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Crop Diversification with Tropical Tuber crops for Food and Livelihood Security

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Abstract

Tropical tuber crops like cassava, greater yam, lesser yam, elephant foot yam, taro, tannia and arrowroot are mostly grown in association with plantation/fruit/tree crops like coconut, arecanut, coffee, rubber, banana, mango, sapota, litchi etc. Intercropping tuber crops both at the immature and mature phases of these perennial crops is a common practice, especially in small and medium sized land holdings. This will help to augment the net income and employment opportunities, serve as insurance crop against risk and natural calamities, enhance the resource use efficiency and ensure food security. In such farms, the produce from the perennials generate the cash income, while the starchy root and tubers partially meet the food requirements of the farm family and the feed needs of farm animals. Cropping systems involving cereals, vegetables, pulses and oilseeds in tuber crops also enable higher employment and income generation. Extensive research in India has proved beyond doubt the agronomic and economic advantages of the cropping systems involving tropical root and tubers. The scope of such crop associations, growth performance, production potential of tuber crops in such systems, management practices for realizing higher tuber yield and economic feasibility of the systems are evaluated in this paper.

Key words: Tropical tuber crops, cropping systems, plantation crops, annual crops, management, productivity, profitability

Tropical tuber crops, including cassava, sweet potato, yams (greater yam, white yam and lesser yam) and aroids like elephant foot yam, taro and tannia form the most important staple or subsidiary food to about 500 million global population. Tuber crops are the third most important food crops of man after cereals and grain legumes. It is estimated that tuber crops provide about 6% of the world's dietary energy, apart from being good sources of β – carotene, anti-oxidants, dietary fibre and minerals. They have higher biological efficiency, can tolerate drought and shade, withstand flooding and salinity to some extent, are adapted to marginal environments, low input situations and adverse soil and climatic conditions. Hence these crops are designated as "climate resilient" or "future crops". They also have immense industrial uses, in the production of starch, sago, alcohol, liquid glucose, vitamin C, as raw material for poultry and animal feed, besides medicinal properties. In India, 4171 x 10^3 MT of cassava is produced in 199 x 10^3 ha and 1460 x 10^3 MT of sweet potato is produced in 128 x 10^3 ha (FAOSTAT, 2018). The major cassava producing states are Tamil Nadu (61%) and Kerala (32%), whereas Odisha (36%), West Bengal (22%) and Uttar Pradesh (21%) are the major states producing sweet potato (Indian Horticulture Database, 2014).

Tropical tuber crops: a popular choice as understorey crops in plantations

Tropical tuber crops, cassava, greater yam, lesser yam, elephant foot yam, tannia and arrowroot can be cultivated in association with plantation crops like coconut, arecanut, coffee, rubber and fruit crops like banana, mango, litchi etc., as these crops are adapted to the same ecological conditions as tree crops (Nayar and Suja, 2004). In such a system, the main crop provides cash income, tuberous intercrops serve as high energy secondary staple to the farm family and feed for farm animals, behave as insurance crop against risk and natural calamities, enhance the resource use efficiency, ensure food security, augment net income and enhance employment opportunities. The scope of such crop associations, growth performance and production potential of tuber crops in such systems, management practices for realizing higher root yield and economic feasibility of the systems are briefly reviewed in this paper:

Coconut + Tuber crops: Performance of cassava, yams (greater yam, lesser yam and white yam), elephant foot yam, tannia and arrowroot as intercrops in coconut garden has been thoroughly researched and production technologies for these crops under intercropping situation has been standardized (Nayar and Suja, 2004; Suja, et al., 2004; Suja, 2005) (Fig. 1). Depending upon the age of the coconut palms the option of tuber crops for intercropping varies (Table 1). Experimental evidences indicated that yield was promoted by 5-15% in coconut under intercropping with tuber crops. Of the various tuber crops, arrowroot produced higher rhizome yield (7%) under intercropping. The yield reduction was lowest for elephant foot yam (11%) followed by taro (12%), lesser yam (17%) and greater yam (20%). Yield reduction was comparatively higher for sweet potato (47%) followed by cassava (33%) and white yam (29%) (Nayar and Suja, 2004). However, in newly established coconut gardens of Odisha, sweet potato variety Samrat proved profitable for intercropping (Nedunchezhiyan et al., 2007). Management practices for intercropping root and tuber crops in coconut gardens are given in Table 2.

Table 1. Option of tuber crops for intercropping in coconut at various stages

Age of coconut palms	Tuber crops
< 8 years	Cassava, Elephant foot yam, Yams
8-25 years	Elephant foot yam, Taro, Tannia, Arrowroot
> 25 years	Cassava, Elephant foot yam, Taro, Tannia, Yams, Arrowroot and Chinese potato

Source: Edison et al. (2006)

Arecanut + Tuber crops: The productivity of root and tuber crops viz., cassava, elephant foot yam, greater yam, sweet potato, taro and arrowroot in association with arecanut palms was evaluated in a number of field experiments (Muralidharan and Nayar, 1979; Sannamarappa and Muralidharan, 1982; Nayar and Suja, 2004). Higher fresh tuber yield was obtained from elephant foot yam as intercrop in arecanut gardens. About 7000 elephant foot yam/yams could be accommodated at a spacing of 90 x 90 cm, leaving 1 m radius from the base of the palms. Care should be taken to manure both the main crop as well as the intercrop separately and adequately. However, higher biomass

Table 2. Management practices for root and tubers intercropped in coconut gardens

Intercrop	Time of planting	Suitable variety	Method of planting, spacing and plant population per ha	Manures		Duration (months)
				FYM (t ha^{-1})	NPK (kg ha^{-1})	
Cassava	May-June	Sree Visakham H-165	Mounds 90 x 90 cm (9,000 plants)	9	50:50:100	8-10
Elephant foot yam	March-April	Sree Padma Gajendra	Pits 90 x 90 cm (9,000 plants)	20	26:20:33	8-9
Greater yam	April-May	Sree Keerthi	Pits 90 x 90cm (9,000 plants)	9	80:60:80	8-9
Lesser yam	April-May	Sree Latha	Pits 75 x 75cm (12,000 plants)	8	60:30:60	7
White yam	April-May	Sree Priya	Pits 90 x 90cm (9,000 plants)	9	80:60:80	8-9
Arrowroot	May-June	Local selection	Raised beds 30 x 15cm (1,30,000 plants)	10	50:25:75	9-10

Source: Nayar and Suja (2004)


Coconut + cassava


Coconut + elephant foot


Coconut + white yam


Coconut + greater yam


Coconut + lesser yam


Coconut + dwarf white


Coconut + arrowroot


Coconut + tannia

Fig. 1. Coconut + tuber crops

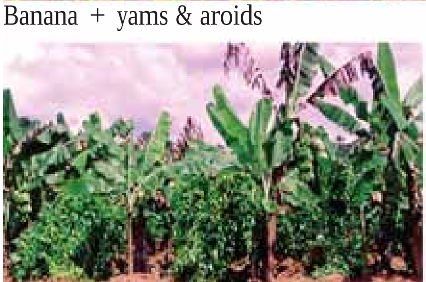
production was recorded in arrowroot indicating its ability to perform well under partially shaded conditions.

Banana + Tuber crops: Raising tuber crops like elephant foot yam, greater yam and white yam in the interspaces of *Nendran* and *Robusta* banana was productive and profitable, besides saving fertilizer inputs (Nayar and Suja, 1996; Nayar and Suja, 1998; Nayar and Suja, 2002) (Fig. 2). Studies conducted at ICAR-CTCRI (Nayar and Suja, 1996) indicated that in between two rows of *Nendran* banana spaced at 3.6 m x 1.8 m, three rows of the tuberous intercrops namely greater yam or elephant foot yam could be planted at a spacing of 90 x 90 cm to accommodate 8000 plants ha^{-1}. It was also found that in such a system the farmyard manure, N and P dose can be reduced to 50%. Further investigations carried out by Nayar et al. (2001) revealed that in *Robusta* banana + *Dioscorea* intercropping system about 6000 plants of *Dioscorea* can be accommodated in a hectare at a spacing of 90 x 90 cm without sacrificing the banana plant population of 2300 plants ha^{-1} (2.4 x 1.8 m). Banana should be fertilized at the full recommended dose and for *Dioscorea* 2/3 recommended level would be sufficient. Yams can be either trailed to banana or using cassava stems.

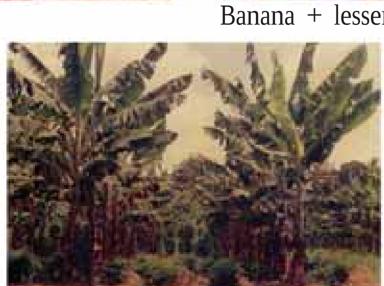
Other Fruit/Tree crops + Tuber crops: The productivity of root and tubers in association with other tree species viz., coffee, rubber, eucalyptus and *Leucaena* has also been investigated (Fig. 3). Elephant foot yam was the most ideal for intercropping in robusta coffee, mango, sapota and litchi orchards (Nayar, 1976; AICRP, 2006; AICRP, 2010). Nayar (1976) identified elephant foot yam as a profitable intercrop in robusta coffee producing yield of 18 t ha^{-1}. The performance of elephant foot yam, greater yam, white yam and tannia intercropped in rubber plantation as influenced by three levels of manuring was evaluated (Nayar and Suja, 2000). Among the tuber crops, higher productivity was recorded for elephant foot yam followed by greater yam. In young rubber plantations during the initial 3-4 years, elephant foot yam/yams could be intercropped. But manuring at the full dose should be done for both the crops. It is possible to accommodate about 6000 plants in 1 ha of rubber plantation after leaving 1.5 m radius from the base of the rubber plants. Ghosh et al. (1987) evaluated the productivity of cassava in association with tree species like eucalyptus and *Leucaena* and found that cassava yield was reduced to 80% under eucalyptus and 70% under *Leucaena* when compared to sole crop yield by third year.

Banana + yams & aroids

Banana + lesser yam



Banana + white yam



Banana + dwarf white yam

Banana + elephant foot yam

Fig. 2. Banana + tuber crops


Rubber + greater yam


Mango + tuber crops (Source: AICRP, 2006)


Sapota + elephant foot yam (Source: AICRP, 2010)


Mango + cassava (Source: AICRP, 2010)

Fig. 3. Other fruits/plantation crops + tuber crops

They attributed this loss in productivity mainly to competition from the tree species for nutrients and moisture in addition to shade effect.

The socio-economic analysis of the integration indicated that tuber crops provided on an average additional yield (10-12 t ha^{-1}), generated added profit (Rs. 1,00,000-1,25,000 ha^{-1}), employment opportunities (150-200 man days ha^{-1}) and enabled sustainable livelihoods (Table 3).

Table 3. Socio-economic analysis of tuber crops in association with plantation crops

Production system	Yield (t ha^{-1})	Net returns(Rs ha^{-1})
Coconut + cassava	10-12	90,000-1,00,000
Yams as intercrop		
Coconut + yams	12-13	1,25,000-1,50,000
Banana + yams	17-18	1,50,000-2,00,000
Rubber + yams	10-12	75,000-80,000
Elephant foot yam as intercrop		
Coconut + elephant foot yam	14-16	2,00,000-2,50,000
Banana + elephant foot yam	16-17	2,50,000-3,00,000
Rubber + elephant foot yam	20-22	3,00,000-4,00,000
Arecanut + elephant foot yam	10-12	75,000-80,000
Tannia as intercrop		
Coconut + tannia	6-7	1,00,000-1,25,000
Banana + tannia	5-6	90,000-1,00,000
Rubber + tannia	6-7	1,00,000-1,25,000
Coconut + arrowroot	15-20	3,00,000-3,50,000

Cropping systems involving cereals, vegetables, pulses and oilseeds in tuber crops enables higher employment and income generation

Short-duration pulses and vegetables were found to be feasible intercrops in tuber crops. In small farms, legumes like groundnut, cowpea, black gram and vegetables like French bean, onion, coriander, were ideal for intercropping in cassava in south India (Prabhakar et al. 1983; Mohankumar and Ravindran, 1990) (Fig. 4). Tuber crops like lesser yam, elephant foot yam etc. can also be grown in association with cassava. Sweet potato and red gram strip intercropping (1:1) was found profitable under upland ecosystem (Nedunchezhiyan, 2011). Pulses like green gram, black gram and soybean could also be intercropped in elephant foot yam but with slight yield reduction of 9% in elephant foot yam (Fig. 4). Of the pulses, black gram was found to be the most suitable. Among the elephant foot yam varieties, Gajendra was the most compatible (ICAR-CTCRI, 2017). Nedunchezhiyan et al. (2008a) reported that elephant foot yam + green gram system was profitable. Maize was identified as a suitable companion crop in greater yam. Greater yam + maize system could produce tuber yield of 17.3 t ha^{-1}, maize yield of 1425 kg ha^{-1}, tuber equivalent yield of 18.73 t ha^{-1}, production efficiency of 89.20 kg ha^{-1} day^{-1} and additional return of Rs. 22, 055 ha^{-1} (Fig. 4) (Nedunchezhiyan et al., 2008b).

Cassava, sweet potato, elephant foot yam or taro can be grown as sequential crops in rice fallows (Mohankumar and Nair, 1990). Sweet potato could successfully establish under zero tillage after harvest of rice under low land ecosystem (Nedunchezhiyan et al., 2013).

Research work carried out for over a decade at ICAR-CTCRI, Thiruvananthapuram, Kerala, indicated that short-duration cassava varieties, Sree Vijaya, Sree Jaya,

Cassava + cowpea

Cassava + groundnut

Maize + greater yam

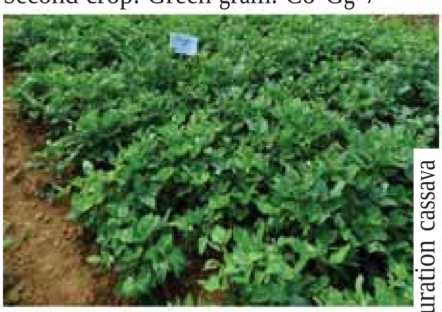
Elephant foot yam + black gram

Elephant foot yam + green gram

Fig. 4. Cropping systems involving annuals in tuber crops

First crop of rice

Second crop: Green gram: Co-Gg-7



Second crop: Black gram: Co-6

Third crop: Short-duration cassava

Rice-pulse-short duration cassava

Rice-short duration cassava + pulse crop

Fig. 5. Crop diversification with short-duration cassava

Vellayani Hraswa and Kalpaka hold promise for crop intensification (Suja et al., 2010a). Nutrient management based on soil test data was appropriate for these varieties (Suja et al., 2010b; Suja et al., 2011). Sequential cropping of vegetable cowpea with short-duration cassava was a feasible option as it enabled saving of nutrients and provided additional income (Suja and Sreekumar, 2015).

Rice-pulse-short-duration cassava proved to be feasible (Fig. 5). Both Vellayani Hraswa and Sree Vijaya were suitable for crop intensification. Green gram, black gram and soybean were equally compatible in rice based sequential cropping systems involving short-duration cassava. There was a possibility to save half FYM and N and full P to short-duration cassava, especially when green gram and black gram preceded cassava in rice based system. The tuber yield of cassava (30.82 t ha^{-1}), energy equivalent (234.07 x 10^3 MJ ha^{-1}), tuber equivalent yield (47.39 t ha^{-1}), production efficiency (131.63 kg ha^{-1} day^{-1}) and profit (additional profit of Rs. 95,758 ha^{-1} over sole cassava) were higher for rice (var. Aiswarya)-black gram (var. Co-6)-short-duration cassava (var. Sree Vijaya) (at the reduced fertility level with saving of half FYM and N and full P) (ICAR-CTCRI, 2015).

In the rice-short-duration cassava + pulse system, there was significant yield reduction (24%) in cassava under intercropping (23.42 t ha^{-1}) over sole cassava (30.82 t ha^{-1}). Green gram, black gram and soybean were equally suitable for intercropping with short-duration cassava (Fig. 5). Rice-short-duration cassava + black gram resulted in higher energy equivalent (189.61x10^3 MJ ha^{-1}), tuber equivalent yield (38.86 t ha^{-1}), production efficiency (107.94 kg ha^{-1} day^{-1}) and profit (added profit of Rs. 52107 ha^{-1} over sole cassava) besides nutrient saving; could save half FYM and N and full P to short-duration cassava (ICAR-CTCRI, 2016).

Conclusion and Future Research

Intercropping roots and tubers in plantation crops/fruit crops, like coconut, arecanut, rubber, banana, mango, sapota is a viable proposition, especially in the southern tracts of Kerala, mainly because of the bimodal rainfall received in the location. It enhances food production, provides additional returns, employment opportunities, enables better utilization of resources and safe guards the farm family from risks and natural calamities.

More comprehensive research efforts are imperative in the following direction:

- Systematic studies on farming systems involving tuber crops and development of profitable tuber crop based enterprises
- Development of sustainable cropping systems involving tuber crops and vegetables
- Development of viable systems involving seed spices/medicinal plants in association with tuber crops

- Screening high yielding varieties and hybrids of tuber crops for shade tolerance. More studies on compatibility of tuber crops with plantation crops are needed.
- Investigations on the rooting pattern, allelopathy and synergestic effects
- Technologies for production of tuber crops with other perennials (other than coconut) need to be standardized
- Socio-economic evaluation of the system

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