Role of Tuber Crops in Farming Systems*

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Tuber crops are the third-most important food crop and about one-fifth of the people of the world, particularly in tropical Africa, parts of tropical America, Pacific Islands and Peninsular India, are dependent on these tubers as their staple or main supplementary food. In India, Cassava occupies about 3.6 lakh ha (production 60.5 lakh tonnes), mostly in Kerala, Tamil Nadu and Andhra Pradesh; and sweet potato occupies 2.25 lakh ha (production 15.5 lakh tonnes), mostly in northern and eastern states, namely, Bihar, Uttar Pradesh, Madhya Pradesh, Orissa and Assam.

Agro-ecological diversity:

The distribution of cassava and sweet-potato indicate that cassava is mainly confined to tropical warm and humid climate with moderate to high rainfall, distributed during south-west and north-east monsoons; while sweet potato prefers pre-dominantly sub-tropical climate though it performs tolerable good in tropical regions under plenty of sunshine. Other tuber crops viz. Aroids (Colocasia, Xanthosoma), Yams (Amorphophallus, Dioscrorea alata, D. esculanta, D. rotundate and Coleus are grown under varying weather conditions ans also under shaded condition. Shade tolerance is an additional advantage of Aroids and Yams and hence best fitted to grow under wide-spaced perennials like coconut, arecanut and tree crops.

Cropping pattern according to regional need:

Based on suitability of agro-ecological factors, consumers' preference, industrial needs, commercial adoption in the locality etc., the appropriate cropping systems have to be formulated.

Suitable multiple-cropping system in cassava:

The intensity of cropping gives maximum yield per unit area in the tropics. Cassava is mainly cultivated in marginal lands of undulating or where other crops have been found to be un-economical; as it is tolerant to a wide range of environmental conditions. It is mainly grown as a rainfed mono-crop without much mixed cropping, year after year in the same field or as an inter-crop under coconut plantations, mostly in Kerala and part of Tamil Nadu.

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Estimates of suitable legumes and other species as inter-crop with cassava are not precisely available in India; though groundnut and cowpea showed a great promise in Kerala and onion in Tamil Nadu. Other inter-crops include frenchbean, maize, pigeonpea, vegetables, pulses, sunflower etc. An agro-economic survey in Colombia showed that about 40% of cassava is grown in mixed-culture (Diaz and Anderson 1977). It was further estimated that in Latin America, the mixed cropping is about 40%. Okigbo(1976) estimated that in Africa, about 50% of cassava is grown in mixed cropping systems. In the humid low-land tropics of Central America, cassava is frequently inter-cropped with maize in areas of lesser rainfall (Rogers 1965) and also it is inter-cropped with common beans (Phascolus vulgaris, L). According to Wagner(1958), the majority of homesteads in Nicoya and Costa Rica include cassava, in association with plantain, pigeonpea, maize and sugarcane. In Brazil which is the world's greatest cassava producer, it is grown in 2 or 3 crop associations, usually inter-cropped with beans (Phasiolus or vigna) maize, cowpeas etc. and sometimes with cotton, rice, cocoa and rubber.

In Malaysia, cassava is seldom inter-cropped, mono-cropping in mostly wide-spread. However, it is estimated that 72% of cassava land was sole cropped, and the remaining 28% under mixed or inter-cropping (Anon 1974) though the information on specific crop combinations and arrangements are not available. Cassava is mainly intercropped with Rubber in Malaysia during the first 2-3 years and relay-cropped with annual crops like groundnut, sorghum, chilli, tobacco and long beans (Vigna)

In Africa(IITA, Nigeria), Cassava is grown not only as a sole crop but is often mixed inter-cropped or relay inter-cropped with short-duration crops (2-4 months) such as maize, cowpea, melons and leafy vegetables. Andrews(1970) and Kassam and Stockinger(1973) reported that the yields of relay and inter-cropping systems are highest when there is a competition gap between cassava and inter-crops. In Southern Nigeria, cassava is often inter-cropped with yams, colocasia and maize which are principle staple food and also with subsidiary crops like bhendi, melons, beans and leafy vegetables.

In Thailand, cassava is essentially grown as a sole crop and inter-cropping is practiced to a very limited extent; with maize in the uplands and with young coconut or rubber plantations.

The most common practice in Congo is to grow a mixture of slow-growing or high-standing crops, eg. cassava, banana or maize which either come to maturity earlier(ie. short-duration crops) or which grow closer for the ground and fill the inter spaces (Jones 1959). In hilly tracts,

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of West Africa, maise, cowpea and cotton are planted as inter-crop in yams; in the following year, cassava is the main crop, with maize and pulses inter-planted(Tech.Rep.of W.Africa 1938-39). Cassava is used as a nurse crop to provide shade for young coffee in Uganda and young clove trees in Zanzibar (Nye and Jameson 1940). In Kerala, mixed cropping of cassava, sweet-potato, bananag yams and vegetables are practised. Similarly, yams are cultivated as subordinate crops with sweet-potato, ginger, turmeric etc.(See Wealth of India 1962)

Identification of suitable legumes species, inter-cropped with cassava:

Earliness of the legumes(naturing within 70-100 days) is essential so that those should reach pod-filling stage before cassava starts to close the rows and shade the intercrop. The legumes should have a non-agressive growth habit(erect or prostrate but not climbing) and cover the ground rapidly. Row width of cassava facilitated inter-cropping of cowpea groundnut,pigeonpea etc profitably and thus contributes to better utilization of space and measure of early sunlight. Among the legumes, the potentiale of groundnut and cowpeas as companion crops for cassava has been realised in CIAT, Cali, Columbia (Ann.Report 1979), India and other countries.

Table I: Competitive effect between diff.legume species and cassava at CIAT, Columbia (Quilichao).

Intercropping system	Legume grain yield			Cassava root yield		
	Monoculture (kg/ha)	Intercropped (kg/ha)	Reduction %	Monoculture t/ha	Intercropped t/ha	Reduction %
Groundnut/ Cassava	1822	1543	15	34.1	28.0	18
Cowpea/ Cassava	1179	459	61	19.3	14.3	26

It may be seen from (Table I) that a consistant balance performance was shown by groundnut, suffering little when inter-cropped and competing much less with cassava; while cowpea reduced cassava yield and suffered greater grain yield reduction. Thus, the vigorous growth and climbing habit of cowpea depressed the cassava yield to a great extent.

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In India, inter-cropping systems with cassava have been/are being standardized since 1968 at the CTCRI, Trivandrum and later at T.N.A.U, Coimbatore, K.A.U, Kerala including groundnut and cowpea, besides other inter-crops. The comparative performance of these two inter-crops with cassava evaluated by several researchers under rainfed conditions, are summerised.

Table 2: Comparative performance of groundnut and cowpea as inter-crop with cassava

	Intercropping system	Legume yield (kg/ha)	Cassava yield (t/ha) Monoculture	Cassava yield (t/ha) Intercropped	Reduction %	Source of information
A.	groundnut/cassava	1790	27.5	25.9	5.8	Singh & Mandal 1968-70
	cowpea/cassava	1000	"	17.8	-1.1	"
B.	groundnut/cassava	2660	20.9	20.3	2.3	Mohankumar & Hrishi 1973
C.	groundnut/cassava	1380	31.3	20.0	36.1	Prabhakar, Mohankumar & Nair 1978-79
	cowpea/cassava	1050	"	25.2	19.5	"
D.	groundnut/cassava	1253	26.6	21.3	19.9	Prabhakar 1983
	cowpea/cassava	3700 (greenpod)	"	21.8	18.0	"
E.	groundnut/cassava	620	24.9	19.7	20.9	Muthukrishnan & Thamburaj 1978
	cowpea/cassava	2030	"	16.6	33.3	"

From the above table, it is clear that inter-cropping of cassava with groundnut and cowpea is economical and mutually beneficial for the soil and crop improvement, instead of growing cassava as a simple crop. Growing of such inter-crops will result in additional income to the farmers.

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Table 3: Comparative performance of other inter-crops with cassava

Inter-cropping system	Inter-crop kg/ha	Cassava yield			Source
		Monoculture (t/ha)	Intercrops(t/ha)	Reduction %	
Maize/cassava	1380	22.6	20.3	10.2	Mohankumar 197
"(fodder)/"	14,609	21.9	21.9	00	"
Pigeonpea/cassava	700	26.5	19.1	27.9	Prabhakar 1983
Greengram/ "	230	20.9	20.5	1.9	Mandal 1968-70
Horsegram/ "	210	30.5	18.3	40.0	
Soyabean/ "	250	20.9	20.0	4.3	Mohankumar 197
Sunflower/ "	700	21.9	19.3	11.9	"
Sesamum/ "	160	30.5	22.8	25.2	Mandal 1968-7
Coleus / "	3420	30.5	28.5	6.6	"

Among these inter-crops, Horsegram, green gram, soyabean and sesamum recorded very poor yield and thus found not remunerative. Pigeonpea required wider space between cassava rows, since reduction in cassava yield is about 28%. Growing maize as inter crop with adequate fertilization recorded good return in India and other countries. Sunflower and coleus can be grown as intercrop with profit.

Table 4: Comparative performance of vegetables with cassava

Intercropping system	Inter-crop yield(kg/ha)	Cassava yield			Source
		Monoculture(t/ha)	Intercropped(t/ha)	Reduction %	
Frenchbean/cassava	1500	26.5	24.8	6.4	Prabhakar 1983
Beans/cassava	1370	18.9	16.6	12.2	"
Cowpea(green)/ cassava	1220	18.9	16.0	15.3	Muthukrishnan & Thamburaj 1973
Onion/cassava	2020	24.9	16.9	32.1	"
Bhendi/ "	2030	24.9	16.6	33.3	"
Bhendi/ "	700	18.9	16.0	15.3	Prabhakar 1983
Cucumber/ "	2310	18.9	15.7	16.9	"
Amaranthus/ "	790	18.9	15.8	16.4	"

Among the leguminous vegetables as inter-crop, frenchbean showed least reduction in cassava yield and thus shown good performance. Growing beans as intercrop with cassava is also common in all over the world. Cowpea, cucumber and amaranthus, being very short duration inter-crops, can be grown with profit. Though onion as intercrop has shown a good return, the reduct in yield of cassava is very high(32%), so also in case of bhendi. Hence sh duration vegetables are recommended.

While growing these as inter-crops, the system and arrangement of planting, selection of suitable variety and their duration, canopy architecture etc. have to be considered.

Duration of tuber & other crops selected as intercrop.

It is a pre-requisite to know the duration of tuber crops and the short-duration inter-crops while fitting a suitable farming/cropping system.

Crop duration (days)							
60	75	90	110	120	180	210	300
Anorphophallus radish Cowpea(green pod)	Cowpea (grain) French bean Beans	Cucumber Knolkhol	Sweetpota- groundnut watermenon sesamun	Colems onion Bhendi gqards maise sunflower soyabean	Colocasia Dioscorea ginger turneric	Anorpho- phallus	Cassava

Table 6: System of planting and suitable varieties

Main Crop	Spacing (Cm)	Intercrop	Spacing (Cm)	Variety
Cassava	90 X 90	groundnut (2 rows)	30 X 15	TMV-2,7, Pollachy-2
"	"	cowpea (2 rows)	30 X 15	B-61, S-288(as veg); S-488 (grain)
"	"	french bean (2 rows)	30 X 20	Contender
"	"	green gran. (2 rows)	30 X 20	Pusa Baisakhi
"	"	maize (1 row)	30 X 30	Pusa safed
"	"	sunflower (1 row)	30 X 30	BSH-1
"	180 x90	Pigeonpea (1 row)	60 X 45	Hyd-2
"	90 x 90	Onion (2 rows)	30 X 10	Pusa red.

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Cassava mixed with other tubers:

When the normal spacing 90 x 90 cm. is adopted, one or 2 rows of short duration intercrops can be conveniently adjusted; however, when the spacing is os increased tp 100 X 90 cm., cassava can be mixed with other tuber crops like Amorphophallus, sweet potato, colas and D. esculanta. Paired row system of growing cassava 60 cm(2 rows) at 120 cm apart (keeping 90 cm intra-row constant is advantageous for introducing inter-crop.

Cover-crops with cassava:

Cassava is a crop with a high erosion index and hence worsening a bad situation while grown as a heavily eroded soil. Under such situation, it is wise to grow cover crops or fast growing grain legumes to check the erosion and also supply cash income for a farmer within 2½ to 3½ months.

Among cover crops like Kudzu(Pueraria Phascoloides), valvet bean(Stizolobium deeringianum), Stylosenthus guyanesis, Desmodium ovalifoliun, Indigofira etc. tested, D. ovalifolium had shown favourable characteristics of easy establishment, produces a dense soil cover, found ideal for controlling erosion and also does not compete much with cassava. All these leguminous cover crops being rich in protein, have an additional advantage to use as excellent cattle feed, if cassava is wide-spaced under a suitable farming system.

Tuber-crop based Mixed-farming system:

The tubers being rich in starch and having very high biological efficiency as energy converters and food calories, the cassava tubers are especially used as cattle, poultry and pig feed as concentrated. Similarly sweet potato vines just before crop harvest are chopped along with jower or maize cadby and fed to cattle in Northern States and it is a palatable green feed for pig. Semi-dried tapioca leaves can also be mixed with straw and fed to cattle.

Hence, suitable mixed farming system is being attempted at CTCRI, including quick growing legume fodder tree like subabool and cover crops like stylo (legumes), Guinea grass in between sparse cassava rows so as to meet the food requirement of the family and balance feed for domestic animals. Such model will be best suited for checking erosion also in the undulating lateritic cassava growing ones.

Role of subabool as green feed and as a standard for Dioscrorea:

Dioscorea vines need good support . Planting of subabool(Hawiian Jiant K.8) at an uniform distance(3-4 m apart) and beheading at about 4 m hight, followed by, periodical loppings would solve the long standing problem of vine support and reduce the cost of tuber production considerably by substituting the conventional method of constructing pandal with bamboo/teak pol and rope. The croppings with green leaf will be the constant source of proteinous feed for the cattle.

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Intensive Cropping System in Coconut and Arecanut Plantations with Tuber Crops.

Krishna Marar (1964) estimated the extent of inter/mixed cropping in coconut gardens in Kerala at 78% and that tapioca was given in 20% of the stands. In Tamil Nadu, 65% of the coconut gardens are covered with popular inter-crops like cassava sorghum, sugarcane etc. In Philippines, Colocasia, groundnut, ginger and pineapple are widely grown in coconut gardens.

Among the tuber crops as intercrop in coconut gardens, cassava, Amorphophallus and Colocasia are the most popular ones. The main reasons for their popularity is to partially meet the food requirements of the farmer's family while the coconut gives the cash income.

When the palms are young, i.e. upto 4-5 years, plenty of solar energy and land area are available for any of the inter-crops to be grown. Similarly, after the age of 25 years, (7.5 m x 7.5 m standard spacing), sufficient sunlight reaches the ground and hence most of the intercrops can be grown. However, between the ages of 8 to 20 years, the canopy developed by coconut almost covers up the ground and very little sunlight penetrates the canopy. During this period, only shade tolerant crops like Colocasia and Amorphophallus can get established which gives satisfactory yields. It is estimated that one ha of coconut garden with adult bearing palms under intensive cropping programme (including tuber crops, pineapple and banana) can sustain a medium sized family on average standard (Nelliat and Krishnaji 1976 and Verghese et al, 1978).

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Table 7. Net returns and additional employment generated/yr/ha of coconut garden inter-cropped with tuber crops (Varghese et al 1978).

Intercrop	Intercrop Yield (t/ha)	Value (Rs/ha	Cost of cultivation (Rs/ha)	Net return Rs/ha	Input: output ratio for inter crop	Addl. income including coconut	Addl. employment Man days	Wo da
Amorphophallus	12.2	9760	3250	6510	3.01	12,010	123	8
Cassava	11.2	4480	2120	2160	2.11	7,860	93	12
Dioscorea alata	10.3	5150	2830	2320	1.82	7,820	64	12
D. esculanta	7.5	4500	2830	1670	1.59	7,170	64	12
Sweet Potato	7.1	2840	2055	790	1.38	6,290	56	26
Coleus	5.6	4480	2035	2445	2.20	7,945	92	23
Colocasia	6.3	5040	2050	2990	2.46	8,940	95	25

Value of intercrops: Cassava: 400, Amorphophallus: 800, D.alata/ escalanta: 500, Sweet potato: 350, Coleus/ Colocasia:800; Coconut: 0.80/nut

The economic evaluation of coconut-based intercropping at Kasaragod (Kerala) under rainfed condition further showed that the net added return per ha was highest in the case of Amorphophallus (Das 1984).

Table 8: Economics of various intercropping systems in coconut gardens.

Crop (s)	Annual cost	Added cost over mono-crop	Annual return	Net profit	Added return over mono crop	Net added return by intercrop
Coconut (monocrop)	5,550	-	13,860	8,310	-	-
" + Amorphophallus	14,100	8,550	25,600	11,500	11,740	3,190
" + D.alata	17,560	12,010	26,820	9,260	12,960	950
" + D.esculanta	14,475	8,925	23,820	9,345	9,960	1,035
" + Cassava	10,660	5,110	20,200	9,540	6,340	1,230
" + Sweet potato	9,530	3,980	18,575	9,045	4,715	735

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Intercropping in areca gardens with tuber crops:

Some of the tubers like Amorphophallus, Yams and Colocasia are capable of giving satisfactory yields under partially shaded condition in Arecanut gardens.

Table 9. Productivity of intercropping with tuber crops in areca garden.

Intercrop	Yield/ (kg/ha)	Net profit (Rs/ha)	Source of information
A. Amorphophallus (Rainfed)	6500	1700	Abraham (1974)
Dioscorea (")	6740	1820	"
B. Amorphophallus (irrigated)	12,000	2550	Bhat (1974)

It may be seen that Amorphophallus had shown consistantly good performance in both irrigated and rainfed condition.

Shade effect of cassava in Coconut garden

Out of 12 cassava cultivars tested at 3 locations (Pilicode, Balramapuram and CTCRI) under coconut plantations aged 20-40 years (Hrishi et al 1976), the performance of H.2304 was satisfactory followed by H.165 and H.1687. However, in open area, all these hybrids recorded more than double the yield. The yield of M-4 was lower than all these hybrids.

Multi-storeyed cropping including Tuber Crops:

Successful growing of a number of annuals, biennials and perennials has been conceived in a high density cropping system, so as to have greater utilization of solar energy and soil resources. The distribution of the root system of such crops should be mutually exclusive and not overlap to any appreciable extent.

1. In a tuber-tuber multi-storeyed cropping system in coconut stand, 8 no. of D.esculanta around coconut palms forms the II tier, 3 rows of cassava in between coconut rows form the III tier, and 3 rows of Amorphophallus or colocasia in IV tier along coconut rows

can accommodate 5250 cassava, 1212 colocasia, 1050 Amorphophallus and 1450 D.esculanta plants in between 175 coconut palms/ha. Such multi-crop system is expected to give additional gross income around Rs.8000/ha, in addition to about Rs.8000/ha/year from constant produce of coconut.

2. During 1983, a new coconut-based high-density multi-species cropping system have been laid out at CPCRI Kasaragod, in which large canopy perennials (Jack-2, Breadfruit-2, Nutmeg-4), medium canopy perennials (Mango-4, sapota-20, clove-85, guava-21, lime-21 subabool 363, pepper-196), small canopy perennials (coffee-2655); Biennials (banana-243, Papaya-249, pineapple 10,496) and tuberous annuals (Amorphophallus-220, Colocassia-220, Cassava-280) have been accommodated, and thus standing in addition to 175 coconut palms, 15,078 crop species of different canopy architecture in a ha space. This is one of the cropping model which is being evaluated periodically. Similar approach also holds good in arecanut gardens.

3. At CTCRI, a tuber crop-based multi-cropping system has been designed in which quick growing forest species like Eucalyptu subabool and fruit crops like banana including coconut occupied the Ist tier; the main crop being cassava in the II tier and short-duration ground crops like groundnut and french bean in the III tier have been included. The performance of each crop is being evaluated.

Intercropping pattern in coconut plantations:

A new crop model is being designed as a collaborative programme of CTCRI-CPCRI, including 4 tuber crops, viz., Cassava, Amorphophallus, Xanthosoma and sweet potato and two rhizomatus crops like ginger and turmeric in an established coconut plantatio with a specific proportion of intercrops. In this model, Cassava is playing a dominant role as intercrop of 4 rows in between two rows of coconut and the interspace cross-wise is occupied with either one of the tuber or rhizomatous crop. If individual

intercrop occupied 1 ha area, the population would have been: Cassava-8400, Xanthosoma or Amorphophallus-2800 each, Sweet-potato: 18,99, ginger or turmeric: 12,600 each. This is being compared with an open area with a population of Cassava 12,350/ha, Xanthosoma or Amorphophallus: 12,350 each, Sweet Potato: 83,330 and ginger and turmeric: 1,11,700/ha each.

Inter-cropping in Banana with tuber crops:

Inter cropping in banana for the first year is a profitable and economic proposition. Among the intercrops tried, ginger recorded the highest production and maximum profit, followed by Colocasia while sweet potato was found to be detrimental to banana growth and yield (Mandal 1975). In Kerala, growing of Amorphophall as intercrop in banana is a common practice and this Banana-Amorpho phallus combination is expected to be very good cropping system.

Rotational Cropping

Multiple cropping of one or two cereals followed by pulse or other crops has been found remunerative. The second crop season of paddy (October-November) has usually limitation of adequate rainfall etc., but the soil moisture remain adeq uate for growing sweet potato, pulses, ground nut and vegetables.

Rotational cropping systems allow a more efficient management of soil, space and better use of solar energy. Sweet potato is grown in various kinds of rotations around the world. It is often alternated with rice. Rice crop has been found to do well after sweet potato. It has its ability to smother and control weeds. Due to its vigorous, almost aggressive growth of the vine.

In many parts of humid tropics, it is possible to grow two crops of sweet potato a year. Thus, sweet potato-based cropping system may be adopted as under:

1. Sweet Potato .. Sweet Potato
2. " .. Rice
3. " .. Rice ... Rice

4 Sweet potato/coleus/colocasia .. Jute/upland rice

5. Sweet potato ... Cowpea ..... Maize

6. Sweet potato ... Radish ..... Khol khol

7. Bhindi ... Knol khol ..... Sweet potato

8. Cowpea ... Sweet potato ... Amaranthus.

Such profitable crop models of short-duration crops are needed to be developed in which residual available soil moisture can be profitably utilised and providing restricted irrigation, another short duration crop can easily be grown.

Two-tier cropping system in sweet potato:

Some of the sweet potato cultivars are found to be shallow-rooted and some of them are deep-rooted. Assuming this different rooting pattern and feeding zone, two-tier cropping system was practiced in a multilocation trial at 5 centres under Coordinated Project, but only at Dholi (N.Bihar) centre, this showed some encouraging results:

Spacing (cm)	Sweet potato yield (t/ha)		
	Shallow rooted	Deep rooted	Cross-4+RS-5 (alternate rows)
30 x 30	14.9	16.9	18.5
30 x 15	19.9	21.5	26.6

Considering the various agro-climatic factors, a suitable cropping pattern for different agroclimatic regions, is suggested.

1. Legumous like cowpea, groundnut can be grown as intercrop without affecting normal yield of cassava. Some vegetables like french bean, cowpea, onion, Amaranthus, bhindi, cucumber etc. can also be grown as catch crop.
2. In mid-land paddy, sweet potato, coleus, Colocasia, short-duration Cassava (CI-590, H.165), cowpea, groundnut, vegetables etc. can easily be grown as rotational crops.
3. Amorphophallus, Colocasia, Yams, Cassava, ginger, turmeric, banana, pineapple etc. can be grown as mixed crop in coconut and arecanut gardens.
4. Cassava can be grown first 3-4 years in rubber, cashew, tea and coffee plantations.

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