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Soil carbon and productivity parameters under Elm (*Ulmus wallichiana* Planch) plantation

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Abstract
The present investigation was carried out in the year 2014-15 on a 22- year old Elm plantation in the Kashmir valley. The soil analysis revealed that there is a decrease in soil moisture (MC), water holding capacity (WHC), organic carbon (OC), available nitrogen (N), phosphorous (P), potassium (K) and sulphur (S) from spring to autumn season. The respective higher values of these parameters were 20.63%, 48.82%, 0.69%, 248.80 kg ha^{-1}, 58.95 kg ha^{-1}, 230.82 kg ha^{-1} and 32.54 kg ha^{-1}. However, bulk density, pH, EC (electrical conductivity), Ca and Mg showed the reverse trend. The maximum values of these variables were 1.11 Mg m^{-3}, 7.15, 0.287 ds m^{-1}, 337.04 ppm and 18.23 ppm, respectively. The majority of the soil variables except bulk density and pH decreased down the profile. All the tested parameters except bulk density and pH were significantly higher under Elm plantation than the open condition.

Keywords: Elm, plantation, soil carbon, productivity parameters

Introduction
Tree plantations bring about significant changes in edaphic, micro-climatic, floral, faunal and other components of the ecosystem through bio-recycling of mineral elements, environmental modifications and changes in floral and faunal composition etc. (Shukla, 2009) [30]. Trees can improve the nutrient balance of soil by reducing nutrient losses from erosion and leaching and by increasing nutrient inputs by way of nitrogen fixation and increased biological activities by providing biomass and suitable microclimate (Schroth and Sinclair, 2003) [26].
Trees are the main source of the soil organic carbon, either from the decomposition of above- or below-ground plant parts, e.g. roots in the form of root death, root exudates and root respiration. Nearly about 40% of the photosynthates synthesized in the trees are lost through the roots into the rhizosphere within an hour and this rate of loss is influenced by many factors, e.g. tree age, biotic and abiotic stresses, etc. The soil organic carbon is thus stored for a long time in the form of humic substances (Kononova, 1966) [15]. The Intergovernmental Panel on Climate Change (IPCC) identified creation and strengthening of carbon sinks in trees and soil which are an option for increasing the removal of CO_2 from the atmosphere. The soil is recognized as one of the carbon pool out of five major carbon pools for the Land Use, Land Use Change in Forestry Sector (LULUCF).

Materials and Methods
The present study was conducted during the year 2014-15 on Elm plantation established by the Department of Forestry, Faculty of Agriculture, SKUAST-K, Wadura in 1992-93 on an abandoned agricultural field. The plantation site is situated at an altitude of 1510 m amsl and lies at 34^{0}3′N latitude and 74^{0}5′E longitude. The assessment of soil carbon and productivity parameters under Elm plantation was done by following the proper sampling techniques and analysis of soil. The area without Elm plantation was taken as control. The soil sampling was done twice in a year viz., spring and autumn season. Soil samples were collected from two depths viz., 0-20 cm and 20-40 cm from each replication. The samples were brought to the laboratory and air-dried. The samples were poured in cloth bags and then analyzed for different response variables that include:

Soil moisture (%): It was determined by using moisture determinance method (Parihar and Sandhu, 1968) [21].

Bulk density (Mg m^{-3}): It was estimated by drying the contents of sample (150 cm^3 in volume) in an oven at 105^{0}C for 18 hours. Bulk density is then determined as per the method (Wild *et al*., 1972) [35].

Water holding capacity (%): It was determined by using brass boxes with holes at the bottom as described by Piper (1994) [22].

Soil pH: 1:2:5 soil water suspension with the help of pH meter (Jackson, 1973) [14].

Electrical conductivity (EC) (ds m^{-1}): 1:2:5 water suspension with the help of conductivity meter.

Organic carbon (OC) (%): Wet digestion method of Walkley and Black (1934) [34].

Available nitrogen (N) (kg ha^{-1}): Alkaline potassium permanganate method of Subbiah and Asija (1956) [32].

Available phosphorous (P) (kg ha^{-1}): Olsen *et al*. (1954) [18].

Available potassium (K) (kg ha^{-1}): Merwin and Peech (1951) [17].

Available sulphur (S) (kg ha^{-1}): Chesnin and Yien (1950) [9].

Available Ca and Mg (ppm): Neutral ammonium acetate (Chapman, 1964) [8] and estimated by atomic absorption spectrophotometer (AAS).

The data of the experiment was analyzed through Randomized Block Design by taking three replications using general linear model of SPSS Statistic version (17.0). The specified data in percentage was subjected to square root and arcsine transformations as suggested by Bartlett (1947) [2].

Results and Discussion

The results of the current investigation have been tabulated in the tables 1, 2 and 3. The perusal of the data revealed that soil moisture percentage was higher under plantation (19.38%) than in open condition (17.93%). It decreased from 19.57% to 17.74% with increase in the sampling depth. This might have happened because of litterfall under plantation resulting in less runoff, decreased infiltration and more retention of moisture in the surface soil. Among seasons, greater soil moisture of 20.63% was noticed in spring season. This may have resulted due to increase in rainfall and melting of snow. The results are in conformity with the findings of Rahman *et al*. (2012) [23], Shameem and Kangroo (2011) [28] and Wagay (2012) [33].

Bulk density of the soil was more under open condition (1.12 Mg m^{-3}) than in plantation (1.09 Mg m^{-3}). This may be due to the fact that there is more soil porosity under plantation resulting in lower bulk density. There is an increase in bulk density from surface (1.09 Mg m^{-3}) to sub-surface (1.16 Mg m^{-3}) soil. This might be due to decrease in soil organic matter and moisture at sub-surface soil. It also increased from spring (1.09 Mg m^{-3}) to autumn season (1.11 Mg m^{-3}). These findings fall in line with the results of Lee *et al*. (2015) [16], Rathod and Devar (2003) [24] and Giri and Rawat (2013) [12].

Water holding capacity (WHC) of soil was higher under plantation (48.78%) than in open condition (44.18%). It decreased down the soil profile from 49.12% to 43.84%. This may have resulted because of higher soil organic carbon in the surface soil under the plantation Also, WHC was greater in spring season (48.82%) as compared autumn season (44.15%). The increase can be attributed to various soil forming factors. These results are in conformity with the findings of Dutta and Agrawal (2002) [11], Semwal *et al*. (2009) [27] and Bhardwaj *et al*. (2000) [4].

Soil pH was relatively lower under plantation than open condition. It also showed an increasing trend from 6.84 to 7.24 with the increase in soil depth. Autumn season showed higher pH (7.15) as compared to spring season (6.92). This may be due to the fact that there is more concentration of organic matter in sampling depth d_1 under plantation. Also increase in pH during autumn season can ascribed to increase in the concentration of calcium and magnesium and decrease in soil moisture. These results conform to the findings of Lee *et al*. (2015) [16], Oraon *et al*. (2014) [20], Bhalla and Gupta (2013) [3], Rathore *et al*. (2011) [25], Sharma *et al*. (2009) [29] and Deekor *et al*. (2012) [10].

Electrical conductivity (EC) of soil increased under plantation (0.366 ds m^{-1}) and decreased from top (0.289 ds m^{-1}) to the sub-surface (0.267 ds m^{-1}) soil. There was also an increase in EC from spring to autumn season. This may have resulted due presence of more organic matter in the top soil under plantation. Also, increased availability of calcium and magnesium may have increased EC in the autumn season. The findings fall in line with the results of Omene *et al*. (2015) [19], Caires *et al*. (2014) [6] and Rathore *et al*. (2011) [25].

The critical scrutiny of the data showed that organic carbon (OC) content of the soil was more under plantation (0.75%) than open condition (0.46%). It was higher in spring (0.69%) compared to autumn season (0.52%). The higher concentration of OC in spring season resulted because of increase in temperature causing an increase in the activity of soil microbes thus accelerating the decomposition of litter. The concentration of soil organic carbon observed a decreasing trend with increase in soil depth. This may be due to less root litter addition to deeper soil depths. These results are in agreement with the findings of Casals *et al*. (2013) [7], Githae *et al*. (2011) [13], Singh *et al*. (2000) [31] and Bisht *et al*. (1989) [5].

The available nitrogen (N) was found to be higher under plantation viz., 267.53 kg ha^{-1} than open condition (189.07 kg ha^{-1}). It was significantly higher in surface soil (251.58 kg ha^{-1}) and during spring season (248.80 kg ha^{-1}). This increase in N can be ascribed to the high litter addition in the surface soil under plantation. The increase in N during spring season may be attributed to the higher rates nitrification due increase in temperature. These observations agree with the results of Casals *et al*. (2013) [7], Sharma *et al*. (2009) [29], Deekor *et al*. (2012) [10] and Bhardwaj *et al*. (2000) [4].

The concentration of available phosphorous (P) was more under plantation (59.81 kg ha^{-1}) than open condition (56.07 kg ha^{-1}). It decreased down the soil profile and recorded higher values in spring (58.95 kg ha^{-1}) as compared to autumn season (56.93 kg ha^{-1}). The increase in availability of P in the surface soil and during spring season may lie under the fact that there is increased decomposition of organic matter due to increase in temperature at the surface soil. These results are well supported by the observations of Oraon *et al*. (2014) [20], Sharma *et al*. (2009) [29], Casals *et al*. (2013) [7] and Singh *et al*. (2000) [31].

The availability of potassium (K) increased under plantation viz., 279.30 kg ha^{-1} due to increased concentration of organic matter. It decreased from spring to autumn season and observed higher values in sampling depth d_1 (230.73 kg ha^{-1}).

The increase in availability of K during spring season can be attributed to increase in temperature causing an increase in rate of mineralization. These findings are firmly supported with the results of Oraon *et al*. (2014) [20], Casals *et al*. (2013) [7] and Bisht *et al*. (1989) [5].

The results pertaining to the availability of sulphur (S) revealed an increase under plantation (38.27 kg ha^{-1}). There was a decrease in available sulphur from spring (32.54 kg ha^{-1}) to autumn season (29.17 kg ha^{-1}). It also decreased from surface to sub-surface soil. This could probably be due to increased proportion of organic matter in surface soil during spring season under plantation. These results conform to the findings of Bannerjee and Nath (1991) [1] and Wagay (2012) [33].

The available calcium (Ca) and magnesium (Mg) were comparatively more under plantation than in open condition. The concentration of Ca and Mg under plantation was 337.05 ppm and 18.09 ppm, respectively. The availability was more in surface soil and increased from spring to autumn season. Increase in the availability of Ca and Mg during autumn season could be due to changes in soil biological processes and decrease in soil moisture. These observations fall in line with the findings of Omene *et al*. (2015) [19], Githae *et al*. (2011) [13] and Wagay (2012) [33].

Table 1: Comparative analysis of soil carbon and productivity parameters under Elm plantation and open conditions.

Parameter	Treatment		CD (0.05)
	Open	Plantation	
MC (%)	17.93 (4.23)	19.38 (4.40)	0.04
BD (Mg m^{-3})	1.12	1.09	0.008
WHC (%)	44.18	48.78	0.96
pH	7.62	6.46	0.20
EC (ds m^{-1})	0.190	0.366	0.01
OC (%)	0.46 (0.67)	0.75 (0.86)	0.02
N (Kg ha^{-1})	189.07	267.53	16.24
P (Kg ha^{-1})	56.07	59.81	0.74
K (Kg ha^{-1})	154.14	279.30	14.30
S (Kg ha^{-1})	23.44	38.27	1.42
Ca (ppm)	309.09	337.05	6.88
Mg (ppm)	17.12	18.09	0.44

Table 2: Effect of sampling season on soil carbon and productivity parameters.

Parameter	Sampling Season		CD (0.05)
	Spring	Autumn	
MC (%)	20.63 (4.54)	16.68 (4.08)	0.04
BD (Mg m^{-3})	1.09	1.11	0.008
WHC (%)	48.82	44.15	0.96
pH	6.92	7.15	0.20
EC (ds m^{-1})	0.269	0.287	0.01
OC (%)	0.69 (0.82)	0.52 (0.71)	0.02
N (Kg ha^{-1})	248.80	207.81	16.24
P (Kg ha^{-1})	58.95	56.93	0.74
K (Kg ha^{-1})	230.82	202.62	14.30
S (Kg ha^{-1})	32.54	29.17	1.42
Ca (ppm)	309.10	337.04	6.88
Mg (ppm)	16.98	18.23	0.44

Table 3: Effect of sampling depth on soil carbon and productivity parameters.

Parameter	Sampling Depth		CD (0.05)
	0-20 cm (d_1)	20-40 cm (d_2)	
MC (%)	19.57 (4.42)	17.74 (4.20)	0.04
BD (Mg m^{-3})	1.04	1.16	0.008
WHC (%)	49.12	43.84	0.96
pH	6.84	7.24	0.20
EC (ds m^{-1})	0.289	0.267	0.01
OC (%)	0.67 (0.81)	0.54 (0.73)	0.02
N (Kg ha^{-1})	251.58	205.02	16.24
P (Kg ha^{-1})	60.61	55.27	0.74
K (Kg ha^{-1})	230.73	202.71	14.30
S (Kg ha^{-1})	34.36	27.35	1.42
Ca (ppm)	340.57	305.58	6.88
Mg (ppm)	18.08	17.13	0.44

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