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***Short communication***

# Carbon sequestration, soil health improvement and livelihood security through mango-based agroforestry system

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## ABSTRACT

**This present experiment on mango-based agroforestry system was carried out at on-farm experimental site of Daspalla block in Nayagarh district, Odisha during 2013-14 to 2016-17 under All India Co-ordinated Research Project on Agroforestry, Odisha University of Agriculture and Technology. The experiment was conducted in a randomized block design consisting of nine treatments, *i.e.* intercrops cluster bean, cowpea, brinjal, okra, blackgram, groundnut, *arhar*, sesamum and sole mango with three replications. Maximum mango tree height (2.46 m), basal girth (18.40 cm) and total tree biomass (0.326 t $ha^{-1}$) was recorded with mango + cowpea as intercrop at 48 month after planting. The highest net return of Rs. 55,340 $ha^{-1}$ and BCR 2.38 was recorded with mango + brinjal system. This system also generates maximum employment of 240 days followed by cowpea (200 mandays $ha^{-1}$) and okra (180 mandays $ha^{-1}$) compared to sole mango (50 mandays $ha^{-1}$). Among different agroforestry system mango + cowpea resulted in maximum improvement in soil organic carbon content (3.77 g $kg^{-1}$), available N (142.5 kg $ha^{-1}$), available P (16.87 kg $ha^{-1}$), available K (257.9 kg $ha^{-1}$), total carbon sequestration (8.36 t $ha^{-1}$) and equivalent $CO_2$ (0.82 t $ha^{-1}$) compared to initial value of organic carbon content (2.88 g $kg^{-1}$), available N (113.4 kg $ha^{-1}$), available P (9.44 kg $ha^{-1}$), available K (194.6 kg $ha^{-1}$), total carbon sequestration (7.03 t $ha^{-1}$) and equivalent $CO_2$ (0.30 t $ha^{-1}$).**

**Key words:** *Mangifera indica*, agroforestry, biomass, carbon sequestration, economics.

Planting of fruit tree is conceived as a potential strategy to meet the needs of local people, protect the environment and helps in conservation of biodiversity. Growing fruit trees with other crops under agroforestry systems gives more return along with protection against weed growth, reduce nutrient loss through leaching and surface runoff. During the initial year of tree establishment growing of different short duration field crops, vegetable and medicinal plants also offer significant opportunity for livelihoods improvement through nutritional and economic security of the poor people. Growing of different fruit and seasonal crops in different multitier system aims at sustainable management of natural resources like soil, water, space and environment. This system mostly comprising combinations of plants with various morpho-phenological features to maximize the natural resource use efficiency and enhanced total factor productivity. Intercropping and mixed cropping has potential to increase total yields above those of mono-cropping using the same resource base (Sangwan *et al.*, 9). Among different fruit trees mango is a multipurpose fruit tree suitable for agroforestry, which yields fruits, timber, fuels, etc. Selection of suitable intercrops in mango based agroforestry system for maximum return as well as to improve the soil fertility status mainly depends upon the agro-climatic conditions of the area, where the crop is grown.

Carbon sequestration in terrestrial ecosystem is referred as the absorption of $CO_2$ from the atmosphere by photosynthesis and their long term storage. Carbon sequestration is a mechanism for the removal of carbon from the atmosphere by storing it in the biosphere (Chavan and Rasal, 2). Carbon sequestration in growing forests is known to be a cost-effective option for mitigation of global warming and global climatic change. Therefore, agroforestry is an attractive option for climate change mitigation as it sequesters carbon in vegetation and soil, produces wood, serving as substitute for similar products that are unsustainably harvested from natural forests, and also contributes to farmer's income (Sudha *et al*, 16). Short rotation tree crops (fast growing trees), either as farm forestry or agroforestry systems, are considered an effective means to mitigate the greenhouse effect, due to their ability to accumulate substantial quantities of carbon in vegetation in a limited period. Hence, the present study was carried out in tribal farmer's field to identify the most profitable inter-cropping system to assess its impact on soil physico-chemical properties and carbon sequestration potential and livelihood security.

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This on farm experiment was conducted in tribal farmer's field in Daspalla block of Nayagarh district, Odisha during 2013-14 to 2016-17 in a new mango plantation planted in 2013 rainy season. The soil of the experimental site was lateritic soil (sandy clay loam texture) with poor in organic matter (organic carbon content 0.37%), available N (217 kg $ha^{-1}$) and P (8.5 kg $ha^{-1}$) but medium in available K (182 kg $ha^{-1}$). The mango grafts were planted in 2013 at 10 m × 10 m spacing. The experiment was laid out as per Randomized Block Design consisting of nine treatments (eight intercrops and sole mango) with three replications. The intercrops, *i.e.* cluster bean, cowpea, brinjal, okra, blackgram, groundnut, arhar, sesamum were sown and brinjal seedlings were transplanted 1.0 m away from fruit trees in both sides during second fortnight of June. The bio-metric observations on main crop mango, physico-chemical properties of the soil, yield and economics of mango based agroforestry system were recorded during the experimentation period. The bio-metric observation of trees, *i.e.* tree height was measured with help of a meter scale and the tree diameter was measured with the help of tree calipers. The physico-chemical properties of soil was measured as per standard procedures: the organic carbon content of the soil sample was determined by Walkley and Black's rapid titration method (Piper, 1950), bulk density was determined by cylinder method, available nitrogen was determined by the method described by Subbiah and Asija (1956), available phosphorus was determined by Bray's-I method (Jackson,1973) and available potassium was determined by equilibrating 5 gram of soil in 25 ml neutral normal ammonium acetate (Jackson, 1973).

Above ground biomass (green weight) of tree was calculated at 48 months of planting using the formula W= 0.25D2H (where, W is the above ground biomass in pounds, D is diameter of trunk in inches and H is the height of the tree in feet). On average 72.5% of green weight is considered as dry matter and rest is moisture. Thus, to calculate dry weight, the green weight is multiplied by 72.5% (Hajra and Pandey, 3). The below ground biomass has been calculated by multiplying the above ground biomass (AGB) by 0.26 factors as the root: shoot ratio. Total biomass is the sum of the above and below ground biomass (Pandya *et al*., 7). Generally, for any plant species 50% of its biomass is considered as carbon (Pearson *et al*., 8). The amount of soil carbon stock that was stored in a soil was calculated using the equation given by Broos and Baldock, (1), *i.e.* SCS (t $ha^{-1}$) = Depth (cm) × Bulk density ($g/cm^3$) × Organic carbon content (%). The total carbon sequestration is the sum of the carbon storage by plant and soil carbon stock. For determination of equivalent $CO_2$ t $ha^{-1}$, the carbon storage by plant was multiplied with 3.67 (44/12, where MW of $CO_2$ = 44 and atomic weight of carbon = 12).

The economics of each treatment was calculated considering the detailed cost of cultivation and market price of the produce. The net return for each treatment was calculated by deducting the cost of cultivation from the market price of produce obtained from each treatment. The net return is converted to return in rupees per hectare. The benefit: cost ratio was calculated by dividing the gross cost of cultivation with cost of cultivation for each treatment. The total labour requirement during one year for management of both mango tree and intercrop was expressed in mandays per year. The data recorded on various characteristics of soil, plant growth, yield and attributing characters were subjected standard statistical procedure.

The growth parameters of mango tree (Table 1) were higher under mango based agroforestry system than sole mango except mango + sesame system. The average height of mango ranged from 0.70 m to 1.13 m at 12 month, 1.01 m to 1.57 m at 24 month, 1.27 m to 2.05 m at 36 month and 1.52 m to 2.46 m at 48 month. The highest tree height of 1.13 m at 12 month, 1.57 m at 24 month, 2.05 m at 36 month and 2.46 m at 48 month were recorded with mango + cowpea followed by mango + blackgram, mango + cluster bean, mango + groundnut. Mango + sesamum system recorded the lowest mango tree height of 0.70 m, 1.01 m, 1.27 m, 1.52 m at 12, 24, 36 and 48 month after planting. The average basal girth of mango trees at 12 month ranged from 4.33 cm to 5.17 cm, at 24 month 5.87- 7.78 cm, at 36 month 9.54- 12.36 cm and at 48 month ranged from 12.76- 18.40 cm. The average crown spread of mango at 12 months varied from 0.70- 1.06 m, at 24 month 1.22- 1.86 m, at 36 month 1.40- 2.0 m and at 48 month 1.87- 2.57 m. The highest tree height, basal girth and tree crown spread of mango was recorded with cowpea. This is due to increased nitrogen availability through nitrogen fixation in the root nodules of cowpea. The increase in tree height was also confirmed by Swain and Patro (14) with mango + cowpea cropping system. Large amounts of biomass produced by the intercrops are recycled in the soil which increase the organic matter content and build up the soil fertility, which also might be the reason for improvement in the vegetative growth. The results are in line with the findings of Singh *et al*. (13) in mango and Swain *et al*. (15) in guava. However, the growth of mango trees is negatively affected when intercropped with sesame. All the growth parameters recorded at different growth stages are lower even compared to sole mango. This is due to higher

**Table 1:** Effect of intercroak on growth performance of mango tree.

| Treatment | Tree height (m) | | | | Tree basal girth (cm) | | | | Tree crown spread (m) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 12 | 24 | 36 | 48 | 12 | 24 | 36 | 48 | 12 | 24 | 36 | 48 |
| Mango + clusterbean | 0.87 | 1.30 | 1.75 | 2.17 | 4.98 | 7.24 | 11.12 | 17.25 | 0.94 | 1.70 | 2.0 | 2.30 |
| Mango + cowpea | 1.13 | 1.57 | 2.05 | 2.46 | 5.17 | 7.78 | 12.36 | 18.40 | 1.06 | 1.86 | 2.0 | 2.57 |
| Mango + brinjal | 0.80 | 1.23 | 1.63 | 2.0 | 4.85 | 6.60 | 10.30 | 16.12 | 0.85 | 1.58 | 1.90 | 2.18 |
| Mango + okra | 0.78 | 1.18 | 1.53 | 1.86 | 4.78 | 6.45 | 10.22 | 15.75 | 0.82 | 1.50 | 1.86 | 2.06 |
| Mango + blackgram | 0.93 | 1.40 | 1.85 | 2.25 | 5.05 | 7.52 | 11.50 | 17.88 | 1.0 | 1.82 | 2.10 | 2.45 |
| Mango + groundnut | 0.84 | 1.32 | 1.75 | 2.08 | 4.96 | 6.92 | 10.80 | 16.62 | 0.90 | 1.64 | 1.96 | 2.25 |
| Mango + arhar | 0.75 | 1.18 | 1.58 | 1.88 | 4.66 | 6.26 | 10.00 | 14.90 | 0.80 | 1.45 | 1.72 | 1.98 |
| Mango + sesamum | 0.70 | 1.01 | 1.27 | 1.52 | 4.33 | 5.87 | 9.54 | 12.76 | 0.75 | 1.36 | 1.64 | 1.90 |
| Sole mango | 0.78 | 1.13 | 1.42 | 1.68 | 4.53 | 6.18 | 9.88 | 13.40 | 0.70 | 1.22 | 1.40 | 1.87 |
| CD at 5% | 0.22 | 0.35 | 0.48 | 0.62 | 0.55 | 1.42 | 1.74 | 2.15 | NS | NS | 0.38 | 0.46 |

competition of sesame with mango for nutrients and water than other intercrops.

The soil parameters (Table 2) were improved over four year period in all the agroforestry systems compared to initial status. Mango + cowpea system recorded the highest organic carbon (3.77%), available N (142.5 kg $ha^{-1}$), P (16.87 kg $ha^{-1}$) and K (257.9 kg $ha^{-1}$) followed by mango + blackgram, mango + *arhar*, mango + groundnut and mango + cluster bean. The leguminous intercrops are responsible for fixation of atmospheric nitrogen and adding sufficient biomass to the soil thereby increasing the available nutrient status compared to other non legume intercrops. Among the mango-based agroforestry systems the lowest soil parameters were recorded with mango + brinjal, i.e. organic carbon 3.23 g $kg^{-1}$ and available N, K 130.3 and 231.7 kg $ha^{-1}$ and mango + sesamum recorded the lowest available phosphorus of 9.82 kg $ha^{-1}$ compared to sole mango (organic carbon 3.15 g $kg^{-1}$ and available N, P, K 122.6, 10.22 and 211.4 kg $ha^{-1}$ respectively. This is attributed to the higher uptake of nutrients by brinjal crop associated with its higher yield.

The increase in organic C content of soil under these intercropping systems might be due to the decomposition of biomass of leguminous crops. Similar findings on increase in organic C contents of orchard soil due to intercropping practices in mango orchard have been reported by Nath *et al.* (6) and Swain and Patro (14). The improvement in available N content of the soil under *in situ* incorporation of intercrops residues might also be due to fixation of atmospheric N through increased enzymatic and microbial activity in the rhizosphere by the aforesaid legume crops and release of bound nutrient after their decomposition in the soil. Similar results of increased available N content of the soil through intercropping in mango orchard have been reported by Kumar and Pandey (4), Swain and Patro (14).

**Table 2:** Soil physico-chemical properties as affected by agroforestry system.

| Treatment | BD (g $cc^{-3}$) | pH (1:2) | OC (g $kg^{-1}$) | Available N (kg $ha^{-1}$) | Available P ( kg $ha^{-1}$) | Available K ( kg $ha^{-1}$) |
|---|---|---|---|---|---|---|
| Mango + clusterbean | 1.45 | 6.94 | 3.60 | 138.6 | 14.10 | 247.2 |
| Mango + cowpea | 1.44 | 6.98 | 3.77 | 142.5 | 16.87 | 257.9 |
| Mango + brinjal | 1.46 | 6.88 | 3.23 | 130.3 | 10.30 | 231.7 |
| Mango + okra | 1.45 | 6.91 | 3.50 | 136.0 | 12.90 | 240.6 |
| Mango + blackgram | 1.44 | 6.96 | 3.71 | 140.4 | 15.33 | 252.8 |
| Mango + groundnut | 1.45 | 6.93 | 3.62 | 137.6 | 13.56 | 245.5 |
| Mango + arhar | 1.45 | 6.95 | 3.67 | 139.3 | 14.42 | 248.2 |
| Mango + sesamum | 1.46 | 6.92 | 3.48 | 134.5 | 9.82 | 236.3 |
| Sole mango | 1.47 | 6.74 | 3.15 | 122.6 | 10.22 | 211.4 |
| Initial | 1.48 | 6.67 | 2.88 | 113.4 | 9.44 | 194.6 |

Among different intercropping systems tried, cowpea recorded the maximum improvement of available P irrespective of intercropping systems. The increase in the availability of P content in the soil also due to beneficial effects of intercropping in increasing P availability in the soil have also been reported by Swain and Patro (14). The increase in availability of K contents in the soil might be due to increase in humus content of soil after decomposition of biomass of intercrops that builds up total population of beneficial microbes in the orchard soil. Similar results of improvement in nutrient status of soil due to intercropping have been reported by Kumar and Pandey (4), Mirjha *et al*. (5) and Swain and Patro (14).

The maximum total tree biomass and equivalent $CO_2$ (Table 3) were recorded with mango + cowpea (0.45 and 0.82 t ha$^{-1}$) which was followed by mango + blackgram (0.39 and 0.71 t ha$^{-1}$), mango + cluster bean (0.35 and 0.64 t ha$^{-1}$) and the minimum total tree biomass and equivalent $CO_2$ were recorded with mango + sesamum (0.13 and 0.25 t ha$^{-1}$). Total carbon sequestration was found to be maximum with mango + cowpea (8.36 t ha$^{-1}$), which was followed by mango + blackgram (8.20 t ha$^{-1}$), mango + *arhar* (8.09 t ha$^{-1}$) and mango + groundnut (8.03 t ha$^{-1}$) respectively and the minimum total carbon sequestration recorded with sole mango (7.03 t ha$^{-1}$). It is due to higher moisture content and higher nutrient status of the soil. The higher biomass with cowpea and *arhar* intercrops is attributed to their inherent ability for higher vegetative growth and resulting in higher biomass of mango trees.

The yield and economics of agroforestry systems (Table 4) indicates that, mango + brinjal produced the highest intercrop yield (9534 kg ha$^{-1}$), net return (Rs. 55,340 ha$^{-1}$) and BCR (2.38) followed by mango + okra (4027 kg ha$^{-1}$, Rs 45,540 ha$^{-1}$and 2.30) and

**Table 3:** Tree biomass, total carbon sequestration and equivalent $CO_2$ in mango-based agro-based system.

| Treatment | Tree above ground biomass (t ha$^{-1}$) | Tree below ground biomass (t ha$^{-1}$) | Total biomass (t ha$^{-1}$) | Carbon storage by plants (t ha$^{-1}$) | Soil carbon stock (t ha$^{-1}$) | Total carbon sequestration (t ha$^{-1}$) | Equivalent $CO_2$ (t ha$^{-1}$) |
|---|---|---|---|---|---|---|---|
| Mango + cluster bean | 0.28 | 0.07 | 0.35 | 0.17 | 7.83 | 8.00 | 0.64 |
| Mango + cowpea | 0.36 | 0.09 | 0.45 | 0.22 | 8.14 | 8.36 | 0.82 |
| Mango + brinjal | 0.22 | 0.06 | 0.28 | 0.14 | 7.07 | 7.21 | 0.51 |
| Mango + okra | 0.20 | 0.05 | 0.25 | 0.12 | 7.61 | 7.73 | 0.46 |
| Mango + blackgram | 0.31 | 0.08 | 0.39 | 0.19 | 8.01 | 8.20 | 0.71 |
| Mango + groundnut | 0.25 | 0.06 | 0.31 | 0.16 | 7.87 | 8.03 | 0.57 |
| Mango + arhar | 0.18 | 0.05 | 0.23 | 0.11 | 7.98 | 8.09 | 0.41 |
| Mango + sesamum | 0.11 | 0.03 | 0.13 | 0.07 | 7.62 | 7.69 | 0.25 |
| Sole mango | 0.13 | 0.03 | 0.16 | 0.08 | 6.95 | 7.03 | 0.30 |

**Table 4:** Intercrop yield, economics and employment generation these mango based cropping systems.

| Treatment | Intercrop yield (kg ha$^{-1}$) | Gross return (Rs. ha$^{-1}$) | Net return (Rs. ha$^{-1}$) | B:C ratio | Employment generated (mandays ha$^{-1}$) |
|---|---|---|---|---|---|
| Mango + cluster bean | 2346 | 35,190 | 10,190 | 1.41 | 145 |
| Mango + cowpea | 3146 | 62,920 | 32,920 | 2.10 | 200 |
| Mango + brinjal | 9534 | 95,340 | 55,340 | 2.38 | 240 |
| Mango + okra | 4027 | 80,540 | 45,540 | 2.30 | 180 |
| Mango + blackgram | 416 | 33,280 | 8,280 | 1.33 | 150 |
| Mango + groundnut | 1465 | 58,600 | 23,600 | 1.67 | 175 |
| Mango + arhar | 843 | 59,010 | 34,010 | 2.36 | 160 |
| Mango + sesamum | 572 | 34,320 | 9,320 | 1.37 | 135 |
| Sole mango | - | - | - | - | 50 |
| CD at 5% | - | 7,460 | 4,320 | 0.06 | - |

mango + arhar (843 kg ha$^{-1}$, Rs 34,010 ha$^{-1}$and BCR 2.36), respectively. The comparative yield and market price is high for vegetables than field crops. Sharma (11) and Singh *et al.* (13) reported that cultivation of brinjal as an intercrop in mango orchard recorded significantly highest yield and Sarkar *et al.* (10) observed the highest benefit cost ratio with brinjal intercrop in young mango orchard. The highest employment was generated by mango + brinjal (240 mandays ha$^{-1}$) followed by mango + cowpea (200 mandays ha$^{-1}$) compared to sole mango (50 mandays ha$^{-1}$).

Mango + brinjal agroforestry system produce the highest net return of Rs 55,340 ha$^{-1}$ with BCR 2.38 and this system also generate maximum employment of 240 mandays ha$^{-1}$ for farmer's family and mango + cowpea system improves the soil health, record higher mango tree growth and carbon sequestration. Therefore, in the initial years of mango plantation the farmers can be benefited by adopting mango + brinjal and mango + cowpea agroforestry system in alternate years which will also ensure additional benefit of better protection of mango trees from weeds and stray cattle and improve their livelihood security.

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