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# Organic black pepper (*Piper nigrum*) cultivation on *Gliricidia* standards in coconut (*Cocos nucifera*) plantations in South Andaman: organic matter production and recycling of nutrients

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ABSTRACT

A study was conducted in 2006–07 to estimate on-farm production of organic biomass, its decomposition and nutrient release in coconut (*Cocos nucifera* L.) – clove (*Eugenia cariophyllata* Thunb.) – *Gliricidia* [*Gliricidia sepium* (Jacq.) Kunth ex Walp.] and coconut–nutmeg (*Myristica fragrance* Houtt. Nees.) – *Gliricidia* plantations. The study was ultimately aimed to prepare a balance sheet of availability and demand of nutrients (N, P, K) in the plantations for organic black pepper (*Piper nigrum* L.) production on *Gliricidia* grown as standards between 2 coconut trees in South Andaman Island. Total organic biomass (litter) from leaf litter and fine root biomass of coconut, clove and nutmeg, coconut husk and pruning biomass of *Gliricidia* was 14.9 tonnes/ha/year in coconut–clove–*Gliricidia* and 14.4 tonnes/ha/year in coconut –nutmeg – *Gliricidia* plantation. Decay rate coefficient of most of the organic biomass ranged from 0.0009 to 0.119/day and decomposition time from 15 to 102 days indicating that nutrient release from the organic biomass was annual in the hot humid climate of the Island. The organic biomass together were found to recycle 190 kg N, 13 kg P and 129 kg K/ha/year in the coconut–clove–*Gliricidia* and 183 kg N, 12 kg P and 122 kg K/ha/year in coconut–nutmeg–*Gliricidia* plantation. Demand of N, P and K in the coconut–clove–*Gliricidia* was 191 kg N, 127 kg P and 365 kg K/ha/year, while it was 226 kg N, 129 kg P and 408 kg K/ha/year in coconut–clove–*Gliricidia* plantation. This indicates that 81–100% requirement of N, 9–10% of P and 30–35% of K can be met by the native trees through organic biomass recycling in the plantations. Organic black pepper production on *Gliricidia* ranged from 0.8 to 1.6 kg/standard.

**Key words**: Black pepper, Decay rate coefficient, *Gliricidia* standard, Nutrient budget, On-farm organic biomass production

Organic black pepper (*Piper nigrum* L.), being a constituent of many traditional/ethnic medicines, fetches a premium price in international market (Anonymous 1999). Farmers in the Andaman Islands are organic black pepper growers by default in their homegardens, which are a multistorey structure like other homegardens of South-east Asia (Millate-E-Mustafa *et al.* 1996, Pandey *et al.* 2007). Coconut (*Cocos nucifera* L.) and arecanut (*Areca catechu* L.) predominate in the homegardens (Pandey *et al.* 2007). Farmers grow black pepper traditionally on a few arecanut palms only for household consumption. Some progressive farmers grow it on *Gliricidia* standards in their coconut plantations at commercial level. The standard provides 3 to 4 times greater canopy cover than arecanut and adds nitrogen-rich pruning biomass to the soil.

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Sufficient organic matter is a constraint for commercial organic black pepper cultivation in the Islands (Magat 1993). Homegardens/coconut plantations are known to produce a reasonably good amount of leaf litter which recycles nutrients required to sustain productivity at low level (Pandey and Singh 2009). In natural systems fine root production and its turnover provide an ample amount of nutrients which contribute to the sustainability of the system (Nadelhoffer *et al.* 1985). But in homegarden/coconut plantations fine root biomass production and amount of nutrients released upon its decay are known less. This study was designed to estimate the on-farm organic biomass production, decomposition and nutrient release in coconut–clove (*Eugenia cariophyllata* Thunb.)–*Gliricidia* and coconut–nutmeg (*Myristica fragrance* Houtt. Nees.)–*Gliricidia* plantations; fine root biomass production and decomposition rate and nutrient release, and to prepare a balance sheet of availability and demand of nutrients in the plantations in South Andaman Island.

## MATERIALS AND METHODS

The study was conducted in 20-year-old coconut–clove and coconut–nutmeg plantations during 2006–07 at a research farm of the Institute at Sipighat, South Andaman Island of India (10°30′–13°42′N lat. and 92°14′–94°14′E long.). In addition a coconut plantation was selected on farmer's field at Meetakhari where black pepper (*Piper nigrum* L.) was grown on *Gliricidia* (*Gliricidia sepium* (Jacq.) Kunth ex Walp.) standards. The study site lies at 315 m above mean sea level. Soils were dystric fluvisols and the parent material was sandstone. The soils are well drained, sandy-loamy in texture, slightly acidic in reaction and moderate to poor in nutrients (Pandey and Singh 2009). The climate is equatorial humid tropical with temperature varying from 23.1 to 30.1°C (maximum in May and minimum in December) and rainfall 3 000 mm/year, mainly occurring from May to November (Pandey *et al.* 2007). Homegardens are the second major land use (4.6%) after forest (86% of total geographical area) in the Island. Garjen Bada (*Dipterocarpus grandiflora* (Blanco) Blanco), Gargen Chhota (*D. gracilis* Blume), Poon (*Calophyllum* spp. L.), Tam Timp (*Artocarpus chaplasha* Roxb.) and Tingam (*Hopea odorata* Roxb.) are dominant tree species in the forest (Pandey *et al.* 2007).

Layout of the studied plantations at Sipighat included coconut planted at 7.5 m × 7.5 m and clove and nutmeg planted quincunx-ally (one in the centre of 4 trees) as intercrops in separate blocks. *Gliricidia* standards were planted in the plantations with stem cuttings (5 cm in diameter and 1 m in length) between 2 coconut trees in 2003 at Sipighat and in 1997 at Meetakhari. Panniyur 5 black pepper was planted at 30 cm distance from the standard in 1 year old standards. At the time of sampling (2006–07) the black pepper vines were 4-year-old at Sipighat and 10- year-old at Meetakhari. Black pepper yield on *Gliricidia* standards was estimated at Meetakhari because the yield was stable at this location.

For the estimation of leaf litter production, 3 litter traps 50 cm × 50 cm size were installed under each clove and nutmeg tree spices. Litter was collected periodically (monthly). Under the coconut trees fallen leaves were collected directly from the floor due to their bigger size. *Gliricidia* standards were pruned 3 times a year, ie August, November and April. All the litter and *Gliricidia* pruning materials were dried at 60°C to constant weight and weighed. Leaf litter as well as pruning biomass production was estimated as a sum of the biomass over a year.

Fine root biomass of coconut, clove and nutmeg was sampled using 3 monoliths (15 cm × 15 cm) under 6 randomly selected trees in all the plantations at 1 month interval. Monoliths were washed with a fine jet of water using successively 2 mm and 0.5 mm mesh screens. Size of the fine root was 0.5 to 2 mm for coconut, 0.3 to 1 mm for clove and nutmeg. Live and dead roots were separated, dried (60°C) and weighed. Fine root biomass production was estimated as increase in live root biomass on successive sampling dates plus increase in dead root biomass.

Air-dried samples (leaf litter, pruning biomass and fine roots) equivalent to 20 g oven-dried were placed in nylon litterbags (20 cm×15 cm, 0.10 mm mesh size) separately. Only 10 g of fine root biomass was placed in the litter bags due to limited amount of samples. A total of 60 bags of each tree species were placed under the tree canopy in May 2006. The litter bags were well in touch with the soil. The litter bags were covered with nylon cloth (>2 mm size) and pegged at corners to avoid disturbances due to high speed wind. Five litter bags of each were retrieved at 30 day intervals, ringed gently to remove any soil and other extraneous material and dried at 60°C to constant weight and weighed, ground to powder and analyzed for N, P and K to know the amount of nutrient released.

Decay rate coefficient (k) of the decomposing organic biomass for the period was calculated through the negative exponential decay model of Olson (1963) and described by Yadav *et al.* (2008).

The oven-dried organic biomass samples were analyzed for N, P and K. For analyses of P and K the samples were digested in a di-acid mixture of 4 : 1 $HNO_3$: $HClO_4$ (Johnson and Ulrich 1959). Nitrogen was analyzed by Kjeldahl digestion method and P and K by the methods described by Allen *et al.* (1974).

Significance of differences in organic matter production by different components, concentrations of nutrients contained in the biomass, nutrients recycled and amount of nutrients required by the studied trees were analyzed by ANOVA carried out by using SPSS (Pc+) statistical package. Means were compared using LSD ($P$<0.05).

## RESULTS AND DISCUSSION

Organic black pepper production on *Gliricidia* standards in the plantation at Meetakhari ranged from 0.8 to 1.6 kg/standard. It was 4 times higher than the traditional black pepper production on arecanut tree.

Component-wise organic biomass (litter) production in coconut-clove-black pepper and coconut-nutmeg-black pepper plantations is given in Table 1. Total organic biomass (leaf litter + *Gliricidia* pruning + fine root) did not differ significantly between the plantations ($P$<0.05). But the highest leaf litter was produced by coconut and lowest by clove in both the plantations. Pattern of leaf litter production in coconut as well as nutmeg was uni-modal with a peak during the dry season (March to April) (Fig 1). On the contrary, we found bi-modal leaf fall pattern in clove (Fig 1). Coconut and nutmeg being evergreen shed their leaves round the year. Coconut trees shed an average one leaf during wet season and two leaves per month during dry season. This aseasonal pattern of leaf litter dynamics in coconut and nutmeg is well known

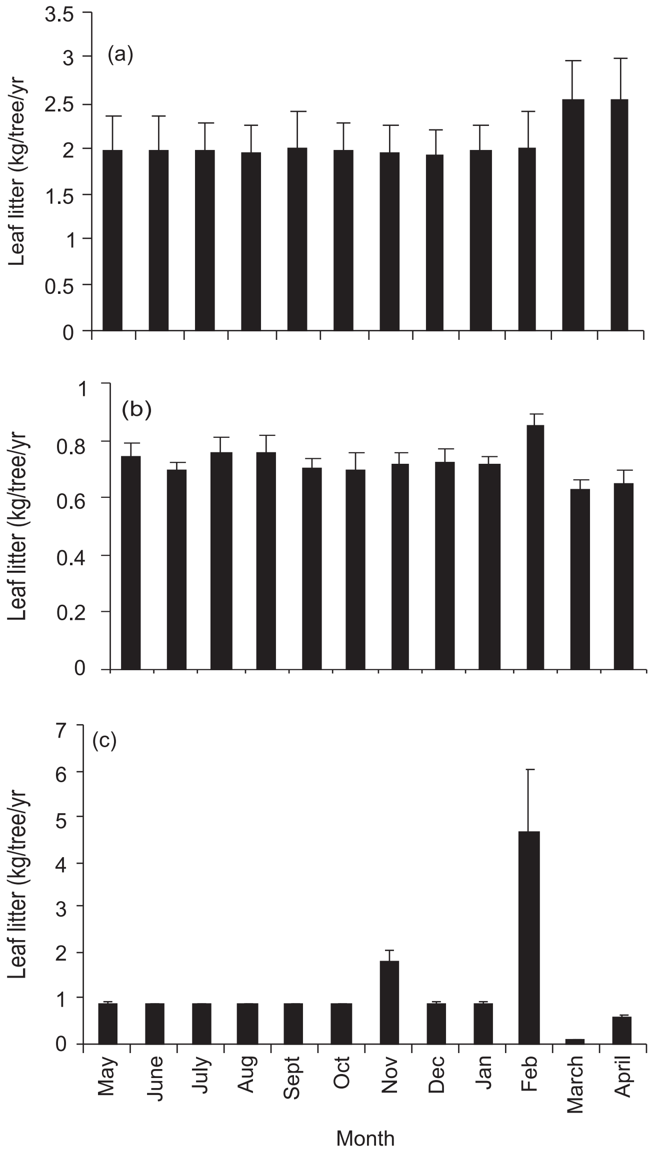


Fig 1 Seasonal pattern of leaf litter fall in (*a*) coconut (*b*) nutmeg and (*c*) clove trees in coconut–clove–*Gliricidia* and coconut–nutmeg–*Gliricidia* plantations at South Andaman Island

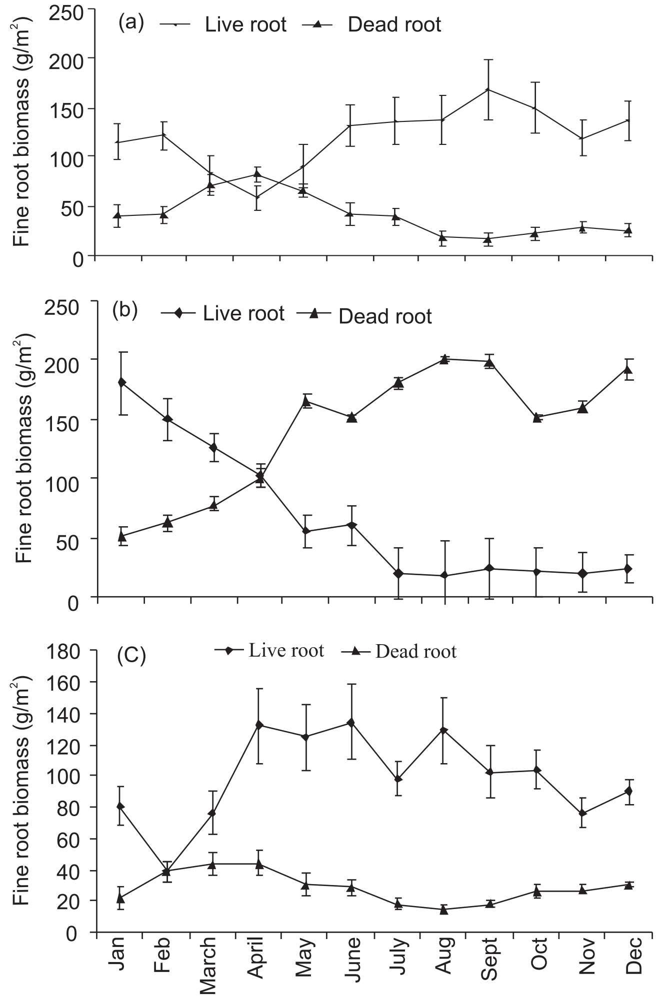


Fig 2 Seasonal pattern of changes in live and dead fine root biomass in (*a*) coconut (*b*) nutmeg and (*c*) clove trees in coconut–clove–*Gliricidia* and coconut–nutmeg–*Gliricidia* plantations at South Andaman Island

(Nair 1993). Clove being a deciduous shrub was found to shed maximum leaves in February (before onset of wet season). Total leaf litter production in our study was well within the range reported in the Javanese homegarden (10 tonnes/ha/year) of Indonesia (Benjamin *et al*. 2001) and forestry plantations (16.3 tonnes/ha/year) (Montagnini *et al.* 1993). But it was higher than evergreen forest of Amazon (7 tonnes/ha/year) (Medina and Cuevas 1996).

We found that fine roots in all the studied trees varied significantly due to trees and season ($P$<0.001). The highest fine root biomass was produced in coconut and lowest in nutmeg (Table 1). Live root biomass was highest during the wet season and declined during dry season in all the trees (Fig 2). Dead root biomass contrasted with the live root biomass and was the highest during the dry season and lowest during wet season. Decline in live root biomass during the dry season could be due to mortality caused by high temperature (Pandey and Singh 1992). No data are available on fine root biomass production in coconut plantations/ homegardens, however, Alpizar *et al*. (1986) reported 1.2 tonnes/ha fine root production in cacao-*Cordia alliodora* and Beer *et al*. (1990) found 2.6 tonnes/ha fine root production in cacao-*Erythrina poeppigiana* plantation. We found that turnover time of the fine roots in all the trees ranged from 38–47, days indicating that amount of nutrients contained in the roots are re-cycled within a year (Table 2). Chesney and Nygren (2002) found 180 days turnover time of fine roots in *E. poeppigianna* in an experiment at Costa Rica. Nadelhoffer *et al*. (1985) have reported that fine root biomass pool is replaced 0.5 to 2.2 times a year. Root litter is known to play an important role in the build-up of organic matter under

Table 1 Organic biomass production and nutrient recycled in coconut–clove–*Gliricidia* and coconut–nutmeg–*Gliricidia* plantations at South Andaman

| Organic biomass | Coconut–clove–*Gliricidia* | | | | Coconut–nutmeg–*Gliricidia* | | | |
|---|---|---|---|---|---|---|---|---|
| | Production (tonne/ha/yr) | Nutrient recycled (%) | | | Production (tonne/ha/yr) | Nutrient recycled (%) | | |
| | | N | P | K | | N | P | K |
| Coconut leaf | 4.52$^{a}$±0.97 | 42.08$^{a}$±3.87 | 0.58$^{a}$±0.07 | 18.60$^{a}$±3.51 | 4.73$^{a}$±0.87 | 44.04$^{a}$±9.56 | 0.60$^{a}$±0.03 | 19.46$^{a}$±4.41 |
| Coconut husk | 2.49$^{bc}$±0.80 | 3.44$^{b}$±0.87 | 4.18$^{b}$±0.87 | 12.55$^{bd}$±4.87 | 2.41$^{b}$±0.46 | 3.44$^{b}$±0.64 | 4.05$^{b}$±0.87 | 12.15$^{b}$±3.98 |
| Clove leaf | 2.53$^{b}$±0.87 | 32.13$^{c}$±10.50 | 0.28$^{c}$±0.03 | 11.64$^{c}$±2.87 | | | | |
| Coconut root | 2.24$^{c}$±0.64 | 23.74$^{d}$±9.78 | 1.12$^{d}$±0.11 | 13.22$^{d}$±4.18 | 2.31$^{b}$±0.49 | 24.49$^{c}$±8.40 | 1.16$^{c}$±0.86 | 13.63$^{b}$±4.12 |
| Clove root | 1.05$^{d}$±0.61 | 13.23$^{e}$±7.87 | 0.84$^{e}$±0.18 | 1.89$^{e}$±0.41 | | | | |
| Nutmeg leaf | | | | | 1.69$^{c}$±0.75 | 23.49$^{d}$±3.14 | 0.09$^{d}$±0.02 | 0.77$^{c}$±0.02 |
| Nutmeg root | | | | | 1.18$^{d}$±0.86 | 13.45$^{e}$±4.27 | 0.25$^{e}$±0.10 | 6.25$^{d}$±2.87 |
| *Gliricidia* prunings | 2.09$^{e}$±0.87 | 75.24$^{f}$±18.87 | 6.06$^{f}$±1.87 | 71.06$^{f}$±5.21 | 2.06$^{e}$±0.92 | 74.16$^{f}$±18.67 | 5.97$^{f}$±0.97 | 70.04±16.85 |
| Total | $^{a}$14.92±6.74 | $^{b}$189.86±34.24 | $^{c}$13.06±3.06 | $^{d}$128.96±24.87 | $^{a}$14.38±7.23 | $^{b}$183.07±31.98 | $^{c}$12.12±4.34 | $^{e}$122.30±21.76 |

Data in a column suffixed with different superscript letters are significant at $P$<0.05
Data in a row prefixed with different superscript letters are significant at $P$<0.05

Table 2 Decay rate coefficient (k) and decomposition time (t) of organic biomass in coconut–clove–*Gliricidia* and coconut nutmeg–*Gliricidia* plantations at South Andaman

| Organic biomass | k (per day) | t (50 %) | t (100%) |
|---|---|---|---|
| Coconut leaf | 0.0098 | 71 | 102 |
| Clove leaf | 0.0134 | 52 | 75 |
| Nutmeg leaf | 0.119 | 58 | 84 |
| Coconut husk | 0.0009 | 756 | 1 093 |
| Coconut root | 0.0215 | 32 | 47 |
| Clove root | 0.0261 | 27 | 38 |
| Nutmeg root | 0.0216 | 32 | 46 |
| *Gliricidia* prunings | 0.065 | 11 | 15 |

trees (Browaldh 1995).

Concentrations of N, P, K in different leaf litter and *Gliricidia* pruning biomass is given in Table 3. Highest C/N ratio (91.3) was observed in coconut husk and lowest (13.3) in *Gliricidia* pruning biomass. Decomposition pattern (weight loss) of different organic matter is given in Fig 3 a, b. It is apparent from the data that except coconut husk, nutrient release from leaf litter, fine roots biomass and *Gliricidia* pruning was annual (Table 2). Total 183–190 kg N, 12–13 kg P and 122–129 kg K/ha/year were recycled through leaf litter, coconut husk, root biomass and *Gliricidia* pruning biomass in the plantations (Table 1). Munoz and Beer (2001) in an old *Theobroma cacao-Erythrina poeppigiana* plantation found 13.9 tonnes/ha/year pruning biomass production that together with leaf litter and fine root turnover recycled 408 kg N, 39 kg P and 228 kg K/ha/year in Cost Rica. Total nutrients (N, P, K) requirement of the coconut, clove, nutmeg and black pepper is given in Table 4. Comparing the demand and recycled N, P, K in the plantations, nearly almost all the requirement of nitrogen is met out by the organic matter, but for P and K additional

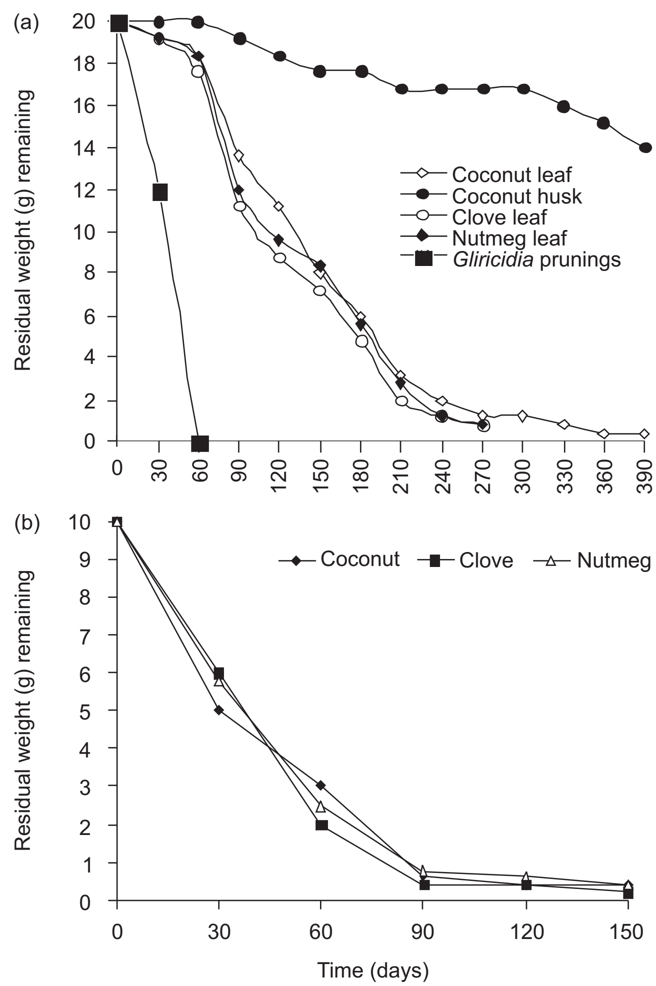


Fig 3 Weight loss pattern of (*a*) different components of organic biomass and (*b*) fine root biomass in coconut–clove–*Gliricidia* and coconut–nutmeg–*Gliricidia* plantations at South Andaman Island

Table 3 Carbon and N, P, K concentrations in the organic biomass in coconut–clove–*Gliricidia* and coconut–nutmeg–*Gliricidia* plantations at South Andaman

| Organic biomass | Carbon (%) | Nutrient content (%) | | | |
|---|---|---|---|---|---|
| | | N | P | K | C/N ratio |
| Coconut leaf | 44$^{a}$±08 | 0.95$^{a}$±0.08 | 0.013$^{a}$±0.001 | 0.42$^{a}$±0.09 | 46.3$^{a}$±1.9 |
| Clove leaf | 46$^{b}$±11 | 1.27$^{b}$±0.04 | 0.011$^{a}$±0.008 | 0.46$^{b}$±0.08 | 36.2$^{b}$±2.8 |
| Nutmeg leaf | 45$^{a}$±09 | 1.39$^{c}$±0.18 | 0.004$^{b}$±0.001 | 0.77$^{c}$±0.08 | 32.4c±2.2 |
| Coconut husk | 42$^{c}$±10 | 0.46$^{d}$±0.11 | 0.56$^{c}$±0.12 | 1.68$^{d}$±0.84 | 91.3$^{d}$±3.8 |
| Coconut root | 44$^{a}$±08 | 1.06$^{e}$±0.07 | 0.05$^{d}$±0.01 | 0.59$^{e}$±0.05 | 41.5$^{e}$±2.9 |
| Clove root | 46$^{b}$±09 | 1.26$^{f}$±0.87 | 0.08$^{e}$±0.01 | 1.89$^{f}$±0.43 | 36.5$^{b}$±3.8 |
| Nutmeg root | 45$^{a}$±06 | 1.14$^{g}$±0.60 | 0.02$^{f}$±0.01 | 0.53$^{g}$±0.03 | 39.5$^{e}$±4.5 |
| *Gliricidia* prunings | 48$^{d}$±07 | 3.6$^{h}$±0.87 | 0.29$^{g}$±0.10 | 3.40$^{h}$±0.84 | 13.3$^{f}$±4.5 |

Data in a column suffixed with different superscript letters are significant at $P<0.05$

Table 4 N, P, K requirements of crops in coconut–clove–*Gliricidia* and coconut–nutmeg–*Gliricidia* plantations at South Andaman

| Crop | Coconut–clove–*Gliricidia* | | | Coconut–nutmeg–*Gliricidia* | | |
|---|---|---|---|---|---|---|
| | Nutrient required (kg / ha /yr) | | | Nutrient required (kg/ha/yr) | | |
| | N | P | K | N | P | K |
| Coconut | 89.0$^{a}$(0.5) | 57.0$^{a}$(0.32) | 213.6$^{a}$(1.2) | 89.0$^{a}$(0.5) | 57.0$^{a}$(0.32) | 213.6$^{a}$(1.2) |
| Clove | 53.4$^{b}$(0.3) | 46.28$^{b}$(0.26) | 135.28$^{b}$(0.76) | | | |
| Nutmeg | | | | 89.0$^{a}$(0.5) | 48.06$^{b}$(0.27) | 178.0$^{b}$(1.0) |
| Black pepper | 48.05$^{c}$(0.132) | 24.02$^{c}$(0.66) | 16.38$^{c}$(1.0) | 48.05$^{b}$(0.132) | 24.02$^{c}$(0.66) | 16.38$^{c}$(1.0) |
| Total | $^{a}$190.45 | $^{c}$127.3 | $^{d}$365.26 | $^{b}$226.05 | $^{c}$129.08 | $^{e}$407.98 |

Data in parentheses are recommended dose (kg/ha) of N, P, K
Data in a column suffixed with different superscript letters are significant at $P<0.05$
Data in a row prefixed with different superscript letters are significant at $P<0.05$

sources of organic matters need to be explored. Jensen (1993) reported 1.6 tonnes/ha/year weed biomass production in Javanese homegardens, Indonesia that contained 22 kg N, 6 kg P and 53 kg K. In our plantations a huge amount of weeds are produced round the year due to high humidity and rainfall. Similarly, almost all homegardens in South Andaman have live fencing of *Gliricidia*, but farmers do not manage it for organic biomass production. Since, farmers in the homegardens do not cultivate crops in ground floor, leguminous cover crops like *Pueraria phaseoloides* may be grown as a source of organic matter. Dinesh *et al.* (2001) found that *P. phaseoloides* cover crop gave 4.7 tonnes/ha/year organic matter that recycled 152 kg N/ha/year at South Andaman. Therefore, further studies are required to quantify biomass production from weeds, *Giricidia* fencing and cover crops for organic black pepper production in homegardens of the Islands. Cowdung may be a good source of organic matter for organic black pepper cultivation in the Islands. Farmers have an average of 4 cows per homegarden in the Islands, and they let their cows to go into nearby forests for free range grazing (Pandey *et al.* 2007). Grasses in the forests are free from the residues of fertilizers, pesticides and other chemicals as they are not fertilized. The cows come back home during evening, but other than milking ones are neither provided with grains or concentrates nor they are allowed to rest in homegardens. If these cows are managed to take rest in enclosures during night, their cow dung might be used as a rich organic source of nutrients for the black pepper cultivation. Animal husbandry is found to be an important source of organic matter for organic farming in Austria where about 10% of the 201 500 farms are under organic management (Schneeberger *et al.* 2002). If animal husbandry is considered as one of the sources of organic matter, it is expected that almost all requirements of N, P and K could be met out by these organic matter produced at on-farm level in the Islands.

Structurally homegardens in the Islands are a multistorey vegetation, but a closer view reveals that generally they possess 2 stories of vertical structure in patches (palm-spice and palm-fruit trees) much like the plantations we used for the study. The data obtained, therefore, can be used to evaluate the suitability of other homegardens and agroecosystems similar in characteristics for organic black pepper cultivation. In most tropical homegardens 2-storey crop combinations are common (Kaya *et al.* 2002). In the homegardens of the Andamans, leaf litter generally decay on their floor which makes coconut, arecanut, fruit and spice productivity, though low, but sustainable (Pandey and Singh 2009). Several researchers have found average nutrient concentration of various homegarden vegetation fractions and ground litter quite similar to the average values reported from tropical natural forests and plantations (Jordan 1985, Jensen 1993). Litter production, decomposition and subsequent bio-element release, which endow sustainability to forests (Heal *et al.* 1997), are therefore relevant to the homegardens (Kumar and Nair 2004). Farmers of the Islands seem to know this secret by virtue of the knowledge they acquired from their ancestors and do not apply fertilizers to the trees in their homegardens. Therefore, they are organic producers of coconut, arecanut, spices etc. by default. But, they do not grow these items on commercial scale, probably due to 3 reasons. First, they lack the knowledge regarding the value of organic black pepper; second, they lack the facility of certification of organic black pepper; third they lack market for their produce. Therefore, extension wings of academic institutions, like Krishi Vigyan Kendra should educate them regarding the prerequisites for organic black pepper certification, and the government should provide them the facility for certification and market through APEDA.

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