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Nutrient dynamics studies in sapota timber based agroforestry system under rainfed conditions

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ABSTRACT : Agroforestry plays a vital role in the biological build up of nutrients and sustaining soil fertility for growing crops and getting higher yields for livelihood security. An experiment on nutrient dynamics was conducted from the year 2006 to 2016 at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad on medium black soils under rainfed conditions. Sapota was planted at 8 x 8 m spacing and one timber tree is planted in between two sapota trees. Five timber tree species *viz., Pterocarpus marsupium, Tectona grandis, Terminalia paniculata, Lagerstroemia lanceolata* and *Terminalia alata* were planted in between two sapota and compared to sole sapota. Field crops *viz.*, soybean and safflower were grown in alleys of sapota-timber trees every year in both *Kharif* and *Rabi* season, respectively. The experiment was laid out in Randomized Block Design with four replications. Both physical and chemical parameters and litter fall was worked out. The integration of timber trees with sapota + field crops, pH, EC, WHC, moisture content was increased as compared to initial values. The nutrient build up of organic carbon, nitrogen, phosphorus, potassium were increased with *Tectona grandis*, *Lagerstroemia lanceolata*, *Pterocarpus marsupium* with sapota + Field crop as compared to other treatments. Hence, the trees in association with annuals could control runoff, improve soil quality, increase productivity and income of the famers.

KEY WORDS : Nutrient dynamics, Litter fall, Sustainability, Agroforestry systems

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INTRODUCTION

Agroforestry system has today become an established approach to integrated land management not only for renewable resource production but for also ecological considerations. It represents the integration of crops with trees to increase the productivity and sustainability of farming system. The trees are the main components of agroforestry which play an important functions *viz.*, reduce evaporation, transpiration, erosion control and nutrient cycling. Trees with deeper rooting system in agroforestry can improve ground water quality

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by serving as ‘safety net’ whereby excess nutrients that have leached below rooting zone of crops taken up by tree roots and recycled through litter fall.

The tree is commonly planted in this region under agri-silvicultural system as boundary planting and intercropped with wheat, maize, turmeric, ginger and elephant foot yam. Besides a nitrogen fixing species, *A. lenticularis* is important for reclaiming degraded and abandoned agricultural lands because of its capability to improve soil properties and has potential for efficient soil and water conservation (Chatrurvedi *et al.,* 2005; Das *et al.,* 2007; Chatrurvedi *et al.,* 2008 and Laik *et al.,* 2009).

Sharma and Sharma (2004) reported that agroforestry can improve soil physical condition, increase Phosphorous status and ameliorate soil for optimum crop and forestry productivity. With population increase, more and more slope lands have been turned into crop fields for grain production, resulting in serious environmental risks such as soil erosion and depletion of soil fertility in the northeast region of India. Lovenstein *et al*. (1991) suggested introducing annual crops between rows of trees in these fields, in order to exploit the soil moisture throughout the profile. Different crop species grown together in the same field at the same time compete with each other for available resources. The maximum amount of attainable biomass for individual species depends primarily on the relative availability of the resources within a production situation. Hence, a study was conducted to see the impact of agroforestry system on soil physical and chemical properties and also improvement in livelihood and quality life of the farmers.

EXPERIMENTAL METHODS

An experiment was initiated at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad under rainfed conditions. The experiment consisted of Sapota fruit tree species planted at 8 m x 8 m spacing on medium black soil. One timber tree was planted in between two sapota trees. The timber tree species *viz., Pterocarpus marsupium, Tectona grandis, Terminalia paniculata, Lagerstroemia lanceolata, Terminalia alata* of uniform rotation were selected for evaluations. Field crops *viz.*, soybean and safflower were sown in the inter space of sapota – timber alleys. The experiment was Randomized Block Design with four replications.

The experiment site had medium black soil with pH 6.85 and available nitrogen 245 kg/ha, phosphorus 19.6 kg/ha and potassium 285 kg/ha. The mean annual rainfall was 779.4 mm received in 57 rainy days and average mean maximum temperature and minimum temperature were 34.7^{o}C in April and 14.6^{o}C in January, respectively with relative humidity of 50 to 85 per cent.

The recommended package of practices was followed for raising soybean. Soybean variety JS-335 was sown in *Kharif*. Seeds were treated with Rhizobium culture, phosphorus solubilizing bacteria (PSB) and bavistin. Seeds 62.5 kg/ha were sown at 30 x 5 cm apart. Recommended fertilizer of 35 : 50 : 35 kg ha^{-1} N:P_2O_5: K_2O ^{1} was applied as basal dose. Suitable plant protection measures were taken up to control pest and disease. Safflower variety A-1 was grown in *Rabi*. Seeds were treated with baviston and about 6 kg /ha seeds were sown in 45 cm x 5 cm apart. Recommended fertilizer of 40 : 40 :20 kg ha^{-1} N:P_2O_5: K_2O was applied as basal dose. Suitable plant protection measures were taken upto control pests and diseases. Silvicultural operation for timber trees *viz.*, pruning the branches in bottom 2/3 height and soil working were done every year before on set of monsoon. Root pruning was made by deep ploughing every year along the tree rows. Observations like height, spread, dbh and clear bole height were recorded. Grain and haulm yield of field crops were recorded every year.

The composite soil was collected from each treatment and was air dried, ground in a wooden pestle with mortar, passed through a 2 mm sieve and stored for subsequent analysis with suitable chemicals. The amount of nutrients (N. P. and K) in soil was determined by semi-micro Kjeldahl technique for N (Peach and Tracy, 1956), absorption spectrophotometer for P and flame photometry for K (Jackson, 1958). Litter fall made by basket method in each treatment from December to March every year and mean litter fall of three years from each trees is presented.

EXPERIMENTAL RESULTS AND ANALYSIS

The results obtained from the present investigation as well as relevant discussion have been summarized under the following heads :

Ameliorative properties of tree species:

The pH of soil (Table 1) was slightly increased *Tectona grandis* with sapota + field crop followed by *Pterocarpus marsupium* with sapota + field crop as compared to other tree species. Electrical conductivity (EC) of soils slightly improved in *Tectona grandis* with sapota + field crop followed by *Terminalia paniculata* with sapota + field crop as compared to other tree species. The potential of using woody perennials has often been emphasized for conservation as well as production on hilly terrains (Young, 1989 and Kang *et al.*, 1990). The effect of perennial vegetation in controlling erosion in forest ecosystems depends on a number of factors such as canopy cover, ground vegetation, litter effects, root effects and changes in the physical properties of the soil (Weirsum, 1985). Agroforestry possibly encompasses some of these properties of perennial vegetation in controlling erosion from agricultural fields (Young, 1989). Use of alley cropping has often been emphasized for erosion control (Young, 1989; Kang *et al.*, 1990 and Rao *et al.*, 1991) reported that although nutritional and productivity aspects of alley cropping or agroforestry measures have been studies quantitative data.

The increase in soil pH resulted in more availability of nutrients to the crops and hence, higher productivity of both trees and field crops. This is supported by the studies of Keltjens (1995) who reported that malnutrition of plants on acid soils is mostly the result of limited soil nutrient availability.

Nutritional build up:

Within ten years of study, there was substantial build up of nutrients N, P, and K as compared to initial status. Nitrogen content had increased by 7- 21 per cent, phosphorus by 36 to 38 per cent and potassium by 40 to 46 per cent with inclusion of timber tree species with sapota based agroforestry system.Nitrogen, phosphorus and potassium build up were higher in soil grown with *Tectona grandis* with sapota + field crop followed by *Lagerstroemia lanceolata* with sapota + field crop and *Pterocarpus marsupium* with sapota + field crop as compared to other tree species.

Sharma and Tripathy (1999) also found an increase in soil available phosphorus with the application of P fertilizer. There was increase in other plant nutrients and organic carbon in the soil in LU-1, LU-2 and LU-3 systems. This may be attributed to the continuous addition of litter, succulent twigs and leaves of trees as well as

Table 1: Soil Physical parameters as influenced by timber tree species and sapota

Sr. No.	Agroforestry systems	pH	EC (dS/m)	Available nutrients (kg/ha) N	P_2O_5	K_2O	OC (%)	S (ppm)	Ca (me/100g)	Mg (me/100g)
1.	S + *P. marsupium+FC*	7.20	0.40	226.4	53.4	224.4	0.49	12.3	22.4	16.7
2.	S + *T. grandis +FC*	7.20	0.46	239.0	53.8	228.0	0.51	13.2	23.0	18.2
3.	S + *T. paniculata +FC*	7.12	0.43	218.6	51.3	219.6	0.48	13.9	23.8	16.9
4.	S + *L. lanceolata+FC*	7.14	0.41	231.4	52.6	225.4	0.49	11.4	21.4	17.2
5.	S + *T. alata+FC*	7.18	0.42	217.4	50.6	221.4	0.47	14.7	23.6	17.2
6.	Sapota +*FC*	7.10	0.39	211.6	44.8	182.4	0.46	11.3	17.4	15.6
7.	Open area	6.90	0.34	196.0	38.7	156.8	0.43	10.7	16.4	14.8

Field crops (FC): Soybean - Safflower

Table 2 : Water holding capacity, moisture content and litter fall parameters as influenced by timber tree species and sapota

Sr. No.	Agroforestry systems	WHC (%)	Moisture at FC (%)	Litter fall (kg/ha)
1.	S + *P. marsupium+FC*	71.4	34.86	3120
2.	S + *T. grandis +FC*	72.29	36.15	5460
3.	S + *T. paniculata +FC*	70.3	35.42	4680
4.	S + *L. lanceolata+FC*	68.6	35.42	3432
5.	S + *T. alata+FC*	71.4	33.84	5304
6.	Sapota +*FC*	64.7	30.29	560
7.	Field crops (FC)	60.7	26.7	-

Field crops (FC): Soybean - Safflower

annual crop residues in the soil and their decomposition. A large body of literature has described the positive effects of agroforestry systems on soils in the tropics (Nair and Latt, 1997 and Young, 1997). The role of woody perennials both N-fixing and non fixing in improving the soil chemical, physical and biological properties has become the subject of investigations in the last decade (Jose *et al.*, 2004 and Sanchez *et al.*, 1983). The increase in available K in LU-4 in the beginning could easily be attributed to the burning forest vegetation in the shifting cultivation. The available potassium subsequently reduced in shifting cultivation and was a little below the initial soil status (105 mg K kg^{-1} of soil), however, it continued to increase in other land use systems. Agroforestry systems are believed to increase or at least maintain the organic matter levels of the soil (Kang and Wilson, 1987 and Szott *et al.,* 1991).

Organic carbon content of soil increased in sapota timber based agroforestry system as compared to initial levels. Both micro nutrient sulphur, calcium, magnesium have increased with inclusion of timber trees with sapota in agroforestry. This was higher in *Tectona grandis*, *Terminalia paniculata* and *Terminalia alata* with sapota + field crop as compared to other tree species.

Physical properties such as water holding capacity, moisture content were increased with inclusion of tree species with sapota based agroforestry system. This may be due to the higher organic carbon content with inclusion of timber trees in sapota based agroforestry system.

Litter fall varies among the tree species. The maximum litter fall was higher in *Tectona grandis*, *Terminalia*, *alata*, *Terminala paniculata*, *Lagerstroemia lanceolata* and *Pterocarpus marsupium* with sapota based agroforestry system.

The litter fall varies with climatic conditions and soil moisture and tree species. Soil physical conditions, in-situ retention of rain water and also reduced soil erosion through runoff. The system has helped in maintaining perfect soil health resources conservation and improved quality of soil.

Crop productivity:

The total productivity of crop was increased in sapota timber based agroforestry system as compared to sole sapota or sole field crops. The yield of different commodities is converted into soybean equivalent yield as per value of market price. The crop productivity is higher in *Pterocarpus marsupium* + sapota + field crop followed by *Terminala paniculata* + sapota + field crop and *Tectona grandis* + sapota + field crop as compared to other tree species.

Plants compete for resources irrespective of whether they are grown in sole stands or as species mixtures. The degree of competition between individual plants depends on the demand and the availability of growth resources, as well as the ability of the plants or plant communities to exploit a shared resource pool (Droppelmann *et al.*, 2000). Therefore, the production system that makes optimal use of resources shows the highest productivity. Agroforestry practices can increase farmer's annual income and livelihood security, particularly in developing countries. The crop productivity in the studies agroforestry systems increased due to amelioration of soil and thus, making more availability of

Table 3 : Growth of timber tree species and sapota and yield of field crops in different agroforestry systems

Agroforestry systems	Tree species			Sapota				Safflower yield (kg/ha)	Crop productivity
	Height (m)	DBH (cm)	Biomass (ton/ha)	Height (m)	Collar diameter (cm)	Fruit yield (kg/pl)	Soybean grain yield (kg/ha)		
S + *P. marsupium* + FC	9.25	25.08	310.0	4.24	12.55	9.08	475.6	120.6	4425.0
S + *T. grandis* +FC	8.97	23.61	218.0	4.14	11.53	8.85	460.4	135.2	3269.0
S + *T. paniculata* +FC	8.63	21.29	236.0	4.15	11.74	5.18	425.0	146.4	3466.0
S + *L. lanceolata* + FC	8.25	19.42	143.0	4.42	12.22	8.78	495.6	158.2	2381.0
S + *T. alata* + FC	8.54	20.02	198.0	4.19	12.46	5.70	415.0	174.4	2999.0
Sapota + FC	-	-	-	4.75	13.75	12.63	575.5	220.6	713.3
Field crops (FC)	-	-	-	-	-	-	652.4	328.5	857.4
S.E.±	0.31	1.33	0.30	0.16	0.46	0.81	13.4	10.6	412.0
C.D. (P=0.05)	0.95	4.11	1.10	0.48	1.38	2.44	39.8	31.4	1236.0

Field crops (FC): Soybean - Safflower

native soil nutrients as well as low fixation of applied phosphorus. The litter fall improved the physical condition of the soil, besides addition of more nutrients and organic matter, the accumulation benefit in terms of commodity yield. The trees component provided fodder, fuel wood and timber material to the farmers as well as enhanced their income triple fold. The annuals utilized water from the top soil layers in the alleys between tree rows while the trees could take up water from deeper layers due to their deep rooting system. This also supported by the findings of Huxley *et al.* (1994).

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