. The income from fish rearing in the system is Rs. 20,000. Pulses (mungbean, blackgram and pigeonpea) taken on the slope and bunds are just enough to meet the protein requirement of the farm family.

Crop Enterprises from the bunds

Seasonal vegetables grown on the bunds are the source income to the farm family and this practice is also labour intensive. Staggered sown vegetables on the bunds give a good return of Rs. 25-30/2.5 m^2/30 days. Binjal and chilly are the most profitable crops as these can be taken by rationing without much labour input in an area of about 200 m^2. Cucurbits taken on the bamboo frame over the trench give a good return. When the whole bund area managed properly with regard to unit area per unit of time, it fetches a return of Rs. 8000- 10,000. From the bund area, 50-60 bunches of banana and about 20 kg of papaya plant can be harvested in a year and the produce is used for consumption as well as sale. The surplus produce gives the net return of Rs 2000 to 3000 which can meet the mid term money requirement of the farm family. An additional amount of Rs 1600 t 1800 per year can be achieved from the disposal of arecanut, aonla, bamboo after 3-4 year, which will go up to Rs. 16000 to 18000 from fifth years onwards with the disposal of 15-20 sticks of bamboo per year, 5-6 quintals of arecanut, 40-50 kg of aonla and 30-40 kg of spices (turmeric and ginger)/ 20 m^2. This monetary return can be utilized by the farm family for the personal needs and the purchase of farm inputs. As the tree like Teak, Sisoo, Acacia have high monetary value after 20-25 years, a farmer can expect a high return upto rs. 1 lakh to 3.5 lakhs from the trees of farm unit. From the bird unit 40-50 kg of meat from red leghorn/ Giriraj is produced every two – three months which give a net return of Rs. 8000-10000 per year. Apart from the meat the 10-12 kg of poultry dropping is used as a manure. Mushroom beds each of 2m^2 taken on the bunds is sold at a profit of Rs. 10 per kg with the expenditure of Rs. 40 per bed. Though flouri-culture is not a profitable but can be used to meet the household religious activity and aesthetic requirement. The system in the subsequent years provides net earnings of Rs. 1,500-3,300 per month besides, high employment generation of 450-500 man days per year, thus restricting the migration of farm community (Sinhababu *et al*., 2007)

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Value addition of tuber crops for off season employment and income generation

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Introduction

Tropical tuber crops have contributed significantly to the nutrition and livelihood of more than 500 million people and several processors and traders in the World. Besides serving as a primary staple for millions in the tropics and subtropics, they also serve as the essential carbohydrate source in animal feeding. Tuber crops are predominantly used as raw material for many food, feed and industrial products. The Central Tuber Crops Research Institute, Thiruvananthapuram and its Regional Centre in Bhubaneswar have developed several food products from tuber crops for use by farmers, general consumers, processors and traders.

Nutritive value of tuber crops

Tubers are rich in carbohydrates, low fat having plenty of calories. Apart from water which forms 50-78% of tissue, the major constituent of tuber crops is starch, ranging from 13-30% in different crops. Tuber crops are rich in dietary fibre and also rich in minerals like potassium, calcium and phosphorus. Tubers are generally low in sodium and high in K:Na ratio which are suitable for patients with high blood pressure. Most of tuber crops contain Vitamin C while orange coloured cultivars of sweet potato, cassava, yams and elephant foot yam are high in β-carotene, which is a precursor of vitamin A. Anti-nutritional factors like cyanogens in cassava, and oxalates in aroids limit their use in diversified products.

Cassava

Traditional food preparation

The simplest and popular mode of consumption of cassava tubers is in the form of mashed tubers. The slices of fresh oil fried tubers form a common snack in most of the households in Kerala state of India. Besides, the boiled cassava is eaten with fish curry or meat, and is a traditional favourite of many Keralites. Roasting is another technique used for cooking the tubers.

Cassava flour based recipes

Cassava flour or meal is usually the final product obtained by pounding or grounding the dried cassava chips. Traditional Indian foods such as *chappathi, upma*, *puttu, idli* and *dosa* can be made from cassava flour. Various dishes like cutlets, *bonda,* bread, biscuits, salad dressings, custard powder, flakes, *sago payas*, vermicelli, spaghetti, macaroni etc can be made from cassava flour.

Cassava rava and porridge

Cassava rava is a pre-gelatinised granular product similar to wheat semolina and ideal for breakfast recipes like *uppuma* and for making desserts like *Kesari*. For preparation of cassava rava, the cassava chips are partially gelatinized, kept for drying and then powdered. The fine grade pre-gelatinised cassava starch (Yuca porridge) can be used to make instant energy drink using hot milk or hot water. Yuca porridge can be fortified with iron/ or calcium and flavoured to obtain a balanced energy drink.

Cassava pappads

Cassava pappad is an important snack food item prepared from flour. The preparation involves gelatinisation of the flour with minimum quantity of water, spreading out the paste on the mat or some similar surface and drying in the sun. After drying, it is stacked in polythene covers. The pappad is consumed by deep frying in oil. The final product undergoes 2-3 times expansion on frying. It is crisp and be consumed as a side dish.

Wafers and sago wafers

Wafers are popular cottage industry products made from cassava starch and sago, which are popular in the state of Tamil Nadu. The wafers are prepared from cassava starch cakes containing 40% moisture. They can be made in different shapes and sizes like round, square, flower patterns etc. Sago wafers are prepared from gelatinising sago pearls. The wafers are deep fried in oil and consumed as an adjunctant.

Fried chips

Cassava fried chips is a high value product having good quality, crispiness and with good shelf life. For production of fried chips the slices of six to eight month tubers with starch content > 20% are treated with dilute acetic acid – brine solution for 1 hr and washed in water. Then, they are parboiled for 1-2 minutes in boiling water, followed by surface drying in the sun for 1-2 minutes. Dried chips are then deep fried in oil to produce light coloured cassava chips of highly acceptable quality (soft and crisp).

Extruded food products

The demand for extruded snack products is expanding at a phenomenal rate in developing and developed countries. Several extruded products from cassava are made in South Eastern European countries. Vermicelli and spaghetti are made from wheat semolina or flour, cassava flour, and other ingredients. Macaroni products which are usually tube-like in form are available in various sizes and shapes. In India, several puffed extrudates from cassava flour and cassava starch were prepared with acceptable taste and quality. Fortification is attempted cassava based extruded fried products through addition of Bengal gram flour, maida, rice flour, egg etc. these products were found to have protein content in the range of 5-10%, and a low oil uptake was an added advantage .

Biodegradable plastics

ICAR-CTCRI, Thiruvananthapuram has developed and patented a technology for manufacturing starch based biodegradable plastics. Cassava starch was blended with polyolefin to make functional plastic articles while inducing biodegradability in appropriate environment. The starch incorporated plastic films (upto 25-40%) posses adequate mechanical strength and flexibility, and can be processed just like normal plastics i.e. heat sealed, printed, coloured etc. the granules and finished products can be stored almost like synthetic plastics and are biodegradable under soil burial conditions. It is patented in India and abroad. The technology can be easily adopted by the existing plastic manufacturers using conventional machines. The plastic film can be used for preparing disposable carry bags, aprons, gloves, caps as well as nursery bags, mulch bags, garbage bags etc.

Moulded articles

Poly (lactic acid) – cassava starch composite based moulded articles were prepared by injection moulding and blow film methods. These can be used as disposable articles for various purposes. A semi synthetic cassava (tapioca) starch based superabsorbent polymer has been developed. The polymer is effective in soil moisture retention and it also improved soil properties such as porosity, water holding capacity and nutrient status. It can be used as a soil additive, especially under controlled conditions such as in greenhouses for plant nurseries, ornamental and medicinal plants for saving on irrigation water.

Bioethanol

From cassava starch, bioethanol can be produced. Fresh cassava tubers, dry chips/flour or starch can be used for production of ethanol. The process consists of three steps – liquefaction, saccharification and fermentation. One tonne of fresh cassava tubers with a starch content of >26-28% would yield around 140-150 litres of 96% alcohol while one tone of dry chips/ flour would yield around 430-440 litres of 96% alcohol under ideal conditions (old patented technology). The CTCRI has recently developed an improved technology for bioethanol production from cassava starch using novel enzymes, derived from genetically engineered micro organisms. This process is time saving and less energy consuming, and can yield 680 litres ethanol from one tonne of dry chips/ flour.

Sweet potato

Traditional food preparation

Sweet potatoes are utilized primarily as human food. The major portion of this crop is eaten as a vegetable, after boiling, baking or frying. Sometimes peeled tubers are sliced and dried in the sun to produce chips, which are then grounded into flour. Sweet potato tubers are also canned, frozen or dehydrated and used in variety of products like purees, candied pieces, soufflé etc. Sweet potato flour is used as a partial substitute for wheat flour in bread and cake making.

Sweet potato jam

Jam is a popular sweet potato product in Philippines. Technology for preparation of sweet potato jam is perfected at CTCRI, Thiruvananthapuram, India. For preparing sweet potato jam, the tubers are washed, peeled, chopped and cooked. The cooked tuber is blended and sieved to obtain fibre-free pulp. This is then mixed with fruit pulps from mango, banana or apple to the extent of 20-30%. After adding the requisite quantity of sugar, the pulp mix is cooked on a low fire till it separates out from the vessel. Food flavour and colour are added to the pulp along with citric acid and preservatives.

Batata shake

The pre-gelatinised sweet potato starch powder can be made by washing, peeling and chipping sweet potato tubers to make chips. These chips are then cooked in boiling water for 5-10 minutes followed by draining and sun drying for 72 hours. The resultant product is then milled, powdered and graded. This pre-gelatinised starch can be mixed with hot milk to make excellent energy drinks.

Sweet potato sauce

The sweet potato sauce technology is developed at CTCRI, Thiruvananthapuram, India. For preparation of sweet potato sauce, the tomato juice is mixed with pulp extracted from sweet potato and then cooked together. The cooking is continued till the pulp content is reduced to half of its original volume. Spices, vinegar, salt and sugar are added and heating continued till the final product reduced to half of its original volume. The finished sauce is then filled into clean, sterilized plain can, sealed and processed for 45 minutes in boiling water and stored for subsequent use.

Sweet potato pickles

For preparation of sweet potato pickles, the cleaned tubers after peeling are cut to ¼ inch cubes and put into vinegar to prevent browning. After soaking for an hour, the cubes are taken, washed in water, drained. Fried and powdered mustard, fenugreek and asafetida are added with ground spices, chili powder, salt and turmeric. The cubes are mixed with above items, fried in oil, and stored in sterile bottles. Pickled sweet potato petioles are popular commercial products in Japan. For preparation, the sweet potato petioles are preserved in soy sauce with the addition of sugar, sesame seeds and chilies, and vacuum sealed in plastic.

Elephant foot yam

The elephant foot yam based traditional food products like deep fried chips and roasted squares are common in Tamil Nadu state of India. Roasted yam squares are prepared by cutting elephant foot yam is cut into squares and cooked with in a ground *masala* paste followed by slow cooking on a pan till the crispiness is obtained. Besides, it is common ingredient of *Sambar*, a savory vegetable stew of drumsticks, okra or lady fingers, potatoes, eggplant, onion and tomatoes prepared with ground spices seasoned with tamarind juice. In Tamil Nadu and Kerala states of India, dishes like *Kaalan*, *Mezukku Puratti*, *Poriyal, Aviyal* are also prepared using elephant foot yam. In Bihar state, elephant foot yam based sweets, pickle, mouth-freshener, pickles, sauce and brewing powders similar to the tea are made by farmers. In Goa, India, the elephant foot yam based soup *Khatkhatem* is prepared by cutting tubers in cube shape which are deep fried before it was added to a simmering pot of a vegetarian stew. Besides, elephant foot yam *chutney* is also prepared, which form important place in Konkani dishes.

Taro

In India, Taro is mainly consumed as fresh tuber. It finds an important place in the Oriya, Bengali and Malayali culinary preparations. In Orissa and West Bengal, the taro chips are commercially produced and marketed by small scale industries. In CTCRI, the process for preparation of low cost taro recipes like taro chips, leaf pakoda etc were standardized.

Arrowroot

The arrowroot tubers are eaten after boiling or roasting. The arrowroot powder is made by grounding dried roots into very fine flour. Unlike cornstarch, it doesn't impart a chalky taste when undercooked. Arrowroot thickens at a lower temperature than does flour or cornstarch. It is recommended to mix arrowroot with a cool liquid before adding to a hot fluid. The lack of gluten in arrowroot flour makes it ideal as a replacement for wheat flour in baking. So it is employed widely in the preparation of pastries, biscuits, cakes, puddings, and jellies. Arrowroot makes clear, shimmering fruit gels and prevents ice crystals from forming in homemade ice cream. In India, it is added to vegetable, fish and meat dishes not only as spice for taste but also as food thickener. The leaves of the plant are used with meat and fish. In Kerala state of India, arrowroot *Halwa* is a popular food, which is recommended for people with digestive disorders. The *halwa* is prepared using arrowroot flour along with Jaggery, nuts, raisings cooked in ghee. In Orissa state of India, the crude starch extracted from East Indian arrowroot is used for preparation of a baby food, 'Palua', which is mixed with milk for feeding babies. Arrowroot is respected as food for infants, invalids and convalescents due to its easy digestibility. Arrowroot flour is used as binder in soups and sauces.

Development of functional foods and neutraceuticals for commercialization of tuber crops

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Introduction

Tropical root and tuber crops are important group of crop species which produce tubers that are used for human food and animal feed. These crops rank third in terms of their contribution to food after cereals and legumes. The popular tropical tuber crops include cassava (*Manihot esculenta*), sweet potato (*Ipomoea batatas*), greater yam (*Dioscorea alata*), white yam (*D.rotundata*), lesser yam (*D.esculenta*), taro (*Colocasia esculenta*), tannia (*Xanthosoma sagittifolium*), coleus (*Solenostemon rotundifolius*) and arrowroot (*Maranta arundiacea*). The root and tuber crops continue to play important roles in feeding large number of population in developing countries. Tuber crops can play a significant role in livelihood improvement of Indian farmers (Nedunchezhiyan and Misra, 2013).

Similarly, malnutrition is a major social challenge in India. It is estimated that around 48% of all children under the age of five are stunted, 74.30% suffer from anaemia, 62% suffer from vitamin A deficiency, and 31.30% suffer from iodine deficiency (IFPRI 2014). Most of the root and tuber crops are rich in minerals, vitamins, antioxidants and dietary fibre. They may play an important role in mitigating hidden hunger through diet diversification. Most of the tuber crops have higher biological efficiency as food producers with high dry matter production per unit area per unit time. The tuber crops have proved to be life sustaining crops in times of natural calamities and famine.
Most of these crops are bestowed with resilience to global warming and climate change and potential for better return under adverse soil and weather condition.

Tubers and root crops are significant sources of a number of compounds, namely, saponins, phenolic compounds, glycoalkaloids, phytic acids, carotenoids, and ascorbic acid. Several bioactivities, namely, antioxidant, immunomodulatory, antimicrobial, antidiabetic, antiobesity, and hypocholesterolemic activities, among others, are reported for tubers and root crops.

Functional and Neutraceutical food

Functional foods are defined as the food or dietary components that may provide a health benefit beyond basic nutrition. A food can be made functional by applying any technological or biotechnological means to increase the concentration of , add, remove or modify a particular component as well as to improve its bioavailability, provided that component has been demonstrated to have functional effect. The interest in developing functional food is thriving, driven largely by the market potential for foods that can improve the health and well-being of consumers. Successful types of functional products that have been designed to reduce high blood pressure, cholesterol blood sugar, and osteoporosis have been introduced into the market (IFIC, 2006).

The term Nutraceutical is a hybrid of nutrition and pharmaceutical. The term nutraceuticals was coined in 1991 by the Foundation for innovation in Medicine to refer to nearly any bioactive component that delivers a health benefit (Hasler, 2002). These are those diet supplements that deliver a concentrated form of presumed bioactive agent from a food, presented in non-food matrix, and used to enhance health in dosages that exceed those that could be obtained from normal food. Such products range from isolated nutrients, dietary, supplements, genetically engineered 'designer' foods and herbal products.

Although the term nutraceuticals is in vogue, there is no universally accepted definition of the term. Broadly put, nutraceuticals can be defined as foods or food derived substances in extracted form, which claim to provide medicinal and health benefits. In fact, the term is so broad that functional foods/beverages, dietary supplements, and any other type of food that provides health benefits fit into the neutraceutical category. However, the term becomes too broad and needs to be differentiated.

Since the early 1990s, there has been a considerable shift in consumer's (especially consumers from developed countries) perspective toward nutraceuticals and functional foods. Currently, consumers are much more conscious and aware about health and many share the perception that the onset of many chronic diseases can be prevented with the proper intake of nutritious diet. Food supplements are not only being consumed for just meeting the recommended dietary allowance but also as a mechanism for performance enhancement and disease prevention.

Functional foods can, thus, have two general types of beneficial effects: to reduce the risk of a disease, and to enhance a specific physiological function (Roberfroid 2002). Disease reduction examples include reducing the risk of cardiovascular disease or dental caries, while physiological benefits include enhanced intestinal function, and mental performance. In reducing the risk of chronic health problems, foods exert their effect incrementally, over years and decades while for physiological functions foods and food components can offer benefits that are immediately evident, such as improved mental alertness, normal gut function, or feeling of higher energy state.

Functional and Neutraceutical foods from tuber crops

1. Protein and fibre enriched functional foods

The cost of making value added snack foods from cassava could be considerably reduced, if wet cassava paste is used instead of cassava flour. Such an innovation was made in making a highly acceptable crisp snack food viz., chitchore from cassava. The wet cassava tuber paste is mixed with ingredients like *maida*, cheese, salt, sugar, baking powder and white pepper. The dough after proofing for 1 h is spread into sheets and cut into small discs of 1 cm diameter. These are then deep fried in oil.

Keeping an eye on the health conscious consumers, mini- papads are developed from cassava flour by adding fibre sources like wheat bran, oat meal, rice bran and cassava fibrous residue. The fibre sources are added to gelatinized cassava slurry and mixed thoroughly. The spicy condiments are also added and spread on plastic sheets which are then dried in the sun for 36 h. The papads are peeled off from the sheets and packed. The deep fried products have soft and crisp texture. Mini- papads with high protein content (7-15%) could be made from cassava flour by adding protein sources like cheese, defatted soy flour, prawn powder and whey protein concentrate along with other spicy condiments. The papads are allowed to dry for 36 h and deep fried in oil before use.

2. Functional pasta from sweet potato and cassava

Cassava is known to be a high starch, high glycaemic food, while sweet potato is a low glycaemic health food. Whilst the global prevalence of diabetes is projected to increase from 4% in 1995 to 5.4% by 2025, approximately 170% increase in diabetic population has been predicted in developing countries, with India topping the list, followed by China. FAO-WHO Expert Consultation recommends the increased consumption of low glycaemic foods rich in resistant starch, non-starch polysaccharides and oligosaccharides. Foods with low glycaemic response are reported to be of use in the treatment of obesity, type 2 diabetes mellitus and in weight management. Considering the projected rise in diabetic population in India to 80 million by 2030 and in an attempt to diversify the use of these root crops, studies were made at ICAR-CTCRI to develop an array of pasta products having high functional value coupled with low starch digestibility. Besides, pasta getting wide popularity among the young Indians and in the metros as a convenient food, transformation to new health and wellness foods is essential to add value to cassava and sweet potato and sustain their cultivation of in India.

i) Protein-enriched pasta

As protein content and gluten strength are critical factors deciding the cooking quality of pasta and since sweet potato lacks gluten, fortification with protein sources like whey protein concentrate (WPC), defatted soy flour (DSF) and fish powder (FP) was attempted to understand their impact on starch-protein network formation. The study showed that slowly digestible functional pasta with good quality could be developed form sweet potato, which also has high protein content. Lack of protein in cassava flour is a major impediment to the development of pasta type of products from it. Nevertheless, technology for making protein rich pasta from cassava through fortification with other ingredients was standardized at ICAR-CTCRI.

ii) Fiber enriched pasta

The rapid increase in lifestyle diseases have led to an increasing awareness among the consumers about the health benefits of dietary fibre, and several reports indicate that diets rich in fibre could reduce the risk from coronary heart disease, cancer, obesity, and diabetes. The physiological effects of dietary fibre depend on the type of fibre, its chemical and physical composition, solubility, etc., and have reported effects like prevention of colon cancer, constipation, etc. Water-soluble dietary fibbers increase the viscosity of food in the intestines and thereby slow down glucose and sterol absorption. Low glycaemic diets rich in dietary fibre have been reported to reduce the insulinemic responses to food and exert hypocholesterolemic action as well as protective effects against certain types of cancer. Several studies have been carried out to improve the nutritional properties of pasta using protein and dietary fibre sources, isoflavones, ω-fatty acid, β-glucans, carotene sources, resistant starches, etc. Cereal bran sources have been used to fortify wheat pasta to enhance their dietary fibre content. The type and amount of added fibre have been reported to influence the cooking and starch degradation in durum wheat semolina pasta.

Sweet potato flour based pasta rich in dietary fibre was made at ICAR-CTCRI using dietary fibre sources like oat bran, wheat bran, and rice bran, with the objective of enhancing the functional value of sweet potato pasta as a prophylactic/therapeutic diet in the prevention or management of conditions like diabetes, cardiovascular conditions, and cancer. Fortification of sweet potato flour with dietary fibre sources resulted in products having slow and progressive starch digestibility and very high percentage of starch remained undigested (RS) after 2 h of digestion under *in vitro* conditions. The slow digestibility of the fibre enriched sweet potato pasta coupled with the high level of residual undigested starch make these pastas ideal foods for diabetic and obese people.

Fibre enriched pasta

Protein enriched pasta

3. Low glycaemic spaghetti from tuber crops

The high incidence of metabolic diseases such as type-2 diabetes, cardiovascular conditions and obesity, among people consuming foods rich in carbohydrates has led to increased research efforts in the development of low glycaemic foods. The effect of fortification of sweet potato flour with banana and legume starches as well as sweet potato starch itself in producing low glycaemic spaghetti (flour based noodles) from sweet potato was investigated. Also the effect of three gum sources such as guar gum, xanthan gum locust bean gum in improving the cooking characteristics and reducing the starch digestibility of sweet potato spaghetti was studied. Sweet potato: maida flour blend was fortified with commercial (edible) gum sources such as guar gum, xanthan gum and locust bean gum at three levels *viz.,* 0.5%, 1.0% and 1.5%. The formulation contained 10% whey protein concentrate which by virtue of its ability to mimic gluten, helped to give excellent binding with starch and also elevated the crude protein content.

Low glycaemic spaghetti

4. Starch noodles from sweet potato

Starch noodles, presently known by different names such as glass noodles, cellophane noodles, vermicelli, *bihon* noodles etc. have been a favourite food in China since 1400 years. They are now produced from purified starches of various plant sources and have become popular in several Asian countries as well. Starch noodles differ in their quality and texture from Asian or Italian pasta/spaghetti, as the latter are made from flour or semolina, although many fortified pasta and noodle products have been attempted by subsequent researchers with a view to improving the quality. Starch noodles have been classified according to the type of raw materials, size of the noodle strands, manufacturing method etc. Traditionally, starch noodle made from green gram starch is considered as the best owing to the transparent appearance, fine threads, high tensile strength and low cooking loss.

Starch noodles from Sweet potato

5. Gluten-free spaghetti from sweet potato

Coeliac disease is an immune-mediated disease affecting approximately 15 million people round the globe. The disease has assumed alarming proportions in the last decade with one in 133 people suffering from coeliac disease in the USA and Canada, one in 100 in UK, one in 200 in Germany and one in 300 in Europe. Coeliac disease patients have intolerance to gluten, the proteins in wheat, rye and barley. Consumption of gluten leads to inflammation of the small intestine ultimately damaging the villi and affecting the absorption of iron, vitamins, minerals etc. A strict gluten-free diet as a lifelong diet strategy is the only treatment for coeliac disease. With the rapid rise in coeliac disease patients and the advent of new techniques to diagnose this chronic health condition, the demand for gluten-free diets has also increased worldwide.

Higher intake of refined sugar by celiac patients than normal individuals has been reported increasing their chances of becoming diabetic patients as well, which stresses the need to develop low glycaemic gluten-free spaghetti for such people. Several researchers have attempted the development of gluten-free pasta and spaghetti products using materials such as buckwheat, maize, quinoa, sorghum etc. However, there was only limited information on the production of gluten-free pasta from sweet potato (*Ipomoea batatas* Lam.). Hence studies were made to develop gluten-free pasta from sweet potato flour-rice flour blends along with additives such as WPC and guar gum.

Gluten-free spaghetti

Cassava Nutrichips*:* This is a high protein snack food made out of cassava flour by mixing with other ingredients like *maida*, groundnut paste, egg, salt, sugar, *sesame*, coconut milk, baking soda and oil. After mixing the ingredients, hot water is added and mixed to form smooth dough. The dough after proofing is made into small balls which are then spread into sheets of 2 mm thickness. This is then cut into diamond shape using a sharp knife and deep fried in oil.

Cassava Nutrichips

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Livelihood opportunities in horticulture sector

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Introduction

Horticulture is one of the largest sectors of Indian agriculture. It contributes around 28 percent of the GDP from about 13.08 percent of the area and 37 percent of the total exports of the agricultural commodities. Our country has witnessed tremendous growth in this sector, which has brought out economic prosperity to the nation through 'Golden Revolution'. The area under this sector was 0.76 million hectares in 1950-51 which has increased to 24.2 million hectares in 2013-14 with a production of 277.4 million tonnes. Today country has got the status of 2nd largest producer of fruits and vegetables in the world.

Horticulture is extremely diversified component of Indian agriculture that deals not only with the cultivation and harvesting of wide range of crops viz., fruit crops, vegetables crops, tuber crops, ornamental crops, medicinal and aromatic crops, spices and plantation crops but also with the production of planting material, post harvest management, marketing, processing and value addition. This vibrant sector with a wide range of low volume high value crops provides lot of employment opportunities directly or indirectly for diverse group of women *i.e.* illiterate, less educated and highly educated. According to Joshi *et al.* (2003) horticultural crops are important contributor to employment opportunities in developing countries. Their production provides twice the amount of employment per hectare of production compared to cereal crop (Ali *et al.*, 2002).

The opportunities lying in horticulture for women are being discussed below-

A. On farm and off farm employment opportunities as labourer: Around 35% of Indian women are illiterate and could be engaged in following activities as labourer-

Nursery and seed production: Commercial fruit and vegetable nurseries is flourishing trade as the demand for quality planting material is increasing day by day. This sector provides better opportunities for a farm woman to earn handsome money due to ease of operation and flexibility of timing. Traditionally they have been in those nursery activities which require less skill and machinery viz., bed preparation, seed treatment, line sowing, filling of polythene preparation, weeding, watering, fertilizer application and seedling bundle preparation. They do not contribute much in grafting and plant protection measures due to lack of technical know- how and the amount of drudgery involved. Therefore, training on grafting and use of women friendly agricultural equipments could be very helpful in empowering them in nursery related activities.

Disease and pest management is very important for nursery seedling production. For this purpose regular need based application of pesticides is necessary which is generally done by knapsack sprayer. The womenfolk find it difficult to shoulder the sprayer and operate by cranking the lever. Cart based pneumatic women friendly sprayer are available to counter this constrains. These are easy to operate and use. Farm women can easily spray pesticides to seedlings with the help of long delivery pipe, without taking the sprayer to all parts of nursery. Women can also be involved in production of quality seed both in vegetable and ornamental crops. Women can perform various seed processing operations like harvesting, threshing, cleaning, drying, sieving and packaging (weighing filling in packets, stapling, labelling, etc.) efficiently.

Horticultural crop production: Traditionally illiterate or less educated women have been working as labourers in various activities of fruit, vegetable and flower cultivation which are labour intensive, simple and low prestige tasks of cultivation viz., collection of seeds, weeding, hoeing, irrigation, harvesting, transport of the produce to short distance and processing. In general they do not take part in operations requiring more physical strength, heavy implements (spade, machines etc.) viz., ploughing, pit digging, spraying of chemicals, mixing of manure, diverting water for irrigation etc. and those requiring greater skill, viz., orchard layout, planting, grafting, pruning and training etc. According to Tripathi *et al*. (2015) women contribution in fruit cultivation includes weeding (80%), field preparation (40%), irrigation (40%), collection of harvest (40%), and sorting and grading (40%). Bhat and Bhat (2014) reported higher involvement of women than the involvement of men in apple cultivation for certain specific horticultural operation such as carrying cow dung on head, digging under plants, application of fertilizer, plucking of apples and transporting of boxes.

Tripathi *et al*., 2015 in two districts (Khurda and Ganjam) of Odisha revealed that women participation is more in cultivation of vegetables as compared to fruits and flower crops. They are playing major role (60-80%) in field preparation, stubble collection, sowing of vegetable seeds, transplanting of seedling and weeding. According to Mankar *et al*., (2013) in Vidarbha region of India farm women engaged in marigold cultivation activities are performing major role in top dressing of fertilizer (40.00%), grading (30.00%), packing (25.00%) and marketing of flowers (40.00%).

Industrial processing plants: Horticulture provides raw material to many industries viz., coir, food processing (jam, jelly, squash, chips, pickle, sauce, ketchup etc.), dry flower, perfumery etc. Coir industry is one of the major sectors that is dominated by women. The role of women in coir sector is as high as 80 per cent and 60 per cent in coconut processing and broom making, respectively. Involvement of women in coconut based handicrafts is up to 40 per cent.The demand for the processed food material is increasing day by day due change in our life style and purchasing power. Women with limited knowledge and skill could be engaged various steps of processing viz., washing, grading, sorting, packing. They have employment opportunities in dry flower sector as they are very creative in nature.

B. Horti-preneurship and self employment opportunities

Beekeeping: It is an ideal, economically-viable enterprise that can be taken up by farm women as a profession as it requires less labour, attention, investment and no permanent holding. Besides, we have available with us the high yielding exotic *Apis mellifera*, commonly called Italian bee. Women can easily learn various operations involved in beekeeping viz., hiving of bees and bee swarms, occasional feeding, queen introduction, prevention of absconding, swarm control, honey extraction etc. A few bee colonies (boxes) kept in a kitchen garden or backyard of the house would add to the income of the farmer woman.

Mushroom Cultivation: Mushroom cultivation is considered one of women friendly enterprises as it is simple, low costing and home bound. It provides great opportunities of income generation to farm women in both semi-urban and rural areas. Women possess skill and patience required for important operation like- harvesting of mushrooms, which are picked at the desirable stage very skilfully without damaging bed and neighbouring pin heads; trimming mushrooms before packing for sale. Other operations like filling of compost, spawning, casing, spraying etc. can be carried out easily by women since these do not require moving out of homes. Women can also be engaged in packing processing, processing and preservation activities. Thus, women can play a vital role in mushroom cultivation without sacrificing their household responsibilities.

Undoubtedly, mushroom cultivation can go a long way in raising overall economic level of women. Therefore, there is an urgent need to impart technical know- how to women so that they can adopt mushroom production as an income generating activity. Manju *et al.* (2012) and Biswas (2014) found the significant impact of awareness and training programmes in disseminating the knowledge of mushroom cultivation.

Processing and value addition: Indian women have been traditionally doing some processing and value addition in fruits and vegetables on small scale like preparation of dehydrated products, preserves, pickles etc. Improved technologies for drying, preparation of minimally processed product (ready to cook vegetables and ready to eat fruits) and diversified processed products (Jam, jelly, murabba, pickle, candy, squash, nectar, ready to serve drinks, marmalades, etc.) from horticultural crops are now available various technologies which could be adopted by women. Many simple farm-produce-processing technologies have been developed using minimum equipment and small investments. Women could be trained easily for handling these equipments/gadgets.

Horti-consultancy and vocational training: Women with diploma and degree in horticulture subject can earn handsome amount of money by providing advice on various aspects of crop cultivation to the growers and entrepreneurs and by providing skill developing vocational training to them.

Floral decorator and landscaping architect: There is a great demand for these personnel from Government agencies, landscape architectural firms and resorts to beautifying the parks, recreational areas, campuses, industrial sites, institutional grounds, shopping mall etc. This job requires sound knowledge of cut flower, loose flowers, potted plants, foliage, grass, dry flowers, floral arrangements and land landscaping.

Commercial nurseries and protected cultivation of vegetables are another area where women have opportunity to earn their livelihood.

C. Job opportunities for highly educated women in Government sector

Generally a good job in horticulture sector requires degree in this discipline. College level education provides more in depth knowledge of the field and offers job opportunities at supervisory or managerial levels while post graduation and doctorate level degree provide very good jobs in the field of horticulture to conduct research or impart teaching.

In research: Though, our country has achieved a great success in horticulture and witnessed "Golden revolution" yet, there are many challenges viz., declining land and water resources, rising energy, taxes and production cost, mounting demand of horticultural produce and climate change, confronting to keep the pace of growth and development in this sector. But this sector is committed to produce surplus to meet the growing demand of ever increasing population. Therefore, in this sector there is lot of demand for the researchers so that new innovative and improved technologies could be developed time to time. Women with master degrees and PhD degree in the horticulture subject may get employment as scientist and subject matter specialist. Besides they can also work as research associates and senior research fellow on contractual basis.

- In education: Lecturer, Reader, Assistant Professor, Associate Professor in Agricultural Universities and Colleges.
- Training Organizer & Training Associate in Krishi Vigyan Kendra (KVK).
- Civil Services: Examination conducted by Union Public Service Commission (U.P.S.C) for IAS/IFS
- As District Horticulture Officer/ District Agriculture Officer through examination conducted by State Public Service Commission
- Technical Assistant / Technical Officers in Agricultural Universities ICAR, DRDO, IARI, & CSIR
- Horticulture Inspector / Fruit & Vegetable Inspector / Marketing Inspector
- Training Assistant in Krishi Vigyan Kendra (KVK)
- Farm Supervisor
- Section Officer (Horticulture / Landscaping), Horticulturist or Supervisor (Horticulture)
- Horticulture Development Officer
- Village Level Worker

D. Job opportunities for highly educated women in private sector

- As Horticulturist / Horticulture Officer or Supervisor (Landscape) in Industries, Farm Houses, Hotels, Golf Courses & Construction Companies etc.
- As Horticulture officer in processing companies of agriculture production
- Marketing jobs

Impediments affecting the opportunity for women in Horticulture

Drudgery: Most of the horticultural activities performed by farm women involve considerable amount of drudgery because most of them are done manually. They use very old tools and equipment which also used by the gents and are not suitable for them. They are performing tasks repetitively with very awkward static posture such as squatting, bending, sitting which is responsible for musculoskeletal disorders and leads to occupational health hazards. Pain in upper and lower limbs, injuries in finger, nail & palm, allergies & injuries in skin are the major problems one can identify easily.

1. Illiteracy: Majority of the farm women are illiterate and are facing serious constraints in carrying out horticulture production activities because of inadequate technical competency. They have less access to information, technology, inputs and credit than men. This has compelled them to follow age old practices which in turn result in poor work efficiency and drudgery.
2. No self decision making power: Although women play an important role in horticulture production, their role in the decision making process regarding buying inputs, selection of crop, selection of variety, planting crops, planning the budget, hiring labour, disposal of produce, etc. is not significant and they play a supportive role.
3. No ownership on land: Though, Indian legislation permits equal rights to men and women, still women do not have ownership on land and pattas are allotted in their husband's name.
4. Limited access to inputs and credit: Farm women have less access to most of the crucial input and credit as they are not land owners.
5. Household responsibilities: She is overburdened due to her multidimensional at home and at farm. Women agricultural labourers are paid much lower wages because of the belief that women have less physical strength than men.

Measures to improve the opportunity for women in Horticulture

- Capacity building: The technical skills of farm women can be developed through organizing training programmes, exposure visits, vocational trainings, group discussions, involving them in national and international trade fairs etc.
- Self help group: The performance of women in horticulture can be enhanced through self help group as they mostly work in groups.
- Development of women friendly horticultural technologies: Many farm women friendly horticultural technologies have been developed in India with a view to reduce the drudgery, to reduce occupational health hazards and to enhance the work efficiency of farm women engaged in Horticulture. Finger Guard for picking flower and vegetable crops, Ring cutter for plucking vegetables like okra, Face protector for reducing occupational health hazards during weeding and harvesting hazards, Protective clothing for reducing occupational health hazards and Fertilizer Trolley etc are some innovative machines which can be used in horticulture
- Access to ICT tools: Access to the information and communication technology is essential for farm women to get the information on various aspects of horticultural crop production viz., packages of practices of crops, weather forecast, mandi prices etc., and to get updated with the recent technological advancement in horticulture.
- Infrastructural facilities like road, electricity, cool chain, etc. must be developed in rural areas for increasing entrepreneurial opportunities
- Family support

Conclusion

Horticulture with a wide range of low volume high value crops e.g. fruit crops, vegetables crops, tuber crops, ornamental crops, medicinal and aromatic crops, spices and plantation crops ,is the fastest growing sector of Indian agriculture. It provides lot of employment opportunities directly or indirectly for diverse group of women *i.e.* illiterate, less educated and highly educated. Besides providing on farm and off farm employment opportunities as labourer, it offers self employment and jobs in government and private sector. While working as labourers, women are exposed to considerable amount of drudgery because most of them are done manually. Women friendly horticultural technologies are available and are needed to be popularized to enhance the working efficiency of women labourer. Training programmes, exposure visits, vocational training, access to ICT tools, formation of self help group and family support could play a vital role in motivating women to opt horticulture as source of self employment. Women youth is needed to be encouraged to opt for horticulture as a subject for higher studies. Thus, opportunities are vast in horticulture sector and are waiting to be tapped by the women.

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Apiculture for improving livelihood and employment generation

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Introduction

Apiculture or beekeeping is a traditional practice intimately associated with our cultural heritage**.** Though honeybees and multifarious use of honey was known to the people from time immemorial, but the ancient practice related to honeybee was **honey hunting** rather than **beekeeping**. Apiculture or the scientific beekeeping in our country is only about a century old practice. Realizing the immense importance of honey bees , apiculture is presently flourishing as a novel enterprise not only as an integral part of our farming system but also as an ideal enterprise especially for landless and very illiterate tribal people for improving their livelihood. Our mother land India is a country of mega-biodiversity with ample scope for beekeeping with the native species i.e. Indian hive bee, *Apis cerana indica* and the introduced Italian species i.e. *Apis mellifera* .Adoption of beekeeping as an enterprise will not only boost up the honey production of the country but also support biodiversity improvement & conservation and enhanced crop yield of several field and horticultural crops to many fold through cross pollination. Honeybees play a significant role in pollinating 60-70% agricultural and horticultural crops for which it is also treated as an important agri-input as it contribute to enhanced yield as fertilizer, pesticides and irrigation etc. Honey bees are utilized for managed bee pollination in apple, litchi,sunflower etc .In addition to honey, bee keeping also provides remunerative benefits through sale of other hive products like bee wax, bee venom, royal jelly and propolis etc. The income can further be raised through the sales of bee colonies, preparing and selling the comb foundation sheets, renting the bee colonies to farmers for effecting the cross pollination in field as well as horticultural crops, renting the honey extractor, trading bee equipments in potential areas, establishing apiculture based floriculture or apiculture based farming system, rendering priced expertise services. It is a very skillful enterprise but can be handled with ease by even a very illiterate person. Numbers of farmers across the country as well as our states have been trained and many of them have taken up this avocation as a mean either to improve their livelihood or for employment generation. As an enterprise, apiculture can be taken up by any person irrespective of age, sex, caste, creeds, qualification, profession, have and have not's etc. It is also a well suited or women friendly enterprise. Women are the vital and productive work force in the Indian economy and their involvement and role in agriculture has been well realized. Women empowerment is also possible through apicultural interventions. Besides, the other attractive features of bee keeping for a person is that,

- It is can be practiced by landless people to people with small land holdings.
- It does not compete with any branch of agriculture.
- It does not require continuous labour.
- Does not require heavy investments. One time investment will give return for over a period of one decades
- Some equipments are required.
- It provides multi source income.

Apiculture or the Scientific Beekeeping is having lot of goodness and values, but then, it is not picking up well to the expected height in many states. Some of the important reasons for this are furnished below.

1. Fear of bee stinging:
Stinging by wild bees, *Apis dorsata* leading to casualty has created havoc in mind of many people. But normally the hived bees do not sting to the extent so as to create panic. Honeybees normally sting under the following situations.

- When adverse weather prevails,
- Queen cells are formed,
- Colony remains queen less for long time,

- While shaking bees off the frame,
- When any bee is injured while inspecting the box.
- Creating situations that irritate the bees.

But the fact is that, mild bee stinging is good for health and it can easily be prevented by smoking gently by help of a smoker or avoided by careful handling of bee colonies, wearing a bee veil & protective dresses. The LD_{50} value of the apitoxin is 2.8mg /kg body weight.

2. Non availability of bee colonies:
Bee colony is the most critical input of bee keeping .Production of bee colonies is totally depend upon the nature. In the breeding season only, some more colonies in compared to natural process may be produced through technological intervention like colony division in *A.c.indica* or mass queen rearing in *A.mellifera* which will remain far behind the requirement. As per the minimum recommendation of 2-3 bee colonies /ha for effecting proper pollination of crops, India requires about 150-200 million colonies as against the present availability of about 1 million colonies. Documented authentic statistics is however not available to estimate the growth rate of apiculture in the country as well as State.

3. Lack of awareness :
Honeys bees are the most fascinating, most studied social insects that has attracted attention of many people. Many people wish and many other start beekeeping without understanding the basic behavior or languages of the honeybees. Keeping bee is a very skillful activity and can be performed easily if the minimum knowledge of bee behavior and their body language is understood. This enterprise is unending as the honey bees have overlapping generations. The population of the bees in a colony only dwindles in accordance to the climatic conditions and availability of bee flora.

4. Non availability of support systems :
The essential inputs like bee colony, bee equipments are not within the reasonable reach of the people. There is neither any open market for these items nor regulatory system for trading apicultural products which creates imbalance in marketing. Further, the government has started extending financial supports through various schemes, but then the financial support remains as a constraint for many of the aspirants.

Scientific Beekeeping:
Apiculture or the scientific beekeeping is an art and science of collecting/procuring colonies of desired honey bee species, hiving them in the standard and specified bee boxes, installing in appropriate sites, managing optimum number of colonies scientifically round the year and harnessing both direct and indirect benefits of the activities.

In addition, the other important facts of scientific bee keeping are:

- Beekeeping does not give immediate direct return to the bee keepers,
- It requires maintenance round the year but yields honey only in honey flow season lasting for more or less 4 - 5 months in a year
- After realization of the total investment towards cost of bee box, colony and hive stand the actual direct benefit to bee keeper starts from honey flow season of second year.
- From third year onwards it gives return with nominal to no investment and continues as long as it is managed carefully and scientifically.

The practice of scientific beekeeping is very simple and easy but it essentially necessitates i) Interest ii) Patience iii) Some preliminary knowledge on bee behaviour as pre requisites and iv) utilization of gained knowledge for achieving success. But unlike other enterprise, it can't be practiced by reading, hearing or seeing the activity without practical involvement. Confucius, 450BC, rightly said that "***Tell me and I will forget; show me and I may remember; involve me and I will understand".*** Hence, for practicing scientific bee keeping successfully **Training is a must**, in which preliminary theoretical and practical knowledge on the following points must be acquired.

1. ACQUAINTANCE WITH TYPES OF HONEYBEES

Beekeeping can be done by using two species of honey bees viz. *Apis cerana* and *Apis mellifera* as per suitability. Success in both the cases depends on quality of bees, management practices and the support of natural condition, particularly availability of the bee flora. Indigenous species, *Apis cerana indica* is amenable for beekeeping in many parts of the country and suitable for stationary bee keeping. The Italian honey bees, *Apis mellifera* in the other hand is a better honey gatherer and docile species with many other desirable traits suitable for commercial bee keeping and performs well if migratory bee keeping is practiced. It gives more return when under condition of migratory bee keeping with diversification.

A honeybee colony consists of single queen, few hundred drones (About 150 in case of *A. cerana* and 750 in *A. mellifera*) and few thousand (About 20-25 thousand in case of *A. cerana* and 50-60 thousand in *A. mellifera*) workers (sterile females).

QUEEN BEE:

- Queen is the perfectly developed female in the colony.
- Queen cells are formed on the lower portion of the comb during honey flow season. They are much bigger and can be well distinguished from other cells.
- Larva excessively fed on royal jelly becomes the queen.
- Queen survives for 2-3 years but lays more eggs during first 12-18 months.
- Queen lays about 800 eggs per day in case of *A. cerana indica* and 1000-1500 eggs per day in *A. mellifera* as per the requirement.
- Queen regulates the colony size in the hive depending upon the food availability and weather conditions and acts as the leader of the colony.
- It is fed on royal jelly and is guarded by a few worker bees.
- Young prolific queen is preferred over the old ones to maintain healthy colony.
- Young queen has the abdomen straight and shining while, in old queen it is bent and dull coloured. Old queen show rat tailed movements.
- From egg laying to emergence of adult queen takes 16 days time.

WORKER BEE:

- Worker bees are sterile females and constitute the real work force of the colony.
- They live for 6 weeks to 6 months, longevity being more in the off season.
- Practically they perform all the duties of the colony excepting reproduction.
- Immediately after emergence as adult they engage themselves for first three days to clean the cells and prime it with royal jelly and make ready for further egg laying by queen.
- Bees of 4-5 days age act as nurse bees and feed the developing larvae in the honey comb.
- Bees of 6-13 days age produce royal jelly mixing the secretions of their salivary and mandibular glands. This royal jelly is used for feeding the young ones for few days and the queen bees for entire life.
- At the age of 10-13 days, they come out of the hive during afternoon hours for play fight and acquaint them with the surroundings.
- At 14-17 days stage ,workers secretes wax from four pairs of wax gland by consuming the honey and deposit the wax scales on the ventral surface of the abdomen which is subsequently used for building ob new hexagonal combs.
- Bees of 18-21 days age act as guard bees and protect their colony from intruders.
- After serving for 3 weeks within the colony, rest of their life they spent for foraging nectar, pollen and water.
- Comb construction, thermoregulation of colony, Colony cleaning, honey drying, storing and capping of honey cells, pollen storing in cells etc all the jobs are very decently performed by the workers of the colony.
- Compared to patchy worker cells, presence of compact worker cells or worker cells in concentric ring is an indication of good colony.
- From egg laying to emergence of worker adult takes 21 days time.

DRONE BEE:

- Drones are the male member of the colony found normally in the breeding season. In other times they are absent or found in very negligible numbers.

- The only work of the drones is to mate with the queen and help in reproduction activity of the colony.
- Drones that contribute to make the queen fertile die soon after the mating.
- Drones have underdeveloped mouth parts and consume much more honey compared to workers
- So drones are tolerated by workers till queen is mated and thereafter they are driven out of the colony after tearing their wings.
- Drone trap can be used to remove drones to keep the colony stronger. Drone cells remain bulged above the surface of the comb.
- From egg laying to emergence of adult drone takes 24 days time.

2. SITE SELECTION

- Site should have ample of bee foraging plants within 1km radius.
  Bee foraging plants- Over 750 bee friendly plants either as source of nectar or pollen or both are available in our country.Some of the important are cited below.
    1. Forest plants:-Sal, Neem, Karanja, Sisoo, Mahul, Acacia, Bael, Tamarind,Eucalyptus, Silk cotton etc
    2. Horticultural plants:-Mango, Litchi, Coconut, Jamun, Citrus, Guava, Banana, Ber, Apple, vegetable and flowering plants
    3. Field crops: Sunflower, Mustard, Sesamum, Pulses, Maize etc.
    4. Weeds, fodder plants and medicinal plants.
- Location specific floral calendar should be prepared as an indicator of suitability of the site. Ideal sites provide flower resources for at least 6-8 month.
- Site should be well ventilated, dry, neat and clean and have source of fresh water.
- It should be well communicated but away from main road as natural as possible.
- While installing the hives it should be at about 2.0-2.5 ft height from the ground level **in** case of *A.c.indica* and about 1 ft in case of *A.mellifera.*
- Between two colonies the isolation gap should be 6-8 ft in case of *A.c.indica* while in case of *A.mellifera* boxes can be kept in close proximity.

3. BEE EQUIPMENTS

The essential bee keeping tools includes standard and specified wooden bee box , hive stand, honey extractor Besides, the other tools required are ant well, nucleus box, capturing hive, smoker, bee veil, queen gate, queen excluder sheets, hive tool etc befitting to the species of bee should be used for beekeeping. The native *A. cerana* is kept in ISI. Standard "A" & "B" type boxes while Langstroth hive is required for exotic species, *A.mellifera*.

4. PROCUREMENT OF COLONY

Bee colony is the most precious and critical input of bee keeping. It cannot be purchased or procured as and when desired. In honey flow season only, the colonies are multiplied by the bee keepers for trading. The selection and procurement of good bee colony is very vital for initial establishment of a colony in new area. In case of *A. mellifera* normally divided colony is purchased or procured from the bee keepers while bee keeping with *A.c.indica* may be started by collecting natural colonies or swarm colonies or divided colonies. The person having fair knowledge about quality of bee colony should purchase/procure the bee colony either from any recognized organization or from bee keepers. Proper understanding of science, technique and skill is prerequisite for capturing the swarm or natural colonies of the Indian hive bee and so also for dividing the colony successfully for colony multiplication.

Desirable characteristics of bee colonies

- Better adoption to floral resources
- High reproductive efficiency of queen bee.
- Easily managed bees.
- No or little Swarming and absconding instinct.
- Good honey gathering efficiency.

- Less prone to disease and natural enemies attack.
- Capable of over wintering well(In case of *A.mellifera*)

5. COLONY MANAGEMENT

Success of bee keeping depends upon the support of nature and good management practices. Best output is obtained when proper seasonal management is done under favourable natural conditions. Fair practical idea should be acquired on management on the following aspects of scientific bee keeping.

1. Seasonal management
2. Colony division
3. Colony union
4. Robbing management
5. Artificial feeding
6. Swarm control
7. Need based requeening
8. Laying worker management

6. MANAGEMENT OF ENEMIES

This honey bee species is attacked directly or affected indirectly by number of natural enemies both in hives as well as in crop foraging sites. Other than the disease, over 2 dozen species of fauna found to be associated with the honeybees either in foraging sites or inhabited the bee hives. Among the species, the greater wax moth, *Galleria mellonella* was the most dominant inimical species. The *Coelioxys sp. , Vespa orientalis,* and three common species of spiders were observed predating on honeybees. The ecoparasitic mite, *Varroa jacobsoni* was also noticed on *A.c. indica*. Many mites and diseases like thai sac brood, foul brood, chalk brood, nosema etc sometimes affect the apiculture adversely.

Wax moth

Among the natural enemies, Wax moth is the most common one; it normally attacks the weaker colonies during rainy season. But fresh combs are seldom attacked by wax moths.

- Regular and periodic cleaning of the bottom board during rainy season, removal and destruction of old combs, manipulating the bees to construct new comb and maintaining populous colony keeps the wax moth infestation under control.
- Old combs can be preserved with PDB (20g) or Phostoxin (0.6g) in enclosed container

Wasp

Wasps are problematic in hilly areas and during summer season. Their menace can be mitigated through the following practices

- Locating the wasp nest and their destruction.
- Covering the hive entrance partially with coconut leaf.
- Use of sticky traps with bait.
- Physical collection and destruction.

7. HONEY HARVESTING

- The honey is the prime hive product and the main attraction of most of the new bee keepers. The surplus honey stored in the hive by the honey bees during the honey flow season is normally extracted by the bee keepers using the honey extractor.
- Honey should be extracted when 70-80% combs in the super chamber is filled with honey and are capped.
- The extraction should be done preferably in the afternoon hour and in a protected area following scientific instructions. Honey should not be kept exposed to air for a longer period. However, the honey extracted should be processed and stored in glass bottles.

Conclusively, beekeeping is a fascinating enterprise benefiting the poor or landless for their livelihood to rich farmers for its commercial exploitation. It helps in maintaining healthy environment for sustenance of human society and conservation of biodiversity. It helps in both food and nutritional security by its high valued products. It is estimated that ,at present cost structure of beekeeping, one time capital investment results in a gains of Rs.2500/hive /annum in case of *Apis cerana indica* and it's three times in case of *Apis mellifera* . A commercial bee keeper can also generate sizeable employment opportunities for rural youths.

Role of women in integrated farming system

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Introduction

Today in India as well as the world over, the biggest challenge agriculture faces is to increase returns on existing agricultural land with environmentally suitable use of inputs, coping in the same time with the climate change impacts, land competition, water shortage, ecosystem services deterioration and food price volatility. In a country like India, the shrinking average farm size in India due to population growth and land competition as well as financial constraints for higher investment in agriculture are constraints due to the fact that almost 80% farm families belong to small and marginal categories. Added to this is the problem of productivity declining due to environmental degradation for example, deforestation, leading to more unstable water resources and soil erosion especially in India.

Female farmers are the invisible farmers whose contribution is immense but not visible because their contribution is primarily seen as part of their household works which is not considered as a formal sector of work. In our country when technologies were introduced, men were the key recipients of it. This was because of the lack of recognition given to women's contribution. Also the agriculture policies in India till recently were male-centric. Men only were seen as the beneficiaries of agriculture sector- so all programs, policies and schemes were addressed from their perspective alone. Now our governmental and non-governmental policies and programs are awakening to female farmers as a commendable contributor to the sector. Due to land competition and low productivity and profitability many of the households are becoming female headed owing to men migrating to the urban centers for other means to earn a living.

Hence, the need for an array of technological solutions to provide sustainable intensification of agriculture globally, each customized for a specific agro-climatic zone. The much anticipated solution lies in a set of advances in the field of improved genetics and improved agricultural practices. While the biotechnological improvements can be expected in the long term period, there is a large space for short term strategies referred to as sustainable and climate friendly systems and techniques. Also there is need for knowledge and understanding of our traditional agricultural practices which were basically eco-friendly in nature. This knowledge is mainly resting with the women. Highly productive, resilient, low emission agriculture requires sound management of land, water, genetic resources and soil nutrients and higher efficiency of these. Due to geometric increase in population, there is huge need to raise the productivity per unit area per unit of time per unit of capital input as bulk of the farmers are small scale and most of the farm land are cultivated under rain fed conditions. There is a range of such production systems such as conservation agriculture, agroforestry, improved livestock production, urban and peri-urban agriculture, organic farming and integrated farming systems.
The word *integrated* is derived from the Latin word "*integrare"* which means to make whole, to complete by addition of parts or to combine parts into whole. The crop, livestock, fish subsystems may function independently in certain farming systems. However, an output from one subsystem which otherwise may have been wasted becomes input to another subsystem resulting in greater efficiency of output of desired products from the land/water area under a farmer's control.

There is synergism in IFS since the working together of the subsystem has greater total effect than the sum of their individual effects. The other related advantages are that it improves their diet, balances the risks among the various farming subsystems, provides fuller employment and generates surplus produce for sale. It is indeed ironical that the food production potential of the tropics where year round is often possible, have not often been realized. It also improves space utilization and the recycling of by-products. Now, the small and marginal farmers are the group which has limited access to off-farm inputs necessary to exploit modern farming technology. So applying IFS is of high value. A major socio-economic benefit is that the inputs for the various subsystems now become intra-farm inputs with less dependence on inter-farm and off-farm inputs.

In this system, an inter-related set of enterprises are used so that the "waste" from one component becomes an input for another part of the system, which reduces cost and improves production and/or income. In other words, we can say that *IFS works as a system of systems*.

The issues of transfer of technology are also addressed well through this holistic approach. It has evolved as a result of the understanding that basically farmers' production environment is much more heterogeneous than had been thought to be earlier. Its a farming system where the, technologies are used not just for their immediate efficiency but for their flexibility too and thus the need to take into account the farmers' perception of uncertainty and security, their long term perspectives and their farming goals. IFS is an actor oriented approach in order to ensure compatibility with the local socio-economic environment.

Integrated Farming System is a paradigm shift from the earlier agricultural research which is reductionist and command-and-control approach. Korten characterizes it as a people centered process rather than the earlier technological blueprint approach.

Its distinguishing characteristic is its interdisciplinary approach-collaboration between a range of different disciplines. It also involves the farmer herself/himself right from the research process. So instead of only focusing on yield increase of a particular crop, IFS focuses on looking at one specific enterprise (or part of it) and identifying improvements that are compatible with the whole farming system.

Example: The following is another example with regard to greater productivity and greater profit to small and marginal group of farmers.

Toor et al, conducted a study in a cluster of four villages in Phagwara Development Block, Kapurthala district, under the ICAR-funded adhoc project entitled "System Approach towards Income Enhancement" during 2003-06. A set of 11 different IFS was developed and implemented in the farms of selected farmers with 1.5 ha holdings. The results of the study indicated that all the IFS, involving crops (rice, wheat and Aloe vera) and livestock (dairy animals, pigs, poultry, fish, rabbits and honey bees), proved more profitable than crops alone (rice-wheat system) in terms of net returns. Further, IFS resulted in better utilization of land, water input and human resources compared to arable farming alone and it also increased employment generation.

Integrated Farming combines the best of modern tools and technologies with traditional practices according to a given site and situation. In simple words, it means using many ways of cultivation in a small space or land. It takes into account the knowledge and experiences of farmers themselves. Traditional agriculture as an indigenous form of farming is a result of the co-evolution of local social and environmental systems that exhibits lot of ecological rationale expressed through use of local knowledge and locally available natural resources. So using it is not just cost-effective but also does not disturb the ecological balance. FAO aptly calls this kind of agriculture as *climate smart agriculture.*

In addition to the above, today in India, a substantial change has already taken place in consumer preferences for graded, packaged and processed food items of daily use in urban market, especially among middle and high classes. This trend is on the increase and will certainly filter down to rural areas also. Low cost improved technologies are required to unleash potential and improve market efficiency and remain competitive simultaneously. Moreover, recent trends have clearly shown the accelerated use of by-products for value addition. For example, now sugarcane is not only used for sugar production but every by-product of it is used economically by sugar mills- bagasse forelectricity generation, pressmud for preparation of high value organic manure and molasses for alcohol production. Similarly, in case of paddy, husk is being used as a very efficient source of fuel in boilers and bran is used for edible oil extraction. Many vegetable oils-earlier considered to be non-edible are being extensively used as edible after development of refining technology. All these advantages and the varied value addition technologies can be used by farmers too.

Integrated farming system is a whole farm management system which aims to deliver more sustainable agriculture. It is a dynamic approach which can be applied to any farming system around the world. It involves attention to detail and continuous improvement in all areas of a farming business through informed management processes.

Classification of Integrated Farming System
Some of the combinations of IFS are as follows:

1. Crops subsystem- multiple cropping comprising a mix of cereal, vegetables, cash crops, legumes and fodder crops – any permutation combination
2. Crops + Livestock subsystems
3. Crop + Fish subsystems
4. Crop + Fish+ Livestock subsystems

Role of women in Integrated Farming System

The fact that environmental degradation has affected women's lives in ways different from men is well established by now. Women have been identified as the key casualties of overall global ecological degradation by many environmentalists. This is mainly attributed to the fact that there exists a clear gender demarcation with regard to tasks both at farm level and at household level. It is women primarily who are responsible for producing, processing and gathering food, fetching water and carrying fuelwood.But owing to this women's perspective of task completion is very much holistic and integrated. Traditionally, they look at farm and household as one unit and not as disparate units.

In India too, women play a very important role in household management including agricultural operations. This is especially true for hilly and tribal areas. As such, one can see further on, a gradual feminization of agriculture owing to men especially the small and marginal level farmers migrating to rural non-farm sectors as well as urban centers too.

Research shows that on average, women are better at multi-tasking as compared to men. They are able to organize their time better and switch from one work to another faster with relative ease as compared to their male counterparts. This is due to the fact that there is social and psychological conditioning in the society, nee Indian society for a girl child to adapt herself to multi-tasking and as she grows to be a woman it continues because she does have to look to several tasks contrary to men. This makes it easier for women to adopt IFS. It is definitely easier for them to further hone their multi-tasking skills at home and at the farm taken together.

Micro-credit in India has turned into a big movement to empower women. It has been adopted by various NGOs as well as the government and has served as a huge medium of women empowerment. Women acquire the biggest strength i.e. social capital by being part of a well-knit group which serves as a forum where they can be their own and also develop their management skills. Integrated farming system can greatly benefit from this movement if SHG women take it up as an enterprise as well as replenishing the needs of their families.

Example: Let's look at women's role in Kumaon Hills. Here the livelihood of the people is dependent on the sound management of its natural resources and their sustainable utilization. Here subsistence farming remains people's main source of livelihood, but it cannot be seen in isolation. Forest, grasslands, farms, livestock and water all were organically linked with each other and everybody respected this link. Farming was done at a subsistence level with forest providing a strong support base. They provided leaf litter for manure to be used by agriculture and fodder for animals. In turn, the livestock manure enriched forests and farms. Good forest especially the broad leaved forest, was essential for preservation of water in springs, which was in turn necessary to irrigate the fields. The linkage between these sectors is well understood by women as they work between sectors and perform multiple tasks. Women's work and knowledge is thus central to bio-diversity conservation and sustainable utilization of resources in hill agriculture.

There is a vast scope to improve the household profitability by judiciously utilizing family labor using innovative practices and ensuring multiple uses of various household and farm resources. This is possible through women empowerment by way of specific trainings and critical need based support.

Thus women especially need to be given training on the new permutation combinations in IFS. Another rationale for enhancing the skill of women with regard to IFS is due to the fact that they are the key custodians of traditional knowledge. When we talk of managing and preserving traditional knowledge, the pivotal role played by women cannot be ignored. It is true that women have much more pragmatic knowledge of the practices in which they are engaged, leading to a kind of specialization. The close association between women and natural resources exists because of their social and economic roles which have for generations required them to provide food, fuel and fodder from the surroundings.Farm women are closer now than ever before towards increased food production with the increased concern of environment and overuse of pesticides.Recognition of Women work participation will shift agriculture from increased production to increased prosperity through development of various gender friendly IFS required for the sustainability of small and marginal farm families, which are the back bone of agriculture globally.

Aquaculture enriched integrated farming system for food and nutrition security

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Introduction

Fish forms an important component of the animal protein supplement of Indian food. Being the cheapest and the safest animal protein source, popularity of fish has increased in the country. Fish is consumed by 55-60% of Indians. Increase in popularity of fish has prompted enormous growth of the aquaculture Industry in the country. As per the available data of 2013-14. India produced 6.58 MMT of fish of which the inland sector produced around 6.14 MMT. While inland production includes both inland capture and aquaculture production, the later contributes 80-85%. Over the years, the changes have been brought in the methods of fish farming. Species spectrum in the culture system has been increased. Culture of fast growing native fish species has been promoted. The aquaculture industry has come up with varied fish farming methods suiting to the need of industrial aquaculture as well as rural fish farming. Today, aquaculture has also been recognised as an important avenue for rural food and nutritional security.

Freshwater aquaculture in India mostly involves polyculture of three Indian major carps, viz., catla (*Catla catla* Hamilton), rohu (*Labeo rohita* Hamilton) and mrigal (*Cirrhinus mrigala* Hamilton), or sometimes with the three exotic carps, viz., silver carp (*Hypophthalmichthys molitrix*), grass carp, (*Ctenopharyngodon idella*) and common carp (*Cyprinus carpio*). More than 83% of the total freshwater aquaculture production (≈ 5.1 million tonnes/yr) in the country is contributed by the carp groups for which carp culture is considered almost synonymous with the freshwater aquaculture. Of late, the necessity to include more species of promise into the freshwater aquaculture systems in the country has been emphasized time and again. Fortunately, our country is blessed with wide species diversity including many promising cultivable species. Attempts on species diversification in recent years have shown enough possibilities for incorporation of some medium and minor carps *viz.*, *Labeo calbasu*, *L. fimbriatus, L. gonius, L. bata, Puntius gonionotus, P. sarana* etc. in the major carp based polyculture systems due to their reasonable growth, consumer preference and price they command in the market. The country also has a rich resource of many small indigenous fish species (SIFS) which are available in almost all types of water bodies and are important for nutritional security. The SIFS are popular among the fish eaters because of their taste and richness in the nutrients. Culture of such species in carp ponds and rice fields has proven its potential in contributing to the nutritional security of the poor people in Bangladesh. Such species are gradually becoming popular among the fish farmers of India. Besides carps, there are many other species such as freshwater prawn (*Macrobrachium rosenbergii* and *M. malcolmsonii*), air-breathing catfishes (*Clarias batrachus, Heteropneustes fossilis, Pangasionodon hypophthalmus, Pangasius pangasius, Ompok spp.*), snakeheads or murrels (Channa striatus, Channa marulius) and freshwater pearls mussel (*Lamellidens marginalis*) have also attracted considerable attention of the aquaculturist, offering scope for diversifying their culture system into more rewarding farming systems.

Freshwater aquaculture in general offers three types of opportunities:- (i) Induced breeding and seed production of important species, (ii) Seed rearing activity and (iii) Grow-out fish farming, with sub-division of each activity as per species and different life stages of the fish. Unlike earlier years, each of the activity has been able to provide scope of round the year activity which has ensured adopting each specialised activity as full time profession. For example, successful off season breeding and extension of breeding season has stretched the hatchery activity throughout the year. Similarly demand for fish seed throughout the year has helped in making seed rearing a full time profession. Further, the wide range of input dependent fish production (2-15 t/ha) through fish farming offers scope to adopt the activity by marginal to commercial farmers depending on their investment capacity as well the kind of water body.

In the following pages, information has been provided on the above activities for carps, since this group form the mainstay of aquaculture in the country. For other species like catfish, prawn and murrel, though pond management and broodstock management and feeding etc, are more or less similar, certain species specific activities are essential for induced breeding and seed production. However, discussed here the details of activity for carps and barbs.

1. Induced breeding and seed production of carps in hatchery

The technology of induced breeding aimed at producing quality seed starts with the broodstock management till the production of spawn in the hatchery. For performing these activities, a hatchery should have the facilities of broodstock raising pond and the hatchery proper with its components like spawning pool, hatching pool, overhead tank, and water supply and drainage systems.

The induced breeding activity for the Indian major carps, minor carps and barbs is almost similar with certain modification for the barb species which are also discussed. Two to three years of healthy fishes are collected and maintained in the broodstock ponds at least 3-4 months before breeding season at the density 1500-2000 kg/ha. They are provided with balanced diet @ 1-2% of the body weight daily. Water replenishment of 20-25% is advisable in the pond in every month. The matured males at oozing condition and females with buldged abdomen and protruding vent are collected from the broodstock pond for breeding. The males and females are kept in the breeding pool under shower separately in two previously fixed breeding hapas, at male and female ratio of 1:1 by number and approximately 1:1 by weight. When pituitary extract is used as inducing agent, females are given two injections, first dose @ 3-6 mg/kg followed by the second @ 8-12 mg/kg at 6 hours intervals, while males are given single injection of 3-6 mg/kg at the time of second injection to the female. However, in case of using synthetic hormones like Ovaprim, Ovatide or Wova-FH, the injection is given only once to both males (0.2-0.3 ml/kg) and females (0.3-0.5 ml/kg). The injected brooders are released in the pool for spawning. In case of breeding *Puntius gonionotus* (silver barb) in eco-hatchery condition, since the hatchlings are extremely small measuring only 3 mm in length, a finer mesh cloth is required for the central screen of the incubation tank to prevent escape of hatchling. Similarly, *P. sarana* was observed to be a batch spawner releasing eggs in weed mass. While provision of aquatic weed in bunches in the breeding tank facilitates its spawning, the strands and leaf surface of weed such as *Hydrilla* acts as a substratum for attaching the typical egg of the species which is provided with a stalk for attachment.

The broods are kept in the pool under shower before and after hormone injection. Water current is allowed in the pool before one hour of estimated spawning time, which triggers the spawning activity. The response time in all these species varies between 8-11 hours at water temperature 27-28°C. Once spawning starts, effective spawning occurs within 1-1.5 hours from the spawning initiation. Fertilised eggs collected from the breeding tank are incubated in the circular incubation tank. Larvae hatch out after an incubation period of 15 hours at 27-30°C temperature. The hatched larva called hatchlings are kept in the incubation tank for another 60-62 hours during which yolk absorption completes and the larvae develop to the tiny fish called spawn. The spawn from the incubation chamber can be collected by cotton hapa or through the outlet of the pool on a water cushion in the spawn collection chamber. The pool is cleaned with 5 ppm $KMnO_4$ for the next operation.

The carp spawn can be transported to long distance in oxygen filled polythene bags. The density of spawn depends on the duration of transport which generally range between 25,000-50,000/bag with 6 litre of water. Short distance transfer, however, may be done by aluminium containers.

2. Seed rearing of carps

Seed of carp generally refers to two life stages such as fry and fingerling. The spawn collected from hatchery are further reared in well prepared nursery pond for 15-20 days to raise them to 1 inch size which is called fry. The fry is further reared in the rearing pond for a period of two and half to three months when it reached about 4 inch size which is called fingerlings. The details of the procedures are discussed below.

2.1 Production of carp fry

Generally small ponds of 0.01-0.1 ha size were considered ideal for spawn rearing of carp fry. However, higher growth and survival of the fry have been observed in relatively bigger ponds up to 0.4 ha size. Rearing of spawn of carps is carried out mostly with monoculture. Availability of suitable natural feed in the nursery pond is the most critical factor for the delicate transition phase of yolk nourishment to commencement of natural feeding. Suitable ecological conditions also play a great role for the survival of these spawn. Such environmental condition is ensured following a series of activities of pre-stocking pond preparation prior to seed stocking that includes aquatic weed clearance, Eradication of predatory and weed fishes, manure application, liming, inorganic fertilisation, aquatic insect control, etc.

Ponds that dry up in summer or could be easily and economically drained present least problems. But perennial ponds if not managed properly, often gets infested with several types of aquatic weeds, which are floating, submerged, emergent and marginal in nature. These aquatic weeds poses several problems as they absorb nutrients arresting pond productivity, harbouring predatory and weed fishes/insects, hindering free movement of fish and netting operations. Although a wide range of manual, mechanical, chemical and biological methods available for control of these weeds, generally the manual method is commonly advocated for weed clearance because of their smaller size and no time requirement for detoxification as in herbicide use.

Presence of predatory and weed-fishes in the ponds severely affect the seed survival through devouring on the stocked seed as well as competing with them for space and oxygen. While the commonly found predatory fishes in fish ponds are murrels, gobi, magur, singhi, pabda, *Wallago*, etc., the weed-fishes include *Puntius*, *Barbus, Oxygaster, Anabas, Amblypharyngodon, Colisa*, etc. Dewatering followed by sun drying the pond is the most effective methods adopted for eradication of these fishes. Other methods used includes

(i) application of mahua oil cake @ 2,500 kg/ha-m three weeks before seed stocking: besides acting as pesticide, it also serves as organic manure after decomposition.
(ii) application of commercial bleaching powder (30% chlorine) @350 kg/ha-m of water (approximately 10 mg/l chlorine)
(iii) Alternatively, application of urea @100 kg/ha-m followed by commercial bleaching powder @175 kg/ha-m after 18-24 hours is also effectively controls these fishes.

Generally soil with slightly acidic to neutral pH (6.5-7.0) is considered productive, while low pH is always associated with low productivity. Therefore, amendment of pond bottom soil is a prime requirement for fish culture. Acidic soils are treated with lime for increasing the soil pH. High dose of organic manures are sometimes used for amending slightly alkaline soil, while alums are used for pH correction in alkaline soil. The characteristic soil pH in most part of the country falls in the acidic range and is amended through application of different types of lime. Lime also helps as a disinfecting agent in pond with a neutral soil pH, corrects water pH and controls of turbidity in subsequent period of culture operation.

Over the years, several phased manuring practices advocated for nursery rearing have shown encouraging results. However, most of these could not be adopted in large scale due to their complex application schedule. Phased manuring with a mixture of groundnut oil cake at 750 kg, cow dung 200 kg and single super phosphate 50 kg/ha have shown to be effective in production of desired plankton. A thick paste of half of the above amounts are prepared by addition of sufficient water and applied as basal dose 2-3 days prior to stocking and the remaining amount is applied later in 2-3 split doses depending on the plankton levels of the ponds.

Varied stocking densities 1.0-10.0 million spawn/ha have been tried in earthen nursery ponds for rearing of carp spawn to fry with application of manures and fertilizers alone and along with other inputs such as supplementary feed, aeration etc. Study conducted at CIFA has shown density of 5.0 million/ha to be ideal for such earthen nursery pond. Use of bigger concrete tanks for seed rearing of carps at high density has also proven to be effective. Nursery rearing of carp spawn at 10-20 million densities (1000-2000/m^2) in the concrete tanks (10 m x 5 m x 1.2 m) system developed at CIFA has shown higher fry survival to the tune of 40-50%. Use of aeration and water exchange in such system has further proven to enhance the seed survival up to 60%. Use of such concrete seed rearing system has made it possible for a farmer to use high density seed rearing in smaller area and harvest 3-4 crops of fry with higher survival level in a season i.e., during June-September.

The spawn are transferred from the hatchery and stocked in nurseries during cool hours, preferably in morning, after due acclimatization to the new environment. The stocked seeds are provided with mixture of finely powdered groundnut oil cake and rice bran at equal proportion by weight as supplementary feed @ 600 g/lakh for the first 5 days and 1200 g/lakh spawn per day for the subsequent days in two equal instalments during morning and evening hours. During 15 days of rearing period the fry attain the size of about 25 mm which is the ideal size for transferring to rearing pond. Harvesting is done by repeated netting with dragnet of 1/8" mesh. Survival levels of 40-50% are normally achieved in well-managed ponds. During a season from June to September at least 2-3 crops of fry can be raised in earthen ponds and 4-5 crops in cements tanks.

2.2 Production of carp fingerlings

Fry are raised for two to three months to fingerling size in a relatively larger rearing ponds of 0.05-0.1 ha area with 1.2 to 1.5 m water depth. Like nursery ponds, the rearing ones also need specialized management for good survival and production of healthy fingerlings. However, some of the basic operation such as clearance of aquatic weeds, soil correction, and control of predatory and weed fishes are similar to the ones discussed for the nursery pond. The aspect of aquatic insect control in this case is not required. Further, the aspects of management involved in manuring, fertilization and water quality management of the rearing ponds are discussed below.

Pond fertilisation includes application of raw cowdung at the rate of 5-10 tonnes/ha depending on the organic carbon load of the soil. While one third of the above amount is applied 8-10 days before stocking, the remaining amount is applied in equal split doses at fortnightly intervals. Application of biogas slurry at 30-45 tonnes/ha in bimonthly split doses is also found to be effective as improvement over raw cowdung application. In case of use of poultry droppings, the dose may be reduced to one third to half of the amount of cowdung. In addition to the organic manures, inorganic fertilisers such as urea and single super phosphate are applied depending on the nutrient status.

While single species culture is practiced in nursery ponds, rearing pond involve culture of mixed species of carp due to their divergent feeding habit and food preference. Usually fry are stocked at 2-3 lakh/ha density. In ponds with facilities for water circulation/exchange or aeration, the density can be further increased to a considerably high level.

Feed requirements of the growing fingerlings are met through the available natural fish food and provision of supplementary feed commonly in the form of mixture of groundnut/mustard oil cake and rice bran/wheat bran at 1.1 ratio by weight. Other ingredients such as fish meal, soybean flour, vitamin-mineral mixture, etc. are also suggested to be incorporated for improving the feed quality. Periodical samplings of the fry at fortnightly interval are done to assess the growth and biomass. Feed is provided at the rate of 8-10% of biomass of fry stocked per day during the first month, which are reduced to 6-8% of the standing biomass during the subsequent two months. Feeding is usually done in moist dough form in equal installments during morning and evening hours. Crumbled pellets may be used for reducing the feed wastage.

Harvesting of fingerlings is done when they attain 80-100 mm length. Fingerlings are effectively harvested by using a closed-meshed drag net. Rearing period can be further extended when bigger size fingerlings or stunted fingerlings are required.

If the fingerlings are to be transported, feeding is usually stopped one day prior to harvesting so as to improve their conditioning. Morning hours with low water temperature is the most preferred time for harvesting. Long distance transportation of fry and fingerlings can be done in polythene bags filled with oxygen. The number of seeds to be packed in each bag would depend on the size of fry/fingerling, duration of transport, quality of water and environmental temperature.

3. Grow-out carp production

Usually ponds of 0.1 to 1 ha size with an average water depth of 1-5-2.5 m is preferred for polyculture of the major and minor carps. However, seasonal ponds with 5 to 6 months holding of 1-1.5 m water depth can also suitably used for culture of the minor carps and the barbs. Essentially, the management practices in carp polyculture involve environmental and biological manipulations for obtaining higher levels of fish production, which can be broadly classified as pre-stocking, stocking and post-stocking operations.

3.1 Pre-stocking pond preparation

The details of the pre-stocking pond preparation have been discussed in seed rearing section. Manipulation of the species ratio in grow-out pond is important for minimizing the inter-specific and intra-specific competition for food available at various trophic levels and zones in a pond. Either single species or more than one species occupying different niches could be utilized in a pond for exploiting the food available at various zones. A proportion of 30-40% surface feeders, 30-35% coloumn feeders and 30-40% bottom feeders is commonly adopted depending on the productivity of the pond. Accordingly, suitable species combination of major and minor carps/barbs may be adopted.

3.2 Stocking density

Decision on the stocking density is an important aspect in the management which depends on pond productivity and the type of rearing protocol to be used. Generally in major carp polyculture, a density of 6000-8000 fingerlings is followed as standard stocking rate per ha for a production target of 4-5 tonnes/ha/yr. In seasonal ponds or where water level becomes limiting during summers it is reduced to 3000 fingerlings/ha to obtain higher growth rate. Stocking densities of 8000-10000 fingerlings/ha has been used for production levels of 5-8 tonnes/ha/yr. Although the major carps are expected to reach an average of a kilogram in the first year, the growth rate is invariably reduced in higher stocking densities. Higher targeted levels of fish production levels of 10-15 tonnes/ha/yr are achieved by resorting to stocking the ponds at a density of 15,000-25,000/ha.

Ponds are stocked with seed after proper acclimatization. If mohua oil cake or bleaching powder is used as piscicide during pond preparation, it must be ensured that toxicity is reduced and oxygen balance is established in the pond prior to seed release. Fingerlings of 10-15 cm size are considered as suitable stocking material of the major carps while size of the fingerlings in minor carps may vary from 4 to 6 cm.

In the single stocking–single harvest cropping pattern, when fingerlings of major carp are used for stocking the grow-out ponds, there remains a large gap between the carrying capacity and standing crop of the pond during the initial months leading to underutilization of the pond productivity. Pond productivity can be effectively utilized with use of the single stocking-multi-harvest cropping pattern where the stocking density can be increased 1.5-2.0 times. In this method, almost one third to half of crop is harvested at the end of six culture months and the leftover stock is reared further with periodic planned harvesting. However, the initial growth of the species hampers in such culture method due to the increase in the intra-specific competition apart from the crowding effect. Therefore, .instead of increasing the number of individuals of the same species (catla, rohu and mrigal) in the pond, different species of minor carps can suitably be incorporated considering their habitat preference and food habit, which would not only reduce the intra-specific competition, but also would increase the utilization of micro niches in the pond. Considering this fact, the concept of intercropping of the minor carps has been advocated in the conventional major carp polyculture system to increase the fish yield. In the intercropping methods, while major carps are stocked at the recommended density (8000-10000 fingerlings/ha), an equal density of minor carps/barbs are released in the pond as additional stock. These minor carps are harvested from the pond after approximately six months of culture letting the major carp to grow further. As mentioned earlier, such intercropping has proven a 30% increase in the fish yield.

3.3 Post-stocking pond management

The post-stocking pond management primarily involves the aspects of intermittent liming and fertilisation, supplementary feeding, water management and health care. In an average productive pond, the post-stocking fertilization measures includes fortnightly application of cowdung @ 0.5 tonne/ha, urea @10 kg/ha and SSP @15 kg/ha. The organic manure and inorganic fertilizers are applied in alternative weeks to maintain the natural productivity status. However, the time of application and dosage can be deferred depending on the water quality and plankton content of the pond. Poultry dropping may suitably be applied in place of cowdung, but at one third of its dose. n intensive carp culture pond, application of *Azolla* as a biofertilizer @ 40 t/ha/yr, supplied at weekly split doses, has proven to supply the full complement of nutrients i.e. 100 kg nitrogen, 25 kg phosphorus, 90 kg potassium and 1,500 kg organic matter. Use of biogas slurry @ 30-45 t/ha/yr or 80-100 litre/day/ha) is advantageous due to its lower oxygen consumption and faster rate of nutrient liberation.

3.4 Supplementary feeding

Supplementary feeding enhances fish production, permitting higher stocking density. While several ingredients of both plant and animal origin have been evaluated on Indian major carps and exotic carp species, the supplementary feed in Indian carp polyculture is mostly restricted to mixture of groundnut/mustard oil cake and rice bran at 1:1 by weight. This combination is often fortified with vitamins and minerals and are used by some fish farmers. Carps require at least 50% natural food, which normally take care of the vitamins and minerals requirements. But in situations where they have to be brought up on artificial diet alone or where supplementary feeding forms a major part, such fortification becomes necessary. With the shift towards intensive fish culture, a qualitative change has been effected by incorporation of different plant and animal protein sources. Further, the formulations of balanced feed have received considerable attention in recent years for making up the deficient essential amino acids and incorporating vitamins and minerals. To hold these components in the feed together, pelletization has been done and their merits in terms of water stability, consumption and utilization by fish have been proven. Extruded floating pellets are now available for carps.

Feed is usually provided at 5% of the stocked biomass in the first month of culture and gradually reduced to 1% within 6 to seven months of culture. The biomass of fish is estimated through monthly sampling and the daily feed ration is calculated as follows:

Feed requirement/day = Estimated fish biomass in the pond x % feeding rate
where, biomass = Average weight of fish X total number of fish stocked x %survival

Survival percentage of 80% is usually considered for estimation of biomass. The daily ration may be divided into two splits and provided in dough form preferably in feed trays or gunny bags hung at uniform distance inside the pond.

Feed intake of fish often reduces following cloudy weather and also in the winter months. Therefore, the daily ration should be modified as per the consumption pattern of the previous meal. In terms of dispensation of the dough feed, the feed mixture is to be provided in the form to dough in trays or gunny bags hung at different places in the pond. Quantitative requirements of feed is important since underfeeding depresses growth while overfeeding results in wastage of feed, the costliest input, leading to deterioration of water quality.

3.5 Aeration and water exchange

Dissolved oxygen is probably the most important single variable regulating production of fish in intensive culture. Aeration may be used mechanically to increase the concentration of dissolved oxygen in ponds. There are several types of aeration. Emergency aeration is employed to prevent fish death during periods of oxygen depletion. Oxygen depletion may occur during prolonged period of cloudy weather. Aeration is also sometimes applied to prevent thermal and oxygen stratification in ponds. Of the three major types of pond aerators available viz., the paddle wheel aerators, the aspirator aerators and the submersible pond aerators, while the first one is a surface aerator which may be ideal for water depth of 1.0 to 1.5 m, the other two type of aerators is considered to be more effective in fish ponds due to their high injection capacity of air into the water, even in deeper ponds.

Water exchange is another important activity, considered to be crucial in aquaculture operations. Due to continuous accumulation of metabolites and decayed unutilized feed, besides heavy organic manuring, the water environments get deteriorated, leading to slow growth of fish species and often leading to outbreak of diseases. Thus, it is necessary to replace certain amount of water at regular intervals, especially during later part of the culture period in case of intensive culture practices.

3.6 Health management

It is said that prevention is better than cure. So prior to stocking, the fish seed should be given a bath of 3-5% potassium permanganate for 15 seconds. Incidence of disease is quite common in high stocking densities. Though mortality is rearely observed in well-managed ponds fish growth is severely affected due to parasitic infection to some extent. Repeated infection is effectively controlled by applying a dose of 0.1 ppm at monthly intervals.

3.7 Harvesting and marketing

Harvesting of fishes is usually done after a culture period of 12 months to one year. However, fishes attaining the marketable size can be harvested periodically to reduce the pressure of density on the pond and thereby providing sufficient space for the growth of other fishes. Replenishment of the harvested species ensures maintenance of ecological balance that the particular species exhibit. Such periodic harvesting with and without replenishment, facilitating stock manipulation, are biological means of increasing fish production.

Usually fresh fish fetches about one and half times higher market price in the local market than those of iced-fish transported from long distance. Further, fishes sold in live condition commands around 30% higher market price than the fresh ones. Thus, the marketing strategy forms an important aspect for higher profit realisation that the fish growers should take advantage.

4. Conclusion

Freshwater aquaculture has been identified as the key areas for meeting the growing demand for fish in the country. Carp culture being the principal component of the sector has tremendous potential for growth in coming years. Higher fish production from this sector can be realised through bringing more area under culture and increasing the production per unit area. Further, carp culture involves easily adaptable technology and offers greater flexibility in use of local resources, which makes it farmers' friendly. The availability of a host of carp culture technologies with varied production levels further provides enough option to the farmers as per their investment capacity.

Duck rearing in IFS: Potential option for income and employment generation

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Introduction

The importance of water for the mankind in 21st century, is beyond ordinary debate, for a multitude of reasons. It is increasingly being essential to conserve every drop of ground water for sustaining the survival of humanity, as threat of its wastage/loss could portend a disaster for everybody. Therefore, scientific community has a responsibility to ensure judicious use of all non-saline available water, so that: unit food-production per unit- water consumption is enhanced and optimized. Accordingly, all scientific-agricultural technologies employing water should invariably employ novelties, aimed at enhancing output of crops and animal husbandry and fishes.

Fitting to the above theme, come the integrated Duck-fish or the Duck-fish-horticulture; Duck-fish-agriculture concepts, which have become very popular across many parts of world. Especially, in the Asian and South east Asian nations, the Duck cum Fish integration is catching up with most farmers, who are increasingly convinced now that these systems not only offer efficient usage of water, but also enhanced productivity in terms of quality and quantity. The latter system: Duck-Fish-horticulture system, is even more appropriate for adoption in Indian conditions, particularly in the coastal states like Orissa, West Bengal, Kerala, Andhrapradesh etc.. Its rationale is simple, which shows how from unit land, unit use of water, and from unit investment the output gets significantly larger in size. Let us then look at the merit of all the available models of integrated farming which can be offered for adoption to fish and duck entrepreneurs. As such, the public also needs to be educated, how from the same traditional water body, more output can be harvested with a simple scientific intervention, by using the Ducks as an efficient layer poultry, so that the productivity of the pond could be near double interms of profit and quality protein output.

Why consider Ducks in an water based integrated agricultural system?

The Ducks (*Anas platyrhynchos*) which constitute nearly 4 to 5% of the total domesticated poultry of India (Animal Husbandry Census, 2012) are endowed with equal or better in production abilities compared to chickens. In our country, in many ways, duck production emerges as a better alternate to chicken production which can contribute substantially to food, income, employment and livelihood security of the masses. However, duck production in India, is still in unorganized form which is carried out in limited scale. Marshy lands and adverse climatic conditions of coastal areas which are not suitable for chicken production and animal husbandry, as a whole, can be effectively utilized for duck production. Ducks usually grow well with locally-available feedstuff and less manpower is needed to raise them using meagrely-equipped facilities. In rural areas, the women folk (including elderly women) and aged people (in age group of 50 to 70 too) can easily be persuaded to manage production of ducks. Small-scale farms remain enormously important because of large number of rural households they support. They also make a useful contribution to food-supply chain of urban populations using recycled resources effectively. While the global Duck population is around 1242 million (1185.74), India's duck population is just 26 million in number (FAOSTAT, 2013). With this germplasm-base, India produces around 38 million tonnes of duck meat and 1.5 billion numbers of duck-eggs annually. In India, ducks are concentrated in coastal regions, especially southern and north-eastern states.

Duck production systems suiting to various farming communities

There are many prevalent Duck farming systems which can be adopted in our country, whose merits can be briefly discussed below.

A. Foraging or free range System

It is a one of the oldest known system for duck-rearing which utilizes the natural resources through foraging mainly in paddy or crop (grain)-fields after harvest. This system of management, however, is a low input technology. As such, foraging the ducks in various possible ecosystems e.g. ponds, rivers, reservoirs, canals, lakes, back-water, miscellanious water-bodies and post-harvest paddy fields is advantageous in many ways.

B. Backyard Rearing System

This backyard duck husbandry system is primarily meant for small and rural farmers. Here, the ducks get mingled with chickens and other avian species, throughout the area. They are mainly confined to the farm premises, but may roam around the village. Under this, Duck needs little care and small supplementary feedings, where they are usually kept enclosed near to farmer's house, at night. Flock-size under this system could range from 5 to 20 ducks. While, during day-time, the ducks are free to roam outside in search of feed, they are brought inside at night, by putting some extra feed in the night-shelters and nests (usually of earthen pots or wooded partitions) for laying eggs. An advantage of this system is that: ducks go out to harvest their feed themselves. Although the performance under this backyard-system is generally lower than that of intensive systems, its hallmark of low or no-cost feed can compensate the disadvantage of lower performances.


Ducks besides a fish pond in traditional Duck-fish integration system.

As such, the native ducks propagated by CARI, RC are considered best for such a system, as these are hardy in nature and can manage their own nutritional needs, with minimal supplemental feeding.

C. Duck-Rice Integrated System

The duck-rice integrated system has been practised in our country since long. Although this duck-raising method accounts for a relatively limited volume of the duck industry, it has attracted more attention in recent years, owing to its connection to organic farming. The rice-duck system provides a measure to benefit both the paddy fields and ducks. Insects, snails, tadpoles, earthworms and weeds constitute the major food sources for ducks, and in turn, the duck's excreta become the manure for the rice/paddy. Water stirring caused by the ducks' activities inhibits the growth of weeds through photosynthesis reduction when the water becomes turbid. Their activities also enhance the rice root, stalk and leaf development, thereby accelerating rice's growth. In addition, duck's active grazing in such a system can directly lead to reduced need for pesticides and fertilizers, thereby benefitting the ecological system. In usual practice, an optimum population of 200-300 ducks/ hectare of paddy field can be recommended to obtain a good rice and duck harvest, in combination. This number can be adjusted based on the input feed-sources (weeds, insect and snails) which are available in paddy fields. The other points that need consideration in this practice could be as follows. (a). Ducklings at 3-4 weeks of age are introduced into the field after transplanted seedlings become rooted, and before introduction they must be trained to get into the habit of flocking and oiling their feathers. (b) A protective fence is however, required to protect ducks from predators such as dogs, wild-cats and foxes and also to prevent them from escaping. (c) Water, by planning, should be kept at a level in which ducks can both swim and walk.

Ducks in growing-paddy field in Duck-rice integration system.

Along with laying ducks, the table ducks (ducks for meat) can be reared in the rice fields post-harvest. Generally farmers purchase ducklings from the hatcheries, 3 to 4 weeks before the rice harvest. The ducks usually selected for this system, are of native meat type, local meat type and or crossbred local x exotic varieties. After 3 weeks of age when the ducklings can consume whole rice grains, they are permitted to enter the newly harvested rice fields. Here, they forage the whole day on leftover or fallen rice grains, insects, shellfishes, small-frog, fish, and water plants. In the late afternoon, they can be moved back to pens or sheds near the household until next morning. The ducks raised in this system, are usually finished at 2.5-3 months of age, when they achieve live weights of 1.6-2.0kg, especially for crossbred varieties. Now-a-days, since mainly high yielding varieties of rice are planted and harvested within a short period, only a limited time can be available for the duck-flocks to scavenge. As the result, this traditional system of post-harvest duck rearing has limited feasibility and is less in vogue.

D. Duck-Fish Integrated System

This system of duck rearing is rather straight-forward system of mixed farming, which happens to be the most popular of the integration systems.

Benefits of fish- cum- duck farming

The duck-fish integration system is usually employed by many farmers, in such areas, where the underground water-table is usually good and standing water is available in the water-body, during most parts of the year. In this, the ducks have access to water for drinking and heat-stress alleviation. Ducks, in this system, only need shelter for resting. Generally speaking, a minimum area of 0.5 square meter per duck is required. Ducks can be housed in a variety of ways. A pen can either be built which floats on the water, or resting on stilts above the water or even can be fixed on bank of the pond. Regarding the advantages of this system, unlike other domesticated poultry, ducks can alone be considered for this system as an active entity, since the ducks are basically waterfowls, which can enter into water-bodies and utilize the system symbiotically. Here, introduction of layer or dual-type Ducks are usually made into the water surface, say a fish-pond in a multi-carping project, for using it as a duck- grazing area. Ducks can then ensure a full utilization of the pond's water in complimentary terms to the fish production. Fish ponds then work as an excellent environment where ducks help prevent them from parasitic infection. Ducks can feed on predators and can help fingerlings to grow better. As a result, it can reduce the demand for protein to 2 - 3% in duck feeds. Duck droppings go directly into water providing essential nutrients to increase the biomass of natural food organisms. The daily waste of duck feed (~ 20 - 30 gm/duck) serves as fish feed in ponds or as manure, resulting in higher fish yield.

Manuring from the ducks get homogeneously distributed without any heaping of duck droppings. Further, by virtue of the digging action of ducks in search of benthos, the nutritional elements of soil get diffused in water and promote plankton production. Ducks also serve as bio aerators, as they swim, play and chase in the pond. This manoeuvring of the surface of pond greatly facilitates aeration. The feed efficiency and body weight of ducks too increase and the spilt feeds could be effectively utilised by fishes. As such, the survival of ducks raised in fish ponds increases by 3.5 % due to clean and healthier environments of fish ponds. As a conservative estimate, duck droppings and left over feeds of each duck can increase the output of fish to 37.5 Kg/ha. Ducks aid to keep aquatic plants in check. As a major advantage of this system, no additional land is required for duckery activities. So, from such a combined Endeavour, It results in high production of fish, duck eggs and duck meat per unit time and water area. It ensures high profit through less unit investment.

In order to ensure that manure supply remains constant, it is best to keep different (duck) age groups at the same time. Once the fish has been harvested the pond will be empty of fish. When one can think of growing a batch of small fish before the old stock is harvested. As a long term policy, after 4 to 5 years of rearing, the ponds need cleaning. The manure remaining in the pond can be taken out and be used for crops or added to compost. Alternatively, the manure in the pond can be utilized by growing some crops in the dry ponds. From the fish production angles, it is however, difficult to prescribe the exact numbers of fish and ducks because the numbers are dependent on many other factors. Most fish species under this system take about 6 months to reach market weight. In such system, the stocking rates could vary from 6000 fingerlings/ha and a species ratio of 40 % surface feeders, 20% of column feeders, 30% bottom feeders and 10-20% weedy feeders are preferred for high fish yields. Mixed culture of only Indian major carps can be taken up with a species ratio of 40% surface, 30% column and 30% bottom feeders.


Ducks in the most popular Fish based integration system
Left: A Duck-Fish-horticulture integration system.(Courtesy, ICAR-CIFA, Bhubaneswar).
Right: Duck cum fish integration system in backwater of Kerala (Alappuzha)

As a major advantage of the Integrated Duck - fish farming, not only it increases fish production but also cuts down the cost of fish culture operations considerably. Where average cost of production in conventional poly-culture with supplemental feeding and inorganic fertilization was Rs. 2.93/kg in Eastern India (Anon, 1976), researchers have recorded the cost of production nearing Rs. 1.61/kg from a duck-fish integrated farming system.

Conclusion

The 21st century's agriculture has got to be a high-tech and resource efficient venture, for the sustenance of the mankind. Envisaging the increasing scarcity of water, in the coming decades, the input-output auditing of water based agriculture vis a vis the efficiency and importance of every agri output has to be ascertained. In this backdrop, the Duck cum Fish and Duck cum water-based enterprises are considered important. This system not only is investment efficient but also, ensures maximum agricultural output per unit water investment. In this system, inter alia, many benefits accruable from raising of ducks on fish ponds, it promotes fish growth, increases fish yields and eliminates pollution problems that might otherwise be caused from excreta, in a duck pen. Fish-duck integration also promotes the recycling of nutrients in the pond ecosystem. In shallow pond areas, a duck usually dips its head to the pond bottom and turns the silt to search for benthos. Due to this digging action, nutritional elements deposited in the pond humus gets released. Further, the ducks also act as pond aerators through their swimming, playing and chasing by disturbing the surface of pond and thereby contribute to the natural oxygenation of water bodies, and making them conducive for higher fish production. Therefore, in summary, the duck-fish integration system has great potential for water-efficient animal husbandry and agriculture/pisciculture.

Back Yard Poultry -A Viable option for Poverty Alleviation

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Introduction

The small and marginal farmers constitute more than 75 per cent of the farming community in India and especially in the state like Odisha it accounts more than 80% of the farming communities. Farmers of marginal, small and semi-medium operational holdings (area less than 4 ha) own about 87.7% of the livestock. In a developing country like India, growth in the livestock sector can definitely contribute to poverty reduction, as the largest share of the rural poor depends on livestock for their daily livelihoods. It has also been observed that the demand for the animal protein source is increasing rapidly in developing countries. Livestock sector is an important sub-sector of the agriculture of Indian economy. It forms an important livelihood activity for most of the farmers, supporting agriculture in the form of critical inputs, contributing to the health and nutrition of the household, supplementing incomes, offering employment opportunities, and finally being a dependable "bank on hooves" in times of need. It acts as a supplementary and complementary enterprise. Hence development of livestock sector would be more inclusive.

Livestock and Poultry Population

As per the 2012 livestock census, the total livestock census has been decreasing @ 3.3 % as compared with the 2007 census. Similarly the total bovine population decreased @ 1.57% and other animals @12.94% whereas the poultry populations increased @ 12.39%. The growth of poultry sector among the livestock sector is more than 5 % per year. Globally, India ranked 3rd in egg production (69.73 billions) and 5th in chicken production (2681, 000 tones) in the year 2012-13. This increase in poultry production has enhanced the per capita availability to 55 eggs and 2.4 kg poultry meat per annum (Basic Animal Husbandry Statistics- 2014).

Table1. The livestock & Poultry Population in 2012 census (Basic AH statistics GOI, 2013-14)

S. No	Species	Livestock Census 2003 (no. in Millions)	Livestock Census 2007 (no. in millions)	Livestock Census 2012 (no. in millions)	Growth Rate (%) 2007-12
1	Cattle	185.2	199.1	190.9	-4.10
2	Buffalo	97.9	105.3	108.7	3.19
3	Yaks	0.1	0.1	0.1	-7.64
4	Mithuns	0.3	0.3	0.3	12.88
Total Bovines		283.4	304.8	300.0	-1.57
5	Sheep	61.5	71.6	65.07	9.07
6	Goat	124.4	140.5	135.2	-3.82
7	Pigs	13.5	11.1	10.3	-7.54
8	Other animals	2.2	1.7	1.48	-12.94
Total Livestock		485.0	529.7	512.05	-3.33
9	Poultry	489	648.8	729.2	12.39

Importance of Rural Poultry

Though major share around 70% of the poultry products come from commercially reared improved breed birds, indigenous source of poultry eggs and meat are always appreciated for their taste and texture, in both rural and organised developed markets. Rural backyard poultry, though still contributing nearly 30% to the national egg production, is the most neglected one. This is in spite of the fact that backyard poultry eggs and meat fetches a much higher price than that from commercial poultry. More than 60% of the poultry products and eggs are consumed in urban and semi urban areas where as the rural consumption is quite low. Market studies show prices per kg live weight for these birds can be 50 –100 % higher than that of industrially produced birds. Though rural backyard poultry is the most potent source for subsidiary incomes for landless poor farmers, it has always been neglected. This is in spite of the fact that their products carry a much higher price than that from commercial poultry. There are plenty of evidence to demonstrate the role of rural backyard poultry husbandry in elevating the food and nutrition security of the poorest households and reducing the livelihood insecurity.

The major limiting factor in the way of increasing consumption of egg and poultry meat in rural area is poor availability. Most of the commercial poultry egg and meat production is centered in the urban and semi-urban areas. Owing to industrial nature of operation, the private sector is not inclined to go to the rural areas, particularly to small farmers and landless farmers including women. The commercial poultry sector is operating through contract farming using high-input and high-output birds. That's why the for the landless farmers the major issues are food security and risk spreading through subsidiary income, which are not addressed by the private commercial sector. In order to overcome this problem, it may be necessary to take up specific rural poultry production programmes with low input technology to meet the requirements of the rural sector that provides a subsidiary occupation, generating subsistence income to boost the nutritional standards, income levels and health of rural masses. The rural poultry or backyard poultry units require very little feeding and provide handsome returns with minimum investment.

Breeds suitable for Rural Poultry Framing

Rural poultry farming involves rearing of improved chicken varieties under free range, semi intensive or intensive conditions. Rearing method largely depends on the type of the bird reared, availability of resources and the preference of the local population for meat or eggs. Specific varieties of birds are available for rearing for meat or eggs and few varieties for both (dual purpose). Having realized the importance of backyard rural poultry farming (RPF) in India, several research organizations, Institutes and SAUs developed different backyard chicken varieties which are presented in the following table.

Table 2. Improved Breeds for Backyard farming

Name	Feather pattern	Purpose	Organization Developed
Gramapriya	Multicolour	Dual	PDP, Hyderabad
Vanaraja	Multicolour	Dual	PDP, Hyderabad
CARI- Nirbhic	Multicolour	Dual	CARI, Izatnagar
CARI- Shyama	Multicolour	Dual	CARI, Izatnagar
Gramalaxmi	Mixed brown	Egg	KAU, Mannuthy
Nicobari	Black and white	Egg	CARI, Portblair
Nandanam Broiler 2 and 3	Multicolour	Broiler	TANUVAS, Chennai

The annual egg production capacity of Gramapriya and Vanaraja birds are 170-180 to 150-160egg/ bird/ year, respectively. First egg lays at 200 to 230 days depending on plane of nutrition and other managemental parameters. Egg weight varies from 55 to 60 gram. Mature body weight 2.5 to 3.5 kg.

Housing management for backyard poultry farming

The commercial birds are reared intensively with proper housing and feeding. But the colourd birds can be either reared intensively or semi intensively (Doley *et al.*, 2009). In rural poultry system housing is provided only during night and adverse weather conditions. Locally available materials are used for construction of houses. Housing with cement concrete roof and concrete floor can be done. Many farmers use country tiles as roof materials. In the fish- poultry integrated system the house can be prepared on the bond or over the water. In the pond ducks can be reared and they feed on the plankton of the pond. The droppings of the birds fall on the pond directly. Poultry dropping is a good manure as they contain more nitrogen, phosphorus and potash as compared with other manure. The production of vegetables can be taken in the bond which can be fertilized with this manure.

No elaborate housing is required for backyard poultry farming but, it should protect the birds from sun, rain and predators. If free range system is practiced the birds are let loose in day time for foraging and at night sheltered in shed. For better production performances certain criteria that can be considered are –

- The poultry house should be in East-West orientation to have better ventilation and also for direct sunlight in winter months.
- During summer direct sun light should be avoided to reduce the summer stress in birds.
- Low cost housing material like wood, bamboo, grass, thatch etc can be utilized.
- The poultry house should be free from water seepage or moisture.
- Floor should be in elevated land or above ground level (minimum 2ft) and free from water crack, easily cleaned, rat proof and durable.
- There should be free air movement in upper part of the shed to reduce gas formation inside the shed.
- Height of the side wall in poultry house is generally 7 ft to 8 ft. The centre height is 9 ft to 12 ft with slope in either side.
- Roofing material like thatch, tiles, asbestos etc can be used.
- Brooder house should have easy ventilation and wire netting which is used for open air ventilation.

Brooding of Chicks

There are two types of brooding viz. Natural brooding and Artificial brooding that can be adopted for backyard poultry farming.

If natural brooding is practiced the local broody hen is used as the indigenous hens are very good sitters. Improved variety of fertile eggs is put into incubation. The hen is provided with nesting materials. Food and water supply is given throughout the incubation period. A broody hen can easily take care for brooding and hatching of 10 to 12 chicks. After hatching the chicks are let loose along with mother for scavenging. There should be provision for separate place inside the shed for young chicks and mother at night.

In artificial brooding provision of artificial heat is necessary. Artificial heat can be provided with electricity, gas, kerosene, wood, sawdust etc. 'Bukharies' also can be used as a source of artificial heat. Wood, charcoal or sawdust is used in 'Bhukaries' and it is an ideal source of artificial heating when there is acute shortage of electricity, gas and kerosene. The optimum temperature is 95° F in first week and it can be reduced 5°F per week up to 6 week till 70°F. Two watt/ chick heat is required up to 6 week in brooder house. The necessity of light in brooder house is to increase feed consumption for maximum growth in a short period and also to prevent stampeding or piling if scared. Initially (up to 6 weeks) there should be provision for at least continuous light up to 48 hours in brooder house and in growing stage (8 to 18 weeks) light hour is 10 to 12. But in laying period light should be for 15 to 16 hours. The provision for extra light may be in the morning or evening or may be morning and evening both. To prevent direct contact with heat a chick guard made up of card board or metallic guard can be used in brooder house. The height of chick guard is 15 to 18" is placed in circular shape at a distance of 3' away from the hover.

The rural poultry framing can be associated with integrated farming. Two models have been tried in Odisha through the NAIP. In the NAIP component- 3 livelihood project operated under OUAT an integrated farming model was tested for three years (2011-13) with crop, vegetables, mushroom, poultry and pisciculture taking 20 farmers in three districts of Odisha like Dhenkanal, Phulbani and

Kalahandi (Panda *et al.,*2013). The integrated model was divided into two categories taking 0.8 ha and 1.6 ha of land. The net return in the 0.8 ha model was Rs. 1,37,907 vs. Rs.12, 739 in the conventional method and total may days created was 555 vs. 204 (Behera *et al.,,* 2014). Similarly in the IFS model of 1.6 ha of land holding the net return was 1,98, 968 vs. 17,052 and the employment generated in man days was 899 vs.400 in the conventional method.

Table.3. Performance of IFS model of 0.8 ha of land

Enterprise	Component yield (REY in t)	Gross return (Rs)	Net return (Rs)	Employment Generation (man days)
Crop (Rice-onion) 7110 m^2	11.96	1,33,964	70,013	320
Mushroom(45 m^2)	10.31	1,14,441	50,755	141
Poultry (45 m^2)	5.20	57,753	12,222	58
Pisciculture (800 m^2)	1.68	18,680	4,917	36
Total system yield	29.15	3,24,838	1,37,907	555
Conventional cropping (rice-green gram) 8000 m^2	4.05	44,999	12,739	204

Table.4. Performance of IFS model of 1.6 ha of land

Enterprise	Component yield (REY in t)	Gross return (Rs)	Net return (Rs)	Employment Generation (man days)
Crop (Rice-onion) 14310 m^2	22.87	2,56,061	1,29,006	633
Mushroom(45 m^2)	9.95	1,10,386	46,700	141
Poultry (45 m^2)	5.13	56,897	10,834	58
Pisciculture (1600 m^2)	3.50	38,855	11,628	67
Total system yield	41.45	4,62,199	1,98,168	899
Conventional cropping (rice-green gram) 16000 m^2	7.21	79,932	17,052	400

Feeding management

Feed is the major input that determines the cost of production of eggs and chicken meat which accounts for 65-75% in broiler and 55-65% in layer. In backyard poultry farming the feed cost is considered to be minimum. Hence, the birds are let loose for scavenging in the open yard and collect the required protein, energy, minerals and vitamins etc from insects, snail, termites, seeds of grasses and weeds, leftover grains, crop residues and household wastes. Feed ingredients like broken rice, wheat or jowar's tear grain, rice bean etc also can be given to the birds. Maize, the principal cereal used in poultry diet as energy source. Otherwise broken rice, wheat or barley, deoiled bran or rice polish can be given to the birds for energy source. As far as the protein source is concerned the birds can be fed either from vegetable source of protein like soyabean meal, ground nut cake, til oil cake , sun flower oil cake etc. Most of the vegetable source of proteins are deficient of critical amino acids like lysine and methionine. Among the vegetable source of protein soyaben meal is rich in lysine and til oil cake is comparatively rich in methionine. Animal source of proteins like fish meal and meat meal are well balanced with essential amino acids. Most of the commercial feed manufacturers are producing feed without any animal protein supplement but adding synthetic lysine and methionine in the diet. Minerals and vitamins also play a major role in the production and growth of the chicks. Number of growth promoters and anti stressors are also being used to optimize growth and egg production and reduce the thermal stress. (Swain et al., 2007, Beura *et al.,* 2012). Number of deficiency diseases can be occurred without addition of minerals and vitamins in the ration of the birds. Especially for layers the requirement of calcium is more which is 3- 4% of the total diet. To meet the calcium requirement of the layer birds oyster shell meal or lime stone is used in the ration. There is a great scope for preparation of low cost feed by utilizing the locally available ingredients not only for the broiler but also in the back yard poultry production. A farmer can prepare a low cost feed by taking maize/ broken rice, oil cakes like ground nut/ til/ sunflower and animal protein supplements like fish meal. The feed should be offered at the evening after returning from scavenging in a rural poultry model. Supplemental feed helps to grow better and produce eggs in much higher rate than non supplemented one. The poultry feed should contain at least 20% protein in starter level, 16% in grower and 18% in laying stage with energy level (ME) 2800 kcal/kg feed in starter, 2600 kcal/kg at grower and 2650 kcal/kg in layer ration.

In layer birds should be fed another 5% of oyster shell meal to meet the calcium demand. Because egg shell constitutes 11-12% of the total egg mass and 94% of the egg shell contains calcium. If there is deficiency of calcium it will lead to decrease egg production, thinning of egg shell, breaking of the eggs while handling and even eggs with no shell have been produced.

Table 5. Composition of a backyard Poultry Feed

Sl No.	Ingredients	Quantity (%)
1	Maize/Wheat/Barley	40-50
2	Broken rice	12-20
3	Oil cakes like Sunflower/Sesame/ GN/ Soyabean	20-30
4	Fish meal/ Dried fish	8-10
5	Deoiled Rice ban/Rice polish	7-10
6	Mineral Mixture	2.5
7	Common salt	0.5
8	Oyster shell meal (Layer)	5

During rainy season poultry feed should not be stored more than 1.5 months to avoid fungus growth (Aflatoxicosis). The space requirement for feeder is 2 to 7 cm at brooding period, 7 to 10 cm during growing stage and 12 to 15 cm / bird at laying stage. The water space should be 0.5 to 1.5 cm during brooding, 1.5 to 2.5 during growing and 2.5 cm during laying period. The birds may be supplied with extra concentrate ration @ 30 to 60 gm/ day/ bird for better performance.

Health care management

Tough poultry farming is very popular and remunerative but proper health care should be undertaken both small and back yard farms. For better health care in backyard poultry farming the birds should be vaccinated against virus diseases in time. The most common and frequent occurring is the Ranikhet Disease (RD) which occur in endemic form and one of the killer disease in poultry. The diseases that mostly effect the birds are Ranikhet disease, Marek's Disease, Fowl pox, Gumbroo disease etc. Regular vaccination schedule may be followed in a poultry farm (Table 6 &7). Deworming for internal and external parasites also should be done to maintain a healthy flock. At least once in three months the birds should be dewormed against broad spectrum anthelmentics. Other diseases that may affect the poultry birds are Coccidiosis, infectious coryza, Salmonellosis etc.

Table.6-Vaccination Schedule for Broiler birds

Disease	Vaccine	Age	Quantity	Route
Marek's disease	Marek's	1st day	0.2 ml	Under neck skin
Ranikhet Disease	F-1 or Lassota strain	5-7 day	one drop	Eyes/nostrils
Gumboro Disease	Gumboro	15-17 day	one drop	Eyes
Ranikhet Disease	F-1 or Lassota strain	21-23 day	one drop	Eyes/nostrils
Gumboro Disease	Gumboro	30-35 day	one drop	Eyes

Table.7. Vaccination schedule for layer birds

Disease	Vaccine	Age	Quantity	Route
Marek's disease	Marek's	1st day	0.2 ml	Under neck skin
Ranikhet Disease	F-1 or Lassota strain	5-7 day	one drop	Eyes/nostrils
Gumboro Disease	Gumboro	15-17 day	one drop	Eyes
Ranikhet Disease	F-1 or Lassota strain	21-23 day	one drop	Eyes/nostrils
Gumboro Disease	Gumboro	30-35 day	one drop	Eyes
Fowl Pox	Fowl pox vaccine	6 week	0.2-0.5 ml	Foot pad/leg
Ranikhet Disease	R_2B strain	8 weeks	0.5 ml	Wing
Ranikhet Disease	R_2B	every 6 month	0.5 ml	wing

The estimate and return for a unit of 100 broiler birds

Non recurring Expenses

- Construction of poultry shed (Pucca house with asbestos roof) @ 300/sqft for 100 sqft =30,000.00
- Feeder, drinker, brooder, Electric appliances etc. @ 50/bird = 5,000.00

Total = 35,000.00

Recurring Expenses

- Cost of day old chicks @ 30.00 for 100 chicks = 3,000.00
- Feed consumed @ 3kg/bird (100x3=300kg) @ 22.00 = 6,600.00
- Litter materials, Medicine and vaccine @10/bird = 1,000.00
- Electric bulb and energy consumption @5/bird = 500.00

Total = 11,100

Income

- Sale of birds (mortality @3%) Weight of the birds 1.65 kg @ 80/kg
  97 birds xRs.132.00/bird=13, 604 say= Rs. 12,804
- Poultry manure Rs. 200.00
- Sale of gunny bags Rs. 150.00

Total = Rs. 13,154

Net Return 13,150-11,100=2,150/ batch

In a year 8 batches of 6 weeks duration and return will be Rs.2,150x8=17,200. The broiler can be raised in a single house or two poultry sheds can be prepared and in a cycle wise new batches can be reared at a gap of 15 days (Panda, *et al.,* 2013). In a year 16 batches can be run and the farmer can get more benefit with little labour. No separate labour is required and either women or men can spare 1-11/2 hrs for this type of integrated farming with poultry. In the integrated farming this litter can be very well used by the fish or for crop/vegetable production.

Conclusion

Thus rural poultry farming not only generates income levels, employment opportunities to small farmers including women but also bring about desired socio-economic changes in rural areas which are vital for rural development and rural prosperity. Thus poultry farming is an integral part of the farming system prevailing in India which can be guided properly for employment and rural livelihood support.

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Pond based Duck rearing

Mushroom in IFS model

Coloured bird in the backyard rearing

Broiler bid rearing in IFS

Orchard rejuvination: Potential option for productivity improvement in fruit crops

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Introduction

It is common to see that every living organism after some period of time loses it efficiency to perform various functions. Likewise, in the fruit plants also there is decline both in quality and quantity of produce. It becomes economically non viable and non ruminative. In India, 30-35 % area under fruit crops is occupied by old, dense and diseased plants. The decline of productivity has been attributed to various factors. Most of the problems are due to faulty management practices. The decline of trees starts with sparse appearance, yellowing and different types of foliage symptoms. The twigs dried up and there is spread of diseases. Such type of decline may be seen in whole orchards on a single tree or patches. It is a rare site to get any plantation free of this malady even intensity varies from plant to plant. The growers do not adopt proper management practices and finally it becomes unproductive. In general the canopy of fruit crops have irregular shape and it is difficult to deal with poor branching system. It is necessary to rejuvenate the old plantation and the orchard will be profitable.

Objective

1. To increase the productivity and economic age of the plant
2. To convert the low yielding and inferior varieties/seedling origin seeds into superior and high yielding trees.
3. To exploit the better root system of the plant.
4. To lessen the time of gestation period
5. To increase the orchard income
6. To reduce the incidence of disease and pests.
7. Increase the photosynthetic surface area.
8. To utilize the orchard area efficiently as lot of biomass are accumulated in the soil.

Rejuvination strategy

1. Providing technical knowhow including plant health coverage and nutritional management program
2. Replantation of old and uneconomical orchards
3. Gap-filling by providing disease free quality seedlings
4. The development agency may prepare comprehensive orchard management program
5. Training is an important component to educate the grower and increase their skill
6. Preparation of calendar of operation of various crops
7. Preparation of booklets and bulletins

Methodology of rejuvenating the existing orchards

1. Identification of old orchards
2. Top and frame working by power pruning saw
3. Procurement of bud wood and scion from genuine sources
4. Frame working with latest available varieties
5. Operations under expert guidance
6. Trees have latent buds which are activated by heading back of branches at certain points to put forth new sprouts which grow into branches forming fruiting area
7. The branches are cut back
8. Imbalance is created in root-shoot ratio as a result new shoots arise from the plants to balance it

Principles of canopy management

Canopy management is the manipulation of tree canopy to optimize the production of quality fruits. The canopy management particularly its components like tree training and pruning. It affects the quality of sunlight intercepted by trees as the tree shape determines the presentation of leaf area to incoming radiation. An ideal training strategy centers around the arrangement of plant parts, especially to develop a better plant architecture that optimizes the utilization of sunlight and promoted productivity. Light is critical to growth and development of trees and their fruits. The green leaves harvest the sunlight to produce carbohydrates and sugars which are transported to the sides where they are needed in buds, flowers and fruits. Better light penetration into the tree canopy improves the growth, productivity, yield and fruit quality. Generally, in close planting quicker shedding becomes a problem. An east west row orientation results in more shedding as compared to western and southern orientation of the trees. Strong bearing branches tend to produce larger fruits. The problem of a fruit grower is initially to build up a strong and balanced framework of the trees. Then equip them with appropriate fruiting. Pruning and training is required to give proper shape to the plants. Some of the basic principles in canopy management are:

1. Maximum utilization of light
2. Avoidance of build up micro climate congenial for disease and pests infestation
3. Convenience in carrying out the cultural practices.
4. Maximizing productivity with quality fruit production.

Rejuvenation of senile orchards

1. Identify senile orchards by survey and bearing behavior
2. Mark the branches which are to be removed
3. Mark those branches which are to be kept for future canopy development at an approximate height of 2-2.5m from the ground level.
4. Heading back operations should be done form August-November
5. At the time of heading back first cut should be given from underside of branch to avoid bark splitting
6. In long and upright branches heading back can be done in 2 or more phases to avoid inconvenience.
7. Cut should be sharp and slant
8. All the pruned wood should be removed from the orchard after heading back
9. Preparation of the field for nutrient and water management
10. Inter-cropping with leguminous crops should be adopted
11. The cut surface should be painted with Bordeaux paste
12. Proper plant protection measures should be adopted
13. Top working can be adopted in the seedling plantation

This technology can be adopted in temperate and tropical fruit crops by studying their tree physiology and environmental condition. The growers will be benefitted in adoption of the technology.

Mushroom production: An alternate income generating activity

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Introduction

Agriculture continues to be the main strength of Indian economy. With the variety of agricultural crops grown today, the country has achieved food security by producing about 260 million tonnes of food grains. However, the struggle to achieve nutritional security is still on. In future, the ever increasing population, depleting agricultural land, climate changes, water shortage and need for quality food products at competitive rates are going to be the vital issues. It is imperative to diversify the agricultural activities in areas like horticulture to meet these challenges and to provide food and nutritional security to our people. Mushrooms are one such component that not only uses vertical space but also help in addressing the issues of quality food, health and environmental sustainability. There is need to promote both mushroom production as well as consumption for meeting the changing needs of food items. Fortunately, mushroom trade has gained importance in recent years possibly for the global shift towards vegetarian food and recognition of mushroom as a functional food. Mushroom cultivation offers an added advantage to recycle agro-waste as carbon pool into good quality protein, much of which otherwise is wasted in the field. This hi-tech horticulture venture has a promising scope to meet the food shortages without undue pressure on land.

Mushroom : The overall scenario

Mushroom farming today is being practiced in more than 100 countries and the production is increasing at an annual rate of 6-7 per cent. Present world production of mushrooms is around 3.5 million tonnes as per FAO statistics. China alone is reported to grow more than 20 different types of mushroom at commercial scale and mushroom cultivation has become China's sixth largest industry. In India, mushroom production shot-up from mere 5000 tonnes in 1990 to over 1,20,000 tonnes in 2013. Today commercially grown species are button and oyster mushrooms, followed by other tropical mushrooms like paddy straw mushroom, milky mushroom, etc. However, the production of white button mushroom is about 70 per cent of the total production of mushrooms in the country.

The research on edible mushroom in Odisha made its humble beginning in the Department of Plant Pathology, College of Agriculture, OUAT, Bhubaneswar in 1972 with a view to generate profitable and sustainable production technology. Having achieved success in developing mushroom cultivation and spawn production technology, research efforts were further strengthened and transfer of technology was initiated with the establishment of 'Centre of Tropical Mushroom Research and Training' in the University with the financial support of Government of Odisha in 1991-92. This research organization paved the way for initiation of commercial mushroom cultivation in the state within two years of its establishment.

In depth study on production of spawn and mushroom cultivation particularly paddy straw mushroom, oyster mushroom, milky mushroom and button mushroom were undertaken. Farmers training programmes and demonstrations on spawn production and mushroom cultivation were then extended to all over the state. Technical assistance was provided for development of individual/group/private sectors in establishing spawn production units and mushroom production centres.

The overall activities of the centre further gained momentum with the establishment of All India Coordinated Research Project on Mushroom in the University during 2009-10 with the financial assistance from Indian Council of Agricultural Research, New Delhi. At present, the total mushroom production of the state has reached an all time high of 15,986 tonnes/annum contributing to over 10 per cent of the country's production.

Paddy straw mushroom (*Volvariella volvacea*), commonly known as the straw mushroom or the Chinese mushroom is considered as one of the easiest mushrooms to cultivate (Fig.1). It is the 6th largest mushroom of the world in terms of production. The flavor is excellent and the cropping cycle is short (21 days). However, this variety has low biological efficiency (15 per cent) and poor keeping quality (12 hours). The production of straw mushroom is very popular in Odisha. Odisha is the only state where straw mushroom is grown commercially for 10 months a year (February-November) involving poor farmers. The cultivation has spread rampantly as a cottage industry involving spawn production in low cost units in villages and outdoor cultivation under the plantations. The rice farmers of the coastal agro-ecological situation in particular have demonstrated a practical way to transform the lingo-cellulosic wastes directly into a highly acceptable, nutritious and delicious food for the people. Odisha produces 9,550 tonnes of straw mushroom per annum contributing to 60 per cent of the total mushroom production of the state.

Oyster mushroom (*Pleurotus* spp.) has species suitable for both temperate and sub-tropical regions (Fig.2). It is the 3rd largest cultivated mushroom of the world. The production figure for the country is 15,000 tonnes/annum. In Odisha, cultivation is restricted to winter months (November-February) and the production stands at 6,310 tonnes/annum contributing to 39 per cent of total mushroom production of the state. *Pleurotus sajor-caju, P. florida* and *Hypsizygous ulmarius* are the ruling species of the state. However, for small scale semi-urban and urban units, *P. eous* (pink mushroom) is gaining popularity owing to its attractive colour along with good taste and flavour. The biological efficiency is very high (100 per cent) and the shelf life is better (24 hours) than straw mushroom. Production cost is low with little longer cropping cycle (45 days). Further, it is suitable for post-harvest processing. However, the consumer demand is limited in the state.

Milky mushroom (*Calocybe indica*) is indigenous tropical mushroom of the country (Fig. 3). However, the commercial cultivation is restricted to south Indian states only. The mushroom is attractive white with excellent keeping quality (3-4 days). Its biological efficiency is also very high (about 100 per cent). The mushroom is not being grown commercially in Odisha probably because the cropping time for both straw and milky mushrooms is same.

The button mushroom (*Agaricus bisporus*) is most popular variety of the country (Fig. 4). At global level it ranks first in terms of production . Punjab is the leading state contributing to 60 per cent of the total production of the country. Being a temperate mushroom, production can be taken up year round in controlled environment or seasonally during winter months. Odisha has just started the commercial production with 126 tonnes/annum at present and it is likely to grow further in future.

Mushroom cultivation is a profitable enterprise. The cost for raising one bed of straw mushroom of 1.5′ x 1.5′ x 1.5′ size comes to Rs.50/- with a production of one kilogram mushroom within a crop cycle of 21 days. The net return is Rs.50/- per bed assuming the market rate at Rs.100/- per kilogram. Likewise, the cost for raising one bag of oyster mushroom is Rs.35/- with a production of 1.5 kilogram mushroom within a crop cycle of 45 days. The net return is Rs.40/- per bag assuming the market rate at Rs.50/- per kilogram. A model small mushroom production unit (300 sq.ft.) with the investment of Rs.25,000/- accommodating 120 beds of paddy straw mushroom per month during summer and rainy season and 225 bags of oyster mushroom per 1.5 month during winter season, gives an estimated net income of Rs.6,000/- per month.

Mushroom cultivation under protected condition: The need of the day

It is imperative to say that mushrooms can not be grown year after year with full commercial access, unless proper growing conditions are provided and adequate facilities are available for the control of diseases and insect pests (Fig. 5). Possibly, such conditions can be fulfilled in shelf growing, by the construction of properly insulated and ventilated mushroom houses accommodating store room, spawn running room, cropping room as well as packing and preservation room.

In Odisha, raising of simplified and low cost thatched mushroom houses are being encouraged for round the year cultivation of mushrooms with greater precision (Fig. 6). The houses are appropriately designed to maintain required temperature and humidity inside, besides having access to ventilation.

The vertical space in the mushroom house can be utilized effectively by raising three-tiered structures (shelves), mandatory for indoor cultivation. Experiments have shown that these low cost houses perform better than outdoor cultivation in terms of productivity. A small low cost house of dimension, 25′ x 12′ can well accommodate 180 beds of paddy straw mushroom or 125 bags of oyster mushroom in a three-tired structure within a crop period of two months. Such a house can be a livelihood option for a small farmer with a monthly net income of Rs.6,000/-. Various modifications of the thatched houses are being designed now-a-days in order to make it more permanent and mushroom friendly. Shade net houses and houses having asbestos roof are therefore, viable alternatives to the thatched sheds. In view of the higher sale price of the produce, off season or winter cultivation of straw mushroom is gaining popularity in the state. Hence, poly house cultivation is being popularized during winter season wherever growers are interested.

Value addition : An inevitable segment

Mushrooms being highly perishable because of their high moisture content and delicate texture, the produce remains acceptable for few hours only at the high ambient temperature of the tropics and sub-tropics. Thus, understanding of post-harvest handling practices plays a significant role in enhancing the availability of quality mushrooms either in fresh or processed form to the consumers and at the same time ensuring remunerative prices to the producers, low cost preservation methods like drying needs to be popularized among the growers to minimize post-harvest losses of mushrooms. Further, development and introduction of new products with wider acceptability and comparatively at low price will increase the demand and consumption of mushroom products. This will in a big way sustain the increasing trend of mushroom production in the country in the years to come.

The road ahead

Odisha leads the country in terms of production of straw and oyster mushrooms. Indoor cultivation of button mushroom has been initiated successfully in the recent past and it is expected to grow further. Moreover, the cultivation method of the low temperature tolerant variety of straw mushroom (*Volvariella bombycina*) for winter season it being worked out in the research centre. Possible introduction of the shiitake mushroom (*Lentinus edodes*) in the state is being explored. Cultivation of straw mushroom in controlled environment with higher biological efficiency (30-45 per cent) has already been initiated in the state with profound success. Preservation of straw mushroom through canning has been done successfully in Odisha for the first time in the country. The state is having the highest number (255) of spawn production units in the country. In spite of the phenomenal growth rate of the mushroom industry in the state, constraints do exist, that need addressal for the benefit of growers.

Mushroom crop needs to be recognized as a horticultural crop in the state. An appropriate mechanism should be developed for effective monitoring of the spawn production units for ensuring spawn quality, as production gets deteriorated owing to use of spawn bottles having inferior quality. Like other horticultural commodities, mushroom marketing ought to be streamlined in order to avoid distress sale. Above all, establishment of processing units with FPO license requires to be encouraged in order to facilitate the export potential of mushroom products.

The Centre of Tropical Mushroom Research and Training along with All India Coordinated Research Project on Mushroom are making concerted efforts in pushing Odisha ahead of other states in mushroom production. This would probably be the appropriate way to search for alternative nutritional sources for our huge population and help achieve non-green revolution.

Mushrooms are truly health foods and promising neutraceuticals. Odisha has tremendous potential for mushroom production owing to the availability of agricultural wastes in abundance, manpower and suitable climate. Further, there is increasing demand for quality products in domestic and export market. Mushroom being a women friendly crop, could be facilitated well with a strong Mission Shakti existing in the state. To be successful in both domestic and export market, it is essential to produce quality fresh mushrooms and processed products devoid of pesticide residues at competitive rates. It is also important to commercially utilize the spent mushroom substrate left after cultivation for making manure or vermin-compost for additional income and total recycling of agro-wastes. It is worthwhile to mention here that few of our entrepreneurs have got recognition at the national and international levels owing to their excellent endeavor in mushroom production. With the untiring efforts of all concerned, possibly Odisha mushroom industry will see a new dawn in the near future.

Fig. 1. Paddy straw mushroom

Fig. 2. Oyster mushroom

Fig. 3. Milky mushroom

Fig. 4. White button mushroom

Fig. 5. Low cost shade house

Fig. 6. Mushroom value addition

Impact assessment of IFS models through participatory approach

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Introduction

Despite the increasing number and sophistication of management tools and methodologies, monitoring the impacts of development efforts continues to be a complex and neglected task. Management focus is generally concentrated more on planning than on other aspects of project administration. Results are usually measured in terms of outputs and sometimes in terms of outcomes. But almost never in terms of impacts

Impacts are often difficult to measure for several reasons

- They do not have always happen as per plans and schedules
- Impacts that are intangible or qualitative are difficult to measure and document credibly and comprehensively
- Unintended, unplanned, unexpected impacts get overlooked unless they are somehow discovered and captured
- The extent to which project activities alone are responsible for impacts is not always clear since there may also be other external factors influencing impacts
- Practical methodologies to assess and document impacts are inadequate

On the other than, development agencies are increasingly exposed to public pressure and are expected to justify how and to what extent expenditures have benefited the intended populations. They are called upon to demonstrate that their projects are creating the expected benefits for their target groups.

Participatory Impact Monitoring/Assessment refers to

A process in which development interveners and local communities jointly observe, document and critically reflect on the effects and changes caused by project interventions

The objectives of PIM/A are threefold

Promoting Learning Process
Improving Communication between stakeholders
Improving Project Steering

PIM/A is not simply a methodology but even more, it represents a philosophy. It is not a one-time event, it has to be periodically undertaken so that programmes and intervention strategies are constantly reviewed and improved.

Indicators for Impact Monitoring and Assessment

Indicators are quantitative or qualitative variables that can be measured or described and, when observed periodically, demonstrate trends; they help to communicate complex phenomena. They represent the abstraction of a phenomenon or a variable. In other words, an indicator is just an indicator. It is not the same as the phenomenon of interest, but only an indicator of that phenomenon (Patton, 1999).

Classification of Indicators

Scientific indicators tend to be measurable in quantitative terms; they are global within a given discipline and are meant to be comparable across space and time.

Grassroots (indigenous/local) indicators are signals used by local people (individuals, groups, communities) based on their own observations, perceptions and local knowledge, applied within specific cultural, ecological and spiritual contexts; they tend to be more descriptive.

Another, classification of indicators says that, they can be broadly classified into two categories, namely; ***final and intermediate***.

Final indicator: when an indicator measures the effect of an intervention on individuals' say ` well-being', we call it a "final" indicator.
For example, literacy may be considered one of the dimensions of `wellbeing', so an indicator measuring it—say, the proportion of people of a certain age who can read a simple text and write their name—would be a final indicator. Sometimes final indicators are divided into ***"outcome"*** and ***"impact"*** indicators.

Impact indicators measure key dimensions of `well-being' such as freedom from hunger, literacy, good health, empowerment, and security.

Outcome indicators capture access to, use of, and satisfaction with public services, such as use of health clinics and satisfaction with the services received; access to credit; representation in political institutions and so on. These are not dimensions of
`well-being 'in themselves, but are closely related. They may be contextual.
Thus, both the ***impact*** and ***outcome*** indicators should constitute the final indicators of impact assessment and monitoring impact.

Intermediate indicator: when an indicator measures a factor that determines an outcome or contributes to the process of achieving an outcome, we call it an ***"input"*** or "***output"*** indicator, depending on the stage of the process—in other words, an "intermediate" indicator.

For example, many things may be needed to raise literacy levels: more schools and teachers, better textbooks, and so on. A measure of public expenditures on classrooms and teachers would be" input" indicators, while measures of classrooms built and teachers trained would be "output" indicators. What is important is that inputs and outputs are not goals in themselves; rather, they help to achieve the chosen goals.

Features of Good Indicators

A good indicator:
• Is a direct and unambiguous measure of progress/change—more (or less) it is unmistakably better.
• Is relevant— it measures factors that reflect the objectives.
• Varies across areas, groups, over time, and is sensitive to changes in policies, programs, institutions.
• Is not easily blown off course by unrelated developments and cannot be easily manipulated to show achievement where none exists.
• Can be tracked (better if already available), is available frequently, and is not too costly to track.

Identification and Selection of Indicators for Impact Monitoring and Assessment

Once a set of goals/objectives of the project have been agreed upon through a participatory analysis processes, the next step is to identify indicators—also in a participatory way—to measure progress toward those goals as a result of an intervention or a development project. The impact monitoring and assessment depend critically on the choice of appropriate indicators. Preferably, they should be derived from the identification and descriptions of relevant variables being given by the clients, with appropriate indicators of them being based on discussion of all the stakeholders.

Basis for Indicators of Impact Assessment

Indicators should comprise comprehensive information about the program outcomes:

- Indicators of the program impact based on the program objectives are needed to guide policies and decisions at all levels of society- village, town, city, district, state, region, nation, continent and world.
- These indicators must represent all important concerns of all the stakeholders in the program: An ad- hoc collection of indicators that just seem relevant is not adequate. A more systematic approach must look at the interaction of the program components with the environment.
- The number of indicators should be as small as possible, but not smaller than necessary. That is, the indicator set must be comprehensive and compact, covering all relevant aspects.
- The process of finding an indicator set must be participatory to ensure that the set encompasses the visions and values of the community or region for which it is developed.
- Indicators must be clearly defined, reproducible, unambiguous, understandable and practical. They must reflect the interests and views of different stakeholders.
- From a look at these indicators, it must be possible to deduce the viability and sustainability of change due to a project program and current developments, and to compare with alternative change/development paths.
- A framework, a process and criteria for finding an adequate set of indicators to assess all aspects of the impact of the program are needed.

These facts must be borne in mind when defining indicator sets.

Appropriate Tools

Participatory Rural Appraisal (PRA) tools are often only seen as appropriate for gathering information at the beginning of an intervention, as part of a process of appraisal and planning. Development workers may talk about having 'done' a PRA, sometimes seeing it as just a step towards getting funding. However, PRA tools have a much wider range of potential uses, and can often be readily adapted and used for participatory monitoring, and for participatory evaluation.

PME methods and examples

The examples documented here are not selected as models to be followed, but as cases of real situations, described by participants as learning experiences worth sharing. To stimulate further thought, particular points of note are given in comment boxes. For each case example, a small information box provides an introduction to the NGO concerned, and indicates the communities with whom they are working.

The examples described are as follows:

Transect walk: is a means of involving the community in both monitoring and evaluating soil conservation changes that have taken place over the period of programme intervention. This method entails direct observation whilst incorporating the views of community members. The case example comes from the Nilgiri hills of Tamil Nadu, where the Keystone NGO is working with tribal communities.

Spider web diagram: in this case is used as a means for participants to monitor and evaluate key areas of a programme. The spider web is a simple diagrammatic tool for use in discussions; it does not entail any direct field observations. The case example comes from the Jawadhu hills of Tamil Nadu, where the SCOPE NGO is working with tribal communities.

Participatory mapping: is perhaps the most easy and popular of participatory tools, used here to evaluate project interventions. The example is taken from Chikmagalur district, Karnataka, where the Vikasana NGO is working with generally poor and marginalised communities.

Photographic comparisons: is another easy visual tool, here used to stimulate community discussions in evaluating programme interventions. In this case, the RWT NGO is working with marginalised communities in Belgaum district, Karnataka.

Matrix ranking: in this case used to evaluate the impact of skills training to women belonging to a shepherd community. The example is taken from Belgaum district, Karnataka, where the RES NGO is working with the shepherd community.

Time line: a tool used to elaborate historical change. In this example, only a simple time line is given, comparing two points in time (usually there would be more). The case is a second one from the Keystone NGO, working in the Nilgiri hills of Tamil Nadu.

Well-being ranking: is described in the final example, being used to differentiate the benefits that different community members have gained from the renovation of a community pond. This example comes from the Prakruthi NGO in Kolar district of Karnataka.

H-form: a simple monitoring and evaluation tool, used in this case to evaluate tank silt application to farm land. The Grama Vikas NGO is working with marginalised farming communities in Kolar district, Karnataka.

The H-form: the method

This method is particularly designed for monitoring and evaluation of programmes. It was developed in Somalia for assisting local people to monitor and evaluate local environmental management. The method can be used for developing indicators, evaluating activities, and to facilitate and record interviews with individuals tank silt application.

Steps in using an H-form

1. Take a large paper and fold it in half length-wise and then fold it in half width-wise, and then half again width-wise. Unfold the paper and darken the 'H' lines with a pen. Exclude the centre vertical line.
2. Write the question in the top centre of the H-form. This should be simple and lucid. If you have a complicated issue, break it up into many small questions. On the left of the horizontal line of 'H' write 0 representing 'not well' and at the right side 10 representing 'extremely well'.
3. If you are working with a group, ask each individual to place their score along the line between 0–10. Give them each many cards or 'post its' (pieces of paper with a sticky backing) and ask them to write/draw out as many reasons for their score. Only one reason should be written on one card.
4. The participants have to write both positive and negative reasons for their score, which are then collected and pasted on to the respective side, as shown in the figure.
5. The participants are then encouraged to read each other's comments or each participant is made to read out the comments they have written. This is a process of sharing and also to encourage discussion.
6. The next step can be to encourage the group to come out with a consensus group score. Once this is achieved, the group discussion can focus on 'steps ahead', ideas of how to make things better, etc.
7. The results of the exercise can be recorded and analysed further as a step towards monitoring and evaluation and documented in a report.

PME as an integral part of all community-based interventions

However interesting a participatory evaluation at the end of a programme might be, without it having been based on a sound system of participatory monitoring throughout the project intervention, the evaluation in itself is limited. Thus, the first conclusion to draw is that monitoring and evaluation should be made a systematic feature of all interventions, seeking community participation from the outset in defining what should be monitored (indicators); how often and by whom the monitoring should be conducted; how this information will be used, etc.

Document unexpected or negative outcomes carefully

In a number of the examples documented, participants voiced only positive outcomes of the intervention. This may be partly due to a wish not to cause offence, but it may also be a genuine inability at the end of an intervention to identify more negative aspects, given a general feeling that the activities were successful. Yet, often the greatest opportunities to learn arise from unexpected findings. Thus, for example, whilst Keystone was surprised to find that dietary habits had changed less than they expected over the course of project interventions, they could use this finding to stimulate further community discussions and learning.

Be flexible in the use of participatory tools

In a number of the examples given, the partner staff had a certain idea on how to approach an exercise, and when they came to the field, they found that they had to adjust their plans because more people had come than expected, or for other reasons. It is best to conduct participatory exercises in a spirit of flexibility, whilst keeping sight of the information that is required for effective monitoring and/or evaluation.

Gender

In most of the exercises documented, a deliberate effort was made to seek out the views of women and men separately. Generally, however, the outcomes were quite similar, so the overall findings were pooled as one. Sometimes differences of perspective can appear relatively minor, but it is nevertheless important that they are discussed to ensure that any underlying differences are fully explored.

Capacity building

A participatory approach to monitoring and evaluation requires not only knowledge of tools, but an overall understanding of community dynamics, and aspects such as facilitating the representation of all groups in discussions and decision-making. It also requires, of course, a clear conceptual understanding of what monitoring and evaluation entail. For both NGO staff and community members alike, regular capacity building through trainings, field exposures and learning 'on the job' are thus an essential aspect of promoting PME in particular interventions, and as a part of organisational culture.

A technology is said to be successful, only when majority of the clientele groups implements it without any inhibition and gets satisfied with the result. Of course, all research innovations cannot be adopted in the field, as they have varied attributes. Hence, location-specific technology generation and target-based technology transfer efforts have to be followed for wider adoption and popularization. There should be sufficient pre-project diagnosis or situational analysis to better characterize research problems. Paradigm shifts in technology development process such as the shift from mono-disciplinary to multi-disciplinary, supply-driven to demand-driven, general to location-specific etc. are the need of the hour.

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