COASTAL SANDY SOIL MANAGEMENT FOR HIGHER COCONUT PRODUCTIVITY

Central Plantation Crops Research Institute

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COASTAL SANDY SOIL MANAGEMENT FOR HIGHER COCONUT PRODUCTIVITY

Introduction

Soil forms the basic natural resource that determines the availability of nutrients and water, the most important inputs that decide the productivity of coconut palm. As coconut palms are committed to soil for many decades, unless the quality of soil is maintained and regularly improved, it is obvious that the yield levels cannot be sustained at higher levels. Whatever impressive may be the genetic potential of coconut palms, satisfactory yields can be expected only if they are cultivated in a suitable environment with proper management. In India, coconut is being grown in different soil types. However, alluvial, laterite, sandy and red sandy loam form the major soil types occupied by coconut. The coastal sandy soil, which occurs all along the coastal tract of the West and East coasts of the Peninsular India in Kerala, Karnataka, Maharashtra, Tamil Nadu, Andhra Pradesh and Orissa, is the most predominant soil type with respect to coconut cultivation. The weather conditions prevailing along the coast is conducive for growing coconut. However, coconut productivity is very low in the coastal sandy soil ranging from 20 to 40 nuts/palm/year, mainly due to poor physico - chemical properties of the soil (Table 1).

Reasons for lower productivity of coconut under coastal sandy soil

- Poor water holding capacity
- High infiltration rate (due to the porosity of sands)
- Easy leaching of nutrients
- Small specific surface area (due to low clay and organic matter)
- Low major nutrient/micronutrient content
- Low cation exchange capacity
- Low organic carbon content

Table 1. General physico- chemical properties of coastal sandy soil

Content	Range
Clay (%)	0.6-10.8
Silt (%)	0.0-7.8
Sand (%)	87.2-95.4
pH	5.52-8.3
Organic carbon (%)	0.00-0.46
CEC (m.e/100 g)	0.4-5.4
Available nitrogen (kg ha^{-1})	30 to 60
Available phosphorus (kg ha^{-1})	10 to 25
Available potassium (kg ha^{-1})	5 to 25
Physical characterstics	
Field capacity (%)	3.8 to 7.2
Permanent wilting point (%)	0.42 to 2.12
In situ bulk density (g cm^{-3})	1.56 to 1.82

Under these conditions, sustainable crop production requires quality improvement in terms of soil physical, chemical and biological environment. Following are the agro techniques standardized at CPCRI, Kasaragod to increase and sustain the productivity of coconut under coastal sandy soil.

2. Agro techniques for coastal sandy soil management

I) Use of husk/coir pith for growing different intercrops in coconut gardens

Coconut is highly amenable for cultivating intercrops because of the wider spacing (7.5 m x 7.5 m) used for planting. However, the physical and chemical properties of coastal sandy soil are not conducive for growing intercrops without proper fertilizer and crop management practices. Under this situation, waste/usufruct materials from coconut palm *viz.*, husk and coir pith comes handy for overcoming this situation. From a well-managed coconut garden of one hectare, about 14-16 tonnes of dry material/year is available in the form of leaves, spathe, bunch waste and husk. From this, 50% contribution is in the form of husk (husk/ coir pith). These wastes/usufructs available *in situ* can be used for moisture conservation and also as a source of nutrient for the crops. Experiments conducted at CPCRI revealed that fodder grass, vegetable crops (amaranthus, pumpkin and ash gourd) and fruit crops (banana and pineapple) could be successfully grown as intercrops in coconut gardens under coastal sandy soil by adopting appropriate soil moisture conservation measures *viz.*, husk and coir pith incorporation in the planting zone. In addition to the extra income realized by intercropping, it has a complementary impact on coconut productivity. This leads to the overall improvement in the productivity of the system as a whole.

a) Fodder grass

A trench of 30 cm width and 30 cm depth and suitable length is taken in the interspaces of coconut palms. Trenches are made with a spacing of 50 cm between trenches (Fig.1). Care should be taken to leave a minimum of 2 m radius around coconut basin. One layer of coconut husk is spread out in the bottom of this trench with its concave surface facing up (Fig. 2). Husks from 5-10 coconuts are required to cover one meter length trench. In the case of coir pith incorporation, similar trench is opened and raw coir pith is applied

Fig.1. Opening of trenches

Fig.2. Husk application in trenches

to a height of 5 cm (Fig. 3). Farmyard manure @ 5 t/ha and vermicompost @ 5 t/ha is applied for both the husk and coir pith applied trenches (Fig. 4). The trenches are then filled with the excavated soil and are ready for planting hybrid Bajra Napier Co 3 fodder grass (stem cuttings or by rooted slips). Cuttings of moderately mature stem and preferably from the lower two third of the stem length sprout better than the older stem. Cuttings with two

Fig. 3. Coir pith application in the trenches

nodes are pushed into the soil with the basal end down, either vertically or at an angle to such a depth that one node remains within the soil and one above the soil surface. The cuttings are planted at a spacing of 50 cm x 50 cm (Fig. 5). For one hectare of coconut garden, approximately 25,000 stem cuttings/rooted slips are required. The best time of planting is June for the areas benefited by South West monsoon and September-October for the areas

Fig. 4. Farmyard manure +vemicompost application over husk

benefited by North East monsoon. As a basal dose, 50 kg N, 40 kg P_2O_5, 40 kg K_2O/ha is applied at the time of planting. Thereafter, only nitrogen @ 75 kg/ha is applied after each harvest is made. However, application of P & K should be repeated once in a year for sustained higher yield of fodder. Sprinkler system of irrigation (20 mm) is provided once in four days. Drip irrigation also can be

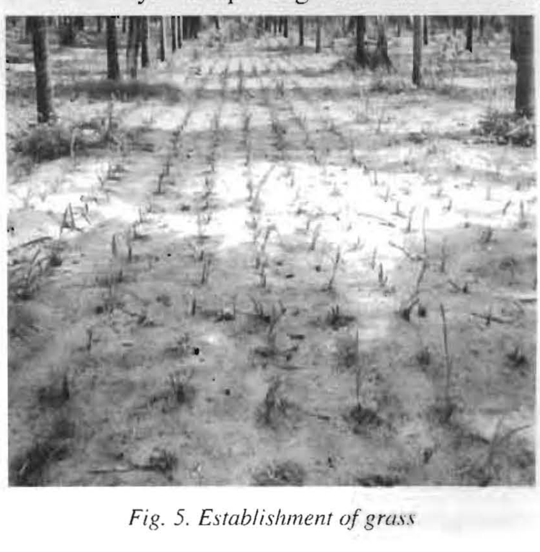

Fig. 5. Establishment of grass

practiced where acute shortage of water exists. First cutting of grass is done 80 days (Fig. 6) after planting and subsequent cuttings are done at 50 days interval. Cutting is done 10-15 cm above the ground level. In general, seven cuttings can be made every year.

Fig. 6. Performance of hybrid Bajra Napier grass Co 3 in coastal sandy soil

Performance of hybrid Bajra Napier Co 3

The amendments (husk and coir pith) added to the soil have sustained influence on growth and yield. The husk (T_1) and coir pith (T_2) application significantly influenced the plant height and the production of tillers/clump compared to the control (T_3) (Figs. 7 & 8). Higher plant height and more number of tillers/clump in the husk/coir pith treatment are mainly due to retention of moisture and nutrients in the rooting zone.

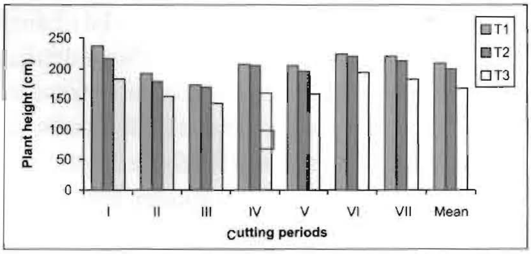

Fig. 7. Plant height as influenced by different treatments

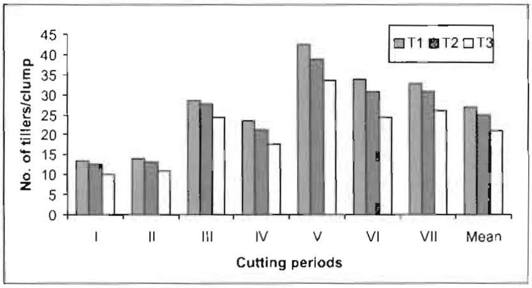

Fig. 8. No. of tillers/clump as influenced by different treatments

Higher green fodder yield was obtained under husk application during each cutting and it was on par with coir pith application and significantly differed from the control treatment (Table 2). Higher green fodder yield under husk and coir pith application is mainly due to the beneficial effects of husk and coir pith application *viz.*, higher soil moisture and nutrient availability and enhanced biological activities in the rhizosphere.

Table 2. Effect of soil moisture conservation measures on fodder yield and crude protein content and yield*

Treatment	Green fodder (t/ha/year)	Crude protein content (%)	Crude protein yield (t/ha/year)
T_1 : Coconut husk burial in the grass planting zone	92	11.83	2.28
T_2 : 5 cm thick coir pith incorporation in the grass planting zone	84	12.13	2.22
T_3 : Control	44	11.47	1.48

*average of 3 years

Findings of the study prove that the grass Co 3 can be successfully grown as an intercrop in coconut garden under coastal sandy soil. From one hectare of coconut garden, around 92 tonnes of green fodder could be produced. This is sufficient to supply green fodder for 8 milch animals. Other advantage of using amendments and growing grass under coconut shade is, increase in crude protein content and crude protein yield.

Effect of husk / coir pith incorporation on soil moisture content

Soil drawn from grass rhizosphere of coconut + grass intercropping system under husk and coir pith treatments retained higher soil moisture content during the rainless period (Nov- May) compared with that in control plots. Further, higher moisture content (2.9 to 3.3 per cent on fourth day after irrigation) was noticed in the treatments husk and coir pith incorporation whereas lower moisture content was noticed in the control treatment (1.3 to 1.5 per cent on fourth day after irrigation) at 0-30 cm. Higher soil moisture content in the coir pith/husk burial treatments is due to the absorption and retention of more moisture in the soil by coir pith/husk materials.

Effect of husk / coir pith incorporation on soil nutrient status

The nutrient status of the soil was analysed and it was found that the incorporation of organic sources husk/coir pith incorporation was found to increase the organic carbon (0.31/ 0.21 %), organic matter (0.54/0.28 %) total nitrogen (0.024/ 0.015 %), available phosphorus (104/103 ppm) and available potassium(19/18 ppm) content compared to control treatment((0.16 %, 0. 28 %, 0.007 %, 119 ppm and 18 ppm of organic carbon, organic matter, total nitrogen, available phosphorus and available potassium, respectively). However the available potassium content was very low in all the treatments which indicate that extra dose of potassium needs to be applied.

Effect of husk / coir pith incorporation on soil microbial parameters

The soil samples collected from the grass rhizosphere of coconut palms at two depths (0-25 and 25-50 cm) under different treatments were analysed for microbial population of bacteria, fungi, actinomycetes, free living nitrogen fixers, cellulose degraders, phosphate solubilizers and *Azospirillum*. Husk/coir pith incorporation influenced the microbial groups in the root zone of fodder grass. In general, higher microbial load was observed under husk/coir pith incorporation treatments compared to control. Between the husk and coir pith incorporation treatments, the population of bacteria, fungi, actinomycetes, cellulose degraders, phosphate solubilizers and *Azospirillum* were higher under husk incorporation whereas fluorescent pseudomonods population was higher under coir pith incorporation.

Advantages of intercropping fodder grass in coconut

By growing hybrid Bajra Napier grass Co-3 as intercrop in one hectare coconut garden under coastal sandy soil along with soil moisture conservation measures, a farmer can rear 6-8 milch animals and can realize a net profit of approximately Rs. 1.00 lakh/ha/year. The maximum profit that could be realized is from dairy followed by coconut. Besides, the farmer can get 35 to 40 tonnes of cow dung, that could be effectively recycled for biogas production and the slurry, cowshed washings and urine pumped to the garden for increasing the productivity of the system.

b) Pumpkin/ash gourd

Pumpkin/ash gourd can also be grown successfully as intercrops in coconut garden using husk/coir pith as amendments. For husk burial, a pit of 60 cm diameter and 30-45 cm depth is opened, and one layer of husk is applied with the concave surface facing up. Husks from 5-10 coconuts would be sufficient to fill one pit (Fig. 9). In the case of coir pith treatment, a pit of the same dimension is opened and 5 kg of coir pith per pit is applied (Fig.10). Farm yard manure @ 2.5 t and vermicompost @ 2.5 t /ha is applied along with 17.5 kg of N, 25 kg of P_2O_5 and 25 kg of K_2O. The pits are then covered with soil and the sowing is taken up. Four to five seeds are sown per pit. Unhealthy plants are removed after two weeks so that only three plants are retained per pit. Irrigation is given once in three to four days during the initial stages of growth. Later irrigation is provided on alternate days during flowering and fruiting periods. Dried twigs are spread on the ground for easy trailing of these creepers. Weeding and raking of the soil are done at the time of fertilizer application. Additional dose of N (17.5 kg) is applied in two equal splits at the time of vining and at the time of full blooming.

Fig. 9. Husk applied in the pit

Fig.10. Coir pith applied in the pit

Performance of pumpkin/ash gourd by incorporation of husk/coir pith

Pumpkin and ash gourd respond well to husk and coir pith application (Fig. 11). Fruit yield of pumpkin and ash gourd increased when soil is incorporated with coconut husk/ coir pith, compared to the control where no soil amendments were used (Table 3). Higher fruit yield was obtained under coir pith application and it was on par with husk application and significantly differed from the control. Higher fruit yield is mainly due to the beneficial effect of coir pith application and husk in the pits *viz.*, higher soil moisture and increased nutrient availability and enhanced biological activities in the rhizosphere.

Fig.11. Performance of pumpkin

Table 3. Effect of treatments on pumpkin and ash gourd yield (t/ha)

Treatment	Pumpkin	Ash gourd
Coconut husk burial	9.46	8.92
Coir pith incorporation	10.12	9.37
Control	6.21	4.89

c) Pineapple

Trench planting

Pineapple can be grown successfully as an intercrop in coconut gardens. Under coastal sandy soil because of its poor water holding capacity, addition of husk / coir pith has facilitated in better crop growth and yield of pineapple. The best planting season is May-June. Planting should be avoided during periods of heavy rain.

Preparation of trenches

Trenches of 1 m width and 30 cm depth are opened 1.5 m apart. In the bottom of the trench, one layer of husk is spread out with concave side facing upwards. Then vermicompost / compost / farmyard manure is applied at the rate of 10 t/ha as basal dressing. Fertilizers are applied at the rate of 8:4:8 g / plant / year N, P_2O_5 and K_2O, respectively. Full dose of P_2O_5 is applied at the time of planting, while nitrogen and K_2O are applied in four splits, during May-June (at planting), August-September, November and May-June (2nd year). After application of fertilizers, they are covered with soil by scraping the sides of the trenches.

Planting

In each trench, two rows of pineapple slips/ suckers are planted 15 cm inside from the edge of the trench. Two trenches can be accommodated in between two rows of coconut (Fig. 12). Triangular method of planting is adopted in each trench so that the plants in two adjacent rows are not opposite to each other. Healthy suckers of uniform size weighing 500-1000 g are selected. Suckers are kept in open space under shade in a single layer for about seven days for drying before planting. After a week, a few of the old and dried leaves were stripped off and the suckers are allowed to dry

Fig.12. Establishment of pineapple

and cure for another seven days in the same place before planting. The cured suckers are dipped in 1% bordeaux mixture at the time of planting.

Irrigation

During summer months, sprinkler system of irrigation is practiced at 0.6 IW/ CPE ratio. It requires five or six irrigations during dry months at an interval of 15 days. Mulching the crop with coconut dry leaves at 6 t/ha will help to conserve moisture.

Induction of flowering

For induction of uniform flowering, 25 ppm ethephon (2-chloro ethyl phosphonic acid) is applied in aqueous solution containing 2% urea and 0.04% calcium carbonate as follows: The aqueous mixture (50 ml/plant) is to be poured into the heart of 12-17 month old plants (33-39 leaf stage) during dry weather. For treating 1000 plants, 50 litres of the solution would be required. The aqueous solution is prepared by taking ethephon 1.25 ml, urea 1 kg and calcium carbonate 20 g, and making to 50 litres with water. Flowering will commence from the 40th day after application and will be completed by the 70th day.

Performance

Pineapple suckers grown under husk/coir pith incorporation produced higher yield of fruits (Table 4). The results showed that the husk and coir pith application as amendments had significantly influenced fruit size and fruit weight (Fig. 13). Higher fruit yield was obtained under husk application and it was on par with coir pith application and significantly differed from the control treatment.

Table 4. Effect of soil moisture conservation measures on pineapple yield*

Treatment	Fruit yield (t/ha)
Coconut husk burial	18.5
Coir pith incorporation	17.3
Control	7.7

*average of two years data

Fig. 13. Pineapple at fruiting stage

d. Banana

Banana when grown in sandy soil needs some amendments (husk / coir pith) for its success as intercrop in coconut garden. Pits of 45 x 45 x 45 cm are opened (Fig. 14), and one layer of husk was put with the concave surface facing up. Husks from 5-10 coconuts would be sufficient to fill one pit (Fig. 15). In the case of coir pith treatment, a pit of the same dimension is opened (45 x 45 x 45 cm) and 5 kg of coir pith per pit is applied (Fig. 16). Application of farm yard manure @ 2.5 kg and

Fig. 14. Pits opened at a 2 m x 2 m spacing

Fig. 15. Pit with husk aplication

Fig. 16. Pit with coir pith application

vermicompost @ 2.5 kg/pit are applied uniformly to all the pits. Suckers/tissue cultured plants are planted in the center of pits at a spacing of 2.0 m x 2.0 m. Fertilizers are fertilizer @ 190 g N, 150 g P_2O_5 and 300 g K_2O / plant / year are applied. Full dose of P_2O_5 is applied at the time of planting, while nitrogen and potassium are applied in six equal splits at monthly interval from the time of planting. Irrigation is given once in three days during summer season.

Performance of banana

Banana responds well to soil moisture conservation measures with husk and coir pith application (Fig. 17). The results showed that the husk and coir pith incorporation as amendments had signficantly influenced the fruit size and bunch weight. Higher fruit yield was obtained under husk application and it was on par with coir pith application. However these treatments significantly differed from the control (Table 5).

Fig.17. Performance of banana

Table 5. Effect of soil moisture conservation measures on banana yield (variety nendran)

Treatment	Fruit yield (t/ha)
Coconut husk burial	11.98
Coir pith application	11.04
Control	6.83

e. Impact of cropping systems on coconut productivity

By taking up intercropping of fodder grass, vegetables and fruit crops, coconut productivity was increased. Higher coconut yield was recorded under coconut + pineapple intercropping system followed by coconut + vegetables and coconut + banana compared to monocropping of coconut. Thus cropping systems and soil conservation measures have a positive impact on coconut productivity (Table 6). Similarly, soil moisture conservation measures play a beneficial role on coconut productivity. Husk burial recorded higher nut yield followed by coir pith application compared to control.

Table 6. Effect of cropping systems and soil moisture conservation measures on coconut yield*

Treatment	Coconut productivity (nuts/palm/year)
Cropping systems	
Coconut + vegetable intercropping	98
Coconut + pineapple intercropping	100
Coconut + banana intercropping	98
Coconut + fodder grass intercropping	89
Coconut monocropping	91
Soil moisture conservation measures	
Coconut husk burial	108
Coir pith application	100
Control	72

**average of 3 years yield data*

f. Economics of coconut based cropping system

The economic analysis performed for different coconut based intercropping systems under coastal sandy soil indicated that all the cropping systems realized higher net returns, compared to monocrop. The net returns ranged from Rs. 45,717/ha/year in case of coconut monocrop to Rs. 1,48,094/ha/year in case of coconut + banana intercropping system (Table 7). The percentage increase in case of net returns over coconut monocrop ranged from 224% in case of coconut + banana inter cropping system to 39% in case of coconut + ash gourd intercropping system.

Table 7. Ecocnomics of coconut based intercropping system under coastal sandy soil (Rs./ha/year)*

Cropping System	Net income	% over coconut monocrop
Coconut monocrop	45717	-
Coconut + fodder grass	82055	89
Coconut + pineapple	100310	119
Coconut + banana	148094	224
Coconut + pumpkin	66755	46
Coconut + ash gourd	63405	39

*based on 2005 to 2007 market prices in Northen Kerala

II) Alley cropping/intercropping of glyricidia in coconut gardens

Even though coconut is a widely spaced crop, the interspace cannot be utilised economically for growing commercial intercrops in coastal sandy soil without adopting proper soil and water conservation measures and irrigation. Therefore, permanent coconut-tree legume intercropping may be well suited under costal sandy soil under heavy rainfall zone. Glyricidia has great potential as a multipurpose tree in agro forestry, which fits well in marginal and sub marginal soils. Experimental results from CPCRI proved that glyricida can be successfully grown as intercrop in coconut gardens in coastal sandy soil (where no other green manure crop can establish), and supply green manure.

Method of planting

A fast growing, multi-purpose tropical leguminous tree, *Glyricidia sepium* is well adapted to coastal sandy soil. The tree is propagated through vegetative cuttings or seeds. One meter long stem cuttings or 3 to 4 month old seedlings raised in poly bags/raised beds can be used for planting. It is preferable that the planting season coincides with the monsoon (South West monsoon/North East monsoon) for better establishment. Spacing of 1 m x 1 m can be adopted. Two or three rows of glyricidia can be planted in between two rows of coconut. Planting can be done as depicted in the Fig.18. Plant stem cuttings or

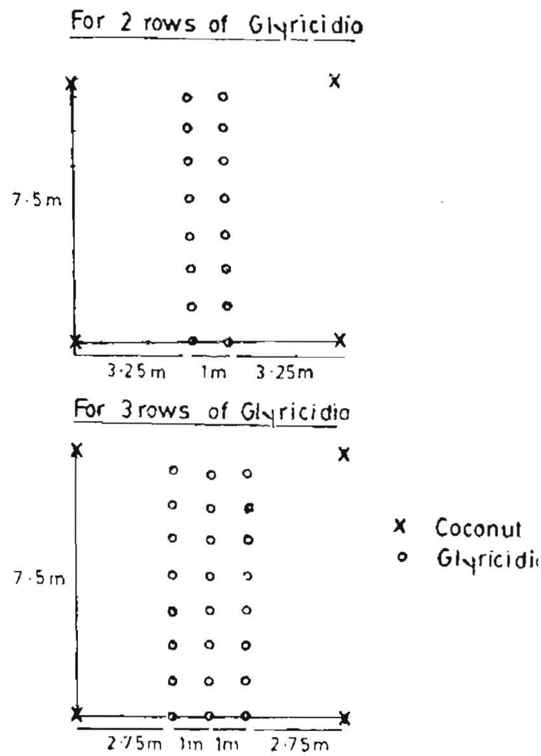

Fig.18. Schematic representation of glyricidia planting in coconut gardens

seedlings in an upright position in pits of 30 cm^3. For better establishment, a basal dose of 50 kg of $P_2O_5ha^{-1}$ may be applied. Height of the plant should always be maintained at 1 m by pruning. Glyricidia intercropping suppresses the weed growth and hence weeding may not be a major problem. As pest and disease of glyricidia is not a major problem, no plant protection measures are required.

Pruning can be started one year after planting. For good management, plants should be pruned at the appropriate time. Pruning should be done at least thrice a year (February, June and October). Three rows of glyricidia in between two rows of coconut with three prunings per year resulted in higher biomass yield of 7970 kg ha^{-1} (Fig.19). The lopping is cut into small pieces and the chopped material is incorporated in the basin area of coconut palm after opening a trench and then covered with soil. The coconut growth is not affected by intercropping with glyricidia. Application of glyricidia prunings from the interspace of one hectare of coconut garden to the coconut palms could meet a major portion of nitrogen (88 per cent), part of phosphorus (27 per cent) and potassium (13 per cent) requirement of coconut palms (Table 8). The *in situ* planting of nitrogen fixing tree species like glyricidia between

Fig. 19. Glyricidia as a green manure crop in coconut garden

coconut rows can also supply micronutrients such as copper, zinc and boron. Further advantages are *in situ* availability, easy decomposability and low cost of the green manure. In addition to this, the microclimate in the coconut garden is also improved.

III) Glyricidia as green manure

The poor soil fertility status of coastal sandy soil can be improved by addition of green manure of glyricidia. The results of a field experiment on substitution of nitrogenous fertilizer with glyricidia green manure in coconut under coastal littoral sandy soil at Central Plantation Crops Research Institute, Kasaragod revealed that incorporation of glyricidia green manure added valuable nutrients such as nitrogen, phosphorus, potassium, calcium and magnesium to the soil (Table 9). Application of glyricidia along with

Table 8. Nutrient substitution through glyricidia loppings in coconut (kg/ha)

Particulars	N	P_2O_5	K_2O
Recommended dose of fertilizer (kg/ha) for 175 coconut palms	87.5	21.0	210.0
Nutrient availability through glyricidia loppings (7970 kg/ha)	77.74	5.68	26.80
% Nutrient substitution	88.0	27.0	13.0

** Nutrient content (%) of glyricidia on dry wt. basis N 3.30 P 0.247 K 1.163*

Table 9. Effect of glyricidia green manuring on organic carbon content and available soil nutrient status in coconut basin at different depths (cm)

Treatment	Organic carbon (%)		Available nutrients (ppm) N		P		K	
	0-25	25-50	0-25	25-50	0-25	25-50	0-25	25-50
T1: 100% NPK through inorganics (control)	0.25	0.24	38.4	31.2	89.82	65.21	35.77	23.08
T2: 25 % N by glyricidia + 75 % N and full PK by inorganics	0.45	0.25	44.5	33.4	107.96	46.5	42.69	27.69
T3: 50 % N by glyricidia + 50 % N and full PK by inorganics	0.43	0.26	46.3	36.4	107.88	28.62	41.54	25.38
T4: 75 % N by glyricidia + 25 % N and full PK by inorganics	0.44	0.33	47.0	37.9	104.24	40.09	43.84	35.77
T5: 100 % N by glyricidia + Full PK by inorganics	0.56	0.31	49.0	38.2	93.88	33.62	43.84	30.00
SE_d	0.08	0.06	1.56	7.68	23.006	19.813	4.682	5.312
CD (P=0.05)	0.17	NS	3.40	NS	NS	NS	NS	NS

inorganic fertilizers was found to increase the nut yield of coconut. When 50 per cent N was substituted by glyricidia (25 kg of glyricidia green leaves) along with 50 per cent of N and 100 per cent of P and K through inorganic fertilizers, higher coconut yield of 52 nuts per palm per year was recorded (44 percentage increase over control). The cost benefit ratio was also most favourable in this treatment (1: 1.82).

For glyricidia green manure incorporation, 1.8 m radius around the palm should be opened to a depth of 20 cm and 25 kg of green manure plus the required inorganic fertilizers are applied and covered with the excavated soil during the first fortnight of September (Fig. 20).

IV) Coconut basin management with leguminous crops

Growing a green manure crop *in situ* and incorporating it into the soil is probably the easiest and most economical method of augmenting the organic matter content in the soil. The following are the benefits of growing legume crops in the coconut basin (2 m radius).

- Prevention of soil erosion.
- Smothering of weeds, thus reducing weeding costs.
- Addition of organic matter to the soil and thus maintaining the structure of the top soil.
- Improving aeration of the soil.
- Protecting the soil and roots of crops from excessive heat of the sun.

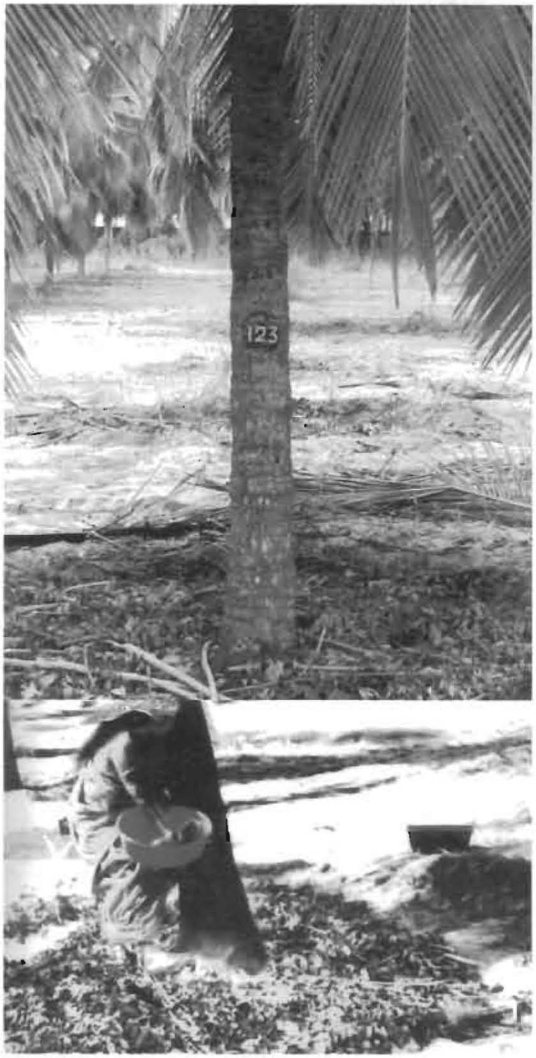

Fig. 20. Glyricidia *green manure incorporation*

- Conservation of soil fertility by using available plant food, which might otherwise be leached away.
- Fixing of atmospheric nitrogen from the air in the case of leguminous plants
- Increase in water holding capacity of the soil

The technique of utilizing of leguminous cover crops as green manures to supply biologically fixed nitrogen and easily decomposable biomass to coconut was standardized at CPCRI. It involves cultivation of crops such as cowpea (*Vigna unguiculata*), and sunn hemp (*Crotalaria juncea*) in coconut basins during the monsoon period from June to August and incorporation of the biomass in respective basins of coconut palms under coastal sandy soil. Sowing of green manure cowpea should be carried out during the month of June by broadcasting 100 g seeds in 2 m radius basins after application of first dose (1/3rd) of inorganic fertilizers recommended for coconut palm. When cowpea and sunn hemp attain 50% flowering, it should be uprooted and incorporated in the basins during second fortnight of August along with 2/3rd fertilizer application. Cowpea and sunn hemp yields about 23 and 25 kg of green biomass, respectively (Figs. 21 and 22). Nutrient

Fig. 21. Performance of cowpea in the coconut basin

Fig. 22. Performance of sunn hemp in the coconut basin

substitution obtained by incorporating cowpea/ sunhemp in coconut basin is given in Table 10.

Table 10. Nutrient substitution through cowpea/sunn hemp

Particulars	N	P_2O_5	K_2O
Fertilizer recommendation for coconut (g/palm/year)	500	120	1200
Nutrient content of cowpea biomas (%)	2.87	0.22	2.14
Nutrient availability through cowpea biomass from one coconut basin (g)	145	11	108
Nutrient substitution through cowpea biomas (%)	**29**	**9**	**9**
Nutrient content of sunn hemp biomas (%)	2.94	0.18	1.43
Nutrient availability through sunn hemp biomass from one coconut basin (g)	142	9	37
Nutrient substitution through sunn hemp (%)	29	8	3

V) Vermicomposting of coconut plantation wastes

The availability of fallen dried coconut leaves from a coconut garden with 175 palms/ha has been estimated as 6 to 7 tonnes /ha/yr. The natural decomposition of these coconut leaves and the nutrient release are very slow due to the high lignin content and the nature of lignocellulose complex of coconut leaf materials. Substantial saving in terms of fertilizer input is possible through effective recycling of the waste biomass. Studies conducted at CPCRI, Kasaragod have revealed that coconut plantation wastes could be effectively converted into rich vermicompost using epigeic earthworms or compost worms such as *Eudrilus* spp. They can fully convert the wastes into vermicasts, leaving behind only mid ribs of the leaves.

Experiments were conducted for vermicomposting coconut leaves by cement tank method/trench method/heap method in the coastal sandy soil situations. For cement tank method, a tank of dimension of 4 m x 1.5 m x 1m was constructed in the interspaces of coconut garden (Fig. 23). Coconut leaves weathered for 2 to 3 months are preferable as they can be used without chopping, thereby saving lot of labour. As the earthworms need

Fig.23. Vermicomposting by tank method

composted organic matter as feed in the initial stages of composting coconut leaves, the collected coconut leaves are to be added with cowdung slurry @100 kg per tonne of leaves and kept for 2 to 3 weeks. Earthworms @ 1000 worms per tonne of coconut leaves are to be introduced. It should be mulched with available organic wastes such as dry grass, straw or coconut leaves. Sufficient moisture is to be ensured by sprinkling water. The composting area should be in a shaded place. Depending on the extent of weathering of leaves used for composting, 70 per cent recovery of the compost is obtained within a period of 75-90 days. The average nutrient composition of the vermicompost recovered was : N 1.84%, P 0.22%, K 0.28%, organic carbon 17.84% and C:N ratio 9.95. From one ha of coconut garden, around 4.2 to 5.6 tonnes of vermicompost can be produced every year. With this, an amount of 25 to 32 kg of vermicopst can be applied to each palm every year. This could meet the entire requirement of nitrogen, 39 to 49 per cent of phosphorus and 4 per cent of potassium. This clearly indicates that the nitrogen and phosphorus requirement could be met through vermicompost. For potassium, the balance should be met through chemical fertilizers. The same technology for vermicomposting was found to work well when tested in large trench taken in the inter spaces of four coconut palms in sandy loam and coastal sandy soil (Fig. 24). As composting is done in the field itself, lot of labour required for transportation of the biomass and compost can be saved.

Fig. 24. Vermicomposting by trench method

VI) Soil moisture conservation measures with coconut wastes

Most of the organic wastes from the coconut garden have high moisture holding capacity and can be very profitably used as moisture regulators and conservators. This gains more practical significance in the light of the fact that soils cannot be rejuvenated with organics in the absence of sufficient moisture. Similarly the full benefits from irrigation can be obtained only if there is sufficient quantity of soil organic matter. Keeping in mind the complementary roles of soil organic matter and moisture conservation, coconut leaves, husk, coir pith and weeded material from the plantation can be utilized directly for mulching.

a. Mulching

Mulching is the application of a layer of organic/inorganic material to the top layer of soil. The objectives of applying mulch are, generally, four fold: to conserve soil moisture in the immediate root area by preventing rapid evaporation, to prevent sudden fluctuations in the soil temperature, to restrict weed growth and to supply nutrients for the plant. It is an important agricultural practice that should be routinely done in the basin of the palm especially in coastal sandy soil.

1) Coconut leaf

Mulching coconut basins with dried fallen coconut leaves during September-May ensures soil moisture conservation and restricts weed growth. In addition, the leaves gradually release nutrients to palms when it decomposes. Coconut leaves can be cut into two or three pieces before using them for mulching. The mulching is best done before the end of the monsoon and before the top soil dries up. To cover one basin (2 m radius) 20 to 25 coconut leaves are required (Fig. 25). Experiments

Fig. 25. Mulching using coconut leaves

conducted at CPCRI revealed that mulching with coconut leaves combined with irrigation treatments recorded significantly higher yield as compared to irrigation without mulching. Unlike the husk and coir pith, leaves cannot hold much moisture before they get composted. Leaf mulch prevents the top soil from getting heated up and this reduces the evaporation from the basin area. The leaves once applied as mulch could last for 1 to 2 years.

2) Coconut husk

Coconut husks are also used as surface mulch around the base of the palm. It can hold moisture to the tune 3 to 5 times of its weight. Approximately, 250 to 300 husks will be required for mulching one coconut basin.

Fig. 26 a. Mulching using coconut husk with concave side facing up (lower layer)

Fig.26 b. Mulching using coconut husk with convex side facing up (top layer)

Mulching is usally done upto a radius of 2 m leaving 30 cm near the palm. Two layers of husk may be buried in the coconut basin with lower layer the concave side of the husk facing upwards. This layer (Fig. 26 a) facilitate absorption of moisture. Second layer (upper) of coconut husk is placed with the convex side facing upwards to arrest evaporation (Fig. 26 b). Effect of this mulch lasts for about 5-7 years.

3) Coir pith

Coir pith, a waste product obtained during the extraction of coir fibre from husk, is very light, compressible and highly hygroscopic. Coir pith when applied, 10 cm thick (approximately 50 kg/palm), around coconut basin is an ideal medium to preserve moisture (Fig. 27). The mulch may be applied during the end of the rainy season. Coir pith can hold moisture upto 5 times of its weight. Due to its fibrous and loose nature, incorporation of coir pith into the soil improves the soil's physical properties and water holding capacity considerably and thereby increases the coconut productivity. Further, by spreading coir pith in the basin, increase in soil temperature and evaporation are arrested. However, it is better to use composted coir pith rather than raw coir pith. The applied material may last for about 4 to 5 years

Fig. 27. Coir pith mulching in the coconut basin

4) Other organic wastes

Mulching of coconut basin could also be done with other organic wastes as weeded materials etc. The weeded materials should be properly dried and then applied.

b. Husk burial: Husk, if buried in the trunch opened in the inter space of coconut (4 m x 3 m x 0.7 m) act as a water reservoir and also supply palms with small amount of potash. A fully soaked husk is able to retain about 5-6 times of its weight of water and is made available to the palms during summer season. Besides, on an average 100,000 husks contain potash equivalent to 1 tonne of muriate of potash, which is also made available to the palm.

c. Burying husk in circular trenches around the coconut palm: Coconut husk can be buried in circular trenches taken around the palm at a distance of 2.5 m away from the trunk. The trenches may be of 0.5 m width and depth. The husks are to be placed in layers with concave surface facing upwards and covered with soil.

VII) Drip irrigation

Poor soil moisture retention characteristics of coastal sandy soils make irrigation very essential. Good irrigation practices are needed to sustain productivity in this soil. In the traditional system of irrigation, irrigation efficiency is only 30 to 50 per cent due to considerable wastage of water. In addition, cost on inputs like labour and energy is quite high for the irrigation system. Under these circumstances, drip irrigation is the most suitable system of irrigation for coconut. The system has an overall application efficiency of around 90%. Some of the major advantages of drip irrigation are: it saves water, energy and labour and is most suited for soils having low water holding capacity. Results of the experiment conducted at CPCRI have shown (water spread from a single point source) that at least six emitters are required for sandy soil (Fig. 28). Under Kasaragod conditions, 32 to 40 litres (66 per cent of open pan evaporation) of water/palm/day can be applied through drip irrigation. Irrigation should be started in the month of November when the soil moisture depletes to 50 per cent of the available soil moisture. In other parts of India especially Tamil Nadu and Andhra Pradesh, water should be provided throughout the year except during rainy season.

The response of coconut to combined effect of drip irrigation and mulching was studied under coastal sandy soil at the Central Plantation Crops Research Institute (CPCRI), Kasaragod, during non-rainy seasons with West Coast Tall variety. All irrigation treatments were on a par with each other but

Fig. 28. Drip irrigation

were superior to the rainfed control (Table 11). The highest nut yield (80 nuts/palm/year) was observed in the drip irrigated treatment at 100 per cent of Eo and was on par with treatments of drip irrigation with 66 per cent or 133 per cent of Eo (78 nuts/palm/year).

Table 11. Influence of irrigation, mulching and their interaction on coconut yield (pooled data for 6 years) in coastal sandy soil

Irrigation Treatment	Nut yield/palm/year No mulch	Mulch	Mean
T1: 66% of Eo through drip	59	76	68
T2: 100% of Eo through drip	65	80	72
T3: 133% of Eo through drip	56	78	67
T4: 100% of Eo through basin irrigation	58	74	66
T5: Rainfed	28	28	28
Mean	53	67	

3. Conclusion

Coconut palms grown under coastal sandy soil conditions, generally will produce only 20-40 nuts/palm/year with moderate management. To make coconut cultivation economically viable and sustainable under coastal sandy soil, more emphasis should be given to improve the soil conditions physically and chemically. In this regard, CPCRI has successfully developed a number of agro techniques *viz.*, moisture conservation practices using husk/coir pith for growing different intercrops, alley cropping of glyricidia, green manuring with glyricidia loppings, basin management with leguminous crops, direct utilization of coconut wastes for soil moisture conservation measures, vermicomposting of coconut plantation wastes and recycling and micro irrigation for increasing the yield of coconut palm. All these techniques need to be adopted in an integrated manner to improve the productivity of the system. By adopting such agro techniques in the coastal sandy soil, we can expect a significant improvement in yield as evident from the results of the experiments conducted at CPCRI.

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