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STUDY THE PHYSICO-CHEMICAL PROPERTIES OF SOIL IN *DALBERGIA SISSOO* BASED AGROFORESTRY WITH *CYMBOPOGON FLEXUOSUS* AS IN INTERSPACE TO IMPROVE MARGINAL WASTELAND IN CHHATTISGARH, INDIA

Sajiwan Kumar[1*] and M.N. Naugraiya[2]

[1]School of Studies in Forestry & Wildlife, Bastar Vishwavidyalaya, Jagdalpur, (CG), India

[2]Department of Forestry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, (CG), India

*Email: skdrsanjuu@gmail.com

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ABSTRACT

This paper focused on the effects of tree and aromatic plant on soil fertility of *Entisols* under agroforestry systems in Chhattisgarh. Relevant literature concerning the effects of trees on soil physical and chemical properties in tropical and subtropical regions is reviewed, covering both natural ecosystems and agro ecosystems. Soil carbon, in the form of organic matter, is considered as an indicator of biological activity as well as in relation to policy issues such as carbon sequestration and climate change. Lastly, attention is given to a study in the Chhattisgarh plain agro climatic zone of the state, where a chronosequence of indigenous agroforestry systems showed clear effects of management practices involving crop & trees on soil fertility. The use of diverse tree species and other practices employed in agroforestry systems can represent alternative forms of increasing soil fertility and maintaining agricultural production with important practical applications for the sustainability of agriculture farming in Chhattisgarh state. Within the array of benefits brought by trees, an important element is the positive effect of trees on soil properties and consequently benefits for crops.

The present investigation was conducted on the Red lateritic marginal wasteland at Dr. Richharia Research and Instructional Farm, Baronda, Department of Forestry, Indira Gandhi Krishi Vishwavidyalaya, Raipur (CG) during two consequent years *i.e.,* 2007-08 and 2008-09. *Cymbopogon flexuosus* was cultivated in rain fed condition as an intercrop under 10 year old *Dalbergia sissoo* and sole crop in open field with an application of 30 kg N, 20 kg P & K comprising eight treatments under split plot design having three replications and production performance of Lemon grass with physical-chemical properties of soil were studied. The physical and chemical properties of soil were found in higher ranged under sole cropping system with statistically significant variation and there was in order of 5.72 to 6.12 for pH; 33.26 to 46.12 per cent for water holding capacity, 0.61 to 0.78 per cent for organic carbon; 151.89 to 182.97 kg/ha for available N in soil; 11.82 to 18.52 kg/ha for available P and 80.02 to 108.04 kg/ha for available potassium in soil. Nutrients status of open barren land was also recorded which was very poor in fertility level as compared to other cropping systems under study.

***Keywords*:** *Entisols*, marginal wasteland, Aromatic plants, Agroforestry, *Dalbergia sissoo; Cymbopogon flexuosus*, etc.

INTRODUCTION

Agroforestry has the potential to provide most or all the ecosystem services. The Millennium Ecosystem Assessment (2005) has categorized the ecosystem services into provisioning service (fuel-wood, fodder, timber, poles etc.), regulating service (hydrological benefits, micro-climatic modifications), supporting service (nutrient cycling, agro-biodiversity conservation), and cultural service (recreation, aesthetics). Agroforestry is playing the greatest role in maintaining the resource base and increasing overall productivity in the rainfed areas in general and the tropical and subtropical regions in particular. Agroforestry land use increases livelihood security and reduces vulnerability to climate and environmental change. There are ample evidences to show that the overall productivity, soil fertility improvement, soil conservation, nutrient cycling, microclimate improvement, and carbon sequestration potential of an agroforestry system is generally greater than that of an annual system (Dhyani *et al.,* 2009). Agroforestry has established itself as one of the most promising land management systems. There exists a tremendous imbalance between demand-supply equilibrium for fulfilling the basic needs of ever increasing human and cattle population. In recent past inclusion of medicinal and aromatic plants in agroforestry land use system has increased due to increased demand by pharmaceutical industries (Nagarajaiah, *et al.*, 2012). Agroforestry systems complement conservation agriculture systems in the provision of soil cover, animal feed, nutrients, household fuel, and hillside protection against soil erosion and wind erosion control through shelter belts (Sims *et al.,* 2009).

In India, agroforestry has been receiving greater attention by researchers, policy-makers and others for its perceived ability to contribute significantly to economic growth, poverty alleviation and environmental quality. Agroforestry is now recognized as an important part of the 'evergreen revolution' movement in the country. India launched National Agroforestry Policy in 2014 and became the first country in the world to have a National Agroforestry Policy. The policy is not only seen as crucial to India's ambitious goal of achieving 33 per cent tree cover but also to mitigate GHG emissions from agriculture sector.

The *Dalbergia sissoo* has been the favored species to grow on farm lands. The preference of *Dalbergia sissoo* in agroforestry is due to its timber value, ready assured market. In Sissoo based agroforestry, choice of component crop species is often difficult due to sub optimal conditions. Hence, there is greater scope to include aromatic plants as intercrops in Sissoo plantation to increase overall productivity. While trees in general can provide a number of environmental benefits in both rural and urban landscapes, and play key roles in ecosystem services provided by natural areas, in this paper we will restrict our focus to the effects of trees on soil fertility, in the specific context of Marginal wasteland *Entisols* locally known as *Bhata soils*.

Although the benefits that trees can provide on rural properties such as food security, household income, economic stability, and thermal comfort (shade) are most often associated with their products, such as fruit, timber, or other items, the inclusion of trees in agricultural systems can also optimize nutrient cycling and have positive effects on soil chemical and physical properties. This process is especially important in tropical soils, where a high degree of weathering has created deep, leached soils that are poor in plant nutrients Ricklefs, 1996; Primavesi, 2001. However, the present-day situation of population growth and increasing pressure on agricultural lands lead to situations where there is demand for more intensive land use and also reclaimation of degraded land for cultivation of crop through agroforestry. Chhattisgarh state of India in particular has as wide range of soil and climatic variation in realms of degraded forests and waste lands which offer a unique situation to try different developmental systems on land use to rehabilitate the environment with renewable green cover of economic species. There is an immense scope to design diverse agricultural systems by incorporating aromatic plant species in such situations. *Cymbopogon flexuosus* is an aromatic plants yield essential oils on steam distillation which have a variety of commercial uses in flavor and fragrances industries and pharmaceutical applications. The rising of the global market for naturopathy products leads and encourage the farmers to turn towards the cultivation of aromatic plants. The limitation of land for major agricultural crops poses a challenge to promote sole cultivation of aromatic plants on prime agricultural land in spite of their commercial potential. Therefore intercropping of aromatic plants as a subsidiary crop in terms of utilization of space and an additional income source for small and marginal farmers is a most suitable and viable option. Present paper gives a brief review of change in soil fertility status in marginal wasteland by such type of tree-crop combinations and further explores amelioration or improvement in soils under tree based silvi-aromatic agroforestry systems.

MATERIALS AND METHODS

The present experiment was conducted in 10 years old plantation of *Dalbergia sissoo* Roxb. based agroforesty system in *Entisols* for two years of cropping seasons *i.e.* 2007-08 & 2008-09 at Dr. Richharia Research and Instructional Farm, Baronda Department of Forestry, IGKV, Raipur (CG). The study site falls under the central region of Chhattisgarh plains agro-climatic zone. The plantation of *Dalbergia sissoo* at the spacing of 5 x 5 m was established in the year 1998; however under storey crop of *Cymbopogon flexuosus* was introduced in July 2007 as an intercrop in interspace. The climate of study site is dry humid sub-tropical with an average annual rainfall of 1250 mm. About 80 percent of the annual rainfall is received from south- west monsoon during June to mid August. Number of rainy days varies from 65 to 79 days. The mean monthly maximum temperature varies from 13.2^{0}C in December to 28.3^{0}C in May with maximum temperature goes beyond 45^{0}C in May and minimum below 10^{0}C in December. The relative humidity lies between 70-90 per cent from mid June to March end.

Physico-chemical features of the *Entisols* locally known as Bhata land, it is also known as red lateritic soil, as land use classification pattern point of view, and it comes under marginal wasteland. In red lateritic soil, the content of organic matter are found in fewer amounts, which is responsible for causing moisture and thermal stress, which affect microbial activity and the availability of nutrients and subsequently affect the growth of plant (Gupta and Sharma 2009). Analysis of physical and chemical characteristics of soil, samples were collected from 16 plots comprising 8 treatments of fertilizers under agroforestry system and solo crop fields as well as one barren field (without any crop) at the depth of 15 to 30 cm, with the help of soil agar. The sample was collected randomly from four points in each plot and bulk of the four samples was used for analysis. The samples were dried in hot air oven at 105^{0}C. Well crushed soil passed through 2 mm sieve and stored. The analysis the physico-chemical properties of the soil were used standard methods. Soil texture determined by Pipette titration method (Piper, 1950), WHC by perforated soil box method (AOAC, 1975), soil pH by Digital pH meter using Soil-water suspension (Jackson, 1958), organic matter determined, method given by Walkley & Black, (1934). Available nutrients *i.e.,* N by Micro-kjeldahl method (Jackson, 1958), P by Olsen's method (Olsen *et al*., 1954) and K by Flame photometer, (AOAC, 1975).

RESULTS AND DISCUSSION

1. Impact of tree and crop management on soil characteristics

Soil of any plantation site gets changed over a period according to utilization and deposition of nutrients through litter accumulation by the crops. The utilization of nutrient depends on the resource availability. Similarly deposition of nutrient in the soil also depends on deposition as well as on the decomposition rate of litters, which further governed by microclimate of the site. In the present study, the status of soil nutrients at different intervals mainly before and after harvesting of Lemon grass were compared and analyzed for N, P, K and organic carbon etc. in sole *C. flexuosus*, sole *D. sissoo* and their intercrop under agroforestry system as well as adjacent barren land, for consistently two years of cropping season in 2007-08 and 2008- 09 and data are presented in tables and figures.

Tree plantations are universally known to result in many beneficent interactions with the surroundings in which they grow. The soil an important natural resources, is influenced greatly by tree plantations in many way. Trees biorejuvenate the soil by adding organic matter, returning nutrients, promoting microbial activity and improving the soil physical properties by litter decomposition (Oven, 1954; Will, 1959; Ovington, 1965; Zevitkovsky and Newton, 1971; James *et al.,* 1972). The physical and chemical properties of soil under rainfed cropping system of *D. sissoo* based agroforestry and sole crop of *C. flexuosus* in *Entisols* was studied along with features of adjacent barren land for two cropping season year.

2. Status of soil characteristics during the period of two year cropping season

Soil samples should be collected during the cropping season 2007-08 and 2008-09 of *C. flexuosus* was analyzed for its physical and chemical characteristics as per standard methods and presented through figures.

Soil pH: The concentration of H^+ ions in the soil media decides the nature of soil, whether it is acidic or alkaline or neutral in nature, which is further directly or indirectly responsible for ultimate growth and performance of any plant grown. The soil pH was increased towards neutral side. The data on soil pH under *D. sissoo* + *C. flexuosus* based agroforestry and sole cropping of *C. flexuosus* for the year 2007- 08 and 2008-09 is presented in figure 1. Perusal of table showed that the maximum soil pH of 6.12 was recorded in sole cropping of *C. flexuosus* and minimum of 5.92 was observed in *D. sissoo* + *C. flexuosus* based agroforestry with insignificant differences (P<0.05 %) for cropping season 2007-08. While for cropping season 2008-09 the maximum soil pH of 5.72 was recorded in soil of sole crop of *C. flexuosus* and minimum of 5.61 was observed in *D. sissoo* + *C. flexuosus* based agroforestry which was insignificantly less (P<0.05 %).

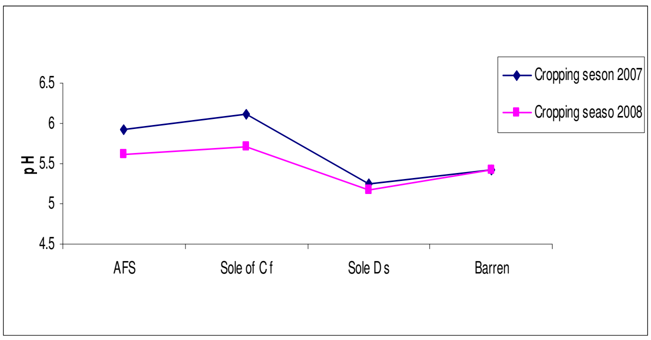

Fig. 1: Impact of cropping system on soil pH

The pH level in sole crop of *C. flexuosus* was slightly less acidic as compared to agroforestry with statistically insignificant in both the year. In sole plantation of *D. sissoo* soil pH was also recorded which was higher sole Lemon grass, adjacent barren land respectively. Thus the pH of soil was found to be influenced by tree canopy but it ranged in limit. The decrease of pH towards neutral point under agroforestry can be attributed to accumulation and subsequent decomposition of organic matter which releases balancing chemicals responsible for diluting the acidity (Haan, 1977). The production of organic acids during the process of decomposition and neutralization action with $CaCO_3$, Whereas higher acidic pH value in soils under agriculture or sole cropping system were found to be regulated in the crop field due to high concentration of $CaCO_3$ (Dasai, 2006). The results were further supported to many workers Nitant *et al.* (1992), Singh *et al.* (1985), Osman *et al.* (2001), Tandel, (2003) and Patel, (2005) and according to them the leaching of base ions escalated by the failure of tree species to recycle the bases adequately may be responsible to shift the soil pH toward neutral. The results are also in according with the results of Singh and Totey (1985). According to Roychoudhary *et al.* (1963), lateritic soils are acidic in nature, deficient in bases and poor in fertility status.

Water holding capacity (WHC): Water holding capacity was tested in the laboratory as per standard methods and results revealed that the availability of hydrophilic organic material in the soil to bind the water molecules. The effect of cropping system *i.e., C. flexuosus* in *D. sissoo* based agroforestry system and sole crop on soil water holding capacity during both the year was found statistically significant. The maximum water holding capacity was observed in *D. sissoo* + *C. flexuosus* agroforestry system (45.62 %) and minimum was observed in sole cropping of *C. flexuosus* (36.13 %) in cropping season 2007-08. While in cropping season 2008-09 the maximum water holding capacity was observed in *D. sissoo* + *C. flexuosus* agroforestry system 46.12 per cent and minimum was observed in sole cropping of *C. flexuosus* 33.26 per cent presented in figure 2.

Water holding capacity in soil was found statistically significant with the maximum under agroforestry system, and minimum in sole of *C. flexuosus*, sole plantation of *D. sissoo* and soil from adjacent barren land were also reported. The water holding capacity has higher in sole plantation site in comparison to barren site. In the agroforestry system and sole of *D. sissoo* has maximum water holding capacity and moisture percentage due to finer texture and high organic carbon content of soils (Semwal *et al.,* 2009). In general maximum water holding capacity decreased down the soil profile under vegetation as well as in barren land (Raina & Gupta, 2009). It was expected trend since the porosity of under tree trends to remain high as compared to open field. Favourable influence of soil organic matter on water holding capacity has also been reported by Sharmanna *et al.* (1967) and Greenland, (1981). The potassium played an important role for mobilization water and nutrients from soil to plants (Beech, 1977). This may be due to higher of accumulation of leaf litter and residue in upper surface, which on decomposition released organic acids and thereby increased water holding capacity. (Gupta & Sharma, 2009). These results are in conformity with the findings of Chandashekharaiah and Prabhakar, (1986),Tandel (2003) and Patel, (2005). Dutta *et al.* (2004) was reported higher water holding capacity with higher amount of organic content available in the soil because organic matter which are of hydrophilic in nature influence water holding capacity directly by absorbing large amount of water and indirectly by improving structure and bulk density of soil (Gupta and Sharma, 2009).

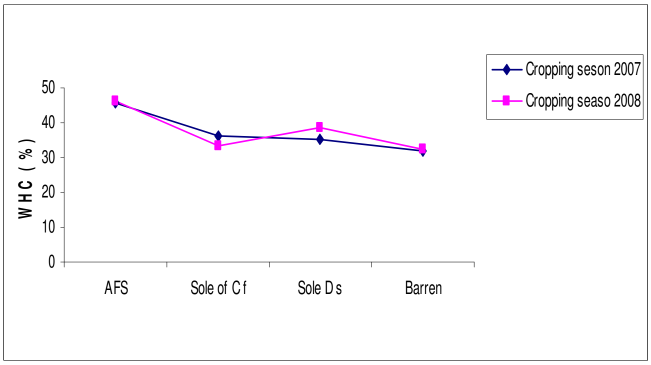

Fig. 2: Impact of cropping system on soil water holding capacity (%)

Organic carbon: Organic carbon is considered as a basic parameter for determining the soil quality. The availability of organic substances in its bio- degradable forms are found to be responsible to build a rich humus soil. The growth performance of plants depends on the availability of organic matter in which organic carbon along with essential minerals are necessary. The result of organic carbon in different cropping system and NPK treatment plots for cropping season 2007- 08 and 2008-09 are presented in figure 3. The data with respect to availability of organic carbon under *D. sissoo* + *C. flexuosus* agroforestry system and sole cropping of *C. flexuosus* was maximum 0.61 per cent in sole cropping of *C. flexuosus* and minimum 0.55 per cent was determined in *D. sissoo* + *C. flexuosus* based agroforestry system with statistically significant differences ($P<0.05$ %) for the cropping season 2007-08. While for cropping season 2008-09 was maximum 0.78 per cent in sole cropping of *C. flexuosus* and minimum 0.68 per cent was determined in *D. sissoo* + *C. flexuosus* based agroforestry system with statistically insignificant difference ($P<0.05$ %).

The organic carbon in the soil of sole *D. sissoo* was also reported which was higher than that soil from adjacent barren land, thus the organic carbon in the soil was found to be influenced by the density of vegetation particularly perennial species Gupta and Sharma, (2008). The concomitant rise of organic carbon in the soil under agroforestry and decline in the soil of open space or barren land (Dutta *et al.* 2004). The similar result also found here in agroforestry system and sole cropping system during tow year observations. Organic matter is the most capable and potent substance greatly influence the soil composition due to humus deposition in man made forest (Verma *et al.,*1982).

The results showed increasing trend of organic carbon with increasing the fertility levels, particularly in presence of potassium which was also found to higher availability of nutrient to plant responsible and ultimately higher accumulation of leaf litter and residue in upper surface (Dutta *et al.,* 2004). Similar results were observes by Ahadiyad *et al.* (2007); Bhardwaj *et al.* (2000) and Kansale *et al.* (1994). Organic carbon plays an important role in improving the physical, chemical and biological health of soil, it brings favorable changes in terms of the soil air, water holding capacity, structure, porosity, bulk density, colour, nutrient storage and availability, cation exchange capacity and microbial population and activity (Kononova, 1996). The increase in organic carbon content therefore is an index of improvement of soil fertility.

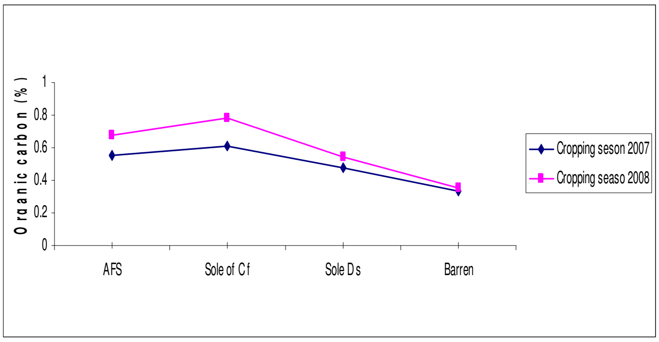

Fig. 3: Impact of cropping system on soil organic carbon (%)

Available nitrogen: The data on available nitrogen in soil under cropping system and NPK fertilizer application for cropping season 2007- 08 and 2008-09 are presented in figure 4. The data with respect to available nitrogen in the soil under *D. sissoo* + *C. flexuosus* agroforestry and sole cropping of *C. flexuosus* showed that available nitrogen was found maximum 163.57 kg N/ha in soil under sole crop of *C. flexuosus* and minimum 151.89 kg N/ha was under *D. sissoo* + *C. flexuosus* based agroforestry system with statistically significant variation for cropping season 2007-08. While cropping season 2008-09 was found maximum 182.97 kg N/ha in soil under sole crop of *C. flexuosus,* whereas minimum was 155.76 kg N/ha under *D. sissoo* + *C. flexuosus* based agroforestry system with was found statistically significant variation.

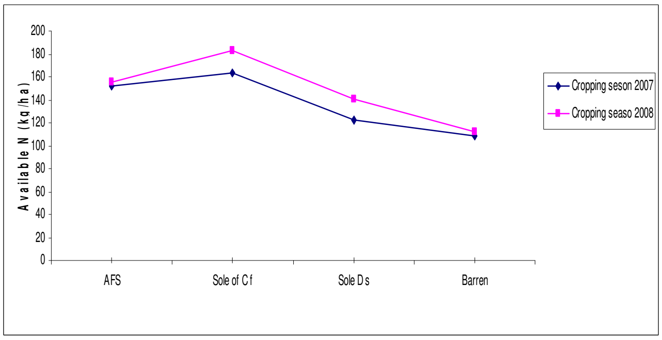

Fig. 4: Impact of cropping system on available N (kg/ha) in soil

Available phosphorus: Nitrogen, Organic carbon and available phosphorus were positively correlated chiefly because all these attributes are intimately linked with soil humus. The pattern of availability of phosphorus and its distribution in soil profile was therefore similar to that of organic carbon and nitrogen. The results on available phosphorus in soil under sole and agroforestry based intercropping farming system for cropping season 2007- 08 and 2008-09 presented in figure 5. The data on available phosphorus in soil under *D. sissoo* + *C. flexuosus* based agroforestry system and sole cropping of *C. flexuosus* during the year 2007- 08 was found statistically significant. The perusal of data revealed that the maximum available phosphorus of 15.81 kg P/ha was observed in sole crop of *C. flexuosus* and minimum of 11.82 kg P/ha was observed in *D. sissoo* + *C. flexuosus* based agroforestry system. Whereas in cropping season 2008-09 the perusal of data revealed that the maximum available phosphorus of 18.52 kg/ha was observed in soil under sole crop of *C. flexuosus* while minimum of 15.04 kg P/ha was observed in soil under *D. sissoo* + *C.*

flexuosus based agroforestry system with statistically significant difference..

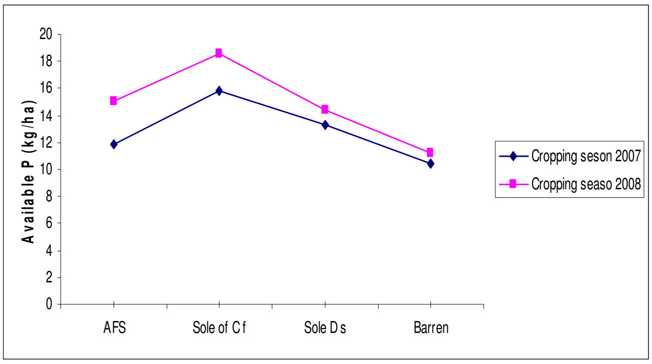

Fig. 5: Impact of cropping system on available P (kg/ha) in soil

Available potassium: Potassium performs very vital processes like regulating transpiration and respiration, influencing enzyme action, synthesis of carbohydrates and proteins etc (Brady, 1996) although its total amount presented in the soil is generally high but the availability is low. The results on available potassium in the soil both sole and intercropping of *C. flexuosus* for cropping season 2007-08 and 2008-09 are presented in figure 6. The effect of cropping system *i.e.,* sole cropping of *C. flexuosus* and intercropping with *D. sissoo* during the year 2007- 08 on availability of potassium in soil showed that was maximum potassium was determined in sole cropping of *C. flexuosus* (84.02 kg K/ha) and minimum of in *D. sissoo* + *C. flexuosus* based agroforestry system (80.02 kg K/ha) with statistically significant variations ($P<0.05$ %). Whereas in cropping season 2008-09 the effect of cropping system *i.e., C. flexuosus* as sole crop and intercrop with *D. sissoo* on availability of potassium in soil was maximum in soil under sole cropping of *C. flexuosus* (108.04 kg K/ha) and minimum in *D. sissoo* + *C. flexuosus* based agroforestry system (100.15 kg K/ha) with statistically significant variation ($P<0.05$ %).

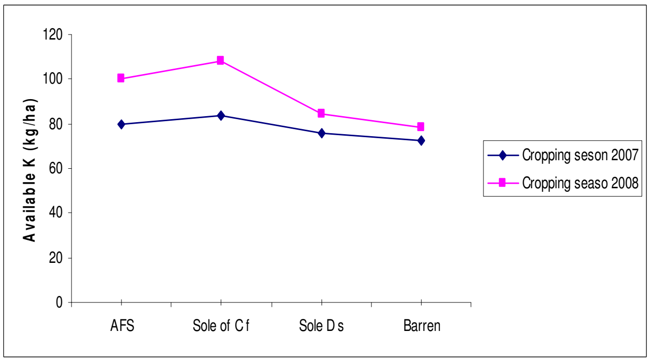

Fig. 6: Impact of cropping system on available K (kg/ha) in soil

The available NPK nutrient in soil showed the utilization and accumulation pattern under different cropping system. The results were found statistically significant with maximum availability of NPK under sole crop of *C. flexuosus* and minimum in agroforestry system. The soil of sole plantation of *D. sissoo* showed the higher level of nutrient availability as compare to soil of adjacent barren land. The pattern of nutrient distribution in different land utilization system was found in similar pattern of current study by Sharma *et al.* (2006), Sharma *et al.* (2007), Singhal *et al.* (1989) and Arunchalam *et al.* (1994), with the remark that high vegetation site had decomposed humus content which further added more nutrient to the soil to maintain mineral richness and fertility as compared to disturbed or less vegetation sites because the accumulated litter underwent decomposition at faster rate.

Enrichment of soil with nutrients in agroforestry system indicates improvement in soil fertility due to presence of *D. sissoo* which is also nitrogen fixing trees as compared to sole cropping of *C. flexuosus*. The availability of nutrients (NPK) depends to large extent upon the amount and properties of organic matter (Haan, 1977). Highest available nutrients (NPK) content were found in plant where $N_{30}P_{20}K_{20}$ dose fertilizer had been applied, this might be due to the fact that there was an appropriate availability of nutrients (NPK) to enhance the biomass and ultimately accumulation of leaf litter higher organic matter with high microbial activities causing high rate of decomposition and mineralization. These results are well supported by Mohsin *et al.* (1996) for N in their study nutrient cycling of Poplar plantation; Singhal and Pawar (1991) for P in their study cropping pattern of Poplar based Agroforestry system and Singh (1999) for NPK in their study impact of various land use on soil properties. Therefore, the available nitrogen content followed the similar trend as that of organic carbon.

Role of rhizobium nodules in roots *D. sissoo* might also be considerable partly due to which the nitrogen fixed by tree during course of crop growth. Nath and Banerjee (1992) also reported similar pattern of nutrient utilization and accumulation in their study agroforestry system with fertilizers. The another reason for high availability of nutrients in soil under tree as well as agricultural crop might be recycling and pumping of these nutrients from deeper layer of soil to the upper layer in the form of decomposition of litter on the surface and the roots below the surface soil. Thus enrichments of soil occur slowly but steady over a period under perennial species vegetation as well as cropping system of agroforestry Sharma *et al.* (2006), Nitant *et al.* (1992), Parthiban & Rai (1994) and Narain and Singh (1990). Over all greater proportion of nutrients at all site occurred in the surface soil, reflecting the massive input of nutrients to the soil through litter fall. Available in presence of microbes which are responsible for redistribution of significant portions of phosphorus in the soil Hannapal *et al.* (1964).

3. Changes of soil properties during course of study

The data with respect to changes of soil pH, WHC, Organic carbon, available Nitrogen, Phosphorus and Potassium in the soil under different land use system *viz.,* agroforestry system of *D. sissoo+ C, flexuosus,* sole crop of *C. flexuosus*, sole plantation of *D. sissoo* and adjacent barren field during the cropping season 2007-08 and 2008-09 was also studied and the results are presented in figures from 1 to 6.

In case of soil pH it was evident from the figure that the soil pH was decreased in second year of cropping, however the pH was reduced maximum by 0.41 in sole crop of *C. flexuosus* followed by 0.31 and 0.08 in soil under agroforestry system and sole crop of *D. sissoo* respectively. The soil pH in barren field was remained same during both the cropping season (Fig. 1). The water holding capacity of soil showed increasing trend in all cropping system except sole crop of *C. flexuosus* after two years of cropping. The WHC was increased by 0.5 per cent in agroforestry system, by 3.2 per cent in sole plantation of *D. sissoo*. While in case of barren field water holding capacity was increased by 0.61 per cent. Whereas in sole crop of *C. flexuosus* water holding capacity was decreased by 2.87 per cent (Fig. 2). The quantity of organic carbon was increased in the in all cases after two years, but the increment of organic carbon was 0.13 per cent in agroforestry system; 0.17 per cent in sole of *C. flexuosus* and 0.21 per cent in sole of *D. sissoo*. In case of barren field organic carbon was increased by 0.04 per cent (Fig.3). The available soil nitrogen was also found to be an increasing pattern in all cropping system. For the agroforestry system the increment was 3.87 kg/ha, for sole of *C. flexuosus* it was 19.4 kg/ha and for sole of *D. sissoo* it was 18.43 kg/ha, while in case of barren field available nitrogen was increased by 1.4 kg/ha (Fig. 4). The available soil phosphorus was also found to increase after second year of different land use or and increment under agroforestry system was recorded 3.12 kg/ha followed by 2.71 kg/ha in sole of *C. flexuosus*, 1.16 kg/ha in sole of *D. sissoo*. However in barren field the available soil phosphorus was increased 0.79 kg/ha (Fig. 5). The status of available soil potassium was lodged an increasing trend in all the land use or two years of cropping and it was maximum in sole of *C. flexuosus* (24.02 kg/ha) followed by agroforestry system (20.13 kg/ha) and sole of *D. sissoo* (8.25 kg/ha). However in the barren field available potassium was increased 5.1 kg/ha (Fig. 6).

The available soil moisture content in crop field up to 50 cm depth was measured from July to March at monthly interval in the *D. sissoo* + *C. flexuosus* based agroforestry system and in sole crop for two cropping season of 2007-08 and 2008-09 and data are presented in table 1. The average data of soil moisture for cropping season 2007-08 showed that it was consistently higher in agroforestry system and increased up to August and afterward it was found in decreasing order up to March. In the month of July soil moisture under *D. sissoo* + *C. flexuosus* based agroforestry system was 21.77 per cent which further increased to 38.58 per cent in August. In the September it get started in to decreased by 11.5 per cent afterward field moisture was dropped in range of 1.29 to 2.84 per cent and it was recorded in order of Sept (27.34 %) > Oct (24.84 %) > Nov (22.42 %) > Dec (19.48 %) > Jan (18.19 %) > Feb (16.58 %) > March (13.74 %). Where in case of sole crop of *C. flexuosus* field moisture was noticed 22.96 per cent in July and it increased to maximum level of 26.59 per cent in August afterward it get droped by 7.94 per cent in coming next month and sequentially droped in every month up to 8.90 per cent in March.

The average data of soil moisture for cropping season 2008-09 also showed that it was consistently higher in agroforestry system. It was increased up to August and afterward found in decreasing order up to March. In the month of July soil moisture under *D. sissoo* + *C. flexuosus* based agroforestry system was 23.15 per cent which further increased to 38.25 per cent in August, and get decreased by 4.88 per cent in September. The field moisture under agroforestry system was recorded in order of Sept (28.27 %) > Oct (25.85 %) > Nov (23.98 %) > Dec (21.23 %) > Jan (20.77 %) > Feb (19.08 %) > March (14.36 %). In case of sole crop of *C. flexuosus* field moisture was noticed 18.52 per cent in July which further increased to maximum level of 24.87 per cent in August, afterward it was get sequentially droped in every coming month up to 7.92 per cent in March (Table 1).

Table 1: Effect of cropping system on available field moisture (%)

Month	Available field moisture (%) on different cropping system			
	Agroforestry system		Sole crop of *Cymbopogon flexuosus*	
	2007-08	2008-09	2007-08	2008-09
July	29.81±5.93	29.46±4.28	22.26±4.20	18.52±3.64
August	38.84±2.87	33.15±4.23	26.59±4.13	24.87±4.18
September	27.34±6.10	28.27±4.78	18.65±4.35	23.45±4.27
October	24.84±4.63	25.85±4.45	17.35±5.27	16.56±5.32
November	22.42±4.57	23.98±3.87	16.46±4.67	15.53±3.21
December	19.48±3.82	21.23±4.09	13.76±3.26	14.89±4.25
January	18.19±3.58	20.77±3.84	13.54±3.97	12.80±4.65
February	16.58±2.26	19.08±3.21	11.29±5.01	12.47±4.41
March	13.74±2.06	14.36±2.50	8.90±4.72	7.92±3.86

Relative humidity: The results of relative humidity in open area and under agroforestry system for 2007-08 and 2008-09 are presented in table 1 and figure 7. The relative humidity under agroforestry system was ranged between 87.48 to 41.58 and 90.29 to 31.73 per cent during 2007-08 and 2008-09 respectively. Where the relative humidity was recorded high due to rains during early July of 2007 and further increased to 88.79 per cent in September and it gradually decreased up to 41.58 per cent. Similar trend was followed in open area where it was found in range of 81.70 to 34.70 per cent. The relative humidity was increased from July to August afterward decreased. In case of second year *i.e.,* 2008-09 the relative humidity was found 80.63 per cent in July and reached to its peak value during August (90.29 %) afterward gradually decreased to 31.73 per cent in March 2009 under tree, while in open area the relative humidity was found in range of 81.67 to 24.98 per cent with similar trend. During first year (2007-08) of crop the relative humidity during different two cropping year was ranged between 77.14 to 88.79; 84.35 to 63.88 and 59.39 to 41.58 per cent for first, second and third crop growth period respectively under agroforestry, while it was ranged 70.15 to 81.70 ; 74.50 to 54.30 and 47.2 to 34.70 per cent respectively in open area. Similar trend was followed during 2nd year of crop under agroforestry system and in open area. In Chhattisgarh plain the variation in relative humidity under agroforestry system and open area during two consequence year of cropping *i.e.,* 2007-08 & 2008-09 showed that it was comparatively higher under trees than open area, where it was recorded higher during rainy season *i.e.,* 1st growth and harvest of crop afterward it decreased as rains off for second and third growth and harvest phase of crop. The relative humidity was gradually decreased to significant level in both the year when temperature increased.

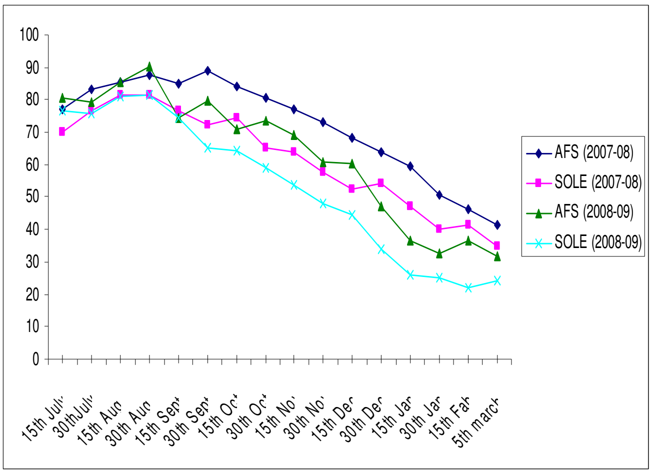

Fig. 7: Changes of air relative humidity (%)

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