

SUSTAINABLE SOIL AND PLANT HEALTH STRATEGIES THROUGH INTEGRATED NUTRIENT AND WATER MANAGEMENT FOR ENHANCED COCOA ECOSYSTEM, RESILIENCE AND YIELD

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Cocoa is proven as a beneficial crop in the plantation ecosystem both in agro-forestry and palm based cropping systems. To increase the productivity of cocoa per unit area, basic and advanced management strategies should be formulated and followed. Quality planting materials of high yielding varieties, selection of favourable agro climatic regions, area expansion in suitable and conducive environments, following seasonal plant based cultural practices from planting to harvesting, need based calendar of operations throughout the crop cycle decides the sustainability of cocoa.

1. Climatic suitability

Cocoa is a perennial crop of humid subtropics and it was introduced along with other beverage crops Tea in the top hill, Coffee in the middle hill and Cocoa in the lower hill. Cocoa can be successfully grown up to 300 m MSL and can be grown

upto 1100-1200 m altitude. Since there is not much area available for expansion it was taken to arecanut and coconut gardens where the microclimate is congenial with 50% shade and 50% sunlight. Seasonal variations in both rainfall and temperature influence the pod setting. Though the existing traditional belt of Western ghats hills and plains falls in high rainfall zone with short dry spells, area expansion happening in areas with 5-6 months dry period or <1250 mm rainfall which necessitated supplementary irrigation. Intensity and distribution of rainfall decide the pattern of cropping. High rainfall in excess of 2,500 mm may lead to fungal diseases like black pod rot due to high humidity. Cocoa growing areas have uniformly high humidity, often 100% during night falling to 70-80 per cent by day. If relative humidity is low, cocoa produce small leaves, curled and withered at tip. The temperature in most of the cocoa growing areas lies between a maximum of 30-32°C and a minimum of 18-21°C. Low temperatures have

Cocoa at CPCRI centres

State	Karnataka		Kerala		West Bengal	Assam
Centre	Vittal	Kidu	Kasaragod	Kayamkulam	Mohitnagar	Kahikuchi
Shade	Arecanut & Coconut	Arecanut & Coconut	Coconut	Coconut	Arecanut & Coconut	Arecanut
Region	West Coast Hills & Plains	West Coast Hills & Plains	West Coast Hills & Plains	West Coast Hills & Plains	Terrai Region	Eastern Himalayan Region
Lattitude	12.78°	12.70°	12.52°	9.15°	26.52°	26.10°
Longitude	75.11°	75.57°	74.97°	76.51°	88.66°	91.61°
MSL	73-92 m	291 m	10.7 m	3.05 m	91 m	50 m
Rainfall	3670 mm	3950 mm	3500 mm	2564 mm	3000 mm	1500 mm
Temperature	28-36°C	25-33°C	23-31°C	32°C	8-35°C	10-35°C
RH	75-80%	80-85%	80%	80-82%	70-80%	85-90%
Soil	Laterite admix with sand & alluvium	Red and sandy laterite	Sandy loam	Sandy loam	Loam	Clay loam
pH	5.25	6.6	5.9	5.0-6.0	5.5	4.5-5.5

*ICAR- Central Plantation Crops Research Institute- CPCRI, Regional Station, Vittal - 574 243

an inhibiting effect on flowering. High temperature reduces pod setting, cause more cherrille wilting, reduces yield and bean size. Without overhead shade, seedlings may be physically damaged by heavy winds causing defoliation. Multi Location Trials on cocoa is running in all centres of CPCRI as well as AICRPP centres in different agro climatic regions which shown the adaptability of cocoa in different cropping systems, soil, climatic situations and management.

2. Soil requirement

Cocoa is grown on a variety of soils, most of the present cocoa plantations are in laterite soils. Black and alluvial soils are also suitable for cocoa

if not too wet or too shallow. The ideal soil for cocoa should have depth-1.5 m, organic matter- 3.5%, C/N ratio- >9, base exchange capacity->12 me/100g soil, base saturation->35%, pH- 6.5 to 7.00 with good water holding capacity. Cocoa is a dicot with tap root and the vertical penetration is up to 3.5 m deep. About 60 per cent of fine roots are within the first horizon of 50 cm depth. Under monocropping situations, root growth of cocoa was concentrated within 25 cm radius from the tree. Lateral spread of active roots was mainly restricted to one meter from the plant, which accounted for 75 per cent of the total root activity and with high CEC cocoa is highly competitive to main crop. Thus, it is essential to meet the water and nutrient demand of both component crops in mixed crop situations.

Cocoa at AICRP centres

State	Andhra Pradesh		Tamil Nadu		Maharashtra	Gujarat	Assam
Centre	Ambajipeta	Vijayarai	Veppankulam	Aliyamagar	Ratnagiri	Navsari	Kahikuchi
Shade	Coconut	Oil Palm	Coconut	Coconut	Coconut	Coconut	Coconut
Region	East Coast	East Coast Hills & Plains	East Coast Hills & Plains	West Coast Hills & Plains	South Konkan Coastal Zone	West Coast/ South Gujarat Heavy Rainfall Zone	Eastern Himalayan Region
Lattitude	16.59°	16.49°	10.47°	10.03°	17.00°	20.06°	26.10°
Longitude	81.56°	81.47°	79.38°	76.06°	73.40°	72.06°	91.61°
MSL	14.05 m	21.0 m	20.7 m	288 m	3 m	11.98 m	50 m
Rainfall	1200-1300 mm	966 mm	1000 mm	858 mm	3000 mm	1500-1700 mm	1500 mm
Temperature	35-39°C	28-37°C	23-31°C	16.8-35°C	20-30°C	20-30°C	10-35°C
RH	85-95%	85-95%	80%	80%	80%	65-70%	85-90%
Soil	Coastal alluvial	Coastal loamy	Sandy loam	Sandy loam	Coastal alluvial laterite	Deep black soil	Clay loam
pH	7.5-8.5	6.8-7.5	5.9	7.0	5.5-7.0	7.5-8.5	4.5-5.5

3. Horticultural Techniques

Optimum spacing: Cocoa is generally grown under coconut, arecanut and oil palm plantations in single hedge system i.e., planting one row of cocoa in between two rows of palms.

Under Areca Palm:

- i. Areca + Cocoa (normal spacing): Areca- 2.7 m x 2.7 m (9 ft. x 9 ft.), Cocoa- 2.7 m x 5.4 m (9 ft. x 18 ft.), 686 plants/ ha.
- ii. Areca + Cocoa (dense spacing): Cocoa- 2.7 m x 2.7 m (9 ft. x 9 ft.), 1372 plants/ ha.
- iii. Areca + Cocoa (wider spacing): Cocoa- 5.4 m

- x 5.4 m (18 ft. x 18 ft.), 343 plants/ ha.
- iv. Areca + Cocoa (new garden): Planting together 3 m x 3 m (10 ft. x 10 ft.), 1111 plants/ ha.
- v. Areca based multi species cropping system (ABMSCS): Areca + Cocoa + Banana + Pepper (trailed on areca) (2.7 m + 5.4 m + 5.4 m + 5.4 m)

Under Coconut Palm:

- Coconut + Cocoa (normal spacing) : Coconut- 7.5 m x 7.5 m
- i. Single hedge cocoa- 2.7- 3 m
 - ii. Double hedge cocoa- 2.5, 2.7, 3 m (depend on

- spacing of coconut)
- iii. Coconut based multispecies cropping system:
Coconut + Cocoa + Banana + Pepper
Coconut + Cocoa + Nutmeg/ Cinnamon + Banana + Pepper

Under Oil Palm:

Oil Palm - 9 x 9 x 9 m triangular planting, Cocoa- 2.5 to 3 m.
Cocoa at 2 m away from palm basin. >15 years old oil palm at square system of planting is good to avoid heavy shade.

Agro-Forestry System:

Permanent shade trees- 8 m, Cocoa- 3 m x 3 m

Cocoa in different cropping systems

Agroforestry system (Permanent shade)



Agroforestry system (Temporary shade)



Monocropping in hilly region



Arecanut + cocoa



Coconut + cocoa



Oilpam + cocoa



Planting: Pits of 60 cm³ are to be dug, left open for a minimum of 15 days to ward off field heat and half filled with mixture of topsoil and organic manure. This size is to break the hard pan if present in the sub-surface and to loosen the soil in the root rhizosphere for better soil aeration and root growth. Soil aeration is most important for production of fine roots, which are required for uptake of nutrients and water. In high rainfall regions, planting will be done at the end of the monsoon or post- monsoon season and in low rainfall regions, with onset of monsoon. The seedlings are sensitive to drought and water stagnation and accordingly provision of irrigation and drainage facilities to be envisaged.

Shade: Traditionally cocoa is an understory crop grown with forest trees both temporary and permanent shade trees. Intensity of shade requirement varies from place to place and growth stages. At seedling stage, cocoa need 75% shade in tropics and 50%

in humid tropics, as they mature shade requirement reduces, since cocoa leaves have a self shading effect. Upto 15 years in the initial years of establishment temporary shade trees like banana, tapioca, *Sesbania*, *Glyricidia* etc. can be grown. Permanent shade tree like *Cola nitida* and other timber trees are being used as shade trees. The combination of permanent and temporary shade trees can also be grown, once the cocoa canopy develops, temporary shade trees can be removed for more light interception and stimulation of flowers and fruits. As such monocropping system of cocoa is not followed like tea, coffee and rubber plantations. Upto certain elevation with humid climate, with shade trees in the surrounding of the plot, some sort of partial monocropping is followed in traditional belts. Asia Pacific region grow cocoa mostly with palms. Trees without overhead shade shown decline in bean size and had short life cycle. Shade and nutrient application are related, shade can be dispensed where the cocoa trees can obtain adequate nutrient and moisture throughout the year.

Nutrition: Nutrient requirement of cocoa depends upon the type of soil, cultivation practices and varies with different cocoa growing regions. In general, nutrient recommendation is made based on soil or plant analysis or both. The nutrient removal by the crop makes the basis of fertilizer application to cocoa. Under average management, 100:40:140 g of N, P₂O₅ and K₂O per tree per year is recommended. For a crop yielding about 2 kg of dry beans (about 60 pods) per tree per year, the average crop removal by pods would be around 96.8, 11.4 and 191.2 g each of N, P and K. Nitrogen and phosphorus demand of cocoa can be met from other sources like atmospheric N, organic matter, irrigation water and rainfall interception. As potassium is not organically bound and not supplied by other sources, it is necessary to apply K in frequent split doses during December to May. The present K dose can be doubled if dry bean yield is more than 1.0 kg per tree. In perennial crops like cocoa, it is difficult to control deficiency of any nutrient after the symptoms develop, so before establishment of garden, it is better to do soil testing.

Fertilizer Schedule

- First dose: April- May (Pre Monsoon)
- Second dose: September - October (Post Monsoon)
- Additional potassium in split doses to get more dry bean yields.

Fertiliser (g/plant/year)	I year	II year	III year onwards
Nitrogen	33	66	100
Phosphorous	13	26	40
Potash	46	92	140
Urea	72	144	220
Rock phosphate	65	130	200
Muriate of Potash	77	154	230
Shallow basins	1 ft	2.5 ft	3 ft

Biomass production and nutrient composition of parts of cocoa

Cocoa produces leaves throughout the year and the biomass production varies with age and growing conditions. Cocoa normally produces 14 kg leaf and pruned biomass, 4 kg pod husk and 2 kg beans per tree per year on dry weight basis. Cocoa under coconut adds litter fall to the extent of 818 to 1985 kg/ha/year. Leaf and bean have higher N and pod husk contains higher K content. Cocoa pruned biomass and leaf litter can be converted into vermicompost with 74% recovery.

Nutrient removal by cocoa crop

Nutrient	Nutrient exported through 1000 kg dry beans	Nutrient removal at yield level of 2 kg dry bean /tree	
		Per Tree	Per Ha (650 trees)
N	48.4 kg	479 g	311 kg
P	5.7 kg	36 g	23.4 kg
K	95.6 kg	429 g	279 kg

Cocoa Farm Wastes for Composting



Cocoa leaves



Pod husk

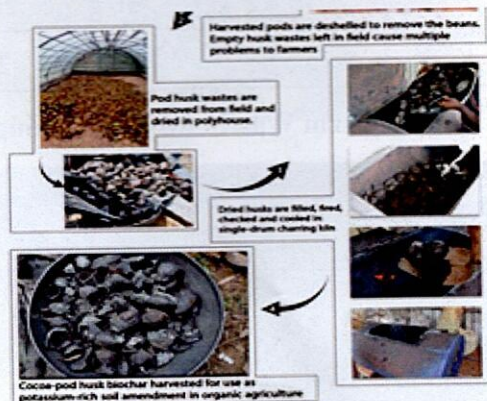


Bean shell

Cocoa Pod Husk as K Source

Cocoa Pod Husk (CPH) can be directly combusted to produce ash rich in potassium—a key fertilizer ingredient and will be a natural amendment in organic/ natural farming methods. In pyrolysis, CPH is heated in the absence of oxygen, yielding Biochar. Though biochar itself is a source of many vital nutrients, it has got high capacity for nutrient sorption, much more than natural organic matter, by some estimates even 10 to 100 times. Cocoa pod husk biochar, with its high potassium content, organic carbon, and non-toxicity to earthworms, offers a sustainable solution for potassium deficiency in soils, particularly in organic agriculture.

Biochar Production from Cocoa Pod Husk



Method and time of application of nutrients

The root studies have shown that majority of the feeding roots of cocoa are concentrated on the

surface and traverse horizontally from 1.0 to 1.5 m, thus nutrients have to be applied on the surface in the cocoa basin and mixed in the soil with mild forking with sufficient moisture. In low rainfall zones, fertilizers can be applied just before onset of monsoon coinciding the months of May-June and second dose after monsoon in September-October. In high rainfall zones, it may be little advanced during early April upto early May, probably two months before peak of main harvest and second dose after pruning for flushing during post monsoon season. Cocoa in the first year of planting should be given 1/3rd, in the second year 2/3rd of the recommended dose and from third year onwards, full dose of fertilizer should be given.

Deficiency and toxicity symptoms of different nutrients

Visual symptoms of nutrient deficiency can also indicate the fertilizer requirement of cocoa. Several studies have been conducted to know the symptoms of nutrient deficiency and toxicity. Simple key for identification of symptoms are given below:

Nutrient deficiency symptoms in cocoa



Potassium deficiency



Zn deficiency

Iron deficiency



Boron deficiency

Manganese deficiency

Nutrient	Deficiency symptoms
Nitrogen	Pale yellow leaves, size reduction, tip scorch in older leaves and petioles showing acute angle with stem.

Phosphorus	Stunted plant growth, size reduction in young leaves, stipules persisting after leaf abscission, young leaves showing acute angle with stem, paler tip and margin in mature leaves, followed by tip and marginal scorch.
Potassium	Pale yellow in interveinal region near leaf margin, quickly becoming necrotic, fusing later, rapid marginal necrosis between veins, yellow zone on inner surface of invading necrotic zone.
Calcium	Necrotic areas in interveinal region near leaf margin quickly fusing into continuous marginal necrosis of older leaves. Unaffected area showing oak leaf pattern.
Magnesium	Necrotic areas commencing in interveinal region near leaf margin, quickly fusing into continuous marginal necrosis of older leaves. Prominent bright yellow zone in advance of necrotic area and islands of necrotic tissue. Unaffected areas showing oak leaf pattern.
Sulphur	Leaves of whole plant pale yellowish or yellowish green in colour, no size reduction, yellow blotches on older leaves, new flush leaves normal in size, at first bright yellow in colour with no green associated with the veins, later becoming pale yellowish green like older leaves.
Iron	Younger leaves showing darker green veins against paler green background, or showing green tinted veins against pale yellowish white or almost completely white background, developing tip scorch.
Manganese	Younger leaves pale yellowish or yellowish green, later developing blurred chlorotic pattern in which the tissues in the vicinity of the midrib, main laterals and tertiary veins are prominently green against pale background, followed by scorching of the tip and distal margin.

Copper	Leaves on young flush small but normal in shape, young shoots frequently showing signs of wilting. Sudden collapse of tissues at tip of leaf, collapsed tissues remaining green for some time, later forming brown edge with apex directed towards midrib. No marked chlorotic pattern.
Zinc	Very young leaves showing prominent dark red veinlets with considerable distortion, chlorosis, crinkling of leaves with very narrow often wavy margin, little leaf, sickle-shaped with small chlorotic patches in distinct row on each side of midrib and main lateral veins, premature defoliation and die back of twigs.

Calcium deficiency is one of the causes for cherelle wilt in cocoa. Foliar and soil application of calcium can reduce cherelle wilting. Important micronutrient disorders reported are Zinc (Zn) and Iron (Fe) deficiencies. Zn deficiency is common in India and the earliest remedy is foliar spraying with a solution of 300g of zinc sulphate and 150 g of lime in 100 litres of water. Soil application of Zn @ 10 - 20 g per tree once in two years is also advisable based on age of the tree.

Iron deficiency is occasionally seen and can be cured by repeated spraying of 1% aqueous iron sulphate solution.

Irrigation

Cocoa is mainly grown in irrigated arecanut and coconut gardens. As rainfall occurs only from June to October, the remaining period remains dry. Sprinkler irrigation is not advisable to cocoa as this will affect the pollination. The studies conducted showed that drip irrigation is better than sprinkler irrigation with respect to growth of the cocoa plants. A study was conducted to find out optimum water requirement through drip irrigation at various levels of fertilizers. It was concluded that 20 litres of water per day per tree through drip irrigation at recommended level of fertilizer (100:40:140g-N:P₂O₅:K₂O/ tree / year) is optimum for achieving maximum yield from cocoa when it is intercropped with arecanut.

Drip irrigation requirement of cocoa can be

computed by considering the following thumb rule. Based on modified penman method, it is derived that one mm of pan evaporation is equivalent to 3.3 lit of water. This will enable farmers to know the water requirement based on weather data of particular location. This implies that 20 lit of water per day per tree are required through drip irrigation if evaporation is 6 mm. Thus, water requirement is less during winter and increases during March - May.

- Flood/ furrow irrigation: Once in five days, 175 litres of water
- Drip irrigation: 20 litres of water/ day/ tree.
- Fertigation: Urea- 107 g , Di Ammonium Phosphate (DAP)-145 g, Muriate of Potash (MOP)-180 g

Pruning

It is an important operation in cocoa especially when it is grown as an intercrop. It is a regular practice in all the cocoa growing countries except in West Africa. The main objective of pruning is to maintain the shape of the cocoa plant to make it more productive and efficient. Formation pruning and maintenance pruning are the two types of prunings generally practiced in cocoa.

Formation pruning: This is practiced for the young cocoa plants. The objectives of this pruning are adjustment of height of the first jorquette and control of vertical growth. For easy operations in the field the preferable jorquette height is 1.5 to 2.0 m. Normally the height at which the jorquette is formed depends upon the shade condition in the garden. Low shade intensity leads to jorquette formation at lower height. When the jorquette is formed at lower height it will be removed at an early stage to facilitate upward growth. The jorquettes have five fan branches. Cocoa plants derived from fan branches tend to produce low and brushwood like canopy. Under such circumstances, the best method is to leave 3-4 branches low down. The decision to control vertical growth depends upon the cropping system and the convenience of the farmer. Generally the vertical height is restricted to first jorquette. All the chupons arising from below the jorquette have to be cut regularly to maintain the height. If there is any damage to the jorquette, then one of the chupons is left for the development of next jorquette. Grafted and budded plants will give bushy appearance in the initial years.

Maintenance pruning: This pruning is done annu-

ally compulsorily on mature trees to maintain the structure, health and vigour of the tree after main harvest.

Pruning in cocoa is necessary

- To decide height of first jorquette, no. of jorquettes/ tree, no. of fans/ jorquette.
- Maintain medium tree size, cone/ umbrella shaped canopy architecture.
- Induce flowering & efficient fruiting.

Formation pruning: In young plants

- Adjust first branching height to 1 m.
- Allow 4 fan branches in 4 directions North South East West.
- Maintain single tier canopy.
- Remove chupons/ upward growing orthotropic shoots/ hanging branches.

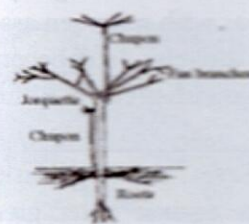
Structural pruning: In old trees

- Canopy spread of 3.8-4.0 m and height 2.7 m under arecanut/ coconut.
- Annual pruning- September.

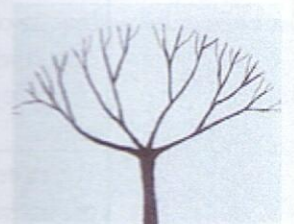
Sanitary pruning

- Remove diseased, dead shoots, rotten, rodent damaged pods, epiphytes, climbers, ant nests.

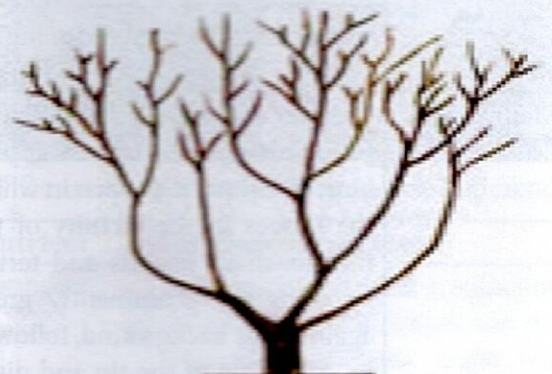
Pruning in cocoa



Plant habit of cocoa



Seedling tree



Grafted tree

Advisory to growers

- Proper cropping system and spacing is most important due to highly competitive nature of cocoa with the main crop.
- Pruning is an essential operation every year for easy adoption of horticultural practices.
- Provision of optimum water and nutrients to both main crop and cocoa is most important.
- Sprinkler irrigation with force will affect flower cushions in stem.
- Cocoa is very sensitive to Zn and K deficiencies. Thus, it is advisable to notice the symptoms at early stages and correct the same.
- Growing of vanilla or pepper or any other climber on cocoa stem is not advisable as it affects the flower cushions.

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