



Production of humic substances and available nutrient status in soil profile under multipurpose tree species of arid and semiarid region

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ABSTRACT

To study the effect of different tree species on organic carbon, production of humic substances and nutrient status in soil profile under different tree species, five blocks of different tree plantations, viz. *Prosopis cineraria*, *Dalbergia sissoo*, *Acacia nilotica*, *Eucalyptus tereticornis* and *Tamarix aphylla* were selected. Seven soil samples depth wise up to 150 cm from each soil profile including six one without plantation (control) was collected and analyzed for organic carbon, humic acid, fulvic acid and available nutrient status in soil. The organic carbon content decreased with increase in soil depth and highest organic carbon was found in surface layer of *Dalbergia sissoo* in comparison to other tree species and control. Similarly humic acid and fulvic carbon decreased with increase in soil depth and maximum humic acid was found under *Dalbergia sissoo* and in fulvic acid, it was highest under *Acacia nilotica* and minimum in control in both the cases. The available nutrients were decreased with increase in depth higher amount of nutrients were found under tree species as compared to control. It may be concluded that tree litter falling from *Acacia nilotica*, *Dalbergia sissoo* and *Prosopis cineraria* was stabilized enough and improved the availability of nutrients in soil. The intercrop may be taken up successfully between the trees of these plantations. In case of *Eucalyptus tereticornis* and *Tamarix aphylla*, more time is needed for stabilization and decomposition of litter for their better management and high returns.

Key words: Available nutrients, Humic substances, Litter, Soil profile, Tree species

The relationship between the soil and the tree species demonstrates the dominance of the plantation factor operative in semi-arid regions. Tree add biomass to the soil in the form of root residue, leaves, twigs, stems and flowers which after decomposition result in the formation of organic matter and release of different plant nutrients (Singh *et al.* 1990). The accumulation of organic material on the forest soil is largely the function of annual amount of litter fall and the annual rate of its decomposition. However, the total litter produced in a unit time, its decomposition rate and loss (erosion) determine the amount of litter and nutrient present in the soil (Murthy *et al.* 1990).

Return of nutrients to soil varies with species, plantation age, decomposition rate, season and spacing (Patel *et al.* 2010). The incorporation of leaf biomass of different tree species has been found very successful and hence widely adapted for improving the physico-chemical characteristics and nutrient status of the soil (Singh and Sharma 2012). The

decomposition rate of leaf biomass is primarily a function of the chemical quality and prevailing weather conditions (Kumar *et al.* 1998). Trees exercise short and long term effects on physico-chemical and biological properties of soils. In short term when litter decomposes as a result of microbial activity, the nutrients contained within it may follow two paths- Mineralization and/or Humification. High quality litter (lower in lignin content) decays fast and releases nutrients rapidly than that of low quality litter (higher in lignin or phenols content) (Swift *et al.* 1978). In view of the importance of litter fall on the soil physico-chemical properties and nutrient release pattern, there is a much need to characterize the surface soil litters for its proper management. The understanding of nutrient availability may also pave the way for getting sustainable production from intercropping. The studies on the influence of tree species on the soil organic carbon and nutrient content in soil are lacking in Haryana. Therefore, the depth-wise status of soil organic carbon, their humification and nutrients status in soil profile were determined under multipurpose tree species of the region.

MATERIALS AND METHODS

The present investigation was carried out at Research Farm of Department of Agroforestry, CCS Haryana

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Agricultural University, Hisar. The CCS Haryana Agricultural University Hisar is located at 29°10'N latitude and 75°46'E longitude at an altitude of 215 m above mean sea level. It has a semi arid and sub tropical climate with hot, dry and desiccating winds during summer and severe cold during winter season. The mean monthly maximum temperature during summer months (May to July) reaches up to 42 to 45°C, while the minimum temperature during winter months (December and January) sometimes goes as low as 0°C or even less. Average rainfall varies from 353 to 447 mm, most of which is received during the months of July-August and few showers of cyclonic rains are received in winter or late springs. The average wind speed is about 7 kmph.

Block plantation (minimum one hectare) of five multipurpose tree species of arid and semi-arid region, viz. *Prosopis cineraria*, *Dalbergia sissoo*, *Acacia nilotica*, *Eucalyptus tereticornis* and *Tamarix aphylla* of about 15 to 20 years old were selected. From each block, one tree, which was surrounded by the trees of the same species on all sides, was selected. One tree selected from each block represented one replication. From the base of tree, four points at a distance of 1 m in east, west, north and south directions were marked. Seven samples, one leaf litter (decomposed and undecomposed) up to a depth of 4 cm and six soil samples from 4-15, 15-30, 30-60, 60-90, 90-120 and 120 to 150 cm depths from periphery of one meter from four directions (East, West, North and South) were collected with the help of an auger. All the four samples collected from the four directions were mixed and homogenized to form a composite sample this make one replication. Similarly, from another block of the same tree species, depth wise samples were also collected to make second replication. In the same way soil samples were collected from the nearby area of plantation which was devoid of trees and undisturbed (control). Thus, soil samples collected from block plantation and area adjacent the plantations (devoid of plantation) were compared to meet the defined objectives of the study.

Samples were air dried, ground by a pestle and mortar and passed through 0.2 mm sieve. These samples were stored in poly bags for further analysis. The samples were analyzed for soil organic carbon, available N and P, available micronutrients (Zn,Cu,Mn and Fe) and humic acid and fulvic acid carbon. The organic carbon in soil samples was determined by Walkey and Black method (1934), available N by alkaline permanganate method (Subbiah and Asija 1956), available P by Olsen's method (Olsen 1954) and available micronutrients were extracted with DTPA (Lindsay and Norvell 1978). The humic and fulvic acids were extracted with 0.1 N NaOH by using the method of Schlichting and Blume (1966). The humification index which determines the degree of humification of organic matter was calculated as ratio of humic acid carbon to total organic carbon and calculated by using $(\text{humic acid}/\text{Corg}) \times 100$ expressions (Bernal *et al.* 1998).

The data of different soil properties were subjected to statistical analysis using ANOVA technique in split plot

design by taking tree species (including control) in main plots and soil depths in sub-plots. Mean separation was done with the critical difference (CD) test at 5% level of significance (Panse and Sukhatme 1989).

RESULTS AND DISCUSSION

Soil organic carbon

Organic carbon content was higher in 0-4 cm layer in control as well as under different plantations (Fig 1). There was a significant decrease in organic carbon content with increase in depth. It was because of high biomass accumulation on the surface layer. Patel *et al.* (2010) and Thakur *et al.* (2012) also observed higher organic carbon in surface layers and gradual decrease downwards in soils under tree plantation. The highest amount of organic carbon (1.6%) was observed under surface layer of *Dalbergia sissoo* plantation which was followed by *Acacia nilotica* (1.5%), *Prosopis cineraria* and *Tamarix aphylla* (1.2%) and *Eucalyptus tereticornis* (1.0%). In general among tree species, on an average highest amount of organic carbon accumulation in soils under different plantation may be attributed possibly to the difference in type of vegetation, litter composition and its humification. Comparatively higher accumulation of organic carbon in soils under *Dalbergia sissoo* and *Acacia nilotica* may be attributed to the higher annual biomass production by these tree species (Kumar *et al.* 1998 and Prasad *et al.* 1991).

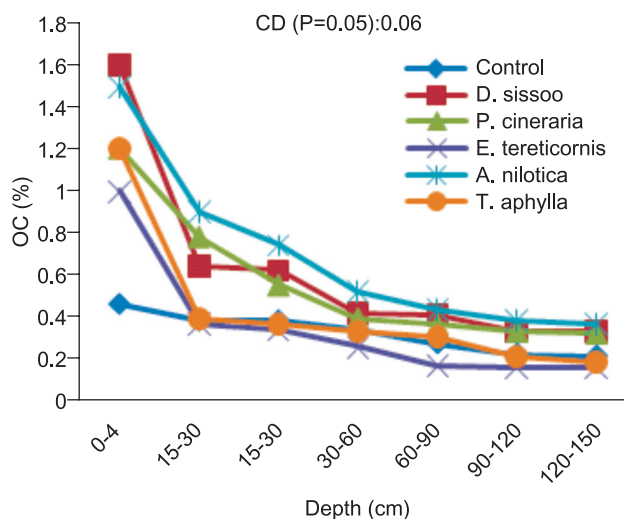


Fig 1 Organic carbon (%) status in soil profile under different tree species

Humic acid production

The humic acid carbon decreased significantly with depth in all soil profiles (Fig 2). The humic acid carbon content varied from 0.3 to 0.07% in control, 0.65 to 0.13% in *Dalbergia sissoo*, 0.55 to 0.19% in *Prosopis cineraria*, 0.81 to 0.13% in *Acacia nilotica*, 0.63 to 0.14% in *Eucalyptus*

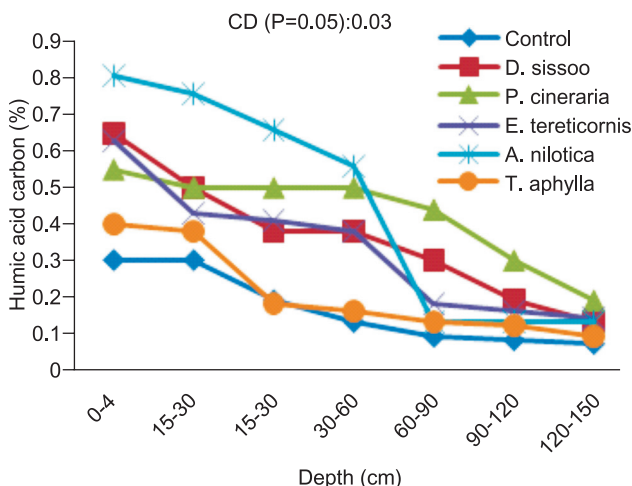


Fig 2 Humic acid carbon (%) production in soil profile under different tree species

tereticornis and 0.4 to 0.09% in *Tamarix aphylla*. The maximum humic acid concentration was recorded in surface soil under *Acacia nilotica* plantation (0.81%) followed by *Dalbergia sissoo* (0.65%), *Eucalyptus tereticornis* (0.63%), *Prosopis cineraria* (0.55%), *Tamarix aphylla* (0.4%) and in control (0.3%). The highest concentration of humic acid carbon in upper soil layer of *Acacia nilotica* plantation showed that the litter might have high amount of lignin and nitrogen content which readily converted into humic substances. All the plantations significantly enhanced humic acid contents over the control at all the soil depths.

Fulvic acid production

The concentration of fulvic acid decreased with the increase in depth of soil profile in all conditions but the maximum production was observed in surface layer (0-4 cm) of *Acacia nilotica* followed by *Eucalyptus tereticornis*, *Dalbergia sissoo*, *Tamarix aphylla* and control (Fig 3). The

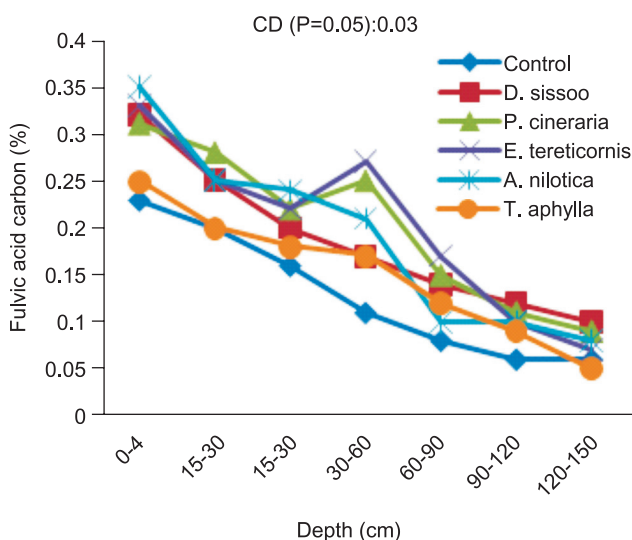


Fig 3 Fulvic acid carbon (%) production in soil profile under different tree species

fulvic acid carbon content varied from 0.23 to 0.06% in control, 0.32 to 0.10% in *Dalbergia sissoo*, 0.31 to 0.09% in *Prosopis cineraria*, 0.35 to 0.08% in *Acacia nilotica*, 0.33 to 0.07% in *Eucalyptus tereticornis* and 0.25 to 0.05% in *Tamarix aphylla*. In general, the production of fulvic acid was lower than that of humic acid production thereby indicating that lignin content of all the tree litters polymerized readily with nitrogen compounds producing humic substances. Prasad *et al.* (1991) also reported higher concentration of humic acid than the fulvic acid content in soils under *sal*, *teak*, *Eucalyptus* and *subabul* plantations.

Humic acid : Fulvic acid ratio (HA:FA ratio)

It is well established that humic acid fractions is more stabilized form of organic matter and mainly help in improving the physico-chemical properties of soil, whereas fulvic acid make the plant nutrient more mobile and increase their availability to the plants. Therefore, the ratio of humic acid and fulvic acid and humification index are often calculated to quantify the mineralization and humification rate to establish the stability stage of different kind of organic matters irrespective of source during their decomposition process. In general, the HA : FA ratio was highest under *Acacia nilotica* (2.2) followed by *Prosopis cineraria* (2.1), *Dalbergia sissoo* (1.9), *Eucalyptus tereticornis* (1.6), *Tamarix aphylla* (1.4) and control (1.2) (Fig 4). The decomposing waste which has HA:FA ratio >1.9 is considered to be stable enough and does not affect the seed germination and plant growth (Iglesias *et al.* 1992). In the present case, only the litter under *Acacia nilotica*, *Dalbergia sissoo* and *Prosopis cineraria* plantation had HA:FA ratio >1.9 in the upper surfaces and would not affect the seed germination and plant growth of intercropping crops. The other litters need some nitrogen and more time for stabilization.

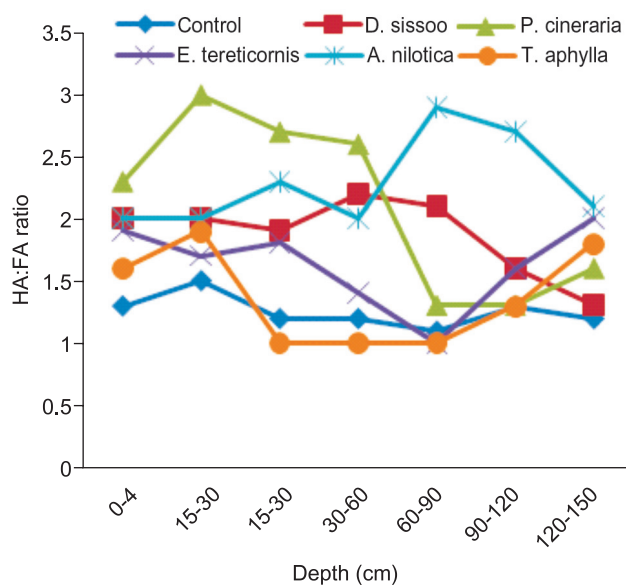


Fig 4 Humic acid: Fulvic acid ratio in soil profile under different tree species

Humification index (HI)

The humification index which determines the degree of humification of organic matter increased up to 30-60 cm soil profile depth under all the tree species except *Tamarix aphylla* and control where an increase was observed up to 15 cm depth. The maximum rate of humification was observed in *Eucalyptus tereticornis* (152.0) and lowest in control (33.3).

Available macronutrients

The available nitrogen was highest (325 ppm) at surface layer of *Acacia nilotica* followed by *Dalbergia sissoo* (310 ppm), *Prosopis cineraria* (285 ppm), *Eucalyptus tereticornis* (280 ppm), *Tamarix aphylla* (250 ppm) and minimum in control (60 ppm) (Fig 5). Like organic carbon, available nitrogen also decreased significantly and gradually with the increase in depth. In contribution towards available nitrogen in soil profile, the tree species can be categorized as *Acacia nilotica* > *Dalbergia sissoo* > *Prosopis cineraria* > *Eucalyptus tereticornis* > *Tamarix aphylla*. Singh and Sharma (2012) also reported higher available nitrogen status in soil under tree plantation in arid region of Punjab. The highest concentration of available nitrogen at surface layer may be due to the accumulation of leaf litter and its gradual decomposition and mineralization. The nitrogen fixing tree species (*Acacia nilotica*, *Dalbergia sissoo* and *Prosopis cineraria*) contributed significantly more nitrogen than non nitrogen fixing tree species (*Eucalyptus tereticornis* and *Tamarix aphylla*). *Eucalyptus tereticornis* and *Tamarix aphylla* being non nitrogen fixing and ever green in nature shed comparatively less amount of biomass resulting less nitrogen in soil. The results of present study are in conformity with the findings of Singh *et al.* (2000).

The Olsen's available phosphorus decreased significantly with increase in soil depth. The available phosphorus in soil profiles varied from 11.9 to 7.8 ppm in control, 29.4 to 10.3 ppm in *Dalbergia sissoo*, 28.7 to 8.1 ppm in *Prosopis cineraria*, 28.0 to 8.2 ppm in *Eucalyptus tereticornis*, 30.8 to 9.5 ppm in *Acacia nilotica* and 28.0 to

8.2 ppm in *Tamarix aphylla*. The concentration of available phosphorus under plantation was significantly more than control. Under tree species, the highest available phosphorus was recorded in *Dalbergia sissoo* (17.2 ppm). The nitrogen fixing tree species helped in accumulation of higher available phosphorus than non nitrogen fixing species (Ahlawat 1993).

Available micronutrients

The DTPA extractable zinc, copper, iron and manganese were estimated in soil profiles under different plant species. In general, the micronutrients concentration was more under surface horizon in control as well as under all the tree plantations. It decreased gradually and significantly with the increase in depth. In comparison to control, the micronutrients concentration was significantly higher in soils under all the tree species. Among tree species, micronutrients were present in significantly more quantity under *Dalbergia sissoo*. The highest accumulation of Zn (4.8 ppm) was observed in surface soils under *Prosopis cineraria*, which was followed by *Dalbergia sissoo* (4.6 ppm), *Acacia nilotica* (4.4 ppm), *Eucalyptus tereticornis* (4.2 ppm) and *Tamarix*

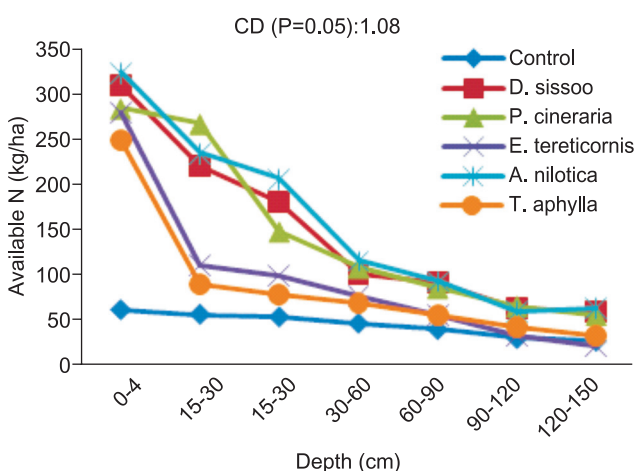


Fig 5 Available nitrogen (kg/ha) in soil profile under different tree species

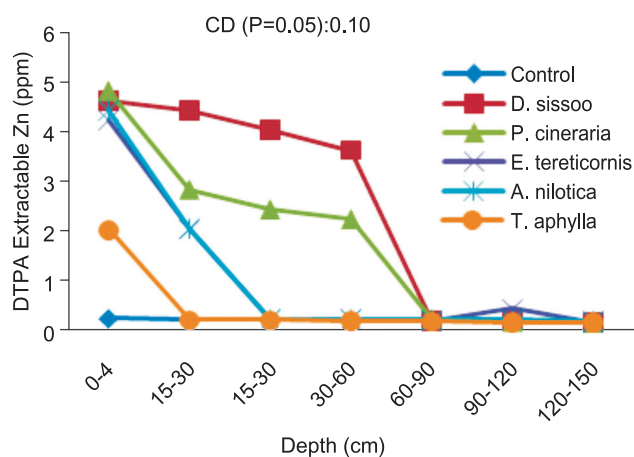


Fig 6 DTPA extractable Zn (ppm) in soil profile under different tree species

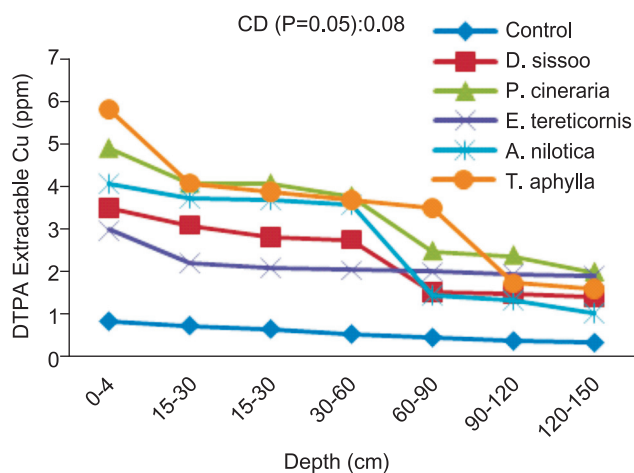


Fig 7 DTPA extractable Cu (ppm) in soil profile under different tree species

aphylla (2.0 ppm) and the minimum was recorded in control (0.2 ppm) (Fig 6). The Zn concentration decreased significantly with increase in depth of the soil. The decrease was more drastic beyond 15-30 cm layer except in case of *Dalbergia sissoo* and *Prosopis cineraria*. Zinc accumulation under *Dalbergia sissoo* was significantly higher in comparison to other tree species and it was lower in *Tamarix aphylla*. The data regarding Cu concentration under control and different plantation revealed that maximum concentration was in the surface layer and decrease with depth in the soil profile (Fig 7). The decrease was gradual and significant. The highest amount was recorded in the soil profile under *Tamarix aphylla* (3.58 ppm) which was followed by *Prosopis cineraria* (3.50 ppm), *Acacia nilotica* (2.81 ppm), *Dalbergia sissoo* (2.48 ppm) and *Eucalyptus tereticornis* (2.27 ppm). The highest Fe concentration on average basis was recorded under *Prosopis cineraria* (7.25 ppm) plantation followed by *Dalbergia sissoo* (6.31 ppm), *Eucalyptus tereticornis* (5.62 ppm), *Tamarix aphylla* (4.88 ppm) and *Acacia nilotica* (4.47 ppm). The Fe concentration was also highest in upper most layers and decreased significantly with depth. Similarly, highest Mn concentration (16.74 ppm) was recorded in surface layer under *Dalbergia sissoo* plantation followed by *Acacia nilotica* (15.92 ppm), *Prosopis cineraria* (9.86 ppm), *Eucalyptus tereticornis* (9.3 ppm) and minimum under *Tamarix aphylla* (8.05 ppm). Like other micronutrients, Mn concentration also decreased significantly with the increase in depth. Singh and Sharma (2012) also observed higher concentration of micronutrients under tree species as compared to control. The difference in status of various micronutrients under tree species could be due to variation in quantity of litter fall and its nutrient composition.

Relationship between different characteristics

A relationship among different components related to nutrient status and humification of organic matter were worked out and the values of coefficient of correlation between them are presented in Table 1. Organic carbon positively and significantly related to nutrient status and humic acid and fulvic acid production, however, relation

with HA/FA and HI was non-significant, indicating its role in nutrient make up and humification. The humic acid and fulvic acid, being the component of humus showed a positive and highly significant relationship ($r=0.886$) among themselves and also showing positive and significant relationship with nutrient status in soil. Humic acid: fulvic acid ratio (HA/FA) and Humification index (HI) showed a poor correlation with nutrient status and organic carbon of soil. The macronutrient (N and P) were showing positive and highly significant correlation with organic carbon and micronutrients, however their relation with HA/FA ratio and HI was non-significant. The micronutrients were also showed non significant correlation with HA/FA ratio and HI except Fe content which were showing positive and significant correlation with HA/FA ratio.

It is clear that organic carbon being store house of humus and plant nutrient contributed positively and significantly towards them which is indicative of its role in building up and maintenance of soil fertility. Different plantations, since contribute towards increased organic matter through litter fall are known to improve soil fertility and maintain it for a longer period.

Organic carbon and nutrient status in soil under plantations were improved mainly because of increased soil organic matter and root activity of trees, more so in the top layer where accumulation of litter took place. Organic carbon and nutrient status were comparatively higher in case of nitrogen fixing tree species, i.e. *Dalbergia sissoo*, *Acacia nilotica* and *Prosopis cineraria*; however, a decreasing trend downward was noticed under the nitrogen fixing tree species. HA/FA ratio was more than 1.9 in the upper surface layer and would not affect the growth and germination of other crops. The maximum humification was observed under *Eucalyptus tereticornis*. Soil organic carbon contributed towards improvement in nutrient build up in soil. With respect to their efficiency in maintaining/upgrading soil fertility and physical conditions of soils, the tree species under study may be arranged as : *Dalbergia sissoo*>*Acacia nilotica*>*Prosopis cineraria*>*Eucalyptus tereticornis*>*Tamarix aphylla*.

Table 1 Coefficient of correlation (r) values between different characteristics

	OC	HA	FA	Ha/Fa	HI	N	P	Zn	Cu	Fe	Mn
OC	1.00	0.772**	0.772**	0.193 ^{NS}	-0.218 ^{NS}	0.941**	0.924**	0.774**	0.628**	0.643**	0.613**
HA		1.00	0.886**	0.514**	0.366*	0.857**	0.713**	0.693**	0.669**	0.682**	0.676**
FA			1.00	0.401**	0.301 ^{NS}	0.847**	0.783**	0.723**	0.669**	0.761**	0.568**
Ha/Fa				1.00	0.590**	0.316*	0.247 ^{NS}	0.348*	0.233 ^{NS}	0.596**	0.205 ^{NS}
HI					1.00	-0.052 ^{NS}	-0.152 ^{NS}	-0.035 ^{NS}	0.172 ^{NS}	0.243 ^{NS}	0.108 ^{NS}
N						1.00	0.906**	0.844**	0.712**	0.741**	0.654**
P							1.00	0.888**	0.646**	0.711**	0.567**
Zn								1.00	0.554**	0.759**	0.564**
Cu									1.00	0.655**	0.409**
Fe										1.00	0.402**
Mn											1.00

*Significance at 0.01 level (two tailed), ** significance at 0.05 level (two tailed)

REFERENCES

- Ahlawat V P. 1992. Status distribution, transformation and availability of phosphorus in typical soil of Haryana. Ph D thesis, CCS HAU, Hisar.
- Bernal M P, Paredes C, Sanche Monedero M A and Cegrra J. 1998. Maturity and stability parameters of compost prepared from with a wide range of organic wastes. *Bioresource Technology* **63**: 91–9.
- Iglesias Timenez E and Perez-Garcia V. 1992. Determinations of maturity indices for city refuse composts. *Agriculture Ecosystems and Environments* **38**: 331–43.
- Kumar Ravi, Kumar Anil and Dhillon R S. 1998. Morphological and physico-chemical characteristics of soil under different plantations in arid ecosystems. *Indian Journal of Forestry* **21**: 248–52.
- Lindsay W L and Norwell W A. 1978. Development of a DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of America Journal* **42**: 421–8.
- Murthy I Y L N, Hazra C R and Kumar A. 1990. Effect of incorporation of tree leaves on soil fertility. *Journal of the Indian Society Soil Science* **38**: 325–7.
- Olsen S R, Cole C V, Watanable F S and Dean C A. 1954. Estimation of available P in soil by extraction with sodium bicarbonate. Circular, US Department of Agriculture. 939.
- Panse V G and Sukhatme. 1989. *Statistical Methods for Agricultural Workers*. ICAR, New Delhi.
- Patel J M, Jaimini S N and Patel S B. 2010. Physico-chemical properties of soil under different tree species. *Indian Journal of forestry* **33**: 565–8.
- Prasad B and Rokima J. 1991. Integrated nutrient management-I. Nitrogen fractions and their availability in calcareous soil. *Journal of the Indian Society of Soil Science* **39**: 693–8.
- Schlichting E and Blume H P. 1966. *Bodenkundliches praktikum*, Paul Parey, Hamburg, Berlin, pp 136–8.
- Singh B and Sharma K N. 2012. Tree growth and accumulation of organic carbon and nutrients in soil under tree plantations in arid zone of Punjab. *Indian Forester* **138**: 453–9.
- Singh B, Tripathi K P, Jain R K and Behl H M. 2000. Fine root biomass and tree species effects on potential N mineralization in afforested sodic soils. *Plant and Soil* **219**: 81–9.
- Singh R, Singh R K and Singh K. 1990. Effect of different plant covers on soil characteristics *Indian Forester* **116**: 795–802.
- Swift M J, Frost P G H, Cambell J C, Hatton K and Wilson K. 1978. Nutrient cycling in farming systems derived from Savanna: perspectives and challenges. *Plant and Soil*.
- Subbiah B V and Asija G L. 1956. A rapid method procedure for the estimation of available nitrogen in soil. *Current Science* **25**: 259–60.
- Thakur C L, Karimullah and Aasif Ali. 2012. Evaluation of different promising agroforestry tree species on the soil health in sub temperate sub humid mid hill zone of Himachal Pradesh. *Indian Journal of Forestry* **35**: 193–8.
- Walkley A and Black T A. 1934. Estimation of soil organic carbon by chromic acid titration method. *Soil Science* **37**: 38–9.