Int J Pharm Bio Sci 2014 Jan; 5(1): (B) 860 - 872

Research Article **Allied Sciences**

International Journal of Pharma and Bio Sciences

ISSN
0975-6299

BIOMASS AND CARBON ALLOCATION IN DIFFERENT COMPONENTS OF *ULMUS WALLICHIANA* (ELM): AN ENDANGERED TREE SPECIES OF KASHMIR VALLEY

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ABSTRACT

Trees have assumed special importance after it was realized that trees could help reduce the emission of atmospheric carbon by trapping it in various pools of carbon viz. above ground biomass, below ground biomass, soil, litter and dead wood. Carbon sequestration through biomass seems to be a cheap and viable option to mitigate the increasing concentrations of greenhouse gases. The study attempted to estimate biomass and carbon allocation of 19 year old *Ulmus wallichiana* plantation under different diameter classes. The DBH of trees in the stand varied from 15.42 cm to 35.87 cm, height from 12.16 m to 24.47 m, basal area between 0.019 m^2 to 0.101 m^2 and volume between 0.101 m^3 to 0.944 m^3 during 2009 and 2010.The average dry stem biomass of the trees at the site varied between 61.14 kg to 566.82 kg, branch dry biomass between 19.10 kg to 179.82 kg, leaf dry biomass between 3.81 kg to 41.33 kg, total above ground dry biomass between 84.05 kg to 787.97 kg, root dry biomass varied from 21.01kg to 196.99 kg and total biomass (above + below ground) varied from 105.06 kg to 984.96 kg.The stem carbon varied from 26.69 kg to 247.47 kg, branch carbon between 8.25 kg to 77.37 kg, leaf carbon between 1.38 kg to 15.04 kg, root carbon between 9.07 kg to 85.11 kg and total carbon between 45.39 kg to 424.99 kg.The stem carbon dioxide mitigation potential varied from 97.68 kg to 905.74 kg, branch from 30.19 kg to 283.17 kg, leaf from 5.05 kg to 55.04 kg, root from 33.19 kg to 311.50 kg and total carbon dioxide mitigation potential varied from 166.11 kg to 1555.45 kg during 2009 and 2010.

KEY WORDS: Biomass, Carbon stock, Carbon dioxide mitigation, *Ulmus wallichiana*

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INTRODUCTION

Carbon dioxide (CO_2) is an important green house gas that influence global climate. Since the beginning of industrial revolution, carbon dioxide concentration in the atmosphere has been rising alarmingly. Prior to the industrial revolution carbon concentration in the atmosphere was around 372 ppm (Sage, 1995).If the pace of increase in carbon concentration remains constant, carbon concentration in the atmosphere would go up to 800-1000 ppm by the turn of this century (Whipps, 1990). Trees can contribute to mitigate green house effect and global warming. Terrestrial vegetation and soil currently absorb 40% of global carbon dioxide emission from human activities (Adam, 2001). Forests are the largest terrestrial reservoir of atmospheric carbon. They remove CO_2 from the atmosphere and store it in the organic matter of soil and biomass. The current carbon stock in tree biomass comprises half of the atmospheric storage and is continuing to grow deforestation the rate of which is decreasing but still high (Watson, 2000). The amount of carbon stored in a forest stand depends on its age and productivity. The terrestrial carbon sink, inferred from changes in the concentrations of atmospheric gases and their isotopic composition is normally attributed to the global increase in productivity (Boisvenue *et al.*, 2006). The reduction in concentration of CO_2 in atmosphere can be achieved either by reducing the demand for energy or by altering the way the energy is used and by increasing the rates of removal of CO_2 from atmosphere through growth of terrestrial biomass (Bhadwal, 2002). The most promising management practices for CO_2 mitigation are afforestation and reforestation of blank areas. On the global scale, deforestation results in the release of approximately 1000 million tons of carbon to the atmosphere each year in the form of CO_2, an important green house gas. This is about 15 per cent of the total human caused emission and is a significant portion of the global carbon cycle that could contribute to global climate change. The earth's terrestrial vegetation plays a pivotal role in the global carbon cycle. Tremendous amounts are actively exchanged between vegetation and atmosphere. Any land use practices that increase vegetation cover or reduce its removal, could have an influence on the global carbon budget by increasing the terrestrial carbon sink. Carbon sequestration is emerging as a major international policy goal in the context of increasing concerns about global climate change. The idea about mitigating it through forest conservation and management was initiated and in 1992 several countries agreed to the United Nations Frame Work Convention on climate change, with the major objectives of developing national inventories of green house gas emission and sinks, and reducing the emission of green house gases (FAO, 2001). At the third meeting of the United Nations Frame Work Convention on Climate Change (UNFCCC) in 1997 in the Kyoto, Japan, the participating countries through what would later become known as the Kyoto protocol, to reduce green house gas emissions to 5 per cent or more below 1990 levels by 2012, which was extended up to 2017 in a recently held Climate Conference in Durban (Cop-17) from November 28 to December 11, 2011 to establish a new treaty to limit carbon emissions. Finally trees are one of the alternatives to increase forest cover which will widen the area of carbon sink. Farmers can be benefited if they raise forest plantations. These plantations shall provide tangible and intangible benefits and carbon credits generated through plantation will provide additional income to the farmers besides all other benefits of raising plantations.

The *Ulmus wallichiana* belongs to family ulmaceae, commonly known as Elm.Before the introduction of *Populus deltoides*, it was the most cultivated multipurpose tree species of Kashmir valley used for timber, fodder, fuelwood, fibre, ropes etc. and now has assumed the status of endangered species in

Kashmir valley (Phartyal *et al*., 2003). It is distributed in temperate areas throughout Europe, North-Southern Asia, Turkey, Israel, Iran, Afghanistan and western Himalayas. In western Himalayas it is found from Kashmir to Nepal and the general altitudinal range is 900-3000 m. It is a deciduous fast growing tree and has got a straight bole up to 33 meters height and can attain a girth of 2.8 meters. Its timber is used for light construction, packing cases, furniture and for agricultural implements (Luna, 2005). Thus keeping in view the growing interest in quantifying the ability to sequester atmospheric carbon, an attempt was therefore made to estimate the biomass and carbon stock of Elm under Kashmir conditions.

MATERIALS AND METHODS

Study area

The experimental site is located between 74.89^{o}East longitude and 34.08^{o}North latitude at an altitude of about 1600 meters above mean sea level. It is roughly 15 km south east to the Srinagar city and the soil of the site is silty loam and is well drained. The climate is generally temperate with severe winter extending from December to March. The region faces a wide temperature range from a minimum of -4^{o}C in winter to a maximum of 33^{o}C in the summers. The annual precipitation of the area is about 676 mm and most of the precipitation is received in the form of snow during winter months. The present study was carried out in *Ulmus wallichiana* (Elm) Plantation Block of Faculty of Forestry during the year 2009 and 2010 at Sher-e-Kashmir university of Agricultural sciences and technology of Kashmir (SKUAST-K),Shalimar.The trees were planted during March, 1990 having 19 years of age.

Demarcation and enumeration for measurements

After survey of the experimental site, a quadrate of size 10 x 10 m was laid at the area and total 24 trees in a particular quadrate were enumerated according to diameter at breast height (DBH). These trees were then classified into three diameter classes viz; 10-20cm, 20-30cm and 30-40cm for measuring various parameters.

Estimations

Volume and tree biomass

Tree biomass was estimated by adopting non-destructive methods for different plant parts viz; stem, branch and leaf.

Stem biomass

The diameters at breast height (DBH) of the trees falling in the plot of size 10 x 10 m were measured with diameter tape and height with Ravi's multimeter respectively. Form factor and volume was calculated by using the following formula given by Pressler (1865) and Bitlerlich (1984).

$$f = \frac{2h_1}{3h}$$

Where, f is the form factor, h_1 = height at which diameter is half of DBH and h is the total height.
The volume (V) was calculated by Pressler's formula:
V = f × h × g Where,f = form factor, h = total height (m) and g = basal area,
g = πr^2 or π (dbh/2)^2 Where, r = radius

Specific gravity

The stem cores were taken to find out specific gravity of wood, taking into account the variation in different parts of the tree, which was used further to determine the biomass of stem using the maximum moisture method (Smith, 1954).

$$Gf = \frac{1}{\frac{M_n - M_o}{M_o} + \frac{1}{G_{so}}}$$

Where,
G_f = specific gravity based on gross volume
M_n = weight of saturated volume sample
M_o = weight of oven dried sample
G_{so} = Average density of wood substance equal to 1.53
Thus weight of stem wood = specific gravity × stem volume
Or
Stem biomass = Specific gravity × stem volume

Branch biomass

The total number of branches irrespective of size was counted on each of the sample tree, then these branches were categorised on the basis of basal diameter into three groups viz; small, medium and large. Fresh weight of two sampled branches from each group was recorded separately. The following formula (Chidumaya, 1990) was used to determine the dry weight of branches:

$$B_{dwi} = B_{fwi} \Big/ 1 + M_{cdbi}$$

Where,
B_{dwi} = oven dry weight of branches
B_{fwi} = Fresh/green weight of branches
M_{cdbi}= Moisture content of branches on oven dry weight basis
Total branch biomass (fresh/dry) per sample tree will be determined as given below:

$$B_{bt} = n_1 b_{w1} + n_2 b_{w2} + n_3 b_{w3} ...... = \sum_{i=1}^{n} n_i b_{wi}$$

Where,
B_{bt} = Branch biomass (fresh/dry) per tree
n_i = Number of branches in the i^{th} branch group
b_{wi} = Average weight of branch of i^{th} group
I = 1, 2, 3 the branch groups

Leaf biomass

Leaves from five branches of individual trees were removed. Five trees per plot were taken for observation. The leaves were weighed and oven dried separately to a constant weight at 80±5^{o}C. The average leaf biomass was then arrived at by multiplying the average biomass of the leaves per branch with the number of branches in a single tree and the number of trees in a plot (Koul and Panwar, 2008).

Total Tree biomass (Aboveground)

The total tree biomass (aboveground) was the sum of stem, branch and leaf biomass.

Root biomass
The root biomass was determined as per the procedure given by (Dury *et al.*, 2002). The aboveground biomass was multiplied with default ratio of 0.25 for hardwood species for estimating root biomass.

Biomass carbon stock
Carbon percentage was estimated by ash content method described by Negi *et al.* (2003). In this method oven dried plant components (bark, leaves, stem wood and root) were burnt into muffle furnace at 400°C. The ash content left after burning was weighed and carbon content was calculated by using the following equation:

Carbon % = 100 – (ash weight + molecular weight of O_2 (53.3) in $C_6H_{12}O_6$

The carbon (%) was then multiplied with the biomass to get biomass carbon stock.
Carbon stock = Biomass × carbon (%)

Carbon dioxide equivalent (CO_2e)
The carbon dioxide equivalent was calculated as per the following equation:
Carbon dioxide equivalent = Carbon stock × 3.66

Statistical analysis
The data was statistically analysed for the computation of standard error (Gomez and Gomez, 1989).

RESULTS AND DISCUSSION

Growth characteristics of Ulmus wallichiana
Perusal of the data in (Table 1) revealed that different diameter classes influenced the growth parameters. The DBH was recorded maximum (35.87 cm/tree) in diameter class 30-40 cm during 2010 and minimum (15.42 cm/tree) under diameter class 10-20 cm during 2009. The increase in DBH with the increase in diameter is due to growth of the trees (Gupta, 1969). The height was recorded maximum (24.47 m/tree) under diameter class 30-40 cm during 2010 and minimum (12.16 m/tree) under diameter class 10-20 cm during 2009. Ahmad *et al.* (1999) has reported that the height increases with the increase in diameter class. The basal area was recorded maximum (0.101 m^2/tree) under diameter class 30-40 cm during 2010 and minimum (0.019 m^2/tree) under diameter class 10-20 cm during 2009. Increase in basal area with the increase in diameter class could be due to increase in diameter (Ahmad *et al.*, 1999). The volume was maximum (0.944 m^3/tree) in diameter class 30-40 cm during 2010 and minimum (0.101 m^3/tree) in diameter class 10-20 cm during 2009.Dey (1996) reported that volume of *Populus deltoides* was highly influenced by diameter class and showed a marked increase from lower diameter class to higher diameter class. Several other workers also support the current findings for DBH, height, basal area and volume (Kishore, 1991; Ahmad *et al.*, 1999; Heriansyah *et al.*, 2007 and Arifin *et al.*, 2008).

Biomass production of Ulmus wallichiana
The results presented on biomass production of *Ulmus wallichiana* (Table 2) indicates that average dry stem biomass of *Ulmus wallichiana* increased with a corresponding increase in diameter class and was recorded maximum (566.82 kg/tree) under diameter class 30-40 cm during 2010 and minimum (61.14 kg/tree) under

diameter class 10-20 cm during 2009. Islam and Masoodi (2007) on the same species reported earlier the stem dry biomass varied between 10.84 to 29.57 kg/tree of 9 year old Elm stand in Kashmir valley. Several other workers also support our findings (Pande *et al.*, 1988 and Singh and Puri, 1990). They reported that with the increase in diameter class the stem biomass showed an increasing trend. The branch biomass also showed an increasing trend with the increase in diameter class and was recorded maximum (179.82 kg/tree) under diameter class 30-40 cm during 2010 and minimum (19.10 kg/tree) under diameter class 10-20 cm during 2009. The branch biomass depends on the average number of branches of the tree. Moreover, differences in the proportions of branches were affected by the model/form and size of the branches and structure of large and small branch sizes in the canopy (Heriansyah *et al.*, 2007). Islam and Masoodi (2007) on the same species reported the branch biomass in the range of 2.66 to 7.63 kg/tree while working on 9 year old Elm stand in Kashmir valley. These results are also in line with the findings of Sharma *et al.* (1990), Mishra *et al.* (1998), Bhardwaj et *al.*, (2001) and Raizada *et al.* (2007). The leaf biomass was recorded maximum (41.33 kg/tree) under diameter class 30-40 cm during 2010 and minimum (3.81 kg/tree) under diameter class 10-20 cm during 2009. The increase in leaf biomass in higher diameter class could be due to more number of branches as compared to lower diameter class. Moreover more the biomass of leaves more would be the photosynthesis and consequently more will be the biomass production. Islam and Masoodi (2007) on *Ulmus wallichiana* stand (9 year old) in Kashmir valley reported the leaf biomass in the range of 0.93 to 2.77 kg/tree). Our results also corroborates with the findings of several other workers (Sharma *et al.*, 1990; Mishra *et al.*, 1998; Bhardwaj et *al.*, 2001 and Raizada *et al.*, 2007). The total above ground biomass was recorded maximum (787.97 kg/tree) under diameter class 30-40 cm during 2010 and minimum (84.05 kg/tree) under diameter class 10-20 cm during 2009.Growth performance and biomass productivity of a 9 year old Elm (*Ulmus wallichiana*) stand was studied by Islam and Masoodi (2007) and they concluded that the total aboveground biomass varied between 14.42 to 39.98 kg/tree. The values in the current study are higher as reported by Islam and Masoodi (2007) because the biomass of tree species depends on the age. The results are also in conformity with the findings of Brenes and Montagnini (2006), Yadava (2010b), Uma *et al.* (2011) and Fonseca *et al.* (2012). The root biomass showed an increasing trend with the increase in diameter class and was recorded maximum (196.99 kg/tree) under diameter class 30-40 cm during 2010 and minimum (21.01 kg/tree) under diameter class 10-20 cm during 2009. Hase and Foeister (1983) reported that trees produce larger root system that needed for uptake of soil resources, thus resulting in higher values in higher diameter class. Several other workers also support our findings (Bhardwaj et *al.*, 2001; Raizada *et al.*, 2007; Yadava, 2010a and Uma *et al.*, 2011) who reported that root biomass is more in higher diameter class as compared to lower diameter class. The biomass productivity was recorded maximum (24.46 t ha^{-1} yr^{-1}) under diameter class 30-40 cm and minimum (8.34 t ha^{-1} yr^{-1}) under diameter class 10-20 cm. Biomass productivity of a 9 year old Elm (*Ulmus wallichiana*) stand in Kashmir valley was studied by Islam and Masoodi (2007) and reported that the biomass productivity at the site varied between (0.78 to 4.93 t ha^{-1} yr^{-1}). The values in the study does not fall in line as reported earlier by many other workers because biomass of species varies considerably according to climatic and edaphic factors even for the same species and also largely depends on the age. These findings also corroborates with the observations made by Brown *et al.* (1986), Rana and Singh (1990) and Heryati *et al.* (2011).

Production of carbon stock of Ulmus wallichiana

It is evinced from the data presented in (Table

3) that stem carbon stock showed an increasing trend with the corresponding increase in diameter class and was recorded maximum (247.47 kg/tree) under diameter class 30-40 cm during 2010 and minimum (26.69 kg/tree) under diameter class10-20 cm during 2009. Terakunpisut *et al.* (2007) has reported that carbon stock is more in trees having a greater diameter as compared to trees having smaller diameter. Our results are in accordance with the findings of Nowak and Crane (2001), Ryan *et al.* (2010) and Rizvi *et al.* (2011). The branch carbon stock was registered maximum (77.37 kg/tree) under diameter class 30-40 cm during 2010 and minimum (8.25 kg/tree) under diameter class 10-20 cm during 2009. The branch carbon stock depends on the average number of branches on the trees. Moreover, it increases with the increase in diameter class. Our results corroborates with the findings of Matala *et al.* (2009), Tolunay (2011) and Rizvi *et al.* (2011). The leaf carbon stock was recorded maximum (15.04 kg/tree) under diameter class 30-40 cm during 2010 and minimum (1.38 kg/tree) under diameter class 10-20 cm during 2009. The increase in leaf carbon stock from lower diameter class to higher diameter class is due to more number of branches in higher diameter class. The present findings are well in agreement with the findings of Ramachandran *et al.* (2007), Ryan *et al.* (2010), Rizvi *et al.* (2011) and Tolunay (2011). The root carbon stock was registered maximum (85.11 kg/tree) under diameter class 30-40 cm during 2010 and minimum (9.07 kg/tree) under diameter class 10-20 cm during 2009. Similar results have also been reported earlier by many other workers (Albrecht and Kandji, 2003; Navar, 2009 and Ryan *et al*., 2010). The total carbon stock was recorded maximum (424.99 kg/tree or 212.49 t ha^{-1}) under diameter class 30-40 cm during 2010 and minimum (45.39 kg/tree or 63.54 t ha^{-1}) under diameter class 10-20 cm during 2009. Our results are in line with the findings of Albrecht and Kandji (2003), Tolunay (2011), Ryan *et al.* (2010) and Rizvi (2011). The carbon productivity was registered maximum (10.55 t ha^{-1} yr^{-1}) under higher diameter class 30-40 cm and minimum (3.59 t ha^{-1} yr^{-1}) under lower diameter class 10-20 cm. Similar results were earlier reported by many other workers (Brenes and Montagnini, 2006; Kumar *et al*., 2009 and Yadava, 2010b).

Carbon dioxide mitigation potential of Ulmus wallichiana

Among the different diameter classes, the stem carbon dioxide equivalent (Table 4) showed an increasing trend with the increase in diameter class and was registered maximum (905.74 kg/tree) under diameter class 30-40 cm during 2010 and minimum (97.68 kg/tree) under diameter class 10-20 cm during 2009. This is due to the fact that CO_2 mitigation is more in higher diameter class as compared to lower diameter class because in higher diameter class, biomass production is more which fixes CO_2 from the atmosphere (Yadava, 2011). This parameter is the most important in determining the potential of a tree species to mitigate the major green house gas, carbon dioxide. These findings are in agreement with the findings of Wang and Fenz (1995); Albrecht and Kandji (2003) and Mehraj and Kumar (2006). The branch CO_2 equivalent was registered maximum (283.17 kg/tree) under diameter class 30-40 cm during 2010 and minimum (30.19 kg/tree) under diameter class 10-20 cm during 2009. Higher mitigation potential of branch in higher diameter class can be due to more biomass (Yadava, 2010a). These results are in conformity with the findings of Lal and Singh (2000), Mehraj and Kumar (2006) and Rizvi *et al.* (2011).The leaf CO_2 equivalent was registered maximum (55.04 kg/tree) under diameter class 30-40 cm during 2010 and minimum (5.05 kg/tree) under diameter class 10-20 cm during 2009. Lal and Singh (2000) have reported that higher mitigation potential of leaf in higher diameter class is attributed to more biomass production. Similar results were also reported earlier by many other workers (Kursten, 2000; Gera *et al*., 2006 and Yadava, 2011). The root CO_2 equivalent was registered maximum (311.50 kg/tree) under diameter class 30-40 cm during 2010 and minimum (33.19

kg/tree) under diameter class 10-20 cm during 2009. Higher mitigation potential of root in higher diameter class is attributed to more root biomass (Yadava, 2010a). Our results are in conformity with the findings of Kursten and Burschel (1993), Wang and Fenz (1995) and Kursten (2000). The total CO_2 equivalent of *Ulmus wallichiana* was registered maximum (753.63 t ha^{-1}) under diameter class 30-40 cm and minimum (256.64 t ha^{-1}) under diameter class 10-20 cm. Kursten (2000) has reported that biomass production is more in higher diameter class which mitigates more CO_2 from the atmosphere as compared to lower diameter class. Our results are well in accordance with the findings of Kursten and Burschel (1993), Lal and Singh (2000) and Mehraj and Kumar (2006).

Table 1
Growth parameters of Ulmus wallichiana trees under different diameter classes

Diameter class (cm)	DBH (cm)			Height (m)			Basal area (m^2/tree)			Stem volume (m^3/tree)		
	2009	2010	Increment	2009	2010	Increment	2009	2010	Increment	2009	2010	Increment
10-20	15.42 (±0.86)	16.16 (±0.94)	0.74 (±0.08)	12.16 (±0.82)	12.53 (±0.90)	0.37 (±0.03)	0.019 (±0.002)	0.021 (±0.002)	0.002 (±0.001)	0.101 (±0.015)	0.120 (±0.018)	0.019 (±0.016)
20-30	26.00 (±1.06)	27.01 (±1.13)	1.01 (±0.11)	20.90 (±0.74)	22.02 (±0.93)	1.12 (±0.11)	0.053 (±0.004)	0.057 (±0.005)	0.004 (±0.002)	0.472 (±0.057)	0.503 (±0.067)	0.031 (±0.062)
30-40	35.18 (±1.66)	35.87 (±1.70)	0.69 (±0.05)	23.80 (±1.46)	24.47 (±1.79)	0.67 (±0.04)	0.097 (±0.009)	0.101 (±0.009)	0.004 (±0.002)	0.895 (±0.120)	0.944 (±0.136)	0.049 (±0.128)

Figures in parenthesis are standard error of mean

Table 2
Production of above and below ground biomass of Ulmus wallichiana trees under different diameter classes

Diameter class (cm)	Stem biomass (kg/tree)			Branch biomass (kg/tree)			Leaf biomass (kg/tree)			Total above ground biomass (kg/tree)		
	2009	2010	Increment	2009	2010	Increment	2009	2010	Increment	2009	2010	Increment
10-20	61.14 (±9.06)	72.24 (±10.91)	11.10 (±1.85)	19.10 (±2.83)	22.58 (±3.41)	3.48 (±0.47)	3.81 (±0.56)	7.05 (±1.06)	3.24 (±0.41)	84.05 (±12.46)	101.87 (±15.39)	17.82 (±2.16)
20-30	283.62 (±34.53)	302.28 (±36.91)	18.66 (±2.38)	88.64 (±12.92)	98.26 (±15.01)	9.62 (±1.33)	26.43 (±4.40)	31.13 (±5.12)	4.70 (±0.92)	398.69 (±49.65)	431.67 (±54.91)	32.98 (±3.76)
30-40	537.06 (±77.35)	566.82 (±80.93)	29.76 (±3.58)	167.82 (±24.64)	179.82 (±26.03)	12.0 (±1.97)	33.56 (±5.47)	41.33 (±6.90)	7.77 (±1.04)	738.44 (±99.62)	787.97 (±99.62)	49.53 (±4.61)

Contd…….

Diameter class (cm)	Root biomass (kg/tree)			Total biomass (kg/tree)			Total biomass (t ha^{-1})		Biomass productivity (t ha^{-1} yr^{-1})
	2009	2010	Increment	2009	2010	Increment	2009	2010	
10-20	21.01 (±3.11)	25.47 (±3.84)	4.46 (±1.03)	105.06 (±15.58)	127.34 (±19.24)	22.28 (±3.17)	147.08 (±21.65)	178.27 (±24.64)	8.34 (±1.17)
20-30	99.67 (±15.36)	108.05 (±16.21)	8.38 (±1.21)	498.36 (±62.06)	539.72 (±78.42)	41.36 (±6.92)	249.18 (±30.09)	269.86 (±33.41)	13.30 (±1.29)
30-40	184.60 (±24.90)	196.99 (±26.51)	12.39 (±1.97)	923.04 (±124.52)	984.96 (±132.27)	61.92 (±9.16)	461.52 (±50.17)	492.48 (±61.93)	24.46 (±3.71)

Figures in parenthesis are standard error of mean

Table 3

Production of above and below ground carbon stock of Ulmus wallichiana trees under different diameter classes

Diameter class (cm)	Stem carbon (kg/tree)			Branch carbon (kg/tree)			Leaf carbon (kg/tree)		
	2009	2010	Increment	2009	2010	Increment	2009	2010	Increment
10-20	26.69 (±3.95)	31.54 (±4.76)	4.85 (±0.92)	8.25 (±1.21)	9.71 (±1.46)	1.46 (±0.25)	1.38 (±0.20)	2.56 (±0.38)	1.18 (±0.16)
20-30	123.82 (±15.07)	132.21 (±16.81)	8.39 (±1.23)	38.14 (±4.64)	42.28 (±4.96)	4.14 (±0.32)	9.62 (±1.41)	11.33 (±2.36)	1.71 (±0.95)
30-40	234.48 (±31.63)	247.47 (±32.88)	12.99 (±2.87)	72.21 (±9.74)	77.37 (±10.31)	5.16 (±0.57)	12.21 (±2.77)	15.04 (±3.01)	2.83 (±0.24)

Contd…..

Diameter class (cm)	Root carbon (kg/tree)			Total carbon (kg/tree)			Total carbon (t ha^{-1})		Carbon productivity (t ha^{-1} yr^{-1})
	2009	2010	Increment	2009	2010	Increment	2009	2010	
10-20	9.07 (±1.34)	10.99 (±1.66)	1.92 (±0.32)	45.39 (±6.73)	54.81 (±8.28)	9.42 (±1.37)	63.54 (±8.21)	76.73 (±9.84)	3.59 (±0.86)
20-30	43.06 (±5.01)	46.68 (±5.27)	3.62 (±0.26)	214.64 (±26.66)	232.50 (±29.54)	17.86 (±3.54)	107.32 (±13.09)	116.25 (±14.57)	5.73 (±0.98)
30-40	79.76 (±9.98)	85.11 (±10.76)	5.35 (±0.78)	398.66 (±53.78)	424.99 (±55.37)	26.33 (±3.84)	199.33 (±21.45)	212.49 (±24.34)	10.55 (±1.43)

Figures in parenthesis are standard error of mean

Table 4

Carbon dioxide mitigation potential of different components of Ulmus wallichiana trees under different diameter classes

Diameter class (cm)	Stem CO_2e (kg/tree)		Increment	Branch CO_2e (kg/tree)		Increment	Leaf CO_2e (kg/tree)		Increment
	2009	2010		2009	2010		2009	2010	
10-20	97.68 (±14.48)	115.43 (±17.44)	17.75 (±8.87)	30.19 (±4.46)	35.53 (±5.37)	5.34 (±2.67)	5.05 (±0.75)	9.36 (±1.42)	4.31 (±2.15)
20-30	453.18 (±55.17)	483.88 (±57.21)	30.70 (±15.35)	139.59 (±17.01)	154.74 (±17.96)	15.15 (±7.57)	35.20 (±5.86)	41.46 (±6.33)	6.26 (±3.13)
30-40	858.19 (±110.24)	905.74 (±116.81)	47.55 (±23.77)	264.28 (±37.65)	283.17 (±44.05)	18.89 (±9.44)	44.68 (±6.57)	55.04 (±6.98)	10.36 (±5.18)

Contd…..

Diameter class (cm)	Root CO_2e (kg/tree)		Increment	Total CO_2e (kg/tree)		Increment	Total CO_2e (t ha^{-1})
	2009	2010		2009	2010		
10-20	33.19 (±4.97)	40.22 (±6.08)	7.03 (±3.51)	166.11 (±19.84)	200.54 (±30.32)	34.43 (±17.21)	256.64 (±8.51)
20-30	157.60 (±19.63)	170.84 (±20.13)	13.24 (±6.62)	785.57 (±97.58)	850.92 (±108.31)	65.35 (±32.67)	409.12 (±51.69)
30-40	271.92 (±44.81)	311.50 (±46.22)	39.58 (±9.79)	1459.07 (±196.85)	1555.45 (±210.79)	96.38 (±48.19)	753.63 (±91.74)

Figures in parenthesis are standard error of mean, (CO_2e= Carbon dioxide equivalent)

CONCLUSION

1. Growth parameters like DBH, height, basal area and volume showed an increasing trend with the increase in diameter class and maximum volume was registered under diameter class 30-40 cm during 2010. However, the increment did not show any particular trend.
2. Biomass production per tree in all the aboveground tree components namely stem, branch and leaf and belowground biomass (root biomass) increased with the increase in diameter class and among the different diameter classes, maximum total biomass was recorded in *Ulmus wallichiana* under diameter class 30-40 cm during 2010.The increment of biomass components (stem,

branch, leaf and root) increased with the increase in diameter class. The biomass productivity was more in higher diameter class as compared to lower diameter class.

3. The higher percentage of biomass contribution was recorded in stem followed by root, branch and leaf respectively during both the years.
4. The carbon stock showed an increasing trend with the increase in diameter class and also increases from 2009 to 2010. Moreover the increment of carbon stock also increased from lower diameter class to higher diameter class and the maximum carbon stock was recorded during 2010 under diameter class 30-40 cm and minimum under diameter class 10-20 cm during 2009. The carbon productivity increased from the lower diameter class to higher diameter class.
5. Carbon dioxide mitigation potential was recorded maximum under the higher diameter class 30-40 cm. during 2010. Among the different components of Elm, stem recorded the maximum mitigation potential followed by root, branch and leaf respectively.
6. The highest growth performance as well as biomass accumulation of Elm shows that the species is highly adapted to environmental and edaphic conditions.

RECOMMENDATIONS

- The trees should be harvested at higher diameter class in order to obtain maximum volume and biomass production.
- *Ulmus wallichiana* proved to be the best for sequestering the maximum amount of carbon stock. Therefore the use of such trees with higher carbon sequestration capacity could improve carbon stocks.
- *Ulmus wallichiana* in Kashmir valley is at the verge of extinction, therefore there is immediate need for the conservation of this species.

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