

## INTEGRATED NUTRIENT MANAGEMENT IN PLANTATION CROPS

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### ABSTRACT

Plantation crops are generally grown on resource poor soils. Unlike annual crops mismanaged perennial crops may never achieve the full production potential with very significant yield reductions and disastrous economic consequences. Plantation crops are managed to get a variety of produces, for e.g., from buds and leaves of tea, berries of coffee, latex of rubber and nuts of coconut palm. Fertilizer management in perennial crops is a continuous battle against soil limiting factors, varying nutrient demands in different stages of their growth. Out of the nutrient requirement of plantation crops *viz.*, 0.43 million tons of nitrogen, 0.24 million tons of  $P_2O_5$  and 0.62 millions tons of  $K_2O$  only 22 per cent is met through use of fertilizers. The huge amounts of crops residues containing appreciable quantity of nutrients produced by plantation crops are often not recycled into the system in a systematic manner. The potential of the nutrients in recycling of biomass generated in coconut, oil palm, arecanut, cocoa and coffee systems has been elaborated as 91740 t N, 11890 t  $P_2O_5$ , 62700 t  $K_2O$  for 2000 AD and a five-fold increase during 2025 AD. These organic forms of nutrients can improve soil health through their effect on soil physico chemical properties and microbial flora. Nevertheless, use of chemical fertilizers is the easiest way of boosting crops yield. However, its cost, government policies and environmental problems associated with it fear of low yields when not applied in balanced proportions deter the farmers from resorting the regular fertilizer application. Considering the behaviour of microbes, lignin-rich nature of the planting material, rate and extent of decomposition, it is necessary that techniques of composing the biomass and recycling by practicing integrated nutrient management assume significance. In fact INM is the key for nutrient management in plantation crops based systems.

There is a need to develop integrated production systems for each of the plantation crops. For tree crops, farming system is the best option for the INM. For each of the plantation crops an inventory of the resources available in the system, their characterisation and behaviour in soil has to be documented. The importance of secondary micronutrients and the INM methods through which these can be enriched in the soil needs investigation. WTO regime has opened up many challenges for plantation crops sector. To produce more and compete globally we need to guard the productivity potential of soil. INM offers many avenues in this direction. Besides the above is a need for a sound extension policy to propagate the benefit of INM in plantation crops systems.

Intensification of the agriculture in India is stripping the country's agricultural land of its precious physical and biological resources. The ever seeking goal of farmers for increased productivity without in any way considering the land resource sustenance will in years to come make irreversible damage to the life support system i.e. land. Earlier concept in 1960s of chemical fertilizers as the panacea for improving

the productivity of crops is not at all relevant today. Infact, it was as early as 1968, when Berry Commoner (Commoner, 1968) drew the world attention to the threat posed by inadvertent use of nitrogenous fertilizers leading to eutrophication and potential nitrate poisoning. The problem of less production and more mouths to feed made us to turn our eyes from this potential hazard. However, studies carried out in Punjab and

elsewhere have made the planners and research scientists take notice and to review the strategy. Still fertilizers will play a crucial role in our efforts to maintain the buoyancy in production. Their efficient use, should be the watch word for the researchers (Abrol & Katyal, 1990). The concept has now been fully revolutionized and the trend has changed towards sustainable agriculture.

Presently, sustainability implies the judicious use of natural resources without affecting its future potential. Technical Advisory Committee of the Consultative Group on International Agricultural Research has defined 'Sustainability as successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources' (TAC, 1989). We may have to understand here

that no single resource is more important to achieving sustainable agriculture than soil, which is store house of essential nutrients for plants, provide water and anchorage to the crops which it supports. It is here that the integrated nutrient management, which lays emphasis on improving and maintaining soil fertility for sustained productivity, forms one of its crucial pillars.

Integrated nutrient management includes the intelligent use of organic, inorganic and online biological resources (BNF) so as to sustain optimum yields, improve or maintain soil's chemical and physical properties and provide crop nutrition packages which are technically sound, economically attractive, practically feasible and environmentally safe (Tandon, 1990). Infact, this covers in short the economics of cultivation as well as environment. As proper

**Table 1. General characteristics and range of available nutrients in soils under plantation crops**

Soil/nutrient Characteristics	Range	Remarks/method
<b>A. General</b>		
pH	3.9-7.0	Varies with rainfall
E.C (ds/m)	0.01-0.3	No salt accumulation
Organic matter (%)	1.0-10.0	Varies with altitude, latitude and cultural practices.
CEC (C molc kg <sup>-1</sup> soil)	2.0-15.0	More than 50% CEC owing to organic matter
Clay mineral	Predominant kaolintie	Very low amount of k-fixing clay minerals
Soil texture	Sandy to clay	Varies with rainfall
Soil group	Latosol/Alluvial	Oxisol, Ultisol, Inceptisol and Entisol
<b>B. Nutrient status (ppm)</b>		
* N	0.01-0.05	Alkaline permanganate
P	1-25	Bray & Kurtz - p2, modified
K	30-250	Morgan's reagent
Ca	400-1500	1M NaCl - NH <sub>4</sub> OAc
Mg	25-55	1M NaCl - NH <sub>4</sub> OAc
S	23-55	0.1M CaC <sub>12</sub>
Zn	0.1-2.0	DTPA
Fe	6.0-12.0	DTPA
Mn	0.2-6.0	DTPA
Cu	0.1-2.0	DTPA
B	0.3-3.8	Water
Si	3-13	1M NaCl

\* - %

hygiene is necessary for human beings to prosper, adequate plant nutrition is of paramount importance for high yields of all crops. This requires careful assessment of not only the total quantities of nutrients needed for maximizing yields but also such factors as the proportions of each nutrient, timing and its placement under different growing environments in different management systems and minimizing the nutrient losses.

### **GEOGRAPHICAL DISTRIBUTION AND SOILS GROWING PLANTATION CROPS IN INDIA**

Plantation and spices crops are grown mainly in the states of Kerala, Karnataka, West Bengal, Assam, Tamil Nadu and Andhra Pradesh. These are mostly grown in humid tropical conditions between 20°N and 20°S of Equator. However, tea and coffee require comparatively cooler climate. The geographic distribution of plantation crops varies with the crop requirement. Tea is grown in high altitude followed by coffee and pepper under hill slopes and cardamom in the valleys of mountainous terrain. Cashew is generally grown on the hills and hill slopes of coastal belt followed by arecanut and cocoa in the valleys in the southern states. Coconut is mainly cultivated in coastal belt of west and east coast of India. Oil palm cultivation has been restricted to the command areas of major irrigation projects in the states of Karnataka, Tamil Nadu and Andhra Pradesh. The cultivation of rubber is on the hilly slopes of West Bengal, Karnataka, North East, Tamil Nadu and Kerala (Nair *et al.*, 1996).

The plantation crops in general are grown on resource poor soils. The major soil types are laterite, red and coastal sand. Apart from these, plantation crops are also grown in alluvial, coral and acid sulphate soils. The soils in general have poor physical properties and low native fertility. Proper on farm management and adequate moisture availability go a long way in determining the productivity of the crops in these soils. Tandon and Ranganathan (1988) have summarized the general characteristics and range of available nutrients in soils under plantation crops (Table 1).

Generally, soils under plantation and spice crops are acidic in reaction. The desirable pH range is 4.5 - 5.0 for tea, 5.5 - 6.5 for coffee, 6.0 - 7.0 for rubber, wide pH range for coconut and for other crops, i.e., slightly acidic to near neutral in reaction. Some soils under plantation crops are very acidic, thereby, toxicity of aluminum, manganese and iron poses problems in many situations. Tea is tolerant to high levels of aluminum, manganese and iron. However, coffee and cardamom are sensitive to aluminum and manganese toxicity. In such conditions, liming is required. Being high rainfall tract and mainly light textured soils, leaching of nutrients take place, thereby depleting the soil of the precious currencies.

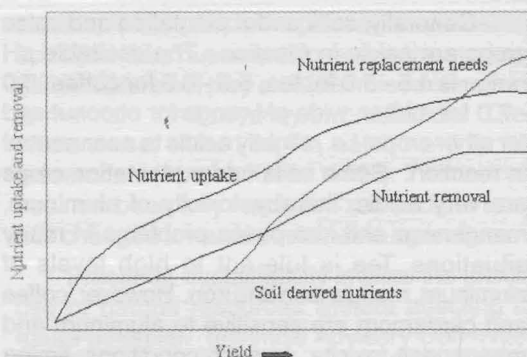
### **INTERACTIONS WITH THE PRODUCTION FACTORS**

Wallace (1984) describes the integration of disciplines viz. plant breeding and evaluation, soil fertilizer and management, weed control, irrigation, plant physiology, entomology, microbiology, pathology, mechanization etc. form the basis for what he describes as a "Multidisciplinary Revolution".

Tropical environments offer unique conditions for the production of high yields of numerous crops, provided the right combinations of management, inputs and other factors influencing output per unit area and unit time are utilized. Unlike annual crops, mismanaged perennial crops may never achieve their full production potential with very significant yield reductions and disastrous economic consequences.

### **NUTRIENT REMOVAL**

Von Uexkull (1978) systematically outlined nutrient uptake, removal and replacement needs as influenced by yield levels. The plantation crops being perennial in nature mine nutrients from limited volume of soil and hence, nutrients have to be replenished to maintain the fertility of the soil. Nutrient replacement needs increase at a faster rate than uptake and removal due to a limited root area for absorption (Fig. 1). Thus, the necessity arises to maintain nutrient supplies



**Fig. 1. Nutrient uptake, removal and replacement needs as affected by increasing yield levels**

at the point of slight luxury consumption, and increased leaching losses.

The nutrient supply is in general based on the nutrient removal, the losses to which the nutrient is prone to in the environment and the expected crop yield. In general, the nutrient removal by different plantation crops is given in Table 2. although variations due to site characteristics will occur, and the nutrient removal at the highest reported yields may differ

from those at average yield levels. The data illustrates the importance of maintaining both a favourable nutrient supply and balance for maximizing yields.

## FERTILIZER USE

By fertilizer management, we refer to the best known times and methods of application, other proven practices and sound decisions for applying the recommended doses of fertilizers to various crops. The management of fertilizer recommendations must also keep in view the end product for which a plant is grown and nourished. For example, tea is grown for its vegetative part (two leaves and a bud), coffee and cardamom for their seeds (the reproductive part), rubber is grown for latex (an exudate from bark), coconut and arecanut for nuts and oil palm for fresh fruit bunches.

Fertilizer management in perennial plantation crops is a continuous battle against soil limiting factors, (physical, chemical and physico-chemical). It requires a constant watch to identify and correct the series of limiting factors encountered in succession in the attempt to

**Table 2. Nutrients removed by various plantation crops**

Crop	Yield	Nutrients (kg/ha)			Source
		N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	
Coconut	40 nuts/palm (173 palms/ha)	56	27.3	84	Pillai and Davis (1963)
Oil palm	25 t fruit bunches	93.5	25.2	111.2	Turner and Gillbanks (1988)
Arecanut	-	79	28	79	Rethinam (1990)
Cocoa	1125 kg dried beans	25.5	11.5	60	Turner and Gillbanks (1988)
Pepper	-	53.3	8.16	1.6	Sadanandan (1994)
Cardamom	-	25.9	9.9	62.5	Korikanthimath (1994)
Coffee	1125 kg coffee	40	16.7	60.4	Turner and Gillbanks (1988)
Tea	1350 kg dried leaves	62.5	10.3	33.9	Turner and Gillbanks (1988)
Rubber	1928 kg dry rubber	19.1	8.7	18.6	Turner and Gillbanks (1988)
Cashew	1000 kg nut	88	25	42	Rethinam (1990)

\* nutrient removal mg/plant

sustain increasing productivity trend. The general fertilizer requirement is given in Table 3.

**Table 3. Fertilizer requirement of adult plantation crops**

Crops	Fertilizer dose			Organic
	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	Manure
<b>Group 1</b>				
Arecanut	100	40	140	12 kg
Coconut	500	320	1200	50 kg
Cashew	500	125	125	
Cocoa	100	40	140	
Oil palm	1200	600	1200	
Black pepper	100	40	140	10 t
<b>Group 2</b>				
Cardamom	75	75	150	10 t
Coffee	140	90	120	
Rubber	30	30	30	
Tea <sup>2</sup>	450	90	450	

1. Fertilizer dose for Group 1 is in g palm-1 year-1 and for Group 2 in kg ha-1
2. Yield of made tea 5000 kg / ha
3. 10 t FYM per hectare

Source : Rethinam (1993)

It is interesting to note from the observations of Nair *et al.* (1996), that the total fertilizer nutrient requirement of the plantation crops is estimated to be around 0.43 million t N, 0.24 million t P<sub>2</sub>O<sub>5</sub> and 0.62 million t K<sub>2</sub>O. However, only 22 % of the fertilizer nutrient requirement of the plantation crops is being met through the use of fertilizers. Thus, there exists a huge gap in nutrient supply.

### EVER INCREASING NEED FOR ALTERNATIVE NUTRIENT SOURCES

The over exploitation of the soil for the increasing productivity has led to a perceptible decline in the soil fertility and soil health. Evidences of unsustainable high yields achieved in green revolution belts viz. Punjab, Haryana, Western Uttar Pradesh, Andhra Pradesh and Tamil Nadu have been noticed inspite of liberal application of NPK. This has been attributed to

multinutrient deficiencies with secondary and micronutrients due to high nutrient mining by the crops (Palaniappan and Prasad, 1992).

The annual population growth rate of our country is around 2 %. The concept of high yield using high inputs will threaten our fragile agricultural system, if the nutrients exported through the economic produce exceed the natural replenishment rate for the nutrients and the externally supplied inputs. It has been rightly pointed out that for the next 50 - 100 years, the agricultural production especially in the developing countries have to be atleast 3 %, to maintain and improve nutrition and health and to enhance self reliance of the resource poor land users (Roy, 1993) without in any way impairing the soil health and environment. Considering the fact that increased chemical inputs can bridge the gap, the concern for soil health and sustainability of yields does call for use of alternative sources of nutrients viz. on farm waste, biofertilizers, FYM and green manures.

Long term fertilizer experiments have highlighted the impact of continuous use of chemicals on soil health. Accumulation of both zinc and phosphorus occurred with their continuous application (Biswas & Benbi, 1989). A buildup of phosphorus can prove antagonistic to zinc and iron nutrition of crops. Similarly, high levels of zinc can cause iron chlorosis (Katyal & Randhawa, 1983). Regular use of physiologically acid or acid producing fertilizers like ammonium phosphate over a period of 5 years to coconut palms lowered the soil pH compared to other P-carriers (Khan *et al.*, 1985). Regular use of ammonium sulphate and urea would result in microsite drop in pH (Abrol & Katyal, 1990), whose impact will be more in poorly buffered acid soils. Heavy metal contamination with cadmium deserves a special mention because of its inadvertent additions through phosphatic fertilizers. In India, experiments on cadmium accumulation in soils are lacking. Nevertheless, long term Swedish field experiments indicated that cadmium accumulation in soil due to phosphatic fertilization over a period of 17 years vary from 20-87 g/ha depending upon the rate of phosphorous used (FAO, 1975). The cadmium

content may reach levels which though not phytotoxic, may be harmful to the animals and human beings. Similarly, attention should be paid to other metals such as mercury, arsenic, lead etc.

The organic sources *viz.* crop residues, biofertilizers, green manures, various biological and industrial wastes are excellent source of plant nutrients, and are ecofriendly having profound impact on the soil health. Further, plantation crops being mostly grown on acidic soils may suffer from aluminium, manganese or iron toxicity. Here, the interaction of these cations in the organic matter may be of considerable importance in controlling soil solution levels of these ions in acid soils. It has been observed that acid soils rich in native organic matter, or amended with large quantities of organic residues, give low Al<sup>3+</sup> conc. in soil solution and permit good growth of crops under conditions where toxicities could otherwise occur (Bloom *et al.*, 1979).

Manganese toxicity that occurs in low pH regimes is reduced by thick organic mulch on cardamom plantations (Aiyar, 1966).

Application of organics has also enhanced microbial activity in the rhizosphere. *Beijerinckia* was observed as dominant N fixing bacteria in the rhizosphere. Twenty one isolates of bacteria, actinomycetes and fungi from the rhizosphere of coconut were found capable of solubilising tricalcium phosphate to varying extent (Nair and Rao, 1976a). Some of the bacteria and fungi isolated from the rhizosphere of coconut produced growth promoting substances. One isolate of *Escherichia* sp. was observed to produce IAA. Two isolates, one of *Aspergillus flavus* and other of *A. fumigatus* produced GLS (gibberelin-like substances) in the culture media (Nair and Rao, 1976b).

In general, nutrient needs of plants is confined to N, P and K. As the yield goal moves up, the nutrients demanded by crops also become varied and complex, hence the supply of NPK is inadequate (Nair *et al.*, 1996). The nutrient need for increasing levels of tea productivity in South India (Table 4) involves secondary and micronutrients in low quantities. Same example is relevant to other crops also.

**Table 4. Emergence of soil limiting factors in relation to productivity of tea in South India.**

Productivity	Limiting factor
Below 800 kg/ha	Nil
800 - 1000 kg/ha	N and K
1000 - 2000 kg/ha	N,P,K,Zn + liming
2000 - 3000 kg/ha	N,P,K,Zn + liming with material containing MgCo <sub>3</sub>
3000 - 4000 kg/ha	N,P,K,Zn,Mng,Si,B + liming; transport process with in the soil
Above 4500 kg/ha	N,P,K,Zn,Mg,Si,B,Mo + liming; transport process with in the soil

Source : Tandon and Ranganatham (1998)

## POTENTIAL OF PLANTATION SYSTEMS

In crop husbandry of plantation crops especially that of coconut and arecanut application of green leaves from external sources is a common practice. Notwithstanding its advantages on soil and crop health, of late, this has turned out to be a costly venture. Plantation crops produce large quantities of biomass *viz.* husk, dried leaves, coir dust, pruning, coffee husk, tea wastes, shedding, oil palm wastes etc. which can be effectively ploughed back into the respective systems to reduce the nutrient

**Table 5. Availability of on farm wastes/byproducts in plantation sector in India.**

Crop/Crop waste	Quantity available
*Coconut (excluding coir pith)	11.2 million t
Areca leaves	0.13 million t
Areca rachis	0.08 million t
Areca husk	0.22 million t
Cocoa shed leaves	360.03 t
Cocoa pruning	12056.33 t
Cocoa pod husk	32900 t
Coir pith	7.5 million t
Coffee husk	0.18 million t
Tea waste	0.22 million t

\* includes spadices bunch wastes, sheath, inflorescences and husks

Source : Biddappa *et al.* (1996)

**Table 6. Quantity of nutrient supplied by organics and that anticipated ('000 t)**

Crop Waste	Growth rate (%)	present (2000 AD)			2025AD		
		N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
Coconut	7.3	79.15	7.6	49.45	460.5	44.24	287.8
Arecanut	3.4	6.84	3.74	9.14	15.78	8.63	21.08
Cocoa	11.6	1.04	0.3.19	2.88	16.17	4.96	44.77
Oilpalm	8.6	0.003	0.000	0.009	0.024	0.004	0.066
Coffee	2.1	4.71	0.233	1.233	7.92	0.392	2.06
Total		91.74	11.89	62.7	500.6	58.23	355.8

requirement of the crop through chemical fertilizers. The quantity of onfarm waste available for recycling in the plantation sector is furnished in Table 5.

Varghese and Rethinam (1994) stated that cut fronds constituted a major source of organic manure in oil palm plantations yielding 10 tonnes of drymatter per hectare, a nutrient value equivalent to 58 kg urea, 30 kg rock phosphate, 120 kg muriate of potash and 70 kg kieserite per hectare. Nair *et al.* (1996) made an attempt to work out total quantity of nutrient supply that is potentially available through plantation wastes (Table 6). The amount of nutrient supplied would be in the order of  $9.2 \times 10^4$  t N,  $1.2 \times 10^4$  t P<sub>2</sub>O<sub>5</sub>,  $6.3 \times 10^4$  t K<sub>2</sub>O annually by 2000 AD.

In general, crop residues contain the remnants of nutrients after the plant has transferred its absorbed nutrients to its economic produce (about 75% of absorbed N and P, 50% of S and 25% of absorbed K) (Tandon, 1991). Thus, crop residues are more important sources of potash as compared to nitrogen and phosphorus.

In the case of most of the plantation crops, it has been observed that potassium is required in more quantity than other nutrients. Infact, the fertilizer recommendation itself is testimony to the important role being played by potassium in crop nutrition. In case of coconut, it was observed that husk accounted for 67 percent of the potassium and 85 per cent of chlorine. This indicates the considerable reduction in fertilizer requirement which can be achieved by leaving the husk in the field where it is quickly broken down, releasing the locked up nutrients to be

recycled (Ouvrier and de Taffin, 1985). One hundred husks will be able to provide 1 kg of potash apart from 270 g N and 150 g P<sub>2</sub>O<sub>5</sub> in the same period (Jothimani, 1994). Effect of husk burial will be observed from third year onwards and beneficial effect lasts for 5-6 years.

## INTEGRATED NUTRIENT MANAGEMENT PRACTICES IN VOGUE

Integrated nutrient management in its true sense as a scientific practice, has not received due attention in plantation crops. The topic has attracted due attention in the recent years.

The present manurial policy for tea in South India is based on INM system where nitrogen doses varies with the organic matter status in the soil and yield level (Table 7). Rate of potassium application is linked to nitrogen dose. A proper N:K<sub>2</sub>O ratio is maintained depending on the height of the pruning in the pruned year and on the sources of nitrogen in the other years (Verma and Palani, 1997). The pruning litter

**Table 7. Recommendation of nitrogen rate for mature tree**

Made tea	N dose (kg / ha) based on O.M.status		
	Low	Medium	High
Minimum	160	120	100
2000	240	200	180
3000	290	250	220
4000	340	300	260
5000	390	350	300
6000	440	400	340
7000	490	450	380

Source : Varma and Palani (1997)

available from the plant has high decomposability and manurial utility. There is enough scope for recycling pruning in tea gardens either by spreading on the floor of tea bushes or burying the pruning. This has helped to increase the organic matter status of soil. A yield increase of 9 % and 3 % was recorded in plots with pruning buried and spread on surface respectively (Table 8). We may also note that in the plots from where prunings are removed from the system, a gradual decline in organic matter of both surface and subsurface soil occurred. Leaf litter from shade trees like *Albizia chinensis* are other sources of organic matter to the tea plant. It was observed that during a four year cycle under South Indian conditions, 89 t of organic matter was lost from the soil. The addition of 20 t of leaf litter, 22 t of tea pruning, 5 t of weeds and 47 t of shade tree litter and loppings maintained the nutrient balance (Venkata Ram, 1975). Thus, estimates of organic matter addition and nutrient mineralisation can have far reaching effects on fertilizer use and overall productivity of the tea gardens.

Coffee in India is a silvi-horticultural crop grown under shade of natural forests. In a mature plantation shade trees contribute to about 10 t ha<sup>-1</sup> leaf litter. The recycling of nutrients and rich microbial population easily sustains a crop level of 325 - 500 kg clean coffee per hectare. In an integrated measure to support large crops, application of FYM or farm compost at 1200 kg ha<sup>-1</sup>, and based on soil test, liming, rock phosphate application, bone meal, wood ash etc. is practiced. Use of neem cake in nematode/white grub infested areas and biofertilizers is also a common practice.

In young coffee plantings, leguminous cover

crops have yielded 6-10 t dry matter per hectare. The coffee pulp and cherry husk are rated higher than cattle manure and have shown to be good ameliorants.

Aranguren *et al.*, 1982 examined Venezuelan coffee plantations that had received little or no fertilizers for 10 years and were grown in association with shade tree, *Erithrina* sp. and *Inga* sp. They found substantial reserve of N in 0-60 cm soil depth. The nitrogen flow associated with litter fall, which was dominated by shade tree fraction, accounted for a transfer of 86 kg N ha<sup>-1</sup>a<sup>-1</sup> out of the total of 189 kg N ha<sup>-1</sup>a<sup>-1</sup>. The decomposition of litter fall was rapid and some evidence of synchrony existed between nitrogen transfer to the soil and nitrogen demand by the crop plants.

Willams and Damit (1978) observed a strong interaction between mulching and fertilization on the yield of Robusta coffee. The inclusion of mulch increased yields by 94 per cent while the combination of mulch and better nutrition increased yields by 145 per cent.

The main spice crops that are grown in plantation scale are black pepper and cardamom. Though shed leaves and other available biomass is used for occasional mulching, no regular biomass recycling is practiced except application of 10 t FYM ha<sup>-1</sup> both in pepper and cardamom estates along with inorganics. For Bush pepper 200g FYM per pot is recommended. Studies have shown that growing of congosigmal grass (*Brassica* sp.) in between rows of pepper vines reduced soil erosion, and soil temperature and foot rot incidence of black pepper, increases subsoil moisture and improves the physical and fertility status of the soil. Secondly, maintenance

**Table 8. Effect of incorporation of pruning on the O.M. status of soil**

Treatments	Organic matter %			
	I cycle		II cycle	
	Surface	Subsoil	Surface	Subsoil
Control (pruning removed)	4.1	2.7	3.6	2.3
Burial of pruning	5.4	3.6	5.9	4.0
Chopping and spreading of pruning	5.0	2.9	4.9	3.0

\* Approximately 3200 kg/ha - Pandiaraj (1991)

**Table 9. Phosphate nutrition of cover crops in relation to growth of Hevea in Sri Lanka**

Phosphate treatments	Girth(cm) at 90 cm			Girth (cm) at 150cm height	
	1972	1973	1974	1975	1976
No P	19.61	27.44	37.65	41.70	45.51
P applied to rubber	20.92	29.89	40.63	44.76	46.71
P applied to cover crop	21.30	31.26	43.32	48.24	49.76
P applied to both	21.76	32.51	44.20	48.66	50.14
LSD	1.38	1.74	2.25	3.23	2.06

Source : Yogaratnam *et al.* 1978

of grass results in a yield of about 30 t of green fodder annually leading to increases in the system productivity (Sadanandan *et al.*, 1992).

In coconut- pepper mixed cropping system, following integrated nutrient management (black pepper vines were manured at 5 kg FYM, 0.5 kg each of neem cake and bone meal and N, P, K at 100, 40, 140 g per year per vine and coconut palms manured at the rate of 50 kg green leaves, 25 kg FYM and N, P, K at 0.34, 0.17, 0.68 kg per palm per year), the soil available nutrients and also the overall productivity of coconut and black pepper increased by 53 and 172 per cent respectively (Sadanandan *et al.*, 1991). FYM and vermicompost have been reported to increase yields of pepper by 119 and 74 %.

In Cardamom, 140 % increase in yield due to neem cake and vermicompost treatment has been reported over application of chemical fertilizers alone. In fact, integration of biocontrol agents and biofertilizers have strengthened the disease resistance especially against *Phytophthora* foot rot of pepper. Physico-chemical characteristics of soil, quality parameters like oleoresin content of pepper, 1,8 cineol and alpha terpinylacetate have been reported to be significantly higher in these plots.

Rubber is grown in soils, which are rich in organic matter, and it is being maintained by the leguminous cover. About 6 t ha<sup>-1</sup> year<sup>-1</sup> of leaf litter from mature rubber plantation (Krishna Kumari and Potty, 1992) and 3 to 5.6 t ha<sup>-1</sup> dry matter by growing leguminous cover crops in young rubber plantations (Kothandaraman *et al.*

1990) are available as natural nutrition to the crop. The inorganic nutrient application which is 50:50:20:7.5 in terms of N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O, MgO respectively during the 3rd year is scaled down to 30:30:30 in terms of N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O from the 5th year mature phase onwards. During planting, the pits receive 12 - 15 kg FYM or compost and in the later years the plantation is maintained with legumes and inorganics according to the desired production level and soil condition.

As part of nutrient management, fertilizing cover crops have been reported to be beneficial to the rubber crop in terms of mineral nutrition and soil fertility status. Applying rock phosphate to the cover crop was superior to an application to the tree only, as reflected in girth measurements. Phosphate can improve the growth of cover crops and the organic matter content of soils, both of which can influence P availability and uptake (Table 9).

In arecanut cultivation, the farmers are giving more emphasis to the application of organics. It has been recommended to apply 12 kg palm<sup>-1</sup> of organic manures to the crop. Studies by Chowdappa *et al.* (1999) have shown that vermicomposting of onfarm available waste materials in areca gardens can meet 50% N, 35 % P and 26% K requirement of the palms. Initial results of the field trial conducted since 1997 at Vittal have shown the superiority of arecanut palms manured fully with vermicompost in terms of growth parameters compared to other treatments.

Growing green manure crops inside the

**Table 10. Mean yield of green matter (1970-72), nutrient content and amount of nutrients added by different green manure crops.**

Crop	Green matter yield (t/ha)	Nutrient composition (%)			Nutrient addition (kg/ha)		
		N	P	K	N	P	K
Calopogonium muconoides	7.14	2.63	0.23	2.80	40.50	7.92	51.91
Pueraria	14.35	3.3	0.24	1.63	99.33	16.5	59.06
Stylosanthes gracilis	12.81	3.3	0.24	1.63	99.33	16.5	59.06
Mimosa invisa	12.62	3.96	0.34	2.00	111.67	21.6	67.90
Sesbania speciosa	5.18	2.70	0.17	1.12	31.32	4.51	15.64
Centrocrema pubescens	6.90	2.54	0.24	1.75	43.43	9.21	36.02
Crotolaria	3.39	2.81	0.27	2.12	20.51	4.51	18.62

garden can solve the problem of non-availability of green leaves for manuring. Green manure is different from FYM in that following its addition there is a deluge in the microbial metabolism. In variance, microbial decomposition during *composting makes FYM comparable to soil organic matter* (Bartholomev, 1965). Consequently release of nutrients associated with FYM is much slower (Katyal, 1980). Various estimates have shown that 40-45 days old green manure crop can supply upto 80-100 kg N/ha. Even if, half of this N is crop usable, a green manure crop could substitute for 50 to 60 kg fertilizer - N/ha (Abrol and Katyal, 1990). The rooting system and canopy characteristics of coconut and arecanut permit raising green manure crops either in basin or in interspaces, of coconut and arecanut garden. If grown in coconut basins 15-20 kg green matter per basin will be added, supplementing about 100-150g nitrogen per palm. In interspaces of coconut, about 3-4 t of green matter will be added, which will be equivalent to 20-111 kg N, 4-21 Kg P<sub>2</sub>O<sub>5</sub> and 15-67 kg K<sub>2</sub>O per hectare (Jothimani, 1994).

Mohapatra *et al.* (1970) recommended growing of leguminous cover crops in the arecanut garden to assimilate the atmospheric nitrogen and enrich the soil. They have tested

cover crops which can be raised in arecanut gardens or in vacant spaces adjoining the arecanut gardens along with their nutrient composition (Table 10).

With little effort *Gliricidia* can be a successful mixed crop in coastal sandy soils. Recent studies at CPCRI indicated that the crop can yield 2.3 t ha<sup>-1</sup> of toppings, which can meet 90% nitrogen, 25% phosphorous and 15% potassium requirement of the palms (Subramanian *et al.* 2000). This also supports the earlier studies by Liyanage and Jayasundera (1988) who reported that *Gliricidia* toppings @ 30 kg palm<sup>-1</sup> meets the total requirement of N and part of P and K, *reducing the cost of inorganic inputs by about 40%*.

Vermicomposting of late has gained quite popularity in the plantation sector for recycling the organic waste available in the system. In coconut gardens, roughly around 8 t ha<sup>-1</sup> of waste in the form of dried leaves, spathe and bunch waste are available. The low cost vermicomposting technology can provide an acceptable ecofriendly organic manure having a C:N ratio of 9.95 with 70% recovery. This organic manure has a nutrient composition of 1.2 - 1.8 % N, 0.12 - 0.2 % P and 0.2 - 0.4 % K. For subsistence farmers, techniques for *insitu*

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vermicomposting in the coconut basins have been developed by CPCRI.

Coir pith is an important waste available from coir industries. Around 7.5 million t is available annually (Kamaraj, 1994), causing environmental concerns in villages. In general pith is acidic in nature, having low bulk density and high porosity. The use of coir pith in agriculture has been reviewed by Savithri and Khan (1994). Field experiment in coconut, on substitution of chemical fertilizers by composted coir pith revealed significantly higher yield after four years in the treatment 50 % NPK applied as composted coir pith + 50 % NPK applied as chemical fertilizers (Annual Report, 1999. Central Plantation Crops Research Institute, Kasaragod. p.239).

Studies on coconut based cropping system involving clove, pineapple and banana as components of the system at Kasaragod have revealed that the treatment, one-third of the recommended dose of fertilizers was observed to be on par with the treatment, full dose of recommended fertilizers upto 14 years without any biomass recycling in the system. Later on, slight yield decline was observed and to offset this decline, the fertilizer levels have to be raised to two-third of the recommended dose. However, availability of biomass of around 12.7 t - 18.2 t per hectare in the system for recycling under various treatments was assessed. This biomass if recycled can enhance the productivity and sustain ability of the system (Table 11). Studies are in progress at Kasaragod on this aspect.

In Oil palm, studies suggest that organics applied palms perform equally to that of chemically fertilized palms. Normally, depending on the availability 75-100 kg of composted onfarm waste is applied to each palm. For vermicomposting, the species *Eudrilus euginae* is found to be efficient. For large scale production of compost, mixed starter method (with top soil, lime, ash and cow dung slurry) and compost as starter may be adopted.

### Thrust areas for future research

The economy of a developing country like India is linked to the agricultural production. We are caught in the vicious cycle of high production dependent on high inputs, jeopardizing the environment in the long run. At the same time majority of the non-estate sector farmers are resource poor.

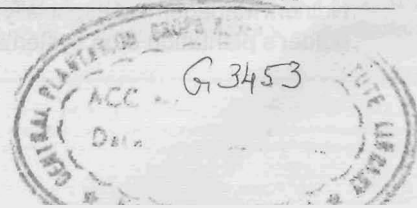
Use of chemical fertilizers is the easiest way of boosting the crop yields, however, its cost, government policies and the environmental problems associated with it, fear of low yields when not applied in balanced proportions deter the farmers from practicing chemical fertilizer application. Infact, the reduction in fertilizer subsidy has widened the N: P: K ratio to 10:3:1 in India and thereby aggravated the nutrition problem. These limitations can be overcome by judicious use of both organics and inorganics that are not only complimentary, but also synergistic and environment friendly.

Thus, alternatives of producing crops with much lower external input investment have to be considered.

**Table 11. Potential for nutrient recycling in coconut based cropping system at Kasaragod**

Treatments	Biomass for recycling	Nutrient recycling (kg/ha)		
		N	P	K
Full	18.196	110.30	13.46	225.10
Two - third	18.497	104.10	10.83	213.50
One - third	16.043	87.10	9.44	187.50
One - fourth	14.133	68.10	10.21	134.20
One - fifth	12.832	58.50	7.04	119.90
Cpmtrol	12.667	56.40	6.72	108.10

(Subramnian Pers. Comm.)



1. There is need to develop integrated production systems for each of the plantation crops in which the components may act freely, without the presence of limiting factors that restrict the attainment of new and higher yields.
2. Our ultimate goal has to be Low external input agriculture or developing a self-sustaining production system. For tree crops like coconut and arecanut the cropping or farming system is the best option for INM. This opens up excellent opportunities to practice low external input agriculture.
3. An integrated approach is required to supply nutrients with different options, suited to a particular region/agro-ecological regions to bridge the gap between the nutrient removed and fertilizer consumed and for the sustainability of crop productivity at a higher level. In organized estate sector with much more research, the inorganic input can be considerably reduced.
4. The vast potential of beneficial microbes associated with plantation crops has not been fully exploited. Emphasis must be given for use of biofertilizers for yield improvement and its subsequent integration in the nutrient management systems.
5. Bench mark data on total nutrient demand, nutrient removal in harvested and non-harvested products and the rate of nutrient accumulation, resources available within the plantation, resources that can be created, its mineralisation potential, rate and extent of decomposition are needed for each crop to arrive at an answer on rate, time, source and placement of various nutrients.
6. Presently, nutrients under investigations are mainly N, P and K and to a certain extent Ca and Mg. With the depletion of nutrients (not supplied) from the soil nutrient pool, there is a need to emphasize on secondary and micronutrients also.
7. To a certain extent information is available on these issues. We need a sound extension policy to propagate the benefits of Integrated Nutrient Management especially in the small holder's plantation crop systems.

With the coming of the WTO regime into picture, terms of trade are likely to worsen further and imported fertilizers are becoming costlier. In this context, it is time we look at other sources of nutrients that are profitable with respect to the economic produce of the plantation crops and lay emphasis on cropping system. Already attention has been focused from monocropping to the cropping/ farming system. Further, emphasis should be on nutrient recycling in the system to make it self-sustaining.

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