A GLIMPSE OF RESEARCH ON TUBER CROPS IN KAU

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FOREWORD

Tropical tuber crops (cassava, sweet potato, yams, aroids, coleus and arrowroot) occupy a leading position among the food crops in the world. They are the third group of cultivated species, after cereals and pulses and occupy a remarkable position in the food security of the developing world due to their high calorific value and carbohydrate content. They are also used as animal feed or as raw material for several industries. Their importance in the future might come from either their potential to substitute cereals, their use as a source of starches, or just as a basis for processed products and is now designated as "Future Crop". Added to these qualities, they are resilient to climate change and can be suitably fitted in diverse cropping systems under varied soil and climatic conditions.

Kerala Agricultural University has made significant achievements in the field of tuber crops research. Plant breeders focus on collection of germplasm and development of new varieties of tuber crops with higher yield and better quality. Scientists in the disciplines of agronomy and soil science are engaged in developing new agro-techniques for tropical tuber crops in different agro-climatic regions. Crop protection divisions develop strategies and products for managing pests and diseases affecting tropical tuber crops. Crop utilization divisions concentrate its activities on value addition and post harvest processing of tropical tuber crops. Scientists of social science divisions are involved in transferring the technologies developed by KAU to its stakeholders.

Scientists of KAU have done remarkable work in varietal improvement, crop production, crop protection and value addition of tuber crops. This venture of compiling the five decades of research in tuber crops is an appreciable task and I am sure that this publication will serve as a reference book for enhancing the productivity of tuber crops as well as for identifying the research priorities in tuber crops. I congratulate all the scientists associated with this compilation and wish all success.

Dr. T. R. Gopalakrishnan
Director of Research
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Vellanikkara
May 10, 2015

PREFACE

Tuber crops have been the staple/secondary staple for one fifth of the world's population. Tropical tuber crops include cassava, sweet potato, yams, aroids and other minor tuber crops. They are considered as secondary food crops for Keralites. Higher biological efficiency and higher dry matter per unit area per day and their resilience to climate change make them inevitable and important component in our food security systems. Besides being the cheapest source of food energy, they offer immense scope as raw material for the preparation of diversified value added products and for various industries. Considering the importance of tuber crops in the food security and rural economy of the state, tuber crop research has been one of the priority areas of research in Kerala Agricultural University.

In this book, we have attempted compilation of research activities in tuber crops undertaken in KAU. Dr. T. R. Gopalakrishnan, our Director of Research and Dr. L. Rajamony, Professor (Research Co-ordination) were kind enough to provide all facilities for this work. We acknowledge with gratitude the valuable contributions of the scientists of our University. We hope that the information compiled in this book will of great use to the students and scientists working in this field.

Vellayani
May 10, 2015

The Editors

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1. Introduction

Tuber crops are the most important food crops after cereals and grain legumes. They form the staple or subsidiary food of about 1/5th of the world's population. Tuber crops are classified into temperate and tropical tuber crops. Potato is the temperate tuber crop. Cassava, sweet potato, yams, aroids and several minor tuber crops add to the genetic diversity of tropical tuber crops. Three of these tropical tuber crops, namely cassava, sweet potato and yams rank among the top fifteen crop plants of the world in area under cultivation (Nayar, 2014). They can be grown in a wide range of soil and climatic conditions and have the capacity to withstand adverse biotic and abiotic stresses. The tropical tuber crops contribute 3.9% of human energy for an average consumption of 28.6 kg capita^{-1} year^{-1}. It is now proposed that this contribution should be doubled to 8 % by 2030 AD in view of the emerging food crisis and ongoing climate change (Nayar, 2014). Besides contributing significantly as a source of food, these crops have immense industrial value for extraction of starch and production of animal feed.

Tuber crops traditionally cultivated in Kerala are cassava, sweet potato, yams, aroids and minor tuber crops like coleus and arrowroot. Since these crops are well suited to small and marginal holdings, they have great potential in a state like Kerala where more than 80% are small and marginal farmers. Besides, our state is not self sufficient in food production. Our over dependence on other states for foodgrains is to be reduced to the possible extent. It is imperative that we have to give more importance to tuber crops especially cassava to compensate our food deficit (Gopalakrishnan *et al.*, 2013). The unique socio-economic features like high population density, small size of holdings, shortage of cereals, fresh market demand for local varieties, etc. are dominant factors influencing the status of tuber crops in Kerala.

1.1 Tuber crops for food security

Tuber crops are high-carbohydrate, low-fat food having plenty of calories. The dry mater content of tuber crops varies from

20-40%. The major constituent in all tuber crops is starch, which varies from 13 – 30% in different crops and within cultivars of same crop. Tuber crops are considered as the most efficient converters of solar energy, cassava producing 250 x 103 cal. $ha^{-1}day^{-1}$ and sweet potato 240 x 103 k cal. $ha^{-1}day^{-1}$ as compared to 176 x 103 k cal. $ha^{-1}day^{-1}$ for rice, 110 x 103 k cal. $ha^{-1}day^{-1}$ for wheat and 200 x 103 k cal. $ha^{-1}day^{-1}$ for maize. They can substitute for cereals due to their higher dry matter production and heavy calorie yield.

Tuber crops are excellent source of dietary fibre. They are rich in minerals especially calcium and phosphorus. While energy released from cassava is comparable to that released from the consumption of cereals, the mineral content of even lowly rated cassava is about 50% more than that of wheat and nearly four times that of rice. The mineral content of taro is 4-8 times that of wheat and rice. Most of them are good sources of vitamin C and some cultivars of sweet potato and cassava contain high amount of β-carotene which is the precursor of vitamin A and has been recently attributed anti- carcinogenic properties. The content of β-carotene in the orange fleshed fresh tubers of sweet potato (up to 8800 IU g^{-1}) is on par with that of wheat (Lilababu and Nambisan, 1993). Lipid content is negligible in tuber crops.

In general, tuber crops are low in protein. The digestibility and quality of cassava proteins are comparable to those of rice (Thampan, 1979). These tubers are generally deficient in cystine and methionine and most of them in lysine and leucine as well. But they are rich in arginine except sweet potato.

The leaves of tuber crops contain very high amounts of protein. They are also rich in minerals like iron and calcium and vitamins and are nutritionally better than other leafy vegetables. Taro leaves, a popular culinary item, contain 40% more protein and 80% more minerals than the aristocratic cabbage (Nayar, 1992).

1.2 Tuber crops- climate resilient crops

In the context of climate change, the production of major food crops like rice and wheat are badly hit due to fluctuations in rainfall and temperature, affecting the food security of our population. In cereals, the flowering and grain filling stages are highly sensitive to environmental stress conditions although vegetative growth is tolerant to these stress conditions. If cereal crops face these stress conditions during their critical growth period, the entire crop will be lost (Naskar and Ravi, 2011). In tuber crops, the economically important part i.e. tuber and shoot grow simultaneously during normal or favourable conditions. These crops cease tuber development as well as vegetative growth and become dormant during unfavourable conditions such as drought. Tuber growth is resumed during favourable conditions. So there is less chance of complete crop failure. Hence they are considered climate resilient crops.

Tuber crops have wide adaptability and hardy characteristics. Cassava, greater yam and white yam can tolerate prolonged drought conditions. Tuber crops like taro, tannia and elephant foot yam are well adapted to shade conditions. Sweet potato is tolerant to saline conditions. In general, tuber crops can tolerate waterlogged conditions for 5 days. Taro can tolerate waterlogged conditions for the entire growth period of 5 months (Naskar and Ravi, 2011 and Ravi *et al.*, 2013).

2. Tuber crops cultivated in Kerala

Tropical tuber crops (Table 1) commonly grown in different agro-climatic regions of Kerala are grouped into five- cassava, sweet potato, yams, aroids and minor tuber crops.

Table 1. Tuber crops cultivated in Kerala.

Popular name	Botanical name	Family
I. **Major tuber crops**		
1. Cassava	*Manihot esculenta* Crantz	Euphorbiaceae
2. Sweet potato	*Ipomoea batatas* (L.) Lam.	Convulvulaceae
3. Yams		
a) Greater yam	*Dioscorea alata* L.	Dioscoreaceae
b) Lesser yam	*D. esculenta* (Lour) Burk	Do
c) African yam /white yam	*D. rotundata* Poir	Do
4. Aroids		
a) Taro/ Colocasia/ old cocoyam	*Colocasia esculenta* (L.) Schott	Araceae
b)Tannia/ Xanthosoma/ new cocoyam	*Xanthosoma sagittifolium* (L.) Schott	Do
c) Elephant foot yam	*Amorphophallus paeoniifolius* (Dennst) Nicolson	Do
II. **Minor tuber crops**		
1. Coleus/ Chinese potato	*Plectranthus rotundifolius*	Lamiaceae
2. West Indian Arrowroot	*Maranta arundinacea* L.	Marantaceae

2.1 Cassava

Cassava is considered as the king of tropical tuber crops as it occupies a dominant role in the global agricultural economy and trade amongst tuber crops. It is the second most important tuber crop after potato in India. It was brought to India by the Portuguese (during the 17th century) who visited India for trade in spice and landed in the Malabar region which is presently part of our state. As a food crop, it was popularized by Shri. Vishakham Thirunal, the then Maharaja of erstwhile Travancore, who ruled the state during AD 1880 to 1885. He encouraged the cultivation of popular varieties of cassava from Malaysia and other places to overcome rice shortage during that period. Cassava saved the people of erstwhile Travancore state when rice import was stopped from Burma (Myanmar) and at subsequent times of food scarcity.

Cassava is mainly raised as a rainfed crop in marginal and small holdings. It is raised as a mono crop, as an intercrop in coconut, banana and rubber during initial 2-3 years of planting and as a mixed crop in homestead gardens. But cassava area under traditional upland rainfed situation is declining gradually in Kerala. On the other hand, the area under lowland situation is increasing with the gradual replacement of rice by cassava (Sasankan *et al.*, 2008). Due to the high cost of labour and lack of timely availability of labour, the farmers have replaced rice with cassava in lowlands. Short duration varieties of cassava are being grown continuously or rotated with banana and vegetables in such lands.

Since cassava has the potential to produce high amount of food per unit area, it can provide substantial food security especially to the weaker sections of the society. Cassava and fish when cooked and consumed together forms a good combination of dietary carbohydrate and protein. It is even preferred as a side dish by the high income group of the society. About 70% of cassava production in the state is used for human consumption. It is also used as an animal feed. Tubers are fed to cattle either in raw form or as dried chips soaked in water. The leaves are also fed to cattle and poultry after wilting. The tubers also serve as an industrial raw material especially for the production of starch. Cassava starch and flour production commenced in Kerala during World War II. But later, problems like unsuitable weather conditions for drying of starch and very high labour cost led to poor industrial utilization of cassava. At cottage industry level, cassava is utilized for preparing fried chips and flour for domestic purpose.

Fresh cassava tubers cannot be stored without spoilage for more than 3 to 4 days after harvest. To overcome this difficulty in marketing and utilization of cassava and to avoid heavy post-harvest losses, the tubers are converted into sun dried or parboiled chips. Parboiled chips have longer storage life and less insect damage than sun dried chips. The chips are also used for preparing cassava flour. A few small scale industries are functioning in the state for the production of cassava flour from chips and dextrin using cassava starch.

2.2 Sweet potato

Among the tuber crops cultivated in India, sweet potato ranks third in importance after potato and cassava. Sweet potato is grown in nearly all parts of the tropical and sub- tropical world and in warm areas of temperate regions. Sweet potato is the shortest duration (3½ to 4 months) tuber crop cultivated in the state. Being short duration, it fits well in the existing cropping systems in the state. It is generally cultivated in summer rice fallows. It can also be grown as an intercrop in young or old coconut gardens. The tubers are boiled and eaten. Cooked tubers are sweeter in taste since starch is converted into sucrose while cooking. A cup of sweet potato per day can prevent night blindness due to its β - carotene content. Tubers are also used as a substitute for potato in preparing cutlets, bonda and puffs. The vines and low grade tubers are used as animal feed. Hence it is also grown as a fodder crop.

2.3 Aroids

Aroids comprise of several plants belonging to the family Araceae that are cultivated for food in most of the tropical and sub-tropical parts of the world. The economic part is the underground stem. Popular aroids cultivated in India and Kerala are colocasia/ taro, xanthosoma/ tannia and elephant foot yam. Taro and tannia are together called cocoyams, taro being old cocoyam and tannia being new cocoyam. Taro is a versatile crop in the sense it can be grown in a variety of soil conditions from the water logged swampy condition to upland rainfed condition. Tannia is larger than taro and best adapted to well drained soil. Aroids are mainly used as vegetable. In addition to corm, leaves of aroids are used as vegetable. Tannia and elephant foot yam are used for making fried chips at the home level. The tubers also possess medicinal properties. They are usually grown as mixed crop in the homesteads.

2.4 Yams

Yams are monocots belonging to the family Dioscoreaceae of which popular edible species are greater yam (*Dioscorea alata*), lesser yam (*D. esculenta*) and African yam / white yam (*D. rotundata*). The tubers are its source of starch (11-39%), protein (6-13% on dry weight basis) and certain vitamins and have high calorific value. Yams are eaten boiled, baked or fried. They are also used as vegetable. These tubers also possess medicinal properties. They are usually grown as intercrop in coconut and banana and as mixed crop in the homesteads. Large scale cultivation of yams is seen in Pathanamthitta district.

2.5 Minor tuber crops

2.5.1 Coleus

Coleus is a minor tuber crop which is grown for its edible tubers. The plant is a bushy annual herb, belonging to the family Lamiaceae. Tubers are used as vegetable and are having special flavour and taste. Compared to other vegetables, coleus tubers have good keeping quality. It is a short duration crop of about 5 months and hence is fitted in multiple cropping programmes. Although starch content of coleus tuber is less than other tubers except elephant foot yam, it contains more protein than cassava or sweet potato or elephant foot yam and is rich in minerals like calcium and iron and certain vitamins including thiamine, riboflavin, niacin and ascorbic acid. These tubers also have medicinal properties. According to Sandhya (1996), the flavonoids present in the tuber help to lower cholesterol level of blood. Coleus is mainly grown in Ernakulam, Thrissur, Palakkad and Malappuram districts especially in lowlands. Also it is grown as an intercrop in rubber during the initial 2-3 years of planting.

2.5.2 Arrowroot

Arrowroot (*Maranta arundinacea* L.) commonly known as 'West Indian arrowroot' is an unexploited minor tuber crop grown as a rainfed crop in limited areas in homesteads under the shade of trees. The economic part rhizome contains on an average 20%

starch. It is valued as a food stuff as well as a source of starch for the preparation of various bakery products, special glue and paste, as a base for face powder, as ice cream stabilizer and in carbonless paper used for computer printouts. In addition, arrowroot has some medicinal values. The starch possess demulcent properties and is used in the treatment of intestinal disorders. It is employed in the preparation of barium meals and in the manufacture of tablets since it produces rapid disintegration. The fibrous material, which remains after the extraction of starch, is used as cattle feed or manure. Extraction of starch can be done even in households adopting a simple procedure. It serves as a raw material for cottage industries providing employment for unemployed women and rural youth. No serious pests and diseases are noted for the crop Thus the necessity for increased cultivation of the crop arises.

3. Area, production and distribution of tuber crops in Kerala

Different tropical tuber crops are grown in all the districts of Kerala (Table 2) in a total area of 89,375 ha in the state (FIB, 2015). More than 70% of area and production of tuber crops are concentrated in the districts of Kollam, Thiruvananthapuram, Pathanamthitta, Idukki, Malappuram, Kottayam and Ernakulam.

Table 2. Distribution of tuber crops in Kerala

Tuber crop	Districts leading in area
Cassava	Kollam, Thiruvananthapuram, Idukki, Pathanamthitta, Ernakulam, Kottayam, Malappuram
Sweet potato	Palakkad, Malappuram, Kazargod, Kannur, Thiruvananthapuram
Elephant foot yam	Waynad, Kollam, Pathanamthitta, Idukki, Malappuram, Alapuzha, Kottayam, Palakkad
Colocasia	Kollam, Pathanamthitta, Idukki, Alapuzha, Malappuram, Palakad, Thiruvananthapuram, Kottayam
Yams	Kollam, Pathanamthitta, Idukki , Alapuzha, Palakkad, Malappuram
Coleus	Palakkad, Thrissur, Malappuram, Ernakulam
Tropical tuber crops	Kollam, Thiruvananthapuram, Pathanamthitta, Idukki, Malappuram, Kottayam, Ernakulam, Palakkad, Alapuzha, Wayanad (> 90%)

Cassava is the most important tuber crop of Kerala. At present, cassava is cultivated in an area of 69,586 ha producing 2,45,8515 tonnes with a productivity of 35.3 t ha^{-1}. Majority of the area under cassava is in Kollam and Thiruvananthapuram districts (FIB, 2015). Sweet potato occupies an area of 247 ha with a production of 4159 tonnes and productivity of about 5.9 t ha^{-1} (FIB, 2014). Other tubers together occupy an area of 19789 ha but the production and productivity details are not compiled.

When data on area and production of cassava during the period from 1975-76 to 1986-87 was analysed, Job and Asan

(1989) found that area and production have been on a decline whereas the productivity has been on the increase. Co-efficient of variation indicated that area and production showed a greater degree of dynamism than productivity. Correlation coefficient analysis revealed that significant positive correlation existed between area and production while there was an absence of correlation between production and productivity.

In the last few years, the distribution of cereals through the public distribution system has adversely affected the consumption of tuber crops. The price structure of these crops and lack of a policy for promoting them have forced a shift to more remunerative horticultural and plantation crops like banana, rubber, coconut, etc.. Kerala accounted for 85.7% of area and 90.4% of production of cassava in India during 1967-68. After 1983-84, a decreasing trend has been noticed in the area and production of cassava and sweet potato in Kerala and more paying crops like banana and rubber are replacing cassava increasingly (Table 3). As a result our contribution towards the area and production of cassava in India is < 40 % recently with Tamil Nadu leading in area and production of cassava in our country. But the productivity of the crop in our state has increased from 14.1 t ha^{-1} during 1967-68 to 35.3 t ha^{-1} during 2012-13 which is more than double the world productivity of cassava.

Table 3. Temporal changes in area under crops in Kerala (in '000 ha)

Year	Rice	Cassava	Sweet Potato	Coconut	Rubber	Banana and other plantains
1984-85	731	233	4.6	687	310	51
1989-90	583	160	2.9	832	396	61
1994-95	503	114	2.0	911	443	73
1999-00	350	112	1.0	900	473	92
2004-05	290	89	0.6	899	481	114
2009-10	234	75	0.4	779	525	100
2012-13	197	70	0.3	798	545	110

(FIB, 2012 and 2015)

4. Research on tropical tuber crops

Research work on cassava was initiated in the year 1942 in India by Dr. A. Abraham, then Economic Botanist of Travancore state. In 1944, Cassava Research Station was established under the Travancore University (now University of Kerala) with its headquarters at Thiruvananthapuram and two substations, one at Ollukkara (Thrissur district) and another at Thiruvalla (Pathanamthitta district) which functioned upto 1963. In 1963, during the third five year plan, Central Tuber Crop Research Institute (CTCRI) was established at Thiruvananthapuram for conducting research on tuber crops with main emphasis on cassava. It has a regional centre at Bhuvaneswar, Orissa. This institute is the only one of its kind in the world carrying out research and development exclusively on tropical tuber crops. During 1968, All India Co-ordinated Research Project (AICRP) on tuber crops was launched by ICAR for conducting and co-ordinating research work on tuber crops with its headquarters at CTCRI, Thiruvananthapuram. At present it operates in 12 SAUs and two sister ICAR institutes.

Considering the importance of tuber crops in the food security and rural economy of the state, tuber crop research has been one of the priority areas of research in Kerala Agricultural University also. The research work on cassava was initially undertaken at Agricultural College and Research Institute, Vellayani, Thiruvananthapuram from 1955 which became a part of the Kerala Agricultural University since its inception during 1971. Most of the research on tuber crops was carried out either in this college or under the AICRP Centre on tuber crops at College of Horticulture, Thrissur (This centre was later discontinued in 1985). The University as well as CTCRI have developed improved varieties, agro-techniques and post harvest technologies for enhancing the production and utilization of tuber crops. A brief account of the research achievements by the University in tuber crop production and utilization technologies are briefly summarized in this book.

CASSAVA

4.1 Cassava

The extent of adoption of recommended practices was least in cassava, as compared to rubber, coconut and rice in Kerala (Sivaramakrishnan, 1981). Bhaskaran *et al.* (1993a) also observed that, in general, the overall extent of adoption of scientific cultivation practices of cassava by the farmers was very low. When the practice-wise extent of adoption was considered, there was low adoption of high yielding varieties and application of less than 25% of the recommendation of fertilizers. This might be due to non-availability of planting material of high yielding varieties, high cost of fertilizers and the belief that fertilizer application reduces taste. It is implied from this investigation that there is an urgent need to multiply the planting materials of high yielding cassava varieties on a large scale for distribution to farmers. In addition, the cassava farmers should be educated on the beneficial effects of fertilizer application.

In spite of its tremendous potentiality to perform under marginal conditions with higher biomass production, cassava could not compete with more remunerative crops like banana. This warrants a situation where cassava farmers need to manage the crop efficiently deriving enormous profit (Anantharaman, 1991). According to Anantharaman and Nair (2004), only half the proportion of cassava farmers could exhibit average managerial efficiency. However, it was seen that cassava farmers who supply raw tubers to industries had significantly higher managerial efficiency. The factors namely closeness with agricultural support system, market perception, achievement motivation, economic motivation, attitude towards scientific management, knowledge on scientific management, cultivated holding area under cassava and irrigation potential were found to have significant contribution and direct effect on the managerial efficiency (Anantharaman and Nair, 2001).

Sasankan (2004) observed that lowland pure crop (28%) constitutes the major production system of cassava followed by upland pure crop (21.54%). The study also revealed that 49% of the total area under cassava in Thiruvananthapuram district was cultivated as pure crop followed by cultivation as intercrop (23%), in the homestead (19%) and as mixed crop (9%). It was observed that the hill zone had 37% of the total area under cassava in the district followed by coastal (33%) and midland (30%). The productivity pattern revealed that coastal zone topped with 17 t ha^{-1} and midland had low productivity. There is not much difference in the productivity between hill and coastal regions. Hilly regions were found to have greater technology gap followed by costal region and mid land region. Wide technology gap was observed in technologies namely cassava mosaic management, application of inorganic fertilizers and storage of planting materials. High wage rate of agricultural labourers was ranked as the most severe production constraint followed by labour and water scarcity. Stiff competition from other major remunerative crops was the important reason for the decline in area under cassava. High wage rate of agricultural labourers and conversion of land were the other important reasons for the decline in area under cassava cultivation. The preference of commercial and less labour intensive crops like rubber, coconut, etc. forced farmers to shift cultivation from cassava to other crops (Sasankan *et al.*, 2007a). The study revealed that processing of cassava was the most important area of training needed by the respondents followed by harvesting, storage and marketing (Sasankan *et al.*, 2007b). Sasankan *et al.* (2008) emphasized the need for generation of production system oriented technologies for cassava. For effective dissemination of innovations/technologies in cassava, the information may be disseminated through radio, newspapers, television and progressive farmers since these sources are the most widely used information sources by the cassava farmers as also reported earlier by Bhaskaran *et al.* (1993b).

4.1.1 Varietal improvement

Among six varieties tested in the agro-climatic conditions of Thrissur, H-2304 gave the highest yield of 28.3 t ha^{-1}. In M-4, the yield was only 15.06 t ha^{-1}. It was found that cassava varieties CO-2 and M-4 were more suited for crop rotation in rice fields (KAU, 1984b).

In a study conducted to identify and define through biometrical approach the readable and reproducible morphological criteria for selecting cassava genotypes for high tuber yield, it was concluded that high yielding genotypes possess short stature and correspondingly shorter internodes. They have more number of leaves and the leaves absciss almost completely in a comparatively short span of time towards tuber maturation (KAU, 1984b). Radhakrishnan (1980) studied the selection parameters in cassava. According to Radhakrishnan and Gopakumar (1984), harvest index and tuber weight were the most influential characters in increasing the tuber yield of cassava.

According to Rekha (1987), ideal plant type of cassava would consist of dwarf stature, minimum number of branches, optimum number of leaves to be retained at maturity, coupled with a reasonable number of tubers, maximum single tuber weight and high girth and length of tuber. Path analysis showed that single tuber weight, tuber girth and tuber length were the factors exerting the greatest influence directly and indirectly upon tuber yield in cassava, indicating the importance of these characters as selection indices for cassava (Rekha *et al.*, 1991).

When seven short duration varieties of cassava viz. Ambakkadan, Mixture, S-856, H1687, Ramanthala, Thottakolli and Thodupuzha local were evaluated in the reclaimed soils as intercrop in coconut garden, no significant differences among treatments could be observed (KAU, 1991a). However, when average yield was worked out, it was found that S-856, a selection from CTCRI, yielded the maximum of 1.567 kg plant^{-1} (27.42 t ha^{-1}). Regarding the number of tubers plant^{-1}, there was no significant difference between treatments. S-856 gave maximum number of tubers plant^{-1}. Tuber dry matter was maximum (40.62%) for Thodupuzha local followed by Ambakkadan (40.57%). All varieties except Thodupuzha local cooked well. Thottakkolli and Mixture were found highly susceptible to cassava mosaic disease.

In a study conducted to select short duration variety of cassava for rice fallows, it was found that M4 had excellent cooking quality even when harvested at 5 months after planting and in all the seasons (KAU, 1991a). Kadathuruthi local and Thottakolli were observed as short duration varieties suited for uplands of Kuttanad. Thoattakolli had the lowest HCN content and Kadathuruthi showed the highest crude protein content in tubers (KAU, 1991b).

Since cassava is mainly used for table purpose in Kerala, local varieties having excellent cooking quality and taste are under cultivation in the state. But these varieties are of long duration and low yielding. The introduced var. M4 is largely under cultivation in in our state due to its excellent cooking quality though it is low yielding and having 10 months duration. For intensive cropping, farmers are in need of short duration varieties especially for cultivation in lowlands. The var. Sree Prakash, released from CTCRI was recommended as a short duration variety for planting in the rice fields after the harvest of the Mundakan crop (KAU, 1998). Later, KAU was successful in releasing three short duration varieties of cassava namely Nidhi (released in 1993), Kalpaka (released in 1996) and Vellayani Hraswa (released in 1998). Of these, Nidhi is tolerant to cassava mosaic and soil moisture stress with low HCN content (20 ppm) in tubers and good cooking quality. It is suitable for thara lands (raised beds) of Onattukara. It is having a duration of 6 months. Kalpaka is a high yielding short duration (6 months) variety suited for growing both as a pure crop (61.2 t ha^{-1}) and as an intercrop in the coconut garden (42.6 t ha^{-1}). It is tolerant to shade. It is also tolerant to cassava mosaic, bacterial leaf spot and spider mite. Vellayani Hraswa is short duration (155-180 days), high yielding (44 t ha^{-1}) variety recommended for southern districts of Kerala. Tubers of this variety have creamy white flesh with very good cooking quality similar to M-4. However, this variety is moderately susceptible to cassava mosaic virus and will not withstand drought (Manju and John, 2011).

4.1.2 Season

The best season of planting of rainfed crop of cassava is May – June which should be harvested before April – May. Otherwise the pre-monsoon showers received during this period will adversely affect the cooking quality of the tubers and as a consequence, the market acceptability of such tubers will also be poor. It was observed that the varieties with more than 10 or 11 months duration may not be suitable for Kerala (KAU, 1985).

4.1.3 Minisett technique

In a study conducted for evaluating the minisetts of planting material in cassava, the two noded setts were compared with the normal setts used by farmers and the vertically planted four noded setts of tender tips in farmers fields. The results revealed that per plant yield from two noded setts (4.75 kg) were comparable to the yield from normal setts (5.20 kg) and superior to vertically planted setts (2.0 kg). As the spacing was reduced in minisett method of planting, the total yield and hence net returns proved to be comparatively higher. The percentage of cassava mosaic virus infected plants were lower in the transplanted setts as screening was done in the nursery. The study thus revealed that the minisett method of propagation can be recommended as a rapid propagation method in cassava especially under conditions of shortage of planting material in cassava (Isaac, 2011).

4.1.4 Nutrient management

Response of cassava to application of nutrients varied with varieties and agro-climatic regions. According to Pillai (1967a), the optimum fertilizer dose for cassava var. M4 was found to be 150 kg N, 130 kg phosphorus, 250 kg potash and 1100 kg of Ca per hectare under the agro-climatic conditions of Vellayani. Application of K increased the edible portion, dry matter and starch content of tubers and decreased crude protein content (Pillai and George, 1978). Vijayan and Aiyer (1969) and Ramanujam (1982) obtained yield responses upto 150 kg N ha^{-1} in Thiruvananthapuram district. Ashokan (1977) obtained maximum tuber yield of cassava var. H-97 due to application of 112.5 kg level of K whereas 150 kg level reduced the yield. The FYM application at the rate of 12.5 t ha^{-1} had given an increase in tuber yield of 2864 kg ha^{-1}. A comparatively high utilization index was observed at 75 kg level of K beyond which a significant decrease was noticed at higher levels of K.

There was increase in percentage of dry matter upto 75 kg level of K whereas starch content of tuber registered an increase upto 112.5 kg level. There was a gradual decline in crude protein and HCN content of tuber when the levels of K fertilization were increased. An improvement in cooking quality was noticed by the application of K. However, FYM application showed a tendency to increase the bitterness. The optimum dose of K under two split application was 115 kg ha^{-1} whereas under three split application the optimum dose was 100 kg ha^{-1}. Ashokan and Nair (1982) reported lack of response beyond 50 kg ha^{-1} of N and K2O at Thrissur for the varieties, M-4 and H-2304. Nair (1982) observed that nitrogen at higher rates of application increased the HCN content of tubers while potassium at higher rates improved the quality of tubers by lowering the HCN content. The optimum N: K ratio was found to be 1:1 or 1:1.25. Split application of N and K is found beneficial.

In the red loam soils of Vellayani, yield of cassava var. H-2304 was found to be significantly superior to that of M4. In both the varieties, K applied during 0 to 4½ months period was significantly superior to other treatments. Potash at 100 kg ha^{-1} was found optimum. At this rate of K application, starch and reducing sugars in the tubers increased, while the HCN content considerably reduced. Again, K increased amylose content and granule size in cassava starch which are mainly responsible for the cooking quality. Critical concentrations of K in the leaves of cassava plants were found to be 0.5-0.9% in the deficient plants and 1.2-2% in the normal healthy plants (KAU, 1984a). At Vellanikkara, the effect of different levels of N and K were not significant on the yield of cassava indicating that the lowest level tried (50 kg ha^{-1}) might be sufficient for the crop in soils of good fertility (KAU, 1984b). Cassava var. M4 gave the maximum yield of 13.2 t ha^{-1} when N and K were applied in three splits (1/3rd at 50% sprout emergence, 1/3rd at 2 months after and 1/3rd three months after planting).

The study conducted on the response behavior of cassava to N and K fertilization in coconut shade at Pilicode (KAU, 1984a) indicated that the tuber yield was more in the open planted crop than in the shade planted crop. Progressive increase of nitrogen increased the tuber yield and the 100 kg level gave 21.04 t ha^{-1} in the open and 12.35 t ha^{-1} in the shade which were 27 and 18% more than the yield of the lowest level of 25 kg ha^{-1}. In respect of potash, the maximum yield of 19.6 t ha^{-1} was obtained at 100 kg level in the open while in the shade the maximum yield of 12.4 t ha^{-1} was obtained at 25 kg level.

Nair and Aiyer (1986) obtained maximum tuber yield of cassava var. H-2304 and M4 due to application of 100:100:100 kg NPK ha^{-1}. Ashokan *et al.* (1988) observed that the tuber yield of the local variety increased by 35% and that of H.1687, the hybrid increased by 67% due to N and K application. Higher levels of N increased HCN content of tuber whereas K had no significant influence. There was a general drop in the soil organic carbon drop after three years of cropping.

The root activity pattern of cassava was studied by Ashokan *et al.* (1989) in var. M-4 planted on mounds using ^{32}P soil injection technique. The highest uptake of ^{32}P was observed from the soil zone at 20 cm lateral distance and 20 cm depth during 90 to 150 days of growth of the rainfed crop. Nearly 50% of the root activity was confined to this soil zone. The roots were found to extend to 80 cm laterally and 80 cm vertically.

In the red and sandy loam soil, the highest tuber yield of cassava was obtained when 50:50:100 kg NPK ha^{-1} given in three split doses (½ at planting, 1/4th each at 60 and 90 days after planting) was found to be sufficient (KAU, 1991a). The optimum time of potassium application to cassava was from the time of planting to 4½ months stage of growth for both hybrid and local varieties and K application beyond 4½ months has no added advantage for this crop (KAU, 1991b). Regarding the manurial dose for Kaduthuruthy local and Thottakolli, the short duration varieties suitable for the uplands of Kuttanad, 50:50:100 kg $N:P_2O_5:K2O$ ha^{-1} was the most economical dose for Thottakolli and 50:50:50 for Kaduthuruthy local (KAU, 1991b).

In a multi locational trial on cassava var. M4, application of 100:50:100 kg NPK ha^{-1} recorded higher tuber yield of 12.5 t

ha^{-1} (KAU, 1991b). In an initial evaluation trial on cassava, the line H-14/75 recorded the highest tuber yield of 12.5 t ha^{-1} at 100:50:50 kg NPK ha^{-1}. In another multi locational fertilizer trial on the hybrid var. H-1687, the highest tuber yield of 31.6 t ha^{-1} was obtained from the treatment at 100:100:150 kg NPK ha^{-1}. The fertilizer dose 100:100:125 kg NPK ha^{-1} in conjugation with 1 kg of FYM $plant^{-1}$ gave the highest cassava tuber yield of 16:63 t ha-1 in the var. M4.

Traditionally, the tribal farmers of Amboori area in the Western Ghats of Thiruvananthapuram district of Kerala do not use chemical fertilizers for cassava cultivation. But considerable reduction in soil fertility has occurred over the years due to monoculturing and erosion of fertile top soil in the slopes, resulting in inconsistent yield levels. Kumar *et al.* (1991a) observed that the tuber yield increased from 3.25 t ha^{-1} in the control to 10.5 t ha^{-1} in the plots receiving three fourth of the recommended dose of fertilizers (37.5:375:37.5 kg NPK ha^{-1}), the increase being about 223%. Hence this dose of fertilizers could be considered as the optimum dose for the medium level management of fertilizers for cassava in the tribal holdings of Amboori.

For October – November planted crop (Kannikappa), the response was observed up to 50 kg each of N, P_2O_5 and K_2O ha^{-1} for the var. M-4 in the soils with medium NPK status (Geethakumari *et al.*,1997). Gopimony *et al.* (2001) opined that in cassava it was not possible to sustain yield by organic practices alone over the years. Hence for crops like cassava, it is essential to apply P and K fertilizers to maintain yield.

Based on a series of field trials, KAU recommends 50:50:50 kg NPK ha^{-1} for the var. M-4 and local varieties, 75:75:75 kg NPK ha^{-1} for the varieties H-97 and H-226 and 100:100:100 kg NPK ha^{-1} for the varieties H-165, Sree Visakham and Sree Sahya (KAU, 2011).

According to Sekhar (2004), a fertilizer dose of 50:50:100 kg NPK ha^{-1} along with FYM at 12.5 t ha^{-1} was found optimum for short duration cassava var. Vellayani Hraswa which produced maximum tuber yield of 47.09 t ha^{-1} and a higher BCR of 3.32 with moderate cooking quality. This variety favours a NPK ratio of 1:1:3 for higher tuber production. The highest starch content in tubers was recorded by 100:100:100 kg NPK ha-1. Maximum protein content was produced in tubers which received NPK @ 100:100:75 kg ha-1. When the treatment NPK @ 100:100:50 kg ha-1 produced tubers with the highest HCN content, the lowest was recorded by the treatments NPK @ 50:75:100 kg ha-1. However, application of 75:50:100 kg NPK ha-1 along with the biofertilizers (Azospirillum+ phosphobacteria) resulted in higher tuber yield of cassava var. Vellayani Hraswa in the reclaimed alluvial soils of Kuttanad (KAU, 2008).

An yield increase in cassava was obtained by the use of urea neem cake blend (5:3) but the tubers were very thin and of poor quality due to low K concentration in plant parts (Sathianathan and Padmaja, 1983). But Vinod (1988) reported better performance of cassava due to application of slow release sources of nitrogen like urea super granule and neem cake coated urea compared to prilled urea. Urea super granule recorded the highest uptake of N and K followed by neem cake coated urea. Though the highest tuber yield of cassava var. Sree Visakham was recorded by urea super granule application followed by neem cake coated urea @ 150 kg N ha^{-1}, maximum net return was obtained from neem cake coated urea (Vinod and Nair, 1992). Quality characters like starch, crude protein and hydrocyanic acid contents were not affected by slow release sources of nitrogen. Thampatti and Padmaja (1995) reported that application of MOP @ 75 kg K_2O ha^{-1} + urea-neem cake blend @ 50 kg N ha^{-1} in two equal splits produced the highest tuber yield of 21.39 t ha^{-1}. It was observed that for yield improvement, the time and rate of application of K_2O are rather more important than urea-neem cake blend.

According to Devi (1995), 50 % potassium (MOP) can be substituted with sodium (common salt) without affecting the tuber yield or quality in soils having low to medium status of potassium. On an overall analysis, the quality was found to be improved by the substitution of 50% of K of MOP by Na of common salt (Devi and Padmaja, 1996). Devi and Padmaja (1999) also reported the superiority of 50% substitution of K by Na in cassava in the laterite soils of Kerala. Devi *et al.* (2001) reported that the tubers from substituted plots had an extended storage life when compared to the tubers which received full dose of MOP as K fertilizer. However, John *et al.* (2003) observed that all economic parameters were found higher with no substitution of K by Na compared to partial and full substitution in a typic kandiustult of Kerala. For cassava var. Sree Vijaya (short duration), application of 100:300:300 kg NPK ha^{-1} along with FYM @ 12.5 t ha^{-1} without any substitution of K either partially or fully with Na is beneficial in enhancing the dry matter content in the plant, nutrient uptake and in producing good quality tubers (John *et al.*, 2007).

The nutrient availability due to the action of soil microbial population under the influence of organic and inorganic ammendments namely glucose, paddy straw and inorganic fertilizers due to rainy, winter and summer seasons of 1988-89 was studied by John and Abraham (1996). The study had shown that there is considerable variation between treatments in the population of soil microflora. A significantly higher population was observed as a result of the interaction effect of seasons and treatments and hence the extent of availability of nutrients.

Studies conducted on AMF association in cassava revealed that the fungal associations in general increased the plant growth and tuber yield in all the common varieties tested (KAU, 1987). However, two common varieties Ambakkadan and Ramanthala were noticed as most responding cultivars. The increase in yield was to the tune of 18 to 24%. Sivaprasad *et al.* (1990) also reported the beneficial effect of the AMF in cassava, the dominant species of AMF being Glomus sp. They reported that the response of cassava to inoculation with AMF varied with the AMF species. Narayanan (1991) reported that inoculation of AMF fungi resulted in better uptake of major, secondary and micro nutrients during the active vegetative phase of the crop. Effect of soil sterilization was not conclusive.

Conjoint use of biofertilizers like Azospirillum and

Phosphobacteria can reduce 50% of N and P fertilizer dose for cassava as reported by Geetha *et al.* (2001). It is beneficial to apply biofertilizer or vermicompost along with 50% of chemical fertilizer for higher yields in cassava and when vermicompost is applied, 20 t ha^{-1} is enough for higher yields. It is economical to apply either Azospirillum and AMF with 75 % recommended fertilizers or vermicompost 20 t ha^{-1} with 50 % of the recommended chemical fertilizers. Use of vermicompost either as a seed inoculant or as an organic source resulted in better biometric characters and yield of cassava. Soil application of biofertilizers such as Azospirillum and AMF mixed with small quantity of cowdung recorded good yield of cassava (KAU, 2005).

In an acid laterite soil of south Kerala, cassava var. M-4 produced a significantly higher tuber yield of 21.32 t ha^{-1} when khondalite (petro fertilizer) was applied @ 1 t ha^{-1} along with 75% of the KAU recommended dose i.e. 38:38:38 kg NPK ha^{-1} and FYM @ 12.5 t ha^{-1} indicating the possibility of substituting 25% chemical fertilizers with Khondalite (Shehana *et al.*, 2006). Application of khondalite, along with FYM also resulted in an increase in water holding capacity, pore space, etc. of soil, apart from lowering the bulk density, particle density and mean weight diameter of soil particles. This emphasizes the beneficial effect of khondalite in improving the soil physical properties for better rooting and bulking in cassava.

Application of FYM @ 12.5 t ha^{-1} or poultry manure @ 5 t ha^{-1} along with 75:50:100 kg NPK ha^{-1} resulted in higher returns from Sree Vijaya and Kariyilapothiyan, two short duration varieties of cassava cultivated in lowlands (Pamila, 2004). No variation between varieties was observed in their response to N level as well as to the sources of organic manure (Pamila *et al.*, 2006). Neither varieties nor sources of organic manure recorded any significant variation in starch content of the tuber. Poultry manure recorded the highest protein content and the lowest HCN content. The taste of the tuber was not affected by the sources of organic manure (Pamila *et al.*, 2011). All these findings suggest the suitability of poultry manure as an alternative to FYM for cassava cultivation in lowlands. Coirpith compost can also be used as an alternate source of organic manure provided it is made cost effective.

In a study to standardize organic nutrition practices for cassava, different sources of organic manure were tried at three different levels viz. 100%, 75% and 50% of the recommended dose of NPK along with one control (KAU POP recommendation-INM). Organic manure as FYM and coirpith compost in 1:1 ratio at 75% recommendation and the same treatment at 50% of the recommendation produced higher yields of 33.04 t ha^{-1} and 31.24 t ha^{-1} respectively. Economic analysis also revealed the superiority of these treatments and FYM and coirpith compost in 1:1 ratio at 50% recommendation generated the highest net profit and benefit cost ratio (Pushpakumari *et al.*, 2013). However, Girijadevi *et al.* (2013) observed that integrated nutrient management for cassava as per KAU POP produced the highest yield of 32.4 t ha^{-1} which was on par with organic nutrition at 100%, 75% and 50% N. Among these organic treatments, 50% N as organic generated higher benefit cost ratio of 3.17 followed by 100% N as organic. The maximum benefit cost ratio was recorded by integrated nutrient management of cassava.

4.1.4.1 Nutrient management through soil / plant analyses

The performance of cassava var. M4 under the modified recommendation based on soil test data and package of practices recommendation was studied in the laterite soil of Kerala. The treatment based on soil test recorded higher tuber yield of 11.36 t ha^{-1} and net profit of Rs. 2093 ha^{-1}. An increase in yield of 11.52% was obtained when fertilizers were applied on the basis of soil test data (KAU, 1991b).

Soil test - crop response correlation study was undertaken in cassava var. M-4 in the laterite soils of Kerala which is the pioneering work in this direction (Swadija, 1997). Multiple regression models calibrated indicated yield predictability of more than 70% using soil test values and applied nutrients as independent variables (Swadija *et al.*, 1998a). Fertilizer prescription equations for specific yield targets of cassava var. M-4 in the laterite soil were derived (Swadija and Sreedharan, 1998). The study has revealed the superiority of fertilizer application based on targeted yield approach over the semi-quantitative approach employed in the soil testing laboratories and generalized state level 'Package of Practices recommendation' for the crop. In this approach, the fertilizer dose can be adjusted in accordance with the specific objective and available resources of the farmer. It also takes care of the maintenance of soil fertility to support sustained crop production (Swadija *et al.*, 1998b).

The investigation to realize the maximum yield potential in cassava through Hunter's 'systematic approach' in fertilizer use by taking into account the nutritional constraints of the soil, manipulating these limiting factors and optimizing the nutrient status could achieve a maximum yield of 42.08 t ha^{-1} over the normal average yield of 20-25 t ha^{-1} under prevailing package of practices recommendations (John, 2003 and John and Venugopal, 2005). The maximum yield was obtained from the short duration var. Sree Vijaya by the application of 100:300:300 kg NPK ha^{-1} along with FYM @ 12.5 t ha^{-1}. The cyanogenic glucoside content showed a decline whereas the starch content was slightly improved due to its treatment (John *et al.*, 2003 and 2005). The highest use efficiency of N, P and K was observed with 100:300:300 kg NPK ha^{-1} along with FYM @ 12.5 t ha^{-1}. Studies on the nutrient balance sheet for the available N, P and K showed a deficit balance for these nutrients after two years of experimentation but a net gain was noted for N and K after the first crop. But application of higher levels of one nutrient led to reduction in the loss of the other nutrients (John and Venugopal, 2006a). Although calcium was identified as one of the limiting nutrients tuber yield, dry matter production, nutrient uptake as well as benefit cost ratio showed a poor or negative response to lime whereas the quality attributes showed a slight improvement. However, there was no significant effect of lime on the soil chemical parameters (John and Venugopal, 2006 b).

According to Geetha (2004), for cassava var. M4, application of 53:12.5:34.5 kg NPK ha^{-1} along with 12.5 t ha^{-1} of FYM was found optimum for higher yields when grown in coconut garden with 50% shade level. The recommendation of NPK was 50% higher level of dose based on nutrient uptake by the crop corrected to soil test values. This treatment was found to be superior to the recommended dose of NPK by KAU (KAU, 2011)

4.1.5 Weed management

By applying oxadiazon at 0.75 kg ha^{-1} + spade weeding at 60 and 90 DAP, the highest tuber yield of 14.1 t ha^{-1} was obtained. Weed population as well as weed dry matter were lowest with the application of 1.5 kg ha^{-1} pendimethalin+ spade weeding at 60 and 90 days after planting and produced a tuber yield of 13.7 t ha^{-1}. Unweeded control plots produced the highest weed dry matter and the lowest tuber yield which were significantly different compared to above treatments (KAU, 2008).

4.1.6 Water management

The most suitable irrigation schedule for cassava is at IW/ CPE ratio of 0.3 when it is grown either as a pure crop or when it is intercropped with cowpea, green gram, black gram or groundnut, after rice during the first crop season (KAU, 1984a).

For better water economy and higher tuber production, irrigation for cassava can be recommended at 100 mm CPE with 25 mm water in all furrows or at 75 mm CPE with 50 mm water in alternate furrows KAU (1985).

4.1.7 Cropping system

4.1.7.1 Cassava as an intercrop

Intercropping cassava in coconut gardens is an accepted practice in many coconut growing countries. Cassava var. Sree Visakham performed better as intercrop in the coconut garden compared to the var. M-4. A planting density of 8000 cassava (90 cm x 90 cm) was found to be optimum for intercropping in one hectare of coconut garden, in which coconuts were planted at 7.5 m x 7.5 m spacing (Nayar, 1986). The application of growth regulators, cycocel and ethrel though decreased the plant height, could not influence either the yield attributes or yield and maturity of cassava tubers. The productivity of cassava intercropped in coconut gardens ranged from 40-50% of sole crop yields mainly due to low sink capacity of storage roots (Nayar and Sadanandan, 1990). The tuber quality of Sree Visakham was comparable to M-4 (Nayar and Sadanandan, 1991).The recommendation of N and P for cassava can be reduced to 50% with full dose of potassium. Intercropping cassava var. Sree Visakham in coconut garden with application of 50 kg N, 50 kg P_2O_5 and 100 kg K_2O ha^{-1} gave the maximum net profit (Nayar and Sadanandan, 1992).

The nutrient-moisture-light interactions in a coconut based homestead cropping system (Ravindran, 1997) revealed that cassava can be successfully raised along with banana, elephant foot yam and vegetable cowpea under the partial shade of coconut giving only half the recommended dose of N and P_2O_5 and full dose of K_2O to the intercrops. It was also observed to be an economically viable proposition (Ravindran and Sreedharan, 2001).

In banana based cropping system, with banana cv. Nendran, planted at a spacing 2 x 2 m and cassava var. Kalpaka (short duration) planted between banana in mounds at a spacing of 1m, the combination of 75% fertilizer for banana and 100% fertilizer for cassava was found to give higher bunch weight, high tuber yield and the highest starch yield and it was on par with treatments receiving full fertilizers for both the crops. The benefit cost ratio was also high (3.18) for this combination. Decreasing the fertilizer dose to 50% for both crops significantly reduced the yield giving a benefit cost ratio of 2.51 (Geetha, 2001a).

4.1.7.2 Cassava based cropping system

Generally, cassava is a tuber crop of 8-10 months duration. The initial growth rate of the crop is comparatively slow and it takes about 2 ½ to 3 months to develop the full canopy. Light penetration decreases gradually as the plant grows. Almost 100% light is permitted till 45 days of planting and then it gradually decreases to 50%, 36%, and 25% at 75 DAP, 90 DAP and 120 DAP as proved by Ashokan (1986) and Ashokan *et al.* (1986). It was also noticed that tuber development starts by three months after planting. In addition, cassava is planted at a spacing of 75-90 cm which results in leaving a considerable land area unutilized by the crops during the early growth period. So we can go for intercropping short duration crops during the initial stage for obtaining additional income at shorter intervals.

Intercropping in cassava was found to be profitable when blackgram, cowpea and groundnut were raised as intercrops with additional fertilizers to them. But greengram was not a promising intercrop with cassava. Though the hydrocyanic acid content of the cassava tubers was found to increase significantly due to legume intercropping, the cooking quality of tubers was not affected (Bhat, 1978). Among the intercrops, groundnut was the best. The fertilizer requirement of the legume when grown as intercrops was slightly less than that required for their pure stands. Cassava + groundnut was reported to be the most remunerative intercropping system followed by cassava + cowpea (Sheela, 1982 and Anilkumar, 1984). According to Sheela (1982), intercropping cassava with cowpea and groundnut at different nutrient levels suppressed the growth of cassava plants in the early stages but later this system stimulated the growth of cassava plants. The tuber yield, yield attributes and the total dry matter production of cassava were reduced by intercropping whereas quality attributes like dry matter, starch, crude protein and hydrocyanic acid content of tuber were improved by intercropping. The increase in hydrocyanic acid content did not affect the cooking quality. The fertility status of soil was improved by legume intercropping at different nutrient levels.

In areas where rainfall is heavy and the soil is of courbe textured nature, intercropping of cowpea with cassava is better than groundnut. Growing intercrops of cowpea, greengram, blackgram or groundnut did not affect the yield of cassava. Intercropping gave an additional yield of 328 kg ha^{-1} groundnut pods, 704 kg ha^{-1} cowpea, 202 kg ha^{-1} greengram and 269 kg ha^{-1} of blackgram. The yield of cassava was not reduced due to intercropping. The organic matter status of soil can be improved by intercropping and incorporating the bhusa to soil. Cassava is considered to be an erosion permitting crop. But Viswambaran and Sasidhar (1985) found that soil loss was significantly reduced when cassava was intercropped with ground nut (KAU, 1984a). Bridgit (1985) observed that intercropping casava with groundnut enhanced growth and yield of cassava and improved the quality characters of tuber.

The intercrops are to be planted soon after planting the main crop of cassava. Generally, it is advised to apply the recommended fertilizer dose to the main crop as well as to the intercrop separately. But studies have shown the possibility of reducing the fertilizer dose by applying a common dose for intercropping system (Sheela, 1982). Sheela (1982) arrived at a common fertilizer dose of 93.75:75:93.75 kg NPK ha^{-1} for cassava intercropped with groundnut and 50:62.5:62.5 kg NPK ha^{-1} for cassava + cowpea. Half N, full P and half K were applied as basal and the remaining half N top dressed after the harvest of intercrop. The highest net returns was obtained from cassava + groundnut system (Sheela and Kunju, 1990).

Altering the orientation of planting rows has been suggested as a viable method for increasing the yield of cassava as well as intercrops. Among the different geometry in cassava based intercropping systems, paired row planting of cassava has certain inherent advantages over traditional planting method. This method facilitates cultural methods easier and reduces the competition for light, nutrient and water. Under traditional method, spacing of 90 x 90 cm is adopted whereas under paired row planting, cassava plants are given a spacing of 45/135 x 90 cm (Fig.1) so that greater interspaces available between the double rows can be utilized for raising intercrops more successfully. Anilkumar (1983) found that stylo can be profitably intercropped with cassava in paired rows. Anilkumar (1984) obtained the highest economic return when cassava was planted in paired rows and groundnut raised in the interspaces of paired rows. The next best system was cassava in normal rows with groundnut in the interspaces of normal rows. Cassava in paired row without intercrop recorded a higher profit than cassava at normal spacing without intercrop. Biju (1989) also obtained the highest value for land equivalent ratio when french beans was raised as first intercrop with cassava in paired rows and the lowest value when groundnut was raised as intercrop with cassava in ordinary method. Studies at Kottarakkara revealed that yield of cassava did not differ significantly due to system of planting or intercropping (KAU, 1991b and Meerabai *et al.*,1991).

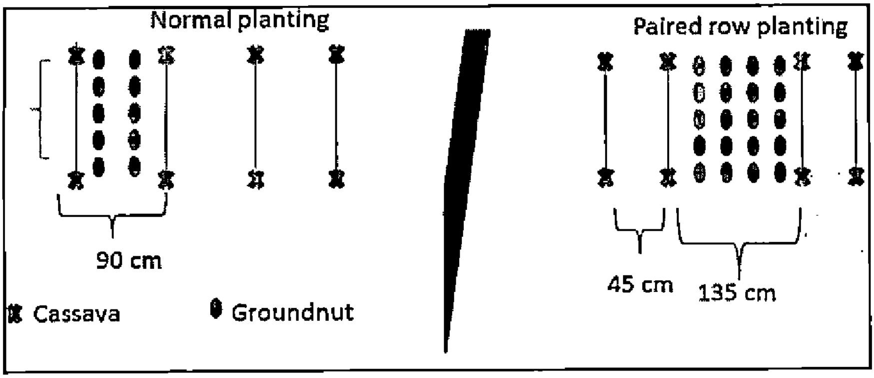

Fig 1. Paired row system in cassava

From the two year trials, the cassava + banana + elephant foot yam cropping system with cassava planted in square cluster (9070 plants ha^{-1}) / triangular cluster (6800 plants ha^{-1}) was found to be the most productive and economical cropping system. Elephant foot yam was found to be shade tolerant and the yield reduction in intercropped situation was only marginal. The floor crops of cowpea and groundnut were successful in the first year. The land equivalent ratio in cassava + banana + elephant foot yam intercropping was 1.7 and this cropping system gave a net profit of Rs. 13,300 ha^{-1}. Sequential intercropping in paired row planted cassava was not successful, but growing groundnut and red gram simultaneously in the interspace was found to be successful; groundnut was harvested after four months, red gram after eight months and cassava after nine months. The fertilizer requirement of intercrop cowpea and groundnut were found to be only about 60-90 per cent of the sole crop recommendation. The main crop of cassava also was benefitted by the application of fertilizers to the intercrops (Ashokan, 1986).

Experiments were also done to know the feasibility of raising a second intercrop after the harvest of the first intercrop with cassava. Biju (1989) reported that the highest profit was obtained from the two intercrops of french bean raised in sequence in the interspaces of cassava planted in paired rows. However, Meerabai *et al.* (1991 and 1992) found that the second intercrop after the harvest of the first intercrop is not feasible due to the shading effect of cassava even in paired rows.

Growing fodder crops as intercrops in cassava will meet the food -fodder requirements of farm families rearing livestock also. Anilkumar (1983) proved that stylo can be profitably intercropped with cassava in paired rows. He reported that growth characters and yield attributes of cassava were not influenced by stylosanthes intercropping and nitrogen levels. No significant reduction in the yield of cassava was observed due to intercropping and levels of nitrogen, but maximum fodder and crude protein yields were obtained from pure crop of stylosanthes. The soil loss was maximum in pure crop of cassava and stylosanthes intercropped plots recorded minimum loss. After three years of experimentation, Sheela *et al.* (1996) reported that raising fodder cowpea as intercrop of cassava, planted in normal or paired rows, is advantageous to enhance the fodder production without reducing the tuber yield of cassava. For this combination, the recommended fertilizer level for fodder cowpea can be reduced to 75% without sacrificing the tuber yield of cassava. But further reduction in fertilizer dose will deleteriously affect the yield of the main crop.

Gayathri (2010) observed the suitability of alley cropping with fodder crops in paired row planted cassava. According to Gayathri *et al.* (2013), intercropping in cassava var. Vellayani Hraswa (planted at a spacing of 60/120 x 90 cm) of duration six months with two rows of palisade grass inter planted with one row of fodder cowpea is the most efficient cassava based fodder production system for food-fodder security, with higher biological productivity (cassava equivalent yield of 19.78 t ha^{-1}), feed quality (crude protein yield of 0.59 t ha^{-1}), economic returns (cassava equivalent income of Rs. 98936 ha^{-1}) and land use efficiency (land equivalent ratio of 1.7).

4.1.8 Pest and diseases

Among the various storage pests of cassava chips, three pests viz. cassava weevil (*Araecerus fasciculatus* Deg.), rice weevil

(*Sitophilus oryzae* L.) and rust red flour bettle (*Tribolium castaneum* Hbst.) were found to be the major ones. The entire quantity of chips was converted into powder during a period of three months after storage by cassava weevil and rice weevil. Raw chips were most preferred by the insects when compared to parboiled chips. Varietal difference was observed in the susceptibility of dried chips to stored pests and the M-4 was fund to be the most susceptible variety (KAU, 1991b).

The causative organisms of Cercospora leaf spot and bacterial blight of cassava have been identified and control measures recommended. Among the diseases and pests of cassava, cassava mosaic disease (CMD) is a serious factor limiting the productivity of cassava. CMD is caused by viruses belonging to the genus *Begomovirus* of the family Geminiviridae. White fly population was maximum during Sept- Oct and November in all the localities. No transmission of the disease by sap as well as by white flies could be obtained. The disease was found to be easily graft transmissible. Electron microscopy of the disease specimen of cassava leaves indicated no conformity evidence of virus. Purification studies were also carried out without success. Studies were also conducted to screen the local as well as hybrid varieties for their relative tolerance/ resistance to the disease (KAU, 1984a and 1997).

Since the crop is vegetatively propagated, the CMD is carried from one crop cycle to the next through the use of infected cuttings as planting material. But meristem culture and virus indexing by use of protein and nucleic acid based detection can be used as a viable strategy for the early detection and elimination of the virus and hence for the production of virus free planting material (Asha, 2012).

4.1.9 Time of harvest

Two varieties of cassava (H-2304 and local) were compared for their yield when harvested at 6, 7, 8, 9, 10, 11 and 12 months after planting. It was concluded that in less fertile soils, these varieties can be harvested even at 6 months after planting without a significant reduction in yield. The edible quality of the tuber was very poor after 10 months. The fibre content of the tuber was very high when harvested at 11 and 12 months after planting (KAU, 1984a). Cassava can be harvested at 8 months after planting for industrial purpose and for culinary purpose the varieties can be harvested from 6 to 10 month after planting, the yield being maximum at the 10th month (KAU, 1985).

4.1.10 Post harvest management and value addition

Parvathy (1987) found that soaking and sun drying cassava for four days was found to be the most effective HCN detoxification method. Lime juice was found to be the most effective ingredient in reducing hydrocyanic acid content. In the feeding trial, gain in weight as well as the weight of tissues like liver, were significantly lower in the test diets when compared to the control. The kidney weights of the group fed raw H-165 cassava and the spleen weights of groups fed raw M-4 and H-165 s well as sundried H-165 were significantly lower than those of the control group. The enzyme rhodanese activity was influenced by the hydrocyanic acid content of the test diets. Liver protein values decreased as hydrocyanic acid content increased. Serum thiocyanate levels and serum and liver cholesterol levels increased as hydrocyanic acid content of the test diets increased.

Satyalekshmi (1989) observed that the HCN content of cassava was completely eliminated by fermentation. She found that the yield of the fermented product gari was higher at 72 hours of fermentation. The moisture content was considerably reduced after the processing of gari and hence had longer keeping quality. No growth of coliform bacteria in fresh gari as well as in 6 and 12 months old gari was found which might be due to the acidic nature of gari. Different snacks like diamond cuts, pakoda, orotti, gari balls and ladoo were prepared from gari. It was found that diamond cuts, pakoda and orotti were highly acceptable.

When fresh cassava tubers were stored in different depths of soil column, it was observed that the percentage of whole tuber damage was the highest at a depth of 15 cm and the least at 45 cm depth. The primary deterioration was maximum at the end of the third week of storage (64.3%). Acceptability scores of cooked tubers were also high for tubers stored in 45 cm depth. As the depth of soil column increased, the cooking time decreased and weight of cooked tubers increased. There was an increase in cooking time as the period of storage increased (KAU, 1991b). Devi (1995) observed that tubers kept in moist soil (20% field moisture capacity) could be stored upto 12 days without deterioration.

The development of proper food processing technology is essential in order to equip the rural people, particularly the women folk for an income generating activity and building up a healthy rural population. Technologies have been standardized for the preparation of energy rich complementary foods like macaroni, noodles, wafers and weaning foods based on cassava with better nutritional and organoleptic qualities and physiological tolerance (Chellamal, 1995). These products could be stored in glass and plastic containers free of insect infestation for about one year and in airtight containers upto 6 months. In addition, various fermented products and vermicelli have also been formulated from cassava.

Mathen (1997) formulated ready to eat products based on cassava. Vermicelli (sweet/ savoury) was formulated with 40% cassava flour, 30% maida, 20% soyflour and 10% sugar (sweet vermicelli)/salt (savoury vermicelli). Cooking characteristics of the developed products were rated as good. The products contained all the nutrients in optimum quantity and exhibited a protein efficiency ratio of 2.2 to 2.4 indicating the quality of protein is good. The other quality parameters like biological value, digestibility coefficient and net protein utilization of the product was also satisfactory. Both sweet and savoury vermicelli got higher scores in the organoleptic tests. The products could be stored upto six months without significant increase in moisture and peroxide contents and insect infestation.

SWEET POTATO

4.2 Sweet potato

4.2.1 Varietal improvement

Analysis of 17 varieties of sweet potato by Pushkaran *et al.* (1978) showed that the yield was influenced by the first order components like girth of tubers, number of tubers and length of tubers, the direct effect of the last two being more pronounced. An increase in the second order component of vine, length of vine, caused a significant increase in tuber yield but was associated with an increase in leaf area which had negative correlation with yield. It is concluded that attempt to increase vine length should be coupled with selection of reduced leaf area.

Different varieties of sweet potato were collected at Vellayani to evaluate their self incompatability and to find out the possible mechanism to overcome self incompatability. Among the 31 varieties screened, only one variety (S-378) showed self compatability (KAU, 1985). The generally high degree of heterozygosity and frequent prevalence of polyploidy in sweet potato are advantageous in mutation breeding. The study of radiosensitivity of species or strains is desirable for mutation breeding so that the optimum exposure of mutagen can be used in each variety. Bai and Nayar (1990) observed cultivar dependent variation in the radiosensitivity in sweet potato. Based on discriminant function analysis, it was possible to group 15 cultivars under three groups viz. sensitive, medium tolerant and tolerant. Irradiation of rooted cuttings was found to be more beneficial compared to irradiation of fresh and rooted cuttings (KAU, 1991b).

Among the sweet potato lines/cultivars evaluated for their performance in coconut garden, the cultivar Kanjangad local excelled others. Kanjangad local was the most suited variety for summer rice fallows (KAU, 1991a). When raised in uplands, Kanjangad local exhibited low weevil incidence and better consumer acceptability (KAU, 1991b). This was later released as the var. Kanjangad in 1992 (Manju and John, 2011). This variety, yielding 12 t ha^{-1} is tolerant to partial shade and is suitable for cultivation during kharif season in uplands as rainfed crop. This variety possesses purple tubers with yellow flesh and moderately tolerant to sweet potato weevil. It is recommended throughout Kerala.

4.2.2 Nutrient management

Thomas (1965) studied the response of certain varieties of sweet potato to graded doses of nitrogen and potash and found that the best fertilizer combination for sweet potato was 80 lbs. nitrogen and 80 lbs. of potash per acre over a basal dressing of 50 lbs. of P2O5. Alexander (1973) observed that the var. H 42 was the highest yielder followed by H41 and the local var. Kottaramchuvala. A reduced dose of 37.5 kg ha^{-1} N as basal and 18.75 kg ha^{-1} as foliar spray was found better. Although significant varietal difference in tuber yield was observed, doses as well as timings of N application were not found to have any effect on the yield of tuber (Nair, 1972).

In the fertile soils of Vellanikkara, 30 kg N and 30 kg K_2O per hectare was found sufficient for the sweet potato var. Kanhangad local (KAU, 1984a). In another study at Chalakudy, nitrogen and potash @ 50 kg ha^{-1} each worked out to be the most economical level for sweet potato (KAU, 1984a). According to Ashokan *et al.* (1984), the most economic dose of potash for upland sweet potato was found to be 60 kg ha^{-1} at Thrissur. In soils rich in N and K, nitrogen and potash each @ 30 kg ha^{-1} was enough for good yield (KAU, 1985). Nair (1987) obtained maximum tuber yield of sweet potato when N @ 50 kg ha^{-1} and potash @ 75 kg ha^{-1} was applied as 2/3rd dose as basal and 1/3rd one month after planting. He observed remarkable influence of nitrogen on vegetative characters of the plant like vine length, number of branches per plant, number of leaves per plant and leaf area index. But he could not observe any influence of varying levels of potash on these characters. According to Oommen (1989), a spacing of 40 x 20 cm and 20 cm deep fertilizer placement resulted in maximum net return. Application of fertilizers at the rate of 100:75:100 kg NPK ha^{-1} recorded maximum net returns. But, Syriac and Kunju (1989) observed that when sweet potato var. Kanhangad local was raised as intercrop in coconut garden, application of 50:25:50 kg NPK ha^{-1} was sufficient for the crop in the highly fertile alluvial soils of Kutanad.

Devi (1990) found that application of 100 kg K_2O ha^{-1} in two equal split doses – half as basal and half as top dressing – in combination with a planting depth of 5 cm was superior for the var. Sree Nandini under the agro-climatic conditions of Thiruvananthapuram district. For summer and kharif season crops, 75:75:75 kg N, P_2O_5, K_2O ha^{-1} was found to be the best for the uplands of Kuttanad. When sweet potato was raised as catch crop in the summer rice fallows, application of 50:50:50 kg NPK ha^{-1} resulted in the highest net returns and maximum water use efficiency (Nair, 1994). Nair and Nair (1995) reported that increased rates of nitrogen supply was helpful in promoting the length of vine, number of leaves $plant^{-1}$ and leaf area index. Both net assimilation rate and crop growth rate were high in the early stages of growth and decreased towards harvest. Higher levels of potassium had a favourable influence on leaf area index, net assimilation rate and crop growth rate. Nair *et al.* (1996) reported the favourable influence of N and K application on tuber number and yield and found that tuber yield was maximum at 50 kg ha^{-1} each of N and K.

Partial substitution of potassium with sodium to the extent of 50% increased the growth attributes, yield attributes, marketable tuber yield and quality attributes like starch, protein, total sugar and cooking quality of sweet potato. Pest incidence was also reduced when K and Na were applied in 50:50 ratio (George, 1995).

Studies on the AMF association in sweet potato (KAU, 1987) revealed that the different cultivars showed varying responses to field inoculation with AMF, with 20- 26% increase in yield. Pushpakumari and Geethakumari (1999) observed that AMF inoculation can reduce the dose of N and P for sweet potato by 50% and concluded that the crop is to be fertilized with 37.5:25:75 kg NPK ha^{-1} along with AMF inoculation for getting maximum yield.

The scope of vermicompost as a potential organic source and partial substitute for inorganic fertilizers in sweet potato was also explored (Sureshkumar, 1998). It has been found that vermicompost is superior to cattle manure along with NPK fertilizers. When inorganic fertilizers was supplemented with vermicompost @ 10 t ha^{-1}, the recommended dose of inorganic fertilizers can be reduced to half without significant change in tuber yield, crude protein and carotene contents.

According to Dhanya (2011), the organic production system was found economically feasible in sweet potato. Full dose of chemical fertilizers should be substituted with FYM or poultry manure or coirpith compost. Poultry manure at 100% recommended dose was the best treatment followed by FYM at 100% dose giving a BCR of 2.03 and 1.81 respectively. The effect of bioinoculant, PGPR mix I, applied @ 1% with the organic manure, had no significant effect on the growth and yield of sweet potato.

4.2.3 Water management

Varughese et al. (1987) obtained the highest yield in sweet potato by the application of irrigation water at IW/CPE ratio of 1.2 compared to the IW/CPE ratios of 0.8 and 0.4. Oommen (1989) observed that irrigating the field of sweet potato at IW/CPE ratio of 0.75 recorded maximum net returns.

When sweet potato was raised as catch crop in the summer rice fallows, irrigation at full CPE during tuber initiation and / or tuber maturity phase recorded significantly higher water use efficiency and net returns as compared to inducing stress during tuber initiation phase (Nair *et al.*, 1996). Tuber yield was positively correlated with number of tubers per plant as reported earlier by Pushkaran *et al.* (1978).

4.2.4 Effect of growth regulators

According to Wahab (1980), both ethrel and cycocel brought about a significant increase in the tuber yield and marketable tuber of sweet potato at Vellayani. Ethrel @ 300 ppm recorded the highest yield accounting for an increase of 54.6 % over the control. In tubers, the percentage of dry matter, starch, sugar and calcium were found to be significantly increased by both the growth regulators. However, the protein content was significantly reduced by both ethrel and cycocel. Application of ethrel as well as cycocel in sweet potato appreciably increased the net profit per hectare. Ethrel @ 300 ppm gave the highest net profit accounting for an increase of 75.6 % over the control. But cycocel spray at concentrations ranging from

500 ppm to 2000 ppm had no effect on the yield of sweet potato at Vellanikkara (KAU, 1984a).

4.2.5 Cropping system

Planting of shallow rooted and deep rooted varieties of sweet potato in the same row to exploit different layers of soil increased production of sweet potato per unit area (KAU, 1984a). Shade studies indicated that sweet potato is a shade sensitive crop since it failed to produce any tuber under shaded situation.

In Kerala, it is a common practice to raise sweet potato as a summer crop in rce fields. Rice-rice-sweet potato is suitable in double cropped paddy lands and rice-sweet potato-fallow in single crop paddy lands. In the wet lands of southern Kerala, rice-rice-amaranthus and rice-rice-sweet potato proved to be profitable cropping sequences as compared to rice-rice-fallow/pumpkin/sesame/vegetable cowpea and rice-coleus/cassava-daincha based on stability analysis and economic analysis of the data of 5 years (2006-2011). The sequences, rice-rice-sesamum and rice-coleus-daincha were found not suitable for southern Kerala (John *et al.*, 2013).

4.2.6 Pest and diseases

In a study conducted for the control of sweet potato weevil Cylas formicarius using different insecticides (KAU, 1985), the tuber infestation percentage ranged from 36.4 in fenthion (two applications) to 69% in quinalphos (one application), the infestation in control being 63%. The pest controlling efficiency of quinalphos 0.05% and fenitrothion 0.05% applied 2 months after planting was superior and on par with two applictaions of fenitrothion, fenthion , chlorodimeform, quinalphos and monocrotophos at the doses tested. Two months after planting appeared to be the vulnerable period of crop growth for which better insecticidal protection is needed. Among the organic materials tried, calophyllum cake gave significant reduction in the percentage of tubers infested by the weevil followed by lemon grass leaves and mahua cake. Cashew shell powder and neem cake were ineffective.

The incidence of sweet potato weevil and intensity of damage in Kerala were assessed (Palaniswami, 1987, Palaniswami *et al.*, 1991 and Palaniswami and Mohandas, 1991). An integrated pest management schedule consisting of removal and destruction of alternate hosts, selection of weevil free planting materials and mulching with Eupatorium or Clerodendron leaves @ 3 t ha^{-1} at 30 days after planting, re-ridging at 50 days after planting, adult weevil trapping with 100 g cut tubers of sweet potato as trap at 10 days interval during 50 and 80 days after planting, timely harvest and destruction of crop residues was found to be effective against weevil incidence without adversely affecting the naturally occurring biotic agents (Palaniswami *et al.*, 1992). Mass trapping of male weevils using sex pheromone was also attempted. The weevils were found most active during the night as evidenced by higher capture of weevils at morning observations than those in the evening observations. Among the trap designs, polythene bag trap was the cheapest one to install. The attraction of the pheromone decreased with increase in the distance of release from the pheromone source. A distance of 25 m was found ideal for placement of traps in the field.

Survey conducted by Jeeva (2001) revealed that sweet potato feathery mottle virus is widely prevalent in the farmer's fields in Thiruvananthapuram district and types and intensity of symptoms varied with variety. The virus was readily transmitted through cuttings, tubers, grafting and also by Aphis gossypii through sap inoculation from infected cuttings. Transmission through seed was not observed. The infection caused reduction in the content of carbohydrate, starch, total chlorophyll, chlorophyll-a, chlorophyll-b and polyphenol oxidase activity in the leaves of susceptible varieties. Storage of vine cuttings for disease management was unsuccessful. Through meristem culture, only 85-96% of virus free sweet potato plants were produced.

Prathapan and Balan (2010) have reported the occurrence of sweet potato flea beetle (*Chaetocnema confinis*) in Kerala and Karnataka as well as in Meghalaya indicating a wide distribution and establishment of this pest in the country. Only females are found in India as in the case of overseas invasive population of the pest.

Parthenogenetic mode of reproduction, capacity to disperse through flight and the ability to thrive on a wide variety of convolvulaceous host plants makes this minute flea beetle a successful invasive pest.

4.2.7 Time of harvest

Most of the sweet potato varieties gave high tuber yields when harvested at 90-105 days after planting (KAU, 1984a). The crop harvested at 120 days after planting recorded high percentage of weevil damage in almost all varieties. Kanjangad local gave maximum yield when harvested at 120 days after planting (KAU, 1984b).

4.2.8 Storage of tubers

Storage of tubers in the exposed condition in the room made them deteriorate quickly than those kept in media like saw dust, dry sand and wood ash. Among the eight materials evaluated for the storage of sweet potato tubers, waste carbon paper was found to be the best medium for storage without sprouting and pest or disease incidence upto 60 days followed by saw dust and coirpith from nutritional, acceptability and shelf life point of view (Thampi, 1994).

4.2.9 Value addition

Studies on processing and value addition in sweet potato have proved that it is possible to develop different types of processed products which may result in increased consumption of tuber in the future and also for building up a healthy rural population.

Energy rich complementary foods like macaroni, noodles, wafers and weaning foods based on sweet potato with better nutritional and organoleptic qualities and physiological tolerance could be prepared as suggested by Chellamal (1995). These products could be stored in glass and plastic containers free of insect infestation for about one year and in airtight containers up to 6 months.

Attempts were also made to develop baked and confectionary products based on sweet potato (Augustine, 1999). Sweet potato flour and maida in 1:1 proportion was identified as the ideal combination, since it secured higher amino acid score and chemical score in the organoleptic evaluation and also could be prepared at reasonable cost. Five baked products, viz. cake, biscuits, nancuts, cookies and bread and five confectionary products, viz. halwa, cheese, toffee, burfi and gulab jamun mix were processed under the study. The products contained all the nutrients in the optimum quantity which were comparable with ISI specification. Both the baked and confectionary products got higher scores in organoleptic studies. Among baked products, biscuits had the highest shelf life and among the confectionary products, toffee had the highest shelf life (Chellamal and Augutine, 2001).

Three preserved products, viz. leather, jam and wine were prepared using two varieties of sweet potato, viz. Kanjangad and Sree Bhadra in plain forms and also in combination with mango and pineapple in three different proportions (Roopa, 2002). An acceptable balancing of the various chemical constituents were seen in the products. The developed products were satisfy FPO quality standards and were cost effective. Sweet potato mango blends were more acceptable for leather while for jam and wine, combination of sweet potato with pineapple was more accepted. The shelf life assessment of the developed products showed satisfactory results. Evaluation of rate technology adoption, after transferring the technology to self help groups, revealed satisfactory results.

TARO

TANNIA

4.3 Taro

4.3.1 Varietal improvement

In a study conducted to evaluate the performance of taro varieties and to identify the most suitable variety for the agro-climatic conditions of Thrissur, the var. 'Panchmukhi' gave the highest yield followed by the var. 'Thamarakannan' (KAU 1984a).

4.3.2 Planting material and planting

Medium sized cormel of about 35-45 g was standardized as the optimum size for planting material of taro (Kamalam, 1979). Production of bigger sized cormels and more yields were observed when side corm was used as planting material (Mohankumar, 1986).

Kamalam (1979) observed that furrow planting was superior to pit and ridge methods due to better soil moisture retention. Maximum marketable cormel yield was recorded at a spacing of 60 x 45 cm (Mohankumar, 1986).

Mulching increased the soil nutrient contents, improved the physical properties of soil, hastened germination and increased cormel yield and total tuber yield as observed by Mohankumar (1986). So he recommended mulching with green leaves @ 12 t ha^{-1}.

4.3.3 Nutrient management:

A linear response in the yield of taro var. Thamarakannan due to application of N from 0 to 80 kg ha^{-1}, phosphorus 0 to 50 kg ha^{-1} and potash 0 to 120 kg ha^{-1} (Pillai,1967b). There was significant increase in starch content due to application of higher levels of N, P and K. In another experiment conducted at Vellanikkara, the maximum yield was recorded with 80 kg ha^{-1} each of N and K_2O (KAU, 1984a). Ashokan and Nair (1984) reported enhanced tuber yield in taro with the application of N upto 100 kg and K upto 90 kg K_2O ha^{-1}.

Mohankumar (1986) observed that application of varying levels of nitrogen and potash had significant effect on increasing the plant height and leaf area index but graded doses of P did not show any significant effect on these traits. He observed that time of application of N and K was significant in the production of cormels. Tuber and total dry matter production of taro var. Thamarakannan increased significantly upto 80 kg N and 100 kg K_2O ha^{-1}. Levels of P2O5 had no significant effect on these characters (Mohankumar and Sadanandan, 1989). Mohankumar *et al.* (1990a) recommended a fertilizer dose of 80:50:100 kg NPK ha^{-1} along with 12.5 t ha^{-1} of FYM in the acid laterite soils of Kerala. They recommended three split applications of N and K - 1/3rd dose when 50% sprouting occur, second 1/3rd one month later and the remaining 1/3rd one month after the previous application and application of full P along with the first split of N and K. The mean weight of cormel, number of cormels per plant and leaf area index was positively and significantly correlated with yield (Mohankumar *et al.* 1990b). Soil analysis revealed that available nitrogen was reduced considerably afeter each crop of taro while there was a buildup of phosphorus in the soil. Higher levels of potassium application resulted in higher availability of potassium in the soil (Mohankumar and Sadanandan, 1991). Rajasree (1993) obtained the highest yield of marketable tubers, net returns and benefit cost ratio of taro var. Thamarakannan with the application of 60:50:160 kg NPK ha^{-1} under open situation.

According to Kumar *et al.* (1991b), taro is a much preferred tuber crop among the tribal farmers of Amboori in Thiruvananthapuram district where application of 60:37.5:75 kg NPK ha^{-1} was found optimum for medium level of management.

4.3.4 Water management

Though traditionally rainfed crop, taro can be grown during summer with limited number of irrigations. The var. Thamarakannan of 4-5 months duration can readily fit in the crop sequence of the rice tracts after the second crop of rice. Thampatti *et al.* (1993) found that summer taro planted in rice fields requires irrigation at 0.3 IW/CPE ratio and nitrogen @ 40 kg ha^{-1}.

4.3.5 Taro as intercrop

Taro was identified as a shade tolerant crop and the best yield was recorded under 25% shade (Bai, 1981). Rajasree (1993) and Geetha (2004) observed that taro could be profitably intercropped in the coconut garden. Vandana (2004) proved that intercropping taro in banana was profitable in the lowlands of southern Kerala. According to Vandana *et al.* (2011), planting banana at 3 x 2 m spacing with two suckers per pit and raising any intercrop (cucumber-amaranthus or taro) is beneficial for getting higher yield per unit area and maximum economic returns.

According to Rajasree (1993), application of 40:50:160 kg NPK ha^{-1} resulted in the highest yield of marketable tubers, net returns and benefit cost ratio when taro var. Thamarakannan was intercropped in the coconut garden. However, Geetha *et al.* (2005) reported that for getting high yield and net return from taro intercropped in a coconut garden with 50 % light infiltration, an NPK dose of 104.79, 12.78 and 64.4 kg ha^{-1} (arrived based on nutrient uptake and soil test values) is ideal.

4.3.6 Value addition:

Liya (2002) evaluated the nutritional quality of four cultivars i.e Pathanamthitta local, Vellayani local, Thamarakannan and Sree Rashmi. Corms of Pathanamthitta local had the highest starch and calcium oxalate content. Vellayani Local exhibited the highest protein content and vitamin C content while Thamarakannan had the highest total sugar tanniacontent. The crude fibre contents of all the four cultivars were on par. Sree Rashmi recorded the maximum organoleptic quality. Value addition was done through the preparation of chips and traditional snack items viz. murukku, wafers and papads. The products made from flour of Sree Rashmi and Thamarakannan had higher organoleptic quality. Glass and pet bottles gave better storage results than LDPE bags. Pappads had a shelf life of only 30 days after which they were subjected to mould attack.

Darshana (2004) developed baked products viz. cake, biscuit and bread from the flour of taro tubers. The flour exhibited better storage qualities and PET containers were suitable for longer storage compared to polypropylene covers. Products prepared from taro had better colour than those prepared from other minor tuber flours except arrowroot. They also got better scores for taste.

Extruded products like sev and vermicelli were developed from taro var. Sree Rashmi and Thamarakannan using maida, tuber flour and soya flour in 50:40:10 proportion (Karolin, 2004). Sev and vermicelli prepared from the var. Thamarakannan had more shelf life than from the var. Sree Reshmi with less moisture content and less microbial contamination (Chellamal *et al.*, 2007).

4.4 Tannia

Shading up to 50% solar radiation was found beneficial for the crop and hence classified as shade loving crop (Pushpakumari, 1989). Under intercropping situations in coconut garden, a medium spacing of 75 x 75 cm and a fertilizer dose of 40:50:100 kg NPK ha-1 were found optimum for tannia (Pushpakumari *et al.*, 1999).

ELEPHANT FOOT YAM

4.5 Elephant foot yam

4.5.1 Planting material and planting

The optimum size of planting material was found to be 1 kg sized corm and it should be planted at a spacing of 90 x 90 cm. However, the highest productivity of 77.2 t ha^{-1} was recorded by planting 750 g corm at a spacing of 50 x 50 cm. As the canopy size was proportional to the size of planting material, it was possible to increase the plant population per hectare when smaller bits were used for planting (KAU, 1984a and KAU, 1985).

Early planting by middle of February was found to be the optimum time of planting for getting maximum yield of corms of elephant foot yam grown as an intercrop in coconut gardens in reclaimed alluvial soils of Kuttanad. The delay in time of planting beyond middle of April significantly affected the growth and yield of the crop. Effect of irrigation was not significant (KAU, 1994). A fertilizer dose of 80:60:120 kg NPK ha^{-1} was sufficient for higher yield in reclaimed alluvial soils. Neither nitrogen nor potassium had any effect on morphological characters. The quality of tubers will be comparable at this nutrient level (Geetha, 2001b).

4.5.2 Nutrient management:

According to Pushpakuamri and Sasidharan (1992), elephant foot yam can be profitably intercropped in the coconut garden by applying only 50% of the fertilizer recommendation for open situation.

Sheela *et al.* (2010) reported that use of vermicompost as an organic source help to reduce organic and chemical fertilizer dose to 3/4th of the recommended dose for elephant foot yam raised as intercrop of coconut. Continuous application of vermicompost improved soil nutrient status and farm made vermicompost was found to be a more remunerative alternate to the traditional organic source viz. cowdung.

In a study conducted to standardize organic nutrition for elephant foot yam, application of 50% of the recommended dose of N as organic along with the basal dose of FYM was found to be economical (Girijadevi *et al.*, 2013).

4.5.3 Water management

For elephant foot yam, irrigating at 0.9 IW/CPE ratio i.e 12 irrigations at an interval of 12 days and mulching with dried leaves, paddy waste or coir dust are found to boost the corm yield (KAU, 1985).

4.5.4 Shade response:

Studies have shown that with increase in shade intensity in the coconut garden, the yield of elephant foot yam as intercrop declined proportionately. Reduction in nutrient requirement (by 50%) was observed under shaded situation compared to open situation. Amongst the various crops intercropped in the coconut garden, elephant foot yam gave maximum net profit followed by greater yam and lesser yam (Pushpakumari, 1989).

4.5.5 Value addition:

Value added products like chips and traditional snack items like viz. murukku, wafer and papads were prepared from the flour of elephant foot yam by Sini (2002). Starch content of the products declined on storage while sugar and moisture content increased slightly. Glass and PET bottles gave better storage results than LDPE bags. Papads exhibited a shelf life of only 30 days after which they were subjected to mould attack. Attempts were made by Darshana (2004) to utilize flour from elephant foot yam for the development of baked products viz. cake, biscuit and bread.

YAMS

Greater Yam

Lesser Yam

African Yam

4.6 Greater yam

Shade had significant influence on the growth and performance of greater yam. The yield declined proportionately as the shade increased. Under shaded situation, the nutrient requirement was same as that for open situation (Pushpakumari, 1989 and Pushpakumari and Sashidharan. 1992). A shade tolerant var. Indu has been released in1998 from RARS, Kumarakom. It was obtained through selection fromTCR-5 (KAU, 2002). It has trailing plant type with shallow tuberisation. It is recommended for reclaimed alluvial soils of Kuttanad. It has a yield potential of 3.93 kg $plant^{-1}$ as inter crop of coconut (Manju and John, 2011).

The scarcity of planting material for cultivation resulted in the increased adoption of the rapid propagation technique using minisetts. Minisetts of yams are planted in nurseries and later transplanted. According to Isaac *et al.* (2013) sprouting of yam minisetts is best in soil medium rather than mixing with FYM or vermicompost or coirpith compost, provided the setts are treated with cowdung slurry and the soil is mulched, which reduces the time in nursery and ensures good crop stand in the main field.

4.7 Lesser yam

Nair (1985) found that a seed size of 130 ± 10 g with a fertilizer dose of 80:80:120 kg NPK ha^{-1} was optimum for economic production of lesser yam in the laterite soils.

The tuber yield under open and 25% shade level were on par beyond which drastic reduction in yield was observed. Under shaded situation nutrient requirement was only 75% that of open situation (Pushpakumari, 1989 and Pushpakuamari and Sashidharan, 1992).

Darshana (2004) prepared flour from the tubers of lesser yam and obtained the highest yield ratio among minor tubers. The flour exhibited better storage qualities and PET containers were suitable for longer storage. The flour could be utilized for developing baked products viz. cake, biscuit and bread.

4.8 African yam

4.8.1 Agro-techniques

Despite superior yield and quality, the introduced African yam or white yam (*Dioscorea rotundata*), has not yet found an appropriate place in the coconut based cropping system of Kerala. Hence, attempts were made to popularize this type of yam by developing appropriate technologies for its cultivation using the var. Sree Priya (Suja, 2001). Seed yam treatment with thiourea (2%) induced early, uniform and better sprouting and established a vigorous crop (Suja *et al.*, 2003a and 2003b). Planting seed yam of 200 g size at a spacing of 90 x 90 cm in the coconut garden resulted in better sprouting and canopy size, higher harvest index (0.6), optimum tuber yield (16.5 t ha^{-1}) and higher profit (Rs. 19,363 ha^{-1}). Application of coirpith compost @ 5 t ha^{-1} along with 80: 60:80 kg NPK ha^{-1} gave higher yield (24.6 t ha^{-1}) and generated higher profit (Rs. 36,187 ha^{-1}) from white yam under intercropping situation. The N: K ratio of 1: 1 proved to be ideal. Coirpith compost and green manure were found to be the suitable alternatives to farm yard manure. Farm yard manure (10 t ha^{-1}) could be substituted with either coirpith compost @ 5 t ha^{-1} or by in situ incorporation of green manure, sunhemp (Suja and Nair, 2006).

4.8.2 Value addition

Darshana (2004) prepared flour from African yam tubers and utilized for the development of baked products, viz. cake, biscuit and bread. She reported that the flour exhibited better storage qualities and PET containers are suitable for longer storage compared to polypropylene covers. The products prepared from yam flour were of low cost.

Karolin (2004) formulated extruded products from African yam var. Sree Priya and Sree Dhanya. The combination with maida, tuber flour and soya flour in proportion 50:40:10 was selected for the development of the products, 'Sev' and 'Vermicelli'. The physical characteristics such as fineness, shape, uniformity of strands, packaging quality and textile strength of the var. Sree priya was found better. Dioscorea based products secured higher scores for all the parameters than taro based products. Sev and vermicelli prepared from the var. Sree Priya had more shelf life than from the var. Sree Dhanya with less moisture content and less microbial contamination (Chellamal *et al.*, 2007).

COLEUS

4.9 Coleus

4.9.1 Varietal improvement

The extent of genetic variability in coleus was quite meagre. The heritability for economically important characters was very less and selection was not useful for the improvement. The shoot characters have not much relevance compared to the tuber characters in determining the yield. The mean performance of the collections under the coconut based farming system was poor compared with the performance in the open. Path analysis projected the need of improving characters like number of tubers per plant, individual tuber weight and tuber girth (KAU, 2002).

Stability analysis of selected mutants of coleus indicated that the ideal plant type for coleus should have optimum tuber number, white coloured delicious non-groovy tubers, optimum starch and protein contents, good texture and medium flavour (KAU, 2005).

Works at RARS Pattambi on varietal improvement of coleus resulted in the release of a high yielding var. Nidhi in 2000. It is a clonal selection from a NBPGR accession IC 85708. It is an early maturing variety (130 – 135 days duration) with an average productivity of 27.9 t ha^{-1} (Manju and John, 2011).

Due to photosensitivity for tuberisation, the availability of coleus tubers in the market is seasonal. The normal planting season is from July to September. If the tubers are available during off season (December to September), they will fetch premium price in the market. It is possible only through the availability of photo-insensitive varieties for cultivation round the year. In vitro mutagenesis for photo-insensitivity to tuberisation in coleus was attempted by Mareen (2000). Mareen and Radhakrishnan (2004) reported that the response of coleus to mutagen varied with concentration as well as with genotype and also induced photo-insensitivity. The study resulted in the release of a photo insensitive mutant, Suphala, in 2006 for year round cultivation (Manju and John, 2011). It is a tissue culture mutant derived from local cultivar. It has an average yield of 15.93 t ha^{-1} and potential yield of 33.21

t ha^{-1}. It has a duration of 120-140 days. It is tolerant to major pest and diseases but not tolerant to drought. It is recommended for the central zone of Kerala. Atul (2012) and Anju (2014) have reported the adaptability of the var. Suphala for year round cultivation in the southern zone of Kerala also.

4.9.2 Planting material and planting

Among the three types of cuttings in coleus, the establishment of terminal cuttings was rapid than median and basal cuttings as reported by Thyagarajan (1969) and Rajmohan (1978). In a study on type of cutting and spacing for coleus conducted at RARS, Pattambi, planting of coleus with tip cuttings at 30 x 15cm spacing as per KAU POP (KAU, 2011) recorded the highest yield. All the treatments using tip cutting and entire vine as planting material were on par. Significant reduction in yield was noticed when inter nodal cuttings were used. Proportion of large sized tubers was more when tip cuttings were used and small sized tubers were more when internode cuttings were used as planting material (KAU 2012).

The ideal planting season in the central zone is from first fortnight of July to second fortnight of August which coincides the peak period of south west monsoon. Yield was low for early and late planted crops. Late planted crops produced bulged stem rather than fully formed tubers. The crop establishment in hot season was generally poor (KAU, 2008). For off season production of coleus, planting on November 1st was found to be the best time of planting (Anju, 2014).

When tuber development in relation to canopy regulation in coleus varieties was studied, it was found that removal of top portion of canopy at different stages of crop growth had no added advantage in terms of crop yield. Incorporation of coirpith, rice husk or saw dust had no added advantage over the POP recommendation (KAU, 2008).

4.9.3 Nutrient management

Thyagarajan (1969) reported that application of nitrogen at 30 and 60 kg per hectare resulted in significant increase in yield of tubers and the response was linear. The levels of P and K tried had no significant effect on the yield of tubers. In an experiment conducted at Nileswar on coleus (KAU, 1978) indicated that optimum requirement of nitrogen and potash were 80 kg ha^{-1} each for that region. According to Geetha (1983) and Geetha and Nair (1993), for economic production of coleus, a fertilizer dose of 60 kg N, 30 kg P_2O_5 and 120 kg K_2O ha^{-1} may be applied in two splits, half the dose nitrogen, and potash and full phosphorus as basal and the balance 30 days after planting. Archana (2001) and Archana and Swadija (2000a) concluded that the recommended dose of 60 kg P_2O_5 ha^{-1} can be reduced to 30 kg along with 60 kg N, 100 kg K_2O and 10 t ha^{-1} of FYM. FYM was found to be the best source of organic manure. If there is scarcity of FYM, half the dose of FYM can be substituted with neem cake on N equivalent basis. Wherever coirpith compost is easily available, FYM can be substituted with coirpith compost and neem cake in equal proportion. Nutrient management studies in the central zone showed that (KAU, 2007) FYM @ 10 t ha^{-1} + 40:20:100 kg NPK ha^{-1} gave comparable yield with POP recommendation of FYM @ 10 t ha^{-1} + 60:60:100 kg NPK ha^{-1}.

Soil test crop response studies have been undertaken in coleus and fertilizer prescription equations for targeted yields of coleus have been developed with and without organic manure in the laterite soils of Kerala (Nagarajan, 2003).

Trials conducted at RARS, Kumarakom revealed that combined application of *Pseudomonas* and AMF for coleus was found to be on par with AMF alone and significantly superior to pseudomonas alone and control (no biofertilizer). The recommended dose of NPK for coleus can be reduced to 75% along with application of AMF without significant reduction in tuber yield (KAU, 2011).

Partial substitution of K (MOP) upto 50% by Na (common salt) resulted in higher yield of coleus and enhanced tuber quality as observd by Neenu (2004). Neenu and Sudharmaidevi (2012a) reported that there exist a synergistic interaction between Na and K, when they were applied at 50:50 proportion as evidenced from higher uptake of nutrients and corresponding increase in yield. Substitution of K with Na in coleus can stimulate starch synthesis upto 75% Na level, but beyond that an adverse effect was observed. Application of Na with full or half the recommended dose of K increased the relative K content in coleus and thus reaffirm the earlier reports that Na is able to replace K for its non-specific functions, sparing K for its more specific functions like starch synthesis (Neenu and Sudharmaidevi, 2012 b).

In a study conducted on nutrient management in coleus in relation to stage of crop at RARS, Pattambi, five treatments with varying doses of NPK and time of application were evaluated. There was no significant difference between treatments. However, maximum yield was recorded from recommended package of practices of KAU. In the farm trials conducted, both organic and inorganic sources of nutrients were equally effective in producing better yield by coleus. The yield per ha under organic system varied from 11.0 t ha^{-1} to 27.0 t ha^{-1} while in organic situation the yield ranged from 8 t ha^{-1} to 25 t ha^{-1} (KAU, 2012).

According to Divya (2008), the recommended dose of inorganic fertilizers for coleus can be reduced to half provided it is applied along with rock dust @ 10 t ha^{-1}. 100% substitution of chemical fertilizers with rock dust @ 10 t ha^{-1} and FYM @ 10 t ha^{-1} can be recommended for coleus whereever rock dust is locally available. Starch content and cooking quality of tubers were also favoured by the application of rock dust (KAU, 2012).

Coleus has great potential for organic cultivation (Atul, 2012). Application of the recommended basal dose of FYM @ 10 t ha^{-1} and 100% recommended dose of NPK (60:60:100 kg ha^{-1}) through organic manures (FYM @ 6 t ha^{-1} + CPC @ 3 t ha^{-1} + wood ash @ 3 t ha^{-1}) along with PGPR mix 1 was necessary for getting higher yields under organic production of coleus (Atul *et al.*, 2013). During the normal planting season, var. Sree Dhara produced higher yield, net income and benefit cost ratio than the var. Suphala. But the var. Suphala which is recommended for year round cultivation is found to be early maturing than the var. Sree Dhara with more marketable tubers.

For off season production of coleus var. Suphala in the southern zone of Kerala, the ideal time of planting is November 15 which recorded higher tuber yield, net income and benefit cost ratio. The lowest yield was recorded when planted on January 1st. Significant and positive correlation was observed between tuber yield and total rainfall received during the cropping period. Modified nutrient dose of 60:30:120 kg NPK ha^{-1} through fertilizers along with FYM @ 10 t ha^{-1} + neem cake @ 1 t ha^{-1} can be recommended for the crop (Anju, 2014).

4.9.4 Effect of growth regulators

The effect of growth regulators like ethrel and cycocel on coleus has been studied by Rajmohan (1978). He observed the positive effect of ethrel on yield of coleus and quality characters of tuber like dry matter, starch and amino acid contents. Ethrel @ 200 ppm is to be given as foliar spray three times at 15 days interval starting from 45 days after planting.

4.9.5 Pests and diseases

Root knot nematode (*Meloidogyne incognita*) infestation is observed to be a serious problem in coleus affecting the quantity and quality of tubers. Sree Dhara is identified as a resistant variety. According to Sosamma (1988), burning of plant material in the field prior to planting and application of nematicides one month after planting was found effective for the control of the nematode. Application of carbofuran @ 1 kg a.i. ha^{-1} was found more effective than phorate. No residue of carbofuran or phorate could be detected in tubers at harvest. Rotting of stored tubers indicated the inefficiency of the treatments for giving protection from the nematode and a need for the second application of the nematicide at tuber setting. Hot water treatments of the tubers prior to storage did not reduce the damage. Integration of soil solarization in the nursery for 15 days with 150 gauge LDPE films and application of *Paecilomyces lilacinus* (15 g m^{-2}) in combination with either neem cake (100 g m^{-2}) or *Bacillus macerens* (15 g m^{-2}) in the main field was found as the effective management strategy for improving the yield and quality of coleus tubers (Nisha, 2005).

4.9.6 Storage of tubers

Poor keeping quality is one of the disadvantages of tuber crops. But coleus is seemed to possess good keeping quality. Archana and Swadija (2000b), Atul (2012) and Anju (2014) observed no variation in the keeping quality of tubers due to treatments. The tubers could be stored for a month without any loss in weight, decay or sprouting. Within 30-45 days after storage, sprouting of 50% of tubers was observed. But no decay of tubers was observed even after two months of storage.

4.9.7 Value addition

The flour was prepared from coleus tubers and utilized for the development of baked products viz. cake, biscuit and bread (Darshana, 2004). The flour was found to be more acidic compared to that from other minor tubers.

4.9.8 Farm machinery:

A self-propelled harvester was developed to alleviate the drudgery of farmers associated with harvesting the coleus (KAU, 2012). The harvester consists of angular tyne fitted vertically on a frame made of GI pipes. A petrol engine of 7.5 hp was used as prime mover. The harvesting unit can be dismantled if needed. The power transmission from engine shaft to the driven shaft is through chain and sprocket. The harvester was tested with three different types of tynes. The results showed that the effective field capacity is the highest for angular tynes at 0.0164 ha hr^{-1}. The harvesting efficiency was 67%.

Coleus peeler was developed and tested so as to use with the conventional grinders/mixers (KAU, 2012). Coleus peeler consists of a peeling unit and a prime mover. The peeling unit is made of a steel drum of diameter 30 cm which is provided with plastic coated steel mesh of size 20 x 20 mm inside. The prime mover is a 0.5 hp motor with a rated speed of 1200 rpm. The drive from the prime mover to the peeling unit is given by V-belt pulley. The raw coleus is fed into the peeling unit and sufficient quantity of water is added. When the motor is switched on, the peeling unit starts rotating and the coleus gets in contact with the mesh provided inside the peeling unit. This removes the skin of the coleus easily. The coleus peeler was tested with different quantity of coleus at different speed. The maximum capacity of the peeler was 2.5 kg at one pass in 5 minutes. Time taken for peeling one kg of coleus was two minutes.

ARROWROOT

4.10 Arrowroot

4.10.1 Different types and nutritive value

West Indian arrowroot (*Maranta arundinacea* L.) was the dominant species of arrow root seen or cultivated in the Western Ghat region of Thiruvananthapuram district (Swadija, 2012). Queensland arrowroot (*Canna edulis* Ker Gawl) was found growing only in a few homesteads in these regions. West Indian arrowroot has great demand either for starch extraction or for consumption after cooking. The rhizomes of West Indian arrowroot contained 25 - 29.8 % dry matter, 20 - 27.3 % starch, 0.7 - 1.1% crude protein and 2.4 - 4.2 % crude fibre on fresh weight basis. The rhizomes of Queensland arrowroot contained 24.7- 27.9 % dry matter, 20.8 - 23.3% starch, 0.81 - 0.98 % crude protein and 2.8 - 3.2 % crude fibre on fresh weight basis. Even when raised under scientific management in different containers, the rhizome yield of Queensland arrowroot collections (mean yield of 181.25 - 243.75 g plant^{-1} in different containers) was much lower than that of West Indian arrowroot (mean yield of 386.25 – 811.67 g plant^{-1} in different containers) although both species were comparable in qualitative characters.

4.10.2 Varietal improvement

Lack of variation in yield and quality characters of arrow root collections (Swadija, 2012) indicated the absence of genetic variability which may be due to vegetative propagation of the crop through rhizome bits. No improved variety has been released in this crop.

4.10.3 Shade response

When the performance of arrowroot under varying shade intensities was evaluated, Geetha (2004) observed that the yield of arrowroot increased with shade upto 50% and thereafter it decreased. The crop produced higher yield under shade compared to open even though the response varied under different shade intensities. This would qualify this crop to be more suited for intercropping in coconut gardens than for cultivation as a sole crop in the open and it can be classified as shade loving. Reduction in yield at 75% shade was only to the tune of 30% which again makes the crop suited one even for the very intense shade situation where most of the other crops fail. The yield attributes like number of tubers per plant and tuber weight per plant also followed the same trend as that of final yield. The leaf area index and leaf area duration also increased with shade upto 50% level leading to higher dry matter production (Geetha *et al.*, 2011a). The highest dry matter production was recorded at 50% solar radiation and the least under intense shade (25% light). The photosynthetic efficiencies recorded as net assimilation rate, crop growth rate and relative growth rate decreased under shade. The nutrient uptake under different levels of solar radiation indicated an increase in the uptake of all the micro nutrients with shade. The highest uptake was observed at 50% light (Geetha *et al.*, 2011b).

4.10.4 Nutrient management

According to Ramesan (1991), application of 150:75:150 kg NPK ha^{-1} resulted in maximum rhizome yield, net returns and benefit cost ratio. Veenavidyadharan (2000) observed that combined application of 10 t ha^{-1} FYM and 120:50:80 kg NPK ha^{-1} is most advantageous for arrowroot intercropped in coconut garden which resulted in the highest net income and benefit cost ratio in the laterite soils of Vellayani. Though higher rhizome yields could be produced by higher levels of FYM, they recorded lower benefit cost ratio (Veenavidyadharan and Swadija, 2000a). Integrated nutrient supply had favourable influence on the quality characters of arrowroot (Veenavidyadharan and Swadija, 200b).

According to Swadija (2012), arrowroot is a remunerative intercrop in the homesteads of Kerala. Higher rhizome yield (18.62 t ha^{-1}), net income (Rs. 74,450 ha^{-1}) and benefit cost ratio (1.99) could be obtained by the application of FYM at 15 t ha^{-1} along with biofertilizers (Azospirillum and Phosphobacteria). The quality characters of rhizome like dry matter, starch, crude protein and crude fibre contents improved during both years of study due to application of even 10 t ha^{-1} of FYM over absolute control. The study indicated the sufficiency of 15 t ha^{-1} of FYM along with biofertilizers (Azospirillum and Phosphobacteria) for realizing higher rhizome yield and improved rhizome quality of arrowroot intercropped in coconut (Swadija *et al.* 2013a and 2013b).

4.10.5 Pest and diseases

No serious pest and diseases are noted for the crop. However, a severe tuber rot was noticed during 1999 in Arrowroot grown at Instructional farm, Vellayani. The symptoms appeared on tuber as black depressions which later spread covering the major area of the tuber. Under moist conditions, grey to black mycelial growth studded with black fruiting bodies (pycnidia) was seen on the infected tubers. In advanced stages the whole tuber became disfigured and dried up to form a black hard mummified structure. The causal organism was isolated on potato dextrose agar medium and identified as Botryodiplodia theobromae. Pathogenicity was established by proving Koch's postulates (Meenakumari *et al.*, 2001).

4.10.6 Value addition

Among the flour prepared from minor tubers, arrowroot flour had the highest reducing sugar, crude fibre and protein contents as reported by Darshana (2004). It exhibited better storage qualities. Insect infestation was not observed in the fresh as well as in the stored flour. PET containers were suitable for long period of storage. The baked products such as cake, biscuit and bread prepared from the flour of arrowroot were highly acceptable.

4.10.7 Farm machinery

Under the WGDP project on arrowroot, a light weight (48 kg) and portable machine with stainless steel parts has been fabricated for starch extraction from fresh rhizomes of arrow root especially for organic and export oriented production of arrow root starch (Swadija, 2012). The marketing channels and price spread of rhizomes and starch of arrow root were identified and demand for starch was assessed. There is a minimum demand of about 25- 30 tonnes of arrow root starch annually for export as well as domestic purposes. There is ample scope for income generation for running a mini agri-business through sustained production of arrow root, extraction of starch using the portable machine and marketing of arrow root starch.

5. Shade response of tuber crops

Based on the results of several studies conducted in KAU, tuber crops are classified as given below based on their response to light intensity

- Shade sensitive- Drastic yield reduction even under low shade. eg. cassava, sweet potato (Ravindran, 1997 and Geetha, 2004)
- Shade intolerant-Decrease in yield reduction proportional to increase in shade. Suited for intercropping if ample light is available. eg. coleus (Bai, 1981 and Krishnankutty, 1983).
- Shade tolerant – Non-significant reduction in yield upto 50% shade. Highly suitable for intercropping. eg. taro, elephant foot yam, greater yam, lesser yam (Bai, 1981; Pushpakumari, 1989 and Prameela, 1990).
- Shade loving – Yield increase with increase in shade, the highest yield at 50% shade. More suited as intercrop than sole crop in the open. eg;- arrow root, tannia. (Bai, 1981; Pushpakumari, 1989 and Geetha, 2004)

Tuber crops are the most preferred intercrops in the interspaces of coconut plantation in South India. In the coconut garden, ample sunlight is available upto 8 years and after 25 years of age of the palm. So shade sensitive crops such as sweet potato are preferred upto 8 years, from 8 to 25 years, shade loving crops like tannia and arrow root and after 25 years, shade tolerant crops like elephant foot yam are preferred.

6. Homestead cropping model involving tuber crops

The homestead gardens of Kerala are heritage systems which exhibit wide varieties of perennials and seasonal crops (annuals) apart from weeds and tremendous structural and functional diversity. A normally followed polycropping system is an effective multi-storeyed spatial arrangement along with seasonally time tested temporal sequence, make the homesteads a storehouse of varied genetic resources. Ravi *et al.* (2006) found that different tuber crops are cultivated in the homesteads in Kollam district of Kerala. The tuber crops are occupying the bottom layer of the multi- storied spatial arrangement. There are as many as six types of tuber crops found in a single homestead. Most of the tuber crops are grown for home consumption and only a very few quantity is sold in the market. Planting and harvesting of these crops follow the same pattern in all the homesteads except cassava which is found throughout the year. The month of November has the maximum number of tuber crops and cassava dominated the homesteads area wise.

Ravindran (1997) studied nutrient- moisture-light interactions in a coconut based homestead cropping system and proved that coconut+ cassava +banana +elephant foot yam + vegetable cowpea system is a viable proposition which gave the highest land equivalent ratio and net returns. It was also found that only 50% of the recommended dose of N and P and full dose of K was required for the intercrop (Ravindran and Sreedharan, 2001). The cropping system model developed based on the results can be adopted in homesteads even with a single coconut palm (Fig.2). Elephant foot yam (20 no.) is raised in a row around the coconut palm at a distance of 3.65 m away from the base of the palm. The banana plants occupy the 4 remote corners at a distance of 4.5 m away from the palm. Cassava (28 no.) is planted in outer rows between banana plants at a spacing of 90 x 90 cm. Vegetable cowpea is planted between rows of cassava and elephant foot yam.

Studies clearly show that there is no deleterious effect in the productivity of palm by growing intercrop. Ravindran (1997) observed that the post experimental leaf nutrient concentration of

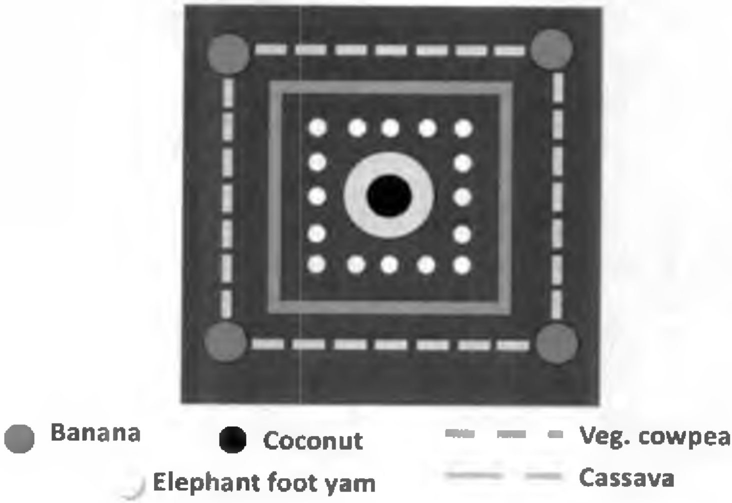

Fig.2 Homestead cropping model involving tuber crops

coconut was higher in cropping system than control plot indicating the nutrition of coconut palm was not adversely affected by raising intercrops in between them. No depletion of soil nutrient status was recorded even after two years of intercropping. Soil moisture status was also not altered by raising different intercrops in coconut garden. The coconut palms were benefitted by the cultural operations given to the intercrops. The expenditure towards maintenance of coconut garden was also minimized in addition to the additional income obtained from the intercrops. Thus intercropping proved to be of great importance to small and marginal farmers.

Multi-storeyed system has also been reported by Girijadevi and Wahab (2007) and Girijadevi *et al.* (2013). They proved that coconut + cassava+ elephant foot yam + vegetable cowpea +ginger system gave a maximum benefit cost ratio of 1.74. Land equivalent ratio, one of the most effective indices of biological advantage for evaluating efficiency and productivity of intercropping system, was more than one in all the systems tried indicating the advantage of intercropping in coconut garden compared to sole cropping. Banana, ginger and elephant foot yam constituted the ideal companion crops in coconut gardens.

7. Future strategies

Shift in area towards more remunerative crops, high wage rate, increase in per capita income and change in food habit of the people have resulted in drastic reduction in area under tuber crops in our state. But to maintain the rhythm of food supply to our growing population, tuber crops have to be retained within the cropping system of small and marginal farmers. Besides, they have high export potential especially to Middle East countries where sizeable Keralites live. These crops are exported in raw tuber form mainly to Gulf countries through Cochin, Mumbai and Chennai seaports and Thiruvananthapuram, Kozhikode and Chennai airports.

Area expansion is possible only through accommodating tuber crops as intercrop in the existing cropping system in uplands and sequential cropping with rice in lowlands for which high yielding, shade and drought tolerant varieties with excellent cooking quality are required. Studies are to be strengthened to develop suitable cropping systems involving tuber crops for each agro-climatic zones and to standardize their agronomic requirements. An understanding of physiological and biochemical mechanism of drought resistance and shade tolerance will help in identifying cultivars suited to drought and shaded conditions.

The yield of tuber crops realized in farmer's fields is far below the potential yield. Productivity enhancement is possible by the adoption of scientific management practices. Inadequate application of organic manures and imbalanced use of fertilizers have been observed which indicates the scope for improving productivity through scientific nutrient management. Integrated nutrient management involving a mix of organic, inorganics and biofertilizers could exploit the yield potential of these crops as well as sustain soil productivity. Traditionally tuber crops are fertilized with only organic manures and they respond well to application of organic manures. They are the most amenable crops for organic farming. Organic farming ensures safe and quality tubers for human consumption and environmental safety. Research works on this line have yielded fruitful technologies.

Tuber crops are infested by a number of insect and non insect pests both in field and storage. Cassava mosaic disease is a major problem limiting the productivity of cassava. Bio-intensive eco-friendly management of pest and diseases is important in the context of increasing health consciousness by people.

Better post harvest management and diversification for the production of value added products is one of the methods to retain tuber crops in the existing cropping systems. This will directly or indirectly lead to generation of more employment opportunities besides elevating the rural economy. Technologies standardized for the preparation of energy rich complimentary foods, baked and confectionary products, chips and traditional snacks from these crops can be exploited at the cottage industries level. Cassava can also be used as a raw material for a number of value added industrial products such as starch, sago, liquid glucose, dextrin, vitamin C and high fructose syrup. The tremendous scope of cassava to enter into agri-business has been undoubtedly proved by the massive growth of starch and sago factories in Tamil Nadu. Recently there has been a renowned interest in the utilization of cassava for ethanol production in the context of Government policy of blending petrol with ethanol upto 5% as mandatory from 2007 onwards.

There are many under exploited tuber crops like arrow root, which possess highly valued starch for food, pharmaceutical and other industries. Certain species of yams are used as raw material for the manufacture of cortisone, steroidal drugs and oral contraceptives. Taro starch particles, being the smallest sized among food crops and easily digestible, are used in food for invalids and infants. Corm of elephant foot yam is used to treat hemorrhoids and acute rheumatism. Medicinal properties of the tuber crops are also not fully exploited.

Taking into consideration the above facts, the University has given emphasis on research in the following lines:

i. Survey, collection, preservation, maintenance and evaluation of germplasm of tuber crops

ii. Standardisation of agro-techniques for tuber crops and breeding for yield, quality, pest and disease resistance

iii. Integrated nutrient management for tuber crops

iv. Standardisation of organic farming practices for tuber crops

v. Cropping systems involving tuber crops

vi. Collection,identification,improvement, maintenance and standardisation of agro-techniques for under-exploited tropical root and tuber crops

vii. Trade oriented production of tuber crops through diversification and development of value added products.

8. Conclusion

In the present scenario of chronic rice shortage and dependence of Kerala on other states for foodgrains coupled with changing climatic conditions affecting the production of our important food crops like rice and wheat, it is necessary to give thrust to climate resilient crops like tuber crops, for ensuring food and nutritional security. Tuber crops not only supply cheap source of energy owing to their tremendous production potential per unit area per unit time but also are nutritionally rich source of ß- carotene, anti-oxidants, dietary fibre and minerals like calcium. Orange fleshed sweet potato is an ideal food supplement in combating vitamin A deficiency. The tubers can be used as a carbohydrate substitute in animal and poultry feed. Besides, they serve as raw material for many industries especially starch industry. In the context of increasing population and the relative rise in the price of fossil-based energy, cassava can be exploited as source of bio-fuel. The tuber crops have the capacity to withstand adverse biotic and abiotic stresses. Hence research should be strengthened to maximize the productivity and exploitation of the industrial potential of these crops. Tuber crops should be given due importance in the agriculture planning of the state and developmental effort should be taken for rapid diffusion of technologies.

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