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Differential responses of arable crops with gamhar (*Gmelina arborea*) and mango (*Mangifera indica*) based agroforestry system in red and lateritic soils of West Bengal, India

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ABSTRACT

In order to identify the appropriate land use system towards enhancing productivity of marginal lands under rain fed conditions, an effort was made to develop agrofoerstry system integrating the arable crops, fruit trees and silvi components. The study involves with Gamhar (*Gmelina arborea*) and Mango (*Mangifera indica*) as silvi and fruit trees respectively intercropped with five arable crops namely Pigeon pea, Ground nut, Okra, Bottle gourd and Maize in *kharif* and Mustard alone in *rabi* season. Data on growth and yield parameters of the tree species were recorded. Analysis of soil pH, Organic carbon, availability of Nitrogen(N), Phosphorous(P) and Pottasium(K) were made during the crop growing period. The economic return from each of the treatments were also determined. The results reveal that among the various intercrops Pigeon pea was found most suitable in respect of soil fertility improvement and Okra for the best economic return.

Key words: Agroforestry, Arable crops, Land use system, Productivity.

INTRODUCTION

Agricultural production in red and lateritic soil under rain fed condition is low and unstable due to its low soil fertility and erosion problems. The irregularities of monsoon behaviour also greatly affects the production potential. Poor management of marginal lands results in land degradation. These marginal lands are not able to sustain arable crops particularly during the drought years. Therefore, there has been a thinking to develop some alternate land use systems for these lands for enrichment of soil fertility and productivity. Fruit-based agroforestry system is an alternative land use system that integrates the cultivation of arable crops, fruit trees and silvi component. It has the inbuilt capacity to increase the productivity and at the same time maintain the nutrient balance as well as environmental security. Due to its technical and economic potential it can sustain agricultural production. Trees and fruit plants has the dominant role to play in all agroforestry systems for sustainable agricultural environmental production. Tree component increases production and income, besides imparting stability to the farming system. Fruit trees, apart from the above advantages also yield valuable bye products like fodder and fuel wood, through their annual pruning and fruits, which are supposed to improve and maintain good health of human beings. The soil quality and its production capacity can be restored and improved by adopting agroforestry systems which provides a way to sustain agricultural production (Thakur and Kumar 2006). Under this system fruit tree can be grown successfully with legumes like moth, guar and cowpea as bonus crops and economic alternative system for marginal and sub marginal lands (Singh, 2006). The different cropping sequences have been verified for producing desired level of production by raising different crops which can be grown successfully underneath fruit plant and tree early stage of growth due to less competition for natural resources like air, sunlight, moisture and nutrients (Pathak and Pathak,2001). Gamhar *(Gmelina arborea)* could be promising tree species in the agroforestry system particularly in red and laterite zone of West Bengal (Banerjee and Dhara,2009). *Gmelina arborea* tree is strong light demander and regenerates naturally. 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 (Dutta and Dhiman, 2001). At this juncture, high value horticultural crop also deserve attention for increasing productivity of the upland areas to bring in prosperity. Moreover, intercropping with rainfed arable crops is of immense importance for bringing in quick returns during first few years. Keeping above facts in view, a field experiment was undertaken to analyse the nutrient enrichment status under different intercroppings for sustainable production in fruit based agroforestry system for rain fed uplands under red and laterite zone of West Bengal.

MATERIALS AND METHODS

Description of the experimental site: The experiment was carried out at Regional Research Station (Red & Laterite

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Zone), Bidhan Chandra Krishi Viswavidyalaya, Jhargram, Paschim Medinipur, West Bengal. The site is situated at 22° 50' N latitude and 87° 00' E longitude at an elevation of 78.77 m above mean sea level (MSL). The climate of the experimental site is humid sub-tropical with short winter and long hot summer. The crop seasons of this region are broadly classified as pre-kharif (March to May), *kharif* (June to October) and *rabi* (November to February). In this area the summer temperature is generally very high and during winter temperature remains generally low. Out of total land area of the research farm, 50-60 percent of the lands are located on upper situation, 20-30 percent land on medium situation and 10-20 percent lands are located on lower situation. The upland soils are coarse textured and are moderately acidic (pH 5.5) and poor in organic matter, total Nitrogen, available Phosphorous and potassium content. So far as the fertility status is concerned, the lands in lower situation are rich whereas those under higher situation are deficient in plant available nutrients. Furthermore, the upland soil are highly susceptible to erosion hazards. The annual precipitation varies between 1200 mm and 1300 mm, about 80% of which are usually precipitated between June and September i.e. during monsoon period. Even within this short period the rainfall may be unevenly distributed. Sometimes monsoon commence early or late and retreat before time. There may be prolonged breaks in rain within the season. Partially or even total crop failures are the usual features of the rainfed agriculture in this region. The soil of the research station where the experiments were conducted fall under the red and laterite zone. About 50-60 per cent of the lands are located on upper situation, 20-30 per cent land on medium situation and 10-20 percent lands are located on lower situation. The upland soils are coarse textured and are moderately acidic (pH 5.5) and poor in organic matter, total Nitrogen, available Phosphorous and potassium and lime. The upland soil are highly susceptible to erosion hazards as a result of which the parent rocks have been exposed. Gravel soil are mostly found here. The land in the lower region are rich in fertility due to the build up of loamy soils. In general the soils are well drained and have low water holding capacity. The soil depth varies from 0.8 to 3 m. The dominant type of clay mineral is kaolinite with low C.E.C. The textural classification of the surface soil is sandy clay loam (sand 46%, silt 31%, clay 26%). The bulk density is about 1.54 gm/cc. The infiltration capacity and hydraulic conductivity of the soil are 1.20 and 0.30 cm/hr. Respectevely.

Experimental details: The fruit plants i.e. Mango (var – Amrapali) were planted at a spacing of 10m × 10m (100 plants/ha) and Gamhar (*Gmelina arborea)* were plated within the two fruit plants (300 tree/ha) during July 2008. The gross plot size: 150m x 50 m. = 7500 m^2. Six intercrops *viz*. pigeon pea (var – UPAS 120), groundnut (var- JL- 24), okra (var – Parvani Kranti), bottle gourd (var – Summer prolific round), maize (var – Kanchan K25), Mustard (var- B9) were grown with standard agronomic package of practices in between the row spaces of Gamhar and Mango. The experiments were conducted during the two seasons of 2011-12 and 2012-13 under 5 (five) years old plantation of mango and gamhar. Eight (8) treatment combinations were taken *viz*. T_1: gamhar + mango - pigeon pea (*kharif*); T_2: gamhar + mango - groundnut (*kharif*) – mustard (*rabi*) ; T_3: gamhar + mango – okra (*kharif*) - mustard (*rabi*); T_4: gamhar + mango - bottle gourd (*kharif*) – mustard (*Rabi*); T_5: gamhar + mango - maize (*kharif*) - mustard (*rabi*); T_6: gamhar + mango; T_7: sole mango; T_8: sole gamhar. Different growth parameters of silviculture tree / fruit tree (height, diameter at breast height / basal diameter and fruit yield) were recorded. The volume yield calculation (for tree species) was done by quarter girth formula postulated by Chaturvedi and Khanna (1982). Data on soil nutrient status is taken both prior to the commencement of the experiment and after completion of two cycles of inter cropping. For economic evaluation of the system, prevailing market price was used. Selling price: wood gamhar = Rs.5000.00/m^3, pigeonpea = Rs.50.00/Kg, okra = Rs.12.00/Kg, groundnut= Rs. 40.00/Kg., sponge gourd = Rs.6.00/Kg, maize = Rs.6.00/Kg, mustard = Rs.40.00/Kg, mango = Rs.15.00/Kg. The data collected during both the years of experimentation were analyzed by following the method of analysis as described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth attributes and volume yield of gamhar tree: Experimental results revealed that all the growth attributing characters of gamhar increased gradually with the increasing age of the plant. The increment of growth were on higher side where the crops were cultivated in the inter spaces in mango-based agro-forestry systems compared to trees under control and thus exhibiting a positive effect of intercropping on tree growth. The results were corroborated with the findings of Gill and Ajit (2005). Different growth characters of gamhar *viz*. height, diameter at breast height (DBH) and volume yield were increased under agroforestry system (Table 1). The height of gamhar 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. gamhar (3.90 m and 15.0cm, respectively) were obtained with treatment T_1: gamhar + mango – pigeonpea, closely followed by T_2: gamhar + mango - groundnut - mustard based agro-forestry system. From the growth parameter of the tree, it is clear that there is a positive role of legume crop as intercrops in agroforestry system. The volume yield of gamhar was significantly increased under different intercrops. The maximum volume yield (4.13 $m^3 ha^{-1}yr^{-1}$) was founded under T_1 system, it was recorded 5.08 percent higher than T_2, followed 8.72, 13.56 and 18.16 percent under T_3, T_4 and T_5 respectively, while the lowest volume yield was recorded (2.90 $m^3 ha^{-1}yr^{-1}$) under T_7, it was obtained 9.94 percent lower than T_6 .

Table 1: Growth attribute of *Gmelina arborea* under different treatments at the age of 5 year.

Treatments	Height (m)	DBH (cm)	Vol. yield (m^3 $ha^{-1}yr^{-1}$)
T_1	3.90	15.00	4.13
T_2	3.80	14.80	3.92
T_3	3.70	14.73	3.77
T_4	3.60	14.52	3.57
T_5	3.51	14.30	3.38
T_6	3.4	14.20	3.22
T_7	3.25	13.90	2.90
T_8	-	-	-
SEM(±)	0.015	0.031	0.027
CD(P=0.05)	0.046	0.066	0.081

Production of fruit (mango) and intercrops yield: The yields of Mango (*Mangifera indica*) and intercrops under different treatments were presented in Table 2. 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 maximum under the treatment T_1: gamhar + mango – pigeon pea (3.00 t/ha), followed by T_2: gamhar + mango - ground nut – mustard (2.80 t/ha). The production of mango was more when legume was intercropped between Mango and Gamhar. The yield of intercrops were found 1.50, 1.50, 5.40, 2.30 and 8.54 t ha^{-1} in pea, ground nut, okra, sponge gourd and maize during *kharif* season. In *rabi* season, the highest mustard yield was observed 0.73 t ha^{-1} under T_2 and lowest was 0.64 t ha^{-1}under T_5.

Table 2: Production of intercrops and fruit (mango) yield.

Treatments	Yield of inter crops (t ha^{-1})		Yield of mango
	Kharif	*Rabi*	(t ha^{-1})
T_1	1.50	-	3.00
T_2	1.42	0.73	2.80
T_3	6.60	0.62	2.60
T_4	2.30	0.52	2.50
T_5	8.54	0.64	2.45
T_6	-	-	2.00
T_7	-	-	1.75
T_8	-	-	-
SEM(±)	0.015	0.015	0.015
CD(P=0.05)	0.048	0.050	0.046

Soil nutrients status: Due to the effective recycling of organic residues from different treatments in the study it was evident that the soil fertility was improved with respect to higher organic C, available soil, N, P and K with different treatment components as compared to treatment T_7 and T_8 of Silvi tree and fruit trees alone. (Table 3 & 4). Under mango based agroforestry system in treatment T_1: gamhar + mango - pea, T_2: gamhar + mango - ground nut - mustard, the soil N improved from 162.5 to 223.5 Kg ha^{-1} i.e. increased 27.4% and 163.4 to 216.2 Kg ha^{-1} i.e. increased 24.4 %, soil P from

Table 3: Changes in pH and organic carbon status in soils during crop growth stages

Treatments	Before sowing		After harvest		Increase (%)	
	pH	Organic C	pH	Organic C	pH	Organic C
T_1	5.5	0.39	5.7	0.52	3.63	33.3
T_2	5.5	0.38	5.7	0.50	3.63	31.5
T_3	5.3	0.37	5.5	0.48	3.77	29.7
T_4	5.3	0.37	5.5	0.46	3.77	24.3
T_5	5.2	0.35	5.4	0.43	3.84	22.8
T_6	5.2	0.33	5.3	0.35	1.92	7.5
T_7	5.1	0.28	5.2	0.30	1.96	7.1
T_8	5.1	0.28	5.2	0.29	1.96	3.5
SEM(±)	0.015	0.015	0.015	0.015	0.015	0.077
CD(P=0.05)	0.046	0.046	0.046	0.046	0.046	0.277

Table 4: Changes in availability of nutrients during crop growth stages:

Treatments	Before sowing of crops			After harvest of crops			Increase (%)		
	N	P	K	N	P	K	N	P	K
T_1	162.5	16.6	172.6	223.5	23.6	198.8	27.3	29.6	13.1
T_2	163.4	16.2	173.8	216.2	22.2	191.6	24.4	27.0	9.3
T_3	164.6	16.5	172.5	212.2	21.4	188.8	22.4	22.8	8.6
T_4	164.2	17.2	172.8	211.5	21.4	188.6	22.3	19.6	8.3
T_5	168.6	14.5	172.5	215.6	17.4	188.7	21.8	16.6	8.5
T_6	145.6	10.5	156.8	163.4	11.2	164.1	10.9	6.2	4.4
T_7	140.5	9.8	157.0	154.8	10.4	164.2	9.3	5.7	4.4
T_8	144.2	9.6	157.4	159.3	10.2	163.8	9.4	5.8	3.9
SEM(±)	0.077	0.061	0.015	0.092	0.035	0.027	0.015	0.022	0.015
CD(P=0.05)	0.277	0.180	0.046	0.271	0.103	0.080	0.046	0.065	0.046

Table 5: Economic return from different treatments under *mango and gamhar* based agroforestry system

Treatments	Income from crops (Rs. ha^{-1})		Income from fruit (Rs. ha^{-1})	Income from tree (Rs ha^{-1})	Gross income (Rs. ha^{-1})
	Kharif	*Rabi*	Summer		
T_1	0.450	-	0.480	0.207	1.137
T_2	0.568	0.292	0.448	0.196	1.504
T_3	0.792	0.248	0.416	0.189	1.645
T_4	0.345	0.236	0.400	0.179	1.160
T_5	0.427	0.256	0.392	0.169	1.244
T_6	-	-	0.320	0.161	0.481
T_7	-	-	-	0.146	0.146
T_8	-	-	0.280	-	0.280
SEm(±)	-	-	-	-	0.008
CD (P=0.05)	-	-	-	-	0.024

16.6 to 23.6 Kg ha^{-1} i.e. increased 29.6% and 16.2 to 22.2 kg ha^{-1} i.e. increased 27%, soil K from 172.6 to 198.8 Kg ha^{-1} i.e. increased 13.1 % and 173.8 to 191.6 Kg ha^{-1} i.e. increased 9.3 %, organic C increased 33.3% and 31.5% respectively. 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. (2003).

Economic return from different mango and gamhar based agroforestry system: The income from different intercrops and fruit and gross income under each treatment are presented in Table 5. The results showed that the integration of crops with components of tree and fruit gave higher gross income than tree and fruit tree alone. The treatment T_3: gamhar + mango - okra - mustard was found to be superior with maximum gross income of Rs. 1.645 lakh. Followed by treatment T_2 = gamhar + mango – ground nut – mustard, Rs. 1.504 lakh. This was followed by treatments T_5, T_4 and T_1 which ranked third, fourth and fifth with the gross income Rs. 1.244 lakh, Rs. 1.160 lakh and Rs. 1.137 lakh respectively. The treatment T_7 gave the minimum gross income of Rs. 0.146 lakh among all treatments.

CONCLUSION

Based on the above study it may be concluded that out of 6(six) intercrops, pigeon pea was found superior intercrop for the improvement of soil fertility and Okra for maximum income. Maximum height, Diameter at breast height(DBH) and volume yield of the tree were obtain for *Gmelina arborea* when intercropped with Pigeon pea. The results further indicate that intercropping of arable crops with trees have promising effect on building up of soil fertility and enhancing farm income.

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