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Evaluation of Mango Based Agroforestry is an Ideal Model for Sustainable Agriculture in Red & Laterite Soil

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Crop productivity on red and lateritic soil is low due to poor management of lands and is not able to sustain arable crops. Again, monocropping neither provides gainful employment opportunity nor generates sufficient income to meet the family expenses. Fruit base agroforestry may be considered as alternative landuse system for these areas. To find out suitable agroforestry model, field experimental was conducted at Regional Research Station (red and laterite zone), Bidhan Chandra Krishi Viswavidyalaya, Jhargram, West Bengal, India. The fruit plants were planted at a spacing of 10m × 10m and *Eucalyptus tereticornis* were planted within the fruit plants and 5m spacing in between two mango rows and at boundary of the field as shelterbelt. The crops *viz.,* Pigeon pea, Black gram, Bottle gourd, Lady's finger and Maize were cultivated during *kharif* and mustard in *rabi* season. Experimental results revealed that all the growth characters of *E. tereticornis* and production of mango were at higher side under agroforestry system as compare to silvi species and fruit tree alone. The maximum gross income was recorded during 5th year when Lady's finger (*kharif*) cultivated as intercropped (Rs. 1.864 lakh ha^{-1} year $^{-1}$) closely followed by Bottle gourd (Rs. 1.666 lakh ha^{-1} year^{-1}). Fruit based agroforestry system is not only increased profitability but also build up the soil health (increase soil OC, pH and available N, P, K). Studies on soil fertility revealed the improvement of soil health were increased under all Fruit based Agroforestry system and maximum improvement was under intercropped with pigeon pea and black gram.

Key words: Agroforestry system; Productivity; Soil health; Profitability; Red and lateritic zone.

Indian agriculture is facing diverse challenges and constraints due to growing demographic pressure, increasing food, feed and fodder needs, natural resource degradation and climate change. Therefore, diversification of landuse systems with agroforestry is a necessary strategy for providing variety of products for meeting requirements of the people, insurance against risks caused by weather aberrations, controlling erosion hazards and ensuring sustainable production on a long-term basis, particularly in view of the effects of climate change[1]. Crop production on red and laterite soil under rainfed condition is low and unstable. It is estimated that nearly 50% of western part of West Bengal under rainfed cultivation which facing some kind of land degradation. Therefore, some alternate land use systems are to be developed for this soil erosion prone zone.

Agroforestry is a collective name for land use systems and technologies where woody perennials (trees, fruit trees, shrubs, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or

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animals, in some form of spatial arrangement or temporal sequence. In agroforestry system, there are different components and interaction between ecological and economic factors[2]. In other words, agroforestry is combination of agricultural technology and foresting in order to complete, variety, productivity, health and sustainability of land[3]. According to the report of the GOI, the forest cover in the country is 675,538 sq.km, constituting 20.55% of its total geographical area[4]. Out of this, dense forest constitutes 2.68% and open forest 7.87%. The GOI emphasized the role of agroforestry for efficient nutrient cycling, nitrogen fixation, addition of organic matter and for improving drainage and underlining the need for diversification by promoting integrated and holistic development of rainfed areas on watershed basis through involvement of community to augment biomass production through agroforestry and farm forestry[5]. Fruit-based agroforestry system integrates the cultivation of agronomic crops, vegetable crops, fruit trees and silvi component. As several authors have pointed out [6,7], all these labels directly or indirectly refer to growing and using trees to provide food, fuel, medicines, fodder, building materials, and cash income.

E. tereticornis is a tree up to 45 m tall or taller; trunk erect, 1-1.8 m in diameter; crown large, *E. tereticornis* is a major source of pollen and nectar, producing a caramel-flavoured honey. This species is popular and widely used for firewood, charcoal good quality pulp and paper. It is also planted in shelter-belts as a windbreak and for shade and a suitable species in reforestation programme. It also returns a substantial amount of nutrients to the soil, thereby minimizing the nutrient losses to a great extent and contributing to soil productivity[8]. Hardy and deep rooted fruit plants like Mango (*Mangifera indica*), Guava (*Psidium guajava*) and Ber (*Ziziphus mauritiana*) can be planted as high value horticultural crops degraded waste lands in red and laterite tract of West Bengal. Moreover, intercropping with rainfed arable crops is of immense importance for bringing in quick returns during first few years. Giri Rao opined that the dry land horticultural fruit trees like, mango, guava etc. integrated with short duration arable crops like, pulses, vegetables, groundnut etc. proved to be the most profit oriented among different agro-production system[9].

Productivity of crops under red and laterite soil in rainfed condition is low and unstable; and often optimum yield cannot be achieved because of aberrant monsoon behavior and erosion prone. Therefore, some alternate land use systems are to be developed for such lands. Fruit-based agroforestry system is an alternative land use system that integrates the cultivation of arable crops, fruit trees and silvi components. To enhance the production capacity experiments on fruit based agroforestry, a field experiment was undertaken to develop a Fruit-based agro-production system for rainfed in red and laterite zone of West Bengal.

MATERIALS AND METHODS

The study has been carried out at Regional Research Station (Red and Laterite Zone) of Bidhan Chandra Krishi Viswavidyalaya at Jhargram, Paschim Medinipur, West Bengal, India during 2011-12 and 2012-13. The study site is located in humid sub-tropical with short winter and long hot summer at 22° 30" N latitude and 87° 0" E longitude and at an elevation of 78.77 m above mean sea level (Fig. 1). The annual precipitation varies between 1100 mm and 1300 mm, about 80% of which are usually precipitated during monsoon period (June – September). Maximum and minimum temperatures during the month of cropping period were found to vary between 25.5°C – 38.8°C and 16.4°C– 28.2°C respectively. The experiment was carried out in upland situation where the soil are coarse texture and acidic (pH 5.5) and poor in organic matter, available nitrogen, phosphorus, potassium and lime content and highly susceptible to erosion hazards. Grafted one year old saplings of mango *cv.* Amrapally (100 Nos.) were planted during August, 2007at 10×10 m spacing. At the same time, 2 months old seedlings of *E. tereticornis* were planted in between two mango plants and 5m spacing in between two mango rows and as boundary plantation of the experimental field for shelter belt. The plot size of experiment was 20 × 20m for each treatment. Six arable crops viz. Pigeon pea (var. UPAS 120), Black gram (var. WBU 109), Lady's finger (var. Parvani Kranti), Bottle gourd (var. Pusa Summer prolific round) and Maize (var. Kanchan-K-25) were grown during *kharif* season (mid June to last October) followed by mustard

crop in *rabi* season (October to March) as intercropping under Eucalyptus-Mango based agroforestry system during 2011-12 and 2012-13 and Mustard (var. B-9/Binoy) was cultivated by using residual soil moisture. The experiment has been laid out in a randomized block design having 8 treatments (T_1: *E. tereticornis* + Mango + Pigeon pea (Fig. 2A); T_2: *E. tereticornis*+ Mango+ Blackgram (Fig. 2B) followed by Mustard; T_3: *E. tereticornis* + Mango + Bottle gourd followed by Mustard; T_4: *E. tereticornis*+ Mango+ Lady's finger (Fig. 2C) followed by Mustard; T_5: *E. tereticornis* + Mango + Maize (Fig. 2D) followed by Mustard; T_6: *E. tereticornis* + Mango (Fig. 2E); T_7: *E. Tereticornis*; T_8 =Mango) with three replications. Intercrops were grown with standard agronomic package of practices. Different growth parameters of silvi species and fruit tree (height, and fruit yield) were recorded. The volume yield calculation for standing tree species was done by quarter girth formula postulated by Chaturvedi and Khanna[10]. Data on soil nutrient status had also been taken both prior to commencement of the experiment and after completion of two cycles of inter cropping.

To evaluate the change in fertility of surface soil, the soil sample was collected two time (before start of experiment and after 2 year harvesting) under each crop during a growing season during 2011-2013. The soil samples were randomly collected at a depth of 0-15 cm using a soil auger in each of the sampling plot and a total of 54 soil sample were used for the analysis. The soil samples were air-dried and gently crushed in a ceramic mortar and sieved through a 2 mm sieve for chemical anal-ysis. Soil pH was measured using a pH Meter[11]. Soil organic carbon (OC) was determined by the Walkley–Black wet dichromate oxidation method[12]. Measuring of available nitrogen in the soil was performed by means of Kajeldal machine[13]. Bray No.1 method was used for measuring of Soil available phosphorus[14]. Soil available potassium was measured using 1N Ammonium acetate method[15]. Economics of different treatment was worked out by taking into account the return obtained from output of tree and crops. The return of tree and crops were analysed on market selling price in which, it was sold.

Deviation (%) from the control was computed by using below equation. The difference between initial and end of experimental soil data recorded under different agroforestry system (Y) and its corresponding lowest value (C). This equation was also used Araya and Stroosnijder[16]:

$$d = \frac{Y - C}{Y} \times 100$$

The data gathered in each observation were statistically analysed using SPSS version 16 software. The critical differences were calculated to assess the significance of treatment means wherever the 'F' test was found significant at 5% level of probability.

RESULTS AND DISCUSSION

Yield Attributes of Silvi Tree

Different growth characters of *E. tereticornis* viz. height, diameter at breast height (DBH) and volume yield were increased under agroforestry system (Table 1). The height of *E. tereticornis* was significantly higher under T_1 when pigeon pea was cultivated as inter crop as compared to rest of all agroforestry system. The maximum height and DBH of the tree i.e. *E. tereticornis* (14.3 m and 17.1 cm during 2011-12 and 16.3 m and 18.0 cm during 2012-13, respectively) were obtained with *E. tereticornis*+ Mango+ Pigeon pea based agro-production system model closely followed by *E. tereticornis*+ Mango+ Black gram based agro-production system models. From the growth parameter of the tree, it is clear that there has a positive role of legume crop as intercrops in AFS.

The volume yield of *E. tereticornis* was significantly increased under different intercropping based agroforestry system. The maximum volume yield (12.94 $m^3 ha^{-1} year^{-1}$) was founded under T_1 system, it was recorded 27.61 percent higher than T_2, followed 49.77, 67.62 and 74.39 percent under T_3, T_4 and T_5, respectively, while the lowest volume yield was recorded (2.63 $m^3 ha^{-1} year^{-1}$) under T_7, it was obtained 32 percent lower than T_6 during 2011-12. Similarly, the highest and lowest volume yield of *E. Tereticornis* were found 15.64 and 2.93 $m^3 ha^{-1} year^{-1}$ in T_1 and T_7 during 2013, respectively. Das *et al.* found that the yield attribute of silvi tree were higher under Agri + Silvi +Fruit+Vegetable based cultural system[17].

Production of Mango

The flower in mango trees have been started from the first year 2008, but fruits were not allowed to bear in the first bearing year. The yield of mango was significantly more under T_1 in both year. The mango yields (1.21 t ha^{-1} and 3.23 t ha^{-1}) was obtained under T_1, followed by T_2. The production of mango was more when legume crops were intercrops in mango based AFS (Fig.3). The mango yield and production of intercrops increased in the year 2012 as compared to year 2011. Evidences from the trails indicated that early supplementary and or complementary relation between some systems components can implied synergistic effects. The results are supported by the findings of Wannawong *et al.*[18].

Table 1. Growth attributes of *E. tereticornis* under different crops during 2011-12 and 2012-13

Mango-based AFS model	2011-12 Height (m)	DBH (cm)	Volume yield (m^3 ha^{-1} year^{-1})	2012-13 Height (m)	DBH (cm)	Volume yield (m^3 ha^{-1} year^{-1})
T_1	14.3	17.07	12.94	16.3	18.0	15.64
T_2	13.5	15.98	10.14	15.3	16.0	13.75
T_3	12.8	15.13	8.64	14.6	16.0	12.87
T_4	12.4	14.96	7.72	14.2	15.8	11.92
T_5	11.8	14.75	7.42	13.3	15.6	11.16
T_6	8.4	10.2	3.43	9.2	10.8	3.49
T_7	7.2	8.8	2.88	8.0	10.4	2.93
T_8	-	-	-	-	-	-
SEm(±)	0.061	0.013	0.013	0.070	0.014	0.012
CD(P=0.05)	0.158	0.039	0.039	0.180	0.037	0.042

Table 2. Soil pH and Organic C before sowing the crops for the tear 2011-12 and at the end 2012-13 i.e after completion of 2 years

Mango-based AFS model	Initial pH	Organic C (%)	Final pH	Organic C (%)	Deviation (%) pH	Organic C
T_1	5.5	0.38	5.8	0.49	66.67	81.82
T_2	5.5	0.37	5.8	0.46	66.67	77.78
T_3	5.4	0.35	5.7	0.43	66.67	75.00
T_4	5.4	0.35	5.7	0.44	66.67	71.43
T_5	5.3	0.34	5.5	0.39	50.00	60.00
T_6	5.3	0.34	5.5	0.38	50.00	50.00
T_7	5.2	0.29	5.3	0.32	-	33.33
T_8	5.1	0.31	5.2	0.33	-	-

Table 3. Effect of different Agroforestry system on Major Nutrient of soil (Kg ha^{-1})

Mango-based AFS model	Initial N	P	K	Final N	P	K	Deviation (%) N	P	K
T_1	174.2	17.4	174.6	234.8	23.6	206.2	67.00	74.19	63.29
T_2	172.8	16.6	174.8	219.8	21.2	198.2	57.45	65.22	50.43
T_3	172	16.4	172.6	213.25	20.8	188.4	51.52	63.64	26.58
T_4	171.6	16.1	172.4	212.6	20.2	186.9	51.22	60.98	20.00
T_5	168.36	12.4	167	202.4	15.6	180.6	41.25	50.00	14.71
T_6	136.2	9.4	133.2	161.25	12.1	146.2	20.16	40.74	10.77
T_7	132.4	8.6	125.2	154.2	10.4	137.6	8.26	11.11	6.45
T_8	124.4	8.4	118.6	144.4	10	130.2	-	-	-

Table 4. Effect of different agroforestry system on economics of red lateritic zone of West Bengal

Mango-based AFS model	2011-12 Tree (Rs. lakh $ha^{-1}year^{-1}$)	Fruit (Rs. lakh ha^{-1})	*Kharif* crops (Rs. lakh ha^{-1})	*Rabi* crop (Rs. lakh ha^{-1})	Total (Rs. lakh ha^{-1})	2012-13 Tree (Rs. lakh $ha^{-1}year^{-1}$)	Fruit (Rs. lakh ha^{-1})	*Kharif* crops (Rs. lakh ha^{-1})	*Rabi* crop (Rs. lakh ha^{-1})	Total (Rs. lakh ha^{-1})
T_1	0.518	0.182	0.625	-	1.324	0.626	0.485	0.615	-	1.725
T_2	0.406	0.170	0.520	0.248	1.343	0.550	0.470	0.536	0.252	1.808
T_3	0.346	0.168	0.588	0.240	1.342	0.515	0.422	0.612	0.248	1.796
T_4	0.309	0.174	0.968	0.232	1.682	0.477	0.479	1.038	0.244	2.237
T_5	0.297	0.173	0.565	0.248	1.282	0.446	0.426	0.584	0.252	1.708
T_6	0.137	0.098	-	-	0.235	0.140	0.171	-	-	0.311
T_7	0.115	-	-	-	0.115	0.105	-	-	-	0.105
T_8	-	0.095	-	-	0.095	0.000	0.108	-	-	0.108
SEm(±)	-	-	-	-	0.005	-	-	-	-	0.005
CD(P=0.05)	-	-	-	-	0.014	-	-	-	-	0.014

Market selling price: *E. tereticornis*= Rs. 4000.00 m^{-3}; Mango= Rs. 15.00 kg^{-1}; Pigeon pea = Rs. 50.00 kg^{-1}; Black gram= Rs. 40.00 kg^{-1}; Bottle gourd= Rs. 6.00 kg^{-1}; Lady's finger= Rs. 15.00 kg^{-1}; Maize= Rs. 6.00 kg^{-1}; Mustard= Rs. 40.00 kg^{-1}

Yield of Intercrops

In *kharif* season, the yield pulse crops were recorded 1.25 and 1.30 t ha^{-1} under pigeon pea and blackgarm, respectively, during 2012. It was observed that pigeon pea was founded 2.34 percent lower during 2013 whereas blackgram was recorded 7.26 percent higher during 2013 (Fig. 4). The bottle gourd and lady's finger were recorded 9.80 and 6.45 t ha^{-1}, respectively, during 2012, whereas 10.20 and 6.92 t ha^{-1}, respectively, were recorded during 2013. During 2012, maize was gained 9.41 t ha^{-1}, it was determined 3.29 percent higher than 2013.

In Rabi season, the mustard yield was significantly affected under different AFS models. The maximum yield of mustard was obtained 0.62 t ha^{-1} under T_1 and T_5 in 2012 whereas, in 2013, same trend was also found and 0.63 t ha^{-1} yield was observed in both above treatments (Fig. 5). The lowest yield was founded 0.58 and 0.61 t ha^{-1} under T_4 during 2012 and 2013, respectively. The yield of mustard was low because it was cultivated using by residual soil moisture without irrigation. Basu *et al.* noted marked reductions in crop yield due to the effect of allelotrophic leachates form *E. tereticornis*[19]. The intercrop yields increased with increase in tree row spacing (or alley width)[20].

Soil Nutrients Status after Two Cycles of Cropping

Due to the effective recycling of organic residues from different AFS components in the study. It was evident that the soil fertility improved as with respect to higher organic C, available soil, N, P and K with different AFS components as compared to system T_7 and T_8 of fruit trees and trees alone at the end of two crop cyclesi.e.in 2011-12 and 2012-13 (Table 2 & 3). Under mango based agroforestry system in model T_1: *E. tereticornis*$_+$ Mango+ Pigeon pea and T_2: *E. tereticornis*$_+$ Mango+ Black gram the soil N increased 34.3 % and 27 %, soil P increased 35% and 27%, soil K increased 18% and 13%, organic C increased 29% and 24%, respectively, after 2 year. This was because of the fact that interaction between tree species and legume crop helped to improve the fertility status of the soil. The findings are in conformity with the results of Biswas *et al.*[21]. Swamy *et al.* obtained that the nutrient status in soils increased significantly after 6 years of planting, possibly as a consequence of increased litter fall (leaves, flowers, fruits, twigs) with plantation age[22].

The maximum deviation of soil pH was observed 66.67 % under T_1 to T_4 followed by 50% under both T_5 and T_6 as compare T_8, while, no deviation found under T_7. The Deviation of OC in soil was observed highest and lowest under T_1 (81.82%) and T_7 (33.33%), respectively. The maximum deviation of nitrogen content (67.00%) was evaluated under T_1, followed by T_2, T_3, T_4, T_5, T_6 and T_7, respectively, in respect to T_8. The deviation of P and K content in soil were also followed same trend as soil N content. Rangasamy *et al.* reported the effected of integration of different components along with cropping for better utilization of natural resources[23].

Economic Return from Different Mango + E. tereticornis Based Agroforestry System Model

The income from different intercrops and fruit and gross income under each AFS model during the study for two consecutive years are presented in Table 4. The results showed that the integration of cropping with components of tree and fruit gave higher gross income than tree and fruit tree alone. The model T_4: *E. tereticornis* + Mango+ Lady's finger followed by Mustard was

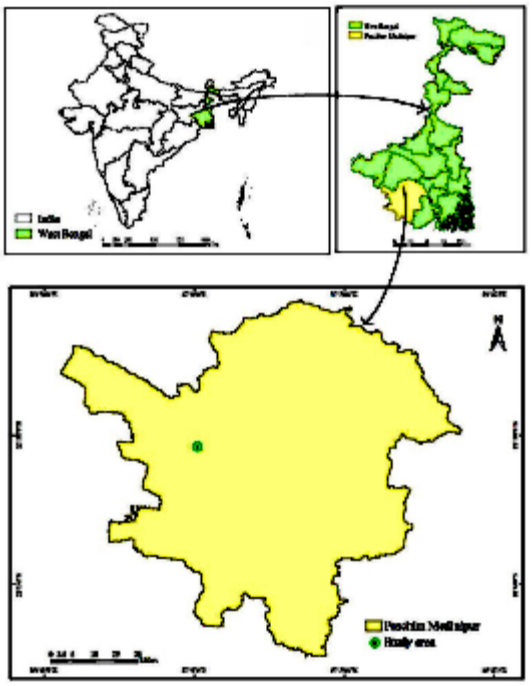

Fig. 1. Location of Regional Research Station (Bidhan Chandra Krishi Viswavidyalaya), Jhargram, Paschim Medinipur, West Bengal, India

Fig. 2. Overview of different Mango based Agroforestry system (A) *E. tereticornis* + Mango + Pigeon pea, (B) *E. tereticornis*+ Mango+ Blackgram, (C) *E. tereticornis*+ Mango+ Lady's finger, (D) *E. tereticornis* + Mango + Maize and (E) *E. tereticornis* + Mango

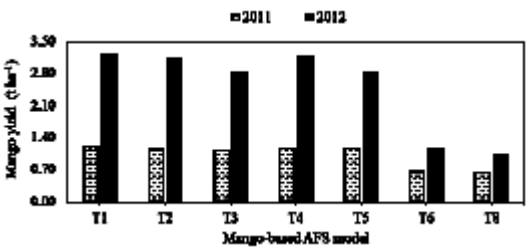

Fig. 3. Production of mango during 4th and 5th year

Fig. 4. Production of *kharif* season intercrops during 2011 and 2012

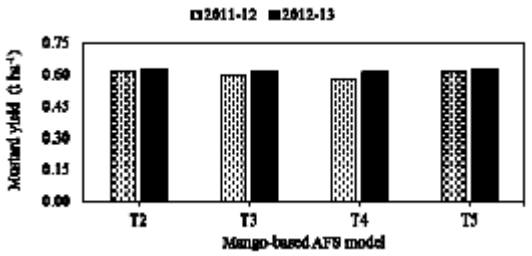

Fig. 5. Production of mustard crop during 2011-12 and 2012-13

found to be superior with maximum gross income of Rs. 1.682 and 2.237 lakh ha^{-1} during the 4th and 5th year of the ongoing experiment. Followed by model T_2: *E. tereticornis*+ Mango+ Blackgram followed by Mustard Rs. 1.808 and 1.343 lakh ha^{-1}. This was followed by model T_3, T_1, T_5, and T_6 which ranked third, fourth, fifth and sixth position in both year, respectively. The model T_8 gave the minimum gross income of Rs. 0.095 lakh ha^{-1} among all models during 2011-12, whereas, T_7 generated minimum gross return during 2012-13. Because the production of mango was low in first year. Prasad et al. stated that the net return and benefit/cost ratio of intercropping in eucalyptus-based agroforestry systems were significantly higher than for sole tree system[20]. Similar findings were also found by Dube *et al*. and Singh *et al*. in the case of eucalyptus and poplar, respectively[24, 25].

CONCLUSION

So far as different fruit-based agroforestry system models are concerned it may be concluded that *E. tereticornis*+ Mango+ Pigeon pea and *E. tereticornis*+ Mango+ Black gram followed by Mustard are the best with respect to improvement of soil health; *E. tereticornis* + Mango+ Ladies finger followed by Mustard and *E. tereticornis*+ Mango+ Bottle gourd followed by Mustard models of agroforestry system can profitably be grown in rainfed uplands under red and laterite Zone of West Bengal which are supposed to improve and maintain good health of that local people throw filling up the deficiency of nutrients by fruits and vegetables. The improvement in soil fertility indicate that there is an immediate need for development of agriculture in rainfed areas together with silvi species, fruit crops like mango, different crops like pulses, cereals, oilseed crops and vegetable crops like lady's finger and bottle gourd for attaining maximum and sustainable gross monetary returns under erosion prone areas of West Bengal, India for marginal and resource- poor farmers.

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