Online ISSN: 2249-4626
Print ISSN: 0975-5896

Global Journals

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- Foliar Diseases of Cotton
- Tree Species in Drylands
- Rural Farming Households
- Growth Curve Modelling

Discovering Thoughts, Inventing Future

VOLUME 13 ISSUE 1 VERSION 1.0

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Global Journal of Science Frontier Research: D
Agriculture & Veterinary Sciences

Global Journal of Science Frontier Research: D
Agriculture & Veterinary Sciences
Volume 13 Issue 1 (Ver. 1.0)

Open Association of Research Society

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Contents of the Volume

i. Copyright Notice
ii. Editorial Board Members
iii. Chief Author and Dean
iv. Table of Contents
v. From the Chief Editor's Desk
vi. Research and Review Papers

1. Chemical and Biological Management of Major Foliar Diseases of Cotton. *1-4*
2. Assessing Climate Risk to Improve Incomes of Rural Farming Households in the Caprivi Region, Namibia. *5-10*
3. Height-Age Growth Curve Modelling for Different Tree Species in Drylands of North Karnataka. *11-21*
4. Diameter-Age Growth Curve Modelling for Different Tree Species in Drylands of North Karnataka. *23-33*

vii. Auxiliary Memberships
viii. Process of Submission of Research Paper
ix. Preferred Author Guidelines
x. Index

Global Journal of Science Frontier Research
Agriculture and Veterinary Sciences
Volume 13 Issue 1 Version 1.0 Year 2013
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Chemical and Biological Management of Major Foliar Diseases of Cotton

By S. N. Chattannavar, G. N. Hosagoudar & S. A. Ashtaputre

Agricultural Research Station

Abstract - A field experiment was conducted during *kharif* 2006-07 and 2007-08 at Agricultural Research Station, Dharwad Farm to evaluation of fungicides, Taqat 500g/ha, Taqat 750g/ha and propiconazole @ 0.1 per cent were effective in controlling the foliar diseases. Maximum yield of 2287.45 kg per hactare was recorded in Taqat 750g/ha. Seed treatment with *P. fluorescens* @ 10 g per kg + foliar spray @ 0.2 per cent on 30, 40, 50, 60, 70, 80 and 90 DAS, seed treatment with *P. fluorescens* @ 10 g per kg + foliar spray @ 0.2 per cent on 30, 50, 70 and 90 DAS, seed treatment with *P. fluorescens* @ 10 g per kg + foliar spray @ 0.2 per cent on 30, 60 and 90 DAS, Copper oxychloride (0.3%) + Streptocycline Sulphate (0.05%) gave better control of the foliar diseases than fungicidal treatments. Maximum yield of 2227.27 kg per hactare was recorded in the seed treatment with *P. fluorescens* @ 10 g per kg + foliar spray @ 0.2 per cent on 30, 40, 50, 60, 70, 80 and 90 DAS and was significantly higher over the control.

Keywords : cotton diseases, management, fungicides, bioagents.

GJSFR-D Classification : FOR Code: 820301, 070199

CHEMICAL AND BIOLOGICAL MANAGEMENT OF MAJOR FOLIAR DISEASES OF COTTON

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Chemical and Biological Management of Major Foliar Diseases of Cotton

S. N. Chattannavar [α], G. N. Hosagoudar [σ] & S. A. Ashtaputre [ρ]

Abstract - A field experiment was conducted during *kharif* 2006-07 and 2007-08 at Agricultural Research Station, Dharwad Farm to evaluation of fungicides, Taqat 500g/ha, Taqat 750g/ha and propiconazole @ 0.1 per cent were effective in controlling the foliar diseases. Maximum yield of 2287.45 kg per hactare was recorded in Taqat 750g/ha. Seed treatment with *P. fluorescens* @ 10 g per kg + foliar spray @ 0.2 per cent on 30, 40, 50, 60, 70, 80 and 90 DAS, seed treatment with *P. fluorescens* @ 10 g per kg + foliar spray @ 0.2 per cent on 30, 50, 70 and 90 DAS, seed treatment with *P. fluorescens* @ 10 g per kg + foliar spray @ 0.2 per cent on 30, 60 and 90 DAS, Copper oxychloride (0.3%) + Streptocycline Sulphate (0.05%) gave better control of the foliar diseases than fungicidal treatments. Maximum yield of 2227.27 kg per hactare was recorded in the seed treatment with *P. fluorescens* @ 10 g per kg + foliar spray @ 0.2 per cent on 30, 40, 50, 60, 70, 80 and 90 DAS and was significantly higher over the control.

Keywords : cotton diseases, management, fungicides, bioagents.

I. Introduction

Cotton, "The White Gold" or the "King of Fibres" enjoys a pre-eminent status among all cash crops in the country and is the principal raw material for flourishing textile industry. India now produces around 290.00 lakh bales of cotton ranging from short staple to extra long staple from an area of 93.73 lakh hectares with productivity of 526 kg per hectare (Anon., 2009). In Karnataka, the area under cotton cultivation is 3.90 lakh hectares with a production of 9.00 lakh bales and an average productivity of 392 kg per hectare (Anon., 2009).

However, the production potential of the crop has not been fully exploited due to several biotic and abiotic factors. The crop suffers from many fungal diseases, of which foliar diseases take a heavy toll. Among the foliar diseases Grey mildew (*Ramularia areola*), Alternaria blight (*Alternaria macrospora*) and Bacterial blight (*Xanthomonas axonopodis pv. malvacearum)* are the important ones. The use of fungicides has become inevitable in controlling the foliar diseases in the absence of suitable resistant cultivars. In view of these fungicides need to be evaluated for their efficacy against the foliar diseases in field conditions.

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II. Material and Methods

A field experiment was conducted during *kharif* 2006-07 and 2007-08 at Agricultural Research Station, Dharwad Farm under rainfed conditions. A randomized block design (RBD) with four treatments replicated five times with a plot size of 5.4 x 4.5 m was adopted. The Abhadita variety was sown during third week of June with a spacing of 90 x 30 cm. The fungicides Taqat (500 g/ha and 750 g/ha) and Propiconazole (0.1%) were sprayed thrice at an interval of 15 days starting from the initial appearance of the disease. Untreated plot was maintained as control. Disease grading was done using 0-4 scale (Sheo Raj, 1988). Percent disease incidence was calculated using Wheeler`s formula (1969) and finally per cent disease control was calculated. Yield was recorded in each treatment.

The experiment on biocontrol of foliar diseases was conducted during *kharif* 2006-07 and 2007-08 at Agricultural Research Station, Dharwad Farm under rainfed conditions in randomized block design (RBD) with five treatments replicated four times with a plot size of 5.4 x 4.5 m. The Abhadita variety was sown during *kharif* 2006-07 and 2007-08 with a spacing of 90 x 30 cm. The different treatments were: Seed treatment with *Pseudomonas fluorescens* @ 10 g/kg seeds + foliar spray @ 0.2 per cent with interval of 10 days i e 30, 40, 50, 60, 70, 80 and 90 DAS, seed treatment with *P. fluorescens* @ 10 g/kg seeds + foliar spray @ 0.2 per cent with interval of 20 days i e 30, 50, 70 and 90 DAS, seed treatment with *P. fluorescens* @ 10 g/kg seeds + foliar spray @ 0.2 per cent with interval of 30 days i e 30, 60 and 90 DAS, and Copper-oxychloride (0.3%) + Streptocycline Sulphate (0.05%). Untreated plot was maintained without spray. Disease grading was done using 0-4 scale (Sheo Raj, 1988). Per cent disease incidence was calculated using Wheeler`s formula (1969) and finally per cent disease control was calculated. Yield was recorded in each treatment.

III. Results and Discussion

Taqat 750g/ha treatment resulted significantly low Alternaria blight per cent disease index (26.32 PDI) followed by propiconazole (26.49 PDI) while Taqat 500 g/ha (27.36 PDI) was least effective. The three treatments of fungicides tested significantly reduced the maximum per cent disease over control. Taqat 750g/ha

Global Journal of Science Frontier Research (D) Volume XIII Issue I Version I Year 2013

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(23.11 PDC) was followed by propiconazole 0.1 per cent (22.61 PDC) and Taqat 500 g/ha (20.07 PDC). (Table 1).

Taqat 750g/ha recorded significantly low Grey mildew per cent disease index (22.36 PDI) followed by propiconazole 0.1 per cent (22.99 PDI) while Taqat 500 g/ha (24.44 PDI) was least effective. The three treatments of fungicides tested significantly reduced the maximum per cent disease over control in case of Taqat 750g/ha (26.08 PDC) followed by propiconazole 0.1 per cent (24.00 PDC) and Taqat 500 g/ha (19.21 PDC). These results are in conformity with the reports of Chattannavar *et al.* (2000a, 2006).

The kapas yield variation among the treatments was non-significant. However, the maximum yield of 2287.45 kg per ha was recorded in Taqat 750g/ha followed by propiconazole 0.1 per cent (2167.48 kg/ha) and Taqat 500 g/ha (2111.28 kg/ha).

Seed treatment with *P. fluorescens* @ 10 g per kg seeds + foliar spray @ 0.2 per cent on 30, 40, 50, 60, 70, 80 and 90 DAS recorded significantly low Alternaria blight with per cent disease index was 23.89 PDI followed by seed treatment with *P. fluorescens* @ 10 g per kg seeds + foliar spray @ 0.2 per cent on 30, 50, 70 and 90 DAS (24.93 PDI), seed treatment with *P. fluorescens* @ 10 g per kg seeds + foliar spray @ 0.2 per cent on 30, 60 and 90 DAS (26.62 PDI) and Copper-oxychloride 0.3 per cent + Streptocycline Sulphate 0.05 per cent (26.13 PDI) were least effective. Seed treatment with *P. fluorescens* @ 10 g per kg seeds + foliar spray @ 0.2 per cent on 30, 40, 50, 60, 70, 80 and 90 DAS showed maximum per cent disease over control of 19.67 PDC followed by seed treatment with *P. fluorescens* @ 10 g per kg seeds + foliar spray @ 0.2 per cent on 30, 50, 70 and 90 DAS (16.17 PDC), Copper oxy-chloride (0.3%) + Streptocycline Sulphate (0.05%) (12.14 PDC) and seed treatment with *P. fluorescens* @ 10 g per kg seeds + foliar spray @ 0.2 per cent on 30, 60 and 90 DAS (10.49 PDC).

Seed treatment with *P. fluorescens* @ 10 g per kg seeds + foliar spray @ 0.2 per cent on 30, 40, 50, 60, 70, 80 and 90 DAS recorded significantly low Bacterial blight per cent disease index (23.61 PDI) followed by seed treatment with *P. fluorescens* @ 10 g per kg seeds + foliar spray @ 0.2 per cent on 30, 50, 70 and 90 DAS (25.21 PDI), seed treatment with *P. fluorescens* @ 10 g per kg seeds + foliar spray @ 0.2 per cent on 30, 60 and 90 DAS (26.09 PDI) and Copper-oxychloride 0.3 per cent + Streptocycline Sulphate 0.05 per cent (24.02 PDI) were least effective. Seed treatment with foliar spray of *P. fluorescens* on 30, 40, 50, 60, 70, 80 and 90 DAS treatment showed maximum per cent disease over control of 19.77 PDC followed by Copper-oxychloride 0.3 per cent + Streptocycline Sulphate 0.05 per cent (18.38 PDC), seed treatment with *P. fluorescens* @ 10 g per kg seeds + foliar spray @ 0.2 per cent on 30, 50, 70 and 90 DAS (14.33 PDC) and seed treatment with *P. fluorescens* @ 10 g per kg seeds + foliar spray @ 0.2 per cent on 30, 60 and 90 DAS (11.34 PDC).

Seed treatment with *Pseudomonas fluorescens* @ 10 g per kg seeds + foliar spray @ 0.2 per cent on 30, 40, 50, 60, 70, 80 and 90 DAS treatment recorded significantly low Grey mildew per cent disease index (19.46 PDI) followed by seed treatment with *P. fluorescens* @ 10 g per kg seeds + foliar spray @ 0.2 per cent on 30, 50, 70 and 90 DAS (20.41 PDI), seed treatment with *P. fluorescens* @ 10 g per kg seeds + foliar spray @ 0.2 per cent on 30, 60 and 90 DAS (21.95 PDI) and Copper-oxychloride 0.3 per cent + Streptocycline Sulphate 0.05 per cent (21.72 PDI) were least effective. Seed treatment with *P. fluorescens* @ 10 g per kg seeds + foliar spray @ 0.2 per cent on 30, 40, 50, 60, 70, 80 and 90 DAS showed maximum percent disease over control of 24.19 PDC followed by seed treatment with *P. fluorescens* @ 10 g per kg seeds + foliar spray @ 0.2 per cent on 30, 50, 70 and 90 DAS (20.49 PDC), seed treatment with *P. fluorescens* @ 10 g per kg seeds + foliar spray @ 0.2 per cent on 30, 60 and 90 DAS (14.49 PDC) and Copper-oxychloride 0.3 per cent + Streptocycline Sulphate 0.05 per cent (15.38 PDC).

The kapas yield obtained from different treatments was significant. The maximum yield (2227.27 kg/ha) was recorded in seed treatment with *P. fluorescens* with foliar spray on 30, 40, 50, 60, 70, 80 and 90 DAS treatment followed by seed treatment with *P. fluorescens* @ 10 g per kg seeds + foliar spray @ 0.2 per cent on 30, 50, 70 and 90 DAS (2197.40 kg/ha) treatment followed by Copper-oxychloride 0.3 per cent + Streptocycline Sulphate 0.05 per cent (2031.07 kg/ha) and seed treatment with *P. fluorescens* @ 10 g per kg seeds + foliar spray @ 0.2 per cent on 30, 60 and 90 DAS (1929.30 kg/ha) (Table 2). The treatment of *P. fluorescens* gave 40.36 per cent disease over control of Alternaria blight, 33.82 per cent disease over control of Bacterial blight and Grey mildew by 42.60 per cent disease over control (Chattannavar *et al.* 2000b).

Under field evaluation of fungicides and bioagents. Among the fungicides Taqat 750g/ha was effective in controlling the foliar diseases and the maximum yield of 2287.45 kg per hectare. Among the bioagents the seed treatment with *P. fluorescens* @ 10 g per kg + foliar spray @ 0.2 per cent on 30, 40, 50, 60, 70, 80 and 90 DAS gave better control of the foliar diseases than fungicidal treatments and the maximum yield of 2227.27 kg per hectare.

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Table 1 : Management of foliar diseases through chemicals during 2006-07 and 07-08

Sl. No	Treatments	AB PDI		Mean	PDC	GM PDI		Mean	PDC	Pooled Yield (kg/ha)
		90 DAS**	120 DAS**			90 DAS**	120 DAS**			
T_1	Taqat 500 g/ha	25.18 (30.13)*	29.54 (32.90)	27.36	20.07	22.12 (28.04)	26.77 (31.18)	24.44	19.21	2111.28
T_2	Taqat 750 g/ha	24.60 (29.73)	28.04 (31.95)	26.32	23.11	20.34 (26.78)	24.38 (29.60)	22.36	26.08	2287.45
T_3	Propiconazole (0.1%)	24.66 (29.80)	28.32 (32.14)	26.49	22.61	20.66 (27.06)	25.32 (30.20)	22.99	24.00	2167.48
T_4	Control	34.19 (35.79)	34.28 (35.85)	34.23	-	27.73 (31.76)	32.77 (34.94)	30.25	-	2093.39
	SE m±	1.451	0.496			0.817	0.692			100.222
	CD at 5%	4.472	1.529			2.516	2.134			NS

**Days after sowing

PDI: Per cent disease index GM: Grey mildew

PDC: Per cent disease over control AB: Alternaria blight

* Figures in parentheses indicate angular transformed values.

Table 2 : Evaluation of *Pseudomonas. Fluorescens* against major foliar diseases of cotton - (pooled data of 2006-07 and 07-08)

Sl. No	Treatments	AB PDI		Mean	PDC	BB PDI		Mean	PDC	GM PDI		Mean	PDC	Pooled Yield (kg/ha)
		90 DAS**	120 DAS**			90 DAS**	120 DAS**			90 DAS**	120 DAS**			
T_1	Seed treatment with *P. fluorescens* @ 10 g/kg seed + foliar spray @ 0.2% on 30,40,50,60,70,80 and 90 DAS **	20.73 (27.06)	27.06 (31.37)	23.89	19.67	18.3 (25.33)	28.93 (32.52)	23.61	19.77	16.04 (23.58)	22.88 (28.59)	19.46	24.19	2227.27
T_2	Seed treatment with *P. fluorescens* @ 10 g/kg seed + foliar spray @ 0.2% on 30,50,70 and 90 DAS **	21.62 (27.69)	28.25 (32.08)	24.93	16.17	20.45 (26.85)	29.98 (33.21)	25.21	14.33	17.60 (24.80)	23.22 (28.79)	20.41	20.49	2197.40
T_3	Seed treatment with *P. fluorescens* @ 10 g/kg seed + foliar spray @ 0.2% on 30,60 and 90 DAS**	24.91 (29.93)	28.33 (32.14)	26.62	10.49	22.34 (28.18)	29.84 (33.09)	26.09	11.34	18.7 (25.62)	25.21 (30.13)	21.95	14.49	1929.30
T_4	Copperoxychloride 0.3% + Streptocyclin Sulphate0.05%	23.68 (29.13)	28.58 (32.33)	26.13	12.14	18.98 (25.85)	29.06 (32.65)	24.02	18.38	20.06 (26.64)	23.39 (28.93)	21.72	15.38	2031.07

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T_5	Control	29.84 (33.09)	29.65 (32.96)	29.74	-	27.40 (31.56)	31.46 (34.14)	29.43	-	23.4 (28.93)	27.95 (31.88)	25.67	-	1718.06
	SE m±	0.273	0.366			0.366	0.555			0.423	0.448			48.349
	CD at 5%	0.841	1.129			1.128	1.711			1.303	1.381			148.979

**Days after sowing

PDI: Per cent disease index

PDC: Per cent disease over control

GM: Grey mildew

AB: Alternaria blight

BB: Bacterial blight

* Figures in parentheses indicate angular transformed values.

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Global Journal of Science Frontier Research
Agriculture and Veterinary Sciences
Volume 13 Issue 1 Version 1.0 Year 2013
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Assessing Climate Risk to Improve Incomes of Rural Farming Households in the Caprivi Region, Namibia

By J.M. Nyambe & A. Belete
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Abstract - While the scientific world blames the severity of climate risk factors on climate change, the assessment of its effects on a rural household remains understudied. The objective of this study is to assess climate risk factors on rural households that practices small-scale agriculture with the aim of improving the incomes of farming households. The paper used cross-sectional data from a sample of 253 respondents who represented households that were based in the flood prone areas of the Caprivi region. Invoking a multivariate regression model revealed that climate risk factors especially flood exacerbates the opportunity cost for obtaining a good harvest and thus exposed farming households to income risk and food insecurity. In view of these findings, old age pension and retirement annuities, the value of livestock and that of food aid proved vital to the income and food security needs of rural households in the study area. Investing in early warning systems and publicizing likely climate risk scenarios may be helpful to rural households in preparing to secure their income sources and thus reducing chances of hunger.

Keywords : climate risk, income risk, yield risk, price risk, climate change, food security.

GJSFR-D Classification : FOR Code: 920406

ASSESSING CLIMATE RISK TO IMPROVE INCOMES OF RURAL FARMING HOUSEHOLDS IN THE CAPRIVI REGION, NAMIBIA

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Assessing Climate Risk to Improve Incomes of Rural Farming Households in the Caprivi Region, Namibia

J.M. Nyambe [α] & A. Belete [σ]

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I. Introduction

Globally, climate variability has become common. In Namibia in general and in the Caprivi region in particular, climate risk factors especially flood is problematic. Although flood and drought are the usual climate risk factors that often affect the Caprivi region, flood is frequent than drought. The frequency and the degree to which flood affects rural households in the Caprivi region reflects how critical it has become on the incomes of those who rely on agriculture for food and income generation. Other regions of Namibia such as Kavango, Ohangwena, Omusati, Oshana and Oshikoto also suffer from annual flood and sporadic droughts but the frequency and the severity of flood as dating back to long historical times shows how serious flood can be in the Caprivi region. This makes the Caprivi region the most historically prone region to flood risk.

Elsewhere, climate change has been recorded as a serious concern in the human security stream. This has to do with the added effect of conflicts arising from disputes over natural resources that are depleting across Africa (Carius, 2009). It further presents a dire to the agricultural sector and the natural environment with regards to long term consequences. Since Africa is known for high poverty incidents, Hansen et al. (2007) suggest that while seeking to address persistent poverty, there is a need to adopt effective and innovative management practices to deal with climate risk. Innovative ways includes sharing climate information and introducing technology and policies that reduces risks. Climate shocks have both ex ante and post ante consequences. Ex ante ones includes losses and damages to agricultural enterprises and infrastructure while post ante refers to the opportunity cost that is associated with conservation strategies. The absence of insurance policies for rural agricultural enterprises is also a drawback to protecting rural livelihoods. Without insurance against losses to rural agricultural enterprises, rural communities would easily face long-term consequences to their livelihoods (Hansen et al., 2007). Taking up insurance is in line with concave utility and risk aversion principles (Kent, 2004). Risk in agriculture can reduce both farm yield and efficiency with a resultant effect of lowering incomes of farming rural households and exposing them to food insecurity. Low farm commodity prices also cause income risk (Macdonal, 2006).

In seeking to improve rural household incomes from a process of managing climate risks, it should be understood that it can be cumbersome. There are complexities as well to the process given the severe variability of climate risk. As a result George et al. (2005) suggests the need for understanding the extent to which climate risk varies, accuracy of climate forecasting, characterising events of dry periods, and understanding issues surrounding climate change. Characterising climate risk factors and offering reliable advice can benefit farmers (George, et al., 2005). So far, very little is reported on climate forecasting in Africa as compared to early warnings in developed countries. Although climate forecasting is imperative in the assessment of economic consequences, it remains an unpopular undertaking with regards to its use in African countries (Arndt and Bacou, 2000).

For the rural setup, formal jobs are scarce and as it is the case in the Caprivi region, formal jobs are confined to the urban centre at Katima Mulilo. This leaves rural job hunters to search for informal jobs,

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which in most cases offers less income benefits compared to in-kind food rewards. By default, this creates sectoral labour-attachment in favouring agriculture as the most attractive sector in the rural areas when it comes to providing employment opportunities. Similarly to this view there is confirmation in a study that was conducted in Slovenia by Bojnec and Dries (2005) in which they found that market liberalization ushered in the opportunity for agriculture to become the mainstay of employment creation in rural areas compared to other sectors.

In the milieu of frequent annual floods, rural farmers in the Caprivi region continue to record poor harvests. This scenario imbeds a negative prospect on the income generating opportunities. Intriguing to the conundrum of declining agricultural output and livelihoods in general is that no empirical study has so far attempted to assess the effects of climate risk in the context of seeking to improve incomes of rural farming households in the study area.

II. Materials and Methods

a) *The study site*

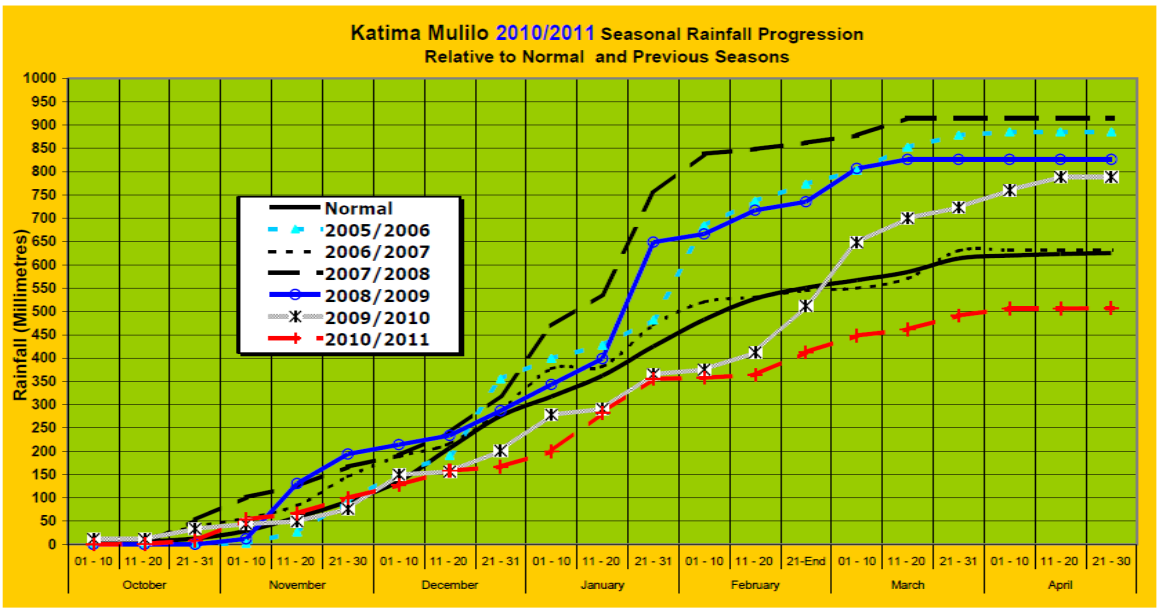
The Caprivi region is situated in the eastern part of Namibia. Namibia has a human population size of 2 104 900 million. Out of this, the population the Caprivi region accounts for is 90 100 (National Planning Commission, 2011). On climatological metrics, the Caprivi region receives an average annual rainfall of 653 mm (Ministry of Works and Transport, 2011; Samsamwater, 2011).

b) *Data gathering process*

The period which this paper focusses on is the 2002/3 to 2007/8 cultivation and harvesting seasons. As the time series data is scanty and at times non-existent, cross sectional data was gathered using a structured questionnaire. The population is that of rural dwellers in the flood plains from which a sample of 253 respondents was drawn from. The respondents were randomly sampled using multi-stage cluster sampling approach. Three constituencies from where the randomly selected households were obtained are: Kabbe, Katima Rural and Linyanti.

c) *Conceptual framework*

Before going deeper into methodological technicalities, the environment in which rural farming households exist first needs to be reflected here. The reflection will take the form of presenting the context of a conceptual framework.



Source : Ministry of Works and Transport (2011)

Figure 1 : Rainfall records for Katima Mulilo for the period 2005 to 2011

For the planting seasons of 2002 to 2007, the rainfall pattern escalated above the average annual record notwithstanding the recorded figures below the average.

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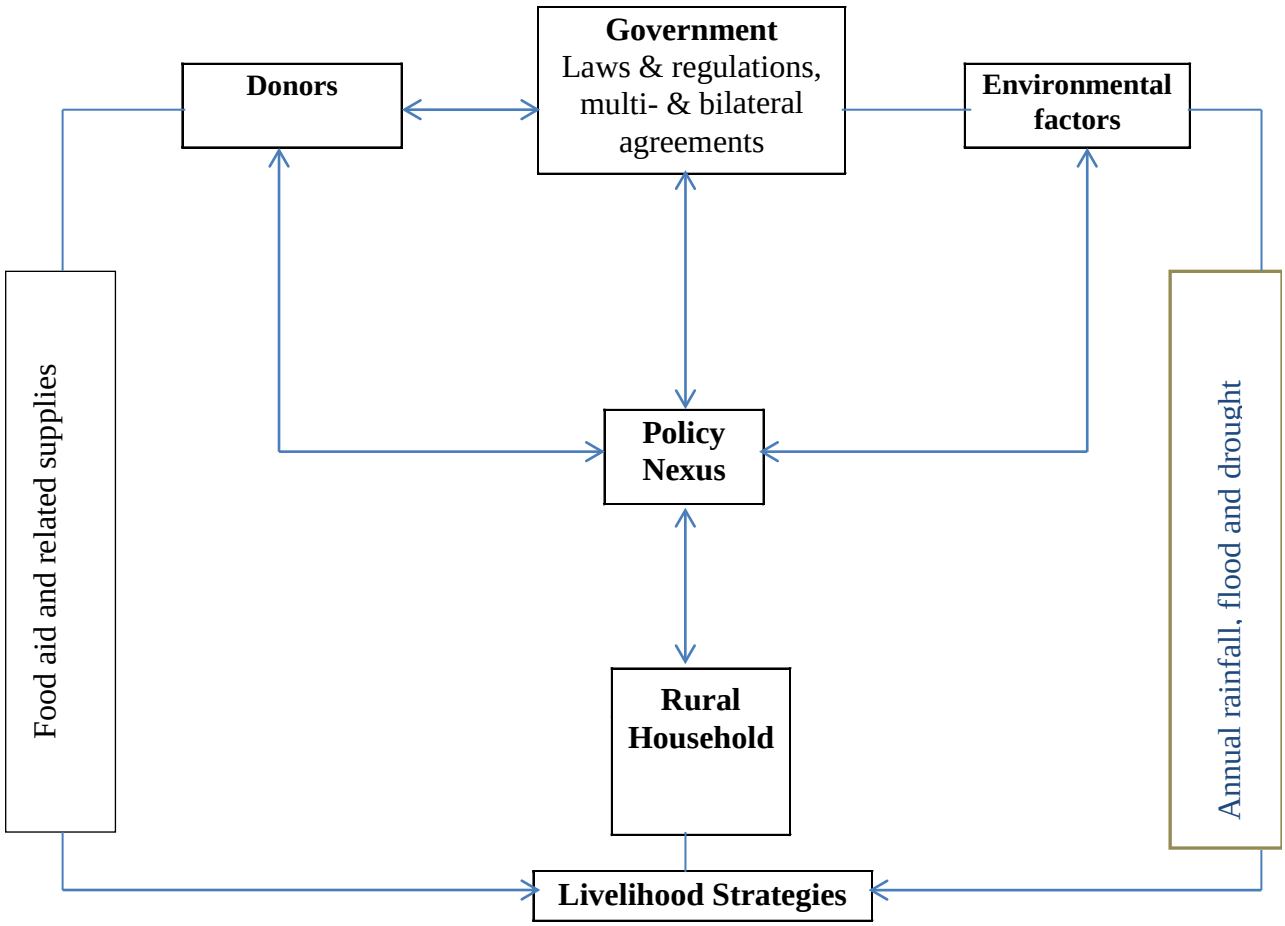

Figure 2 : Conceptual framework for rural farming households in the Caprivi

Figure 2 presents the relationship between a rural household and its supportive structures. The government and donor agencies have for decades been offering material support to needy households when climate risk factors strikes. Climate risk factors are nested under environmental factor category. Existing laws and regulations includes domestic and international legal instruments that seek to advance human welfare. Among such pertinent instruments are the United Nations General Assembly resolution 2200A (XXI) of 16 December 1966 on the International Convention of Economic, Social and Cultural Rights, Part III, Article 11 (United Nations, 1966); the Namibian Constitution, the Rural Development Strategy, and the Agricultural Policy.

A rural household shares the policy nexus with the government and donor agencies. It is within the policy nexus-platform that ideas on policy instruments are first generated and later crafted with the aim of improving the livelihoods of rural farming households. Amidst possibilities of emergency reliefs when conditions necessitate such, rural households have their own livelihood and coping strategies from the perspectives of farm, non-farm nature, and remittances. It is the livelihood and coping strategies which rural people have been employing over the years which sustained them in the past. However, the increasing climate risk factors are making it difficult for rural farming households to manage their day to day lives. Even with various coping strategies being brought on board, the way climate risk affects the livelihoods of farming households requires an entire calculus of tested interventions especially when considering the desire to induce the elements of self-sufficiency. In an attempt to find solutions to problems that affect livelihoods Mahul (2001) studied risk analysis using a production function that leaned heavily on the random weather index and also on production shocks that are not insurable.

The complexity of climate risk factors is found in the fact that climate risk issues are exogenously determined outside the realm of a rural household. In the immediate and short-run period, the common interventions have so far been the provision of food aid and other needed supplies. These support actions are temporal and difficult to sustain as they also depend on economic situations in donor countries. With drought, Iglesias et al. (2007) suggests the need to operate irrigation systems with sustained hydrological resources.

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They argue that irrigation reservoirs are essential for water consumption smoothing. While many people in the study area are involved in agriculture in one way or the other, their income sources varies. Both non-farm and farm activities remains important income sources. The extent to which an income source can generate the needed income makes it an important source that needs to be secured.

d) Model

A multivariate regression model was constructed for empirical analysis purposes. The truncated yet unconstrained model inculcates among others the un-biasedness element in its construction. In general, multivariate regression models have been used widely in empirical studies and they take various forms depending of the nature of study including the nature of the data that is available. The model developed in this study can be written using natural log format as follows:

$$LnY = \delta + \kappa_1 Ln\psi_1 + \kappa_2 Ln\psi_2 + ...\kappa_n Ln\psi_n + \kappa\mu$$

Where Y = Rural household income, κ = Parameters for estimation. Other variables including income differential ones are as follows:

Ψ_1 = Pension,

Ψ_2 = value of livestock in the hands of a rural household expressed in Namibia dollars (N$),

Ψ_3 = Value of food aid received in a year expressed in N$,

Ψ_4 = Age of the head of the household expressed in years

Ψ_5 = Household size expressed in numbers, and

μ = Error term.

LN= Natural Log

Variables are statistically accepted at the 95% level of significance. Considering that drought is less frequent in the Caprivi region compared to flood, flood makes crop farming less reliable and riskier compared to livestock farming. Though flood reduces accessibility to pastoral land, livestock enterprises are much more adaptable compared to crop farming in the study area. In the model, effects of climate risk are implicit in the yield. In other words, at the time a yield is obtained, climate risk factors would have already imputed their effect on the total yield. Thus in the model, income is treated as a proxy that captures the effects of climate risk. Climate risk would trigger a yield risk which may also lead to an income risk, holding all other things constant.

III. Results and Discussion

a) Socio-economic Features of the Respondents

The respondents who were interviewed have socio-economic characteristics that are displayed in Table 1. In Table 1, the average labour in numbers available to the household during the cultivation and harvesting season is 3 persons. These are adults who supply needed labour to the household. The average income which the household receives per month from all its sources is US$76.67 with the average remittance received standing at US$23 per month.

Table 1 : Socio-economic characteristics of respondent

Description	Measurement	Statistics
Average available household labour during the cultivation season	In numbers	24
Average monthly income	In US$	76.67
Average remittance receipts per month	In US$	23
Average farm size	In hectares	6
Gender orientation	Ratio of male to female	96:157
Average education level	In years	6
Average household size	In numbers of people	5
Average old age pension	In US$	54

N = 253; US$1 = N$8.20

Remittances are included in the actual income received by households. More women were interviewed compared to men. Respondents spent on average 6 years in school and they came from households with an average family size of 5.

b) Model Output

Variables	Coefficients	Std. Error	T	Sig.
(Constant)	5.674	0.051	111.940	0.000
Ψ_1	0.001	0.000	31.364	0.000
Ψ_2	1.720E-5	0.000	2.223	0.027
Ψ_3	0.010	0.004	2.392	0.018
Ψ_4	0.001	0.001	1.781	0.076
Ψ_5	-0.018	0.017	-1.102	0.271
Adjusted R^2	0.808			

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Table 2 above shows the model simulation output. Although not presented in Table 2, the simulation yielded an F test of 220.236 which was based on a 5% level of significance. The associated p-value is 0.000, which makes the model tenable. In Table 2, among the explanatory variables that were entered in the model are: pension (old age and retirement annuities) fund, the value of livestock owned by a rural household and the value of food aid received by a rural household. A variable was considered to be statistically significant when its p-value was $\leq$ 0.005. By applying these criteria to the model results, it shows that the three variables pension fund, the value of livestock owned by a rural household and the value of food aid received by a rural household are all statistically significant with p- values of 0.000, 0.027 and 0.018 respectively.

On the coefficient side, a variable may have little impact on the dependent variable but remain statistically significant. An extension on this provides that instead of considering coefficients that are too close to zero as zero, the slopes of their t statistics should not be ignored (Ghadim *et al*, 2005; Alemu *et al*, 2003). Following the insightful view of Ghadim *et al* (2005) and Alemu *et al* (2003), in the current model a unit change in the amount of pension fund in the hands of a rural household could lead to an increase in the income of the respective rural household by 0.001, *ceteris paribus*. A unit increase in the value of livestock in the hands of a rural household could potentially increase household income by 0.00001720 while all other explanatory variables are held constant. Again, a unit increase in the value of food aid received by a rural household has an incremental effect of 0.010 on the income of a rural household.

With regard to the t statistics, pension fund (31.364), the value of livestock (2.223) and the value of food aid (2.392) are all statistically significant. The significance of the t values of the three explanatory variables corresponds in acceptance with their p values, which were discussed earlier. As for the other two explanatory variables, age of the head of a household and household size, their t statistics and p values rendered them insignificant. Overall, the adjusted R2 of 80.8% is acceptable in that 81% of the variation in rural income is explained by the explanatory variables that were included in the model.

The results obtained from the model indicate how climate risk affects the rural household. High rainfall and drought have an impact on the income of the household in that the value of food at the disposal of the household may be reduced when climate risk factors are at the extreme. This aspect is implicit in the response variable that was tested in the model, since the total harvest is a function of a number of factors, including rainfall. At the time when a harvest is obtained, climate risk factors would have already had their effect on the crop produce. Another way to look at it is that when severe climate risk factors are experienced, the value of food aid provided may be reduced owing to the value of own produce in the response variable, which in this context would be very low or non-existent. It is by theoretical implication, that when this happens, it would have a reduced influence on the household income. Though both drought and flood affect livestock, drought can cause a more serious set-back to the livestock of a rural household. The effect occurs in terms of reduced value of livestock owned by the household. Should this occur, there will be a transitory effect on the income of the household.

IV. Conclusion

Climate risk factors will increasingly continue to affect rural households. Reliable policies are needed in order to assist rural households to secure their livelihoods through improving their income situations. There is a great need for rolling out climate risk awareness campaigns in rural areas where flood is problematic. Those should take into consideration survival options so that any targeted support measure may fit the needs of the affected households. In line with this consideration, suggesting the needed to introduce new crop varieties with a shorter growth cycle would be vital so that at the time when flood is imminent, such crops would have matured and be ready for harvesting.

As a means to secure incomes of rural households, there is a need to explore the possibility of extending production loans to rural farming households so that when an opportune time comes, they may be able to access the needed inputs for production purposes and have to repay after they have marketed their products. Another area of intervention that needs urgent attention is that of extending research to explore the possibility of rolling-out crop insurance for small-scale farmers. This will add value to current unsecured livelihoods and will also play an important role in reducing income losses at the household level. Therefore, improving incomes would most likely to have a positive impact on the food security situation of rural households and thus reduce the threat from hunger in the study area.

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Global Journal of Science Frontier Research
Agriculture and Veterinary Sciences
Volume 13 Issue 1 Version 1.0 Year 2013
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Height-Age Growth Curve Modelling for Different Tree Species in Drylands of North Karnataka

By S. B. Devaranavadgi, Sharan Bassappa, Jolli, R.B, S.Y. Wali & Bagali, A.N
College of Agriculture, Bijapur

Abstract - Among 24 tree species tested for height and age relationship under agroforestry systems of northern dry zone of Karnataka, Gompertz model fitted well for 9 species, Weibull model for 7 species, Exponential model found well suited for 5 species and Richards model for 3 species respectively. Among the different models tried in predicting height growth for 24 different species Gompertz was found better for Acacia auriculiformis (R^2 = 0.9974), Acacia nilotica (R^2 = 0.9981), Bahunia purpurea (R^2 = 0.9971), Butea monosperma (R^2 = 0.9992), Casuarina equsitifolia (R^2 = 0.9914), Cassia siamea (R^2 = 0.9986), Inga dulce (R^2 = 0.9968), Samanea saman (R^2 = 0.9995), and Tamarindus indica (R^2 = 0.9976). Hence, Gompertz model can be best adopted while predicting height growth of native species grown under dry land situation.

Keywords : height, age, model, species, growth.

GJSFR-D Classification : FOR Code: 070508, 100107

HEIGHT-AGE GROWTH CURVE MODELLING FOR DIFFERENT TREE SPECIES IN DRYLANDS OF NORTH KARNATAKA

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Height-Age Growth Curve Modelling for Different Tree Species in Drylands of North Karnataka

S. B. Devaranavadgi [α], Sharan Bassappa [σ], Jolli, R.B [ρ], S.Y. Wali [ω] & Bagali, A.N [¥]

Abstract - Among 24 tree species tested for height and age relationship under agroforestry systems of northern dry zone of Karnataka, Gompertz model fitted well for 9 species, Weibull model for 7 species, Exponential model found well suited for 5 species and Richards model for 3 species respectively. Among the different models tried in predicting height growth for 24 different species Gompertz was found better for Acacia auriculiformis (R^2 = 0.9974), Acacia nilotica (R^2 = 0.9981), Bahunia purpurea (R^2 = 0.9971), Butea monosperma (R^2 = 0.9992), Casuarina equsitifolia (R^2 = 0.9914), Cassia siamea (R^2 = 0.9986), Inga dulce (R^2 = 0.9968), Samanea saman (R^2 = 0.9995), and Tamarindus indica (R^2 = 0.9976). Hence, Gompertz model can be best adopted while predicting height growth of native species grown under dry land situation.

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I. Introduction

Tree height and diameter relationship is an important component in yield estimation, stand description, and damage appraisals (Parresol, 1992). Many height and diameter equations have been developed for various tree species (Wykoff *et al.,* 1982; Huang *et al.,* 1992). Among the variety of mathematical equations, sigmoidal or non-linear growth functions are widely used in developing tree height and diameter equations. Foresters often use height-diameter models to predict total tree height (c-I> based on observed diameter at breast height (DBH) for estimating tree or stand volume and site quality. Therefore, estimations of tree or stand volume and site quality rely heavily on accurate height-diameter functions. There is no standard height/age relationship for trees because of the influence of both internal and external factors on height growth but the basic pattern is sigmoidal.

Growth models assist forest researchers and managers in many ways. Some important uses include the ability to predict future yields and to explore silvicultural options. Models provide an efficient way to prepare resource forecasts, but a more important role may be their ability to explore management options and silvicultural alternatives. For example, foresters may wish to know the long-term effect on both the forest and on future harvests of a particular silvicultural decision, such as changing the cutting limits for harvesting. With a growth model, they can examine the likely outcomes, both with the intended and alternative cutting limits, and can make their decision objectively. The process of developing a growth model may also offer interesting and new insights into the forestry. Growth models may also have a broader role in forest management and in the formulation of forest policy. The same could be used as an advantage and in conjunction with other resource and environmental data, to make prediction, formulate prescriptions and guide forest policy decisions into stand dynamics. Hence looking to the importance of growth models in forestry, the present study was carried out to develop growth models for different tree species under dryland conditions of north Karnataka.

II. Materials and Methods

The experiment was conducted at Regional Agricultural Research Station, Bijapur of University of Agricultural Sciences, Dharwad, Karnataka from 1990-2000. The soils of the experimental site were analyzed for various physico-chemical properties (Sand 25%, Silt 23%, Clay 52%, bulk density 1.43 g/cc, pH- 8.5, EC- 0.34 dSm^{-1}, $CaCO_3$ 18.5% and soil depth 30-35 cm). The average rainfall of the site is 594 mm with 39 rainy days. 24 tree species *Viz.*, *Acacia auriculiformis, Acacia catechu, Acacia nilotica, Leucaena leucocephala, Albizzia lebbeck, Azadirachta indica, Bahunia purpurea, Butea monosperma, Casuarina equsitifolia, Cassia siamea, Dalbergia sissoo, Delonix regia, Emblica officianalis, Eucalyptus citriodara, Eucalyptus hybrid, Hardwickia binata, Anogeissus latifolia, Inga dulce, Peltoferrum ferrugeneum, Pongamia pinnata, Prosopsis juliflora, Samanea saman, Syzygium cumini* and *Tamarindus indica* were planted in 1990 at RARS Bijapur and data were collected at one year interval till 2000. The experiment was laid out in Randomized Complete Block Design (RCBD) with 2 replications. The trees were planted at a spacing of 2m x 2m and examined for 11 consecutive years. For developing growth curves the average height (m) of trees was measured using marked poles were recorded.

Developing height growth curves for 24 different tree species was done by selecting five non-linear models to compare fitness of these models to data (Thornley and France, 2007). The rationality behind the use of these growth models lies in the fact that these

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models have some important parameters enabling to comment on the growth process.

1. Gompertz model	Y = a*exp (-exp(b^-cx)) Where a, b, c are the parameters in the model.
2. Exponential model	Y=a*exp (-b/(x+c)) Where a, b and c are the parameters.
3. Weibull model	Y = a(1-b*exp (-c*x^d)) Where a, b, and c are the parameters.
4. Richards model	Y=a*(1-exp (b*x))^c Where a, b and c are the parameters in the model y is age and X is diameter.
5. Korf model	Y=a*exp (-b*x^-c) Where a ,b and c are the parameters in the model

III. Results and Discussion

Among the different models tried in predicting height growth for 24 different species Gompertz was found better for *Acacia auriculiformis* (R^2 = 0.9974), *Acacia nilotica* (R^2 = 0.9981), *Bahunia purpurea* (R^2 = 0.9971), *Butea monosperma* (R^2 = 0.9992), *Casuarina equsitifolia* (R^2 = 0.9914), *Cassia siamea* (R^2 = 0.9986), *Inga dulce* (R^2 = 0.9968), *Samanea saman* (R^2 = 0.9995), and *Tamarindus indica* (R^2 = 0.9976) and Weibull model for *Leucana leucocephala* (R^2 = 0.9987), *Dalbergia sissoo* (R^2 = 0.9978), *Eucalyptus citriodara* (R^2 = 0.9982), *Hardwickia binata* (R^2 = 0.9889), *Anogeissus latifolia* (R^2 = 0.9982), *Peltoferrum ferrugeneum* (R^2 = 0.9998) and *Pongamia pinnata* (R^2 = 0.9991).

Exponential model found suitable for *Acacia catechu* (R^2 = 0.9921), *Emblica officianalis* (R^2 = 0.9991), *Eucalyptus hybrid* (R^2 = 0.9933), *Prosopsis juliflora* (R^2 = 0.9966) and *Syzygium cumini* (R^2 = 0.9927) and Richards model was found better for *Albizia lebbeck* (R^2 = 0.9994), *Azadirachta indica* (R^2 = 0.9989) and *Delonix regia* (R^2 = 0.9984) (Table 1 and Figure 1).

Among 24 different tree species tested for height and age relationships Gompertz model fitted well for 9 species showing faster early growth but slower approach to asymptote with a longer linear period about inflection point (Thornley and France, 2007). Arid conditions of the experimental site might also impart such slow approach to the asymptote. Weibull model better fitted for 7 species with highest R^2 and lesser standard error and parameters with asymptote t-values. But overall performance of model is better in which all models were showed R^2 between 0.98 and 0.99. Despite considering initial years of growth of all tree species which are characterized by exponential growth period, the exponential model did not show robustness in predicting in all species. Somez (2009) also reported that Gompertz model fit well in height estimation of *Picea orientalis.*

Among the five growth models tested in this study, Korf model showed least fit in almost every species hence considered to be least robust for all species. Among other four models, Gompertz model showed best fit with highest R^2 value and least standard error for 9 species. Interestingly the fast growing introduced species *Prosopsis juliflora* (a ubiquitous introduced species) showed best fit with respect to exponential model. Hence, it may be preliminarily concluded that Gompertz model can be best adopted while predicting height growth of native species. Mean prediction error, standard deviation and R^2 served the criteria for comparing model prediction performance of growth functions. In this Gompertz function showed superiority over other models for 9 species in height – age relationship.

Typically the asymptotic coefficient is the least stable parameter in non-linear growth functions. The least-squares of these growth functions may result in biologically unreasonable upper asymptotes, especially when there are few data observations near the asymptote. Extrapolation, using the models beyond the data range, may produce overestimation or underestimation for large-sized trees. To circumvent the problem some researchers constrained the growth functions by fixing the asymptote at a constant value, such as an available big tree record, while estimating all other parameters in the models (Brewer et al., 1985, Zhang, 1997).

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Table 1 : Comparison of the Observed values of tree height (m) with that estimated by best-fit model and coefficient of determination, standard error, Mean Prediction Error (MPE), Standard Deviation (SD) with respect to different tree species under semi-arid regions of north Karnataka

T_{1-} *Acacia auriculiformis*

Age (years)	Estimated values	Observed values	Growth model
1	0.196	0.52	Gompertz model
2	0.841	0.81	
3	1.994	1.41	
4	3.326	2.41	R^2=0.9974
5	4.505	3.19	
6	5.392	3.70	SE=0.1279
7	5.998	4.50	
8	6.390	5.32	MPE= -0.7250
9	6.633	5.90	
10	6.782	6.40	SD = 0.6462
11	6.872	6.80	
15	6.988		Y=7.005*exp (-6.034*exp (-0.523*X))
20	7.004		
25	7.005		
30	7.005		
35	7.005		
40	7.005		
45	7.005		
50	7.005		

T_{2-} *Acacia catechu*

Age (years)	Estimated values	Observed values	Growth model
1	0.647	0.46	Exponential model
2	1.665	0.61	
3	2.437	1.23	
4	2.994	1.85	
5	3.406	2.51	
6	3.720	2.92	R^2=0.9921
7	3.967	3.49	
8	4.166	3.91	SE=0.1516
9	4.329	4.16	
10	4.465	4.21	MPE = -0.6113
11	4.581	4.3	
15	4.907		SD = 0.4095
20	5.149		
25	5.301		Y=5.966*exp (-3.0001/(X+0.3501))
30	5.405		
35	5.481		
40	5.539		
45	5.585		
50	5.621		

T_3-*Acacia nilotica*

Age (years)	Estimated values	Observe d values	Growth model
1	0.900	0.48	Gompertz model
2	0.891	0.68	
3	1.549	1.23	
4	2.341	1.75	R^2=0.9981
5	3.187	2.71	
6	4.013	3.24	SE=0.0882
7	4.767	3.83	
8	5.420	4.40	MPE =-0.7304
9	5.967	4.70	
10	6.410	5.22	SD =0.4096
11	6.763	5.44	Y=7.9211*exp (-2.9119exp (-0.2918*X)
15	7.541		
20	7.831		
25	7.900		
30	7.916		
35	7.920		
40	7.921		
45	7.921		
50	7.921		

T_4-*Leucaena leucocephala*

Age (years)	Estimated values	Observed values	Growth model
1	0.183	0.38	Weibull model
2	0.712	0.63	
3	1.536	1.66	
4	2.582	2.72	
5	3.764	3.81	R^2=0.9987
6	4.997	4.91	
7	6.200	5.72	SE=0.1648
8	7.312	7.61	
9	8.291	8.64	MPE= 0.0372
10	9.114	9.2	
11	9.777	9.60	SD= 0.2358
15	11.137		
20	11.444		Y=11.465*(1-exp (-0.0161*X^1.993))
25	11.464		
30	11.465		
35	11.465		
40	11.465		
45	11.465		
50	11.465		

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T_5-*Albizzia lebbeck*

Age (years)	Estimated values	Observed values	Growth model
1	0.161	0.15	Richards model
2	0.816	0.83	
3	1.791	1.81	
4	2.835	2.81	
5	3.793	3.72	R^2=0.9994
6	4.600	4.69	
7	5.244	5.30	SE=0.0635
8	5.742	5.72	
9	6.118	6.01	MPE =0.000393
10	6.398	6.44	
11	6.604	6.63	SD =0.05685 Y=7.1478*(1-exp (-0.3316*X)) ^ 2.9981))
15	7.001		
20	7.120		
25	7.143		
30	7.147		
35	7.148		
40	7.148		
45	7.148		
50	7.148		

T_6-*Azadirachta indica*

Age (years)	Estimated values	Observed values	Growth model
1	0.083	0.34	Richards model
2	0.521	0.83	
3	1.271	1.26	
4	2.146	1.89	
5	2.995	2.53	R^2=0.9989
6	3.738	3.29	
7	4.350	3.88	SE=0.0553
8	4.834	4.21	
9	5.206	4.56	MPE =-0.305522
10	5.487	4.97	
11	5.696	5.21	SD =0.33923
15	6.108		
20	6.236		Y=5.2672*(1-exp (-0.3253*X)) ^ 3.3731
25	6.261		
30	6.266		
35	6.267		
40	6.267		
45	6.267		
50	6.267		

T_7-*Bahunia purpurea*

Age (years)	Estimated values	Observed values	Growth model
1	0.493	0.64	Gompertz model
2	0.912	0.83	
3	1.445	1.485	
4	2.039	2.005	
5	2.639	2.51	R^2=0.99711
6	3.200	3.21	
7	3.698	3.76	SE=0.0943
8	4.120	4.19	
9	4.467	4.55	MPE =0.004599
10	4.745	4.71	
11	4.965	4.885	SD =0.08428
15	5.447		
20	5.626		Y=5.6821*exp (-3.265*exp (-0.4934*X))
25	5.669		
30	5.679		
35	5.681		
40	5.682		
45	5.682		
50	5.682		

T_8-*Butea monosperma*

Age (years)	Estimated values	Observed values	Growth model
1	0.105	0.109	Gompertz model
2	0.313	0.29	
3	0.650	0.69	
4	1.060	1.01	
5	1.469	1.502	R^2=0.99924
6	1.827	1.84	
7	2.114	2.105	SE=0.0289
8	2.330	2.31	
9	2.487	2.49	MPE =-0.000145
10	2.598	2.59	
11	2.674	2.69	SD =0.02582
15	2.803		
20	2.831		Y=2.836*exp (-4.932*exp (-0.4029*X))
25	2.835		
30	2.836		
35	2.836		
40	2.836		
45	2.836		
50	2.836		

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T_9-*Casuarina equsitefolia*

Age (years)	Estimated values	Observed values	Growth model
1	0.765	0.95	Gompertz model
2	1.114	1.14	
3	1.506	1.335	
4	1.918	1.78	
5	2.327	2.3	R^2=0.9914
6	2.718	2.81	
7	3.077	3.12	SE=0.1197
8	3.399	3.5	
9	3.680	3.72	MPE =0.003605
10	3.923	3.9	
11	4.129	4.04	SD =0.10707
15	4.660		
20	4.932		Y=5.0717*exp (-2.3623*exp (-0.2219*X))
25	5.025		
30	5.056		
35	5.067		
40	5.070		
45	5.071		
50	5.072		

T_{10}-*Cassia siamea*

Age (years)	Estimated values	Observed values	Growth model
1	0.616	0.69	Gompertz model
2	0.951	0.91	
3	1.356	1.375	
4	1.813	1.805	
5	2.299	2.23	R^2=0.9986
6	2.793	2.75	
7	3.276	3.365	SE=0.0604
8	3.732	3.715	
9	4.152	4.19	MPE =0.00174
10	4.531	4.57	
11	4.867	4.805	SD =0.05406
15	5.814		
20	6.372		Y=6.721*exp (-2.918*exp (-0.2002*X))
25	6.590		
30	6.672		
35	6.703		
40	6.714		
45	6.718		
50	6.720		

T_{11}-*Dalbergia sissoo*

Age (years)	Estimated values	Observed values	Growth model
1	0.360	0.52	Weibull model
2	0.902	0.85	
3	1.493	1.49	
4	2.077	2.01	
5	2.626	2.65	R^2=0.9978
6	3.123	3.13	
7	3.560	3.51	SE=0.0147
8	3.936	3.99	
9	4.255	4.31	MPE =-0.01784
10	4.519	4.42	
11	4.736	4.51	SD =0.09959
15	5.248		
20	5.458		Y=5.5179*(1-exp (-0.0675*X^-1.4036))
25	5.506		
30	5.516		
35	5.518		
40	5.518		
45	5.518		
50	5.518		

T_{12}-*Delonix regia*

Age (years)	Estimated values	Observed values	Growth model
1	0.110	0.16	Richards model
2	0.412	0.31	
3	0.810	0.69	
4	1.230	1.21	
5	1.630	1.63	R^2=0.99841
6	1.987	1.93	
7	2.296	2.31	SE=0.0464
8	2.555	2.52	
9	2.769	2.73	MPE =-0.046169
10	2.944	2.81	
11	3.085	3.02	SD =0.0571543
15	3.416		
20	3.564		Y=3.627*(1-exp (-0.2439*X))^2.284
25	3.608		
30	3.621		
35	3.625		
40	3.626		
45	3.626		
50	3.627		

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T_{13}-*Emblica officianalis*

Age (years)	Estimated values	Observed values	Growth model
1	1.445	0.83	Exponential model
2	2.566	1.35	
3	3.565	1.88	
4	4.413	2.79	
5	5.123	3.43	R^2=0.9991
6	5.722	4.06	
7	6.230	5.11	SE=0.10013
8	6.665	5.68	
9	7.041	6.03	MPE =--1.2767
10	7.368	6.12	
11	7.656	6.24	SD =0.35296
15	8.523		
20	9.218		Y=11.975*exp (-5.674/(X+1.684))
25	9.681		
30	10.011		
35	10.259		
40	10.451		
45	10.604		
50	10.730		

T_{14}-*Eucalyptus citriodara*

Age (years)	Estimated values	Observed values	Growth model
1	0.760	0.79	Weibull model
2	1.769	1.76	
3	2.830	2.83	
4	3.878	3.73	
5	4.878	4.65	R^2=0.9982
6	5.811	5.89	
7	6.667	6.41	SE=0.1373
8	7.443	7.42	
9	8.139	8.12	MPE = -0.104144
10	8.758	8.64	
11	9.304	8.85	SD =0.15763
15	10.871		
20	11.861		Y=12.539*(1-exp (-0.0625*X^-1.2829))
25	12.282		
30	12.447		
35	12.508		
40	12.529		
45	12.536		
50	12.539		

T_{15}-*Eucalyptus hybrid*

Age (years)	Estimated values	Observed values	Growth model
1	0.661	0.82	Exponential model
2	1.325	1.23	
3	2.069	1.84	
4	2.822	2.82	
5	3.545	3.41	R^2=0.9933
6	4.222	4.94	
7	4.849	5.29	SE=0.192
8	5.425	5.72	
9	5.952	5.89	MPE =0.04334
10	6.435	6.21	
11	6.878	6.49	SD =0.32964
15	8.321		
20	9.601		Y=15.879*exp (-11.356/(X+2.573))
25	10.519		
30	11.205		
35	11.737		
40	12.161		
45	12.507		
50	12.794		

T_{16}-*Hardwickia binata*

Age (years)	Estimated values	Observed values	Growth model
1	0.260	0.31	Weibull model
2	0.716	0.73	
3	1.274	1.46	
4	1.893	2.09	
5	2.543	2.59	R^2=0.9889
6	3.204	3.11	
7	3.859	3.55	SE=0.1023
8	4.496	4.78	
9	5.106	5.39	MPE =0.02612
10	5.682	5.62	
11	6.219	5.91	SD =0.20883
15	7.958		
20	9.280		Y=10.403*(1-exp (-0.0253*X^-1.495))
25	9.938		
30	10.227		
35	10.342		
40	10.383		
45	10.397		
50	10.401		

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T_{17}-*Anogeissus latifolia*

Age (years)	Estimated values	Observed values	Growth model
1	0.194	0.38	Weibull model
2	0.632	0.62	
3	1.221	1.24	
4	1.892	1.82	
5	2.588	2.39	R^2=0.9982
6	3.262	3.31	
7	3.882	3.88	SE=0.0899
8	4.428	4.46	
9	4.891	4.86	MPE =0.020796
10	5.270	5.19	
11	5.570	5.91	SD =0.14163
15	6.189		
20	6.349		Y=6.366*(1-exp (-0.03101*X^-1.7359))
25	6.365		
30	6.366		
35	6.366		
40	6.366		
45	6.366		
50	6.366		

T_{18}-*Inga dulce*

Age (years)	Estimated values	Observed values	Growth model
1	0.767	0.81	Gompertz model
2	1.208	1.23	
3	1.730	1.79	
4	2.297	2.21	
5	2.874	2.79	R^2=0.9968
6	3.430	3.34	
7	3.945	3.86	SE=0.1023
8	4.406	4.29	
9	4.807	4.61	MPE = -0.08557
10	5.150	4.99	
11	5.438	5.19	SD =0.097399
15	6.162		
20	6.512		Y=6.6737*exp (-2.7339*exp (-0.236))
25	6.624		
30	6.658		
35	6.669		
40	6.672		
45	6.673		
50	6.674		

T_{19}-*Peltoferrum ferrugeneum*

Age (years)	Estimated values	Observed values	Growth model
1	0.129	0.22	Weibull model
2	0.435	0.31	
3	0.873	1.72	
4	1.411	3.17	
5	2.020	3.95	R^2=0.9998
6	2.673	4.63	
7	3.346	4.72	SE=0.179
8	4.018	4.57	
9	4.673	4.81	MPE =0.7.02075
10	5.295	5.08	
11	5.874	5.29	SD= 0.925451643
15	7.669		
20	8.808		Y=9.334*(1-exp (-0.0139*X^1.78))
25	9.205		
30	9.309		
35	9.330		
40	9.334		
45	9.334		
50	9.334		

T_{20}-*Pongamia pinnata*

Age (years)	Estimated values	Observed values	Growth model
1	0.160	0.13	Weibull model
2	0.547	0.49	
3	1.085	1.09	
4	1.709	1.82	
5	2.356	2.34	R^2=0.9991
6	2.980	2.89	
7	3.545	3.56	SE=0.0583
8	4.031	4.06	
9	4.429	4.42	MPE = -0.003014
10	4.742	4.77	
11	4.979	4.96	SD =0.052112
15	5.407		
20	5.486		Y=5.5911*(1-exp (-0.0295*X^1.8292))
25	5.491		
30	5.491		
35	5.491		
40	5.491		
45	5.491		
50	5.491		

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T_{21}-*Prosopsis juliflora*

Age (years)	Estimated values	Observed values	Growth model
1	0.084	0.96	Exponential model
2	0.489	1.35	
3	1.106	1.97	
4	1.772	2.62	
5	2.408	3.11	R^2=0.9966
6	2.988	3.62	
7	3.507	3.99	SE=0.0938
8	3.967	4.41	
9	4.375	4.71	MPE = 0.56302
10	4.738	4.92	
11	5.062	5.03	SD =0.30899
15	6.063		
20	6.889		Y=10.295*exp (-8.329(X+0.7335))
25	7.448		
30	7.851		
35	8.155		
40	8.391		
45	8.581		
50	8.736		

T_{22}-*Samanea saman*

Age (years)	Estimated values	Observed values	Growth model
1	0.642	0.68	Gompertz model
2	1.063	1.01	
3	1.562	1.59	
4	2.096	2.06	
5	2.625	2.66	R^2=0.9995
6	3.116	3.13	
7	3.553	3.54	SE=0.0366
8	3.928	3.91	
9	4.241	4.23	MPE =0.000455
10	4.496	4.54	
11	4.702	4.68	SD =0.03281
15	5.173		
20	5.365		Y=8.158*exp (-3.0564*exp (-0.2759*X))
25	5.416		
30	5.430		
35	5.433		
40	5.434		
45	5.434		
50	5.434		

T_{23}-*Syzygium cumini*

Age (years)	Estimated values	Observed values	Growth model
1	0.520	0.58	Exponential model
2	0.789	0.72	
3	1.056	0.98	
4	1.308	1.36	
5	1.542	1.65	R^2=0.9927
6	1.757	1.72	
7	1.953	1.92	SE=0.0656
8	2.131	2.09	
9	2.294	2.33	MPE =0.0000665
10	2.442	2.46	
11	2.578	2.56	SD =0.05874
15	3.020		
20	3.413		Y=5.381*exp (-10.74/(X+3.595))
25	3.696		
30	3.909		
35	4.074		
40	4.206		
45	4.314		
50	4.404		

T_{24}-*Tamarindus indica*

Age (years)	Estimated values	Observed values	Growth model
1	0.285	0.37	Gompertz model
2	0.555	0.49	
3	0.909	0.89	
4	1.309	1.29	
5	1.713	1.78	R^2=0.9976
6	2.090	2.09	
7	2.422	2.37	SE=0.0528
8	2.700	2.7	
9	2.926	2.96	MPE =0.00197
10	3.105	3.13	
11	3.244	3.21	SD =0.047194
15	3.540		
20	3.644		Y=3.3674*exp (-3.459*exp (-0.3023*X))
25	3.667		
30	3.672		
35	3.674		
40	3.674		
45	3.674		
50	3.674		

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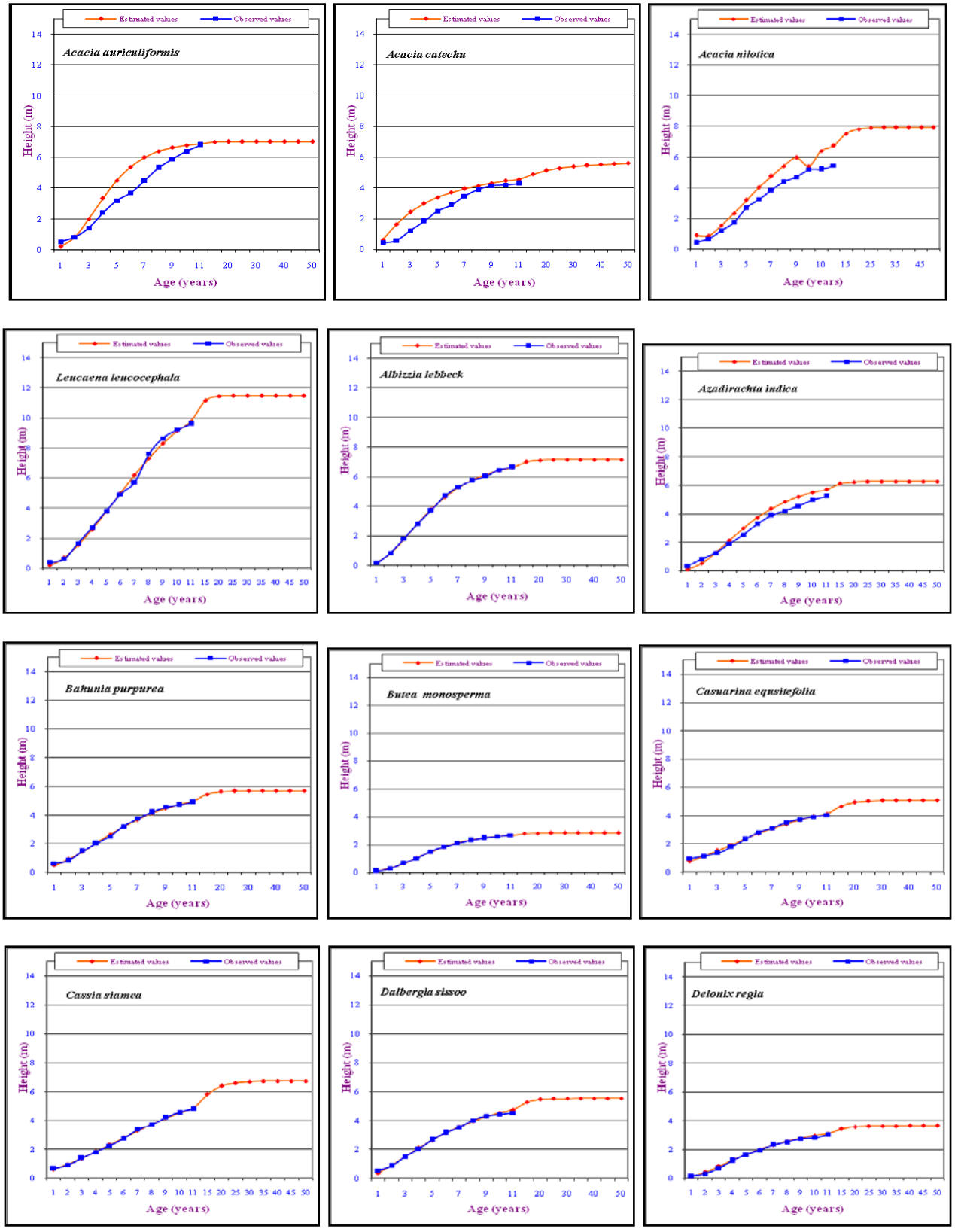
Figure 1 : Height-age growth curves of different tree species under semi-arid regions of north Karnataka



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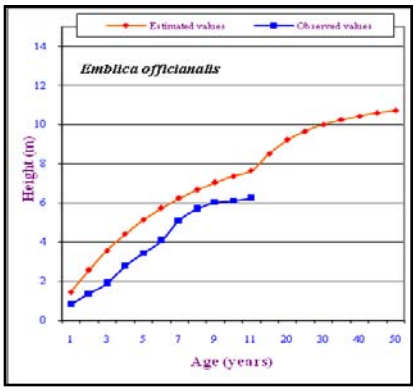

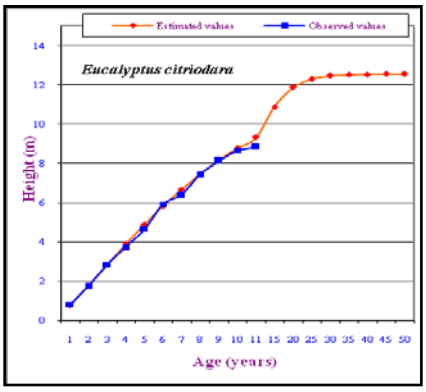

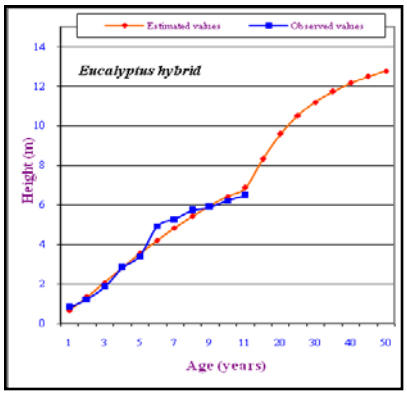

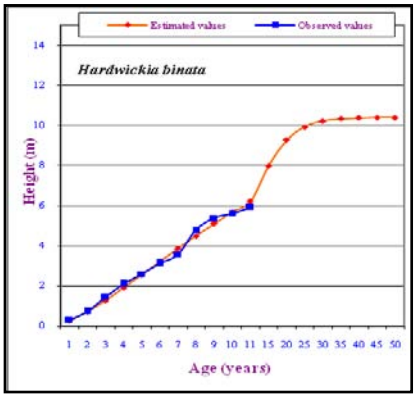

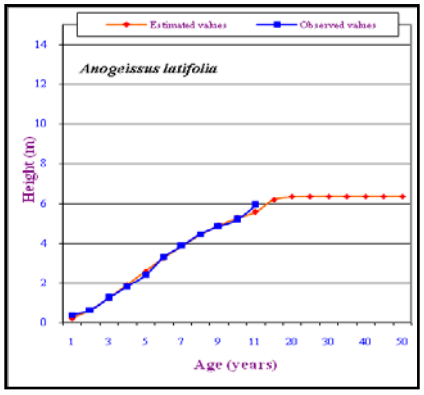

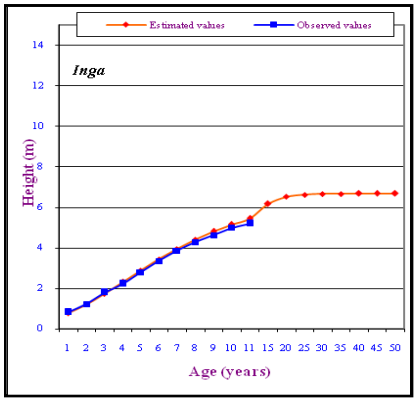

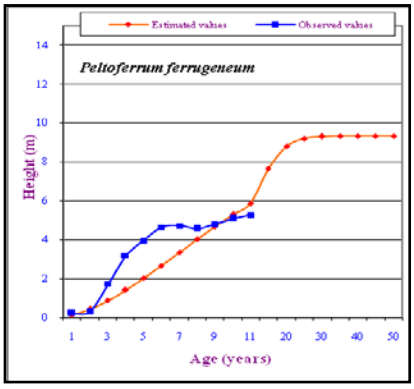

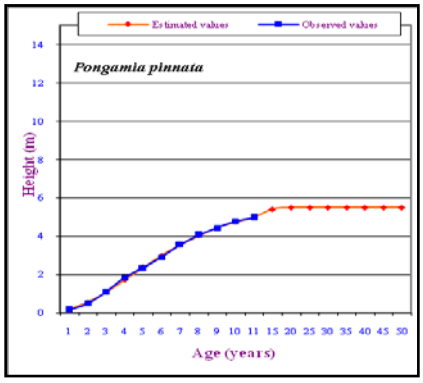

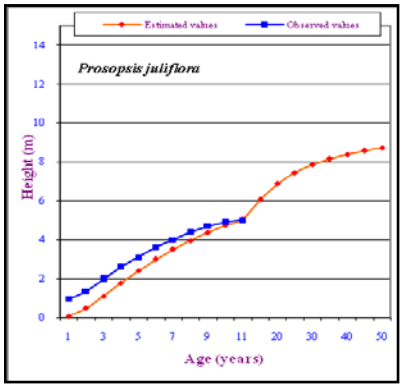

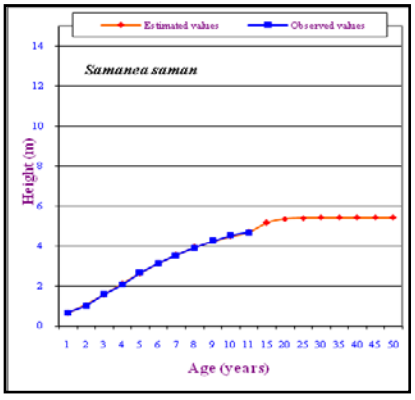

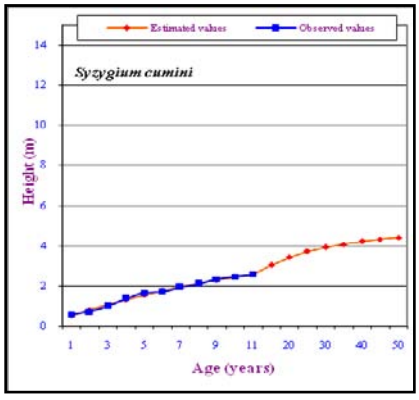

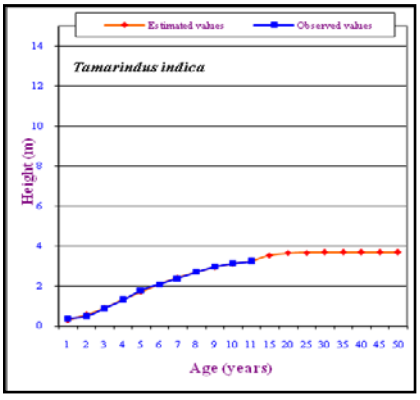

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Global Journal of Science Frontier Research
Agriculture and Veterinary Sciences
Volume 13 Issue 1 Version 1.0 Year 2013
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Diameter-Age Growth Curve Modelling for Different Tree Species in Drylands of North Karnataka

By S. B. Devaranavadgi , Sharan Bassappa, Jolli , R.B, S.Y. Wali & Bagali, A.N
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Keywords : height, age, model, species, growth.

GJSFR-D Classification : FOR Code: 070101, 070501

DIAMETER-AGE GROWTH CURVE MODELLING FOR DIFFERENT TREE SPECIES IN DRYLANDS OF NORTH KARNATAKA

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Diameter-Age Growth Curve Modelling for Different Tree Species in Drylands of North Karnataka

S. B. Devaranavadgi [α], Sharan Bassappa Jolli [σ], R.B, S.Y. Wali [ρ] & Bagali, A.N [ω]

Abstract - Among 24 tree species tested for diameter and age relationship under Agroforestry systems of northern dry zone of Karnataka, Gompertz model fitted well for 20 species, Exponential model for 2 species, Weibull model found well suited for one species and Richards model for one species, respectively. Among the different models tried in predicting diameter growth for 24 different species Gompertz model was found better for Acacia auriculiformis (R^2 = 0.9956), Acacia catechu (R^2 = 0.9972), Acacia nilotica (R^2 = 0.9938), Bahunia purpurea (R^2 = 0.9950), Butea monosperma (R^2 = 0.9968), Casuarina equsitifolia (R^2 = 0.9979), Cassia siamea (R^2 = 0.9986), Dalbergia sissoo (R^2 = 0.9944), Delonix regia (R^2 = 0.9953), Emblica officinalis (R^2 = 0.9944), Eucalyptus citriodara (R^2 = 0.9983), Eucalyptus hybrid (R^2 = 0.9988), Hardwickia binata (R^2 = 0.9969), Anogeissus latifolia (R^2 = 0.9962), Inga dulce (R^2 = 0.9931), Peltoferrum ferrugeneum (R^2 = 0.9978), Prosopsis juliflora (R^2 = 0.9989), Samanea saman (R^2 = 0.9982), Syzygium cumini (R^2 = 0.9976) and Tamarindus indica (R^2 = 0.9953). Hence, Gompertz model can be best adopted while predicting diameter growth of native species grown under dry land situation.

Keywords : height, age, model, species, growth.

I. Introduction

Tree height and diameter relationship is an important component in yield estimation, stand description, and damage appraisals (Parresol, 1992). Many height and diameter equations have been developed for various tree species (Wykoff *et al.,* 1982; Huang *et al.,* 1992). Among the variety of mathematical equations, sigmoidal or non-linear growth functions are widely used in developing tree height and diameter equations. Foresters often use height-diameter models to predict total tree height (c-I> based on observed diameter at breast height (DBH) for estimating tree or stand volume and site quality. Therefore, estimations of tree or stand volume and site quality rely heavily on accurate height-diameter functions. The general diameter/age relationship is represented by the cumulative growth curve (CGC) which is sigmoidal for biological systems.

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Growth models assist forest researchers and managers in many ways. Some important uses include the ability to predict future yields and to explore silvicultural options. Models provide an efficient way to prepare resource forecasts, but a more important role may be their ability to explore management options and silvicultural alternatives. For example, foresters may wish to know the long-term effect on both the forest and on future harvests of a particular silvicultural decision, such as changing the cutting limits for harvesting. With a growth model, they can examine the likely outcomes, both with the intended and alternative cutting limits, and can make their decision objectively. The process of developing a growth model may also offer interesting and new insights into the forestry. Growth models may also have a broader role in forest management and in the formulation of forest policy. The same could be used as an advantage and in conjunction with other resource and environmental data, to make prediction, formulate prescriptions and guide forest policy decisions into stand dynamics. Hence looking to the importance of growth models in forestry, the present study was carried out to develop growth models for different tree species under dryland conditions of north Karnataka.

II. Materials and Methods

The experiment was conducted at Regional Agricultural Research Station, Bijapur of University of Agricultural Sciences, Dharwad, Karnataka from 1990-2000. The soils of the experimental site were analyzed for various physico-chemical properties (Sand 25%, Silt 23%, Clay 52%, bulk density 1.43 g/cc, pH- 8.5, EC-0.34 dSm^{-1}, $CaCO_3$ 18.5% and soil depth 30-35 cm). The average rainfall of the site is 594 mm with 39 rainy days. 24 tree species *Viz.*, *Acacia auriculiformis, Acacia catechu, Acacia nilotica, Leucaena leucocephala, Albizzia lebbeck, Azadirachta indica, Bahunia purpurea, Butea monosperma, Casuarina equsitifolia, Cassia siamea, Dalbergia sissoo, Delonix regia, Emblica officinalis, Eucalyptus citriodara, Eucalyptus hybrid, Hardwickia binata, Anogeissus latifolia, Inga dulce, Peltoferrum ferrugeneum, Pongamia pinnata, Prosopsis juliflora, Samanea saman, Syzygium cumini* and *Tamarindus indica* were planted in 1990 at RARS Bijapur and data were collected at one year interval till 2000.

Global Journal of Science Frontier Research (D) Volume XIII Issue I Version I Year 2013

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The experiment was laid out in Randomized Complete Block Design (RCBD) with 2 replications. The trees were planted at a spacing of 2m x 2m and examined for 11 consecutive years. For developing growth curves the diameter at breast height (DBH) (cm) using vernier caliper were recorded.

Developing diameter growth curves for 24 different tree species was done by selecting five non-linear models to compare fitness of these models to data (Thornley and France, 2007). The rationality behind the use of these growth models lies in the fact that these models have some important parameters enabling to comment on the growth process.

1. Gompertz model	Y = a*exp (-exp(b^-cx)) Where a, b, c are the parameters in the model.
2. Exponential model	Y=a*exp (-b/(x+c)) Where a, b and c are the parameters.
3. Weibull model	Y = a(1-b*exp (-c*x^d)) Where a, b, and c are the parameters.
4. Richards model	Y=a*(1-exp (b*x))^c Where a, b and c are the parameters in the model y is age and X is diameter.
5. Korf model	Y=a*exp (-b*x^-c) Where a ,b and c are the parameters in the model

III. Results and Discussion

Among the different models tried in predicting diameter growth for 24 different species, Gompertz model was found better for *Acacia auriculiformis* (R^2 = 0.9956), *Acacia catechu* (R^2 = 0.9972), *Acacia nilotica* (R^2 = 0.9938), *Bahunia purpurea* (R^2 = 0.9950), *Butea monosperma* (R^2 = 0.9968), *Casuarina equsitifolia* (R^2 = 0.9979), *Cassia siamea* (R^2 = 0.9986), *Dalbergia sissoo* (R^2 = 0.9944), *Delonix regia* (R^2 = 0.9953), *Emblica officinalis* (R^2 = 0.9944), *Eucalyptus citriodara* (R^2 = 0.9983), *Eucalyptus hybrid* (R^2 = 0.9988), *Hardwickia binata* (R^2 = 0.9969), *Anogeissus latifolia* (R^2 = 0.9962), *Inga dulce* (R^2 = 0.9931), *Peltoferrum ferrugeneum* (R^2 = 0.9978), *Prosopsis juliflora* (R^2 = 0.9989), *Samanea saman* (R^2 = 0.9982), *Syzygium cumini* (R^2 = 0.9976) and *Tamarindus indica* (R^2 = 0.9953).

Exponential model found suitable for *Leucana leucocephala* (R^2 = 0.9958) and *Pongamia pinnata* (R^2 = 0.9987). Whereas, Richards model was found better for *Albizia lebbeck* (R^2 = 0.9986) and Weibull model for *Azadirachta indica* (R^2 = 0.9983) (Table 1 and Figure 1).

Among five growth models tested in diameter and age relationship study, Korf, Richards and Weibull models showed least fit in almost every tree species. Among other two models Gompertz model showed best fit with highest R^2 and lest standard error. Among 24 different tree species, Gompertz model showed best fit for 20 species among which sixteen species were native to semiarid conditions. Gompertz model showed faster early growth but slower approach to asymptote with a longer linear period about inflection point (Thornley and France, 2007) and reported to be more accurate than any other models of forest growth (Zhang, 1997). Arid conditions of the experimental site might also impart such slow approach to the asymptote. Exponential model better fitted for two species with highest R^2 and lesser standard error and parameters with asymptote t-values. Richards model showed best fit for one species *i.e. Albizia lebbeck* and Weibull model for one species *i.e., Leucana leucocephala* which is an introduced fast growing tree species. Despite considering initial years of growth of all tree species which are characterized by exponential growth period, the exponential model did not show robustness in predicting in all species. But overall performance of models was better in which all models were showed R^2 between 0.98 and 0.99 except Korf and Weibull model. Mean prediction error, standard deviation and R^2 were adopted as criteria for comparing model prediction performance of growth functions. The apparent reason for high R^2 values associated with linear models is that the data set usually belongs to the second phase of tree growth and which is linear in nature (Srivastava and Ajit, 2002). In this Gompertz function showed superiority over other models for 20 species in DBH – Age relationship.

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Table 1 : Comparison of the Observed values of tree diameter (cm) with that estimated by best-fit model and coefficient of determination, standard error, Mean Prediction Error (MPE), Standard Deviation (SD) with respect to different tree species under semi-arid regions of north Karnataka

T_1- *Acacia auriculiformis*

Age (years)	Estimated values	Observed values	Growth model
1	1.068	0.82	Gompertz model
2	1.788	1.55	
3	2.631	2.51	
4	3.515	3.34	
5	4.367	4.21	
6	5.140	4.99	R^2=0.9956
7	5.807	5.5	
8	6.363	5.91	SE=0.2652
9	6.815	6.21	
10	7.175	6.89	MPE=-0.28976
11	7.457	7.01	
15	8.071		SD =0.15321
20	8.299		
25	8.354		
30	8.367		
35	8.370		
40	8.371		
45	8.371		
50	8.371		

T_2- *Acacia catechu*

Age (years)	Estimated values	Observed values	Growth model
1	0.587	0.76	Gompertz model
2	0.963	0.99	
3	1.450	1.41	
4	2.033	1.89	
5	2.687	2.44	
6	3.382	3.12	R^2=0.9972
7	4.090	3.88	
8	4.783	4.51	SE=0.0622
9	5.444	5.11	
10	6.057	5.67	MPE =-0.20924
11	6.615	6.01	
15	8.269		SD =0.2115
20	9.315		
25	9.750		Y=10.03*exp (-3.44*exp (-0.192*X))
30	9.922		
35	9.988		
40	10.014		
45	10.024		
50	10.028		

T_3-*Acacia nilotica*

Age (years)	Estimated values	Observed values	Growth model
1	1.293	0.89	Gompertz model
2	1.574	1.43	
3	1.884	1.89	
4	2.219	2.35	R^2=0.9938
5	2.577	2.66	
6	2.955	3.01	SE=0.0567
7	3.347	3.44	
8	3.750	3.8	MPE =-0.004601
9	4.161	4.2	
10	4.574	4.61	SD =0.14957
11	4.988	4.99	Y=12.331*exp (-2.471*exp (-0.0193*X))
15	6.579		
20	8.283		
25	9.583		
30	10.511		
35	11.144		
40	11.565		
45	11.840		
50	12.018		

T_4-*Leucaena leucocephala*

Age (years)	Estimated values	Observed values	Growth model
1	0.314	0.81	Exponential model
2	0.902	1.21	
3	1.722	1.81	
4	2.664	2.55	
5	3.649	3.44	R^2=0.9958
6	4.627	4.49	
7	5.571	5.53	SE=0.2121
8	6.467	5.99	
9	7.309	6.09	MPE =-0.4726
10	8.096	6.34	
11	8.829	6.69	SD =0.85675
15	11.290		
20	13.550		Y=25.3495*exp (-13.881/(2.1612+X))
25	15.206		
30	16.464		
35	17.448		
40	18.238		
45	18.886		
50	19.427		

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T_5-*Albizzia lebbeck*

Age (years)	Estimated values	Observed values	Growth model
1	0.377	0.46	Richards model
2	1.051	1.01	
3	1.816	1.86	
4	2.584	2.55	
5	3.314	3.21	R^2=0.9986
6	3.983	4.01	
7	4.584	4.76	SE=0.1186
8	5.116	5.89	
9	5.582	6.79	MPE =-0.4359 SD =0.6092
10	5.987	7.99	
11	6.337	8.88	Y=8.324*(1-exp (-0.17225*X))^1.68031
15	7.300		
20	7.885		
25	8.138		
30	8.245		
35	8.291		
40	8.310		
45	8.318		
50	8.321		

T_6-*Azadirachta indica*

Age (years)	Estimated values	Observed values	Growth model
1	0.361	0.330	Weibull model R^2=0.9983
2	0.983	0.780	
3	1.728	1.560	
4	2.529	2.410	
5	3.342	3.290	SE=0.11055
6	4.138	4.110	
7	4.894	4.760	MPE =-0.15801
8	5.596	5.550	
9	6.237	6.110	SD =0.14015
10	6.812	6.420	
11	7.320	6.880	Y=9.954*(1-exp (-0.0369* X^1.4948))
15	8.752		
20	9.568		
25	9.847		
30	9.928		
35	9.948		
40	9.953		
45	9.954		
50	9.954		

T_7-*Bahunia purpurea*

Age (years)	Estimated values	Observed values	Growth model
1	0.386	0.510	Gompertz model
2	0.935	0.880	
3	1.741	1.550	
4	2.697	2.490	
5	3.669	3.560	R^2=0.9950
6	4.556	4.410	
7	5.305	5.220	SE=0.05654
8	5.905	5.790	
9	6.366	6.310	MPE =-0.09723
10	6.712	6.620	
11	6.967	6.830	SD =0.088346
15	7.447		
20	7.582		Y=7.61*exp (-4.24*exp (-0.352*X))
25	7.605		
30	7.609		
35	7.610		
40	7.610		
45	7.610		
50	7.610		

T_8-*Butea monosperma*

Age (years)	Estimated values	Observed values	Growth model
1	0.803	0.86	Gompertz model
2	1.1598	1.21	
3	1.584	1.76	
4	2.063	2.29	
5	2.581	2.71	R^2=0.99681
6	3.121	3.19	
7	3.667	3.71	SE=0.03183
8	4.203	4.26	
9	4.719	4.88	MPE =0.10029
10	5.206	5.29	
11	5.658	5.71	SD =0.06277
15	7.081		
20	8.102		Y=9*exp (-2.85*exp (-0.165*X))
25	8.595		
30	8.820		
35	8.921		
40	8.965		
45	8.985		
50	8.993		

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T_9-*Casuarina equsitefolia*

Age (years)	Estimated values	Observed values	Growth model
1	0.859	0.86	Gompertz model
2	1.333	1.39	
3	1.882	1.95	
4	2.469	2.61	
5	3.055	3.19	R^2=0.9979
6	3.613	3.72	
7	4.121	4.22	SE=0.0251
8	4.570	4.69	
9	4.957	4.99	MPE =0.0891
10	5.284	5.37	
11	5.556	5.69	SD =0.0454
15	6.227		
20	6.541		Y=6.68*exp (-2.61*exp (-0.241*X))
25	6.638		
30	6.667		
35	6.676		
40	6.679		
45	6.680		
50	6.680		

T_{10}-*Cassia siamea*

Age (years)	Estimated values	Observed values	Growth model
1	0.805	0.86	Gompertz model
2	1.266	1.31	
3	1.813	1.92	
4	2.411	2.56	
5	3.022	3.17	R^2=0.99865
6	3.615	3.88	
7	4.167	4.28	SE=0.02165
8	4.664	4.73	
9	5.099	5.1	MPE =0.09001
10	5.474	5.49	
11	5.790	5.82	SD =0..76942
15	6.594		
20	6.991		Y=7.18*exp (-2.76*exp (-0.232*X))
25	7.120		
30	7.161		
35	7.174		
40	7.178		
45	7.179		
50	7.179		

T_{11}-*Dalbergia sissoo*

Age (years)	Estimated values	Observed values	Growth model
1	0.622	0.910	Gompertz model
2	0.966	1.260	
3	1.508	1.710	
4	2.129	2.380	
5	2.780	2.810	R^2=0.9944
6	3.418	3.530	
7	4.011	4.190	SE=0.04591
8	4.540	4.620	
9	4.997	5.090	MPE =0.15335699
10	5.382	5.460	
11	5.700	5.780	SD =0.093458
15	6.466		
20	6.805		Y=7.94*exp (-3.29*exp (-0.256*X))
25	6.902		
30	6.929		
35	6.937		
40	6.939		
45	6.940		
50	6.940		

T_{12}-*Delonix regia*

Age (years)	Estimated values	Observed values	Growth model
1	0.846	0.56	Gompertz model
2	1.148	0.99	
3	1.495	1.38	
4	1.88	1.76	
5	2.293	2.19	R^2=0.99536
6	2.725	2.69	
7	3.165	3.26	SE=0.03124
8	3.604	3.68	
9	4.033	4.12	MPE =-0.0638
10	4.447	4.45	
11	4.841	4.7	SD =0.12016
15	6.159		
20	7.229		Y=8.44*exp (-2.65*exp (-0.142*X))
25	7.821		
30	8.129		
35	8.286		
40	8.363		
45	8.402		
50	8.421		

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T_{13}-*Emblica officianalis*

Age (years)	Estimated values	Observed values	Growth model
1	0.757	0.61	Gompertz model
2	1.213	1.19	
3	1.774	1.62	
4	2.410	2.33	
5	3.086	3.01	R^2=0.9944
6	3.767	3.61	
7	4.424	4.39	SE=0.0508
8	5.037	4.99	
9	5.592	5.43	MPE =-0.1098
10	6.085	5.99	
11	6.513	6.28	SD =0.0656
15	7.671		
20	8.303		Y=8.65*exp (-3.02*exp (-0.215*X))
25	8.530		
30	8.609		
35	8.636		
40	8.645		
45	8.648		
50	8.649		

T_{14}-*Eucalyptus citriodara*

Age (years)	Estimated values	Observed values	Growth model
1	0.813	0.970	Gompertz model
2	1.604	1.760	
3	2.625	2.530	
4	3.753	3.580	
5	4.864	4.810	R^2=0.9983
6	5.871	5.890	
7	6.729	6.880	SE=0.03955
8	7.429	7.340	
9	7.983	7.990	MPE =-0.00771
10	8.409	8.310	
11	8.733	8.670	SD =0.11633
15	9.387		
20	9.597		Y=9.65*exp (-3.41*exp (-0.321*X))
25	9.639		
30	9.648		
35	9.650		
40	9.650		
45	9.650		
50	9.650		

T_{15}-*Eucalyptus hybrid*

Age (years)	Estimated values	Observed values	Growth model
1	0.755	0.910	Gompertz model
2	1.490	1.610	
3	2.443	2.360	
4	3.501	3.410	
5	4.550	4.630	R^2=0.9988
6	5.507	5.610	
7	6.328	6.390	SE=0.03191
8	7.001	6.990	
9	7.536	7.210	MPE =-0.05821
10	7.952	7.580	
11	8.268	7.990	SD =0.18594
15	8.914		
20	9.125		Y=9.18*exp (-3.43*exp (-0.3173*X))
25	9.169		
30	9.178		
35	9.180		
40	9.180		
45	9.180		
50	9.180		

T_{16}-*Hardwickia binata*

Age (years)	Estimated values	Observed values	Growth model
1	0.676	0.950	Gompertz model
2	1.277	1.360	
3	2.043	2.120	
4	2.892	2.910	
5	3.739	3.780	R^2=0.9969
6	4.521	4.610	
7	5.202	5.290	SE=0.1366
8	5.771	5.820	
9	6.231	6.310	MPE =0.099634
10	6.595	6.780	
11	6.877	6.990	SD =0.07222
15	7.474		
20	7.684		Y=7.744*exp (-3.299*exp (-0.3022*X))
25	7.731		
30	7.741		
35	7.743		
40	7.744		
45	7.744		
50	7.744		

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T_{17}-*Anogeissus latifolia*

Age (years)	Estimated values	Observed values	Growth model
1	0.589	0.86	Gompertz model
2	1.186	1.29	
3	1.971	2.06	
4	2.854	2.99	
5	3.734	3.65	R^2=0.9962
6	4.541	4.61	
7	5.236	5.41	SE=15316
8	5.807	5.91	
9	6.261	6.29	MPE =0.078329
10	6.613	6.55	
11	6.882	6.92	SD =0.10077
15	7.429		
20	7.607		Y=7.654*exp (-3.524*exp (-0.3183*X))
25	7.644		
30	7.652		
35	7.653		
40	7.653		
45	7.653		
50	7.653		

T_{18}-*Inga dulce*

Age (years)	Estimated values	Observed values	Growth model
1	0.492	0.810	Gompertz model
2	1.074	1.260	
3	1.868	1.910	
4	2.768	2.550	
5	3.659	3.620	R^2=0.9931
6	4.461	4.510	
7	5.134	5.230	SE=0.29147
8	5.672	5.710	
9	6.089	6.020	MPE =0.02059
10	6.402	6.310	
11	6.635	6.550	SD =0.14686
15	7.081		
20	7.210		Y=7.239*exp (-3.789*exp (-0.3429*X))
25	7.234		
30	7.238		
35	7.239		
40	7.239		
45	7.239		
50	7.239		

T_{19}-*Peltoferrum ferrugeneum*

Age (years)	Estimated values	Observed values	Growth model
1	0.762	0.77	Gompertz model
2	1.295	1.36	
3	1.921	2.09	
4	2.574	2.68	
5	3.199	3.21	R^2=0.99783
6	3.760	3.55	
7	4.240	4.19	SE=0.04753
8	4.635	4.56	
9	4.952	4.99	MPE =0.02788
10	5.202	5.38	
11	5.396	5.47	SD =0.112312
15	5.807		
20	5.953		Y=5.9972*exp (-2.776*exp (-0.2972*X))
25	5.987		
30	5.994		
35	5.996		
40	5.997		
45	5.997		
50	5.997		

T_{20}-*Pongamia pinnata*

Age (years)	Estimated values	Observed values	Growth model
1	0.737	0.810	Exponential model
2	1.321	1.370	
3	1.958	1.880	
4	2.600	2.560	
5	3.221	3.310	R^2=0.9987
6	3.807	3.910	
7	4.355	4.490	SE=0.7327
8	4.862	5.010	
9	5.331	5.540	MPE =-0.56951
10	5.764	5.880	
11	6.163	6.010	SD =0.10793
15	7.485		
20	8.683		Y=14.884*exp (-12.477/(3.1516+X))
25	9.555		
30	10.216		
35	10.732		
40	11.147		
45	11.486		
50	11.770		

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T_{21}-*Prosopsis juliflora*

Age (years)	Estimated values	Observed values	Growth model
1	0.709	0.81	Gompertz model
2	1.379	2.06	
3	2.209	3.11	
4	3.085	4.32	
5	3.908	5.61	R^2=0.9989
6	4.620	6.61	
7	5.202	7.35	SE=0.1074
8	5.658	8.26	
9	6.005	8.76	MPE =-0.0217
10	6.263	8.9	
11	6.453	9.13	SD =0.1160
15	6.813		
20	6.916		Y=6.939*exp (-3.221*exp (-0.3449*X))
25	6.934		
30	6.938		
35	6.938		
40	6.938		
45	6.938		
50	6.938		

T_{22}-*Samanea saman*

Age (years)	Estimated values	Observed values	Growth model
1	0.802	1.01	Gompertz model
2	1.403	1.56	
3	2.145	2.38	
4	2.960	2.99	
5	3.779	3.76	R^2=0.9982
6	4.550	4.61	
7	5.238	5.38	SE=0.10406
8	5.828	5.99	
9	6.320	6.41	MPE =0.102446
10	6.721	6.82	
11	7.043	7.01	SD =0.08791
15	7.769		
20	8.058		Y=8.158*exp (-3.0564*exp (-0.2759*X))
25	8.132		
30	8.151		
35	8.156		
40	8.157		
45	8.157		
50	8.157		

T_{23}-*Syzygium cumini*

Age (years)	Estimated values	Observed values	Growth model
1	0.736	0.830	Gompertz model
2	1.111	1.210	
3	1.546	1.620	
4	2.014	2.110	
5	2.491	2.560	R^2=0.9976
6	2.952	2.990	
7	3.384	3.420	SE=0.07545
8	3.774	3.810	
9	4.120	4.280	MPE =0.056182
10	4.419	4.460	
11	4.675	4.550	SD =0.07098
15	5.342		
20	5.688		Y=5.8668*exp (-2.591*exp (0.2213*X))
25	5.807		
30	5.847		
35	5.860		
40	5.865		
45	5.866		
50	5.867		

T_{24}-*Tamarindus indica*

Age (years)	Estimated values	Observed values	Growth model
1	0.893	0.760	Gompertz model
2	1.262	1.560	
3	1.683	2.280	
4	2.137	2.970	
5	2.606	3.310	R^2=0.9953
6	3.073	3.760	
7	3.524	4.010	SE=0.1082
8	3.949	4.420	
9	4.341	4.790	MPE =0.46213
10	4.695	5.010	
11	5.012	5.390	SD=0.25991
15	5.927		
20	6.500		Y=6.904*exp (-2.46*exp (-0.185*X))
25	6.741		
30	6.840		
35	6.879		
40	6.894		
45	6.900		
50	6.903		

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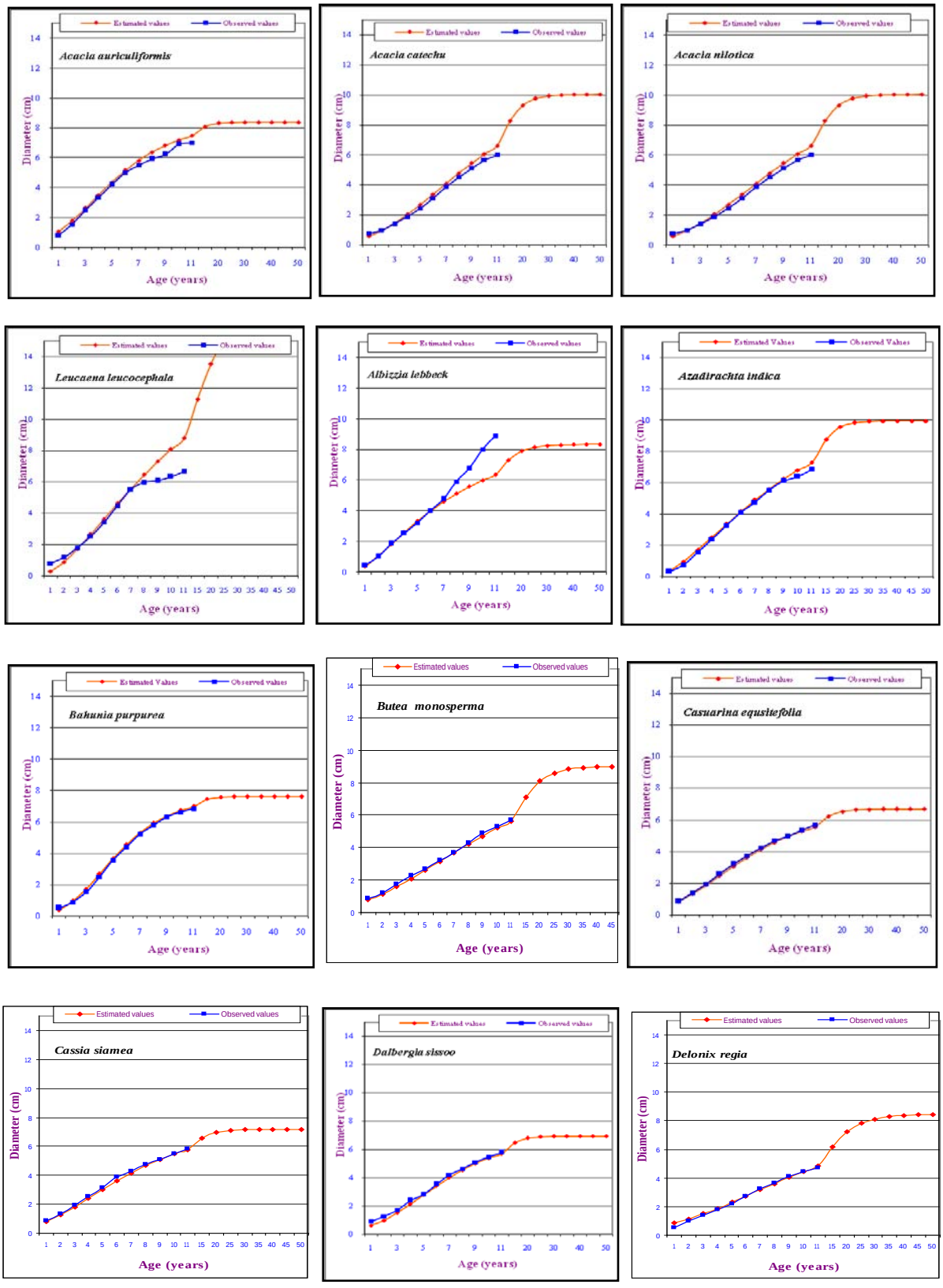
Figure 1 : Diameter-Age growth curves of different tree species under semi-arid regions of north Karnataka



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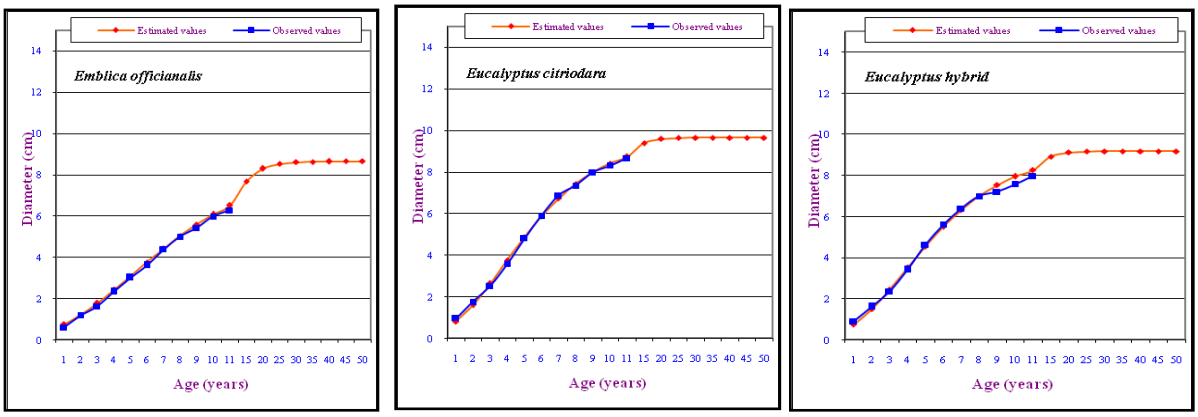

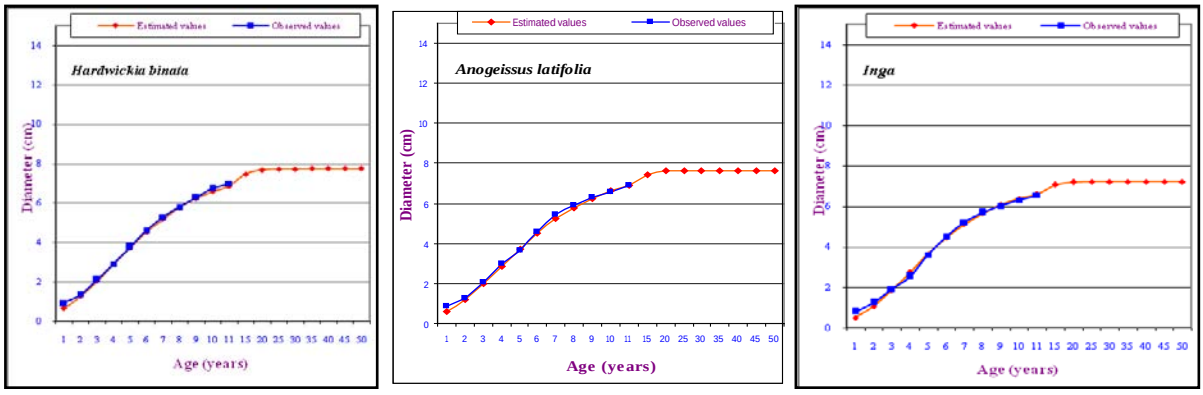

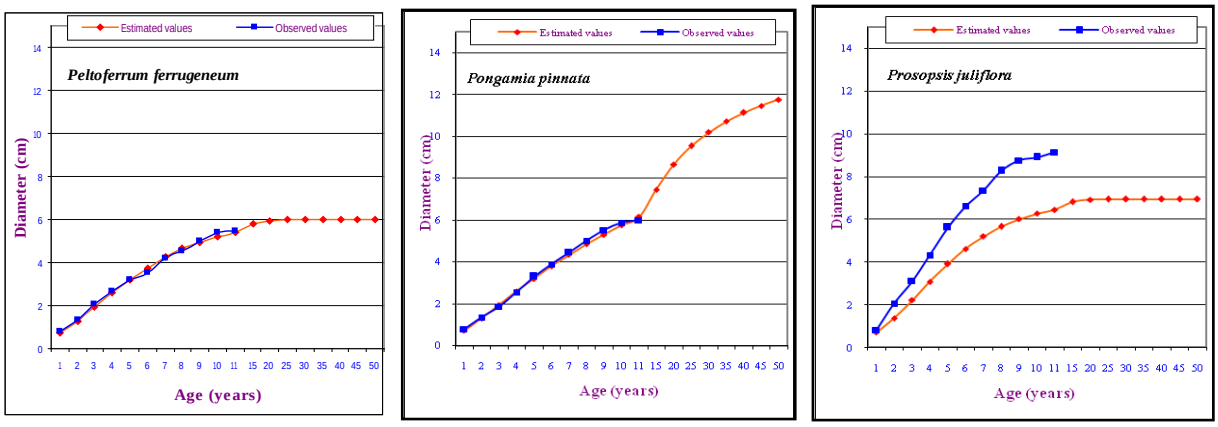

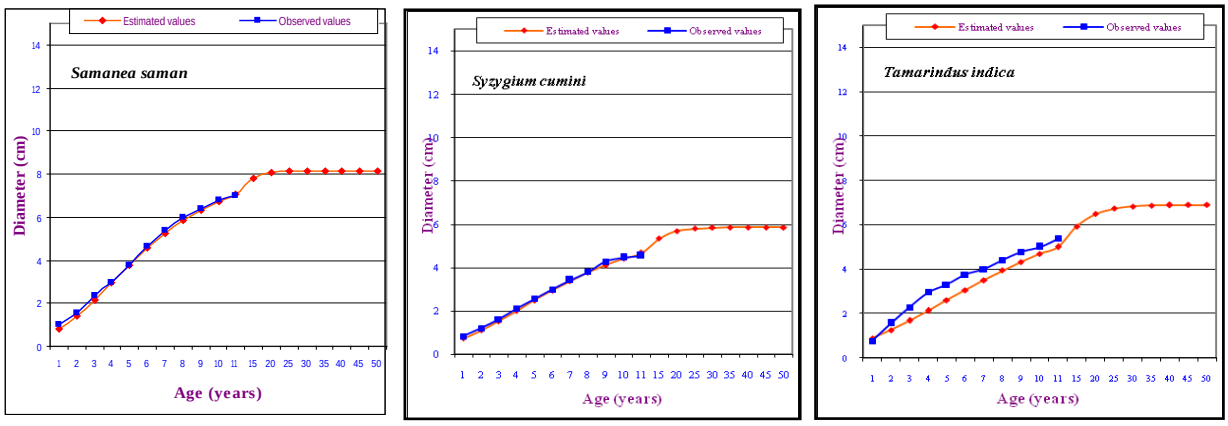

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- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
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- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

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- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

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Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
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Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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Index

A

Alternaria · 1, 2, 3, 4, 5, 7
Auriculiformis · 15, 16, 17, 19, 29, 30, 31, 33

B

Baldcypress · 27, 41

C

Chattannavar, · 4, 5
Climatological · 10

E

Exogenously · 12

I

Infrastructure · 8
Interdisciplinary · 41

L

Liberalization · 10

O

Oxychloride · 1, 2, 3, 4

P

Propiconazole · 1, 5
Pseudomonas · 2, 4, 5

Q

Questionnaire · 10

R

Randomized · 1

S

Streptocycline · 1, 2, 3, 4

U

Unconstrained · 12

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ISSN 9755896

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