Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(3): 18-23
Received: 13-03-2019
Accepted: 15-04-2019

Tarun Kumar
Department of Forestry, CCS Haryana Agricultural University Hisar, Haryana, India

Bimlendra Kumari
Department of Forestry, CCS Haryana Agricultural University Hisar, Haryana, India

Sandeep Arya
Department of Forestry, CCS Haryana Agricultural University Hisar, Haryana, India

Prashant Kaushik
Instituto de Conservacion y Mejora de la Agrodiversidad Valenciana, Universitat Politecnica de Valencia, Valencia, Spain

Correspondence
Tarun Kumar
Department of Forestry, CCS Haryana Agricultural University Hisar, Haryana, India

Effect of different spacings of *Eucalyptus* based agroforestry systems soil nutrient status and chemical properties in semi-arid ecosystem of India

Tarun Kumar, Bimlendra Kumari, Sandeep Arya and Prashant Kaushik

Abstract
Experiment was conducted in research area of Forestry Department, CCS Haryana Agricultural University, Hisar during 2015-16 to study the effect of different spatial arrangements **(**3×3 m, 6×1.5 m and paired row 17×1×1 m) on *Eucalyptus* based agroforestry system performed better as compared to sole crop in respect of various soil chemical properties and available nutrients status in soil at different soil depths. Among the different spacings organic carbon was found maximum (0.43%) under 3×3 m spacing in soil at different depths. The electrical conductivity had lowered in soil at different depths from its initial status under different spacings of *Eucalyptus* plantations. However, the soil pH did not show any considerable changes in all depths of *Eucalyptus* plantation. Results revealed that available N, P and K in soil at different depths increased significantly under different spacings of *Eucalyptus* based agroforestry system in all the treatments from its initial values in soil at different depths. The highest available soil N (166 kg ha), P (11.4 kg ha) and K (206.6 kg ha) were recorded in surface soil under 3×3 m spacing as compared to other spacings.

Keywords: Agroforestry, *Eucalyptus*, nutrient status, spacing, soil depth, soil properties

Introduction
The most important benefit of agroforestry systems is the enhancement in total production by improving soil fertility (Singh, 2010) [21]. It have been help in carbon sequestration and maintenance of soil productivity by reducing soil erosion and improving salt affected soils by lowering down the water table. Agroforestry can also be an appropriate technology in areas with fragile ecosystem and subsistence farming. Because of access to deeper nutrient pools than the crop, tree absorbs nutrient from deeper root zone and returns nutrients through litter fall and root turnover to the subsurface, thus helping in accumulating nutrients and improving soil physical properties (Singh and Rathod, 2006) [22] and nutrient-use efficiency in the system (Buresh *et al*., 2004) [2]. Increasing human population is placing unprecedented demand for food and natural resources. This large amount of food production cannot be achieved by the agricultural sector only. The solution of this problem is through a combination of technological improvements and involvement of other natural ecosystems (Licker *et al*., 2010) [12]. Biomass production is directly or indirectly related to the availability of plant nutrients besides the growth rate of the species. Due to high density plantations more number of trees is available in a unit area. Also, some amount of nutrient is returned to the soil through leaf litter, hence the overall nutrient cycling studies can help to know the nutrient balance and nutrient removal from the plantation area (Bhardwaj *et al*., 2001). Also the increase in clay and silt content and decrease in sand content and an appreciable increase in the cation exchange capacity, organic carbon content, total and available nutrients were observed under *Eucalyptus* tree plantation (Balamurugan *et al*., 2000) [1]. *Eucalyptus* plantation can ameliorate salinity and sodicity of soil by improving decreasing soil EC, pH and SAR (Nasim *et al.*, 2007) [14]. However, effects of *Eucalyptus* cultivation on soil, especially the fertility-related, are not well defined. So the knowledge about the impact of *Eucalyptus* on soil nutrient reserves as well as on soil organic matter is essential to define sustainable agroforestry practices. It is also likely that the changes in soil chemical properties, particularly in soil organic matter, differ after several *Eucalyptus* rotations, varying with the soil type and dominant climate conditions. The purpose of this study was to evaluate effect of different spacings of *Eucalyptus* based agroforestry system on soil chemical properties and nutrient status.
Among the agroforestry tree species, *Eucalyptus* is of paramount importance due to its fast and uniform growth, self-pruning, ability to coppice and small canopy as compared to most of the

agroforestry tree species. *Eucalyptus* clones have revolutionized the productivity and profitability of the plantations in many states of our country (Lal, 2005) [11] through integration into the various farming systems and their planting has resulted in high economic profitability compared with traditional crop production. Farmers' raised interest in eucalypt farm forestry has now caused for conversion of croplands into eucalypt woodlots (Dereje *et al.*, 2012) [5]. *Eucalyptus* plantation results in improvement in soil nutrient (N, P, K, and organic matter) as compared to natural soil (Jan *et al.*, 1996) [10].

Material and Methods

The present study was conducted at research farm of Forestry Department, CCS Haryana Agricultural 'University, Hisar, Haryana, situated at 29° 10 N latitude and' 75 40 E longitudes at an elevation of 215 m above mean sea level. The climate of the study area is semi-arid and mainly characterized by a hot summer, a short rainy season and a cold winter. Maximum rainfall is received during June to September (monsoon season). The mean annual rainfall is about 450 mm and the mean annual temperature ranges between 16 °C and 20 °C. Already established 8 years old *Eucalyptus* plantation planted at 3×3 m, 6×1.5 m and 17×1×1 m (paired row) spacings were used to carry out the present investigation. Barley crop in rabi and dhaincha in kharif were raised in association with *Eucalyptus* plantation with the recommended cultural practices under different spacings during the entire study period. The textural class of the soil is 'sandy loam' and soil chemical properties and available nutrient status of soil at the time of *Eucalyptus* plantation are depicted in Table 1 and 2. Four soil samples were collected randomly under different spacings in three replicates from three depths (0-30, 30-60 and 60-90 cm). Soil samples were taken before sowing of crops and also from control field for the study of various soil chemical properties (pH, electrical conductivity and organic carbon) and available nutrients (nitrogen, phosphorus and potassium). The samples were air dried, grind in a wooden pestle with mortar, passed through a 2 mm stainless steel sieve and stored for subsequent analysis. The soil pH and electrical conductivity were determined in soil: distilled water suspension (1:2). The available N in the soil was determined by alkaline permanganate method (Subbiah and Asija, 1956) [23], Soil organic carbon was determined by Walkley and Black (1934) [24] rapid titration method. available P by sodium bicarbonate method (Olsen *et al.*, 1954) [16] and available K by neutral normal ammonium acetate method (Jackson, 1973) [9]. The experiment was conducted in randomised block design and data obtained during the course of this investigation, were analysed by using standard statistical procedure (Panse and Sukhatme, 1989) [18].

Table 1: Initial soil chemical properties of the experimental field

Spacings	pH (1:2)				EC (dSm-1)				Organic carbon (%)			
	Depth (cm)				Depth (cm)				Depth (cm)			
	0-30	30-60	60-90	Mean	0-30	30-60	60-90	Mean	0-30	30-60	60-90	Mean
3×3 m	7.62	7.68	7.90	7.73	6.60	1.54	1.50	3.213	0.43	0.31	0.30	0.35
6×1.5 m	7.70	8.02	8.18	7.96	6.36	1.58	1.42	3.120	0.40	0.30	0.26	0.32
17×1×1 m	7.76	7.82	7.92	7.83	6.28	1.20	1.18	2.887	0.38	0.28	0.23	0.30
Control	7.61	8.02	8.22	7.95	6.21	1.36	1.58	3.05	0.31	0.32	0.26	0.29
Mean	7.67	7.93	8.00		6.36	1.42	1.42		0.38	0.30	0.26	
CD at 5%	Spacing: 0.132 Depth:- 0.132 Spacing × Depth: NS				Spacing: 0.228 Depth:- 0.228 Spacing × Depth: NS				Spacing: 0.026 Depth:- 0.026 Spacing × Depth: NS			

Table 2: Initial soil available nutrient status of the experimental field

Spacings	Available N (kg ha-1)				Available P (kg ha-1)				Available K (kg ha-1)			
	Depth (cm)				Depth(cm)				Depth (cm)			
	0-30	30-60	60-90	Mean	0-30	30-60	60-90	Mean	0-30	30-60	60-90	Mean
3×3 m	166.0	111.2	99.6	113.2	11.4	8.48	6.94	8.97	206.6	168.8	142.0	172.46
6×1.5 m	150.4	107.6	98.8	102.2	10.8	8.08	6.56	8.50	202.0	160.8	128.6	163.80
17×1×1 m	151.6	102.8	94.2	109.5	10.9	8.76	5.66	8.13	196.6	166.4	127.2	163.40
Control	151.2	107.9	92.1	103.4	10.3	9.4	5.53	8.07	195.2	163.1	125.4	166.23
Mean	155.0	107.3	96.9		11.1	8.68	6.42		200.1	164.7	130.8	
CD at 5%	Spacing: 2.54 Depth:- 2.54 Spacing × Depth: 4.40				Spacing - 0.205 Depth:-0.205 Spacing × Depth 0.356				Spacing:-2.134 Depth:-2.134 Spacing × Depth: 3.696			

Results and Discussion

The initial status of the available soil nutrients under various soil depths are given in Table 1 and 2. A nominal increase in soil pH was observed with increase in depth under different treatments of spacings. In case of electrical conductivity of soil, the significant differences were observed among different soil depths of all the spacings and control. However, among spacings, the differences were non-significant. The electrical conductivity was recorded highest in surface soil (0-30 cm) under different *Eucalyptus* spacings and it decreased sharply from surface soil to the lower depths under all the spacings of *Eucalyptus* plantation. The organic carbon of soil was higher under *Eucalyptus* plantation spaced at 3×3 m. However, there was significant decrease in organic carbon with the increase in soil depth. -The available nitrogen varied from 151.2 (control) to 166.0 kg ha^{-1} (3×3 m) and it decreased with the increase in soil depths. The available phosphorus in these soils is low with the mean value of 11.4 kg ha in surface soil. As like nitrogen, available phosphorus also decreased with the increase in soil depths. The potash content did not differ significantly with spacing; however, it decreased with increase in soil depth from 0-30 to 30-60 cm.

After 8 years of plantation, the soil pH did not differ significantly from initial values in all the spacings as well as at different depths (Fig. 1). The electrical conductivity was highest in surface soil (0-30 cm) under different *Eucalyptus* spacing and it decreased sharply from surface soil to the lower depths in all the spacings (Fig. 2). The electrical conductivity of soil decreased from its initial mean value 6.36 of surface soil to 3.21 dS m^{-1} i.e. about 50 per cent decrease. Almost similar trend was observed in deeper soil layers under different spacings as well as control. The decrease in electrical conductivity was more distinct in surface soil as compared to lower layers. The electrical conductivity of surface soil decreased from 6.60 to 3.21 dS m^{-1} under 3×3 m spacing of *Eucalyptus* and from 6.28 dS m^{-1} to 3.03 dS m^{-1} in control. The magnitude of decrease of electrical conductivity was almost same under different spacings and it decreased with depths from its initial status. The reduction of soil EC under the tree cover can be attributed to accumulation and subsequent decomposition of organic matter which releases organic acids (Gupta and Sharma, 2009) [8]. The soil organic carbon was significantly influenced by tree spacing as well as soil depths. It increased from its initial status under different soil depths of spacings of *Eucalyptus* based agroforestry system and control (Fig. 3).

The organic carbon in soil increased with the decrease in tree spacing and was found maximum (0.43%) under 3×3 m of *Eucalyptus* spacing in surface soil and it followed the order: 3×3 m> 6×1.5 m>17×1×1 m > control. Similar trend was also observed in lower depths. The lesser organic carbon content under the sole cropping systems may be attributed to continuous cropping with subsequent removal of plant residues. The organic carbon contents of surface soil under 3×3 m, 6×1.5 m, 17×1×1 m spacings increased by 23, 19, and 7% over sole crop, respectively. High organic matter content in the intercropping treatment could be ascribed to the fact that leaf fall before and during crop sowing period on the soil which incorporates in to the soil through tillage practices and their partial decomposition adds to the soil organic matter. These findings are in agreement with Gupta and Sharma (2009) [8]; Das and Chaturvedi (2005) [4]; Yadav *et al*. (2008) [25]. The perusal of data presented in figure 4 depicted an improvement in available nitrogen of soil in different depths from its initial status under different spacings of *Eucalyptus* plantation and sole crop. Available soil nitrogen increased significantly under different spacings of *Eucalyptus* based agroforestry system and sole crop from its initial values. Available N content was maximum (166.0 kg ha) in surface soil under 3×3 m spacing and it decreased with the increase in the spacings and depths. As like organic carbon, available nitrogen was significantly influenced by tree spacing because amount of available N depends upon organic matter. The magnitude of increased available N was highest under 3×3 m spacing and lowest in control. Under 6×1.5 m and 17×1×1 m spacings, the magnitude of the increment was at par and was 24 and 22%, respectively. The trend was similar at lower depths under different spacings and control. The increase in N content of soil under *Eucalyptus* agroforestry systems is attributed to addition of organic matter in soil in the form of litter fall and fine root biomass. The mineralization of organic matter releases nutrient into the soil (Osman *et al*., 2001) [17]. Available phosphorus of soil also exhibited similar trend like soil nitrogen (Fig. 5). Mean available phosphorus in control was 9.6 kg ha^{-1} while, it ranged from 10.8 to 11.4 kg ha^{-1} in different *Eucalyptus* spacings. Among all the different tree spacings, the highest available soil P (kg 11.4 ha^{-1}), was recorded under 3×3 m spacing while it was lowest under control (10.9 kg ha) in surface soil. Among the different soil depths, available phosphorus in the soil increased significantly under different spacings and control after 8 years of *Eucalyptus* plantation. As like N, lowest P was also recorded in 60-90 cm soil depth under different spacings

Potassium content of soil, where *Eucalyptus* trees were intercropped with barley, was higher in 3×3 m spacing and increased from 172.4 kg/ha (2015-16). as compared to the 6×1.5 m and paired row planting 17×1×1 m. The average content of available potassium was under 6×1.5 m and 17×1×1 m spacing the magnitude of the increment was significantly lesser than 3×3 m spacing during 2015-116. It was found at par for 6×1.5 m and 17× 1×1 m spacings, before and after experiment in 2016. Available potassium content of soil where *Eucalyptus* trees were intercropped with crops was higher as compared to the sole crop (Fig. 6). Mean increases in available K were observed to 40, 25, 15 and 12 per cent under 3×3 m, 6×1.5 m, 17×1×1 m and control, respectively over its initial values. The higher nutrient status under closer spacings might be due to the addition of large quantity of leaf litter. The higher decomposition of leaf litter favors the higher nutrient status of the soil. Similar findings were also observed by Singh and Sharma (2007) [20] in poplar. The higher available nutrient content in agroforestry system over the agriculture system may be attributed to litter-fall addition from trees as well as addition of root residues of crops and trees. These findings were supported by (Gupta and Sharma, 2009) [8]. On account of recycling of organic matter, higher organic carbon and available N, P and K contents were observed in the soil under intercropped *Eucalyptus* plantations than at a site without trees and the contents varied depending upon the intercrops. The impact of agroforestry systems on soil fertility in terms of higher organic matter content, total nitrogen, available phosphorus and potash in the top soil has been reported by Rizvi *et al*. (2011) [19] as well

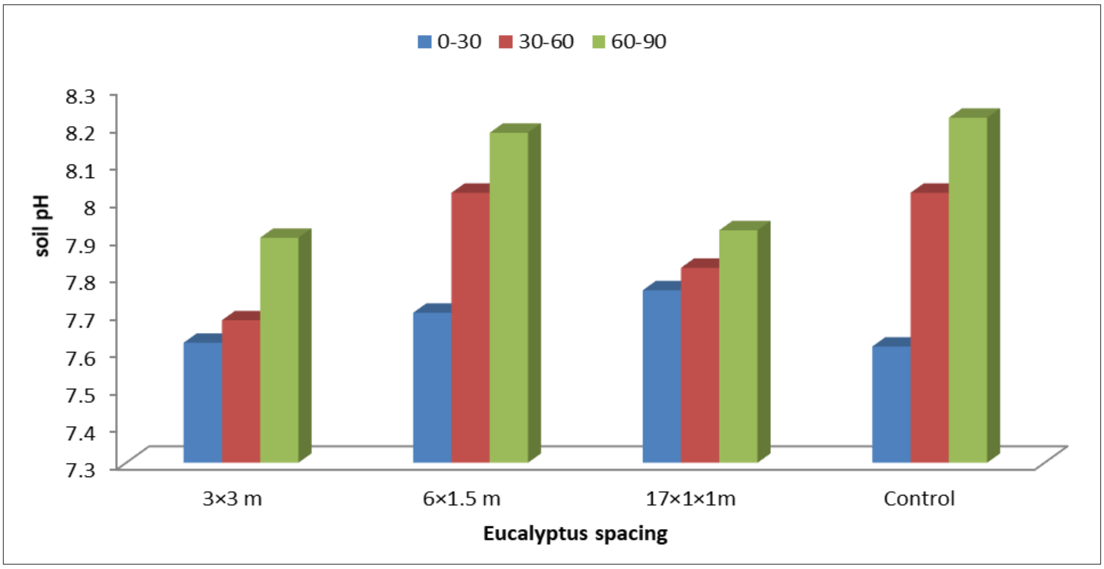

Fig 1: Soil pH under different *Eucalyptus* plantation and control

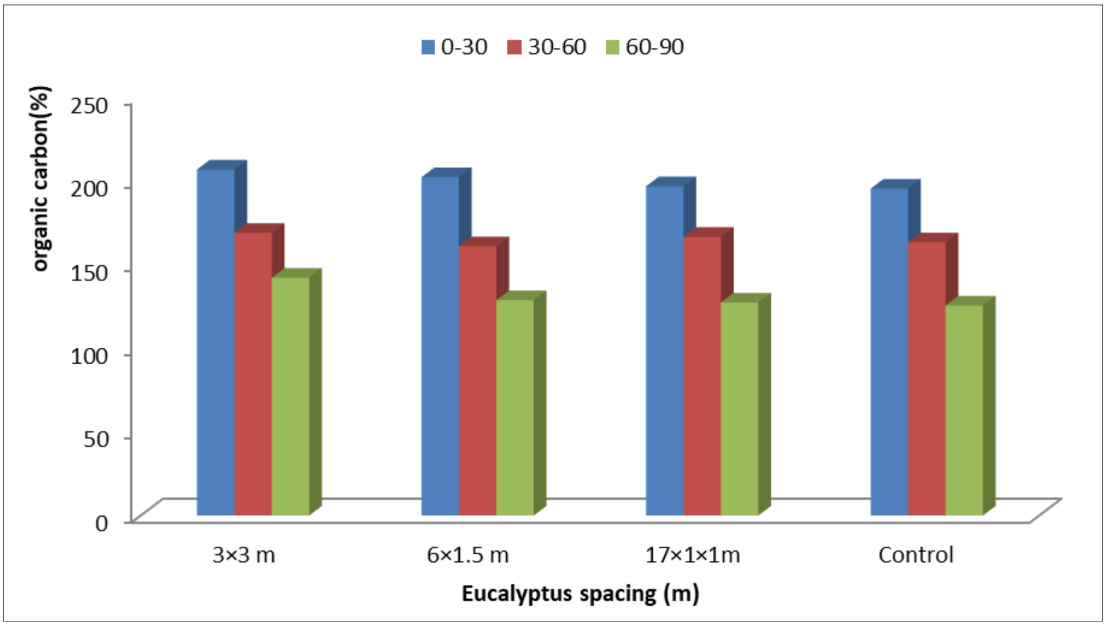

Fig 2: Electrical conductivity (dS m) of soil under different spacings of *Eucalyptus* plantation and control

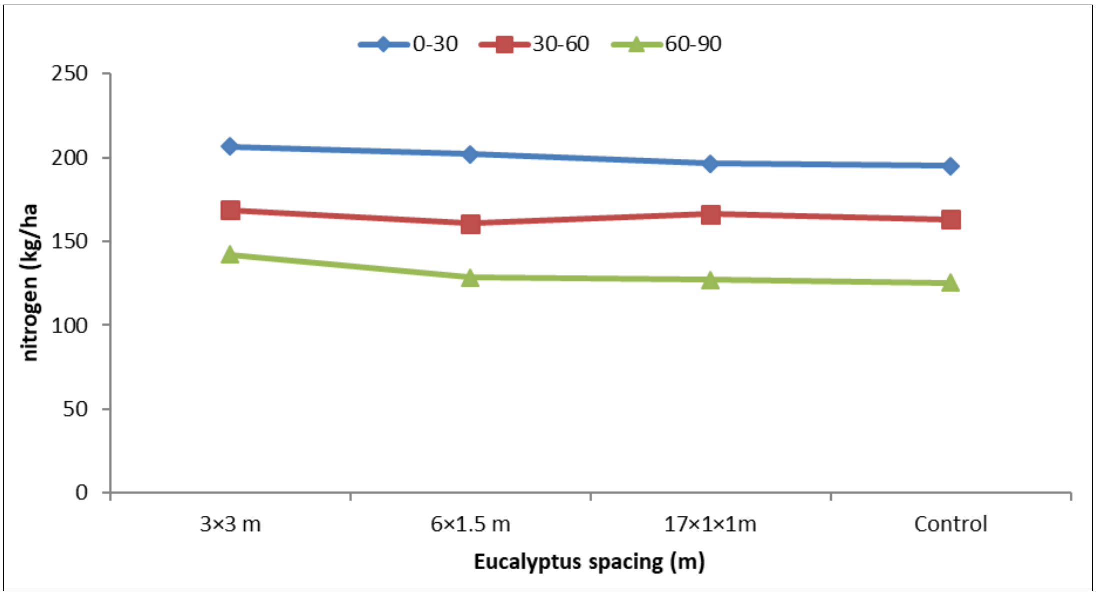

Fig 3: Organic carbon (%) of soil under different spacings of *Eucalyptus* plantation and control

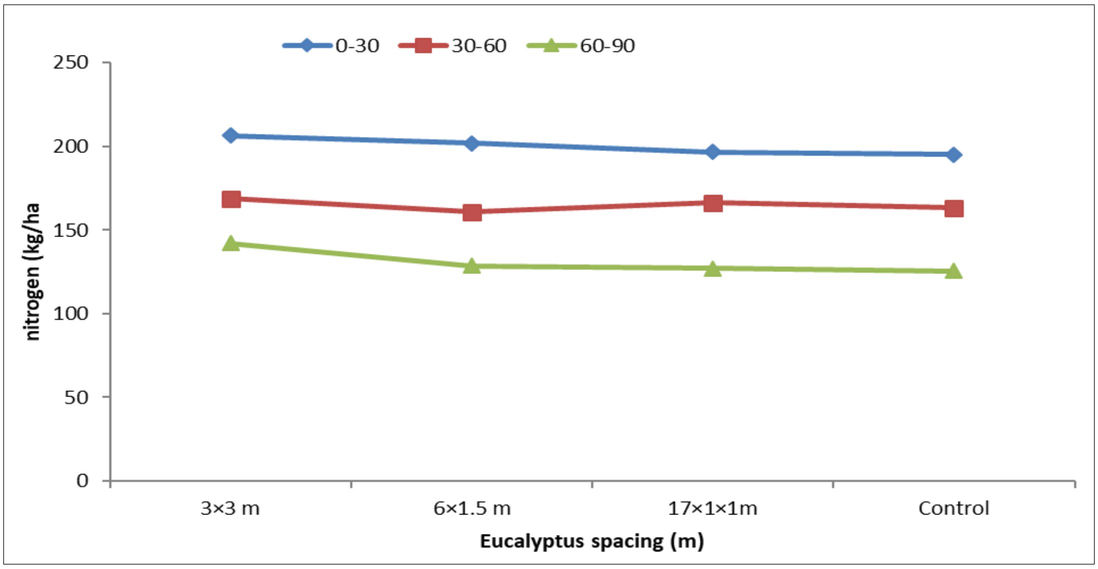

Fig 4: Available nitrogen (kg /ha) of soil under different spacings of *Eucalyptus* plantation and control

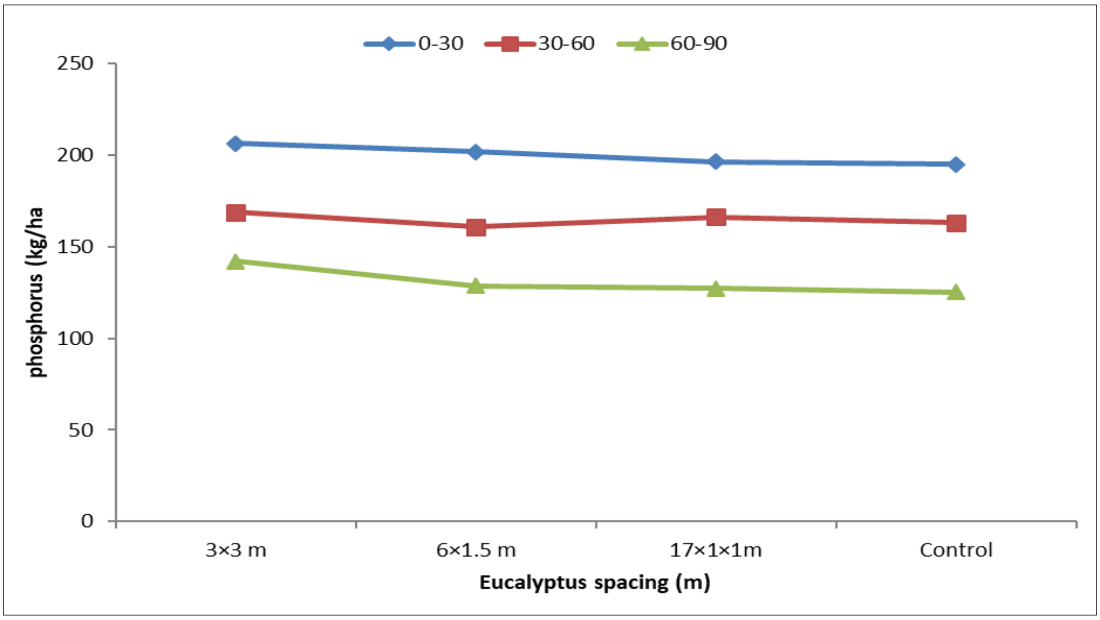

Fig 5: Available phosphorus (kg /ha) of soil under different spacings of *Eucalyptus* plantation and control

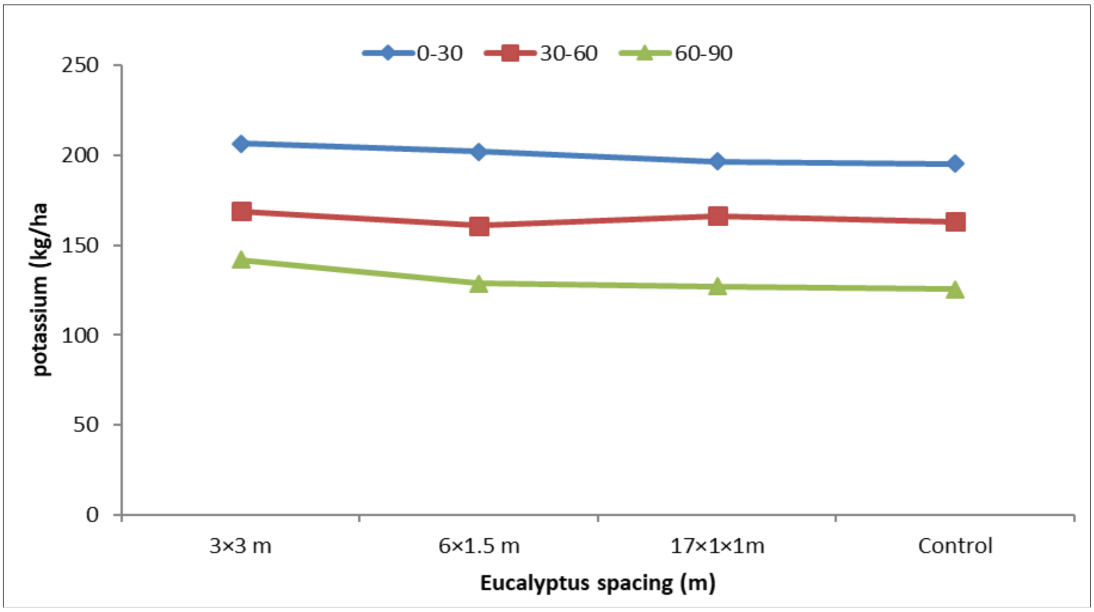

Fig 6: Available potassium (kg /ha) of soil under different spacings of *Eucalyptus* plantation and control

References

1. Balamurungan J, Kumaraswamy K, Rajarajan A. Effect of *Eucalyptus* citriodora on the physical and chemical properties of soils. Journal of Indian Society of Soil Science. 2000; 48:491-495.
2. Buresh RJ, Rowe EC, Livesley SJ, Cadisch G, Mafongoya P. Opportunities for capture of deep soil nutrients. In: van Noordwijk M, Cadisch G and Ong CK, editors. Belowground interactions in tropical agroecosystems: concepts and models with multiple plant components. Wallingford: CABI International, 2004, 109-125.
3. Chauhan SK, Ritu. Towards agro-ecological health: diversifying traditional crop rotation through agroforestry in Punjab, India. Asia-Pacific Agroforestry News. 2005; 27(3-4):6.
4. Das DK, Chaturvedi OP. Structure and function of Populus deltoides agroforestry system in eastern India: 1 Dry matter dynamics. Agroforestry Systems. 2005; 65:215-221.
5. Dereje J, Mulugeta L, Kassa H. Expansion of eucalypt farm forestry and its determinants in Arsi Negelle District, south central Ethiopia. Small Scale Forestry. 2012; 11:389-405.
6. FAO. Advancing agroforestry on the policy agenda. Agroforestry Working Paper No. 1, Rome: FAO, 2013.
7. Fukushima T, Morimoto Y, Maundu P, Kahindi B, Fondo J. Local preference of indigenous fruit trees in Coast Province, Kenya. African Environment Science and Technology. 2010; 4:872-885.
8. Gupta MK, Sharma SD. Effect of tree plantation on soil properties, profile morphology and productivity index: poplar in Yamunagar district of Haryana. Annals of Forestry. 2009; 17:43-70.
9. Jackson ML. Soil Chemical Analysis. Prentice hall of India Pvt. Ltd., New Delhi, 1973.
10. Jan MN, Dimri BM, Gupta MK. Soil nutrient changes under different ages of *Eucalyptus* monocultures. Indian Forester. 1996; 122:55-60.
11. Lal P. Integrated development of agroforestry plantations and wood based industries. In: Agroforestry in 21 century (Eds. K. Chauhan, S.S. Gill, S.C. Sharma and Rajni Chauhan). Agrotech Publishing Academy, Udaipur, 2005, 296-303.
12. Licker R, Johnston M, Foley JA, Barford C, Kucharik CJ, Monfreda C *et al*. Mind the gap: how do climate and agricultural management explain the 'yield gap' of croplands around the world? Global Ecology and Biogeography. 2010; 19:769-782.
13. Murthy IK, Gupta M, Tomar S, Munsi M, Tiwari R, Hegde GT *et al*. Carbon sequestration potential of agroforestry systems in India. Journal of Earth Science and Climate Change. 2013; 4:1-9.
14. Nasim M, Qureshi RH, Saqib M, Aziz T, Nawaz S, Akhtar J *et al*. Properties of salt affected soil under *Eucalyptus* camaldulensis plantation in field conditions. Pakistan Journal of Agriculture Science. 2007; 44:401-414.
15. Ndayambaje J, Mohren G. Fuelwood demand and supply in Rwanda and the role of agroforestry. Agroforestry Systems. 2011; 83:303-311.
16. Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. United States Department of Agriculture Circular, 1954, 939.
17. Osman KT, Rahman MM, Barua P. Effects of some forest tree species on soil properties in Chittagong University Campus, Bangladesh. Indian Forester. 2001; 127:431-442.
18. Panse VG, Sukhatme PV. Statistical Methods for Agricultural Workers, 4th Edition, ICAR, New Delhi, 1989, 359.
19. Rizvi RH, Dhyani SK, Yadav RS, Singh R. Biomass production and carbon stock of poplar agroforestry systems in Yamunagar and Saharanpur districts of northwest India. Current Science. 2011; 100:736-742.
20. Singh B, Sharma KN. Tree growth and nutrient status of soil in a poplar (Populus deltoides Bartr) based agroforestry system in Punjab, India. Agroforestry Systems. 2007; 70:125134.
21. Singh G. Rainfall dependent competition effected productivity of V. radiata in Hardwickia binata agroforestry in Indian Desert. Indian Forester. 2010; 136:301-315.
22. Singh G, Rathod TR. Growth, production and resource use in Colophospermum mopane based agroforestry system in north-western India. Archives of Agronomy and Soil Science. 2006; 53:75-88.
23. Subbiah BV, Asija GL. A rapid procedure for the estimation of the available nitrogen in soils.Current Science. 1956; 25:259260.
24. Walkley A, Black IA. An examination degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science. 1934; 37:29-37.
25. Yadav RS, Yadav BL, Chhipa BR. Litter dynamics and soil properties under different tree species in a semi-arid region of Rajasthan, India. Agroforestry Systems. 2008; 73:1-12. s