International Journal of Plant Physiology and Biochemistry Vol. 4(5), pp. 120-125, April 2012
Available online at http://www.academicjournals.org/IJPPB
DOI: 10.5897/IJPPB12.014
ISSN-2141-2162 ©2012 Academic Journals

Full Length Research Paper

Inter correlation between soil properties and growth of *Azadirachta indica* in various types of plantations of Jodhpur region (Rajasthan, India)

Verma Puneet[1]* and Kishan Kumar V. S.[2]

[1]Department of Statistics and Information Management, Reserve Bank of India, 3rd floor, 8-9, Vipinkhand, Gomti Nagar, Lucknow – 226010, Uttar Pradesh, India.
[2]Forest Research Institute, New Forest P.O., Dehra Dun 248 006, Uttar Pradesh, India.

Accepted 22 March, 2012

Physico-chemical properties do not vary rapidly for short distance in arid and semiarid regions in absence of plantation or some manual intervention. In case of barren land, it is difficult to enhance soil health and its productivity until and unless a large quantity of fertilizer and irrigation facilities are employed. Application of high dose of fertilisers and insecticides result in short-term increase in production, but it deteriorates the quality of soil and eventually reduces its productivity. There are hundreds of instances where trees improved the soil productivity. Microbial communities in soil have large impact on overall soil health due to production of secondary metabolites, nutrient recycling and decomposition. Various researches have demonstrated that *Azadirachta indica* extract also acts as an antimicrobial agent and affects the structure and function soil microbial community. Therefore, it was critical to examine how its extract from different types of plantations becomes necessary to fully appreciate ramifications of its use on the environment for improving soil fertility. For the study, soil samples were collected from 53 different sites, in and around Jodhpur, Rajasthan, India, where *A. indica* was growing in different types of plantations. The data was analyzed for different properties of soil for separate types of plantations.

Key words: *Azadirachta indica*, pH, electrical conductivity (EC), organic matters (OM), Kruskal Wallis test, sigmoidal growth modal.

INTRODUCTION

The arid regions of India cover an area of 317,090 km^2 (nearly 40%). The region extends over seven states viz: Rajasthan, Gujarat, Punjab, Haryana, Maharashtra, Karnataka and Andhra Pradesh. The north-western part of the country itself constitutes almost 90% of the total arid zone. Rajasthan occupies country's 10.4% of land area and alone accounts for 60% of the arid zone of India. The overall water resource in this state is less than one percent of that of the country and the rainfall in most part of the state is erratic and scanty (Verghese, 1999). Jodhpur falls in hot arid western plain agro-ecological region (Yadav et al., 2002). The harsh environmental condition of arid region limits the choice of trees that can be planted there. Various tree species are recommended for sandy plains and shallow soils. *Azadirachta indica* is common for both the regions. It has wide climatic adaptability and can be grown in hot and dry regions receiving low annual rainfall of 500 mm or less (Tewari, 1992). Moreover, in the recent times, *A. indica* has drawn global attention as a multipurpose tree.

Soil is a primary medium for growth and development of trees and therefore knowledge of properties of soil across the field, is helpful for yield regulations and other managerial decisions. Soil properties decide whether the soil has the potential to store enough water to keep

*Corresponding author. E-mail: pverma@rbi.org.in. Tel: +91-0522-2394338. Fax: +91 522 2393650.

plants growing through a drought, to withstand a flood and to provide the right combinations of chemicals (N, P, K, etc.) to plants so that they will grow properly. Knowledge of soil in regard to its potential use, distribution, optimum use of land and in respect of supporting features for limited types of trees is important for almost all the areas, particularly in arid areas where choice of plantation is very limited. *A. indica* can grow on a wide range of soils including saline and alkaline (Chaturvedi et al., 1985).

The effect of trees on soil formation and nutrient cycling has been recognized for a long time (Shear and Stewart, 1934; Zinke, 1962; Challinor, 1968; Alban, 1982; Crozier and Boerner, 1986; Mladenoff, 1987; Boerner and Koslowsky, 1989; Boettcher and Kalisz, 1990; France et al., 1989; Johnson and Todd, 1990; Binkley et al., 1992; Hobbie, 1992; Gower and Son, 1992; Norden, 1994; Binkley, 1996; Bockheim, 1997; Finzi et al., 1998a, b; Amiotti et al., 2000). Several authors have demonstrated the existence of a close interaction between plant and soil (Hobbie, 1992; Van Breemen, 1993; Van der Putten, 1997). Van Breemen (1993) reviewed studies on the influence of plants, soil animals and microorganism on their physical substrate. He concluded that in many cases these organisms appeared to affect soil fertility, soil moisture content and other soil properties in such a way that with time the substrate becomes more favourable for the growth of plants and soil organism. Apparently, there is a clear impact of tree on improvement of soil irrespective of any farming system (Venkataramanan et al., 1983).

The reaction of the soil solution can be defined by an index using the concentration of hydrogen ions in the soil solution. This index is called pH. The pH scale goes from 0 to 14, with 7 as the neutral point. From pH value 7 to 0, the soil is increasingly acidic and from 7 to 14, the soil is increasingly alkaline or basic. As the amount of hydrogen ions in the soil increases, the soil pH decreases, thereby making it more acidic. Soil pH is a useful attribute in deducing whether soil is acidic, neutral or alkaline which influences the solubility of various compounds, the relative bonding of ions to exchange sites and the activity of various microorganisms (Mc Lean, 1973). It is largely determined by soil composition and hydrolysis reactions associated with various organic and inorganic soil components (Thomas and Hargrove, 1984). Effect of dilution on soil pH has been discussed extensively by Landon (1991). The effect of soil pH on the solubility of minerals or nutrients is considerable. Before plants can use a nutrient, it must dissolve in the soil solution. Most minerals and nutrients are more soluble or available in acid soils than in neutral or slightly alkaline soils. The soil pH can also influence plant growth by its effect on activity of beneficial microorganisms. Bacteria that decompose soil organic matters (OM) are hindered in strong acid soils. This prevents OM from breaking down, resulting in an accumulation of organic matter and the tie up of nutrients, particularly nitrogen, which are held in OM.

Soil is made up of solid, liquid, and gases. It can conduct electrons. Soil gases are insulators and do not conduct electricity, whereas its solid (like clay particles) and liquid (like soil water solution) part play a major role in the movement of electrons. The ions in the solution are called electrolytes, which also conduct electric current. The electrons move through different pathways in the soil and ride along the surfaces of particles that are in contact with each other. Since the pathways in the soil are related to soil texture, soil electrical conductivity (EC) is found to be related to soil texture. Soil texture relates to factors that have a major impact on growth such as water holding capacity etc. Soil EC measures the amount of salt (like sodium and calcium) in the soil as well as the other soil properties. It does not assesses how much change in inputs is needed across the field, but helps to view the entire field's soil differences quickly and identifies where soils change across the field. Soils that are rich in clay have much more particle-to-particle contacts and thus higher EC. Sandy soils have low number of particle contacts and are poor conductors. Water has a strong effect on the values of soil EC. It is commonly expressed in units of milliSiemens per meter (mS/m). It is important to note that yields are not always higher in high soil EC areas.

Soil OM is to soils like what blood pressure is to humans. OM level indicates the health of the soil. It is measured in percentage. OM ranges from less than 0.2% in desert soil to over 80% in peat soil. In temperate region soil, it ranges between 0.4 and 10.0%, with humid region averaging 3 to 4% and semi-arid soils 1 to 3%. OM makes up the nutrient source for all the living organisms in soil. The complex of micro-organisms that are responsible for the decomposition, nitrification and nitrogen fixation in the soil surface are essential components of the entire ecosystem. OM is a food for earthworms that are responsible for aeration, with their waste contributing to the overall chemical and physical properties of the soil. It also provides beneficial physical influences by reducing erosion, evaporation and improving water-holding capacity. Since OM contains about 50% carbon, 40% oxygen, 5% hydrogen, 4% nitrogen and 1% sulphur, the amount of organic matter is a predictor of the amount of carbon in soils. OM is influenced directly by temperature; hence, soils in warm climates lose OM faster with tillage. Soils in arid, semiarid and hot regions commonly have less organic matter.

With a view to understanding the effect of soil parameters on the growth behaviour of *A. indica* plantations, a study was taken up in three different types of plantations in the hot arid region of Jodhpur, Rajasthan in India.

MATERIALS AND METHODS

The data used in the study was collected from various places in and

Table 1. Plantation-wise descriptive statistics of soil properties.

Soil property	Type	N	Min value	Max value	Mean	SD
	AFP	19	7.80	8.30	8.08	0.15
pH	IP	10	8.10	8.50	8.29	0.12
	AP	24	8.10	8.50	8.32	0.12
	AFP	19	0.38	0.82	0.58	0.14
EC (mS/m)	IP	10	0.28	0.55	0.39	0.10
	AP	24	0.10	0.50	0.28	0.11
	AFP	19	0.54	1.02	0.87	0.10
OM (in percentage)	IP	10	0.67	0.86	0.75	0.06
	AP	24	0.25	0.66	0.45	0.10

Note N is the number of soil samples from plantations.

around Jodhpur, Rajasthan, India. The area lies between 24 to 29° latitude and 70 to 76° longitude. This region is characterized by large variation in seasonal temperatures. Summer temperature often exceeds 46 to 48°C, especially during May and June. In December and January, the night temperature occasionally reaches 2°C owing to cold waves. The mean annual rainfall in the area varies from 120 to 200 mm. The majority of the rainfall is received during the south-west monsoon season (July to September). The mean monthly relative humidity in the area fluctuates largely from 15 to 88%, during a year. The mean evaporation in the area varies from 2.7 to 4.7 mm per day in winter and 13.5 to 15.3 mm in summer season. Strong wind regime is the characteristic feature of the summer and monsoon season in the area, which often causes soil erosion. Wind speeds, as high as 130 km per hour, are experienced during the summer months. Dust storms are also common in the region (3 to 17 days per annum). Droughts are a recurring feature of the area and often persist continuously for 2 to 3 years or more.

Silvicultural treatments in the experimental stands are on the higher level and better controlled than in commercial forests. In general, they are made for particular research in research centres. Results based on such kind of the data may not be suitable when applied to general forests and therefore, such sites were not considered. In the study area, it is observed that *A. indica* can be mainly grouped into the following three types:

1. Agro forestry plantations (AFP): where it is planted on boundary of the agricultural fields/farms.
2. Institutional plantations (IP): where it is planted in temples, schools or in any private campuses.
3. Avenue plantations (AP): where it is planted on roadsides.

Overall, 53 sites were selected randomly within 50 km of Jodhpur in three different direction major roads (that is, Nagaur, Pali and Barmer). For this purpose, the soil samples were collected from a depth of 50 cm and 10 meter far from well established more than 7 years of age of *A. indica* trunk and analyzed for their different physico-chemical properties.

The data were analyzed with the help of Statistical Package for Social Sciences (SPSS). Since there were three types of plantations, it was reasonable to test the homogeneity of the central tendency between all types of the plantations for their soil properties. This may also help to sort out whether separate study for different plantation is required or not. Therefore, plantation-wise soil properties (pH, EC and OM) were tested for their homogeneity using Kruskal Wallis test. It was assumed that there were three mutually independent random samples measured on at least an ordinal scale and drawn from any continuous distributions (not necessarily symmetric) that are identical except for central location, as measured by the medians, μ_1, μ_2, and μ_3. The null hypothesis is that these medians are equal, that is, H_o: $\mu_1 = \mu_2 = \mu_3$ and the alternative hypothesis is that at least two of these samples differ only with respect to location (median), if at all. If k independent samples of sizes (n_1, n_2, … n_k) are to be tested for their homogeneity, combine all the samples to one large sample, sort the result from smallest to largest and assign ranks and then find $\bar{R}_i$, the average of the ranks of the observations in the i^{th} sample. The test statistic, KW, is then

$$KW = \frac{12}{N(N+1)} \sum_{i=1}^{K} n_i \left(\bar{R}_i - \frac{N+1}{2} \right)^2;$$

where; N = $n_1 + n_2 + \dots n_k$

The null hypothesis is rejected if KW> χ^2_{k-1}. The corresponding *p* value is obtained from the Chi-square table and the null hypothesis rejected if *p* is less than 0.05. Wilcoxon (1945) Signed rank test was also applied to test difference between pairs. The sum of the ranks for the less frequent sign is standardized. An attempt is made to correlate the growth pattern with the soil parameters.

RESULTS AND DISCUSSION

Plantation wise, descriptive statistics of the values of soil characteristics of these desert soils (pH, EC and OM) collected from the selected sites are given in Table 1. The table shows that in each characteristic, there is very little deviation from its mean value.

Table 2 shows Kruskal Wallis test statistics on all three (pH, EC and OM) considered soil properties. From the

Table 2. Kruskal Wallis test statistics on soil properties.

	Soil pH	Soil EC	Soil OM
Chi-Square	20.48	32.60	39.70
df	2	2	2
Asymp. Sig.	0.00	0.00	0.00

Table 3. Wilcoxon signed rank test statistics for each pair of types of plantation.

Pair	AFP - IP			AFP - AP			IP - AP		
Soil properties	PH	EC	OM	PH	EC	OM	PH	EC	OM
Z	-3.053	-3.038	-3.399	-4.317	-5.003	-5.437	-.833	-2.548	-4.510
Asymp. Sig. (2-tailed)	0.002	0.002	0.001	0.000	0.000	0.000	0.405	0.011	0.000

Table 4. Schumacher's model for the three plantation types.

Plantation	Form of equation
AFP	Height =14.40 * Exp (-9.11/ (age + 4.70))
IP	Height =14.89 * Exp (-7.63/ (age + 1.99))
AP	Height = 21.30 * Exp (-55.10/ (age + 37.48))
AFP	dbh = 103.81 * Exp (-34.88/ (age+ 9.37))
IP	dbh = 61.05 * Exp (-13.31/ (age + 1.06))
AP	dbh =105.48 * Exp (-54.47/ (age + 17.27))

Source: Puneet and Kishan, 2006.

Table 2, it was observed that soil properties are different at least two types of the plantations.

Table 3 shows Wilcoxon signed rank test statistics for each pair of types of plantation significance. Table 3 shows asymptotic significant values for each pair of plantations for pH, EC and OM. It was seen that pH values of soil in AFP differ from IP and AP but it is not significantly different for AP and IP. Whereas the other two soil properties EC and OM differs significantly among all types of the plantations.

The fact that soil parameters (except in one case) vary significantly among the plantation types perhaps points to the management of the plantation. For example, an avenue plantation very rarely gets any soil treatment whereas, AFPs are supposed to get regular soil treatments and manure.

Schumacher's sigmoidal growth model (Schumacher, 1939) is reported to be the best model for predicting height and dbh of *A. indica* for ages between 2 and 50 years in the same arid areas for all three types of the plantations (Puneet and Kishan, 2006). The equations developed for these plantations are shown in Table 4.

From these equations on plots (Figures 1 and 2 shows height and growth pattern of dbh of *A. indica* in all three types of plantations, respectively), it is clearly seen that there is significant difference in growth of height and dbh in all types of plantations. It is also observed that the growth of AFP is better than IP and AP whereas growth of IP is better than AP.

Since growth of height and dbh of *A. indica* varies for the plantations, and soil properties of the same plantations also vary, it may be concluded that there is a high correlation between soil and *A. indica* biomass, which may be found in further specific silvicultural study. Soil is not the only factor for the growth of any specific tree but species properties are equally important. This may be the reason *A. indica* is surviving better than other species of different trees. Therefore, it may be concluded that not only soil influences a tree but tree is simultaneously influencing soil to keep itself in existence and *A. indica* is such tree which has the capacity to do so. This may be due to decomposition of their leaf litter having pH 8.2 lower than normally found soil in such areas.

Conclusion

The growth of *A. indica* in terms of height and dbh is very high in AFP and therefore decomposition of its extract (leaf and seed littering) for such plantation will also be higher than AP and IP. Similarly, IP is higher than AP. The significant change in soil pH between AFP – AP and AFP – IP may be due to more decomposition of leaf having lower pH than such sandy soil. Most vegetables need a neutral to slightly acidic soil. If the soil pH is not right, then some nutrients will be unavailable. *A. indica* at AFP helps to keep the soil pH value and therefore improve the fertility of the soil. Because of the different pattern of growth in various types of the plantations both EC and OM of soil varies significantly among each of the three types of plantations and with the higher leaf lettering it increase EC and OM of the respective soil to make it more fertile and productive.

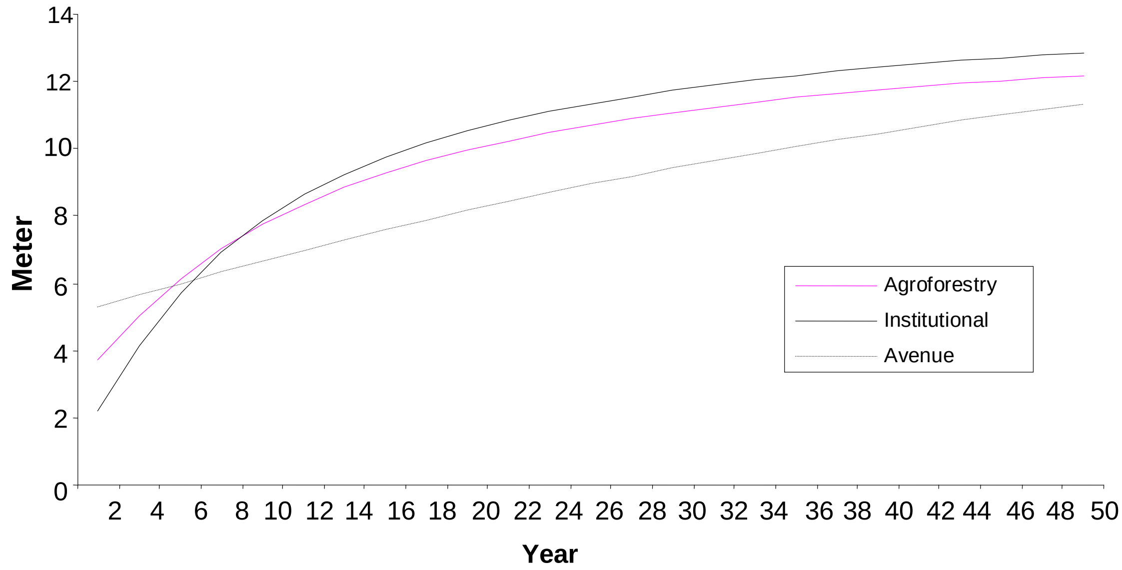

Figure 1. Height of *Azadirachta indica* in different types of plantations in arid areas.

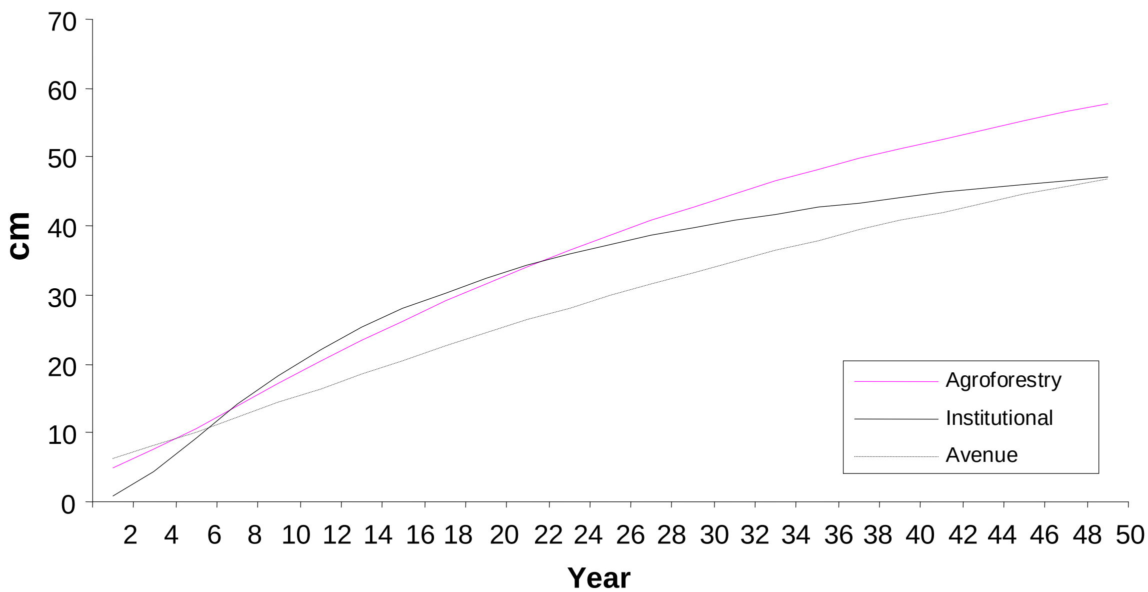

Figure 2. dbh of *Azadirachta indica* in different types of plantations of arid areas.

REFERENCES

Alban DH (1982). Effect of nutrient accumulation by aspen, spruce, and pine on soil properties. Soil Sci. Soc. Am. J., 46: 853-861.

Amiotti NM, Zalba P, Sanchez LF, Peinemann N (2000). The impact of single trees on properties of loss- derived grassland soils in Argentina. Ecology, 81: 3283-3290.

Bockheim JG (1997) Soils in Hemlock- hardwood ecosystem mosaic in the southern Lake Superior Uplands. Can. J. For. Res., 27, 1147-1153.

Binkley D (1996). The influence of tree species on forest soils: Processes and patterns. In: D. J. Mead, and I. S. Cornforth (Eds.) Proceedings of the trees and soils workshop. Agronomy Society of New Zealand Special Publication # Canterbury.

Binkley D, Sollins P, Bell R, Sachs D, Myrold D (1992). Biogeochemistry of the adjacent conifer and conifer- hardwood stands. Ecology, 73: 2002-2033.

Boerner REJ, SD Koslowsky (1989). Microsite variation in soil chemistry and nitrogen mineralization in a beech-maple forest. Soil Bio. Biochem., 21: 795-801.

Boettcher SE, PJ Kalisz (1990). Single tree influence on soil properties I the mountains of eastern Kentucky. Ecology, 71: 1365-1372.

Challinor D (1968). Alternation of surface soil characteristics by four tree species. Ecology, 49: 268-290.

Chaturvedi AN, Bhat DN, Singh UN, Gupta NN (1985). Response of certain forest tree species to varying pH level under pot culture. Van

Vigyan, 23(3-4): 79-84.
Crozier CR, REJ Boerner (1986). Stemflow induced soil nutrient heterogeneity in a mixed mesophytic forest. Bartonia, 52: 1-8.
Finzi AC, Canham CD, Van Breemen N (1998a). Canopy tree soil interactions within temperate forests: species effect on pH and cations. Ecol. Appl., 8: 447-454.
Finzi AC, Van Breemen N, Canham CD (1998b). Canopy tree soil interactions within temperate forests: species effect on carbon and nitrogen. Ecol. Appl., 8: 440-446.
France EA, Binkley D, Velentine D (1989). Soil chemistry change after 27 years under four tree species in southern Ontario. Can. J. For. Res., 19: 1648-1650.
Gower ST, Son Y (1992). Differences in soil and leaf litterfall nitrogen dianamics for five forest plantations. Soil Sci. Soc. Am. J., 56: 1959-1966.
Hobbie SE (1992). Effect of plant species on nutrient cycling. Trend in Ecol. Evol., 7: 336-339.
Johnson DW, Todd DE (1990). Nutrient cycling in forests of Walker Branch Watershed, Tennessee: roles of uptake and leaching in causing soil changes. J. Environ. Qual., 19: 97-104.
Landon JR (1991). Booker Tropical Soil Manual. Longman Scientific & Technical, New York.
Mc Lean EO (1973). Testing soils for pH and lime requirement. In: Soil Testing and Plant Analysis (Revised edition), L.M. Walsh and J.D. Beaton (eds), Science Society of America Soil Madison. pp. 77-95.
Mladenoff DJ (1987). Dynamics of nitrogen mineralization and nitrification in hemlock and hardwood tree fall gaps. Ecology, 68: 1171-1180.
Norden U (1994). Influence of tree species on acidification and mineral pools in deciduous forest soils of south Sweden. Water, Air Soil Pollution, 76: 363-381.
Puneet V, Kishan kumar VS (2006). Growth study of height and dbh of *Azadirachta indica* in arid areas, J. Timber Develop. Asso. India, 52(1-2): 39-56.
Shumacher FX (1939). A new growth curve and its application to timber yield studies. J. For., 37: 819-820.
Shear GM, WD Stewart (1934). Moisture and pH studies of the soil under forest trees. Ecology, 15: 134-153.
Soil Survey Staff (1993). Soil Survey Manual (revised and enlarged edition). United State Department of Agricultural Handbook No. 18, USDA, Washington.
Tewari DN (1992). Monograph on Neem. International Book Distributors, Dehradun.
Thomas GW, Hargrove WL (1984). The chemistry of soil acidity: In: Soil acidity and liming (second edition), F. Adams (ed.), pp. 3-56. Agronomy Series No. 12, American Society of Agronomy, Madison.
Venkataramanan CB (1983). Return of nutrients by the leaf litter of blue gum (*Eucalyptus globules*) and black wattle (*Acacia* spp.) plantation of Nilgiris in Tamil Nadu. Indian Forester, 109(6): 370-378.
Verghese KA (1999). Disparities in agriculture and demographic features across agro-climate region in Rajasthan. J. Hum. Ecol., 25-32.
Van Breemen N (1993). Soils as biotic constructs favouring net primary productivity. Geoderma, 57: 183-211.
Van der Putten WH (1997). Plant-soil feedback as a selective force. Trends in Ecol. Evol., 12: 169-170.
Yadav SS, Swami BN, Shyampura RL (2002). Caracterisation, classification and suitability evaluation of arid soils of western Rajasthan. 17th WCSS, 14-21 August 2002, Thailand.
Wilcoxon F (1945). Individual comparisons by ranking methods, Biometrics, 1: 80-83.
Zinke PJ (1962). The pattern of influence of individual forest trees on soil properties. Ecology, 43: 130-133.