Nitrogen fixing trees in coconut based mixed cropping system

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By integrating nitrogen fixing trees in the coconut-based mixed cropping system the use of chemical fertilizers could be minimized. Reduction in the use of nitrogenous fertilizers checks the emission of nitrous oxide which has about 300 times the warming capacity of carbon dioxide, the major green house gas. The tree species introduced in the system will also assimilate carbon dioxide from the atmosphere and store it in the tree biomass and soil.

Introduction

In coconut-based mixed cropping system trees and shrubs of economic importance, annual or perennial crops and herbaceous seasonal crops are grown together in the same unit of land occupied by coconut. The trees and other woody components in the system are known to perform both productive and protective functions. Besides yielding food and medicines, they improve soil structure, minimize soil and water loss, enhance soil life and nutrient cycling, and influence microclimate and soil moisture regime. Some trees are also known to benefit the system as a whole by fixing atmospheric nitrogen and making it available to the associated crops through nitrogen transfer and other mechanisms. These trees, known as nitrogen fixing trees, exert a profound influence on the nitrogen status of the soil and minimize the need for external sources of nitrogen in the form of chemical fertilizers. In this way nitrogen fixing trees improve soil health and the quality of local environment.

Nitrogen Fixation

Nitrogen fixing trees belong to both leguminous and non-leguminous groups. In the leguminous trees nitrogen fixation takes place in the nodular structures developed on their roots. These nodules are formed as the result of a symbiotic relationship with certain bacteria called Rhizobia which are capable of fixing nitrogen in association with many species of leguminous plants. All the strains of Rhizobia, however, do not have the same capacity to fix nitrogen in root nodules. They are, therefore, grouped into effective and ineffective strains. The effective ones form well developed nodules, which are red or pink in colour and present in limited number on the upper part of the root system. On the other hand, the ineffective strains produce nodules in large numbers which are generally small, white and scattered all over the root system.

Among the nodulating legumes there are three categories of trees. One category nodulates only with the fast growing strains of *Rhizobium* whereas the other category nodulates only with the slow growing strains which are designated as *Bradyrhizobium*. The third category is capable of nodulating with both the *Rhizobium* and *Bradyrhizobium*. Apart from the leguminous trees, a large number of non-leguminous trees also nodulates with another group of nitrogen fixing microorganisms. These organisms

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are known as *Frankia* species which are actinomycetes. The host trees are known as actinorhizal trees. The common species of actinorhizal trees belong to the genera *Alnus*, *Casuarina* and *Allocasuarina* and secondarily, *Coriaria*.

Leguminous trees differ in their capacity to fix nitrogen and, hence, fall into two distinct groups. Those belonging to one group exhibit a high nitrogen fixing capacity whereas trees of the other group show only a low potential. Trees representing the former group are known to fix nitrogen in the range of 100-300 kg per ha per year. *Acasia mangium*, *Casuarina equisetifolia*, and *Leucaena leucocephala* belong to this category. Trees with low nitrogen fixing potential are known to fix only less than 20kg nitrogen per ha per year. *Sesbania sesban* and some species of *Acasia* like *A. albida*, *A. senegal* etc. belong to this category. The symbiotic association between leguminous trees and nodulating organisms can provide most of the nitrogen required by the host trees. Such association also contributes nitrogen to the soil through shed leaves and other plant parts including root debris and nodules.

Increased supply of carbohydrates to the root nodules from the host tree enhances nitrogen fixation. This indicates that nitrogen fixing trees with high photosynthetic efficiency can be potentially high nitrogen fixers. On the other hand, in trees with low photosynthetic efficiency the nodulating organisms often become parasitic. Likewise, nitrogen fixation will suffer when the nitrogen fixing trees are exposed to environmental stress such as drought, excessive shade, extremes of high or low moisture combined with high temperature, very low soil pH, and high content of soluble salts in the soil. The optimum temperature regime for nitrogen fixation is 25-30 degrees Celsius. When temperature exceeds this limit nodulation and nitrogen fixation become less efficient.

Nitrogen fixation fails when the nitrogen status of the soil is high. In such condition the root nodule organisms fail to fix nitrogen from the air but feed on soil nitrogen. The leguminous and other nitrogen fixing trees then compete with the component crops including coconut in the mixed cropping system for soil nitrogen. Similarly, deficiency of phosphate, calcium and potash in the soil limits the growth of nitrogen fixing trees and also inhibits nodulation and nitrogen fixation. In this regard the role of micorrhizal fungi living in symbiotic association with the feeder roots of higher plants is important. These fungi enhance the mobility of phosphorus in the soil and also of other nutrients like zinc, copper, molybdenum and potash. The increased availability of phosphorus and molybdenum has a stimulating influence on nitrogen fixation. In general, mocorrhizal associations are more common among nitrogen fixing trees.

Though the nitrogen fixing trees have the potential to enrich the fertility status of the soil through biological nitrogen fixation, the effect becomes manifest only when the conditions are optimum for the purpose. In general, the requirements for successful nitrogen fixation are the presence of efficient strains of nodulating organisms; low level of soil nitrogen; adequate availability of phosphorus, lime, potash and molybdenum; optimum soil moisture and good drainage; neutral to slightly acidic soil reaction and a temperature regime of 25-30 degrees Celsius.

Compatible Nitrogen Fixing Trees under Coconut

1. Gliricidia (*Gliricidia maculata* H.B.K.) (Syn. *Gliricidia sepium* Jacq.)

Gliricidia is a versatile green manure and shade tree commonly found in many parts of the world. In India it is extensively used for live fencing, providing support to black pepper and betel vines and shade to shade loving crops such as coffee, cocoa etc. The green lopping of the tree are valued as a green manure for different crops. About five decades ago special campaigns were organized regularly in Kerala for promoting the cultivation of gliricidia. But with more reliance on the use of chemical fertilizers in subsequent years the importance once assigned to green manure crops has waned and as time passed gliricidia has been slowly relegated to an insignificant position by the farming community. The apathy of farmers towards gliricidia cultivation was also strengthened by the propaganda that the tree, whether it is grown along the fence or in open fields, will compete with cultivated crops standing nearby for nutrients and water.

As a leguminous tree crop gliricidia promotes excellent nodulation on the roots and enriches

the fertility of the soil. It can be propagated easily through stem cuttings at the commencement of monsoon seasons, though seed propagation is also possible. The plant grows fast with the first trimming of green foliage becoming possible six months after planting. Large quantities of green lopping become available twice a year. The average annual yield of green foliage per ha is 10-15 tonnes. The foliage containing 23 percent crude protein and 1.2 percent calcium forms an excellent green manure. In a study in Sri Lanka hedge rows of gliricidia were established (2,000 plants) between coconut palms in one ha with a stand of 165 palms. The tree crop was pruned periodically and the trimmings applied to the coconut palms, which saved artificial nitrogen application. The results showed that 50 kg of fresh gliricidia biomass is sufficient to meet the annual nitrogen requirement of a mature coconut palm. In the studies in other countries the estimated annual addition of nitrogen by gliricidia is 13 kg per ha.

Gliricidia foliage also exhibits nematicidal properties. The foliage could be easily regulated in accordance with the requirement of the crops to which gliricidia provides shade or support for climbing. It coppices easily and puts up many branches. The foliage is also relished by cattle. The less recognized features of the tree are its usefulness as a timber and firewood source as well as a flowering tree. The tree which grows to over 10m high produces timber of good quality. The timber gives good finish and has been found suitable for furniture, agricultural implements and even for heavy construction. The wood has excellent fuel qualities with a calorific value of 4,900 kcal per kg. The tree has ornamental values as well. It produces dense masses of attractive white or pink flowers which are also a good source of forage for honey bees. A tree possessing such desirable characteristics has to receive an appropriate place in the coconut-based cropping system.

2. Coral Tree (*Erythrina indica*)

Erythrina is a small to medium sized thorny tree. It is propagated through cuttings or seeds. Larger cuttings of 1.5-2.0 m long establish more quickly and grow vigorously. Such cuttings on establishment serve as living and long lasting fence posts or as support for betel vine, black pepper, vanilla etc. The tree grows to a height of 10-15 m with a spreading crown and is used as an excellent shade tree in coffee and cocoa plantations. The tree also serves as ornamental by producing blood-red or red-and-yellow flowers in clusters at the branch tips.

The tree responds to pruning. The regrowth is faster when at least 15 percent of the foliage is left undisturbed. The annual yield of green foliage is from 10 to 50 kg per tree. The dry foliage usually contains 1-3 percent nitrogen. One disadvantage is that the tree sheds leaves and remains bare for long periods. Despite this, coral tree is a good source of green leaf manure and nitrogen. The estimated nitrogen fixation by the tree is 60 kg per ha per annum for a plant population of around 2,000.

3. Agati (*Sesbania grandiflora* (L.) Pers.)

Agati with a life span of over 20 years is grown in many States in India in monocrop culture as well as in agroforestry combinations. Though it can withstand water stress, it is best suited in areas favoured with an annual rainfall of over 1,000 mm. The propagation is through seeds or cuttings. It has a rapid growth rate particularly during the first three or four years and grows to a height of 10 m or more with a stem diameter of around 30cm. The tree on cutting back coppices rapidly, but frequent pruning or pollarding is not tolerated.

The exuberant foliage of agati is a good green manure. The foliage yield is more than 50 tonnes per year from one ha of pure crop. The estimated nitrogen fixing potential of agati is upto 600 kg per ha per year. The leaves, flowers and pods are all edible. The leaves contain 36 percent crude protein on dry weight basis and serve as good source of minerals and vitamin A. The flowers which are butterfly like and up to 10cm long are used as food. The tender long pods are also used as a vegetable in many places. The seeds constitute one of the richest sources of protein. The protein content is about 40 percent by weight of seeds. The leaves and pods are also relished by cattle. The digestibility of agati leaves is better than that of common forage grasses. The stem is a good fuel source, though not of comparable quality with that derived from traditional firewood trees. The wood with a fibre length of 1.1mm is suitable for pulping. The pulp derived from debarked wood has been found to produce better quality

of paper. The bark of the tree on cutting back yields a gum and a tanning agent.

Agati is a good shade tree for crops like coffee, cocoa, cardamom etc. The tree also serves as a good live support to pepper, betel and vanilla vines. The leaves shed by the tree provide good soil mulch and benefit the companion crops. In impoverished soils agati grows vigorously even without prior inoculation. In such soils the plant establishes easily, smothers weed growth and binds the soil with its extensive and deep root system. Agati is, therefore, a highly suitable leguminous nitrogen fixing tree crop for inclusion in coconut-based cropping system and also for regenerating eroded and impoverished lands.

4. Mangium (*Acasia mangium* Wild)

Mangium is a fast growing leguminous tree. Among the nitrogen fixing trees mangium exhibits high nitrogen fixing potential of 250 kg per ha per year and tolerance to adverse soil conditions. It puts up rapid growth even in highly eroded and degraded hill slopes and also tolerates water logging and soil pH of as low as 4.5. The optimum rainfall that favours normal growth of the tree is 1,000mm and above. Prolonged drought of 2-4 months, average minimum temperature of less than 15 degrees Celsius and average maximum temperature of over 34 degrees Celsius are not conducive to good performance of mangium.

Mangium is propagated through seeds either by direct sowing or by raising seedlings. Two to three month old seedlings are used for planting out. The tree commences flowering within two to three years after planting and matures by about 14 years. At maturity the tree would have attained a height of 25 m with a diameter at breast height of 30cm. The wood of mature mangium makes excellent particle board and serves as good quality timber. It could also be used for furniture and cabinet making and also as door frames. Mangium wood has a high calorific value of 4,800-4,900 kcal per kg and, hence, makes good fuel.

Cattle and goat relish the leaves of mangium. The tree is susceptible to attack by different pests and diseases. Mealy bugs and the nymph of a lepidopterous insect damage the roots and flowers. Disease incidence is mostly on young plants. The affected ones show general wilting, chlorosis and premature defoliation. Heart rot of mangium is regarded the most serious of all diseases. Mature and over mature trees are most commonly affected. In different places where mangium is cultivated 10 to 50 percent of the grown-up trees are found to have been affected by the disease.

5. Subabul (*Leucaena leucocephala*)

Subabul is a fast growing tree reaching up to 10m in height with a stem diameter of 10cm by the age of three years. The propagation is through seeds either by direct sowing or planting seedlings. It puts up branches after coppicing and produces large quantities of foliage. The dry weight of annual foliage yield ranges from two to 20 tonnes per ha and the nitrogen fixing capacity is upto 500 kg per ha.

The tree is susceptible to insect infestation. The seeds are known to be toxic to non-ruminant animals because of the presence of an amino acid mimosine. The foliage is an excellent source of high protein fodder for the cattle. The wood with a calorific value of 4,000 kcal per kg serves as good firewood.

6. Perennial Pigeon Pea (*Cajanus cajan* (L.) Millsp.)

Perennial pigeon pea is a shade and drought tolerant perennial shrub. It has a strong stem which grows to a height of 4-5 m. The plant produces large quantities of biomass with a dry weight, excluding that of grains, of up to 15 tonnes per ha per year. The estimated nitrogen fixing capacity is 40-50 kg per ha per year.

7. Casuarina (*Casuarina equisetifolia*)

Casuarina is a tall evergreen tree growing to a height of about 30m. The propagation is through seeds and cuttings. In coconut holdings the tree is generally planted along the border. The tree is a good source of firewood and charcoal. It improves organic matter and nitrogen status of the soil. The annual litter fall is 25-30 tonnes per ha and the annual nitrogen fixing potential is between 60 and 230 kg per ha.

The nitrogen fixing capacity could be enhanced by inoculating selected clones with effective strains of *Frankia.* Inoculated clones have been found to fix up to 90 kg of nitrogen per ha per year at a planting density of 2,000 trees per ha. With irrigation during summer months casuarina puts up good vegetative growth with enhanced nitrogen fixing capacity.

Conclusion

By integrating nitrogen fixing trees in the coconut-based mixed cropping system the use of chemical fertilizers could be minimized. Reduction in the use of nitrogenous fertilizers checks the emission of nitrous oxide which has about 300 times the warming capacity of carbon dioxide, the major green house gas. The tree species introduced in the system will also assimilate carbon dioxide from the atmosphere and store it in the tree biomass and soil. In this way the nitrogen fixing tree population in the system contributes to climate change mitigation besides supporting important ecosystem services. It is, however, important to observe that the expected level of nitrogen fixation takes place only in soils deficient in nitrogen. Although nitrogen fixation is impeded in fertile soils the trees could still perform protective functions benefiting the system as a whole.

Area and Production of Coconut - 2008-09

States /Union Territories	2007-2008 AREA ('000 Hectares)	% share	Production (Million nuts)	% share	Yield (Nuts /ha)	2008-2009 (Final) AREA ('000 Hectares)	% share	Production (Million nuts)	% share	Yield (Nuts/ ha)
Andhra Pradesh	101.32	5.32	1119.26	7.59	11047	104.00	5.49	970.00	6.17	9327
Assam	19.00	1.00	136.00	0.92	7158	18.80	0.99	147.10	0.94	7824
Goa	25.50	1.34	127.60	0.87	5004	25.61	1.35	128.18	0.81	5005
Gujarat	16.40	0.86	138.30	0.94	8433	15.98	0.84	157.42	1.00	9851
Karnataka	405.00	21.28	1635.00	11.09	4037	419.00	22.12	2176.00	13.83	5193
Kerala	818.80	43.02	5641.00	38.26	6889	787.77	41.58	5802.00	36.89	7365
Maharashtra*	21.00	1.10	175.10	1.19	8338	21.00	1.11	175.10	1.11	8338
Nagaland	0.90	0.05	0.20	0.00	222	0.92	0.05	0.55	0.00	598
Orissa*	51.00	2.68	275.80	1.87	5408	51.00	2.69	275.80	1.75	5408
Tamil Nadu	383.37	20.14	4968.20	33.70	12959	389.60	20.56	5365.00	34.11	13771
Tripura*	5.80	0.30	11.40	0.08	1966	5.80	0.31	11.40	0.07	1966
West Bengal*	28.60	1.50	355.50	2.41	12430	28.60	1.51	355.50	2.26	12430
A & N Islands	21.60	1.13	80.60	0.55	3731	21.69	1.14	82.00	0.52	3781
Lakshadweep*	2.70	0.14	53.00	0.36	19630	2.70	0.14	53.00	0.34	19630
Pondicherry	2.20	0.12	26.60	0.18	12091	2.10	0.11	30.70	0.20	14619
All India	1903.19	100.00	14743.56	100.00	7747	1894.57	100.00	15729.75	100.00	8303

Source: Directorate of Economics & Statistics, Ministry of Agriculture, Govt. of India.

*For 2008-09, data of 2007-08 repeated