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SYSTEMS APPROACH IN COCONUT FOR HIGHER PRODUCTIVITY AND PROFITABILITY

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(Indian Council of Agricultural Research)
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I. INTRODUCTION

Coconut is an important plantation crop in the coastal regions of India. In Goa, the crop is being cultivated in an area of 25068 ha with a production of 122.02 million nuts. The average productivity of the crop is poor (4868 nuts/ha) owing to the non-adoption of high yielding varieties, lack of proper spacing and under planting, non-removal of senile palms, inadequate or lack of fertilizer and irrigation management, labour scarcity and high cost of labour. The crop is mostly cultivated by small and marginal farmers providing livelihood to millions. The income derived form these small holdings is not sufficient to sustain even the small families. In addition, coconut as mono crop provides employment only for part of the year under rainfed conditions and consequently the family labour remains unemployed for longer parts of the year.

In order to step up the production and enhance family income and employment opportunities, growing of compatible annual and perennial crops with coconut and integration with allied agro-enterprises needs attention of farmers. These practices will enable the farmers to meet their varied needs, balances their nutrition and helps to reduce the cost of production through recycling of on-farm generated resources. However, selection of crop species and varieties, spacing and other management practices to be followed are to be given prime importance to harness the full potential of the system.

The different systems that can be followed with coconut can be broadly classified into three categories as

1) Inter cropping
2) High density cropping
3) Farming system

II. INTER CROPPING IN COCONUT GARDENS

1. Scope for intercropping

Coconut being widely spaced owing to its morphological features provides ample opportunities for cropping in the inter-spaces.

Sahasranaman and Pillai (1976) observed that only 23 per cent of the soil on area basis is effectively utilised by the coconut roots in a coconut plantation planted at 7.5 m spacing. The effective root zone of an adult bearing palm growing under normal management is confined laterally within a radius of 2 m around the base of the palm. About 74 per cent of roots do not extend beyond this distance. On depth basis, the top 30 cm layer is practically devoid of functional roots and 80 per cent of the roots are found between 30 and 120 cm depth from surface. It was further confirmed that more than 80 per cent of the root activity was confined to a lateral distance of 2 m from the trunk. This shows that on an area basis,

A view of coconut garden

of total available land in a pure palm stand is not effectively utilised by coconut roots and can support many more crops (Thomas Verghese, 1976). Thus, the active root zone of coconut is confined to 25 per cent of the available land area and the remaining area could be profitably exploited for raising subsidiary crops (Srinivasa Reddy and Biddappa, 2000).

2. Canopy structure and light utilisation in coconut

The venation structure of the coconut crown and the orientation of leaves allow part of the incident solar radiation to pass through the canopy and fall on the ground. The leaves in a coconut palm crown are not randomly distributed but clumped around growing point. This non-random distribution will greatly influence photosynthetically active radiation (PAR). Age, spacing, soil fertility, varietal characteristics, leaf area and time of the day influence the light penetration through the canopy.

Reynolds (1995) observed that the amount of light transmitted ranged from five per cent in a five to ten year old D X T hybrid at a density of 650 palms/ha to about 90 per cent in a 60-70 year old plantation at a density of 120 palms/ ha.

It is estimated that as much as 56 per cent of the sunlight was transmitted through the canopy during peak hours (10-16 hours) in palms aged around 25 years. This diffused sunlight facilitates growing a number of shade tolerant crops in the interspaces.

Studies were conducted at ICAR Research Complex for Goa in this direction. The per cent transmission of photosynthetically active radiation (PAR) through a 12 years old coconut canopy during different months of the year is depicted in figure.

It was observed that the mean transmission values of PAR ranged from 23.1 to 36.6 per cent. The transmission of PAR was least during December–February (23.1–27.1% PAR) while it was highest during March–May (31.3–36.6% PAR).

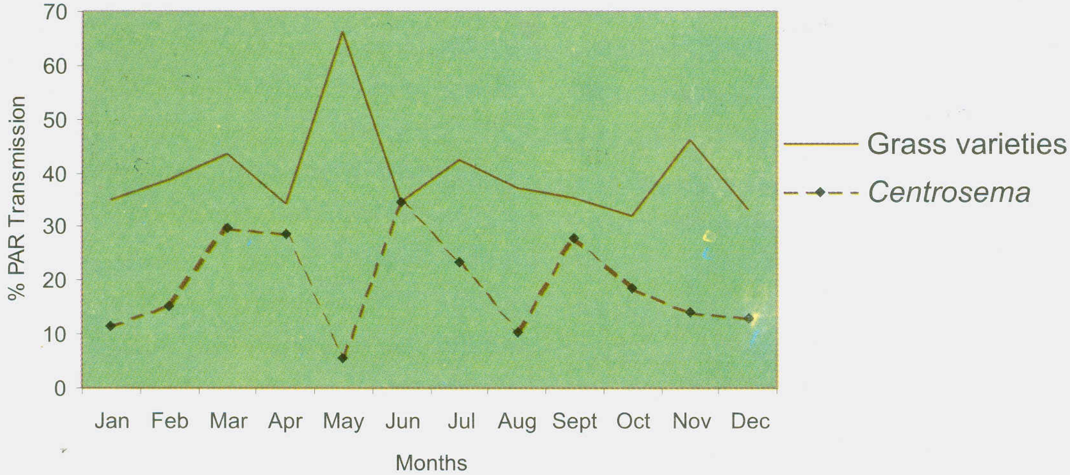


Fig . Per cent PAR transmission through coconut canopy during different months of the year.

Based on the growth habit of palm and amount of light transmitted through its canopy, the life span of coconut palm can be divided into three distinct phases *viz.* planting till full development of canopy (about 8 years), young palms (8 – 25 years) and later stage palms (more than 25 years).

3. Suitability of intercrops for coconut garden

Among the suitable inter crops in coconut are food crops such as cereals, pulses, oilseeds, root crops, pasture legumes, grasses and vegetables ; tree crops like cocoa and spice crops like clove, nutmeg, cinnamon, pepper ; fruits like banana, pineapple, custard apple, papaya, lime, pomegranate, jack, mango, sapota, guava and passion fruit (Bavappa, 1990). There is also scope for floricultural inter crops in coconut plantations.

4. Intercropping of annuals and seasonal vegetables in coconut

Field experiments were conducted at ICAR Research Complex for Goa during 1993-96 to identify profitable annuals/ seasonal crops for intercropping in coconut. Coconut garden at a spacing of 8 x 8 m selected for the trial at 11 years age allowed 40 per cent of the photosynthetically active radiation through the canopy. Three annual crops viz., ginger, turmeric and pine apple and four vegetable crops for each season viz. okra, cucumber, cluster beans and ridge gourd for *kharif* season, chillies, brinjal, cluster beans and vegetable cowpea in *rabi* and tomato, bhendi, vegetable cowpea and amaranthus in summer were tried in the experiment replicating thrice in a randomized block design on rotation basis in each season both in the open light conditions and the inter-spaces of coconut. Care was taken to leave 1.8 m radius area free around the palm. All the crops including coconut were maintained with recommended package of practices. The economics was worked out by taking into consideration the prevailing market prices for each of the produce during the season and the cost of the inputs during the year.

The results revealed that ginger (Sangli local) and turmeric (Krishna / PCT-13) are suitable annual inter crops for intensive management with May-June planting with better yields (37.15 q/ha and 70.62 q/ha, respectively) and net returns (Rs. 33,950 and Rs. 28, 290/ ha, respectively). Ginger and turmeric generated additional on–farm employment to the tune of 153-158 mandays/ha. Pine apple is a stable inter crop (40.57 q/ha) for low input situations as reflected both in terms of plant crop and ratoon yields and their monetary returns (Rs.5000/ ha). The labour input for pine apple was nearly two-thirds of that of ginger and turmeric, besides requiring less fertlizer and irrigation. Thus, ginger can be a suitable inter crop for high input management systems while pine apple can suit many of the local low input situations.

A series of locally preferred vegetables were tried to select the best vegetable crops and their varieties for intercropping in coconut. It was observed that for *kharif* season, okra with an average yield potential of 7.5 q/ha can result in an additional monetary return of Rs. 4,150/ha while another crop, cluster beans with a mean potential yield of 5.71 q/ha was the next best in the order. These crops also have a potential to provide

Pineapple - a suitable intercrop for coconut garden.

Local brinjal - a profitable crop for october planting in coconut garden.

Table 1. Average yield and economics of intercrops in coconut.

Crop	Yield (Q/ha)	Gross returns (Rs/ha)	Cost of cultivation (Rs/ha)	Net returns (Rs/ha)	Employment (man days/ha)
I. Annuals					
Ginger	37.15	64,500	30,550	33,950	153
Turmeric	70.62	59,300	30,010	28,290	158
Pine apple	41.17	17,240	12,240	5,000	103
II. Sesonals					
Kharif					
Okra	7.47	6,990	2,840	4,150	52
Cluster beans	5.71	5,130	3,680	1,450	60
Rabi					
Chilies	3.82	4,820	5,440	--	112
Brinjal	36.89	17,730	5,440	12,290	101
Vegetable cowpea	1.05	2,100	2,450	--	52
Cluster beans	4.49	5,830	5,030	800	75
Summer					
Vegetable cowpea	2.42	4,840	3,070	1,770	62
Okra	6.02	6,030	3,820	2,210	83
Coconuts	4,206 nuts	17,990	14,340	17,540	62

employment to an extent of 52-60 man days/ha. Other two vegetables viz. cucumber and ridge gourd were found not suitable for intercropping during *kharif* season as they were prone to Anthracnose disease under shade. Brinjal is a stable (36.89 q/ha) and a remunerative (Rs.12,290 / ha) inter crop for October-November planting as compared to chillies, cluster beans and vegetable cowpea. Cluster beans growth was affected when planted in October as compared to planting in June in terms of plant height (93 cm against 186 cm during *kharif*), number of fruit bunches and the yield (4.49 q/ha against 5.71 q/ha during *kharif*). Although chillies comes up better under coconut shade (with 120 cm plant height, 10 fruiting bunches/plant and 13 fruits/ branch), it is prone to mites and leaf curl disease. Similarly, vegetable cowpea was also found to be affected by coconut shade leading to lesser monetary returns.

To meet the vegetable scarcity during summer, a short duration crop like okra can be successfully grown in coconut garden by sowing in January-February to harvest about 6.02 q/ha of fruits with a net return of Rs. 2,210/ha. Amaranthus was not that suitable inter crop for summer while in tomato, fruit set was observed less (2-3 fruits/plant) and found susceptible to bronze wilt virus disease.

Thus, it may be concluded that ginger and turmeric are profitable intercrops in coconut for intensive management while pine apple is for low input management. Further, a vegetable rotation of okra-brinjal-okra for *kharif-rabi*-summer seasons, respectively will not only give intermittent seasonal returns but also better annual return (Rs. 18, 650/ha) (Manjunath *et al.*,1998).

The intercropping was also found to have a positive influence on the main crop coconut (Table 2). This was reflected through increase in percentage of trees bearing nuts (40 % of trees during pre-intercropping against 89 per cent after three years of intercropping) and the nut yield (516 nuts during pre-intercropping period against 3,411 nuts after three years of intercropping in 0.6 ha area). The increase in nut yield suggests that the intercrops have not competed with the main crop and instead contributed synergistically which may be due to additional input the coconut has received in terms of irrigation, fertilizer, weed control, etc.

Table 2. Effect of intercropping on the yield of coconut.

	Nut yield*			
	Before Intercropping		After Intercropping	
	1992-93	1993-94	1994-95	1995-96
No of coconut palms	101	101	100**	100**
No. of nut bearing palms	40	72	88	89
% of trees bearing nuts	40	71	88	89
Total nut yield	516	2,142	3,326	3,411
Nut yield /palm	13	30	37	39

* nut yield recorded from June to May each year

** One palm was removed due to red palm weevil attack.

5. Inter cropping forage grasses in coconut

As dairy industry is still in its infancy in Goa, with majority of the milk and its products being imported from neighbouring states, the costs are exhorbitant. The shortage of nutritious green forage is one of the main reasons for the lack of stabilised dairy production. As such, intercropping perennial forage grasses in coconut to identify a high yielding and palatable forage grass was envisaged. Further, legume forages make a superior quality balanced cattle feed as they are the rich sources of protein and minerals for the cattle. Legumes in combination with forage grasses form a nutritious and palatable forage by balancing the nutrition which can reduce the requirement of concentrates for the Dairy substantially. Legumes also add organic matter to the soil in the form of their roots left after harvesting of the crop. Due to their extensive root system, they have better soil binding effect, thereby resist soil erosion. The profuse vegetative growth and dense foliage of legumes provide a protective soil cover and avoid beating action of rain drops, thus, they save the most fertile top soil. Further one hectare of legumes add on an average 15-35 kg nitrogen to the soil.

Keeping these points in view, an experiment was initiated at ICAR Research Complex for Goa, Old Goa during 1996-97 to identify a profitable forage grass/ legume species and their varieties for intercropping in coconut under local agro-climatic conditions. The experiment was laid out in a Randomised Block Design with three replications by inclusion of seven high yielding forage grass varieties / hybrids in Benaulim variety of coconut in a nine year old coconut garden under protective irrigation. The crops were maintained with recommended package of practices.

The soils of the experimental site was lateritic and acidic reaction (pH 5.88), low in available nitrogen (160 kg / ha), medium in available phosphorus (33 kg/ha) and available potassium (206 kg/ha). The mean PAR transmitted through the coconut canopy was 43 per cent during the period. The observations were collected in terms of different growth and yield attributing characters.

The plant height was highest (173.2 cm) in hybrid napier NB-21 forage grass while the number of tillers was maximum in guinea grass (21.3 / hill). The leaf width was maximum (2.26 cm) in case of PBN-16. The inter-nodal length was better (17.4 cm) in guinea grass. Hybrid napier PBN-16 also recorded higher weight of leaf (175 g) to the weight of stem (285 g/ tiller) indicating better leaf to stem ratio (0.61) and higher mean forage yield (19.64 t/ha/harvest) compared to NB-21 (16.74 t/ha/ harvest), thus suggesting its superiority over NB-21 (Table 3).

Table 3. Growth and yield attributes in different forage grasses as inter crops in coconut.

Forage Grass	Pl. height (cm)	Tillers/hill	Leaf : Stem	Moisture (%)	Forage yield (t/ha/harvest)
Guinea	132.6	21.3	0.47	75.8	12.04
Setaria	105.7	18.2	0.55	86.5	5.88
PBN-16	148.7	12.3	0.61	75.6	19.64
DHN-1	198.6	11.0	0.43	69.5	11.17
DHN-2	187.7	12.1	0.91	63.2	15.70
DHN-3	163.3	14.4	0.96	67.7	12.00
NB-21	173.2	13.4	0.54	86.8	16.74

PBN - 16, a high yielding hybrid napier forage grass for intercropping in coconut

Fodder grasses were analysed for different nutritive parameters like neutral detergent fibre (NDF), acid detergent fibre (ADF), hemi-cellulose, cellulose and crude protein (CP) both in leaf and stem separately.

The crude protein content was highest (10.5%) in PBN-16 leaves as compared to NB-21 leaves (8.75%) and further the cellulose content was also higher in PBN-16 (34.3%) in contrast to 26.7 per cent cellulose in NB-21. This clearly shows the supremacy of PBN-16 over NB-21 hybrid napier particularly for the milch cattle.

Table 4. Nutritive parameters of forage grasses.

Forage grass	NDF	ADF	Hemicellulose	Cellulose	CP
	Nutritive parameters (% on DM basis)				
Guinea					
Leaf	42.86	26.51	16.35	20.18	7.85
Stem	50.37	28.40	21.97	26.85	8.75
Total	46.62	27.45	19.16	23.52	8.30
Setaria					
Leaf	57.6	38.95	18.65	27.75	7.25
Stem	62.48	40.16	22.32	35.35	4.75
Total	60.04	39.55	20.48	31.55	6.00
PBN-16					
Leaf	44.90	20.81	24.09	30.66	10.50
Stem	77.75	58.90	18.85	37.93	6.75
Total	61.32	39.85	21.47	34.29	8.63
NB-21					
Leaf	44.00	20.60	23.40	23.10	8.75
Stem	70.45	58.70	11.75	30.39	5.25
Total	57.22	39.65	17.57	26.74	7.00

6. Intercropping of forage legumes in coconut

A separate trial was laid out on intercropping of forage legumes in coconut with inclusion of two species of *Stylosanthes*, viz. *Stylosanthes scabra* and *Stylosanthes hamata*, and a perennial legume forage creeper *Centrosema pubiscens* were compared with local cowpea for fodder (Manjunath and Sundaram, 2001).

The mean data on growth and yield contributing characters of different forage legumes as inter crops in coconut is given in Table 5. Highest plant height (68.1 cm) was recorded in *Stylosanthes scabra* owing to its erect growing habit while *Centrosema* had the least height (14 cm)

Table 5. Growth and yield attributing characters of forage legumes as inter crops in coconut (mean of three years).

Forage legume	Plant height (cm)	No. of leaves /plant	No. of branches Primary	Secondary	Max. Vine length(cm)	Leaf: Stem
Stylosanthes scabra	68.1	297.6	7.1	29.7	082.3	0.93
Stylosanthes hamata	46.8	275.4	6.3	40.0	060.6	1.34
Centrosema	14.0	210.1	6.9	32.9	167.2	1.84
Fodder cowpea	5.0	17.5	2.3	01.3	120.9	0.70

due to its creeping nature. The number of trifoliate leaves were also higher in *Stylosanthes scabra* (298 / plant). Fodder cowpea although had a lower leaf number (18 / plant) had a good leaf canopy coverage. All the perennial forage legumes had significantly higher branches per plant as compared to fodder cowpea. However, the vine length was higher in *Centrosema* (167.2 cm). The forage succulency and palatability as reflected in terms of leaf to stem ratio was also higher in *Centrosema* (1.84:1) suggesting its superiority over others.

The mean legume forage yield recorded in different harvests for three years is presented in Table 6. Practically three harvests can be taken in a year in all the crops. While the rate of growth is faster in monsoon, the growth was found to be slow during winter. Although the forage yield in the first harvest was statistically non-significant, *Centrosema* recorded relatively higher forage yield (5.75 t / ha). Further, the forage yield of *Centrosema* was significantly superior to other forage crops both in second and third harvests (8.70 and 7.53 t / ha in coconut garden, respectively). The mean total forage yield recorded for three years clearly indicated that *Centrosema* yielded almost double (21.98 t/ha/ year) over other forage legumes tried in the experiment mainly due to its creeping nature covering the complete soil surface, rooting at each inter node, ability to withstand partial shade with production of huge biomass.

Table 6. Legume forage yield (t/ha of coconut garden) during different harvests in a year.

Forage legume	I Harvest	II Harvest	III Harvest	Total for the year
Stylosanthes scabra	3.92	4.99	2.96	11.98
Stylosanthes hamata	3.38	5.97	2.19	11.54
Centrosema pubiscens	5.75	8.70	7.53	21.98
Fodder cowpea	5.35	3.05	2.43	10.83
C.D (P=0.05)	NS	2.36	2.72	2.57

***Centrosema pubiscens*, a perennial legume for quality improvement in forages**

Among the four legumes tested for their nutritive value, the fodder cowpea recorded maximum Crude Protein (18.75 %) as compared to either *Stylosanthes scabra* (12.7 %) or *Stylosanthes hamata* (13.6 %). Although *Centrosema* had a lower Crude Protein (10.1 %), the per hectare Crude Protein yield (CP x forage yield / ha) was more (2.21 t) as compared to fodder cowpea (2.03 t) owing to higher forage yield (21.98 t/ ha) of the former. The Cellulose content which is another important nutritive parameter for the ruminants followed a similar trend as that of Crude Protein, with fodder cowpea recording higher Cellulose content (28.4%) followed closely by *Stylosanthes scabra* (26.5 %) and *Stylosanthes hamata* (25 .0 %) and the least in *Centrosema* (20.4 %) (Table 7).

Table 7. Nutrient content of forage legumes (% on DM basis).

Forage legume	Moisture	NDF	ADF	H.Cellulose	Cellulose	CP
Stylosannthes scabra						
Leaf	81.2	35.5	19.0	16.5	25.8	15.15
Stem	76.5	57.8	43.0	14.8	27.3	10.25
Total	78.8	46.6	31.0	15.6	26.5	12.70
Stylosanthes hamata						
Leaf	80.3	30.2	20.0	10.2	24.2	14.87
Stem	74.1	53.0	38.4	14.6	25.8	12.25
Total	77.2	41.6	29.2	12.4	25.0	13.56
Centrosema pubiscens						
Leaf	76.0	38.8	18.4	20.4	21.4	10.50
Stem	68.6	61.5	39.0	22.5	19.4	9.62
Total	72.3	50.2	28.7	21.5	20.4	10.06
Fodder cowpea						
Leaf	82.3	17.8	9.4	8.4	19.0	--
Stem	78.5	77.7	58.9	18.8	37.9	–
Total	80.4	47.7	34.1	13.6	28.4	18.75

Effect of forage legumes on soil fertility

The effect of growing of these forage legumes on soil fertility is given in Table 8. It was observed that inter cropping of forage legumes did not affect the soil reaction much except for fodder cowpea cultivation which marginally decreased the soil reaction (5.42 to 5.88 pH). However, there was an increase in the soil organic carbon build up with all the forage legumes which may be due to increased root activity and biomass addition on intercropping legumes that might have favoured carbon mineralisation through increased population of soil micro organisms.

There was an improvement in number of bearing coconut palms after intercropping forage legumes. The positive impact on coconut production was visible from third year onwards due to the long gestation period from

Table 8. Soil fertility parameters as influenced by intercropping of legume forages.

Treatments	Soil reaction(pH)	Organic carbon (%)	Organic matter (%)
Before intercropping			
forage legumes	5.88	0..99	1.71
After intercropping			
Stylosanthes scabra	6.06	1.36	2.34
Stylosanthes hamata	5.85	1.50	2.59
Centrosema pubiscens	5.84	1.38	2.38
Fodder cowpea	5.42	1.35	2.33

flower primordia initiation to nut harvest in coconut. The yields were also stabilised later with continuous cropping of legume forages which may be due to the increased build up of soil fertility (Table 9).

Thus, the study clearly indicated the superiority of multi-cut forage legume *Centrosema* for intercropping in coconut owing to its better vine growth, rooting pattern, leaf : stem ratio, forage yield and positive impact on soil fertility building and coconut yield.

Table 9. Effect of intercropping of legume forages on coconut.

Year	No. of coconut palms in bearing	Total no. of nuts collected / year	Nut yield / palm/year
1995-96	6	167	28
1996-97	7	105	15
1997-98	11	99	9
1998-99	12	345	29
1999-2000	11	222	20

III. HIGH DENSITY CROPPING SYSTEM IN COCONUT

For better utilization of solar energy and soil resources, a high intensity cropping system with a new dimension in crop production -air space need to be utilized. In this, crops having different stature and rooting pattern need to be selected to form compatible combinations.

The feasibility and success of these crops architecture depends on the top floor crop. The crown habit of coconut is ideally suited for this. The pepper vine having its canopy 2-8 m on the coconut trunk can be the second floor crop while banana with 7-8 feet height forms the third strata. The ground canopy could be occupied with shade tolerant crops like pine apple.

1. High density cropping system

A new block of coconut based high density cropping system model was established during the year 2000-01 at ICAR Research Complex for Goa, Old Goa (Singh *et al.*, 2002). The model included pineapple (variety Giant Kew), banana (Tissue cultured - Grand Nain Williams) in the interspaces of coconut. *Glyricidia* was planted as a bund crop cum windbreak.

a) Yield of coconut in the system

With intercropping, the yield of coconut was 86 nuts/palm/year while in monocrop it was 51nuts/palm/year by the year 2002. The average yield recorded in coconut over three years i.e. from 1999-2001 showed that there was increase in the nut yield in both the systems. However, the increase in nut yield in monocrop was from 21 to 51 nuts/year/palm, while in the intercrop, the nut yield increased from 42 to 86 nuts/palm/year, thus showing a clear impact of intercropping in increasing the productivity of coconut.

Table 10. Coconut yield under mono crop and coconut based cropping system.

Year	Nut yield in mono crop (15 palms)			Nut yield in cropping system (40 palms)		
	Mean yielding palms	Number of nuts harvested	Nuts/ palm/ year	Mean yielding palms	Number of nuts harvested	Nuts/ palm/ year
1999	4.3	91	21.0	12.3	513	41.6
2000	7.0	242	34.6	16.3	892	54.9
2001	4.7	195	41.8	21.0	1122	53.4
2002	8.7	446	51.4	31.3	2688	85.8
Total		974			5215	

b) Yield of banana in the system

Tissue cultured banana (Variety Grand Nain Williams), yielded 75 bunches weighing 1433 kg from the system (0.2 ha) in first year. Average bunch weight was 21 kg/bunch. The total production of banana from the system was 14,470 kg/ha of coconut garden.

From the first ratoon crop, about 65 bunches were harvested weighing about 616.7 kg. The average bunch weight was found to be 14.7 kg/bunch. The total number of hands harvested were 316, while the total number of fingers were 4724. The average number of hands/ bunch was 7.5, while the average number of fingers/ bunch was 112.

A total of 135 bunches were harvested from an area of 0.2 ha. Total weight of bunches obtained was 2359.9 kg and the average bunch weight of tissue culture banana obtained in the system was 17 kg/ bunch. Total number of hands harvested was 1019, while the total number of fingers was 13962. The average number of hands/bunch worked out to be 7.55 and the average number of fingers/bunch was 103.4.

High density cropping systems in coconut - a view

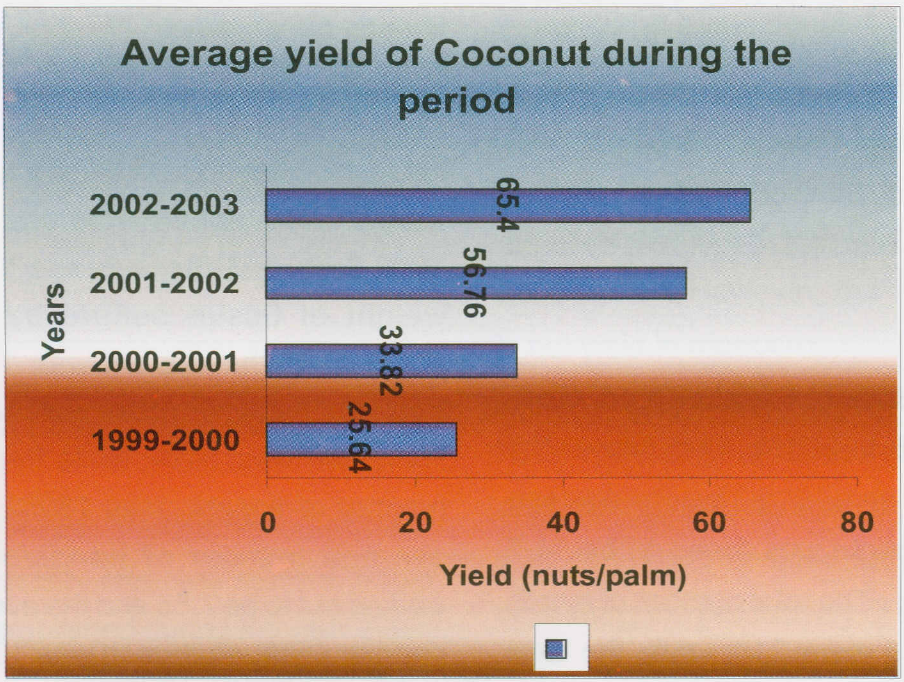


Table 11. Yield and yield attributes of banana as an intercrop in coconut during different periods.

Months	No of bunches	No of hands	Mean no. of hands /bunch	No of fingers	Mean no. of fingers bunch	Total weight (kg)	Avg. wt. /bunch (kg)
October-2001	3	27	9.0	339	113.0	96.1	32.0
November	12	95	7.9	1359	113.2	338.9	28.2
December	22	170	7.7	2300	104.5	401.1	18.2
January-2002	11	95	8.6	1294	117.6	176.5	16.0
February	12	79	6.5	1121	93.0	171.7	14.3
March	15	108	7.2	1381	92.1	249.0	16.6
April	02	16	8.0	152	76.0	40.5	20.2
May	05	39	7.8	591	118.2	83.8	16.8
July	02	24	12.0	397	198.5	62.7	31.3
September	01	07	7.0	87	87.0	14.4	14.4
October	12	97	8.1	1366	113.8	224.3	18.7
December	01	07	7.0	105	105.0	12.0	12.0
January-2003	03	19	6.3	255	85.0	37.5	12.5
February	11	68	6.2	970	88.2	129.1	11.7
March	08	62	7.6	873	109.1	116.1	14.5
April	05	34	6.8	487	97.4	62.2	12.4
May	06	45	7.5	616	102.7	90.4	15.1
June	02	09	4.5	101	50.5	19.1	9.6
July	02	18	9.0	169	84.5	32.7	16.4
Total	135	1019		13962		2359.9	
Mean	**7.1**	**53.6**	**7.6**	**734.8**	**102.6**	**124.2**	**17.4**

c) Yield of pineapple in the system

Pineapple planted in the month of June 2000 started fruiting from April 2001. A total yield of 1044.5 kg was obtained during the year from an area of 0.2 ha. Average fruit weight was 1.73 kg. Average length of the fruit was 19.9 cm and girth was 16.6 cm. Crown length recorded was 37.8 cm. The T.S.S of the fruit ranged from 11 to 19 per cent in different periods. A total of 1063 suckers yielded about 1044 kg fruits from the system.

From the period April 2002 to July 2003, two ratoon crops of pine apple were taken. In the first ratoon, 16 harvests were made wherein the total number of fruits harvested was 359 weighing 425.3 kg. In the second ratoon 10 harvests were taken wherein 108 fruits weighing a total of 115.5 kg were obtained. The average fruit weight was found to be 1.1 kg. Average length of fruit was 17.4 cm while the width was 36 cm and the crown height was 14.3 cm. The average TSS was 19 per cent.

Table 12. Yield of pineapple harvested from the coconut based cropping system during the period.

Month	Number of harvests	Number of fruits	Weight (kg)
April - 2001	4	34	73.0
May	8	303	459
June	4	388	479
July	1	1	2.5
November	2	9	10.7
February - 2002	2	11	19.2
April	4	41	59.5
May	7	113	133.5
June	4	199	226.5
February - 2003	1	6	5.75
March	4	54	44.5
April	1	5	6.0
May	4	33	47.5
June	1	16	17.5
Total	**42**	**1213**	**1584.1**

d) Biomass generation in *Glyricidia*

Glyricidia planted on the bunds acted as wind break and also used as green manure in the system. In the year 2000-2001, 100 kg of green manure was obtained, while in the year 2002-2003, 500 kg was harvested.

e) Biomass from the system

As regards biomass, in the year 2000-01, 297.5 kg (1525 kg/ha) of banana stems were obtained from the system which was used for the preparation of compost. Coconut leaf wastes collected from the bio-system was 969.9 kg (4850 kg/ha) from an area of 3000 m^2 (with 60 palms) in the system. Other wastes recorded i.e. weeds, spathes and crown of pineapple worked out to be 662 kg from the system including banana waste. Most of the wastes were used for the preparation of compost for recycling in the system. The composting resulted in 3.0 t of compost.

In the year 2002-03, 868 kg (4340 kg/ha) of coconut leaflets, 339.6 kg (1698 kg/ha) of petioles and 511.0 kg (2555 kg/ha) of banana stems, grasses, pineapple wastes were obtained from the system, which was utilized in the preparation of compost. The compost recorded was 3.8 tonnes.

f) Effect on soil fertility

Soil samples from coconut based high density cropping system block were collected and analyzed for nutrient content.

The pH of soil was found acidic. The average pH ranged from 4.46 to 5.82 in the block. The pH was the lowest in interspaces of crops planted. EC of soil ranged from 0.074 to 0.1248 ds/cm. Organic carbon (OC) was high around crop basins, while in the interspaces it was found medium (0.63 per cent). The OC percent ranged from 0.63 to 1.55 per cent. In general phosphorus and potassium contents were high around crop basins and in the interspaces.

g) Economic analysis of the system

In the year 2001-02, the gross income obtained from the system was Rs.1,25,285/ha with a net return of Rs.73, 545/ha. The Cost : Benefit ratio of the system was 1:1.4 as compared to 1:0.22 in the mono cropping system.

In the year 2002-03, the gross income obtained from the system was Rs. 2,00,748/ha while the net return was 1,55,365/ha. The Benefit : Cost ratio (BCR) of the system was 1:3.42, as compared to 1:0.22 in the monocropping system.

The average net profit obtained from the individual crops were; coconut-Rs.34,796, pineapple-Rs.11,238, banana-Rs.59,471 and *Glyricidia*-Rs.2,250. This indicates that banana is the most profitable intercrop in coconut followed by pineapple.

Table 13. Average nutrient content of soil around crop basins and interspaces in coconut based high density cropping system.

	Banana basin	Coconut basin	Pineapple basin	Inter-spaces	Overall nutrient status
pH	5.82	5.81	5.70	4.50	5.50
EC(ds/cm)	0.08	0.10	0.10	0.10	0.10
O.C(%)	1.08	1.55	0.90	0.60	1.05
P(kg/ha)	90.0	99.5	94.6	55.5	84.9
K(kg/ha)	412.0	685.2	451.2	327.6	469.0

Table 14. Economic analysis of coconut based high density cropping system.

Sl.No	Crop	Labour		Fertilizer		Irrigation		Total cost/ha (Rs)
		No/ha	Cost/ha (Rs)	Quantity (kg/ha)	Cost/ha (Rs)	Hrs	Rs	
1.	Coconut	15	7400	89:89:214 (NPK)	4752	60 hrs	1800	13952
2	Pineapple	10	1000	1.2:1.7:0.5 (NPK 1 trench x60 trenches)	1.2x60x5=360 1.7x60x4.4=448.8 0.5x60x4.6=138 946x5=4730	40 hrs	1000	7676
3	Banana	15	1500	200:100:300g (NPK/plant) Furadon Neem cake Blitox 500g Streptocycline	0.45x130x5=292.5 0.62x130x4.4=357.5 0495x130x4.6=296 946x5=4730 Rs.80 2x5.5x130=1430 Rs.105, Rs.350	40 hrs	1000	22255
4	Black pepper	10	1000	-	-			1000
5	Glyricidia	5	500	-	-	-	-	500
	Total							45383

OUTPUT

	Yield in exp.plot (kg)	Yield/ha (kg)	Produce x rate	Gross return (Rs)/exp. Plot (0.2ha)	Gross Income/ha (Rs)
Coconut	3134	15670 nuts	3134x7	21938	109690
Pineapple	540	2700	540x8	4320	21600
Banana	2360	11800	2360x8	18880	94400
Black pepper	-	-	-	-	-
Glyricidia	500	2500	500x2	1000	5000
Wastes Banana leaf & stem Coconut leaves, Coconut petiole	 511 868 340	8593	1719x1	1719	8595
Total				**47857**	**2,39,285**

Net Return = Rs. 2,00,748 - Rs. 45,383 = Rs. 1,55,365
C:B ratio = 1:3.42

2. Prospects of mixed cropping spices with coconut

Among the important spice crops suitable for the region, black pepper, clove and nut meg are important.

a) Black pepper

Black pepper, "King of Spices" is mostly cultivated in arecanut or coconut gardens as mixed crop in Goa state, besides the vines sometimes trailed on either mango or jack fruit trees in homestead situations. Major commercial plantations are comprising of local strains, selected and perpetuated from the wild populations by the ancestral generations. The stretches of Western Ghats in Sanguem, Sattari, and Canacona taluks of Goa are the home for wild natural population of black pepper, including the related species too. The natural population has lot of variation with respect to morphological characters of vines, berry yield and yield components, and biotic and abiotic stress.

At present black pepper is cultivated in about 480 hectares with yield estimated at 100 tonnes annually (Anonymous, 2001). Although improved varieties namely Paniyur-1 and Karimunda have been introduced in the State, majority gardens comprise of desirable local strains domesticated since long time. This genetic stock offers vast scope for selection of promising clones with combined tolerance / resistance to biotic and/or abiotic stress. Thus, these plus vines along with the improved varieties already introduced in the state, will add new dimensions to the black pepper cultivation in Goa. Further, there is also need to characterize the local promising strains with respect to qualitative characters like volatile oil, oleoresins, piperine and starch contents. Multiple varieties including the local selections will offer better choice of varieties for specific locations and thereby mitigate the danger of biotic and abiotic threats. This will help in reducing the farmers' risk of losing the crop due to afore mentioned factors.

Still vast area can be brought under this crop in the State, since all the arecanut and coconut gardens do not have black pepper as mixed crop. Instances are also there, where black pepper is planted with fast growing timber species–*Acacia mangium* in Sanguem taluka. On the similar line, silver oak (*G. robusta*) can also be tried in high ranges as standard which will serve the dual purpose. This kind of silvi-horticulture approach will form the alternative land-use systems for hilly areas.

Non-availability of healthy genuine planting material on time is the immediate bottleneck to be addressed for achieving area expansion and boosting the production in the state. Therefore, timely availability of the planting material has to be ensured by creating adequate infrastructures for this purpose.

Piper *longum*: There is also need to create awareness about potential of cultivating long pepper which also has great demand.

Coconut based spice gardens are invariably the land use pattern in foot hill areas or valleys in Goa. Multiple tree spices like nutmeg (*Myristica fragrans*), clove (*Syzygium aromaticum*), cinnamon (*Cinnamomum zylanicum*), all spice (*Pimenta dioica*), Perennial chillies, etc, are the common components included in densely populated palms, besides black pepper trailed on palms. Generally such gardens are organically maintained with characteristic poor yielding features.

Table 15 : Some characteristic features of locally cultivated black pepper strains in Goa as compared with improved varieties.

S.No.	Traits	Local strains	Paniyur-1	Karimunda
1	Green pepper yield (Kg/vine)	1.8 -3.0	3.8	2.0
2	Spike length (cm)	6.5 -12.4 cm	15.8	10.6
3	Number of berries/spike	76 - 88	108	64
4	Dry berry recovery	34 -35.2	34.2	34.0
5	Leaf shape	Ovate, cordate	Cordate	Ovate
6	Reaction to biotic and abiotic stress	To be studied	Susceptible to pests & diseases	Drought & shade tolerant,

However, optimal levels of production can be achieved only when the components are arranged in spatial and temporal sequence in a production system (Korikanthimath and Desai, 2003).

3. Prospects of mix cropping of vanilla with coconut

Vanilla is obtained primarily from the fully grown but unripe fruits or "beans" of a climbing orchid *Vanilla planifolia* Andrews (*V. fragrans* (Salisb.) that have been subjected to fermentation-curing process to produce the characteristic aroma. It is indigenous to wet low land forests in South-Eastern Mexico, Guatemala and other parts of Central America. The substance chiefly responsible for the unique fragrance and flavour of the vanilla bean is vanillin ($C_8 H_8 O_3$). Among the food flavours, vanilla has a prime position. Vanilla essence is largely used in the preparation of ice creams, chocolates, bakery products, puddings, pharmaceuticals, liquors and perfumes. Vanilla is the second most expensive spice traded on the world market next only to saffron.

The vanilla flavour industry was based on the processed beans of the vanilla plants. With the advent of chemical technology to produce vanillin/ ethyl vanillin, the synthetic substitutes have taken over the use of vanilla beans. However, vanilla bean is still the most preferred food flavour spice.

Vanilla (*Vanilla planifolia* Andrews), a tropical orchid, has gained importance as a source for natural vanillin responsible for its fragrance and flavour. Vanilla beans are the export commodity of high value. The keen interest evinced by the major consumers like the USA, France, Germany and Japan for Indian vanilla beans of higher quality is the key factor for area expansion under vanilla cultivation in India. Studies on the economics of vanilla cultivation in India have indicated high rate of returns to the extent of Rs.26,49,700 from one hectare in a progrmme of 20 years period.

Agro-climatic conditions of Goa are suitable for commercial cultivation of vanilla, the second most expensive spice in the world. This crop can be conveniently introduced into the State for incorporating in arecanut or coconut gardens. Very high value of this spice will not only enhance the profits per unit area in coconut gardens but also help to sustain the arecanut plantations based infrastructure, which otherwise have turned out to be uneconomical. A few innovative farmers have ventured out for the cultivation of this spice as inter-crop/mixed crop in coconut and arecanut based farming systems and are harnessing the benefits, as there is well defined systematic marketing network already existing in the neighbouring States. Financial feasibility studies of such systems reported else where have indicated the viability of mixed cropping of vanilla in coconut garden in lower elevation and low rainfall area under irrigation. In view of this, there is also need to develop facilities to ensure the timely availability of good planting material along with scientific, location specific technical know-how.

Vanilla can be successfully cultivated as an inter-crop in the coconut gardens. In the coconut gardens, in between two rows of coconuts, two rows of standards/ support plants/cuttings like *Glyricidia* are introduced at 6' x 6' spacing. On to these standards the vanilla is planted, this way the damage due to frond and nut fall in coconut gardens are avoided. The standards provide the additional shade required in the coconut gardens for vanilla.

Economic analysis

It is estimated that about 3,500 ha of area will come under full bearing by 2009-10 under the AEZ. They will yield on an average about 300 kg/ ha of processed beans. At the prevailing international market price of US$ 200/ kg, the produce will fetch foreign exchange of Rs. 705 crores or US$ 150 million annually. The total production during the project period of 10 years will be 5,013 MT valued at US$ 1,003 million or Rs. 4,712 crores. However, to work out realistic returns, average International price for the past 10 years has been taken excluding the historic high and low prices. This comes to US$ 47/ kg and assuming an exchange rate of Rs. 47/ US$, the projected export earnings for the project period will be US$ 236 million or Rs. 1,107 crores (Sudarshan, 2003).

IV. FARMING SYSTEM APPROACH IN COCONUT

Coconut, a crop of small and marginal farmers provides livelihood for millions. The income derived from small holdings is not sufficient to sustain even the small families. In addition, coconut as a monocrop provides employment only for about 150 mandays /ha/year under rainfed conditions and consequently the family labour remains unemployed for larger parts of the year. Further, small holding size, presence of large senile palms, over crowding, low productivity, labour scarcity and high cost of labour, lack of irrigation are resulting in high cost of production in coconut (Sai Ram *et al.*,1997).

Coconut based farming systems involving cultivation of compatible crops in the inter-spaces of coconut and integration with allied enterprises like dairying, offer considerable scope for increasing production and productivity per unit area, time and input by efficient utilisation of resources like sunlight, soil, water and labour (Srinivasa Reddy and Biddappa, 2000).

1. Intercropping forage grass-legume mixtures

Grass-legume mixtures are always desirable because of their complementary functions in providing nutritive, succulent, palatable forage for the animals. Together, they are capable of producing greater quantities of digestible dry matter and protein throughout the growing season than either of the components. Legumes usually maintain their quality better than grasses even at maturity and being rich in protein enhance the forage value and also add substantially the much needed nitrogen to the soil. The mixture also improves the physical condition of the soil, checks soil erosion, resists the proliferation of weeds and withstands the vagaries of weather better than pure stand.

Field investigations were carried out to identify a suitable forage grass with legume combination for intercropping in coconut (Manjunath et al., 2002b). Six hybrid napier forage grasses with NB-21 as control in 1:1

ratio of intercropping with *Centrosema pubiscens*, a perinial forage legume were evaluated in a Randomized Block Design. The crops were planted in the interspaces of coconut leaving a basin of 1.8 m radius from coconut. Recommended package of practices were followed both for grass and legume combinations and for coconut. Further, dairy integration with the forage produced from coconut garden and recycling of wastes from coconut and dairy for betterment of soil were studied.

The green grass harvested along with perennial legume forage *Centrosema pubiscens* grown in between the lines of forage grasses in different harvests during a year is given in Table 16. The mean total forage mixture yield for the year differed significantly among the treatments. Hybrid napier PBN-16 + *Centrosema* combination gave significantly superior mixture yield (82.57 t/ha) and was followed by DHN-3 + *Centrosema* combination (75.22 t/ha). These two combinations recorded 27.4 and 16.0 per cent increase in yield over control NB-21 + *Centrosema* (64.82 t/ha). The better performance of these two hybrid napiers could be attributed to their increased tillering (52.6 and 52.1 per cent respectively, higher over NB-21), higher leaf width, reduced inter-nodal

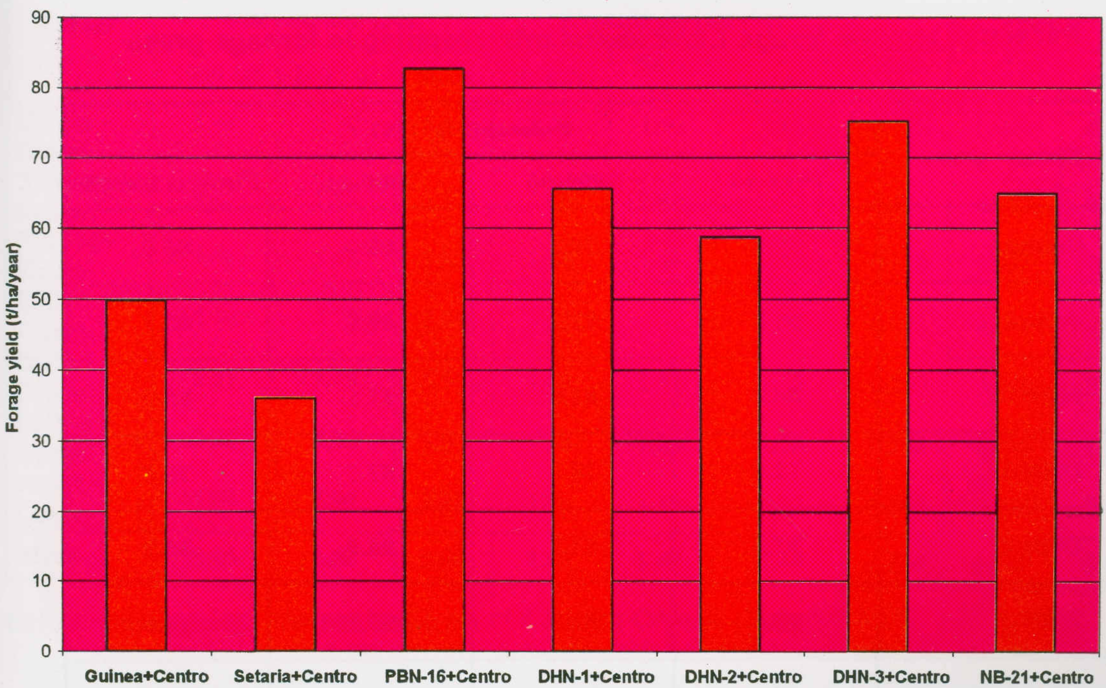
Table 16. Combined green grass and legume mixture yield (t/ha) of different forage grasses as inter crops in coconut during different harvests in a year.

Intercropped forage	Green grass and legume mixture yield (t/ha)				
	I Harvest	II Harvest	III Harvest	IV Harvest	Total yield
Guinea + Centro	10.88	8.31	10.47	20.07	49.73
Setaria + Centro	6.54	8.20	9.30	11.88	35.92
PBN-16 + Centro	27.19	16.85	15.74	22.79	82.57
DHN-1 + Centro	18.51	12.99	9.40	24.61	65.51
DHN-2 + Centro	12.18	12.49	14.53	19.55	58.75
DHN-3 + Centro	22.93	16.29	13.15	22.85	75.22
NB-21 + Centro (Control)	14.42	12.93	13.73	23.74	64.82
C.D. (P = 0.05)	**6.80**	**3.11**	**2.54**	**-**	**11.92**

length, better leaf to stem ratio and higher dry matter content as compared to NB-21.

In general, the yield levels of the legume were low due to higher shade prevailed under grass cover. The PAR received on legume canopy varied from 5.5 to 34.6 per cent of the open light conditions depending on intercropped forage grass, its stage of growth and period of the year. Although, the PAR received on grass canopy ranged from 31.9 to 66.3 per cent, the transmission of PAR reaching ground canopy was less due to the shading by dense foliage of forage grasses. The obstruction to the light transmission was observed more with fast growing hybrid napiers than slow growing ones which also further varied with the season.

The palatability studies with different grass + legume mixtures indicated that the mixture of DHN-3 + *Centrosema* was more palatable by the cows (87.4%) with least wastage and this was followed by Guinea + *Centrosema* mixture (85.1%) while the hybrid napier DHN-1 with *Centrosema* recorded lowest palatability (75.2%).



Performance of forage grass combinations with legume as intercrop in coconut.

Perennial legume forage *Centrosema* intercropping in foreage grass

Forage grass	Palatability (%)			
	1998-99	1999-00	2000-01	Pooled mean
Guinea	90.9	79.2	88.0	86.0
Setaria	86.8	82.2	88.0	85.7
PBN-16	86.8	81.0	87.1	85.0
DHN-1	72.0	78.4	87.7	79.4
DHN-2	85.4	84.3	88.8	86.2
DHN-3	92.8	82.0	85.1	86.6
NB-21 (Control)	86.4	81.4	83.3	83.7

Effect of forage intercropping on soil

Although the effect of forage crops intercropping on soil pH and EC was not significant, there appeared to be continuous build up of soil organic matter compared to initial level with intercropping. The increase in the organic matter content of soil may be due to the higher root biomass of intercropped forages decayed in the soil along with the shed leaves of both grass and legume and addition of recycled compost. The increased recyclable biomass in soil environment might have stimulated higher soil microbial biomass which ultimately resulted in increased organic carbon content (Table 18).

Table 18. Soil fertility changes after intercropping of forage grass varieties / hybrids with *Centrosema.*

Forage	Soil fertility parameters								
	Soil reaction (pH)			Organic carbon (%)			E. C. (dsm^{-1})		
	1999-00	2000-01	Mean	1999-00	2000-01	Mean	1999-00	2000-01	Mean
Guinea + Centro	5.48	5.70	5.59	1.20	1.59	1.40	0.120	0.049	0.085
Setaria + Centro	5.25	5.89	5.57	1.26	1.47	1.37	0.130	0.051	0.091
PBN-16+ Centro	5.48	5.83	5.65	1.56	1.41	1.49	0.110	0.052	0.081
DHN-1 + Centro	5.59	5.78	5.69	1.32	1.32	1.32	0.096	0.054	0.075
DHN-2 + Centro	5.31	5.78	5.55	1.68	1.41	1.55	0.230	0.048	0.139
DHN-3 + Centro	5.40	5.80	5.60	1.50	1.50	1.50	0.200	0.040	0.120
NB-21 + Centro	5.64	5.98	5.81	1.26	1.59	1.43	0.068	0.049	0.059
Mean	**5.45**	**5.82**	**5.64**	**1.40**	**1.47**	**1.44**	**0.136**	**0.049**	**0.093**

Before intercropping, the soil had a pH of 5.88 and Organic Carbon-0.99 %

Further, it was observed that continuous raising of forage grass and legume combinations with the recommended fertilizer application have not reduced the initial soil N or P_2O_5 and in fact raised the native levels of these nutrients after two years of continuous cropping. However, there was a general decline in the potassium level of the soil after intercropping even after recommended fertilizer application suggesting the need to enhance the recommended K levels. This was also evident from the deficiency of potassium noticed in most of the grasses after two years of continuous cropping.

Table 19. Soil fertility changes after intercropping of forage grass varieties / hybrids with *Centrosema*.

Forage	Soil fertility parameters								
	Available N (kg/ha)			Available P_2O_5 (kg/ha)			Available K_2O (kg/ha)		
	1999-00	2000-01	Mean	1999-00	2000-01	Mean	1999-00	2000-01	Mean
Guinea + Centro	388	514	451	98.2	69.0	83.5	270	132	201
Setaria + Centro	408	476	442	79.0	63.4	71.2	232	300	266
PBN-16+ Centro	504	456	480	82.2	73.4	77.8	284	138	211
DHN-1 + Centro	428	428	428	81.0	72.3	76.7	260	178	219
DHN-2 + Centro	544	456	500	27.4	95.4	61.4	306	132	219
DHN-3 + Centro	486	486	486	53.4	86.5	70.0	350	284	317
NB-21 + Centro	408	514	461	55.4	54.8	55.1	200	180	190
Mean	**452**	**476**	**464**	**68.1**	**96.2**	**82.1**	**271.7**	**192**	**232**

2. Integration of dairy enterprise

Inclusion of dairy in crop plans increases the farm income and labour employment in both irrigated and un-irrigated small farms. On un-irrigated small farms, dairy enterprise plays a vital role in augmenting the farm returns and labour employment. Hence, there is considerable scope for diversification by including dairy enterprise thereby increasing the farm returns (Devadoss *et al.,* 1985).

An estimate shows that there is a deficiency of animal feed to an extent of 16 per cent of straw, 64 per cent green fodder and 80 per cent of concentrates and further, cost of feed constitutes 60-65 per cent of total cost of milk production. Feeding green forage to dairy animals is much cheaper than feeding concentrates with crop residue. Therefore, success of dairy depends on continuous supply of green fodder round the year (Ramamurthy, 1999).

Performance of integrated dairy as measured in terms of day to day milk production and dung production by feeding with different grasses and *Centrosema* is presented in Table 20.

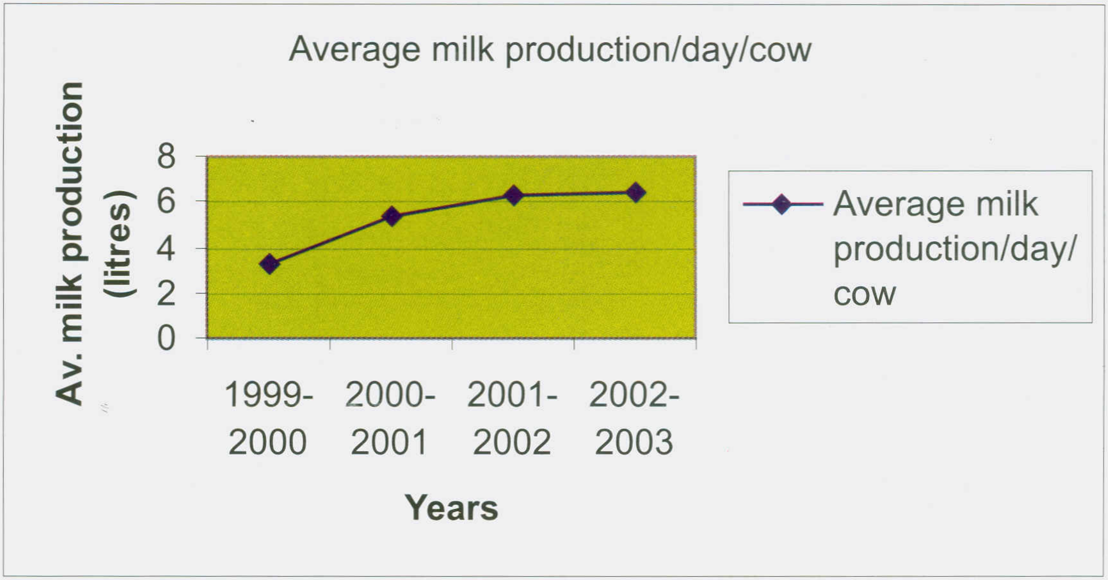
Integration of dairy with coconut intercropped with forage crops is a profitable and sustainable system

Table 20. Milk (l/cow/day) and dung (kg/cow/day) production as affected by feeding of different forage grasses with *Centrosema*.

Forage grass	Milk production (l/cow/day)				Dung production ((kg/cow/day)			
	98-99	99-00	2000-01	Pooled mean	98-99	99-00	2000-01	Pooled Mean
Guinea	4.91	4.32	5.13	4.79	13.18	15.30	13.40	13.96
Setaria	3.83	4.37	4.60	4.27	12.13	16.10	13.90	14.04
PBN-16	7.53	3.82	5.03	5.46	12.18	13.70	14.40	13.43
DHN-1	8.56	3.68	4.78	5.80	11.26	13.00	13.70	12.65
DHN-2	9.04	3.97	5.29	6.10	12.57	14.30	12.70	13.19
DHN-3	8.12	4.08	5.04	5.75	12.67	16.00	12.80	13.82
NB-21	8.67	4.12	4.95	5.91	11.15	15.50	12.30	12.98

The integrated dairy unit with two milch cows (Jersy x Sindhi) maintained in the experiment yielded on an average 4.5 litres of milk/cow/day. The forage grasses with the legume formed the major feed for the cattle. A constant milk yield was obtained from the dairy throughout the year as the cows were fed regularly with green grass from the intercropped coconut plot. The daily nutrient requirement of these lactating cows was worked out in terms of dry matter (DM), digestible crude protein (DCP), metabolisable energy (ME) and total digestible nutrients (TDN) based on their body weight, requirement for their maintenance and production of milk and accordingly a ration of 25 kg green grass/cow/day was adopted, in addition to the concentrates. As the average green grass production was around 72 t/ha/year, the land to cow ratio thus worked out to be 0.25 ha for two cows under protective irrigated conditions when high yielding forage grasses like PBN-16 and DHN-3 are grown as inter-crops in coconut.

The mean yield of milk from cows was not much affected by the feeding of different forage varieties with *Centrosema*.



Graph showing milk production during the study period

However, Guinea+ *Centrosema* forage relatively yielded more milk (4.73 litres/cow/day) and was followed by DHN-2 + *Centrosema* combination (4.63 litres / cow/day). This may be due to the higher palatability of the forage mixtures with better nutritive value and dry matter digestibility.

3. Quantification and periodicity of coconut waste production

Coconut being a perennial crop produces large quantities of usufructs/wastes/by-products which can be recycled to the field, thereby substituting a part of crop nutrient demand. There is ample scope to conserve the available by-products for sustaining the production in coconut. These wastes/surplus residues can be recycled back to the soil by various methods such as mulching, *in situ* incorporation and composting, which leads to improvement in soil physico-chemical and biological properties, thereby, having a profound impact on yield of the crop. Further, under integrated farming systems, recycling of organic wastes *viz*. crop residue, animal dung, urine etc. leads to a substantial saving in the cost of fertilizer inputs, thereby increasing the cost-benefit ratio (Biddappa *et al*., 1996).

The recyclable manurial resources from coconut garden such as leaflets, spathes, weeds etc. were quantified periodically to assess their potential for recycling as manures to sustain the system. On an average about 2.55 tonnes of coconut wastes (1.8 t coconut leaflets + 0.75 t spathes, weeds etc.) on dry weight basis would be available for recycling from a hectare of coconut garden leaving the hardy coconut frond for fuel purpose (3.19 t/ha on dry weight basis) which accounted for more than 50 per cent of the total wastes produced (5.74 t/ha) (Table 21).

Further, it was noticed that major production (72.8%) of recyclable manurial resources from coconut was from September to January with November to December as peak period (38% of total). This may be due to the physiological stress that the plant undergoes with the withdrawal of monsoon rains and setting in of sudden deficiency of moisture. During May-June, a second peak of leaf waste production (13%) was observed coinciding with the peak summer, when the evapo-transpirative demand of the crop is higher which might have resulted in moisture stress and subsequent leaf fall. However, it was least during July with the onset of rainfall (Table 21).

Table 21. Quantification and periodicity of recyclable coconut waste production.

Months	Recyclable waste (kg on % dry matter basis)/ha		
	Leaflets	Leaf petiole	Spathes, weeds etc.
January	192	341	138
February	94	166	138
March	32	57	
April	76	135	
May	121	214	
June	121	214	
July	22	39	
August	23	41	
September	216	382	98
October	216	382	98
November	321	568	138
December	369	653	138
Total	**1803**	**3192**	**748**

Total waste production = 5.74 t/ha. Potential quantity for recycling: 2.55 t/ha.

4. Quantification of recyclable wastes from the integrated dairy enterprise

The quantity of recyclable wastes obtained from the integrated dairy enterprise, was 5.29 t of cow dung and litter waste on an average which resulted in about 2.35 t of FYM.

Table 22. Quantification of recyclable wastes from the integrated dairy under coconut based farming system.

	Recyclable wastes/cow		
	1998-99	1999-00	Mean
Cowdung (kg/day)	12.5	14.3	13.4
Litter waste (kg/day)	3.9	6.0	5.0
Total (kg/day)	16.4	20.3	18.4
Total waste (t/year)	5.99	7.41	6.70
FYM Production (t/year)	2.66	2.04	2.35

5. Recycling of nutrients through dairy integration

By systematic recycling of all usufructs produced by coconut, it is possible to plough back 20.7 kg N, 10.5 kg P_2O_5 and 30.8 kg K_2O per ha annually. This is because in general crop residues contain approximately 25 per cent N and P, 50 per cent sulphur and 75 per cent K of total absorbed nutrients by the plant (Jothimani, 1994). Considering the average nutrient content of FYM produced from the dairy as 0.5 : 0.4 : 0.5 per cent NPK, the potential for recycling of nutrients through dairy integration with forage production from a hectare of coconut garden was 11.8 kg N, 9.4 kg P_2O_5 and 11.8 kg K_2O.

Further, it was observed that by using 1260 kg coconut usufructs 1,035 kg cowdung and 488 kg weeds and other wastes, about 1,814 kg of good coconut compost was prepared. In a farming system situation of one ha coconut garden with two milch cows, it was observed that about 2.55 tonnes of coconut usufructs, 6.70 tonnes of cow dung and litter waste and about 1.40 tonnes of weeds and other wastes are at the disposal of farmer. Using these recyclable wastes, an estimated quantity of 5.62 t of coconut compost was produced on the farm.

Table 23. Recycling of nutrients * through coconut compost preparation from one ha of coconut garden.

Recycled manure	Quantity produced (t/ha)	Recycled nutrients (kg/ha)		
		N	P_2O_5	K_2O
FYM	2.35	11.8	9.4	11.8
Coconut compost	5.62	28.1	22.5	28.1
Additional	3.27	16.3	13.1	16.3

* Considering the average nutrient content of FYM as 0.5 : 0.4 : 0.5 % NPK

A view of compost preparation using coconut wastes.

However, when coconut wastes were recycled in the form of compost using the recyclable manurial resources from dairy, a total of 28.1 kg N, 22.5 kg P_2O_5 and 28.1 kg K_2O could be recycled back to the field. This accounted for an additional 16.3 kg N, 13.1 kg P_20_5 and 16.3 kg K_2O with the extra effort of coconut compost preparation. In addition, other beneficial effects of recycled compost such as increased growth of beneficial micro organisms, improved water holding capacity, better soil structure, improved aeration etc. could also be obtained.

Further, preparation of compost right on the farm reduces the dependency on externally purchased inputs and their transportation cost, which not only saves investment cost but also brings in stability to the returns in the long run.

6. Farming systems and the Rhizosphere microflora

The population of bacteria, fungi and actinomycetes were higher in the root zone of coconut due to mixed farming, as compared to coconut as monocrop at all the depths (Table 24). Similar pattern of enhanced microbial population was observed in the root zone of Napier grass at 0-25 cm depth as compared to coconut mono cropping. Lowest number of microbial population was recorded in the inter-spaces of coconut monocropping (Anonymous, 1991).

Table 24. Microflora in the root zone of coconut under mixed farming and mono cropping of coconut.

Crop	Soil depth (cm)	Bacteria x 10^6	Fungi x 10^3	Actinomycetes x 10^5
Coconut mixed farming	0-25	8.03	9.33	9.50
	25-50	3.23	8.55	2.89
	51-100	3.03	2.45	2.50
Napier grass	0-25	8.73	3.22	5.23
	25-50	1.87	2.33	2.45
	51-100	1.30	1.56	1.11
Coconut monocrop basin	0-25	2.27	2.27	3.67
	25-50	2.73	3.03	4.00
	51-100	1.43	1.07	1.67
Coconut monocrop inter-space	0-25	1.27	0.47	4.33
	25-50	0.67	0.77	2.33
	51-100	0.37	0.77	2.00

(Anonymous, 1991)

7. Nut yield in coconut

It is more profitable to integrate a number of subsidiary crops and animal components with coconut than to grow it as a mono crop (Das,1991). In the study on farming systems with coconut both the number of bearing palms and the nut yield per palm were less under monocropping compared to improved cropping system (Manjunath *et al*., 2002a). However, intercropping forage crops with coconut by following recommended package of practices for the crops improved both the percentage of nut bearing palms and the nut yield. The improvement in nut yield can be attributed to the better availability of soil moisture and nutrients applied separately both for the coconut and intercropped forages. The improved soil environment resulted in enhanced fruit set as was reflected both in terms of number of bearing palms and the palm yield.

Table 25. Intercropping of forage grasses in influencing coconut yield /ha.

Period/ Year	No of palms in bearing	Total nuts collected/ year	Nut yield /palm/year
Pre-experimental period (Mean of two years)	117	1569	13
Experimental period			
1999-2000	149	2389	16
2000-2001	171	4700	27

System approach enhances yield of coconut substantially

8. Employment potential of coconut based farming system

Integration of cropping with suitable enterprises like dairy, poultry, mushroom, etc., seems to be the best alternative not only to augment income of the farming community but also to bring improvement in employment and thereby increasing the overall profitability of the farm.

In India, agricultural diversification has been adopted as a income augmentation and employment generation strategy by Government of India during 1992 for the Eighth Plan. This is because, the diversification of farm enterprises is often suggested as the means for rapid economic development in India. The income and employment prospects of poor rural groups can be considerably enhanced by changing the size and composition of livestock enterprises to favour income-wise more important dairy animals (Maria Saleth, 1997).

The details of employment under different options of coconut based farming system is provided in Table 26. It was observed that monocropping of coconut generated 77 mandays of employement, the majority of the works being men oriented (93.5%). Further, intercropping of forage grasses in coconut depicted a potential of 142 mandays of employment, 60 per cent being men oriented works. In total, forage intercropping in coconut generated gainful employment of 219 mandays. Compared to a monocropped situation, intercropping added an additional 142 mandays of employment. Further, if family labour could be employed for this additional activity, an estimated Rs.11,920/- could be the additional revenue in terms of wages for the farm family.

Table 26. Employment potential of a coconut based farming system in a hectare of garden per year.

Farming system	Labour requirement (mandays)			Additional labour units (mandays)			Additional income (Rs./ha)		
	Men	Women	Total	Men	Women	Total	Men	Woman	Total
Coconut alone	72	5	77	-	-	-	-	-	-
Coconut+grass	157	62	219	85	57	142	8500	3420	11920
Dairy alone	91	46	137	-	-	-	-	-	-
Coconut+grass+dairy	248	108	356	176	103	279	17600	6180	23780

* Labour wages calculated @ Rs. 100/day for men labour and Rs. 60/day for women.

Maintenance of two milch cows round the year required 137 mandays, which was an additional employment available on the farm. Thus, in the overall integrated system, nearly 356 mandays of employment was involved showing the potential for employment of a person throughout the year. In contrast to monocropping of coconut (77 mandays), the integrated system thus required an additional 279 mandays of employment, which when engaged by the family labour, could lead to an additional income of Rs.23,780 per hectare of land in a year. Further, integrated dairy provided regular employment throughout the year for maintenance of cows with forage production. Thus, coconut based integrated system presents a higher degree of resource use efficiency, productivity and sustainability.

9. Economics of farming system approach in coconut

By optimising the existing resources and introducing supplementary enterprises under existing technology, the returns of farmers could be increased. Das (1991) concluded that it is more profitable to integrate a number of subsidiary crops and animal components with coconut than to grow it as a monocrop.

The economics of maintaining a coconut based farming system unit in terms of gross returns, cost of maintenance, net returns for both the years of experimentation and their pooled mean along with benefit-cost ratio is presented in Table 27 (Manjunath *et al.*, 2002a).

Gross returns

The gross returns from one hectare of coconut alone were Rs.18,370/year. However, it increased by 197 per cent over monocropping when forage crops were intercropped. Further, when two milch cows were added to the system, a mean gross returns of Rs.94,870/ year which was nearly five times of mono cropping of coconut, was obtained. The higher gross return with intercropping was mainly due to the high yielding nature of the hybrid napiers intercropped. Good milk yield from dairy throughout the year with continuous supply of green forage resulted in higher gross returns.

Table 27. Economics of a coconut based farming system in a hectare of garden for a year.

Component	Gross returns (Rs/ha/year)			Cost of maintenance (Rs/ha/year)			Net returns (Rs/ha/year)			B : C ratio
	1999-00	2000-01	Mean	1999-00	2000-01	Mean	1999-00	2000-01	Mean	
Coconut alone	17300	19440	18370	11850	12440	12150	5450	7000	6225	0.51
Grass inter crop alone	36400	36000	36200	19150	14550	16850	17250	21450	19350	1.15
Coconut + grass intercrop	53700	55440	54570	31000	26990	28995	22700	28450	25575	0.88
Coconut + grass* + dairy	92050	97690	94870	63720	61350	62535	28330	36340	32335	0.52

- With the presumption that extra grass yield is sold @ Rs. 500/t.

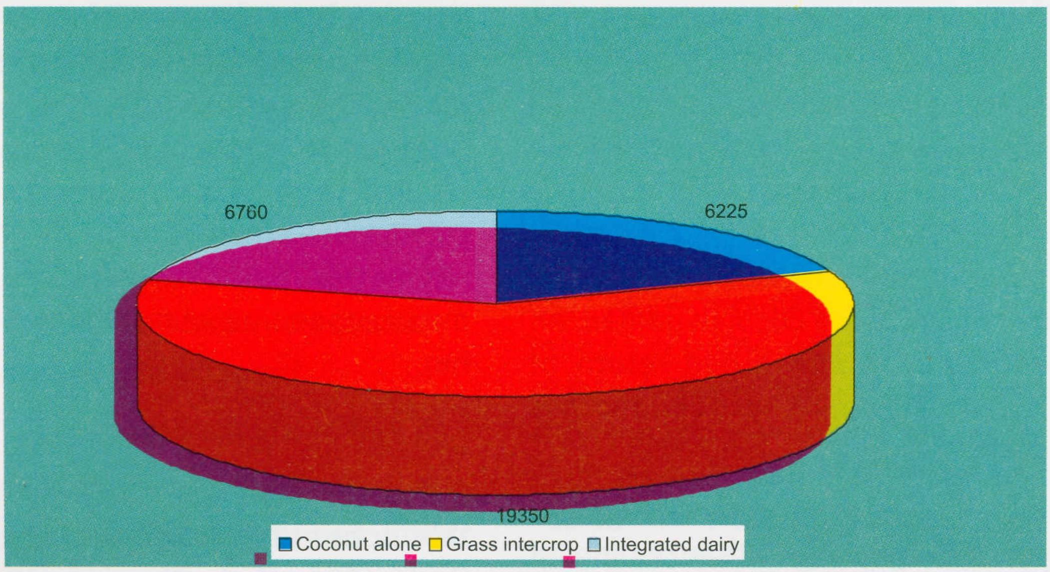
Thus, if a farmer owning a hectare of coconut garden, integrates all the components *viz.* intercropping high yielding forage grass with legume (PBN-16+ *Centrosema*) and maintains a unit of two milch cows on the farm, recycling the FYM produced from the dairy back to the coconut garden, an estimated mean gross return of Rs.94,870 could be obtained per hectare.

A coconut based integrated system involving intercropping of forage grasses in a hectare of garden and maintenance of two milch cows resulted in a production of 4,700 coconuts, 1,648 litres of milk and 60.7 tonnes of surplus green forage besides 4.70 tonnes of FYM produced on the farm. This resulted in a substantial enhancement of gross returns (Rs.76,500/ha) compared to a monocropped situation (Rs.18,370 / ha).

Cost of production

The mean cost of cultivation for the coconut worked out to be Rs.12,150/ha during the experimental period. Similarly, for intercropping forage and legume an additional cost of Rs.16,850/ha was incurred making the total to Rs.28,995/ha for coconut + forage intercropping.

The cost of cultivation increased by 138.6 per cent with intercropping forage crops compared to monocropping (Table 27). Further, the cost of maintenance of two milch cows worked out to Rs.33,540 during the period. Thus, in total to maintain coconut based integrated farming unit in a hectare of garden, a total of Rs. 62,535 was incurredexcluding the fixed costs involved in dairy shed construction etc. The higher cost with dairy integration was due to the establishment costs including feed and labour.



Net returns from integrated coconut based farming systems (pooled mean of two years)

Net returns

Monocropping of coconut was found non-remunerative in terms of net returns (Rs.6,225/ha) (Table 27). However, the net returns from a high yielding forage grass (PBN-16) with legume (*Centrosema)* intercropped in coconut was estimated at Rs.19,350/ha, thus totaling the net returns to Rs.25,575/ha for coconut intercropping with forage grass.

Further, with the integration of dairy (two milch cows), additional returns(Rs.6,760/year) were added. High yielding nature of hybrid napiers used for intercropping coupled with on-farm generation of inputs in terms of feed for cattle and manure for the crop resulted in higher net returns.

The mean net returns from two milch cows was Rs.17,710/year. Thus, the overall net returns of coconut intercropping with high yielding forage grass and integrated with a small dairy unit was estimated as Rs.32,335/year.

Benefit : cost ratio

The benefit : cost ratio was found higher for intercropping of forage crops compared to all the others as the hybrid napiers used were multi-cut (perennial) high yielding ones with least maintenance cost. The ratio of returns to cost was higher for forage grass intercropping alone (1.15). Intercropping of forage grass in coconut improved the benefit : cost ratio(0.88) compared to mono-cropping of coconut (0.51).

The benefit cost ratio was 0.53 for dairy maintenance while the overall integrated unit recorded a benefit cost ratio of 0.52. Thus, the results clearly indicate the advantage of system approach in coconut for better productivity and profitability.

V. PROSPECTS OF VALUE ADDITION IN COCONUT

Under the present global scenario, competitiveness through higher productivity and value addition through product diversification and by-product utilization are the prime themes for sustained development of coconut industry in India. Coconut kernel contains carbihydrate 20 per cent, fat 36 per cent, and protein 4 per cent at moisture content of 50 per cent. Storage/ seasoning, husking, splitting, shelling and drying are the major unit operations involved in copra industry. The coconut is largely consumed in fresh form in culinary preparations. Much effort is needed to promote processing and value addition of coconut to safeguard the interest of coconut growers. Of late there is a growing tendency to promote the use of nuts for tender coconut water. Further, conversion of nuts into copra and their various value added products have been developed by CPCRI, Kasaragod, CFTRI, Mysore, CDB, Cochin etc. Products such as desiccated coconuts, desiccated coconut powder, coconut cream, nata-de-coco, coconut based handy crafts, shell powder, shell charcoal, and shell based activated charcoal are some of the examples of value addition in coconut.

Recently, Snow Ball Tender Nut (SBTN) technology is developed by CPCRI, Kasaragod to scoop out tender kernel ball containing water for direct consumption. Further, coconut chips as value added products at home scale industry is a right step in this direction.

VI. RECOMMENDATIONS

1. Ginger and turmeric are profitable intercrops in coconut for intensive management while pine apple is for low input management. A vegetable rotation of okra-brinjal-okra for *kharif-rabi*-summer seasons, respectively will not only give intermittent returns but also better annual return.

2. High density cropping with coconut involving banana, pineapple and pepper with *Glyricidia*, a green leaf manure crop on border bunds is more profitable. Banana as an intercrop can yield upto 11.8 t/ha. Pineapple could yield 7.92 t/ha. Economic analysis of the system revealed that, C: B ratio of the system can be increased substantially from high density cropping.

3. Hybrid napier PBN-16 is a suitable forage grass for intercropping in coconut with higher forage yield (19.64 t/ha/harvest) compared to NB-21 (16.74 t/ha/harvest) with higher leaf to stem ratio (2.11), thus suggesting its suitability over NB-21.

4. The perennial forage legume *Centrosema* is observed to have more vine length (167.2 cm), higher leaf to stem ratio (1.8) yielding 21.98 tonnes of legume forage yield in three harvests of a year in a hectare of coconut garden under protective irrigated conditions. The nutritive value of the legume although was found low (10.1 % Crude Protein and 20.% Cellulose),the total nutrients yield/ha was found more. Cultivation of forage legumes also increases the organic carbon build up of soil and in turn improvement in number of bearing coconut palms and stability in the coconut yield.

5. Intercropping in coconut with forage grass and legume combination is both productive and profitable. Hybrid napiers PBN-16 and DHN-3 with perennial forage legume *Centrosema* yields significantly higher yields (82.58 t and 75.22 t/ha of green forage per hectare in coconut garden, respectively).

6. DHN-3 + *Centrosema* is more palatable by the cattle (87.4%) with least wastage and Guinea + *Centrosema* (85.1%) is next best in palatability (75.2%).

7. The integration of dairy unit with coconut production with two milch cows and even with an average milk yield of about 4.5 litres of milk/cow/day was found much profitable.

8. Coconut based integrated system can recycle nutrients to an extent of 28.1 kg N, 22.5 kg P_2O_5 and 28.1 kg K_2O from 5.62 tonnes of coconut compost which is available on the farm.

9. Intercropping forage crops with coconut will not reduce coconut yield and in fact improves nut bearing palms and nut yield.

10. An additional 142 mandays of employment could be generated through intercropping of coconut compared to monocropping. The integrated farming system model in coconut in a hectare could generate 356 man days of employment in a year.

11. Gross returns can be enhanced by 197 per cent over monocropping when forage crops were intercropped in coconut. Further, if two milch cows could be added to the system, gross returns can be increased by nearly five folds.

12. Monocropping of coconut is non-remunerative (Rs.6,225/ha-net returns). However, with intercropping of forages, the net returns can be substantially increased (Rs.25,575/ha). Further, with the integration of dairy (two milch cows), additional returns (Rs.6,760/year) can be added.

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