

Long Term Effects of Manure and Fertiliser on Plantation Crops in Humid Coastal Soils

Available information on the effect of long term application of manures and fertilisers on the productivity of plantation crops like coconut, coffee, tea and rubber grown in the coastal humid soils of South India and the influence of manuring on soil characteristics and leaf nutrient contents are reviewed in this paper. The crops respond very well to fertiliser application, but the importance of a particular nutrient element varies from crop to crop. Fertiliser application, in general enhanced soil available P and K contents, but available N was seldom affected.

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Plantation crops are grown in an area of about 3.3 million ha in India. They occupy only 2% of the total cultivated area, but contribute 80% of the export earnings from agricultural commodities. The major area of plantation crops is in the three southern states of Karnataka, Kerala and Tamil Nadu. Among the plantation crops tea, coffee, rubber and cardamom are grown mostly on commercial scale adopting scientific methods of production, whereas coconut, arecanut and pepper are grown mostly in homesteads, often without adopting the recommended package of practices. Cashew is grown under neglected conditions in poor soils, which are not suitable for other crops.

Fertiliser requirements and use for plantation crops are influenced by a number of factors (16). They are:

1. Once planted, the crops remain productive for periods ranging from 20 to more than 80 years.
2. Roots are coarse, less efficient and less evenly distributed through the top soil, but make better use of water and nutrients in the subsoil.
3. They are grown on soils having serious chemical and physical constraints. As the fields are rarely ploughed, correction of structural and chemical defects and fertiliser distribution and incorporation are more difficult.

4. Plantation crops generally have relatively lower N and P requirements and higher K and Mg requirements than annual crops growing on the same soil.

These crops are characterised by a long pre-bearing period lasting even upto 7 or 8 years and the influence of management practices applied in the early years lasts during the entire productive life. Response to fertiliser application is manifested after a time lag in crops like coconut. Hence, experiments on plantation crops are usually of longer duration. The results of long term fertiliser experiments conducted on plantation crops like coconut, coffee, tea and rubber in the humid coastal soils of South India are reviewed in this paper with reference to their effect on yield, soil characteristics, leaf nutrient content, etc.

Coconut

Coconut is cultivated in an area of 1.23 million ha in India with an annual production of 6400 million nuts. It is grown under highly heterogeneous soil conditions ranging from coastal sand to clay, from poorly drained low lying marshes to well drained uplands and hill slopes and strongly acidic to highly calcareous soils (8).

A long term fertility management experiment was initiated as early as 1919 at the then Central Coconut Research Station (now Central Plantation Crops Research Institute), Ka-

saragod. The treatment details given in Table 1. In the beginning commercial fertilisers were not available, the nutrients were obtained through natural sources. Each palm manurial treatment received 2 kg fish guano, 18 kg of wood ash, 18 kg of green leaves per annum in 1950 and 1.36 kg ammonium sulphate, 0.9 kg superphosphate, 0.9 kg potassium sulphate of potash and 20 kg green manure per year thereafter. The recommended fertiliser dose of 500 g N + 320 g P + 1200 g K₂O/palm/year was adopted from 1968 with urea, urea + superphosphate and urea + superphosphate + potassium sulphate as sources of N, P and K, respectively.

During period I (1922-39) the mean yield recorded was 37 nuts/palm/year in plots receiving tillage and manuring (Plot 1), tillage only (Plot 2), and no tillage and no manuring (Plot 3), respectively. The variation in yield was reported to be greater in plot 2 compared to plot 1 (7).

Palms receiving cultivation and manuring, yielded on an average 44 nuts/palm/year as against 44 in palms receiving cultivation only and 15.8 nuts under neglect during period II (1933-79). A detailed examination of the yield revealed that palms receiving cultivation alone recorded greater increase in productivity during period II compared to period I. There was a decline in yield from 1956 onwards due to senility. However, the magnitude of yield decrease was higher

Table 1—Treatment schedules during the different periods in the long term experiment at Kasaragod

Plot No.	Period I (1919-32)	Period II (1933-71)	Plot No.	Period III (1972-82)
1	Digging round and manuring	Cultivation and manuring	I	Cultivation+chemical fertilisers+organic manures
			II	Cultivation+chemical fertilisers
2	Digging round but no manuring	Cultivation but no manuring	III	Organic manuring+forking in
			IV	Cultivation alone
3	No digging and no manuring (neglect)	No cultivation and no manuring (neglect)	V	Weed control using herbicides only
			IV	No weed control and no manuring (neglect)

Table 2—Yield of coconut genotypes under different fertiliser levels (July 1981-June 1983)

Genotype	Yield of nuts/palm/year		
	M ₀	M ₁	M ₂
WCT	34	67	84
COD×WCT	46	92	95
WCT×COD	26	79	80

the years. The cumulative yield during the 13th to 22nd years of planting (1976-1985) at zero level of N, P and K was 136.6, 192.8 and 27.6 nuts/palm, respectively. This clearly shows the importance of K in the nutrition of coconut palm.

The data presented in Table 3 also shows the importance of balanced fertiliser application for achieving higher nut yield in coconut as evident from the significant NK, PK and NP interactions. Application of either N or P without K drastically reduced the nut yield. The response to any one of these nutrients was also observed to be substantial, only when the other nutrients were present in adequate amounts.

In coconut, the response to manuring is manifested only after many years of continuous application. Mulyar and Nelliath (9) reported that in an experiment conducted at Kasaragod during 1953-1965, significant response to N was noticed after 2 years and to K after 4 years, but response to P was significant only after 9 years. The effect of N on copra yield was marked in the first three years of the experiment, but was small later on. In the case of P and K the situation was reverse. Though the mean increase in copra production due to K application over the 10-year period was only 13.9%, it was 21.8% for the last year of experiment.

Effect on soil physical properties

Joshi et al (4) studied the effect of long term cultural and manurial treatments on physical and water retention characteristics of red sandy loam soil. Plot receiving tillage + chemical fertilisers + organic manures recorded 0.33% organic carbon which was higher than that of tillage

palms receiving cultivation alone without manuring (from 51.7 nuts in 1933-48 to 38.9 nuts in 1959-72) than in cultivation and manuring plot (from 63.9 nuts in 1933-48 to 59.6 nuts in 1957-72). The mean yield of palms in the neglected plot was 14.1 and 16.5 nuts during 1933-48 and 1957-72, respectively. This shows that the minimum level of productivity without any input is around 15 nuts/palm/year.

As the palms became senile, underplanting was done in 1967. In 1972, each plot was subdivided into two and revised treatments were imposed. During the period III (1972-82), some of the palms died due to senility. Minimum deaths were recorded in plots I and II, which received cultivation + organic manure & chemical fertilisers and cultivation + chemical fertilisers. The mean yield/palm/year was 46.3, 40.4, 31.8, 23.7, 20.2 and 9.3, respectively in plots I, II, III, IV, V and VI. This clearly revealed that for obtaining a reasonably good yield, application of organic manures and fertilisers is essential along with regular cultivation of interspaces.

The response of these coconut genotypes viz., West Coast Tall (WCT), Showghat Orange Dwarf (COD) × WCT, and WCT × COD to three levels of fertilisers, i.e., no manure (M₀), 500 g N + 500 P₂O₅ + 1000 g K₂O (M₁) and 1000 g N +

1000g P₂O₅ + 2000 g K₂O/palm/year (M₂) was studied since planting of the seedlings (5). Fertiliser application had a positive effect on the early bearing of palms. The data revealed that I₁ dose of fertiliser doubled the yields of WCT and COD × WCT palms and increased the yield of WCT × COD hybrid three times. The hybrids COD × WCT and WCT × COD did not respond to higher level (M₂) of fertiliser application (Table 2).

Wahid et al (17) reported the results of a long term fertiliser experiment being conducted exclusively with chemical fertilisers at the Coconut Research Station, Balaramapuram, Kerala since 1964. The nutrient levels are: no N (N₀), 340 g N (N₁) and 680 g N (N₂), no P (P₀), 225 g P₂O₅ (P₁) and 450 g P₂O₅ (P₂) and no K (K₀), 450 g K₂O (K₁) and 900 g K₂O (K₂) per palm per year.

The results revealed that higher levels of N and K application significantly influenced the nut yield. The nut yield per palm under N₀, N₁ and N₂, respectively were 3, 12 and 16 after 12 years, and 43, 48 and 60 after 20 years of planting. Similarly, per palm yield under K₀, K₁ K₂, respectively were 0, 12 and 19 nuts after 12 years and 7, 68 and 77 after 20 years of planting. The response to P was observed upto P₁ level only. Further increase in P₂O₅ level decreased the nut yield marginally during most of

Table 3—Effect of nutrient interactions on the cumulative yield per palm, 1976-85

Treatment	Nitrogen levels			Phosphorus levels			Mean
	N ₀	N ₁	N ₂	P ₀	P ₁	P ₂	
K ₀	37	22	25	47	24	13	28
K ₁	179	324	451	267	384	304	318
K ₂	194	399	498	265	363	464	364
P ₀	139	161	279				193
P ₁	134	357	281				257
P ₂	138	227	415				260
Mean	137	248	325				

CD—126.

+ chemical fertilisers plot (0.24%). The two treatments did not differ in respect of their influence on water holding capacity, bulk density, particle density and porosity.

Influence on soil and leaf nutrient status

Khan et al (15) reported that regular application of chemical fertilisers over a 18-year period to coconut in red sandy loam soil resulted in a minimal increase in mineralisable N. The mineralisable N content ranged from 72 to 95 ppm under different treatments. However, the effect on leaf N content was more pronounced. The N content of 14th leaf was raised 1.6-1.7% in M₁ (500 g N + 500 g P₂O₅ + 1000 g K₂O/palm/year) and M₂ (double the M₁ dose) levels from 1.4% at M₀ level. Application of M₂ dose apparently had no effect on leaf N content. The available P content of soil was only 15 ppm in the no manuring treatment. It was improved to 64 and 93 ppm at M₁ and M₂ levels of fertiliser application, respectively. In spite of this huge increase in soil available P, leaf P levels could not be raised to the critical level even after 18 years of continued fertiliser application. Available K level was very low (19 ppm) in M₀ plot and was increased to 55 and 70 ppm at M₁ and M₂ levels of manuring. The low soil K status in M₀ plots was reflected in poor K content in the leaf, which was raised just above the critical level of 0.8-1.0 with fertiliser ap-

plication. Application of M₂ level, however, did not have any advantage over the M₁ dose.

Continued application of ammonium sulphate over a period of 22 years in a red loam soil resulted in a gradual reduction of soil pH. The values of pH were 4.9, 4.5 and 4.4 at N₀, N₁ (0.35 kg N) and M₂ (0.70 kg) levels, respectively (17). The available Mn content decreased with increase in doses of ammonium sulphate, values being 40.4, 31.3 and 25.9 ppm at N₀, N₁ and N₂ levels, respectively. On the other hand, regular application of 0.35 kg N/palm/yr as ammonium sulphate improved the available S status of soil two-fold. The enrichment was noticed even at 75 cm depth. Application of superphosphate @ 450 g P₂O₅/palm/yr increased the available P content of surface soil (0.25 cm) by 25 times. Phosphorus application decreased exchangeable K in the soil to 62.4 ppm from 85.8 ppm in the control (P₀). This might be due to replacement of K from the exchange sites in the soil by Ca present in the superphosphate.

In general, there was a build up of exchangeable K and organic carbon in plots receiving muriate of potash application. The soil exchangeable K content was also observed to depend on N application, with increasing doses of N application reducing the soil exchangeable K. This could be due to removal of K⁺ ions from the exchange sites by NH₄⁺ and H⁺ ions generated dur-

ing the nitrification process. Application of ammonium sulphate, superphosphate and muriate of potash did not influence the availability of Fe, Zn, Cu and Mg significantly.

Regular application of ammonium sulphate significantly increased the leaf N, Ca and Mg contents compared to control, but depressed leaf K content. Increasing levels of potassium application increased the leaf K content. The values were 0.54, 1.37 and 2.15 per cent at K₀, K₁ and K₂ levels, respectively. Application of superphosphate did not have any appreciable effect on leaf N, P, K, Ca, Mg and S contents.

Coffee

Coffee occupies an area of 0.23 million ha in India, of which Karnataka accounts for more than 50%. Coffee soils are mostly derived from granite and gneisses and occasionally from basalts and schists. They are lateritic in nature and are highly leached with an acidic pH (8). The soils are rich in organic matter and moderate to high in available potassium. But the P content is low to medium indicating the need for application of P (3).

Effect on yield

The first manurial trial in coffee was initiated in the year 1904 by Lehman. Iyengar and Awatramani (3) had summarised the results of a permanent manurial experiment carried out on Arabica coffee for over 25 years at Central Coffee Research Institute, Balehonnur (Table 4). The results showed that application of N alone increased the yield by 250 kg/ha over control (no manuring), while inclusion of P at 50 kg P₂O₅/ha fur-

Table 4—Response of Arabica coffee to fertilisers in a permanent experiment

Treatment	Yield (kg/ha)
1. Control	714
2. N ₅₀ P ₀ O ₀	966
3. N ₅₀ P ₁₀ K ₀	1136
4. N ₅₀ P ₁₀ K ₅₅	1074
5. N ₅₀ P ₀ K ₅₅	906

ther increased yield by 170 kg/ha. Addition of K at 65 kg K₂O/ha did not result in any yield increase.

In a later study at Kalpetta, Kerala, also on Arabica coffee, average yields for 12 seasons indicated that there was a linear increase in yield with increase in application of N:P₂O₅:K₂O from 40:30:40 (3383 kg ripe cherries/ha) to 160:120:160 kg/ha (3916 kg ripe cherries/ha) (8). There was no further increase in yield with the application of still higher dose of fertilisers.

Soil and leaf nutrient status

Raju and Deshpande (12) studied the influence of long term application of N, P and K on the soil pH, soil available nutrients and nutrient status of leaves in coffee. The soil nutrient status (0-25 cm depth) was determined after more than 20 years of continued application of chemical fertilisers. The results showed that continued use of fertilisers resulted in a significant decrease in the pH of the soil. The mean pH was 6.63 in the control (no fertiliser) and 5.30 at the highest fertiliser level of 495:374:495 kg NPK/ha. The available N status did not show any appreciable difference due to graded doses of fertiliser application. Application of higher levels of fertilisers increased the soil available P, K, Fe and Mn contents, but had no effect on the available Cu and Zn contents. The available P, K, Fe and Mn contents were 6, 197, 0.7 and 3.7 ppm, respectively, in the control plot and 461, 417, 4.7 and 144 ppm at the highest fertiliser dose.

Application of graded levels of NPK fertilisers did not influence the leaf N, Fe and Cu contents. The leaf P, K and Mn contents were increased by application of higher levels of fertilisers, but leaf Zn showed a gradual decrease. The leaf N content was 2.31% in the control and ranged from 2.49 to 2.59% in the fertilised plots. The leaf P and K contents were only 0.14 and 1.71% in the control plots compared to 0.16 and 2.28%, respectively, at higher levels of manuring. At the highest level of fertiliser application leaf Mn and Zn contents were 388 and 18.3 ppm as against 63 and 23.1 ppm, respectively, in the control.

Tea

South India, with an area of about 75,000 ha accounts for about one-fifth of the Indian acreage under tea. It produces 150,000 t of made tea, about 22% of the Indian production. Tea soils are mostly laterites, acidic in nature with a mean pH of 4.61, rich in organic matter (3.56 and 2.93% in 0-22.5 cm and 22.5-45.0 cm depths) and poor in available K. The mean available P is 34 ppm in the surface soil and 17 ppm in sub-soil (1). No permanent or long term manurial experiment is in progress on tea, except a few aimed at studying the effect of skipping of nutrients.

Ranganathan (13) reported that visual symptoms of potassium deficiency on tea plants was observed six years after withholding potassium application, but yield decrease was noticed in the very first year. The yield reduction was 17% in the first year and became 32% in the 13th year of withholding K application compared to plots receiving 40 kg K₂O/ha.

Potassium applied in the pruned year had a significant effect on the yield of tea in the pruned and subsequent years (14). For tea pruned at 35-40 cm height, increasing the K₂O level from 80 kg/ha to 140 and 200 kg/ha increased the yield not only in the pruned year, but also in other years (Table 5). For entire cycle, the yield increase was 6 and 12%, respectively, for 140 and 200 kg K₂O/ha, over 80 kg/ha.

In the case of tea pruned at 50-55 cm, application of 200 kg K₂O/ha

during the pruned year increased the yield by 3% over 150 kg/ha. For tea skiffed at 70 cm height, application of 390 kg K₂O/ha in the pruned year increased the tea yield by 5.1% and was found to be more advantageous than 240 kg/ha.

Rubber

Rubber is grown in about 400,000 ha and Kerala accounts for the lion's share of this area. Rubber cultivation is mostly confined to laterite and lateritic types of soil. In addition, it is also grown in red soils, forest soils and alluvial soils (2). Two long term fertiliser experiments, one on rubber grown in association with legumes ground cover and other in association with natural ground cover are in progress at Rubber Research Institute of India, Kottayam since 1971 using the clone RRIM 6000. The soil at the experimental site was low in available P, medium in available K and high in organic carbon and available Mg contents. In the experiment under legume ground cover, *Pueraria phaseoloides* was maintained from the second year, but it started drying from fifth year due to shading by rubber plants. Under natural ground cover, the undergrowth was slashed at regular intervals to avoid competition to rubber.

The experiments were laid out in split plot design with application of uniform dose of fertilisers (400 kg of 10:10:4:1.5 fertiliser mixture/ha) during first four years or first seven years as main plot treatments. The subplot treatments involved factorial combinations of two levels each of N,

Table 5—Effect of K applied in the pruned year to tea pruned at 35-40 cm height

Levels of K ₂ O (kg/ha)	Yield of made tea (kg/ha)				
	Pruned year	2nd year	3rd year	4th year	Total for the cycle
80	904	2597	3169	2634	9304
140	1056	2800	3349	2687	9892
200	1184	3020	3535	2718	10457
CD (0.05)	94	201	333	NS	391

N : 120 kg/ha in pruned year and 240 kg/ha in subsequent years.

P₂O₅ : 80 kg/ha in pruned year and 30 kg/ha in subsequent years.

P, K and Mg and two no manure plots. Under legume cover, the N levels were 20 and 40 kg/ha whereas under natural ground cover the levels were 40 and 80 kg N/ha. Levels of P, K and Mg were the same in both the experiments, viz., 0 and 20 kg P₂O₅, 16 and 32 kg K₂O and 0 and 6 kg MgO/ha/year.

Results during the immature phase (10) revealed that under legume ground cover girth increment showed negative response to application of higher levels of N and P (40 kg N and 20 kg P₂O₅/ha) compared to lower levels (20 kg N and 0 kg P₂O₅) and positive response to application of 32 kg K₂O/ha. With natural ground cover, N alone had a significant influence and application of 80 kg N/ha was found superior to 40 kg/ha.

Results during the first five years of tapping showed that under legume cover, N and P had no positive effect on yield. In the first year of tapping, application of 32 kg K₂O/ha recorded higher yield compared to 16 kg K₂O/ha (15).

In rubber grown in association with natural ground cover, fertiliser application was found advantageous and manured plots recorded higher yield compared to unmanured control. Application of 80 kg N/ha was superior to 40 kg/ha. The mean yield was higher in legume cover area during the first three years of tapping. But the trend got reversed in the later years (Table 6).

Results obtained so far have shown that while making fertiliser recommendations for rubber due consideration has to be given to the history of ground cover maintenance. When legume cover is not established, application of higher doses of N dur-

Table 6—Mean annual yield of rubber (kg/ha) under legume cover and natural cover

Year	Legume cover	Natural cover
1980	1175	1145
1981	1948	1685
1982	1949	1796
1983	2010	2115
1984	2293	2369

ing the initial years of tapping is necessary for obtaining higher yields, whereas in legume maintained areas there is scope for saving nitrogenous fertilisers (15).

Pushpadas et al (11) have reported that application of graded levels of N, P and K for 15 years did not have any significant effect on the leaf nutrient contents. Application of nitrogen in the form of ammonium sulphate depressed the soil pH and available K, Mg and Cu contents. Application of phosphorus as rock phosphate increased soil pH and available P, Mg and Ca contents. Potassium (muriate of potash) application increased soil pH and available K content.

Constraints

Plantation crops being perennials, experiments are generally conducted for long periods. The major constraints encountered in conducting long term manurial experiments in these crops are enumerated below:

1. Large areas are required for laying out field experiments. These crops are often grown in slopy lands with undulating topography and it is very difficult to get sufficient area with uniform depth, texture and fertility status for experimentation.
2. Crops like coffee, tea and cardamom are grown under shade. Differences in species of shade trees and quantity of organic matter recycled through leaf fall, loppings, etc. result in soil fertility variations which interfere with experimental results and interpretation of data.
3. Once planted, the crop remains for decades. Hence it is not possible to switch over to high yielding varieties/clones as and when they are released.

4. The influence of adverse weather conditions such as drought if often manifested over a period of time, which confounds the response to nutrients and management practices.

5. There is only limited scope for incorporating improved management practices at a later date.

Conclusion

Results of long term experiments conducted on different plantation

crops clearly establish the need for balanced fertiliser application to realise higher yields and to sustain high productivity during the life span of the crop. For crops like rubber, fertiliser recommendations are required to be made based on the ground cover management. Establishment of legume ground cover helped to reduce the requirement of nitrogenous fertilisers. In coconut, K and N are the most important nutrients. In coffee, highest response is obtained for N application, followed by P and often negligible to K. In tea, N and K are the two nutrients for which maximum response is obtained and the fertiliser management followed during the pruned year influences the crop performance during the entire pruning cycle.

Suggestions for Future Research

Comprehensive long term permanent manurial experiments are required to be laid out in different regions with improved high yielding varieties/clones of plantation crops. No such experiment has so far been reported in crops like cardamom and tea. The effect of long term usage of organic manures and chemical fertilisers on the physical, chemical and biological characteristics of soils needs to be evaluated. These crops are grown in slopy lands with high to very high rainfall conditions. Improper management and disturbance of vegetative cover may lead to soil degradation and soil erosion. This is to be studied in detail. Attempts may also be made to work out the nutrient balance of plantation crop ecosystems and to study the interaction of manurial practices with other aspects like ground cover maintenance, tillage, shade regulation, etc.

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