



On-farm evaluation of pigeonpea (*Cajanus cajana* L. Millsp.) - neem (*Azadirachta indica* A. Juss.) agroforestry systems in the Deccan Plateau

Doddabasawa, B.M.Chittapur¹, M. Mahadeva Murthy

10.18805/LR-3941

ABSTRACT

The performance of neem based agroforestry system was studied during 2016-17 under rainfed ecosystem on farmers' fields on participatory mode in Yadgir district in the North-eastern dry zone (Zone II) of Karnataka. Grain and biomass yields and harvest index of pigeonpea did not vary significantly among the agroforestry systems. However, significantly lower grain (1192 kg ha⁻¹) and biomass (5563 kg ha⁻¹) yields of pigeonpea were recorded at 5 m distance away from the neem tree line (P=0.05) compared to the distances of 10 m (1450 and 6942 kg ha⁻¹, respectively) and 15 m (1449 and 6720 kg ha⁻¹, respectively) away from the tree line. Significantly higher grain yield (1520 kg ha⁻¹) was observed in control without any proximity of trees compared to the agroforestry systems which accounted for a mean reduction of 11 per cent in yield. Among different agroforestry systems, significantly higher tree height was recorded in bund planting (7.61m) followed by boundary planting (7.38 m) and scattered planting (6.46 m) whereas the crown spread recorded was significantly lower in bund planting (6.27 m) followed by scattered planting (6.38 m) and boundary planting (6.68 m). There also existed non-significant difference in girth, volume and biomass of neem trees grown in different agroforestry systems. Further, the physicochemical properties of soil were found improved in agroforestry systems compared to control and the trend varied among the different agroforestry systems.

Key words: Agroforestry systems, Tree volume and biomass, Productivity, Soil properties.

INTRODUCTION

The rainfed ecosystems are ecologically more fragile, characterized with inadequate and ill distributed rainfall, scarcity of soil moisture, low organic carbon, fluctuation of water table, higher evapotranspiration and soils highly susceptible to erosion. Therefore, the productivity of agriculture has declined or remained stagnant over years in spite of breakthroughs in crop varieties and crop husbandry. These days, tree based land use system is projected as a panacea for all problems in rainfed ecosystem. In fact, tree based land use system is an age old traditional practice followed by millions of farmers wherein farmers retain the useful trees on the farmland mainly to get fodder, fuel wood, timber, fruits and other minor forest products singly or together. That apart, trees are also extending many ecosystem services such as shade, protection and demarcation of land and congenial living habitat (Chittapur *et al.*, 2017).

The traditional agroforestry land use systems are complex in structure and function with both complementary and competitive effects (Muturi *et al.*, 2005). However, yet it is to be ascertained whether the traditional agroforestry systems are ecologically more desirable, economically viable and socially preferred. Often these land use system have significant species diversity and density variation of useful plants which are managed through planting or by selection and management of naturally regenerated plants on the farm land by the farmers (Schroth *et al.*, 2004).

Department of Forestry and Environmental Science, University of Agricultural Science, GKVK, Bengaluru-560 065, Karnataka, India.

¹University of Agricultural Sciences, Raichur-584 102, Karnataka, India.

Corresponding Author: Doddabasawa, College of Agriculture, Bhimarayanagudi, Yadgir-585 287 Karnataka, India. Email: dkpatil2020@gmail.com

How to cite this article: Doddabasawa, Chittapur, B.M. and Murthy, M.M. (2020). On-farm evaluation of pigeonpea (*Cajanus cajana* L. Millsp.) - neem (*Azadirachta indica* A. Juss.) agroforestry systems in the Deccan Plateau. Legume Research. 43(1): 87-92.

Submitted: 12-09-2017 **Accepted:** 12-12-2017 **Published:** 16-07-2018

However, today trees on farm land are under threat due to intensification of agriculture though trees are ecologically important to maintain favorable conditions for crop production through creation of healthy microclimatic conditions, enhanced soil fertility and reduced soil erosion besides providing food and fodder in the off season (Coulbaly *et al.*, 2014). The irony is, the various ecological and economical benefits offered by the system are considered just as additional benefits and hence, loose the focus of the producer.

The farmers are more normally interested in the direct and immediate benefits viz., crop yield/fodder which would probably reduced in presence of trees though there accrue

ecological and economical benefits. At times, they appear suspicious of any benefit that is not cognizable. Hence, under the circumstance understanding the nature of interaction between the tree and crop is of utmost importance to determine the management practices in agroforestry systems. Moreover characterization of component interaction in agroforestry system is important in determining the nature and extent of competition and complementarity between tree and crop.

Traditionally most preferred agroforestry system practiced by the farmers under rainfed ecosystem is scattered planting which is also called as parkland system and also farmers prefer the trees on the bunds and farm boundaries with varying density of 15 to 40 trees per hectare. The indigenous system with many different tree species were reported from many parts of the tropical countries of the world. *Faidherbia albida* in semi arid tropics in Western Africa (Vandenbelt 1992), *Vitellaria paradoxa* and *Parkia biglobosa* in semiarid sub-Saharan Africa (Bremen and Kessler, 1995) and *Prosopis cineraria* with millets in Rajasthan (Tejwan, 1994), Kalaichelvi and Swaminathan (2002) reported medicinal perennial trees grown as boundary planting in agroforestry systems but the reports on the neem (*Azadirachta indica*) based indigenous agroforestry systems are rare though neem is predominant on farmlands in tropical India providing growers with various goods and services. With this background a study was undertaken to know the nature and extent of competition or otherwise of neem tree on associated pigeonpea [*Cajanus cajan* (L.) Millsp.], crop in neem based agroforestry system under rainfed ecosystem.

MATERIALS AND METHODS

The study was undertaken in Yadgir district of North eastern dry zone (Zone II) of Karnataka during 2016-17 on farmers' fields on participatory mode. The climate of the region is dry semi arid with cool winters and dry hot summers. The average rainfall is around 750 mm and mean annual temperatures range from 18.6 to 32.5°C and mean elevation ranges from 350-680 m. The soils are deep to very deep black soils and medium black soils in major areas while sandy loam and light textured soils are also found in some pockets. The major crops grown are pigeonpea, bengalgram, soybean, groundnut, greengram, pearl millet (bajra), sorghum, sunflower and safflower under rainfed condition, and chilli, cotton, sugarcane, paddy and maize under irrigated condition.

Bund, boundary and scattered planting were the major traditional agroforestry systems practiced by the farmers in the rainfed ecosystem in the region with neem, babul, ber, tamarind and mango, however neem found to be dominant tree in terms of frequency of occurrence and density mainly due its multiple utility and adoptability. Hence, for the study purely neem based agroforestry systems were selected and 4 farmers in each system with a plot size of one hectare were selected and as the plots were located in different locations average of 4 farmers without trees representing the locations were taken as control for comparison. The pigeonpea is the major field crop grown in the region under rainfed ecosystem. The system components, cropping pattern and other details are given in the Table 1. Further, the soil particle analysis was carried out to know the genetic difference in the soil characteristics and the soil of the study area belonged to sandy clay loam texture (sand - 66.19 to 74.19 %, silt - 5.10 to 9.04 % and clay - 20.04 to 28.72 % at 0-15 cm depth).

The productivity of the pigeonpea - neem based agroforestry system was assessed in terms of yield and biomass. The biomass and grain yield of pigeonpea was recorded with a net plot size of 6 m x 5 m and the sample plots were laid out randomly with 3 replication at a distance of 5 m, 10 m and 15 m from the tree line and total plots laid were 9 in each farmers field whereas in control 9 plots of 6 m x 5 m were laid out randomly in the entire field. The mature crop was harvested at ground level, later grain and haulm were separated. Further, they were dried and weighed and were computed, averaged and extrapolated to per ha basis. The harvest index of the crop was calculated with the following equation (Donald, 1962).

$$\text{Harvest Index (\%)} = \frac{\text{Economic yield (kg/ha)}}{\text{Biological yield (kg/ha)}} \times 100$$

The tree biomass was calculated by non-harvesting method by taking the measurements of girth and height of the standing trees and then volume was calculated. 20 trees were randomly selected in each agroforestry system and mean girth, height and volume of tree was worked out. The tree height was measured with help of Ravi altimeter from the ground level to the tip of the tree and expressed in meter (Chaturvedi and Khanna, 1981), tree girth at breast height (1.37 m) from the ground level was measured, and crown spread was measured by taking the width of the crown in North-South and East-West direction by projecting the

Table 1: The details of the prominent neem based agroforestry assessed in the study.

Systems	Tree species	Average number of trees ha ⁻¹	Average age of trees (Years)	No. of farmers	Area of sample plot	Crop		Variety
						Kharif	Summer	
Bund planting	Neem	26.75	25	4	1ha farmer ⁻¹	Pigeonpea	Fallow	TS3R
Boundary planting	Neem	39.00	25	4	1ha farmer ⁻¹	Pigeonpea	Fallow	TS3R
Scattered planting	Neem	18.25	25	4	1ha farmer ⁻¹	Pigeonpea	Fallow	TS3R
Control (without trees)	-	-	-	4	1ha farmer ⁻¹	Pigeonpea	Fallow	TS3R

perimeter of the crown vertically to the ground and calculated by using the following formula (Chaturvedi and Khanna, 1981).

$$\text{Crown spread} = (D_1 + D_2)/2,$$

where D_1 - crown width in North-South direction

D_2 - crown width in East-West direction.

Further, the tree volume was calculated with the following formula (Chaturvedi and Khanna, 1981).

$$V = \frac{g^2}{4\pi} \times h$$

where 'g' is girth at breast height (cm), 'h' is height in (m), π is 3.4125

The composite soil sample collected at a depth of 0 - 15 cm analysed for physic chemical properties following standard procedures (Table 2). The data was analyzed for univariate analysis and one way ANOVA at a significance level of 0.05 and further, to know the difference between the means post hoc test was performed using Duncan test at significance level of 0.05 by using SPSS (Statistical Package for Social Science) version 20.0.

RESULTS AND DISCUSSION

To know the tree crop interface the crop yield and biomass were measured at different distances from the tree line. Non-significant differences were observed in grain yield, biomass yield and harvest index among the different agroforestry systems (Table 3). However, significantly lower grain (1192 kg ha⁻¹) and biomass (5563 kg ha⁻¹) yields were recorded at 5 m distance away from the tree line compared to a distance of 10 m (1450 and 6942 kg ha⁻¹, respectively) and 15 m (1449 and 6720 kg ha⁻¹, respectively) away from the tree line. However, differences in harvest index with respect distance from the tree line were not significant.

Significantly higher grain yield (1520 kg ha⁻¹) was observed in control without proximity of trees compared to the agroforestry systems; the latter accounted an average of 11 per cent reduction in arable crop yield. Whereas, the grain yield did not differ significantly among the various agroforestry systems though numerically higher yield was observed in boundary planting (1378 kg ha⁻¹) followed by bund planting (1370 kg ha⁻¹) and scattered planting (1357

Table 2: Methodology used to analyze the soil properties.

Particulars	Methodology	Reference
pH	1:2.5 soil water suspension with the help of digital pH meter	Jackson (1973)
EC(ds/m)	1:2.5 soil water suspension using conductivity bridge	Jackson (1973)
Organic Carbon (%)	Walkley and Black rapid titration method	Walkley and Black (1934)
CEC (C.mol(p+) kg ⁻¹)	Neutral normal ammonium acetate saturation method	Black (1965)
Particle size distribution (Texture)	Particle analysis with international pipette method	Piper (1950)
Dispersion Ratio	Sedimentation velocity of soil particles	Baruah and Barthakur, (1998)
Bulk Density (gm ⁻³)	Keen- Rackzowski box method	Black (1965)
Porosity (%)	Keen- Rackzowski box method	Black (1965)
MWC (%)	Keen- Rackzowski box method	Black (1965)
Available N (kg ha ⁻¹)	Alkaline potassium permanganate method	Subbiah and Asija (1956)
Available P ₂ O ₅ (kg ha ⁻¹)	Spectrophotometric (Olsen Extraction method with 0.5 M NaHCO ₃ , pH of 8.5)	Jackson (1973)
Available K ₂ O (kg ha ⁻¹)	Flamephotometric (Extraction with N NH ₄ OAc of pH 7)	Jackson (1973)

Table 3: Growth performance of pigeonpea at different distances from the tree line in different agroforestry systems.

Agroforestry systems/ Distance	Grain yield (kg ha ⁻¹)				Biomass yield (kg ha ⁻¹)				Harvest index (HI)			
	Bund planting	Boundary planting	Scattered planting	Mean	Bund planting	Boundary planting	Scattered planting	Mean	Bund planting	Boundary planting	Scattered planting	Mean
5 m	1195 (± 54)	1173 (± 57)	1208 (± 76)	1192 ^a (± 59)	5632 (± 381)	5521 (± 298)	5537 (± 309)	5563 ^a (± 304)	21.25 (±0.51)	21.25 (±0.47)	21.80 (±0.34)	21.43 (±0.48)
10 m	1453 (± 91)	1482 (± 85)	1414 (± 120)	1450 ^b (± 95)	6657 (±569)	6738 (± 747)	6942 (± 565)	6779 ^b (± 586)	21.85 (±0.57)	22.08 (±1.33)	20.43 (±1.10)	21.45 (±1.22)
15 m	1460 (± 147)	1480 (± 79)	1449 (± 68)	1463 ^b (± 95)	6657 (±569)	6732 (± 760)	6720 (± 603)	6703 ^b (± 603)	21.98 (±1.81)	22.13 (±1.97)	21.65 (±1.28)	21.92 (±1.56)
Mean	1369 (± 160)	1378 (± 165)	1357 (± 151)	1368 (± 76)	6315 (± 686)	6331 (± 831)	6399 (± 792)	6348 (± 751)	21.69 (±1.81)	21.82 (±1.33)	21.29 (±1.10)	21.60 (±1.17)
F test(P)												
AFS				0.852 ^{NS}				0.926 ^{NS}				0.535 ^{NS}
Distance				<0.05				<0.05				0.534 ^{NS}
AFS*Distance				0.858 ^{NS}				0.969 ^{NS}				0.403 ^{NS}

Table 4: Productivity of pigeonpea in different agroforestry systems.

Systems	Grain yield (kg ha ⁻¹)	Haulm yield (kg ha ⁻¹)	Harvest index (HI)
Bund planting	1370.00 ^a (±88.41)	6315.83 (±449.38)	21.73 (±0.76)
Boundary planting	1378.00 ^a (±23.28)	6331.04 (±377.98)	21.82 (±1.04)
Scattered planting	1357.00 ^a (±61.83)	6399.83(±293.99)	21.23(±0.25)
Control	1520.00 ^b (±80.05)	6840.00 (±530.63)	22.25 (±0.87)
F test (P)	<0.05	0.295 ^{NS}	0.374 ^{NS}

Note: Values in the parentheses indicate the standard deviation,

^{a-c} Values within the column with same letter are not significantly different at P <0.05.

Table 5: Growth performance of neem trees in different agroforestry systems.

Agroforestry systems	Average growth performance of neem trees in different agroforestry systems			
	Girth (cm)	Height (m)	Crown spread (m)	Volume (m ³)
Bund planting	70.35 (±17.95)	7.61 ^b (±0.98)	6.27 ^a (±0.40)	0.325 (±0.18)
Boundary planting	78.62 (±14.72)	7.38 ^b (±0.86)	6.68 ^b (±0.53)	0.381 (±0.15)
Scattered planting	74.21 (±19.05)	6.46 ^a (±0.82)	6.38 ^{ab} (±0.58)	0.309 (±0.16)
F test (P)	0.315 ^{NS}	<0.05	<0.05	0.350 ^{NS}

Note: Values in the parentheses indicate the standard deviation,

^{a-c} Values within the column with same letter are not significantly different at P <0.05

kg ha⁻¹). Similar was the situation with regard to biomass and harvest index (Table 4). However, numerically higher values for grain and biomass yield were observed in control in comparison to agroforestry systems.

The lower grain and biomass yield near the tree line could be ascribed to the competition offered by trees for light, moisture and nutrients with field crops through shading and root extension in to crop land. The finding highlighted the fact that the competition effect was more near the tree line compared to away from the tree line. In the present study, competition effect of trees was registered up to 5m distance from the tree line. That means while selecting the tree species for agroforestry systems light crown and deep rooted species should be selected or the timely pruning management are imposed for shoot (branches) and roots to reduce the competition effect on the crops to desirable levels (Gaddanakeri, 1991). The results are in line with Muthuri *et al.* (2005) who observed reduction of grain, biomass yield and harvest index of maize in agroforestry system over sole maize and reported nearly 36% of grain yield reduction close to the trees rows at a distance up to 5 m. Thus in the present investigation the lower grain yield in the agroforestry compared to the sole crop is mainly attributed to the competition effect of neem trees for light, moisture and nutrients with field crops.

Further, numerically higher grain yield was recorded in boundary planting followed by bund planting and scattered planting this suggests that boundary planting has minimal effect on the crop compared to the scattered planting where trees are in crop/land and, therefore, had higher competitive effect all round the tree whereas in bund planting it would be on two sides and in boundary planting it would be on only one side of the crop. The findings are in line with Chauhan *et al.* (2015).

Productivity of neem in agroforestry systems

Growth performance of neem trees in different agroforestry systems was measured to know the competition/complementary effect of crop on neem. Significantly higher tree height was recorded in bund planting (7.61 m) followed by boundary planting (7.38 m) and scattered planting (6.46 m) whereas the crown spread recorded was significantly lower in bund planting (6.27 m) followed by scattered planting (6.38 m) and boundary planting (6.68 m) (Table 5). However, there existed non-significant differences in girth, volume and biomass of neem trees grown in different agroforestry systems.

The higher tree height and lower crown spread was recorded in bund planting. This suggested that the trees grown on the bund are better managed through pruning that made the trees to grow straight but tall and cause less shading effect, in turn this also reduced the overall crown spread of the trees. On the other hand, scattered planting recorded lower tree height which may be attributed to absence of competition from perennial component particularly in the off season (winter/summer) as found in bund or boundary system and consequently the trees in scattered planting need not have to outgrow any fellow tree except the under-grown vegetation hence it grew less tall compared to trees in other systems. Besides, high frequent intensity of pruning of trees inside the field might have further suppressed the growth of the trees. However, overall biomass did not differ significantly mainly because the management techniques applied in bund planting and scattered planting were the same. Whereas, thick planting of trees in the boundary might have reduced the biomass on individual plant basis, however, at the age at which the observation made, there occurred non-significant differences in the biomass of the trees grown in different agroforestry

systems, which probably would not be the case as the trees grow and years pass. The findings are in line with Avinash and Ansari (2013).

Significantly lower soil bulk density was recorded in boundary planting (1.50 Mg m^{-3}) followed by bund planting (1.59 Mg m^{-3}) and scattered planting (1.60 Mg m^{-3}) in comparison to control (1.64 Mg m^{-3}) whereas non-significant differences occurred with regard to soil moisture holding capacity, while agroforestry system had higher soil moisture holding capacity compared to the control (without trees) (Table 6). Significantly higher porosity was observed in boundary planting (43.49%) followed by bund planting (39.91%) and scattered planting (39.81%) than under control (37.45%), whereas, non-significant differences occurred in dispersion ratio, and the trend revealed lower values in agroforestry systems compared to control.

Improvement in soil bulk density, higher soil moisture holding capacity and porosity in agroforestry systems could be attributed to the addition of organic matter through leaf by perennial component mainly composed of trees. Among the agroforestry systems significantly lower soil bulk density and higher porosity in boundary planting was due to higher density of trees in the boundary planting which in turn added higher organic matter. The lower dispersion ratio in agroforestry systems could again be ascribed to the organic matter added by tree component in these systems as against control which acts as cementing agent for developing

stable aggregates which in turn improved the soil structure.

Soil pH, EC and organic carbon and CEC did not reveal significant differences (Table 7). Numerically higher organic carbon and CEC were recorded in boundary planting (0.74%, $14.33 \text{ cmol (p+) kg}^{-1}$) followed by bund planting (0.65%, $14.61 \text{ cmol (p+) kg}^{-1}$) and scattered planting (0.66%, $12.26 \text{ cmol (p+) kg}^{-1}$) compared to control (0.48%, $10.73 \text{ cmol (p+) kg}^{-1}$). Further, significantly higher soil available N was recorded in boundary planting ($319.56 \text{ kg ha}^{-1}$) followed by scattered planting ($287.59 \text{ kg ha}^{-1}$) and bund planting ($276.50 \text{ kg ha}^{-1}$) and the lowest soil available N was observed in control ($208.90 \text{ kg ha}^{-1}$). Whereas, P and K varied non-significantly, with numerically values with agroforestry systems compared to the control.

Numerically lower pH and EC values with agroforestry systems could be attributed again to the organic matter in these systems which upon oxidation produced various organic acids which dissolved the salts that lead to loss of basic cations through leaching. Similarly, higher available N, P and K in agroforestry systems could be attributed to contribution of these elements on decomposition of organic matter which were already high, besides to management practices. Organic matter is the important source of both N and P. Trees on the farm land enhance the soil fertility through constant addition of organic matter (Kohil *et al.* 2007). The improvement of soil fertility depends on the

Table 6: Soil textural class and physical properties of different agroforestry systems.

Agroforestry systems	Soil particle size class (%)			Textural class	Bulk density Mg m^{-3}	MWC(%)	Porosity(%)	Dispersion ratio
	Sand	Silt	Clay					
Bund planting	68.66	7.66	23.67	Sandy Clay Loam	$1.59^b (\pm 0.04)$	$43.87 (\pm 9.43)$	$39.91^b (\pm 1.59)$	$20.46^a (\pm 1.77)$
Boundary planting	66.19	5.10	28.72	Sandy Clay Loam	$1.50^a (\pm 0.01)$	$44.29 (\pm 5.00)$	$43.49^c (\pm 0.47)$	$20.09^a (\pm 3.77)$
Scattered planting	69.69	9.04	21.27	Sandy Clay Loam	$1.60^b (\pm 0.04)$	$43.42 (\pm 11.01)$	$39.81^b (\pm 1.67)$	$22.12^{ab} (\pm 4.38)$
Control(without trees)	74.19	5.77	20.04	Sandy Clay Loam	$1.64^b (\pm 0.05)$	$41.95 (\pm 9.10)$	$37.45^a (\pm 1.25)$	$25.88^b (\pm 2.16)$
F test (P)	<0.05				0.989 ^{NS}	<0.05	0.075 ^{NS}	

Note: Values in the parentheses indicates the standard deviation, MWC- Maximum water holding capacity.

^{a-c} Values within the column with same letter are not significantly different at $P < 0.05$.

Table 7: Soil chemical properties of different agroforestry systems.

Systems	pH (1:2.5)	EC (1:2.5) (ds/m)	OC (%)	CEC (cmol(p+)kg ⁻¹)	Available N	Available P ₂ O ₅ (Kg ha ⁻¹)	Available K ₂ O
Bund planting	7.13 (± 0.44)	0.08 (± 0.04)	0.65 ^{ab} (± 0.17)	14.61 ^b (± 3.11)	276.50 ^{ab} (± 81.03)	69.61 ^b (± 10.47)	217.26 (± 42.32)
Boundary planting	6.85 (± 0.42)	0.08 (± 0.06)	0.74 ^b (± 0.08)	14.33 ^{ab} (± 2.14)	319.56 ^c (± 35.50)	64.91 ^{ab} (± 10.48)	234.45 (± 45.55)
Scattered planting	6.97 (± 0.56)	0.06 (± 0.04)	0.66 ^{ab} (± 0.15)	12.26 ^{ab} (± 1.85)	287.59 ^{ab} (± 70.62)	62.01 ^{ab} (± 12.96)	234.66 (± 34.83)
Control(without trees)	7.31 (± 0.42)	0.12 (± 0.01)	0.48 ^a (± 0.10)	10.73 ^a (± 2.03)	208.90 ^a (± 16.22)	48.26 ^a (± 10.26)	191.35 (± 25.52)
F test (P)	0.478 ^{NS}	0.357 ^{NS}	0.109 ^{NS}	0.113 ^{NS}	0.093 ^{NS}	0.090 ^{NS}	0.364 ^{NS}

Note: Values in the parentheses indicates the standard deviation,

^{a-c} Values within the column with same letter are not significantly different at $P < 0.05$.

amount and pattern of litter fall which varies with the species, age, growth, tree density, phenology, intercrops and season (Bhardwaj *et al.* 2001). In addition to this, diammonium phosphate fertilizer was the most commonly used fertilizer in crop production by farmers and more so to pigeonpea. Long time application of this form of P has led to gradual build in the soil. Application of P often exceeds P requirement of the crops cultivated. The findings are in line with Adewole and Adeoye (2014).

Thus, the extent of competition with pigeonpea was of higher order near the neem tree line suggesting necessary management of tree and crop to overcome the negative effect of trees on associated crop. Pruning management especially during cropping season and crop management like selective fertilization would be helpful. The investigation also enlightened that the tree growth grown in different patterns and density in the farm land also get affected. However, merely on yield based productivity assessment of the system is incomplete and therefore economical and ecological benefits of neem trees must be considered while evaluating the productivity of the systems which would be meaningful for promotion of tree land use system.

REFERENCES

- Adewole, M.B. and Adeoye, G.O. (2014). Assessment of soil properties and crop yield under agroforestry in the traditional farming system. *African Journal of Agricultural Research*. 9(27):2119-2123.
- Avinash, J. and Ansari, S.A. (2013). Quantification by allometric equations of carbon sequestered by *Tectona grandis* indifferent agroforestry systems. *Journal of Forestry Research*. 24: 699-702.
- Baruah, T.C. and Barthakur, H.P. (1998). *A Text Book of Soil Analysis*, Vikas Publishing House Pvt. Ltd, New Delhi.
- Bhardwaj, S.D., Panwar, P. and Gautam, S. (2001). Biomass production potential and nutrient dynamics of *Populus deltoids* under high density plantations. *Indian Forester* 117: 144-153.
- Bremen, H and Kessler, J.J. (1995). *Woody Plants in Agro-ecosystems of Semi arid Regions*. Springer Verlag, Berlin.
- Black, C.A. (1965). Methods of soil analysis. *Can. J. Soil sci.* 62: 595-597.
- Chaturvedi, A.N. and Khanna, L.S. (1981). *Forest Mensuration*. International book distributors, Dehradun.
- Chauhan, S.K., Sharma, R., Singh, B. and Sharma, S.C. (2015). Biomass production, carbon sequestration and economics of on-farm poplar plantations in Punjab, India. *Journal of Applied and Natural Science*. 7: 452-458.
- Chittapur, B.M., Doddabasawa, and Umesh, M.R. (2017). On-farm crop diversity for sustainability and resilience in farming. *Agriculture Reviews*. 38: 191-200.
- Coulibaly, Y.N., Mulia, R., Sanou, J., Zombre, G., Bayala, J., Kalinganire, A. and Noordwijk M.V. (2014). Crop production under different rainfall and management conditions in agroforestry parkland systems in Burkina Faso: observations and simulation with WaNuLCAS model. *Agroforest. Syst.* 88: 13-28.
- Donald, C.M. (1962). In search of yield. *The Journal of the Australian Institute of Agricultural Science*. 28: 171-178.
- Gaddanakeri, S.A. (1991). Investigation on effect of *Leucaena* live bund on growth and yield of companion rabi crops under rain fed condition. Ph. D. Thesis, Univ. Agric. Sci. Dharma (India).
- Jackson, M.L. (1973). *Soil Chemical Analysis*. Printice Hall of India, New Delhi.
- Kalaichelvi, K. and Swaminathan, A. A. (2009). Alternate land use through cultivation of medicinal and aromatic plants— A review. *Agriculture Reviews*. 30: 176-183
- Kohil, R.K., Singh, H.P., Batish, D.R. and Jose, S. (2007). Ecological interactions in agroforestry: In: *Ecological Basis of Agroforestry*. [Batish D R, Kohil R K, Jose S, Singh H P (eds)] CRC Press Taylor and Francis Group, New York. pp 5.
- Muthuri, C.W., Ong, C.K., Black, C.R., Ngumi, V.W. and Mati, B. M. (2005). Tree and crop productivity in *Grevillea*, *Alnus* and *Paulownia*- based agroforestry systems in semi-arid Kenya. *Forest Ecology and Management*. 212: 23-39.
- Piper, C.S. (1950). *Soil and Plant Analysis*. Interscience, New York.
- Schroth, G., Da-Fonseca, G.A.B., Harvey, C.A., Gascon, C., Vasconcelos, H.L. and Izac, A.M.N. (2004). *Agroforestry and Biodiversity Conservation in Tropical Landscapes*. Island Press, Washington.
- Subbiah, B.V. and Asija, G.L. (1956). A rapid procedure for estimation of the available nitrogen in soils. *Current Science*. 25: 259-260.
- Tejwani, K.G. (1994). *Agroforestry in India*. Oxford and IBH, New Delhi, India.
- Vandenbelt, R.J., (1992). *Faidherbia albida* in the West African semi arid tropics. ICRISAT, Patancheru, India, 206p.
- Walkley, A.J. and Black, A. (1934). Estimation of soil organic carbon by chromic acid titration method. *Soil Science*. 37: 29-28.