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GROWTH PERFORMANCE OF TIMBER SPECIES UNDER FOREST PLANTATIONS IN DIFFERENT AGRO-CLIMATIC ZONE OF JHARKHAND, INDIA

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ABSTRACT

Forest department in Jharkhand undertook large scale plantations in the forestland. Trees planted on forest lands for primarily environmental benefits are being managed as per the needs of local people who have rights in those forests. These plantations have enhanced the forest cover by 942 Km^2 between 2001 and 2011. These plantations created all over the state provided an excellent opportunity to evaluate the growth performance of timber species in field conditions. This paper presents the growth performance of timber species under plantation forestry in different agro-climatic conditions (subzones or regions) in the state of Jharkhand. The scientific understanding of growth performance of these species would help the entrepreneurs and forest department in exploring the different combination of species for economic viability as well as ecological benefits. There is nearly 2.5 million ha fallow agricultural land area available for tree planting under private forestry in Jharkhand. However, among other support systems for tree cultivation on such lands, the choice of species and management practices are important component for tree growers.

Key words: Forest plantations, Growth performance, Timber species, Agro-climatic zones, Jharkhand.

Introduction

The potential of plantation forestry has been widely recognized in reducing pressure on greater areas of natural forests and generating positive environmental effects as they replace degraded marginal agricultural lands. Plantation forests have become increasingly significant in the world's future timber supply and it is important that they be managed well from production, environmental, social and economic perspectives. However, in order to develop a healthy future forest stock through plantation forestry there are a number of issues and challenges that need to be properly addressed starting from nursery management, plantation techniques, choice of species and plantation sites, human resource development and adequate funding for the plantation programme. The studies aiming to improve the silvicultural understanding of species by assessing their growth and performance in actual plantings in India are very few (Nath *et al.*, 1989; Nath *et al*., 1990; Nath *et al*., 1991; Tewari *et al*., 1996; Kumar and Reddy, 2000; Amanulla *et al*., 2004; Roy *et al*., 2006; Verma and Kumar, 2012; Tewari *et al*., 2013) in India. Performance of different tree species in field experimental trial were studied by Prasad *et al*. (1998); Tomar *et al.* (2003); Sinha and Sharma (2002); Gill and Ajit (2004); Singh *et al*. (2004); Mahari (2005) and Khan *et al*. (2006). There is little published data available to compare performance of different species in field (actual) plantations even though species choice and site-species matching based on growth performance are key decisions in reforestation projects.

Forest department in Jharkhand undertook large scale plantations in the forestland after the creation of Jharkhand as new state of carved from erstwhile state of Bihar on 15th November 2000 in eastern part of India. Trees planted on forestlands for primarily environmental benefits are being managed as per the needs of local people who have rights in those forests. These plantations carried out have enhanced the forest cover which is evident from the successive reports of Forest Survey of India (ISFR-2001, 2003, 2005, 2009, 2011 and 2013). The total forest cover of the state in the year 2001 was 22,531 Km^2, which increased to 23,473 Km^2 by the year 2011 with a total gain of 942 Km^2 during the period. However, scientific evaluation of growth, productivity, suitability as well as compatibility of species mixtures has not been carried out barring a recent monitoring of these plantations by Regional Centre of National Afforestation and Eco-development Board in 2007. These plantations created all over the state between 2002 and 2007, provided an excellent opportunity to evaluate the growth performance of timber species in actual plantings. Commercial viability of the different combination of species can be explored by the entrepreneurs and forest

Choice of timber species for plantations in Jharkhand would revolve around *Acacia auriculiformis, Dalbergia sissoo, Tectona grandis* and *Gmelina arborea.*

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department for economic as well as ecological benefits only with the scientific understanding of growth performance of these species. There is nearly 2.5 million ha fallow agricultural land area available for tree planting under private forestry as evident from increasing trend of such fallow lands in Jharkhand (Fig. 1). However, among other support systems for tree cultivation on such lands, the choice of species and management practices are important component for tree growers. This paper

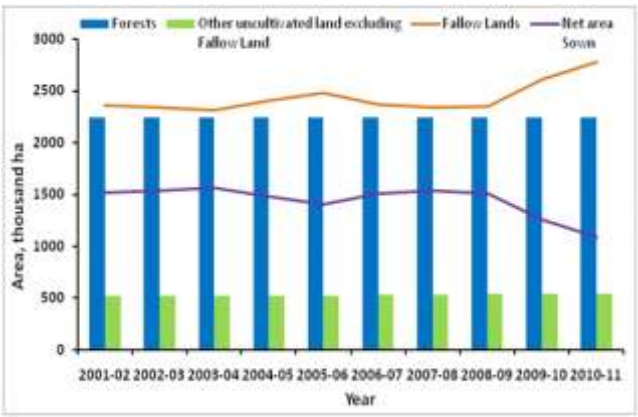

Fig. 1: Land use pattern of Jharkhand

presents the growth performance of timber species under plantation forestry in different agro-climatic conditions (subzones or regions) in the state of Jharkhand.

Material and Methods

The study area, Jharkhand is located in the eastern part of India having 21° 55' to 25° 35' Latitude and 83° 20' to 88° 02' Longitude. The state comprises of Chhota Nagpur Plateau, which forms a part of Deccan bio-geographic province. It is a hilly undulating plateau characterized by predominantly tropical forests and tribal settlements and is primarily rainfed. Nearly 85% of the rainwater is contributed by South-West monsoon from June to September. The state falls under the tropical monsoon climatic region and forms a part of Agro-climate zone VII of India known as Eastern plateau and hill region. The three well-defined seasons are cold-weather season, from November to February and hot-weather season lasts from March to mid-June. The state is having very versatile temperature ranging from minimum of 4-5 °C to a maximum of 44-45 °C. Minimum temperature of coldest month in Jharkhand lies between 5 °C to 12 °C whereas the warmest month, is characterized by maximum temperatures from 30 °C to 42 °C. The Tropic of Cancer cuts across the state passing through the middle of the Ranchi city, the capital of the state. High temperatures in Ranchi in December usually rise from about 50 °F (10 °C) into the low 70s F (low 20s C) daily while in May high temperature lie in the upper 90s F (about 37 °C) and low temperatures in the mid-70s F (mid-20s C).

Based on rainfall, temperature, terrain and soil characteristics, the state has been further divided in to three agro-climate sub zones (IASRI, 2008) namely Subzone IV-Central and North Eastern Plateau comprising districts of Hazaribagh, Chatra, Ramgarh, Dhanbad, Bokaro, Giridih, Koderma, Jamtara, Deoghar, Godda, Dumka, Pakur, and Sahebganj characterized by humid and sub humid tropical monsoon climate and low water holding capacity of soil; Subzone V-Western Plateau comprising districts of Ranchi, Khunti, Palamu, Gumla, Lohardaga, Garhwa, Latehar and Simdega characterized by sub humid to subtropical monsoon climate; Subzone VI-South Eastern Plateau comprises districts East Singhbhum, West Singhbhum, Saraikela-Kharsawama characterized by humid to sub-tropical monsoon climate (Fig. 2).

Fig. 2: Study area with districts and agroclimatic regions of Jharkhand

The forest plantations sites of the study area spread all over the three agro-climatic regions of Jharkhand viz., the Central and North East Plateau, Western Plateau and South Western Plateau and plantations were done during 2002 to 2007. The total forest plantations covers 540,000 hectare during 2002-2007 period in all the three agro-climatic zones. Nearly 0.1 % of the total planted areas were taken as sampled area, which was 540 ha. The total sampled area was equally distributed into 540 plantation sites, truly representing the plantation years, administrative districts and agro-climatic zones. The number of selected plantation sites was decided based on the proportion of area plantation. Sampling design involved two levels of stratification, first the agro-climatic zone (region) level and second the administrative district. The total number of selected sites in a district was depending on total

forest area undertaken for plantation and random sampling method was employed for the selection of plantation sites in a particular district for this study. At each selected sites, 10 square quadrates of 0.1 hectare were laid randomly and growth attributes of the planted tree species like height, collar girth and girth at breast height etc. were recorded following the quadrat method (ISFR, 2009).

The tree level information recorded in 2009 on tree status (live or dead/cut), species, row and column location in the plot, height, collar girth (CG) at six inches above ground and girth at breast height (GBH) for all the trees on a plot. Trees that were dead, defective at GBH or possessing a broken top were not used in this study. Growth performance of each species in a particular agro-climatic region was assessed on the basis of measured mean height, mean collar girth and mean girth at breast height. A very high correlation (0.89) was obtained between height growth and girth growth for all the species, therefore height of the trees has been taken as growth performance variable in this study.

The data was statistically analysed using two way analysis of variance (ANOVA) for comparing the performance of species at the zone level with the assumption that growth performance is dependent on two source of variations i.e. species and growth period in a given region. The growth periods were 2, 3, 4, 5, 6 and 7 years depending upon the year of creation of the plantation i.e 2002 to 2007 with survey year being 2009. The mean height of the trees of each species per site was used as the dependent variable, whereas the species and plantation age in years as the independent variable responsible for the height growth. The analysis of Variance (ANOVA) for two way classifications was calculated using statistical software SPSS for different regions which shows the significance and / or non significance of the difference in mean of growth parameters.

Result and Discussions

Based on the survey done in 2009 for the plantation years between 2002 to 2007, in all three agro-climatic subzones of state; a total of 540 sites were randomly selected proportionately distributed on the basis of total plantation area in each administrative district in all zones. Within each selected sites, 10 random plots of size 0.1 hectare square were laid. A total of 1,114,515 trees were surveyed and measurements were taken with 61.78%, 29.71% and 8.49% of trees from subzones IV, V and VI, respectively.

The distribution of forest tree species was skewed in all the zones. In subzone IV, maximum plantation was of *Acacia auriculiformis* species (48.57%) followed by *Cassia siamea* (15.02%), *Acacia catechu* (8.85%), *Dalbergia sissoo* (7.57%), *Embellica officinalis* (4.24%), *Tectona grandis* (2.25%), bamboo species (2.17%), *Pongamia pinnata* (1.56%). In subzone V, the planted species composition is different from subzone V with *Dalbergia sissoo* species (19.26%), *Gmelina arborea* (17.01%), *Acacia catechu* (14.58%), *Cassia siamea* (13.24), *Acacia auriculiformis* (8.42%), Bamboo species (4.63%), *Tectona grandis* (4.51%), *Melia azedarach* (2.44%), *Haplophragma adenophyllum* (2.24%), *Butea monosperma* (2.05%). The composition of planted species in subzone VI is quite different from subzone IV and V with *Acacia auriculiformis* (36.76%), *Anacardium occidentale* (14.40%), *Tectona grandis* (13.23%), *Cassia siamea* (8.10%), *Terminalia arjuna* (6.40%), bamboo species (3.36%), *Astonia scholaris* (3.24%), *Gmelina arborea* (2.29%), *Pongamia pinnata* (1.83%), *Melia azedarach* (1.82%).

The descriptive statistics of growth parameters of timber species were calculated using the survey data and are presented as average height (Ht) with standard error (SE) of tree species along with mean of collar girth (CG) and girth at breast height (GBH) in Annexure I. They represent the indicative growth of different species at different ages, though from different sites in an agro-climatic zone. The standard error explains the variation in plantation sites which are very small in most of the cases. The growth graphs and growth equations for *Acacia auriculiformis, Cassia siamea, Dalbergia sisoo, Melia azedarach, Gmelina arborea,* and *Tectona grandis* are presented as Annexure II.

The comparison of tree growth of prominent species along with years of plantation (age) was done in three different zones of the state, which are explained in the following two way ANOVA Tables 1, 2 and 3. It was observed that growth of different tree species in subzone IV and subzone V are statistically significant whereas in the third zone, the growth are statistically non significant. After performing Tukey analysis, it was found that species *Cassia siamea* and *Gmelina arborea* are statistically significant (critical difference value of 1.90) from other species like *Melia azedarach*, *Acacia auriculiformis*, *Acacia catechu*, *Tectona grandis* etc. in subzone IV and almost same pattern is followed in Subzone V with grouping of *Gmelina arborea, Acacia catechu* and *Melia azedarach* together followed by grouping of *Melia azedarach, Cassia siamea, Acacia auriculiformis, Tectona grandis* with C.D value of 2.05. However, for subzone VI, species *Cassia siamea, Acacia auriculiformis,*

Table 1 : Analysis of Variance (ANOVA) for Agro-climatic Subzone IV of Zone VII

Source of variation	df	Sum of square	Mean sum of square	F Value	Pr > F
Species	9	86.12	9.57	3.64	0.0017*
Years	5	276.18	55.24	21.03	<.0001*
Error	45	118.19	2.63		
Total	59	480.48			

*Significant at 5%, R-square = 0.75

Table 2 : Analysis of Variance (ANOVA) for Agro-climatic Subzone V of Zone VII

Source of variation	df	Sum of square	Mean sum of square	F Value	Pr > F
Species	7	82.67	11.81	3.87	0.0032*
Years	5	292.06	58.41	19.15	<.0001*
Error	35	106.76	3.05		
Total	47	481.50			

*Significant at 5%, R-square = 0.79

Table 3 : Analysis of Variance (ANOVA) for Agro-climatic Subzone VI of Zone VII

Source of variation	df	Sum of square	Mean of sum of square	F Value	Pr>F
Species	4	12.53	3.13	1.69	0.191
Years	5	141.16	28.23	15.26	<.0001*
Error	20	36.99	1.85		
Total	29	190.68			

*Significant at 5%, R-square = 0.80

Table 4 : Subzone wise comparison of tree species

Species	F value (Sig. level of Zones)	CD Value	R Square
Acacia auriculiformis	29.32 (<.001)*	1.79	0.91
Cassia siamea	17.78 (0.001)*	2.03	0.91
Dalbergia sissoo	3.94 (0.055)**	3.73	0.75
Tectona grandis	7.70 (0.009)*	1.95	0.88
Gmelina arborea	0.26 (0.780)		0.75

*Significant at 5% **Significant at 10%

Tectona grandis and Dalbergia sissoo do not show significantly different growth performance in terms of their mean height with C.D. value of 1.63.

The growth of individual tree species, which was present in all the zones and available in different age group were compared (Table 4). The growth of *Acacia auriculiformis, Cassia siamea,* and *Tectona grandis,* species were statistically significant, however growth of *Dalbergia sissoo* and *Gmelina arborea* are statistically non-significant. The best performance of *Acacia auriculiformis* was in subzone IV with respect to subzone V and subzone VI. The performance of *Cassia siamea* and *Tectona grandis* are better in subzone IV and subzone VI as compared to subzone V. *Dalbergia sissoo* and *Gmelina arborea*'s growths are same in all the subzones of the state.

Conclusion

The growth performance studies based on agro-climatic conditions are only plausible options which can be utilized by tree growers to make choice of the species for future plantations and growth projections. As per the present study the choice of timber species in Jharkhand as a whole would revolve around *Acacia auriculiformis, Dalbergia sissoo, Tectona grandis* and *Gmelina arborea* since *Cassia siamea, Acacia catechu* and *Melia azedarach,* do not have comparable timber value in the market. *Gmelina arborea* and *Tectona grandis* were found to be most promising species. However, *Gmelina arborea* was found to be having lowest plantation density and problems with form. The growth parameters obtained for different timber species from this study may be treated as minimum expected growth performance of these species when planted on agricultural fallow lands since these forest plantations were undertaken in degraded forest sites and without much intensive management. It is also recommended that these study plots are converted into tree re-measurement plots.

झारखण्ड, भारत के विभिन्न कृषि-जलवायवीय क्षेत्र में वन रोपणों के तहत प्रकाष्ठ प्रजातियों का वृद्धि प्रदर्शन

मदन प्रसाद सिंह और संजय सिंह

सारांश

झारखण्ड में वन विभाग ने वन भूमियों में बड़े पैमाने पर रोपण किया है। मुख्यत: पर्यावरणीय लाभों के लिए वन भूमियों पर रोपित वृक्षों का प्रबंधन स्थानीय लोगों की आवश्यकताओं के अनुसार किया जा रहा है, जिनका इन वनों पर अधिकार है। इन रोपणों ने 2001 और 2011 के बीच 942 वर्ग कि.मी. वनावरण बढ़ाया है। क्षेत्र अवस्थाओं में प्रकाष्ठ प्रजातियों के वृद्धि प्रदर्शन का मूल्यांकन करने के लिए राज्य भर में सृजित इन रोपणों ने एक उत्कृष्ट सुअवसर उपलब्ध कराया है। इस शोध पत्र में झारखण्ड राज्य में विभिन्न कृषि जलवायवीय अवस्थाओं (उप क्षेत्रों अथवा क्षेत्रों) में रोपण वानिकी के तहत प्रकाष्ठ प्रजातियों का वृद्धि प्रदर्शन प्रस्तुत किया गया है। इन प्रजातियों के वृद्धि प्रदर्शन की वैज्ञानिक समझ, आर्थिक व्यवहार्यता साथ ही साथ पारिस्थितिकीय लाभों के लिए प्रजातियों के विभिन्न संयोजनों को खोजने में उद्यमियों एवं वन विभाग की सहायता करेंगी। झारखण्ड में निजी वानिकी के तहत वृक्षारोपण के लिए लगभग 2.5 मिलियन हैक्टेयर परती कृषि भूमि क्षेत्र उपलब्ध है। तथापि इस प्रकार की भूमियों पर वृक्ष खेती के लिए अन्य सहायक प्रणालियों में, प्रजातियों की पसन्द और प्रबंधन पद्धतियां वृक्ष उत्पादकों के लिए महत्वपूर्ण घटक हैं।

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Growth Statistics of Timber Species from subzones of Agro-climatic Zone VII Eastern Plateau and Hill Region in Jharkhand

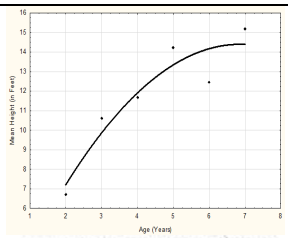
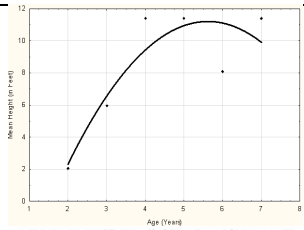
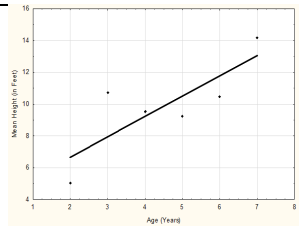
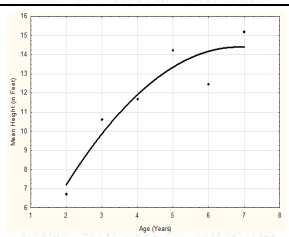
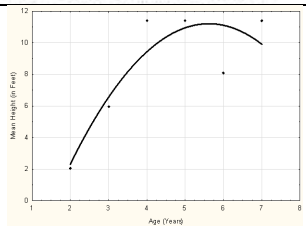
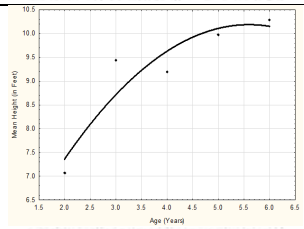
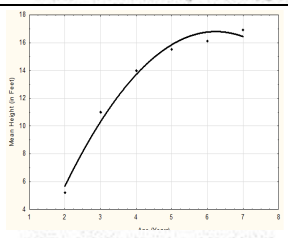
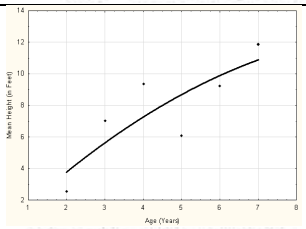
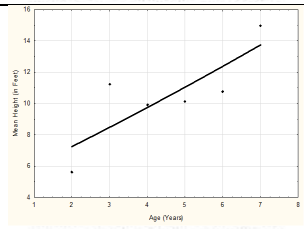
Annexure I

Species	Means	SubZone IV Central and North Eastern Plateau						SubZone V Western Plateau						SubZone VI South Eastern Plateau					
		Growth Period (in years)						Growth Period (in years)						Growth Period (in years)					
		2	3	4	5	6	7	2	3	4	5	6	7	2	3	4	5	6	7
Acacia auriculiformis	Ht. (±SE)	6.73 (±0.03)	10.62 (±0.02)	11.67 (±0.02)	14.22 (±0.04)	12.45 (±0.03)	15.18 (±0.04)	2.04 (±90.03)	5.95 (±0.09)	11.42 (±0.08)	11.4 (±0.1)	8.07 (±0.12)	11.4 (±0.08)	5.02	10.71 (±0.05)	9.54 (±0.04)	9.22 (±0.12)	10.48 (±0.11)	14.18 (±0.17)
	CG	4.13	7.29	7.95	9.96	8.4	10.31	1.38	6.15	10.19	10.12	8.39	9.8	4.17	10.62	8.54	6.95	8.04	13.99
	GBH	2.39	4.75	5.41	6.69	5.78	7.4	0	3.48	7.05	6.77	5.94	7.03	1.24	6.93	5.51	4.45	5.93	11.16
Acacia catechu	Ht (±SE)	6.62 (±0.07)	10.24 (±0.06)	10.78 (±0.05)	12.96 (±0.12)	12.13 (±0.07)	15.55 (±0.08)	7.35 (±0.1)	6.15 (±0.06)	9.99 (±0.1)	10.04 (±0.1)	10.29 (±0.09)	14.21 (±0.07)	-	7.27 (±0.74)	7.43 (±0.38)	-	10.55 (±0.43)	8 (0)
	CG	4.69	7.5	7.07	8.33	7.57	11.31	6.01	5.25	7.81	8.65	9.21	11.92	-	6	5.49	-	7.9	10
	GBH	2.18	4.85	4.59	5.25	5.49	8.17	4.27	3.28	6.07	6.55	6.99	9.84	-	2.43	3.61	-	5.75	8
Cassia siamea	Ht (±SE)	5.2 (±0.04)	11.02 (±0.05)	13.97 (±0.04)	15.54 (±0.05)	16.13 (±0.05)	16.89 (±0.05)	2.55 (±0.03)	7.04 (±0.06)	9.37 (±0.04)	6.07 (±0.13)	9.24 (±0.1)	11.86 (±0.07)	5.63 (±0.09)	11.23 (±0.11)	9.93 (±0.16)	10.11 (±0.13)	10.76 (±0.22)	14.99 (±0.15)
	CG	4.7	9.6	10.87	12.05	14.52	13.61	2.29	6.41	9.37	6.79	8.49	13.19	4.73	9.92	7.83	7.49	8.19	14.7
	GBH	1.85	5.99	7.24	8.17	10.55	9.62	0.35	4	5.93	5.46	5.69	9.55	2.18	6.52	5.2	5.06	5.95	11.78
Dalbergia sisoo	Ht (±SE)	4.13 (±0.05)	8.09 (±0.12)	14.15 (±0.07)	15.75 (±0.1)	18.02 (±0.08)	18.72 (±0.09)	6.4 (±0.07)	7.29 (±0.05)	11.89 (±0.09)	10.85 (±0.11)	11.37 (±0.1)	16.96 (±0.17)	7.74 (±0.15)	8.34 (± 0.37)	4.71 (±0.27)	6.54 (±0.19)	10.58 (±0.46)	12.73 (±0.43)
	CG	3.93	7.58	10.99	11.91	13.17	14.67	5.08	5.79	8.7	9.3	10.27	13.56	5.3	6.25	3.93	7.05	7.4	13
	GBH	1.62	4.17	7.1	8.15	9.29	10.55	3.29	4.1	6.65	7.39	7.3	10.83	3.18	4.35	1.71	3.95	5.24	10.37
Melia azedarach	Ht (±SE)	8.77 (±0.21)	8.77 (±0.21)	9.99 (±0.11)	15.1 (±0.12)	11.06 (±0.6)	15.3 (0.17)	4.91 (±0.08)	7.22 (±0.13)	9.82 (±0.1)	10.59 (±0.14)	9.54 (±0.09)	16 (±0.92)	5.48 (±0.18)	9.17 (± 0.27)	10.1 (±0.28)	11.32 (±0.29)	-	11.15 (±0.35)
	CG	8.45	8.45	8.88	9.86	8.05	12.12	4.18	5.53	8.9	9.18	8.89	12.54	4.07	7.17	7.47	8.42	-	9.97
	GBH	4.87	4.87	6.03	7.43	5.73	9.14	2.05	4.03	6.06	5.99	6.35	9.46	1.76	4.86	5.05	6.32	-	5.88
Gmelina arborea	Ht (±SE)	10.11 (±0.29)	10.11 (±0.29)	9.59 (±0.25)	12.02 (±0.17)	18.04 (±0.23)	20.02 (0.06)	3.54 (±0.03)	4.88 (±0.05)	9.95 (0±.09)	7.83 (±0.09)	15.6 (±0.12)	22 (±0.15)	7.11 (±0.19)	10.39 (±0.17)	11.16 (±0.2)	10.4 (±0.35)	-	11.63 (±0.63)
	CG	11	11	7.2	9.02	16.61	16.87	3.16	4.24	8.35	8.03	15.06	16.84	4.63	8.44	7.61	7.45	-	9.06
	GBH	7.03	7.03	4.9	6.62	12.38	16.87	0.98	2.33	6.02	5.91	12.11	12.88	2.82	4.84	5.12	5.13	-	5.38
Tectona grandis	Ht (±SE)	3.93 (±0.1)	11.44 (±0.06)	11.76 (±0.27)	12.55 (±0.2)	10.47 (±0.12)	8.92 (±0.2)	3.45 (0.05)	7.29 (±0.04)	9.25 (±0.14)	3.49 (±0.09)	8.38 (±0.12)	9.14 (±0.06)	6.5 (±0.1)	9.42 (±0.11)	8.41 (±0.2)	9.79 (±0.1)	11.58 (±0.13)	12.43 (±0.08)
	CG	3.61	9.89	8.74	9.21	8.1	7.95	2.86	9.2	6.92	3.94	7.03	6.54	4.59	7.25	5.98	7.19	8.59	10.14
	GBH	0.94	5.6	5.9	6.27	5.32	4.65	0.68	5.65	5.22	2.23	4.74	4.56	2.48	4.42	3.83	5.01	6.26	6.51
Bombax ceiba	Ht (±SE)	3.96 (±0.2)	7.57 (±0.41)	8	13.25 (±0.38)	17.14 (±3.47)	12.93 (±0.71)	3.17 (±0.09)	8.54 (0.1)	-	5.67 (±0.26)	7.94 (±0.42)	9.1 (±0.52)	-	-	-	10.42 (±0.56)	-	-
	CG	3.09	7.23	5	10.25	11.21	11.59	2.32	7	-	4.58	7.33	8.75	-	-	-	7.52	-	-
	GBH	1.11	3.91	2	7.9	7.86	8.52	0.99	5.6	-	3.17	5.14	6.2	-	-	-	5.48	-	-
Haplophram gaadenophyllum	Ht (±SE)	8.97 (±0.22)	14.02 (±0.25)	7.33 (±1.76)	11.94 (±0.34)	8.14 (±0.15)	-	3.79 (±0.17)	-	8.4 (±0.1)	11.85 (±0.24)	12.85 (±0.3)	8.8 (±0.2)	2.82 (±0.09)	-	6.25 (±1.03)	10.42 (±0.58)	-	-
	CG	5.86	10.25	3.67	8.71	5.46	-	2.71	-	6.62	9.83	10.79	6.75	2.95	-	4.75	7.79	-	-
	GBH	3.78	6.74	1.67	6.73	3.41	-	0.82	-	4.6	8.15	8.98	4.29	0	-	2.75	5.52	-	-
Ailanthus excelsa	Ht (±SE)	5.3 (±0.26)	6.17 (±0.09)	10.64 (±0.23)	10.4 (±0.36)	12.61 (±0.31)	-	-	-	10.44 (±0.07)	11.12 (±0.13)	-	9.96 (±0.06)	-	11.7 (±0.67)	3.92 (±0.38)	9.5 (±0.56)	-	-
	CG	3.61	4.46	7.11	6.69	7.11	-	-	-	9.78	10	-	9.96	-	10.5	3.5	6.83	-	-
	GBH	1.96	3.22	4.82	4.46	5.51	-	-	-	6.85	6.16	-	5.64	-	7.2	0.92	4.67	-	-
Eucalyptus	Ht (±SE)	-	-	-	4.1 (±0.28)	17.59 (±0.45)	15.53 (±1.03)	-	3.33 (±0.05)	9.03 (±0.08)	-	10.85 (±0.2)	13.41 (±0.35)	-	-	-	5.46 (±0.2)	-	-
	CG	-	-	-	2.48	14.18	13.03	-	4.66	8.34	-	12.71	9.63	-	-	-	4.17	-	-
	GBH	-	-	-	2.19	9.98	10.97	-	2.26	6.66	-	10.06	7.53	-	-	-	2.03	-	-

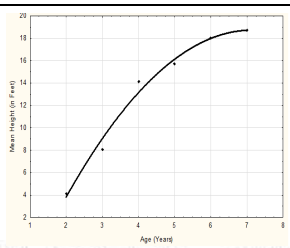
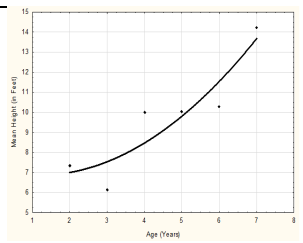
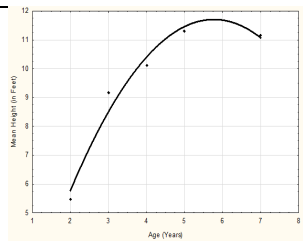
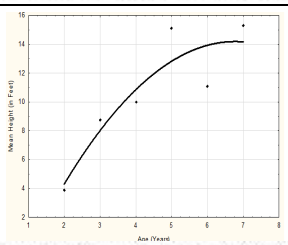
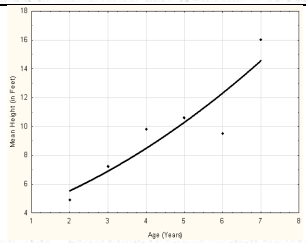
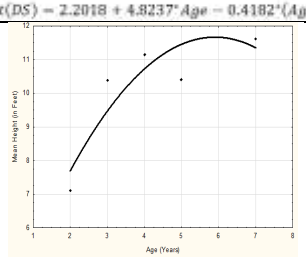
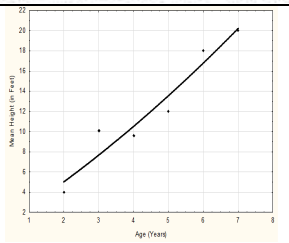
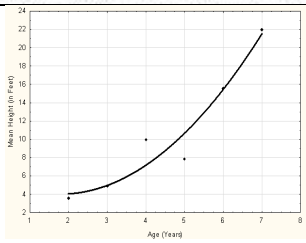
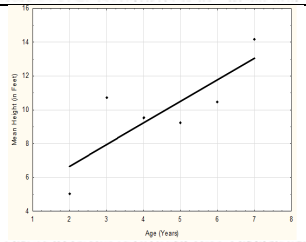
SE: Standard error; Ht: Average height of trees in feet; CG: Average collar girth of tree; GBH: Average girth at breast height of tree

Annexure II

Growth Graphs and equations of Timber Species from subzones of Agro-climatic Zone VII Eastern Plateau and Hill Region in Jharkhand

Subzone IV	Subzone V	Subzone VI
		
$Ht(AA) = 0.0555 + 4.1024^{*}Age - 0.3049^{*}(Age)^{2}$	$Ht(AA) = -10.2552 + 7.6439^{*}Age - 0.6885^{*}(Age)^{2}$	$Ht(AA) = 4.0281 + 1.3176^{*}Age - 0.0042^{*}(Age)^{2}$
		
$Ht(TG) = 0.0555 + 4.1024^{*}Age - 0.3049^{*}(Age)^{2}$	$Ht(TG) = -10.2552 + 7.6439^{*}Age + 0.6885^{*}(Age)^{2}$	$Ht(TG) = 3.3394 + 2.4462^{*}Age - 0.2185^{*}(Age)^{2}$
		
$Ht(CS) = 0.0555 + 4.1024^{*}Age - 0.3049^{*}(Age)^{2}$	$Ht(CS) = -0.5747 + 2.3881^{*}Age - 0.1072^{*}(Age)^{2}$	$Ht(AA) = 4.0795 + 1.1484^{*}Age - 0.017^{*}(Age)^{2}$

AA: *Acacia auriculiformis*, CC : *Cassia siamea*, DS: *Dalbergia sisoo*, MA: *Melia azedarach*, GA *Gmelina arborea*, TG: *Tectona grandis*

		
$Ht(DS) = 10.0148 + 8.0397^{*}Age - 0.562^{*}(Age)^{2}$	$Ht(DS) = 4.7974 + 0.6684^{*}Age + 0.129^{*}(Age)^{2}$	$Ht(DS) = 2.2018 + 4.8237^{*}Age - 0.4182^{*}(Age)^{2}$
		
$Ht(MA) = 5.7015 + 5.8739^{*}Age - 0.4336^{*}(Age)^{2}$	$Ht(MA) = 3.4675 + 0.8141^{*}Age + 0.11^{*}(Age)^{2}$	$Ht(MA) = 2.5656 + 3.0853^{*}Age - 0.2614^{*}(Age)^{2}$
		
$Ht(GA) = 0.3.091 + 2.161^{*}Age + 0.0976^{*}(Age)^{2}$	$Ht(GA) = 6.0761 - 2.3053^{*}Age + 0.6446^{*}(Age)^{2}$	$Ht(GA) = 4.0281 + 1.3176^{*}Age - 0.0042^{*}(Age)^{2}$

AA: *Acacia auriculiformis*, CC : *Cassia siamea*, DS: *Dalbergia sisoo*, MA: *Melia azedarach*, GA : *Gmelina arborea*, TG: *Tectona grandis*