APPLICATION OF PROBABILITY DISTRIBUTION AND STATISTICAL MODELS FOR PRODUCTIVITY OF *Acacia mangium*

Thesis submitted to the
University of Agricultural Sciences, Dharwad
in partial fulfillment of the requirements for the
Degree of

MASTER OF SCIENCE (AGRICULTURE)

IN

AGRICULTURAL STATISTICS

By

SHILPA V.

DEPARTMENT OF AGRICULTURAL STATISTICS
COLLEGE OF AGRICULTURE, DHARWAD
UNIVERSITY OF AGRICULTURAL SCIENCES,
DHARWAD - 580005

MAY, 2013

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1. INTRODUCTION

India has a Geographical area of 3,287,240 sq. km. It is the seventh largest country of the world after Russia (1,70,75,000 sq. km), Canada (99,76,132 sq. km), China (99,76,132 sq. km), the U.S.A. (90,72,340 sq. km), Brazil (85,11,965 sq. km) and Australia (76,82,300 sq. km) (Jacob P. Koshy, 2012). India accounts for about 2.4 per cent of the total surface area of the world. India's Forest Cover accounts 6, 84,340 (sq. km) which is 23.81% of its total geographical area of the country as of 2010 (According to a World Bank report published in 2012). Forest cover of the country as per the present assesement is 67.71million hactare, out of this,5.46m ha is very dense forest, 33.26 million ha is moderately dense and rest 28.99m has open including 0.44m ha mangroves. However excluding the area (18.16m ha.) not available for tree planting/afforestation due to climate/rocks etc., Approximately 1.2 billion people, making 20% of the world's population depend directly on agroforestry products and services in rural and urban areas of developing countries (Leakey and Sanchez, 1997). Almost, the entire 76 million ha recorded forest area is owned and managed by the State Governments in India. India occupying just 2.5 per cent of the land area of the planet earth has to support nearly 15 per cent of the world's human population and equally large, but mostly unproductive livestock. Therefore, the forests are under intense biotic pressures leading to degradation of forest re. In India, 32 million ha of forest area has less than 40 per cent crown cover density. Forests in India have very low (65 m^3/ha) growing stock compared to the world average of 110 m^3/ha. Likewise, mean annual increment is very low at 0.5 $m^3ha^{-1}yr^{-1}$ compared to the world average of 2.1 $m^3ha^{-1}yr^{-1}$.

Agroforestry is receiving long overdue attention as a resource efficient, environmentally positive and proModelable method of farming. Incorporating trees in farming and range management can provide many beneModels. Agroforestry is a collective name for land use systems involving trees combined with crops and animals on the same unit of land. It actually involves cycling of nutrients and flow of energy through various tropic levels interacting positively with higher ecological efficiency. From the early *taungya* systems to scattered trees on farm lands, agrisilviculture, silvipasture, agrihorticulture, hortipasture, energy farms, farm boundary planting, aquaforestry, home garden, slash and burn agriculture etc. are various forms of Agroforestry systems practised throughout India. Agroforestry means many things to different people.

It is often applied to the integration of trees, typically one species grown for timber, with pasture; but it may also include more complex systems that include trees with a variety of crops, both annual and perennial species, and animals. The definition developed by Lundgren and Raintree (1982) is one of the simplest and most comprehensive, i.e. "Agroforestry is a collective name for land-use systems and techniques where trees are deliberately used on the same land management unit as agricultural crops and or/animals, either in the same form of spatial arrangement or temporal sequence. In agro-forestry systems there are both ecological and economic (*and cultural*) interactions between the different components."

The advantages of agroforestry systems include the potential for increased resource use efficiency both above and below ground, with roots reaching 10-80 meters depth of some trees and canopies reaching 5-70 meters high. Trees can draw upon re, groundwater, nutrients, etc., that are unavailable to annual plants. Trees are often immune from all but the most severe droughts and can provide emergency fodder for animals when nothing else is available. Trees can also provide many other beneModels, including reduction in pest problems, sale including: firewood, biofuel, timber, food, fodder, building material, material for tools, fiber, medicine,etc. A number of other beneModels include soil improvement, shade, windbreak, groundwater management, erosion control, habitat for wildlife, and, selenium harvesting. This wide range of products and purposes combine with the increased resource base to help minimize risk for the farmer. By spreading out cultural and management requirements over the year these systems can also reduce peak workloads and ensure a more stable economy. These beneModels and advantages have become increasingly well known and appreciated in recent years, although J. R. Smith first described them almost sixty years ago (Smith, 1929).

Growth is a fundamental property of biological systems, occurring at the level of populations, individual animals and plants, as well as within organisms. Much research has been devoted to Modeling growth processes, and there are many ways of doing this, including: mechanistic Models, time series, stochastic differential equations etc. Sometimes we simply wish to summaries growth observations in terms of a few parameters, perhaps in order to compare individuals or groups.

Growth refers to the increase in dimensions of one or more individuals in a forest stand over a given period of time (eg. volume growth in m^3/ha/ y). Yield refers to their final dimensions at the end of a certain period. (eg. volume in m^3/ha). In even-aged stands, a growth equation might predict the diameter growth, basal area or volume in units per annum as a function of age and other stand characteristics, whereas a yield equation would predict the diameter, stand basal area or total volume production attained at a specified age. In an uneven-aged stand, yield is the total production over a given time period, while growth is the rate of production. Growth and yield are related mathematically (if yield is y, growth is the derivative dy/dt).

A statistical Model is a set of mathematical equations which describes the behaviour of an object of study in terms of random variables and their associated probability distributions. If the Model has only one equation it is called a single-equation Model, whereas if it has more than one equation, it is known as a multiple-equation Model.

In mathematical terms, a statistical Model is frequently thought of as a pair (Y, P) where Y is the set of possible observations and P the set of possible probability distributions on Y. It is assumed that there is a distinct element of P which generates the observed data. Statistical inference enables us to make statements about which element(s) of this set are likely to be the true one.

Three notions are sufficient to describe all statistical Models.

- ❖ We choose a statistical unit, such as a person, to observe directly. Multiple observations of the same unit over time are called longitudinal research. An Observation of multiple statistical attributes is a common way of studying relationships among the attributes of a single unit.
- ❖ Our interest may be in a statistical population (or set) of similar units rather than in any individual unit. Survey sampling offers an example of this type of Modeling.
- ❖ Our interest may focus on a statistical assembly where we examine functional subunits of the statistical unit. For example, Physiology Modeling probes the organs which compose the unit. A common Model for this type of research is the stimulus-response Model.

Modelling:- The goal of Modelling is to understand reality mathematically. A Model is considered a simplified representation of reality. Many complex interactions and results are depicted with simplicity to reach a decision.

It is expected to be a good representation of those factors that influence production and management. Modeling has been used in natural sciences since centuries in one way or the other. Models have been built in the physical, biological and social sciences.

Various researches have defined modeling in their own way viz.

- ✓ "Modeling is described as a representation of our so called 'real world' in mathematical terms", so that we may gain a more precise understanding of its significant properties, and which may hopefully allow some forms of prediction of future events.
- ✓ Model is reality scaled down and converted to a form we can comprehend.
- ✓ A mathematical Model is a Model whose parts are mathematical concepts, such as constants, variables, functions, equations, in equalities etc.

Purpose of Modelling:

- ✓ Foremost among these is the need to predict new results, or new features, which may be of the form of extension of existing results, or of a more radical nature. The predictions are often of conditions likely to exist at some future data there may on the other hand, be predictions of events for which direct experimental evidence is unobtainable.
- ✓ Not all situations are modeled for this purpose. In some, it is sufficient to be able to describe the working of the system by mathematical means in order to obtain a greater understanding; many of great physical theories do this, although they make predictions as well. What is not usually involved in such descriptions is an element of control.
- ✓ It is useful to draw a distinction between Models for understanding and Models for prediction and to assist management in the making of decisions.
- ✓ Building a Model can help to analyze data from experiments and observation plots.
- ✓ It can help to synthesize and communicate existing knowledge and to identify gaps inour understanding.
- ✓ It can help to focus research plans and to anticipate results, so that measurement programmes and techniques can be planned accordingly.
- ✓ Modelling may be the most efficient way to examine experimental data, investigate implication sand formulate optimal silvicultural guidelines.
- ✓ One of the most enduring uses of Modelling in forestry is for growth and yield prediction.

ROLE OF FOREST MODELS

Growth estimation of living trees and stands is needed by managers for many purposes which including:

- Yield prediction,
- Long term productivity monitoring,
- Socio economic analysis of forest influences,
- Marketing, and
- Planning for harvesting.

Why we use Modelling in agroforestry

In agroforestry tree component is retained for a long period of time (say 8 to 35 years or more).

Now to develop growth and yield Models, one has to harvest trees at different intervals to get a complete range of data. It amounts to say that we will have to wait for years together to get the growth / yield information of the tree component. However, using the Modelling tools we can predict the growth / yield of the tree component at a very early stage.

Probability Distributions*:* Probability distributions are a fundamental concept in statistics. They are used both on a theoretical level and a practical level.

The mathematical definition of a discrete probability function, p(x), is a function that satisfies the following properties

1. The probability that x can take a specific value is p(x). That is

   $$P[X = x] = p(x) = p_x$$

2. p(x) is non-negative for all real x.
3. The sum of p(x) over all possible values of x is 1, that is

$$\sum_j p_j = 1$$

Where, j represents all possible values that x can have and p_j is the probability at x_j.

Some practical uses of probability distributions are:

- To calculate confidence intervals for parameters and to calculate critical regions for hypothesis tests.
- For univariate data, it is often useful to determine a reasonable distributional Model for the data.
- Statistical intervals and hypothesis tests are often based on specific distributional assumptions. Before computing an interval or test based on a distributional assumption, we need to verify that the assumption is justified for the given data set.

Acacia mangium (mangium)

Acacia mangium is indigenous to North Eastern Australia and Eastern Indonesia. *Acacia mangium* was introduced in India during 1990 and its cultivation is mainly confined to high rain fall areas like Western Ghats of Karnataka and Kerala, North Eastern hill regions and Eastern coasts. In Karnataka it was introduced about two decade back in the Southern part of the Western ghats. At present, *Acacia mangium* is cultivated over an area of 3000 ha in the state and an increase of 150 ha annually in last couple of years (Patil *et al*., 2012)

Acacia mangium also known as mangium is one of the most widely used fast-growing tree species. *Acacia mangium* is an important multipurpose and nitrogen fixing tree species for low lands. Its desirable properties include rapid growth, good wood quality and tolerance of a wide range of soils and environments. *Acacia mangium* grows up to 30 meters tall, often with a straight trunk.

Due to its rapid growth and tolerance of very poor soils, *Acacia mangium* is playing an increasingly important role in efforts to sustain a commercial supply of tree products viz., fuel, wood, timber, poles etc., while reducing pressure on natural forest ecosystems.

Acacia mangium grows fast; it can achieve a mean annual diameter increment of up to 5 cm and a height of up to 5 m in the first 4-5 years. It is reported to grow 3 m tall in the first year in Sabah and Sumatra, and in the Philippines it reached an average height of 8.3 m and diameter 9.4 cm after 2 years.

However growth declines rapidly after 7 or 8 years. Except under ideal conditions or over periods of more than 20 years, the tree will probably not exceed 35 cm in diameter and 35 m in height. In Sabah, 14-year-old trees were 30 m tall and 40 cm in diameter (Maarito Kallio, 2011).

Optimal growth of trees is achieved most effectively if vesicular arbuscular mycorrhizal fungi such as *Glomus fasciculatus* and *Gigaspora margarita* are present in combination with Rhizobium. Technologies for the commercial production of rhizobial and VAM innoculants are now available in Southeast Asia.

Acacia species are pioneers that demand full light for good development; in shade, *Acacia mangium* growth is stunted and spindly. Trees are renowned for their robustness and adaptability, which makes them good plantation species. Survival rate of *Acacia mangium* is high, 60% when planted as a wind break in Imperata grassland and over 90% when planted on more favourable sites.

Plantation canopy cover occurs after 9 months to 3 years, depending on soil fertility, weediness and initial spacing. In Sabah in a plantation with an initial spacing of 3 x 3 m, the canopy closed in first year. In the first year, the plantation should be protected from livestock, as they browse the trees, and it should be weeded, taking particular care to remove climbers, creepers and vines. *Acacia mangium* has been found very sensitive to herbicides. As trees have a tendency to produce multiple leaders from the base, singling is carried out at 4-6 months after planting.

Taxonomy

- Botanical name : *Acacia mangium* Willd.
- Family : Leguminoseae
- Subfamily : Mimosoideae
- Synonyms : *Rancosperma mangium* (Willd.) Pedley
- Vernacular/common names: Common names in Indonesia: mangga hutan, tongke hutan (Ceram), nak (Maluku), laj (Aru), Jerri (Irian Jaya).
- Common names in other countries:black wattle, brown salwood, hickory wattle, mangium, sabah salwood (Australia, England); mangium, kayu SAFODA (Malaysia);

Uses

- The pulp is suitable for the manufacture of bags, wrapping papers.
- *Acacia mangium* wood is used for making attractive furniture, door frames, window parts, moldings, agriculture implements,
- The leaves can serve as forage for livestock.
- Fallen branches and dead leaves can be used as fuel.
- The saw dust provides good-quality substrate for edible mushrooms.
- *Acacia mangium* helps in fixing the atmospheric nitrogen and increases soil biological activity and rehabilitates the physical and chemical properties of the soil.
- *Acacia mangium* trees can also be used as fire breaker tree with diameters of 7 cm or more are commonly fire resistant.

Global distribution:

Acacia mangium has been introduced to Bangladesh, Cameroon, Costa Rica, Hawai'i, Indonesia, Malaysia, Nepal, Papua, and the Philippines. Duke *et al* (1983) report the following. "Often in grasslands and on margins of lowland primary forests altitudes of 10-50 m (33-164 ft). Probably capable of ranging from 3 tropical very dry to moist through subtropical dry to wet forest life zones. *Acacia mangium* withstands annual precipitation of 10 to 45 dm (40 to 180 in) or more and mean maximum temperature of 31-34 C (88-93 F) in summer and 12-25 C (54-77 F) in winter."

Wood:

India is a significant importer of forest products. Logs account for 67 percent of all wood and wood products imported into India due to local preference for unprocessed wood. In trade year 2008-2009, India imported logs worth $1.14 billion, an increase of about 70% in just 4 years.Indian market for unprocessed wood is mostly fulfilled with imports from Malaysia, Myanmar, China etc..Indian market are growing for partially finished and ready-to-assemble furniture.

India imports small quantities of temperate hardwoods such as ash, oak, walnut, beech, etc. as squared logs or as lumber. India is the world's third largest hardwood log importer.In 2009, India imported 332 million cubic meters of roundwood mostly for fuel wood application, 17.3 million cubic meters of sawnwood and wood-based panels, 7.6 million metric tonnes of paper and paperboard and about 4.5 million metric tonnes of wood and fiber.

Characteristics of *Acacia mangium* wood

- *Acacia mangium* wood is diffuse and porous.
- The sapwood of *A. mangium* is narrow and light coloured.
- *Acacia mangium* is a medium weight hardwood.
- The heartwood is pale olive-brown, grey brown to pink, darkening to a reddish brown or dark red, and often attractively streaked.
- *Acacia mangium* has a density of 560–1000 kg/m3 at 15% moisture content. The grain is straight to shallowly interlocking with an even, fine to medium texture.
- *Acacia mangium* wood is easy to work with all tools. It planes easily to a smooth, lustrous surface using cutting angles of 15–25° and finishes well with sharp tools.

Special features of study

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. Appropriate statistical Models are used for predicting the yield of component crops in agroforestry systems. Growth Models may also have a broader role in forest management and in the formulation of forest policy.Growth Models can be used for prediction of productivity of *Acacia mangium* and it also helps us to know the appropriate spacing and fertilizer dosage required to attain maximum plant height for different Sources. With these ideas an effort was made to address the following objectives.

Objectives

- To identify suitable statistical Models for estimating the productivity (height/dbh) of *Acacia mangium* in respect of different Sources, fertilizer level and spacing.
- To Model the suitable probability distribution for growth (height/dbh) in respect of different Sources, fertilizer level and spacing in selected combination.

a) Sources:-Kerala, Bangalore, Chikkamangalore, Thirthahalli.

b) Fertilizer:-25:50:25, 50:100:50, 75:150:75 NPK gm/tree.

c) Spacing:-4x1 m, 4x2m, 4x3m.

2. REVIEW OF LITERATURE

The universal acceptance of Statistics as an essential tool for all types of analysis for all areas of research has made to study the different statistical techniques used in data analysis. Selecting suitable statistical procedures for given experiment must be based on expertise in statistics and in subject matter of research /experiment. Some of the important review of past research works in the field has been compiled to enable better understanding of the research in various regions, method of analysis on the research subject.

The chapter is presented under the following headings:

2.1 To identify suitable statistical Models for estimating the productivity (height/dbh) of *Acacia mangium* in respect of different Sources, fertilizer level and spacing.

2.2 To Model the suitable probability distribution for growth (height/dbh) in respect of different Sources, fertilizer level and spacing in selected combination.

2.1 To identify suitable statistical Models for estimating the productivity (height/dbh) of *Acacia mangium* in respect of different Sources, fertilizer level and spacing.

Graham *et al*. (1985) conducted study on the general uses of Models to forecast growth and yield to quantify a scientific hypothesis and to explore the logical outcome of a series of hypotheses which are difficult to test experimentally. They designed a Model to explore the logical outcome of series of hypotheses on climatic control of productivity. The Model which was intended to predict a single year was driven by daily air temperature, RH, wind speed, precipitation and incoming solar radiation. Its uses were discussed in locating and designing field experiments and in making educate judgments about current practical management.

Holdaway (1986) conducted study on Modelling tree crown ratio data on 71373 trees from forest surveys in Wisconsin and Minnesota were used to develop a Model for estimating crown ratio from stand B.A. (Basal Area) and individual stem dbh the variables reflect general competition for light within a stand and the ability of an individual tree to compete. Validation of the Model with data on 150000 trees in Wisconsin, Minnesota and Michigan showed that the mean error in crown ratio estimation was -2% for conifers and +3% for broadleaved species.

Jain *et al.* (1991) developed regression equations (Volume) over bark =-0.00458 +0.000361*D^2H and (Volume) under bark =-0.046176 + 0.00087438*D2 representing the relations between volume and diameter at breast height. The independent variables considered were D^2H and D^2. They also reported that it is often difficult, and even erroneous, to Model a single equation to the whole range of diameters, and in these cases it is advisable to divide the diameter range into small segments and derive a Model (equation) for each separately.

This technique was applied to diameter and volume data from two types of Eucalyptus plantations in the Punjab block unirrigated plantations and canal side strip plantations. The 'piecewise' Models were shown to give more accurate results than a single Model, and based on these, local volume tables were presented for both plantation types, giving total volumes over and under bark over a 10-40 cm DBH range for both types of plantation.

Pinol (1994) has derived that the yield prediction functions for both total merchantable and sawn timber yield for teak (*Tectona grandis*) plantations for 282 temporary sample plots by regression analysis. The temporary plots represented a wide range of site qualities, stand densities and ages of teak in the Philippines. Point sampling was used to gather data. The yield Models derived was expressed as functions of stand age, site index and initial spacing. Separate tree volume equations for total merchantable tree volume and sawn timber tree volume were derived from 224 sample trees. A site index guide equation and plot site index equation at 40-years base age were also developed.

Eero Forss *et al*. (1996), conducted a study on Growth Models for unthinned *Acacia mangium* plantation in south Kalimantan in Indonesia, sample size of 24 unthinned semipermanent plots were selected for the study, the data was analysed using statistical tools like Chapman and Richards Model, stand level growth Models. The results showed that the coefficient is β=0.78592, and error of prediction in the Model is 0.213(n=2615). The standard error of the estimate for β is 0.00392.

Latif, *et al.* (1997) developed Models to estimate the stand dominant height, stand height, stand diameter, stand basal area growth and stand volume yield per hectare. The yield prediction Models derived in the study could satisfactorily be used for moluccana plantations within a stand age of 1-12 years and site indices of 12.0 to 32.0 m based on a base age of 12 years.

Du ji Shan *et al*. (1998) used Richards's growth Model and the Schumacher growth Model, which include stand density index, age and site quality index as parameters for basal area growth prediction Models, Based on a survey of 14 unthinned plots and 36 thinned plots of *Cunninghame lancelet* from Jiangxi Province were included for the study and reported that the Richards Model Models the data better than the Schumacher Model, and that the Richards Model can be used for basal area prediction in both thinned and unthinned stands of *Cunninghame lancelet*.

Rajiv pandey *et al*. (1998) used measurements made on felled trees of *Populous deltoids* 'G-3' from a sample population in a plantation at the experimental farm in Himachal Pradesh (India) to investigate the suitability of six volume prediction Models based on tree height (h) and diameter at breast height (d). The measurements made on the trees included h, d and actual volume. The Models were assessed using both the criterion of R^2 >0.9, and a cross-validation technique. Models with R^2 >0.9 did not pass the entire validation test. Two volume estimation Models are recommended on the basis of the analysis, one based on a function of in (DH) and the other on a function of DH; both provide values of ln (V).

Thapa (1999) conducted biomass study of *Acacia auriculiformis*, *A. catechu*, *Dalbergia sissoo*, *Eucalyptus camaldulensis* and *E. tereticornis* on a five and Half-year-old Fuelwood Species Trial under Short Rotation' through destructive sampling at Tarahara, Sunsari District of Nepal. The lowest Furnivall Index (FI) was the main criteria for selecting a Model. Among the six Models tested, a transformed Model from a power equation was selected. Selected prediction Models of tree components and aboveground wood (green as well as oven dry), and their coefficient of determination (R^2) values, regression constant and coefficient, correction factor, precision and bias per cent of five species are presented. With the exclusion of branch wood Models; R^2 is higher in a range of 88.7% for oven dry stem wood of A. catechu to 99.3% for aboveground wood Model of *D. sissoo*. However, R^2 is less than 80% in branch wood (green and oven dry) of A. *auriculiformis*, *E. camaldulensis* and *E. tereticornis* showing moderate relationship between branch wood and diameter at breast height. In the case of *E. tereticornis*, precision is more than 49% which leads to low reliability in biomass estimation resulting in true biomass deviation in a range of approximately 49.51 to 56.74%, so biomass Models could not be used for estimation of tree components and aboveground wood. Despite it, generally, precision per cent of the selected Models has been found less than 15%. Bias per cent was found quite large for allometric branch wood Model comparatively to stem wood and aboveground wood Models. *D. sissoo* had less than 10% bias. Bias per cent was the highest (23.11%) for green branch wood *of A. auriculiformis*. Others had in a range of 0.5% for green aboveground wood Model of D. sissoo to 18.4% for green and oven dry branch wood Models of *E. tereticornis.*

Li Feng Ri *et al*. (2000) presented a theoretical derivative of the generalized korf growth equation based on the biological characteristics of the tree growth and made comparisons with other growth Models (Logistic, Mitscherlich, Gompertz and Chapman-Richards). The Korf equation is regarded as a general growth function and can be used in two ways associated with the value of the power exponent p of the innate growth rate, q, in the equation. These are the Korf-A equation (p>1) and the Korf-B (0<p<1). The Gompertz equation (p=1) Models between these two Korf equations, but all three types are independent. After discussing the properties of the two Korf equations they concluded that the Korf-A equation could be used to describe the growth of trees, while the Korf-B equation could be applied to describe biological population growth.

Rahaman and Ahmad (2000) considered the current growth estimation and future yield prediction Models of gamar (Gmelina arborea) using data from 171 plots in Chittagong Hill Tracts, Bangladesh. All plots were laid in well-stocked gamar plantations of every age class from 1 to 17 yr. Twenty of the 171 sample plots were selected and kept separately to validate the growth and yield Models. Data from the remaining 151 plots were used to formulate the Models which include stand diameter and height function, number of trees per hectare prediction Model, basal area and stand volume equation. The derived Models would help to determine the optimal harvest age of gamar plantation and prescribe the best financial investment in forestry compared with other competing uses of land.

Wang jing *et al*. (2000) developed tree growth prediction Models based on grey system theory by utilizing data from 202 temporary plots and stem analyses of 206 trees of Dahurian larch (*Larix gmelinii*) in 10 forestry bureaux of Yakeshi Forestry Administrative Bureau in the Daxing'an Mountains of the Inner Mongolia Autonomous Region [Nei Menggu], China. The precision of the Models was evaluated by residual and posterior residual tests was noticed that dbh and volume and concluded that the Grey System Models performed better than statistical Models.

Liu-JianQuan and Chen Jiang (2003) showed based on actual height increment and its corresponding central diameter, the growth of tree height and diameter of 21-year-old Pinus sylvestris var. mongolica plantations in Jiayuguan and Jiuquan, Gansu, China, was studied and a correlation formula for growth and meteorological factors was established. The meteorological and soil factors influencing growth of P. sylvestris var. mongolica were analysed using computer software.

Results indicated that annual evaporation, sun lighting, <more or =>10 degrees C accumulated temperature, extreme high temperature, total cation, total anion, and total salt were the dominant factors. On the other hand, average temperature, frostless period, extreme low temperature, pH value, total K and organic matter were the secondary factors. Annual precipitation, temperature diurnal range and total N were the supplemental factors. Two prediction Models which can be used to predict tree height and diameter as well as to manage P. sylvestris var. mongolica were developed.

Bechtold (2004) reported that the mean crown diameters of stand-grown trees 5.0-in diameter at breast height and larger were Modelled as a function of stem diameter, live-crown ratio, stand-level basal area, latitude, longitude, elevation, and Hopkins bioclimatic index for 53 tree species in the western United States. Stem diameter was statistically significant in all Models, and a quadratic term for stem diameter was required for some species. Crown ratio and/or Hopkins index also improved the Models for most species. A term for stand-level basal area was not generally needed but did yield some minor improvement for a few species. Coefficients of variation from the regression solutions ranged from 17 to 33percent and Model R^2 ranged from 0.15 to 0.85. Simpler Models, Based solely on stem diameter, are also presented.

Newaz and Mustafa (2004) have developed the growth and yield prediction Models for hybrid acacia (Acacia auriculiformis x A. mangium) using simultaneous equation method. Models were selected for the species to estimate the stand height, stand dominant height, stand diameter and stand basal area per hectare and total volume yield per hectare. Paired t test, 45-degree line test, percent absolute deviation and biological principle of stand development were used for the validation of chosen Models. The results suggest that the Models derived were statistically and biologically acceptable and could be satisfactorily used for stands of Hybrid Acacia of ages 4-7 years based on a base age of 6 years in the central region of Bangladesh.

Harwood et *al*. (2004) conducted a study on The Effect of Inbreeding on Early Growth of *Acacia mangium* in Vietnam, samples were collected from six seed orchards of *Acacia mangium* in different locations in Vietnam and were analysed using a non-orthogonal analysis of variance, the result showed a significant reduction of 15% in mean height and 16% in mean dbh at age 18 months. This conclusion is based on 32 maternal genotypes across five orchards, and a larger number of paternal genotypes. The lack of significance of the family-by crossing status interaction also supported the generality of inbreeding depression of growth in *A. mangium*.

Maheshwarappa *et al.* (2004) while developing prediction Models for estimation of pink disease development in Acacia hybrid plantation made an assessment of the disease severity using 0-3 scale in three plantations of the Hosanagar Division. The observed Disease Severity Index (DSI) values were fitted to autoregression method for calculating the disease severity in relation to time. The autoregression Model Fitted with auto correlation coefficient R=0.976. Similarly, the disease severity was predicted using Logistic Model with coefficient of determination R^2=0.945 and estimated DSI Y=5.59+0.16x. Since the autocorrelation coefficient value in autoregression method is high (0.967) which is robust method.

Zhang *et al.* (2004) derived Prediction Models of foliage and branch biomas based on the foliage distribution within the crown and the pipe Model theory. Resulting Models were fitted for data collected from intensively managed loblolly pine (*Pinus taeda* L.) plantations in the Lower Coastal Plain and Piedmont of Georgia. They found that diameter outside bark at the base of the live crown, crown height, and crown length is key predictors of foliage biomass. Together they produce reliable predictions of foliage and branch biomass for stands managed under a wide array of silvicultural treatments. The Model indicates that an annual fertilization treatment significantly increased foliage and branch biomass in the Lower Coastal Plain. However, in the Piedmont, complete control of competing vegetation significantly increased foliage and branch biomass. It was found that a significant fertilization-age interaction for foliage and branch biomass was also in Piedmont stands.

Shah Newas *et al.* (2005) conducted a study on growth and yield prediction Models for *Acacia (A.auriculiformis x A.mangium)* Grown in the plantations of Bangladesh, the sample size of 317 individual *acacia* hybrids were selected, the data was analysed using the simultaneous eqation method, yield and site index Models, the results showed that the Models derived were statistically and biologically acceptable and could be satisfactory.

Irianto *et al*. (2006) conducted a study on Incidence and spatial analysis of root rot of *Acacia mangium* in Indonesia, the sample size of 500 trees were selected for the study, the data was analysed using the statistical tools like ANOVA using SAS, histogram, normal distribution, GenStat, generalized linear mixed Model the results showed that GLMM statistical analysis revealed there were no significant differences between provenances (p = 0.353). A large range in root rot incidence was detected (3.2–28.5%) in the plantations surveyed.

Venn *et al*. (2006) conducted a study on stand yield Models for Australian *Eucalypt* and *Acacia mangium* plantations in the Philippines. The Models are of the Chapman-Richards type. Industrial *A. mangium* plantations are estimated to yield a total of 322 m3/ha over a 13-year rotation, while farm plantations are estimated to yield 76 m3/ha over a 9-year rotation. Over a 75-year rotation, industrial plantations of average Australian eucalypts are predicted to yield 280 m3/ha, while farm plantings are estimated to yield 74m3 / ha over a 10-year rotation. Industrial plantings of Australian species provide yields comparable to those for traditional species; however, smallholder yields are unexpectedly poor.

Newaz and Kamaluddin (2006) noticed that Acacia auriculiformis is a very fast growing species belonging to the family Leguminosae that have been introduced in the plantations in Bangladesh for their faster growth and wide range of adaptability. The present study aimed at development of growth and yield prediction Models for the species using simultaneous equation method. Models were selected for the species to estimate the stand height, stand dominant height, stand diameter, and stand basal area per hectare and volume yield per hectare. Paired t-test, 45-degree line test, per cent absolute deviation and biological principle of stand development were used for the validation of chosen Models. The results suggest that the Models derived were statistically and biologically acceptable and could be satisfactorily used for stands of Acacia auriculiformis of ages 3-9 years and site indices of 13.47 to 19.20 m based on a base age of 6 years in the central region of Bangladesh.

Raizada *et al.* (2007) biomass predicted Models for 17 year old Acacia nilotica trees raised on salt affected vertisols of the semi and tropics in Karnataka, India. A. nilotica was raised at 8x8 m spacing with an under storey of three grass species - Cenchrus ciliaris, Dicanthium annulatum and Chloris bourneii for the production of fodder. Wide variations occurred in the trees sampled by random selection in the plantation, with respect to diameter (3.1 to 16 cm) and tree height (3.5 to 5.1 m). Leaf biomass varied from 0.5 to 3.1 kg/tree, contribution by big branches (>2 cm diameter) varied from 3.81 to 24.13 kg/tree.

Total above ground biomass ranged from 26.5 to 100.74 kg/tree. Prediction Models with the best Model were in the linear form with R^2 values of 0.8261, 0.9162 and 0.8665 for predicting bole, utilizable and total above ground biomass.

Luiz Marcelo Brum Rossi *et al*. (2007) conducted a study on Potential Forest Species for Plantations in Brazilian; fifteen species were tested, in plots with 81 plants each, being 49 measurable ones. The height and diameter at breast height (DBH) were evaluated at 6, 12, 18, 24, 38 and 48 months of age, the data was analysed through regression Models.

The results showed that in the first case, *A. mangium* had superior performance, with 181.25 m^3 ha^{-1}, at 4 years, followed by *S. amazonicum* and the *Eucalyptus* clones 0321, 1270, 1232 and 0103 (volumes varying from 94.2 to 133.2 m^3 ha^{-1}). In the case of the MAI (Mean Annual Increament) in volume, two species can be detached: *A. mangium* (45.3 m^3 ha^{-1} yr^{-1}) and the *Eucalyptus* clone 0321 (34 m^3 ha^{-1} yr^{-1}) the species with best performance and growth were *Acacia mangium* and the *Eucalyptus* hybrid clone 0321.

Fabiano de Carvalho Balieiro *et al.* (2007) conducted a study on evaluation of the throughfall and stemflow nutrient contents in mixed and pure plantations of *Acacia mangium*, *Pseudosamenea guachapele* and *Eucalyptus grandis in* Brazilthe .The data was analysed through statistical tools like, The effect of throughfall and stem flow were evaluated using General Linear Models considering the rainfall as covariate.

Multiple comparisons tests and linear regression procedures were applied to data using the SAEG software Genetic and Statistic Analysis System, the results showed that only 52.2% of the incident rainfall in the mangium plantation reached the soil, whereas 78.7, 78.5 and 82.6% reached the soil under guachapele, eucalyptus and the mixed crop, respectively. Values of precipitation loss due to canopy interception were estimated at 14.4, 11.9, 15.6 and 11.8% in the pure stands of mangium, guachapele and eucalyptus and in the mixed crop of guachapele and eucalyptus. Mangium canopy intercepted and led to its trunk more rainfall (33.4%) than guachapele (9.4 and 5.9%) and eucalyptus in pure and mixed stands (5.6%) (P=0.05)

Kamaruzaman Jusoff (2008) conducted a study on Estimating *Acacia mangium* Plantation's Standing Timber Volume Using an Airborne Hyperspectral Imaging System in Malaysia. The study area selected was a wild unmanaged *A. mangium* plantation situated in Lebuh Silikon, Universiti Putra Malaysia. 29 samples of individual tree were selected, data was analysed using statistical tools like *simple* linear regression Models, the results showed. The value for R^2 was 0.801, which showed 80.1% erratum data could be evaded. The equation developed in this study was V = 0.1045 + 0.0111(CA) where it provided a mean for predicting volume from the crown size measurement using the airborne sensor. The total standing timber volume mapped and quantified by the UPM-APSB's for the study site of 0.8 ha *A.mangium* plantation was about 20.73 m^3 with a mapping accuracy of 80.45%.

Mohammed H. Mohammed *et al*. (2009) conducted a study on Effect of tree density and tapping techniques on productivity of gum *talha* from *Acacia seyal* var. *seyal* in South Kordofan, Sudan, and The data for the study was collected from September 2007 to February 2008. A sample of 167 *A. seyal* individual trees*,* growing in pure natural stands of different tree densities (dense, medium and slight), were selected based on the diameter at breast height (DBH, 6.7-36.9 cm) for gum tapping experiments.

The statistical tools used were Correlations and Logistic regression Models were applied. The results showed that individual trees of *Acacia seyal* in different strata vary in gum yields. The overall mean of the gum yield was 13.68 g/tree/season. The outcomes of the Logistic regression Model showed that 59.3 percent of the predictionswere correctly classified.

Tiryana *et al*.(2009) conducted the study on Modeling Spatial Variation in Stand Volume of *Acacia mangium* Plantations Using Geographically Weighted Regression,data was collected from Bogor, West Java, Indonesia, 247 circular sample plots .The data was analyzed using ordinary multiple linear regression(MLR) and geographically weighted regression(GWR) methods. The results showed that the effects of stand age and basal area were not constant over the study area, which resulted in the variability of stand volume of *Acacia mangium* plantations.

Haruni Krisnawati *et al.* (2009) conducted a study on dominat height and site index Models for *Acacia mangium willd*. plantations in South sumatra, data was collected from 197 permanent plots of unthinned *A.mangium*, the data was analysed through statistical Models like chapman-richards, Lundqvist-korf and Mcdill-amateis were tested for Modelting site index Models for *Acacia mangium* wild.plantations in south Sumatra, the results showed that the Models had a superior performance in terms of predictive ability and flexibility in use when compared to previously developed Models for *A.mangium*.

Haruni Krisnawati *et al*. (2010) conducted the study on generalized height-diameter Models for *Acacia mangium* wild. Plantations in south Sumatra, the Sample size was 13,302 trees was selected and the data was analysed through Six commonly used non-linear growth functions (i.e.Gompertz, Chapman-Richards, Lundqvist-Korf, Weibul, modified Logistic, and exponential). The results showed that the six base Models produced almost identical Models with a relatively high root mean squared error (± 3.4 m) and a relatively low proportion of the total variation in observed tree height (52.5 - 53.4%). The Lundqvist-Korf (LK) Model performed slightly better than the other Models based on the goodness of Model as well as bias and standard errors of the predictions.

Md. Enamul Kabir *et al.* (2010) conducted a survey on Productivity and suitability analysis of social forestry woodlot species in Dhaka Forest Division, Bangladesh, social suitability of three species, *Acacia auriculiformis* Benth *Acacia mangium* Willd and *Eucalyptus* camaldulensis Dehnhin 8-year-old monoculture plantations for reforestation of woodlots in Dhaka Forest Division, Bangladesh. The prevailing site conditions of the studyarea were suitable for all three species. Seven regression Models were tested to find the best-Model Model for volume and productivity calculation of each species, namely simple linear regression Model, single factor ANOVA was employed on average height, age, trees remaining per plot, and volume of each species across the four forest ranges. Survival at 8 years was highest for *A. auriculiformis* (2200 stem ha_1, i.e. 85% survival) followed by *A. mangium* (2100 stem ha_1, i.e. 81% survival) and E. camaldulensis There was no significant difference in height growth across ranges for either *A. mangium* or *A. auriculiformis .*

ChawChaw Sein Ralph Mitlöhner (2011) conducted a study on *Acacia mangium* Willd. Ecology and silviculture in Vietnam, the samples were collected from 104 *Acacia mangium* plots representing different age classes (1–7 years), data was analysed through Michailow's growth function to estimate the diameter and height of the stand, Richards' generalisation (1959) of Bertalanffy's growth Model was used to estimate stand volume. the results showed that the samples yielded minimum increases in volume of 0.8 m3 at 1 year of age and 197.4 m3 at 7 years of age, giving an average of 60.7 m3 /year in volume for these plantations, the average annual increases in volume of *Acacia mangium* are from 0.5 m3/year to 41.6 m3/year, with an average of 13.9 m3/ year for every variable.

Matsumura *et al*. (2011) conducted a study on Yield Prediction for *Acacia mangium* Plantations in Southeast Asia; the sample plots used in this study was located on Peninsular Malaysia. Growth curves were taken from forest stand data collected in 1995 and 2006 from a lowland *Acacia mangium* plantation growing in an area formerly mined in Chikus .data was analysed using least squares estimation via Mitscherlich equations, the results showed that Diameter growth showed a similar results, but total stand volume was less than that in Sumatra because of different stand densities. As for the basic stand growth Model, its prediction slightly overestimated actual values, and should be re-examined in light of observed forest stand data.

Maarit Kallio *et al.* (2011) conducted a study on *Acacia mangium* Willd.: ecology, silviculture and productivity in Indonesia, the data was collected from 209 sample trees and was analysed using the several Models (volume Models-volume) and, tabulation method, the results showed that in the first 2–3 years, height increases moderately up to 10–15 m and then increases sharply up to 25 m at about 5 years, after which the height levels off.

Marilyn S. Combalicer1 *et al*. (2011) conducted a study on Aboveground biomass and productivity of nitrogen-fixing tree species in the Philippines, The study was conducted in Mt. Makiling Forest Reserve (MFR) and La Mesa Watershed in the Philippines, It has a total land area of 4,244 ha and it was analysed using statistical software package (SPSS 16.0 program, SPSS Inc., Chicago, Illinois, U.S.A.). Productivity variables were compared using paired t-test.

Duncan's multiple range test (DMRT) was used for multiple comparisons. Results of the study showed that aboveground net primary productivity (*ANPP)* and nitrogen productivity were higher in the 20-year-old *A. auriculiformis* (6.28 tons ha-1 yr-1 and 267.23 kg kg-1 yr-1, respectively) and *A. mangium* (6.43 tons ha-1 yr-1 and 221.72 kg kg-1 yr-1, respectively) stands which were attributed to their higher values of litterfall and aboveground biomass and carbon.

Roscinto Ian c. Lumbres *et al.* (2011) conducted a study on Evaluation of height-diameter Models for three tropical plantation species (Gmelina, Mahogany and *Acacia mangium* Willd.)in the Philippines, The data was collected from the different plantation areas,and analysed using seven commonly used nonlinear growth Models, To evaluate the Models developed, coefficient of determination (R^2), root mean square error (*RMSE*), mean difference (*MD*) and absolute mean difference (*AMD*) were used as performance criteria for each species and Model.

The results showed that the R^2 of all Models in all three species ranged from 0.812 to 0.995 while the RMSE ranged from 1.755 to 3.024 m On the other hand, the overall *MD* ranged from -0.035 to 0.142 m while the *AMD* ranged from 1.460 to 2.422 m.. All Models were able to determine the relationships between height and DBH and Model the data well with the exception of the Korf/Lundqvist and Schnute Model for *A. mangium.* Furthermore, the Exponential Model was the best Model for the *G. arborea* and *A. mangium*, whereas the best Model for the *S. macrophylla* was the Korf/Lundqvist Model based on the four performance criteria using the rank analysis.

Le Dinh Kha *et al.* (2011) conducted a study on Growth and wood basic density of acacia hybrid clones at three locations in Vietnam the samples size 27 clones of the interspecific hybrid *Acacia mangium X A. Auriculiformis* and seedling controls of the parental species. The data was analysed using the statistical tools like regression, correlation, linear Model, simpler fixed-effects Model, Best Linear Unbiased Estimators.The results indicated that significant differences (P\0.001) in height and diameter at breast height (DBH) among 22 tested clones at 4 years.

At Long Thanh, twelve hybrid clones did not differ significantly in DBH at age 3 years, but did (P\0.001) at age 5 years. At the two northern sites the acacia hybrid clones had significantly greater DBH than control seedlots of the parental species, Mean wood basic density at breast height of the acacia hybrid clones was 539 kg m-3 at Yen Thanh at age 8 years, and 473 kg m-3 at Long Thanh at age 5 years; density for *A. mangium* at Long Thanh was only slightly lower than the hybrid clones at 461 kg m-3.

Linear regressions of Pilodyn penetration (PP) at breast height on wood basic density explained 60% of the variance in density of treatments (clones and control seedlots) at Yen Thanh and 36% at Long Thanh. There were significant differences between hybrid clones in PP at all three trial sites. Clonal DBH performance was not strongly correlated across the three trial sites; Pearson correlations of clone mean DBH between pairs of sites ranged from -0.47 to 0.20. Clonal rankings for PP were more stable, with Pearson correlations between pairs of sites ranging from r = 0.71 to 0.78.

Patil *et al.* (*2012*) conducted a study on Growth and productivity of *Acacia mangium* clones on shallow red soil at Main Agricultural Research Station, UAS, and Dharwad. The field experiment consisted of five clones of *A. mangium* clones *viz., A. mangium hybrid clone SV – 40, A. mangium*, *A. Spring well*, *A.mangium hybrid clone* (Seeds), *A. hybrid* clone (root) ,The seedlings of each clones were raised in polybags under nursery conditions for one year. These seedlings were planted in 30 cm x 30 cm x 30 cm pit at 2 m x 2 m spacing. Each treatment consisted of sixteen trees and was laid out in Randomized Block Design with four replications,the results showed that the Mean annual increment of height and DBH were significantly higher in *A. mangium* hybrid clone SV – 40 as compared to the *A. springwell*. Mean annual increment in DBH was lowest in *A. mangium* clone seed (1.03) and *A. mangium* clone (root) (1.01) as compared to other tried. This may be due to better growth and productivity of this clone under degraded marginal soils.

2.2 To Model the suitable probability distribution for growth (height/dbh) in respect of different Sources, fertilizer level and spacing in selected combination.

Li meng *et al.* (1998) fitted the Weibul distribution to diameter frequency data sets for *Larix olgensis* plantations in [Heilongjiang Province] China, and found that the Model was satisfactory. The parameter prediction Models (PPM) and parameter recovery Models (PRM) were developed based on the three parameter Weibul distribution for stand attributes based on the findings he concluded that the estimated precision of the PRM was better than that of the PPM.

Siipilehto (2000) considered in his paper to predict a Model for describing stand structure in terms of tree height (h) and diameter at breast height (dbh). The research material consisted of data collected from 64 stands of Norway spruce (Picea abies) and 91 stands of Scots pine (Pinus sylvestris) located in southern Finland. Both stand types contained birch (Betula pendula and B. pubescens) admixtures. The traditional univariate approach (Model I) of using the dbh distribution (Johnson's SB) together with a height curve (Nyasaland's function) was compared with bivariate approaches, Johnson's SBB distribution (Model II) and Model I epsilon. In Model I epsilon within-dbh-class h-variation was included by transforming a normally distributed homogeneous error of linearized Nyasaland's function to concern real heights. Basal-area-weighted distributions were estimated using the maximum likelihood (ML) method. Species-specific prediction Models were derived using linear regression analysis. The Models were compared with Kolmogorov-Smirnov tests for marginal distributions, accuracy of stand variables and the dbh-h relationship of individual trees. The differences in stand characteristics between the Models were marginal. Model I gave a slightly better Model for spruce, but Model II was better for pine stands. The univariate Model I clearly resulted in a too narrow marginal h-distribution for pine. It is recommended that a constrained ML method is applied for a reasonable dbh-h relationship, rather than using a pure ML method when Modelting the SBB Model.

Koichi yamamot *et al.* (2003) conducted a study on Moisture Distribution in Stems of *Acacia mangium, A. auriculiformis* and Hybrid *Acacia* Trees, the samples of 56 A. mangium, 14 *A. auriculiformis*, and 14 hybrid *Acacia* trees from Malaysia, Vietnam, and Philippines were surveyed and analysed using the tabular method, Highest moisture content found in the inner heartwood was 253% for both *A.mangium* and hybrid *Acacia.* In sapwood, the moisture contents were 149% and 154%, respectively.Most trees of these 2 species had "wet-heartwood" which refers to the higher moisture content of heartwood compared to the surrounding sapwood.

Ouypornprasert (2005) conducted a study on *Acacia mangium willd* as structural component and shear walls in Thailand, the physical and mechanical properties of 40 samlple species were selected for the study, the samples were analysed using chi sqare test and Kolmogorov smirnov test and used different distribution like normal distribution, uniform distribution, shifted exponential distribution, log normal distribution, gamma distribution, beta distribution,the results showed that the properties would be represented well by normal distribution.

Palahi *et al.* (2006) predicted Models for the diameter distribution of *Pinus sylvestris, P. nigra and P. halepensis* in Catalonia, Spain, using the truncated Weibul function as the theoretical distribution. The parameter Models allow one to use individual-tree Models in the imulation of stand development when only stand-level data are collected in forest inventories. Parameter Models for the diameter distribution of stand basal area were developed. The data consisted of permanent sample plots from the Spanish National Forest Inventory in Catalonia. A total of 1780 empirical distributions of P. sylvestris, 1204 distributions of P. nigra and 1535 distributions of P. halepensis were used as Modelling data. The empirical data represent left-truncated distributions, as the smallest diameter measured in the field was 7.5 cm. Two different approaches, namely, regression (two-step method) and optimization approach (one-step method), were used to find the coefficients of the parameter Models. In the two-step Modelling method, the Weibul parameters were first estimated separately for every empirical distribution by maximizing the log-likelihood function of the Weibul density function.

In the second-step, regression analysis was used to find the relationship between Weibul parameters and stand basal area, number of trees per hectare and elevation of the site. The one-step method used optimization to find such coefficients for the parameter Models, which minimized the mean of the squared differences between empirical and predicted cumulative tree frequencies in the whole Modelling data. The onestep optimization method performed better than the two-step regression method for all tree species. The parameter prediction Models developed in this study enable the prediction of the diameter distribution of P. sylvestris, P. nigra and P. halepensis in Catalonia from limited stand information.

Anita Firmanti *et al.* (2007) conducted a study on Effective Utilization of Fast-Growing *Acacia mangium* Willd. Timber As a Structural Material, A total sample size of 120 specimens were selected for the study, the collected data was analysed using statistical tools like ANOVA, linear regression, and parametric analysis, normal distribution, log-normal distribution and Weibul distribution, the results showed the difference in strength and rigidity characteristic of timber from the two locations, a mean comparison, using ANOVA, *F*-tests at 95% confidence interval for modulus of elasticity (MOE), MOE and MOR (modulus of rupture) of *A. mangium* timber from Indramayu and Banten were 0.81, 0.16 and 1.20, respectively. The strength characteristic values of modulus of rupture (MOR) based on Non-parametric point estimate (NPE) and non-parametric lower estimate (NTL), 5% tolerance limit of normal distribution, log-normal distribution, and Weibul distributions were 18.2, 15.2, 14.7, 19.6 and 22.4 mega pascal, respectively.

Lei (2008) conducted a study on Evaluation of three methods for estimating the Weibul distribution parameters of Chinese pine (*Pinus tabulaeformi),* 86 sample plots located in Chinese pine stand in Beijing were selected for the survey, the sample plots were analysed using Weibul distribution for tree diameter, the parameters were estimated using three methods [Maximum likelihood estimation method (MLE), Method of moment (MOM) and Least-squares method (LSM)] and these estimates were compared and evaluated on the basis of the mean square error (MSE) and sample size. For these sample plots, the moment method was superior for estimating the parameters of Weibul distribution .The results showed that the MOM produced the best estimate 152 times out of 256 diameter frequency distribution measurements, which is approximately 59.3%, followed by the LSM 69 times (27.0%) and the MLE 35 times (13.7%), respectively. The good results of the MOM in terms of the number of times for the lowest values of MSE indicated that the MOM was a superior method to estimate the diameter distribution of Weibul function for Chinese pine stands in Beijing

Sara Bastien-Henri *et al*. (2010) conducted a study on Biomass distribution among tropical tree species grown under differing regional climates in Smithsonian Tropical Research Institute and Yale School of Forestry and Environmental Studies. The samples of 18 species was collected from Panama, the data was analysed using non-parametric Wilcoxon rank sum tests, Aitchison log ratio transformation and ANCOVA, the results showed that Eight species displayed significant differences in at least one of stem, branch, or leaf biomass, and in five species, differences were observed in the biomass of all three compartments (Wilcoxon rank sum test, $P \leq 0.1$). The slopes of biometric trait log10-transformed total biomass relationships were parallel for both Aitchison-transformed and non-Aitchison-transformed variables (site by covariate interaction, $P > 0.05$ in every case). Subsequent and ANCOVAs conformed to the assumptions of parametric analyses (Levene's test for equality of error variance, $P > 0.05$, residuals normally distributed)

Damien Caillaud *et al*.(2010) conducted a study on Modeling the Spatial Distribution and Fruiting Pattern of a Key Tree Species in a Neotropical Forest: Methodology and Potential Applications in Panama, the data was analysed through spatial distribution. Maximum likelihood method, Poisson point process Models. linear mixed-effects Models fixed-effects Models, mixed-effects Models,The results showed that the random effect associated to ''tree id'' was significant in the fruit-production and fruiting-peak Models (fruit-production, sd = 0.49, p,1023; fruiting-peak: sd = 15.49, p,1023; fruitingperiod:sd=1.74, p= 0.40), while the random effect associated to "season id'' was significant only for the fruit production Model (fruit-production : sd= 0.87, p,1023; fruiting-peak: sd = 5.04, p = 0.12; fruiting-period: sd = 1.94, p = 0.44).

As expected, the DBH had a significant, positive effect on fruit production (intercept c1 =2.12, coefficient c2 = 1.50 1023, p = 0.033), these methods can also be used to generate stochastically resource distribution data using parameter values fixed a priori.

Peter H. Thrall *et al.* (2011) conducted a study on Symbiotic Effectiveness of Rhizobial Mutualists Varies in Interactions with Native Australian Legume Genera, the statistical tools used in the study were binomial probability distribution, normal distribution, ANOVA, linear mixed Models, the resuls showed plant growth performance was consistently as good as or better with this strain than the average performance of sympatric strains (Fig. 1). This difference was not statistically significant across all host species (P = 0.2025), but contrast tests for individual hosts revealed that for P. ulicifolium, although WG only nodulated 56% of the plants, it was significantly more effective than the sympatric strains (P =0.0165). two of the host species (G. lotifolia, H. violacea) demonstrated significantly higher growth with their sympatric strains while two host species (D. retorta, P. ilicifolium) achieved the highest growth with strains originating from other host species (Fig. 4b). Nodulation was overall 5% higher for allopatric interactions compared to sympatric host-strain interactions, and this difference was statistically significant (88% vs. 93%, respectively; P = 0.0297).

3. METHODOLOGY

This chapter has important components of research. To realize the various objectives of the study by using an appropriate methodology to describe the characteristics of the study area, the nature and source of data, various statistical tools and techniques employed for data analysis. This methodology is described under the following headlines.

3.1 Description of the study area

3.2 Materials

3.3 Nature and Source of Data

3.4 Statistical Tools and Techniques Employed for Analysis

3.1 Description of the study area

As per the opeRational jurisdiction of KSDA (Karnatake State Department of Agriculture), the Karnataka is divided into 10 Agroclimatic zones viz. North eastern transition zone (zone 1), North eastern dry zone (zone 2), Northern dry zone (zone 3), Central dry zone(zone 4), Eastern dry zone(zone 5), Southern dry zone(zone 6), Southern transition zone (zone 7), Northern transition zone (zone 8) , Hilly zone (zone 9) and parts of Coastal zone (zone 10) as shown in the Figure 3.1..The experimental site situated in Farm forestry department, University of Agricultural Sciences, Dharwad. Dharwad is in Northern Transition Zone (zone 8) of Karnataka, with latitude of 15°26' north, a longitude of 75°07' east and at an altitude of 678 m above mean sea level. Total geographic area of Dharwad is 427329 ha. The annual rain fall in this zone is 749.48 mm, major proportion of rainfall is received during June, July, August, September and October with heavy rains in July and September. The highest mean monthly maximum temperature recorded during May was 37.0°C which was 0.05°C higher as compared to the average maximum temperature of 56 years of same month. The lowest mean monthly temperature was recorded in December 13.1°C. Relative humidity was higher during June to September. The total number of rainy days (77days) was more than the average of previous 34 years (55.31 days).

3.2 Materials

The data for this study was procured from AICRP on Agroforestry (All India Co-ordinated Research Project on Agroforestry) UAS Dharwad. Experimental data contains information on parameters like height, diameter at breast height (DBH) of *Acacia mangium* from 1997-2008 for Sources and 2001-2008 for spacing and was used for the study.

3.3 Nature and Source of Data:

The details of the experiment as per AICRP on agroforestry UAS Dharwad is as under,

Year of start : 1997-2008

Design : Split plot design

Replication : Three

Main plot : Kerala, Bangalore, Chikkamangalore, and Thirthahalli.

Spacing: 4x1 m, 4x2m, 4x3m.

Sub plot :-Fertilizers : 25:50:25, 50:100:50, 75:150:75 NPK gm/tree.

Crop :-*Acacia mangium*

3.4 Statistical Tools and Techniques Employed For Analysis

The data collected by the AICRP (All India Coordinated Research Project on Agroforestry) UAS, Dharwad over the years for a different character was used for the present study. In order to investigate the objectives laid out for the present study the following statistical tools were employed.

- Evaluation of linear and non-linear Models.
- Modelting of probability distributions.

Different Sources of Acacia mangium

Fig 3.1 Map showing the agroclimatic zones of Karnataka in general

Table 3.1: General view about the Sources, Spacing and Fertilizer level combinations considered for analyzing the height and diameter at breast height

Sl No	Particulars		Combinations
1	Sources	Kerala(S_1)	Kerala(S_1)x25:50:25(F_1)
			Kerala(S_1)x 50:100:50(F_2)
			Kerala(S_1) x 75:150:75(F_3)
		Bangalore(S_2)	Bangalore(S_2) x25:50:25(F_1)
			Bangalore(S_2)x 50:100:50(F_2)
			Bangalore(S_2)x 75:150:75(F_3)
		Chikkamangalore(S_3)	Chikkamangalore(S_3)x 25:50:25(F_1)
			Chikkamangalore(S_3)x 50:100:50(F_2)
			Chikkamangalore(S_3)x 75:150:75(F_3)
		Thirthahalli(S_4)	Thirthahalli(S_4) x 25:50:25(F_1)
			Thirthahalli(S_4)x 50:100:50(F_2)
			Thirthahalli(S_4) x 75:150:75(F_3)
2	Spacing	4x1m(SP_1)	4x1m(SP_1)xNo fertilizer(F_0)
			4x1m(SP_1)x50:100:50 (F_1)
		4x2m(SP_2)	4x2m(SP_2) x No fertilizer (F_0)
			4x2m(SP_2) x 50:100:50(F_1)
		4x3m(SP_3)	4x3m(SP_3) xNo fertilizer (F_0)
			4x3m(SP_3) x50:100:50 (F_1)

Plate. 1. Source of Acacia mangium: Chikkamagalore

Plate.2. Acacia mangium under 4 x 1 m Spacing (S_1)

Plate.3. Acacia mangium with Fertilizer level (F1) – 50:100:50 NPK g/tree

Plate.4. Acacia mangium with Fertilizer level (F_3) – 75:150:75 NPK g/tree

Parameters considered:

Growth parameters of *Acacia mangium* i.e. height and dbh,

Non linear growth Models

Forest growth Models are widely used to simulate the development of individual trees and to Model the dynamics of forest ecosystems. In order to determine the reliability of Model predictions, it is often necessary to run the Model many times. Usually most growth Models used for forest growth Modelling are nonlinear. 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.

Polynomial Model

Polynomial regression is a form of linear regression in which the relationship between the independent variable *x* and the dependent variable *y* is Modeled as an *n*th order polynomial. Polynomial regression Models a nonlinear relationship between the value of *x* and the corresponding conditional mean of *y*, denoted E(*y*|*x*), In general, we can Model the expected value of *y* as an *n*th order polynomial, yielding the general polynomial regression Model,

$$y = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + \cdots + a_n x^n + \varepsilon.$$

Where,

y is dependent variable

$a_{i,}$ are Unknown parameters, i= 0, 1,2…,n

x is independent variables.

These Models are popular for the following reasons.

1. Polynomial Models have a simple form.
2. Polynomial Models have well known and understood properties.
3. Polynomial Models have moderate flexibility of shapes.
4. Polynomial Models are a closed family. Changes of location and scale in the raw data result in a polynomial Model being mapped to a polynomial Model. That is, polynomial Models are not dependent on the underlying metric.
5. Polynomial Models are computationally easy to use.

However, polynomial Models also have the following limitations.

I. Polynomial Models have poor interpolatory properties. High-degree polynomials are notorious for oscillations between exact-Model values.

II. Polynomial Models have poor extrapolatory properties. Polynomials may provide good Models within the range of data, but they will frequently deteriorate rapidly outside the range of the data.

III. Polynomial Models have poor asymptotic properties. By their nature, polynomials have a finite response for finite x values and have an infinite response if and only if the x value is infinite. Thus polynomials may not Model asymptotic phenomena very well.

IV. Polynomial Models have a shape/degree trade off. In order to Model data with a complicated structure, the degree of the Model must be high, indicating and the associated number of parameters to be estimated will also be high. This can result in highly unstable Models.

Rational function

A Rational function Model is a generalization of the polynomial Model. A Rational function is basically a division of two polynomial functions. That is, it is a polynomial divided by another polynomial. In formal notation, a Rational function would be symbolized like this:

$$f(x) = \frac{s(x)}{t(x)}$$

Where s(x) and t(x) are polynomial functions, and t(x) can not equal zero.

A Rational function is simply the ratio of two polynomial functions.

$$y = \frac{a_n x^n + a_{n-1}x^{n-1} + \dots + a_2 x^2 + a_1 x + a_0}{b_m x^m + b_{m-1}x^{m-1} + \dots + b_2 x^2 + b_1 x + b_0}$$

With *n* denoting a non-negative integer that defines the degree of the numerator and *m* is a non-negative integer that defines the degree of the denominator. For Modelting Rational function Models, the constant term in the denominator is usually set to 1. Rational functions are typically identified by the degrees of the numerator and denominator.

Logistic Growth Model

Logistic Model was developed by Belgian mathematician Pierre verhulst (1838). It is one of the simplest 'S' shaped growth curve.A biological population with plenty of food, space to grow, and no threat from predators, tends to grow at a rate that is *proportional to the population* -- that is, in each unit of time, a certain percentage of the individuals produce new individuals. If reproduction takes place more or less continuously, then this growth rate is represented by

DP/dt = rP,

Where P is the population as a function of time t, and r is the proportionality constant. We know that all solutions of this natural-growth equation have the form

$P(t) = P_0 e^{rt}$,

Where P_0 is the population at time t = 0. In short, unconstrained natural growth is exponential growth. Of course, most populations are constrained by limitations on re -- even in the short run -- and none is unconstrained forever. We may account for the growth rate declining to 0 by including in the Model a factor of 1 - P/K -- which is close to 1 (i.e., has no effect) when P is much smaller than K, and which is close to 0 when P is close to K. The resulting Model,

$$\frac{dP}{dt} = rp\left(1 - \frac{p}{K}\right)$$

is called the Logistic growth Model or the Verhulst Model. The word "Logistic" has no particular meaning in this context, except that it is commonly accepted. A Logistic growth curve is also called a sigmoidal curve.

Richards Model

This Model was proposed by Richards (1959).

Richards Model: y=a/ (1+exp (b-cx) ^ (1/d))

Where a, b, c, d are the parameters in the Model

y is the dependant variable and

x is independent variable

In the Richards Model, the inflection point is not fixed but Modeled by an additional parameter. This makes the Richards growth Model highly flexible and inclusive of most other sigmoid growth Models. The Richards growth Model generally Models plant growth data well and has been widely used in plant ecology and forestry. Estimating the inflection point as a free parameter seems biologically reasonable since there is no general theory that predicts at what growth stage plants experience their maximum growth rate, and the inflection point has been shown to depend on density (Damgaard *et al.,* 2002).

One biologically undesirable feature of the Richards growth Model is that when maximum growth rate is obtained early in plant growth, i.e. the growth curve has a low inflection point; initial growth is not exponential (Birch 1999).

Gompertz Model

The Gompertz Model is based upon a Model given by Gompertz in 1825 for the hazard in life table, and than used as a growth Model by Wright in 1926.

Gompertz Relation: y=a*exp (-exp (b-cx))

Where

x is a independent variable.(dbh, height).

y is a dependent variable (age in years)

a b, c are the parameters in the Model

The Gompertz Model is very popular and used in various fields such as population studies, animal growth in situation where growth is asymmetrical about the point of inflection and analyzing reliability data. It is most applicable when the data set follows a smooth curve. The Parameter Estimation for the Gompertz Models can be carried out by Using Least Squares in nonlinear regression as well as using linear regression methods.

Weibul Model

This Model was proposed by Weibul (1951).

Weibul Model: y=a-b*exp (-c*x^d)

Where a, b, c and d are the parameters in the Model

The Weibul is very flexible and also has theoretical justification in many applications.

Uses of the Weibul Model

1. Because of its flexible shape and ability to Model a wide range of failure rates, the Weibul has been used successfully in many applications as a purely empirical Model.
2. The Weibul Model can be derived theoretically as a form of Extreme Value Distribution, governing the time to occurrence of the "weakest link" of many competing failure processes. This may explain why it has been so successful in applications such as capacitor, ball bearing, relay and material strength failures.
3. Another special case of the Weibul occurs when the shape parameter is 2. The distribution is called the Rayleigh Distribution and it turns out to be the theoretical probability Model for the magnitude of radial error when the *x* and *y* coordinate errors are independent normals with 0 mean and the same standard deviation.
4. It is more popular statistical Model for life data and it is also used in many other applications like weather forecasting, Modelting data of any kind (both qualitative and quantitative data).

Sinusoidal Model

The Sinusoidal speech Model represents a speech signal as a linear combination of

Sinusoids with time-varying parameters {amplitudes, frequencies, and phases}.

A Sinusoidal Model to approximate a sequence Y_i is:

$$Y_i = C + \alpha \sin(\omega T_i + \varphi) + E_i$$

Where, C is constant defining a mean level, α is an amplitude for the sine wave,

ω is the frequency,

T_i is a time variable,

φ is the phase, and E_i is the error sequence in approximating the sequence Y_i by the Model.

Logarithmic Model

The Logarithmic Models are of the form

$$y = a + b \ln x$$

The Logarithmic Model has a period of rapid increase, followed by a period where the growth slows, but the growth continues to increase without bound. This makes the Model inappropriate where there needs to be an upper bound.

Several physical applications have Logarithmic Modelse like earthquakes, the intensity of sound, and the acidity of a solution.

Features

- Increases without bound to right
- Passes through (1,a),
- Very rapid growth, followed by slower growth,
- Common log will grow slower than natural log
- b controls the rate of growth

Morgan-Mercer-Flodin (MMF) Model

MMF Model was given by Morgan in 1975. The Morgan-Mercer-Flodin family function is nonlinear sigmoid growth functions. The general form of the Morgan-Mercer-Flodin family function (MMF) is

y= (a*b+c*x^d)/ (b+x^d)

Where,

x is a independent variable.(dbh, height).

y is a dependent variable (age in years)

Where a, b, c, & d are the parameters in the Model

Significance of R^2 :- Significance of (R^2) is tested using the formula

$$F = \frac{(R^2)/p}{(1-(R^2))/n-p-1}$$

Where, p is the number of independent variables

n is the sample size

Root-mean-square error (RMSE) is a frequently used measure of the differences between values predicted by a Model or an estimator and the values actually observed. These individual differences are called residuals when the calculations are performed over the data sample that was used for estimation, and are called *prediction errors* when computed out-of-sample. The RMSE serves to aggregate the magnitudes of the errors in predictions for various times into a single measure of predictive power. RMSE is a good measure of accuracy, but only to compare forecasting errors of different Models for a particular variable and not between variables, as it is scale-dependent.

Probability Distributions:

One common application of probability distributions is modeling univariate data with a specific probability distribution. This involves the following two steps:

- Determination of the "best-Modelting" distribution.
- Estimation of the parameters (shape, location, and scale parameters) for that distribution.

There are various methods, both numerical and graphical, for estimating the parameters of a probability distribution.

- Method of moments
- Maximum likelihood
- Least squares etc

Weibul distribution

In probability theory and statistics, the Weibul distribution is a continuous probability distribution. It is named after Waloddi Weibul, who described it in detail in 1951, although it was first identified by Fréchet (1927) and first applied by Rosin & Rammler (1933) to describe the size distribution of particles.

The probability density function of a Weibul random variable *x* is:

$$f(x;\lambda,k) = \begin{cases} \frac{k}{\lambda}\left(\frac{x}{\lambda}\right)^{k-1} e^{-(x/\lambda)^k} & x \geq 0, \\ 0 & x < 0, \end{cases}$$

where $k > 0$ is the *shape parameter* and $\lambda > 0$ is the *scale parameter* of the distribution. Its complementary cumulative distribution function is a stretched exponential function. The Weibul distribution is related to a number of other probability distributions; in particular, it interpolates between the exponential distribution ($k = 1$) and the Rayleigh distribution ($k = 2$).

If the quantity *x* is a "time-to-failure", the Weibul distribution gives a distribution for which the failure rate is proportional to a power of time. The *shape* parameter, *k*, is that power plus one, and so this parameter can be interpreted directly as follows:

- A value of $k<1$ indicates that the failure rate decreases over time. This happens if there is significant "infant mortality", or defective items failing early and the failure rate decreasing over time as the defective items are weeded out of the population.
- A value of $k=1$ indicates that the failure rate is constant over time. This might suggest random external events are causing mortality, or failure.
- A value of $k>1$ indicates that the failure rate increases with time. This happens if there is an "aging" process, or parts that are more likely to fail as time go on.

Uses:-The Weibul distribution is used

- In survival analysis
- In industrial engineering to represent manufacturing and delivery times
- In extreme value theory
- In weather forecasting (To describe wind speed distributions, as the natural distribution often matches the Weibul shape)
- To Model fading channels in wireless communications, as the Weibul fading Model seems to exhibit good Model to experimental fading channel measurements In General insurance to Model the size of Reinsurance claims, and the cumulative development of Asbestosis losses.
- In forecasting technological change (also known as the Sharif-Islam Model)

Maximum Likelihood Estimation

Maximum-likelihood estimation was recommended, analyzed (with flawed attempts at proofs) and vastly popularized by R. A. Fisher between 1912 and 1922 (although it had been used earlier by Gauss, Laplace, T. N. Thiele, and F. Y. Edgeworth). Reviews of the development of maximum likelihood have been provided by a number of authors.Much of the theory of maximum-likelihood estimation was first developed for Bayesian statistics, and then simplified by later authors.

In statistics, Maximum-Likelihood Estimation (MLE) is a method of estimating the parameters of a statistical Model. When applied to a data set and given a statistical Model, maximum-likelihood estimation provides estimates for the Model's parameters. The method of maximum likelihood corresponds too many well-known estimation methods in statistics. MLE would accomplish this by taking the mean and variance as parameters and finding particular parametric values that make the observed results the most probable.

Properties

- Maximum-likelihood estimators have no optimum properties for finite samples, in the sense that (when evaluated on finite samples) other estimators have greater concentration around the true parameter-value. However, like other estimation methods, maximum-likelihood estimation possesses a number of attractive limiting properties: As the sample-size increases to infinity, sequences of maximum-likelihood estimators have these properties:
- Consistency: a subsequence of the sequence of MLEs converges in probability to the value being estimated.
- Asymptotic normality: as the sample size increases, the distribution of the MLE tends to the Gaussian distribution with mean θ and covariance matrix equal to the inverse of the Fisher information matrix.
- Efficiency, i.e., it achieves the Cramér–Rao lower bound when the sample size tends to infinity. This means that no asymptotically unbiased estimator has lower asymptotic mean squared error than the MLE (or other estimators attaining this bound).

Applications

Maximum likelihood estimation is used for a wide range of statistical Models, including:

- linear Models and generalized linear Models;
- exploratory and confirmatory factor analysis;
- structural equation Modeling;
- many situations in the context of hypothesis testing and confidence interval formation;
- Discrete choice Models.

The Weibul distribution, introduced by Bailey and Dell (1973) has been applied extensively in forestry due to

- ❖ Its ability to describe a wide range of unimodal distributions including reversed-J shaped, exponential, and normal frequency distributions,
- ❖ The relative simplicity of parameter estimation, and
- ❖ Its closed cumulative density functional form (e.g. Bailey, Dell 1973; Schreuder, Swank 1974; Schreuder et al. 1979; Little 1983; Rennolls et al. 1985; Mabvurira et al. 2002), and
- ❖ Its previous success in describing diameter frequency distributions within boreal stand types (e.g. Bailey, Dell 1973; Little 1983; Kilkki et al. 1989; Liu et al. 2004; Newton et al. 2004, 2005).

Principle

Suppose there is a sample x_1, x_2... x_n of n independent and identically distributed observations, coming with probability density function

$$f(x) = (\gamma/\theta)\, x^{\gamma-1} \exp(-x^{\gamma}\ /\theta) \quad x>0,\ \gamma>0,\ \theta>0. \qquad (1)$$

The likelihood function of this sample is

$$L(x_1,x_2 \ldots x_n;\gamma,\theta)= \prod_{i=1}^{n} (\gamma/\theta)\, x_i^{\gamma-1} \exp(-x_i^{\gamma}\ /\theta) \qquad (2)$$

On taking Logarithms of (2), differentiating with respect to γ and θ in turn equating to zero , we obtain the estimating equation

$$\left.\begin{aligned} \frac{\partial \ln L}{\partial \gamma} &= \frac{n}{\gamma} + \sum_1^n \ln x_i - \frac{1}{\theta}\sum_1^n x_i^{\gamma} \ln x_i = 0 \\ \frac{\partial \ln L}{\partial_\theta} &= -\frac{n}{\theta} + \frac{1}{\theta^2}\sum_1^n x_i^{\gamma} = 0 \end{aligned}\right\} \qquad (3)$$

On eliminating θ between these two equations and simplifying, we have

$$\left(\frac{\sum_1^n x_i^{\gamma} \ln x_i}{\sum_1^n x_i^{\gamma}} - \frac{1}{\gamma}\right) = \frac{1}{n}\sum_1^n \ln x_i \qquad (4)$$

which may now be solved for, ML estimators $\hat{\gamma}$. This can be accomplished with aid of standard iterative procedure,but in most instances a simple trial and error approach will suffice. Once two values γ_1 and γ_2 have been found with in a sufficiently narrow interval such that $\gamma_1 < \gamma < \gamma_2$, linear interpolation will yield the required values.

With $\hat{\gamma}$ thus determined, θ is estimated from the second equation of (3) as

$$\hat{\theta} = \sum_1^n x_i^{\hat{\gamma}} / n \qquad (5)$$

The symbol (^) is employed here to distinguish M.L. estimators from the parameters being estimated.

4. RESULTS

In this chapter some of the main points of statistical analysis are presented in the form of results under following headings.

4.1 Prediction Models

4.2 Predicted values

4.3 Growth curves

4.4 Weibul distribution

4.1 Prediction Models

Statistical Models in biological studies are gaining a lot of importance in forestry as well as agroforestry; these Models play a vital role in prediction of height, dbh, yield, severity of pest and disease etc. Considering the importance of various Models in forestry an effort is made to build the Models for the prediction of diameter and height growth by considering the various parameters. In the present study we have considered the past growth performance of *Acacia mangium* of different Sources, fertilizer level and spacing over many years. These prediction Models were Fitted and presented in the tables. The parameters of the Model were estimated by iteration method and converged after different iterations. They are shown in the graphs presented under the heading 4.2.

4.1.1 Height prediction Models for Sources and fertilizer level

The different Models were tried for predicting height growth of *Acacia mangium* with different Sources and fertilizer levels. In case of combination Kerala (S_1) x25:50:25(F_1) out of different Models tried, Rational Function (R^2=0.989, SE=0.273 and RMSE=0.241) was proved better followed by Weibul Model (R^2=0.980, SE=0.375 and RMSE=0.330), MMF Model (R^2=0.980, SE=0.375 and RMSE=0.330) and Logarithm Model (R^2=0.977, SE=0.358 and RMSE=0.358). For the second combination Kerala (S_1) x50:100:50(F_2), out of different Models tried Rational Function (R^2=0.982, SE=0.325 and RMSE=0.288) was proved better followed by MMF Model (R^2=0.967, SE=0.445 and RMSE=0.394), Weibul Model (R^2=0.967, SE=0.447 and RMSE=0.396), and Logarithm Model (R^2=0.946, SE=0.501 and RMSE=0.503). For the third combination Kerala (S_1) x 75:150:75(F_3), out of different Models tried Rational Function (R^2=0.981, SE=0.352 and RMSE=0.310) was proved better followed by Weibul Model (R^2=0.976, SE=0.399 and RMSE=0.352), Logarithm Model (R^2=0.965, SE=0.421 and RMSE=0.420) and Richards Model (R^2=0.948, SE= 0.587 and RMSE=0.517).(Table 4.1.1(a)).

For the second source and their combination, Bangalore(S_2) x25:50:25(F_1) out of different Models tried, Rational Function, (R^2=0.970, SE=0.382 and RMSE=0.338) was proved better followed by, MMF Model(R^2=0.970, SE=0.413 and RMSE=0.365), Weibul Model (R^2=0.970, SE=0.416 and RMSE=0.368) and Logarithm Model (R^2=0.970, SE=0.369 and RMSE=0.371), For the second combination Bangalore(S_2) x50:100:50(F_2), out of different Models tried Weibul Model (R^2=0.991, SE=0.194 and RMSE=0.171), was proved better followed by MMF Model (R^2=0.991, SE=0.194 and RMSE=0.171), Logarithm Model (R^2=0.991, SE=0.173 and RMSE=0.172) and Rational Function(R^2=0.990, SE=0.202 and RMSE=0.178). For the third combination Bangalore (S_2) x75:150:75(F_3),out of different Models tried Rational Function, (R^2=0.979, SE=0.316 and RMSE=0.279) was proved better followed by Weibul Model (R^2=0.978, SE=0.327 and RMSE=0.288), MMF Model (R^2=0.978, SE=0.327 and RMSE=0.288) and Logarithm Model (R^2=0.976, SE=0.298 and RMSE=0.296).(Table 4.1.1(b)).

Table 4.1.1(a): Selected Models for Kerala(S_1)x25:50:25(F_1);Kerala(S_1)x 50:100:50(F_2); Kerala(S_1) x 75:150:75(F_3) for height

Combination	Name of the Model	Model Equations	R^2	SE	RMSE
S_1F_1	Rational Function	y=(-370.216+512.827x)/(1+70.015x-1.86x^2)	0.989**	0.273	0.241
	Weibul Model	y=14.747-61.633*exp(-1.594*x^0.177)	0.980**	0.375	0.330
	MMF Model	y=(19.77*0.63+16.13*x^0.416)/(0.632+x^0.416)	0.980**	0.375	0.330
	Logarithm Model	y=2.481+2.943*ln(x)	0.977**	0.358	0.358
S_1F_2	Rational Function	y=(60818031.41+83856448.89x)/(1+11024498.96x-223011.01x^2)	0.982**	0.325	0.288
	MMF Model	y=(26.425*0.32+11.37*x^0.62)/(0.32+x^0.624)	0.967**	0.445	0.394
	Weibul Model	y=10.901-179.632*exp(-3.029*x^0.162)	0.967**	0.447	0.396
	Logarithm Model	y=2.797+2.681*ln(x)	0.946**	0.501	0.503
S_1F_3	Rational Function	y=(-59.410+85.149x)/(1+10.892x-0.234x^2)	0.981**	0.352	0.310
	Weibul Model	y=12.361-77.427*exp(-2.044*x^0.189)	0.976**	0.399	0.352
	Logarithm Model	y=2.744+2.829*ln(x)	0.965**	0.421	0.420
	Richards Model	y=8.961/(1+exp(-2.322-0.524x))^(1/0.048)	0.948**	0.587	0.517

** Significant at 1 percent
Y is the height increment,
X is the age.

Table 4.1.1(b): Selected Models for Bangalore (S_2) x25:50:25(F_1); Bangalore (S_2) 50:100:50(F_2); Bangalore (S_2) x 75:150:75(F_3) for height

Combination	Name of the Model	Model Equations	R^2	SE	RMSE
S_2F_1	Rational Function	y=(-12.715+22.488x)/(1+3.149x-0.076x^2)	0.970**	0.382	0.338
	MMF Model	y=(49.54*0.42+24.59*x^0.2)/(0.42+x^0.18)	0.970**	0.413	0.365
	Weibul Model	y=15.050-37.721*exp(-1.103*x^0.199)	0.970**	0.416	0.368
	Logarithm Model	y=2.621+2.555*ln(x)	0.970**	0.369	0.371
S_2F_2	Weibul Model	y=16.661-24.877*exp(-0.594*x^0.259)	0.991**	0.194	0.171
	MMF Model	y=(7.85*1.96+24.08*x^0.29)/(1.96+x^0.29)	0.991**	0.194	0.171
	Logarithm Model	y=2.866+2.305*ln(x)	0.991**	0.173	0.172
	Rational Function	y=(-0.197+4.686x)/(1+0.548x-0.008x^2)	0.990**	0.202	0.178
S_2F_3	Rational Function	y=(-1.628+7.057x)/(1+0.931x-0.022x^2)	0.979**	0.316	0.279
	Weibul Model	y=20.544-26.585*exp(-0.410*x^0.282)	0.978**	0.327	0.288
	MMF Model	y=(5.36*3.14+28.89*x^0.33)/(3.14+x^0.33)	0.978**	0.327	0.288
	Logarithm Model	y=2.765+2.429*ln(x)	0.976**	0.298	0.296

** Significant at 1 percent
Y is the height increment,
X is the age

Table 4.1.1(c): Selected Models for Chikkamangalore (S_3) x25:50:25(F_1); Chikkamangalore (S_3): 50:100:50(F_2); Chikkamangalore (S_3) x 75:150:75(F_3) for height

Combination	Name of the Model	Model Equations	R^2	SE	RMSE
S_3F_1	MMF Model	y=(2.2*34.77+9.27*x^3.85)/(34.77+x^3.85)	0.992**	0.259	0.230
	Richards Model	y=9.167/(1+exp(3.367-1.284x))^(1/1.600)	0.987**	0.323	0.286
	Logistic Model	y=9.205/(1+9.032*exp(-1.076x))	0.986**	0.306	0.291
	Weibul Model	y=9.128-7.308 *exp(-0.079*x^2.432)	0.986**	0.337	0.299
S_3F_2	MMF Model	y=(2.37*31.27+9.46*x^3.61)/(31.27+x^3.6)	0.986**	0.339	0.301
	Logistic Model	y=9.384/(1+7.260 *exp(-0.968x))	0.978**	0.394	0.373
	Richards Model	y=9.401/(1+exp(1.608-0.915x))^(1/0.824)	0.978**	0.421	0.373
	Gompertz Model	y=9.510*exp(-exp(1.001-0.684x))	0.976**	0.406	0.384
S_3F_3	MMF Model	y=(2.49*29.42+9.8*x^3.47)/(29.42+x^3.46)	0.986**	0.344	0.304
	Richards Model	y=9.784/(1+exp(1.246-0.836x))^(1/0.696)	0.979**	0.429	0.379
	Logistic Model	y=9.749/(1+6.743 *exp(-0.921x))	0.978**	0.402	0.380
	Gompertz Model	y=9.888*exp(-exp(0.957-0.653x))	0.978**	0.410	0.388

** Significant at 1 percent
Y is the height increment,
X is the age

For the third source and their combination, Chikkamangalore (S_3) x 25:50:25(F_1) out of different Models tried, MMF Model (R^2=0.992, SE=0.259 and RMSE=0.236), was proved better followed by Richards Model (R^2=0.987, SE=0.323 and RMSE=0.286), Logistic Model

(R^2=0.986, SE=0.306 and RMSE=0.291), and Weibul Model (R^2=0.986, SE=0.337 and RMSE=0.299). For the second combination Chikkamangalore (S_3) x 50:100:50 (F_2), out of different Models tried MMF Model (R^2=0.986, SE=0.339 and RMSE=0.301) was proved better followed by Logistic Model (R^2=0.978, SE=0.394 and RMSE=0.373), Richards Model (R^2=0.978, SE=0.421 and RMSE=0.373) and Gompertz Model (R^2=0.976, SE=0.406 and RMSE=0.384). For the third combination Chikkamangalore (S_3) x75:150:75(F_3), out of different Models tried MMF Model (R^2=0.986, SE=0.344 and RMSE=0.304) was proved better followed by Richards Model (R^2=0.979, SE=0.429 and RMSE=0.379), Logistic Model (R^2=0.978, SE=0.402 and RMSE=0.380), and Gompertz Model (R^2=0.978, SE=0.410 and RMSE=0.388). (Table 4.1.1(c)).

For the fourth source and their combination, Thirthahalli (S_4) x 25:50:25(F_1) out of different Models tried, Rational Function (R^2=0.977, SE=0.422 and RMSE=0.376), was proved better followed by Weibul Model (R^2=0.974, SE=0.449 and RMSE=0.397), MMF Model (R^2=0.974, SE=0.449 and RMSE=0.397), and Logarithm Model (R^2=0.973, SE=0.401 and RMSE=1.402). For the second combination Thirthahalli (S_4) x50:100:50(F_2), out of different Models tried MMF Model (R^2=0.951, SE=0.597 and RMSE=0.527) was proved better followed by Rational Function (R^2=0.947, SE=0.619 and RMSE=0.545), Weibul Model (R^2=0.946, SE=0.623 and RMSE=0.549) and Gompertz Model (R^2=0.944, SE=0.594 and RMSE=0.559). For the third combination Thirthahalli(S_4) x 75:150:75(F_3), out of different Models tried MMF Model (R^2=0.947, SE=0.659 and RMSE=0.583) was proved better followed by, Weibul Model (R^2=0.947, SE=0.66 and RMSE=0.585), Logarithmic Model (R^2=0.941, SE=0.614 and RMSE=0.616) and sinusoidal Model (R^2=0.923, SE=0.795 and RMSE=0.702).(Table 4.1.1(d)) .

4.1.2 Height prediction Models for spacing and fertilizer level

The different Models were tried to predicting height growth of *Acacia mangium* with different spacing and fertilizer levels. For first spacing and their combinations, 4x1m(SP_1)xNo fertilizer(F_0) out of different Models tried, Rational Function (R^2=0.957, SE=0.270 and RMSE=0.220) was proved better followed by Weibul Model (R^2=0.938, SE=0.323 and RMSE=0.265), MMF Model (R^2=0.938, SE=0.325 and RMSE=0.265) and Logarithm Model (R^2=0.934, SE=0.273 and RMSE=0.273). For second combination 4x1m (SP_1) x50:100:50(F_1), out of different Models tried Rational Function (R^2=0.969, SE=0.201 and RMSE=0.165) was proved better followed by MMF Model (R^2 = 0.96, SE=0.227 and RMSE=0.185), Weibul Model (R^2=0.96, SE=0.23 and RMSE=0.187) and Richards Model (R^2 = 0.96, SE=0.23 and RMSE= 0.187). (Table4.1.2 (a)).

For the second spacing and their combination, 4x2m(SP_2) x No fertilizer (F_0),out of different Models tried Rational Function(R^2=0.975, SE=0.286 and RMSE=0.235) was proved better followed by Weibul Model(R^2=0.951, SE=0.399 and RMSE=0.328), MMF Model(R^2=0.9 5, SE=0.4 and RMSE=0.328) and Logarithm Model (R^2=0.950, SE=0.33 and RMSE=0.331) .(Table 4.1.2(a)).For second combination, 4x2m(SP_2) x 50:100:50(F_1) out of different Models tried, Weibul Model (R^2=0.966 SE=0.270 and RMSE=0.220) was proved better followed by MMF Model (R^2=0.966, SE=0.27 and RMSE=0.22).

Table 4.1.1(d): Selected Models for Thirthahalli (S_4) x 25:50:25(F_1); Thirthahalli (S_4) x 50:100:50(F_2); Thirthahalli (S_4) x 75:150:75(F_3) for height

Combination	Name of the Model	Model Equations	R^2	SE	RMSE
S_4F_1	Rational Function	y=(-2.791 +6.964x)/(1+0.792x-0.019x^2)	0.977**	0.422	0.376
	Weibul Model	y=22.002 -32.158*exp(-0.495*x^0.277)	0.974**	0.449	0.397
	MMF Model	y=(7.68*2.49+27.46*x^0.37)/(2.49+x^0.37)	0.974**	0.449	0.397
	Logarithm Model	y=2.269 +3.076*ln(x)	0.973**	0.401	0.402
S_4F_2	MMF Model	y=(1.47*7.89+9.47*x^2.09)/(7.89+x^2.087)	0.951**	0.597	0.527
	Rational Function	y=(-2.574+6.145x)/(1+0.555x-0.001x^2)	0.947**	0.619	0.545
	Weibul Model	y=9.688-12.179 *exp(-0.502*x^0.779)	0.946**	0.623	0.549
	Gompertz Model	y=8.983*exp(-exp(0.829-0.561x))	0.944**	0.594	0.559
S_4F_3	MMF Model	y=(4.84*9.32+70.24*x^0.34)/(9.32+x^0.34)	0.947**	0.659	0.583
	Weibul Model	y=34.109-38.422*exp(-0.193*x^0.359)	0.947**	0.660	0.585
	Logarithm Model	y=2.065+3.112*ln(x)	0.941**	0.614	0.616
	Sinusoidal Model	y=-18.537+29.318*cos(0.050x+5.493)	0.923**	0.795	0.702

** Significant at 1 percent
Y is the height increment,
X is the age.

Table 4.1.2(a): Selected Models for 4x1m(SP_1)xNo fertilizer (F_0); 4x1 m (SP_1) x 50:100:50 (F_1); 4x2m(SP_2) x No fertilizer (F_0) for height

Combination	Name of Model	Model Equations	R^2	SE	RMSE
SP_1F_0	Rational function	y=(4919929.33+15045079.70x)/(1+2308948.46x-45656.13x^2)	0.957**	0.270	0.220
	Weibul Model	y=9.569-44.816*exp(-2.182*x^0.153)	0.938**	0.323	0.265
	MMF Model	y=(-5.1*0.54+9.69*x^0.5)/(0.54 +x^0.501)	0.938**	0.325	0.265
	Logarithm Model	y=4.611+1.350*ln(x)	0.934**	0.273	0.273
SP_1F_1	Rational Function	y=(975187.72+7228255.65x)/(1+1280154.543x-43226.36x^2)	0.969**	0.201	0.165
	MMF Model	y=(4.5*180.6+118.9*x^0.77)/(180.6+x^0.77)	0.960**	0.227	0.185
	Weibul Model	y=17.750-13.170*exp(-0.043*x^0.860)	0.960**	0.228	0.187
	Richards Model	y=7.520/(1+exp(49.771-6.832x))^(1/119.099)	0.959**	0.230	0.187
SP_2F_0	Rational function	y=(16012204.3+47230914.5x)/(1+7154710.820x-241494.77x^2)	0.975**	0.286	0.235
	Weibul Model	y=22.200-24.844*exp(-0.344*x^0.263)	0.951**	0.399	0.328
	MMF Model	y=(2.24*3.49+28.36*x^0.30)/(3.487+x^0.30)	0.951**	0.400	0.328
	Logarithm Model	y=4.497+1.888 *ln(x)	0.950**	0.330	0.331

** Significant at 1 percent
Y is the height increment,
X is the age

Logarithm Model (R^2=0.964, SE=0.227 and RMSE=0.227) and Gompertz Model (R^2=0.94, SE=0.325 and RMSE=0.720). (Table4.1.2 (a)).

For the third spacing and their combination, 4x3m(SP_3) xNo fertilizer(F_0), out of different Models tried Rational function (R^2=0.997, SE= 0.085 and RMSE=0.068) was proved better followed by Logarithm Model (R^2=0.997, SE=0.070 and RMSE=0.069), MMF Model (R^2=0.997 , SE=0.087 and RMSE=0.069) and Weibul Model (R^2=0.997, SE=0.087 and RMSE=0.070). For the second combination 4x3m (SP_3) x50:100:50 (F_1), out of different Models tried Rational Function, (R^2=0.992, SE=0.165 and RMSE=0.136) was proved better followed by MMF Model (R^2=0.991, SE=0.171 and RMSE=0.140), Weibul Model (R^2=0.991, SE=0.172 and RMSE=0.141) and Logarithm Model (R^2=0.988, SE= 0.163 and RMSE=0.162). (Table4.1.2 (b)).

4.1.3 DBH prediction Models for Sources and fertilizer level

The different Models were tried to predicting DBH growth of *Acacia mangium* with different Sources and fertilizer levels. For first source and their combination, Kerala (S_1) x 25:50:25(F_1) out of different Models tried, MMF Model (R^2=0.985, SE=0.517 and RMSE=0.456) was proved better followed by Weibul Model (R^2=0.985, SE=0.517 and RMSE=0.457), polynomial Model (R^2=0.985, SE=0.555 and RMSE=0.464) and Rational Function (R^2=0.985, SE=0.514 and RMSE=0.475). For the second combination Kerala (S_1) x50:100:50(F_2), out of different Models tried Rational Function, (R^2=0.985, SE=0.468 and RMSE=0.413) was proved better followed by MMF Model (R^2=0.977, SE=0.568 and RMSE=0.501), Weibul Model (R^2=0.977, SE=0.570 and RMSE=0.503) and Logarithm Model (R^2=0.968, SE=0.592 and RMSE=0.591). For the third combination Kerala (S_1) x75:150:75(F_3), out of different Models tried Rational function Model (R^2=0.993, SE=0.316 and RMSE=0.284), was proved better followed by Weibul Model (R^2=0.988, SE=0.410 and RMSE=0.363), MMF Model (R^2=0.988, SE=0.411 and RMSE=0.363) and sinsoidol Model(R^2=0.978, SE=0.543 and RMSE=0.483) .(Table 4.1.3(a)).

For the second source and their combination, Bangalore(S_2) x25:50:25(F_1) out of different Models tried, Rational function (R^2=0.992, SE=0.330 and RMSE=0.297), was proved better followed by Weibul Model (R^2=0.991, SE=0.351 and RMSE=0.310), MMF Model (R^2=0.991, SE=0.351 and RMSE=0.310) and Logarithm Model (R^2=0.985, SE=0.389 and RMSE=0.389), For the second combination Bangalore(S_2) x50:100:50(F_2), out of different Models tried MMF Model (R^2=0.993, SE=0.249 and RMSE=0.229) was proved better followed by Weibul Model (R^2=0.993, SE=0.256 and RMSE=0.226), Gompertz Model (R^2=0.992, SE=0.251 and RMSE=0.236) and Rational Function (R^2=0.993, SE=0.260 and RMSE=0.256). For the third combination Bangalore(S_2) x75:150:75(F_3), out of different Models tried Weibul Model (R^2=0.992, SE=0.274 and RMSE=0.241), was proved better followed by MMF Model (R^2=0.992, SE=0.274 and RMSE=0.241), Rational function (R^2=0.992, SE=0.270 and RMSE=0.268) and Gompertz Model (R^2=0.987, SE=0.328 and RMSE=0.310).(Table 4.1.3(b)).

For the third source and their combination, Chikkamangalore(S_3) x 25:50:25(F_1) out of different Models tried, MMF Model (R^2=0.987, SE=0.379 and RMSE=0.334) was proved better followed by Rational function (R^2=0.987, SE=0.379 and RMSE=0.339).

Table 4.1.2(b): Selected Models for 4x2m (SP_2) x 50:100:50(F_1); 4x3m (SP_3) xNo fertilizer (F_0); 4x3m (SP_3) x50:100:50 (F_1) for height

Combination	Name of the Model	Model Equations	R^2	SE	RMSE
SP_2F_1	Weibul Model	y=11.004-35.985*exp(-1.699*x^0.160)	0.966**	0.270	0.220
	MMF Model	y=(7.93*0.57+11.54*x^0.4)/(0.57+x^0.4)	0.966**	0.270	0.220
	Logarithm Model	y=4.501+1.543*ln(x)	0.964**	0.227	0.227
	Gompertz	y=7.771*exp(-exp(0.197-0.431x))	0.938**	0.325	0.720
SP_3F_0	Rational Function	y=(0.045+6.971x)/(1+0.996x-0.019x^2)	0.997**	0.085	0.068
	Logarithm Model	y=3.567+1.734*ln(x)	0.997**	0.070	0.069
	MMF Model	y=(7.36*1.25+17.19*x^0.3)/(1.25+x^0.3)	0.997**	0.087	0.069
	Weibul Model	y=12.707-20.725*exp(-0.818*x^0.229)	0.997**	0.087	0.070
SP_3F_1	Rational Function:	y=(-4.072+16.42x)/(1+2.176x-0.04x^2)	0.992**	0.165	0.136
	MMF Model	y=(10.6*0.59+12.5*x^0.42)/(0.6+x^0.42)	0.991**	0.171	0.140
	Weibul Model	y=10.718-25.819*exp(-1.342*x^0.248)	0.991**	0.172	0.141
	Logarithm Model	y=4.079+1.930*ln(x)	0.988**	0.163	0.162

** Significant at 1 percent
Y is the height increment,
X is the age

Table 4.1.3(a): Selected Models for Kerala (S_1) x25:50:25(F_1); Kerala (S_1) x50:100:50(F_2); Kerala (S_1) x 75:150:75(F_3) for dbh

Combination	Name of the Model	Model Equations	R^2	SE	RMSE
S_1F_1	MMF Model	y=(1.23*20.73+64.04*x^0.7)/(20.7+x^0.73)	0.985**	0.517	0.456
	Weibul Model	y=37.048-35.788*exp(-0.083*x^0.728)	0.985**	0.517	0.457
	Polynomial Model	y=2.09+2.18x-0.16x^2+0.01x^3-0.0001x^4	0.985**	0.555	0.464
	Rational Function	y=(1.797+2.916x)/(1+0.156x-0.004x^2)	0.985**	0.514	0.475
S_1F_2	Rational Function	y=(-8.560+20.272x)/(1+2.012x-0.069x^2)	0.985**	0.468	0.413
	MMF Model	y=(3.6*10.29+84.99*x^0.39)/(10.3+x^0.39)	0.977**	0.568	0.501
	Weibul Model	y=43.473-46.689*exp(-0.174*x^0.407)	0.977**	0.570	0.503
	Logarithm Model	y=3.644+4.163*ln(x)	0.968**	0.592	0.591
S_1F_3	Rational Function	y=(-1.551+9.291x)/(1+0.886x-0.031x^2)	0.993**	0.316	0.284
	Weibul Model	y=44.247-44.153*exp(-0.102*x^0.545)	0.988**	0.410	0.363
	MMF Model	y=(0.18*14.9+66.5*x^0.57)/(14.85+x^0.56)	0.988**	0.411	0.363
	Sinusoidal Model	y=-12.831+27.742*cos(0.062x+5.342)	0.978**	0.543	0.483

** Significant at 1 percent
Y is the height increment,
X is the age

Table 4.1.3(b): Selected Models for Bangalore (S_2) x25:50:25(F_1); Bangalore (S_2) x 50:100:50(F_2); Bangalore (S_2) x 75:150:75(F_3) for dbh

Combination	Name of the Model	Model Equations	R^2	SE	RMSE
S_2F_1	Rational Function	y=(-0.694+5.741x)/(1+0.443x-0.009x^2)	0.992**	0.330	0.297
	Weibul Model	y=30.342-35.344*exp(-0.277*x^0.395)	0.991**	0.351	0.310
	MMF Model	y=(3.85*4.79+39.09*x^0.47)/(4.79+x^0.473)	0.991**	0.351	0.310
	Logarithm Model	y=3.138+4.018*ln(x)	0.985**	0.389	0.389
S_2F_2	MMF Model	y=(3.18*7.6+13.58*x^1.599)/(7.61+x^1.599)	0.993**	0.249	0.220
	Weibul Model	y=12.635-10.441*exp(-0.232*x^1.060)	0.993**	0.256	0.226
	Gompertz Model	y=12.307*exp(-exp(0.385-0.371x))	0.992**	0.251	0.236
	Rational Function	y=(1.846+3.119x)/(1+0.141x+0.004x^2)	0.993**	0.260	0.256
S_2F_3	Weibul Model	y=19.758-20.532*exp(-0.294*x^0.525)	0.992**	0.274	0.241
	MMF Model	y=(0.155*4.61+24.31*x^0.65)/(4.61+x^0.65)	0.992**	0.274	0.241
	Rational Function	y=(1.616+4.107x)/(1+0.288x-0.004x^2)	0.992**	0.270	0.268
	Gompertz Model	y=12.964*exp(-exp(0.291-0.288x))	0.987**	0.328	0.310

** Significant at 1 percent
Y is the height increment,
X is the age

Table 4.1.3(c): Selected Models for Chikkamangalore (S_3) x 25:50:25(F_1); Chikkamangalore (S_3) x 50:100:50(F_2); Chikkamangalore (S_3) x 75:150:75(F_3) for dbh

Combination	Name of the Model	Model Equations	R^2	SE	RMSE
S_3F_1	MMF Model	y=(1.14*4.04+15.2*x^1.19)/(4.04+x^1.186)	0.987**	0.379	0.334
	Rational Function	y=(-0.286+5.592x)/(1+0.369x-0.002x^2)	0.987**	0.379	0.339
	Weibul Model	y=14.431-16.303*exp(-0.437*x^0.667)	0.986**	0.387	0.342
	Logarithm Model	y=3.861+3.691*ln(x)	0.985**	0.355	0.356
S_3F_2	MMF Model	y=(3.46*16.25+14.8*x^2.3)/(16.25+x^2.29)	0.994**	0.308	0.271
	Gompertz Model	y=14.312*exp(-exp(0.672-0.433x))	0.992**	0.340	0.322
	Weibul Model	y=14.218-11.881*exp(-0.154*x^1.388)	0.992**	0.371	0.328
	Logistic Model	y=13.99/(1+4.16*exp(-0.53x))	0.990	0.377	0.627
S_3F_3	Rational Function	y=(-0.892+6.729x)/(1+0.411x-0.007x^2)	0.964**	0.826	0.730
	MMF Model	y=(0.48*4.6+21.45*x^1.002)/(4.6+x^1.002)	0.962**	0.843	0.742
	Weibul Model	y=22.955-27.247*exp(-0.373*x^0.515)	0.962**	0.848	0.747
	Richards Model	y=15.349/(1+exp(-1.508-0.377x))^(1/0.117)	0.954**	0.933	0.821

** Significant at 1 percent
Y is the height increment,
X is the age

Weibul Model (R^2=0.986, SE=0.387 and RMSE=0.342) and Logarithm Model (R^2= 0.985 , SE=0.355 and RMSE=0.356), For second combination Chikkamangalore(S_3) x 50:100:50 (F_2), out of different Models tried MMF Model (R^2=0.994, SE=0.308 and RMSE=0.271) was proved better followed by Gompertz Model (R^2=0.992, SE=0.340 and RMSE=0.322), Weibul Model (R^2=0.992, SE=0.371 and RMSE=0.328) and Logistic Model (R^2=0.990, SE=0.377 and RMSE=0.627). For the third combination Chikkamangalore (S_3) x75:150:75(F_3), out of different Models tried Rational function (R^2=0.964, SE=0.826 and RMSE=0.730) was proved better followed by MMF Model (R^2=0.962, SE=0.843 and RMSE=0.742), Weibul Model (R^2=0.962, SE=0.848 and RMSE=0.747), and Richards Model (R^2=0.954, SE=0.933 and RMSE=0.821). (Table 4.1.3(c)).

For the fourth source and their combination, Thirthahalli (S_4) x 25:50:25(F_1) out of different Models tried, Sinusoidal Model (R^2=0.984, SE=0.392 and RMSE=0.346) was proved better followed by Richards Model (R^2=0.983, SE=0.412 and RMSE=0.364), Gompertz Model (R^2=0.982, SE=0.397 and RMSE=0.375) and Rational Function (R^2=0.984, SE=0.395 and RMSE=0.449). For the second combination Thirthahalli (S_4) x 50:100:50(F_2), out of different Models tried MMF Model (R^2=0.985, SE=0.565 and RMSE=0.499) was proved better followed by Weibul Model (R^2=0.981, SE=0.645 and RMSE=0.571), Richards Model (R^2=0.980, SE=0.657 and RMSE=0.582) and Logistic Model (R^2=0.980, SE=0.623 and RMSE=0.590). For the third combination Thirthahalli(S_4) x 75:150:75(F_3), out of different Models tried MMF Model, (R^2=0.984, SE=0.529 and RMSE=0.466) was proved better followed by Weibul Model (R^2=0.984, SE=0.533 and RMSE=0.478), Gompertz Model (R^2=0.981, SE=0.532 and RMSE=0.501) and polynomial Model (R^2=0.986, SE=0.527 and RMSE=1.528).(Table 4.1.3(d))

4.1.4 DBH prediction Models for Spacing and fertilizer level

The different Models were tried to predicting height growth of *Acacia mangium* with different spacing and fertilizer levels. For first combination, 4x1m (SP_1) xNo fertilizer (F_0) out of different Models tried, MMF Model (R^2=0.994, SE=0.211 and RMSE=0.172) was proved better followed by Weibul Model (R^2=0.994, SE=0.217 and RMSE=0.177), Gompertz Model (R^2=0.991, SE=0.236 and RMSE=0.215), and Logistic Model (R^2=0.989, SE=0.260 and RMSE=0.237). And for second combination 4x1m (SP_1) x50:100:50(F_1), out of different Models tried Weibul Model (R^2=0.987, SE=0.287 and RMSE=0.254) was proved better followed by Richards Model (R^2 = 0.984, SE=0.327 and RMSE=0.266), MMF Model (R^2=0.983, SE=0.334 and RMSE=0.271) and Logistic Model (R^2=0.959, SE=0.460 and RMSE=0.419). (Table 4.1.4(a)).

For the second spacing and their combination 4x2m(SP_2) x No fertilizer (F_0), out of different Models tried MMF Model (R^2=0.975, SE=0.534 and RMSE=0.434), was proved better followed by Weibul Model (R^2=0.975, SE=0.535 and RMSE=0.436), Gompertz Model (R^2=0.971, SE=0.510 and RMSE=0.465) and Logistic Model (R^2=0.969, SE=0.528 and RMSE=0.481).(Table 4.1.4(a)).

And for second combination, 4x2m (SP_2) x 50:100:50(F_1) out of different Models tried, Rational function (R^2=0.985, SE=0.439 and RMSE=0.358) was proved better followed by Weibul Model (R^2=0.985 SE=0.440 and RMSE=0.359), MMF Model (R^2=0.985, SE=0.440 and RMSE=0.359) and Logarithm Model (R^2=0.982, SE=0.393 and RMSE=0.392).

Table 4.3.1(d): Selected Models for Thirthahalli (S_4) x 25:50:25(F_1); Thirthahalli (S_4) x 50:100:50(F_2); Thirthahalli (S_4) x 75:150:75(F_3) for dbh.

Combination	Name of the Model	Model Equations	R^2	SE	RMSE
S_4F_1	Sinusoidal Model	y=5.908+5.740*cos(0.187x+4.244)	0.984**	0.392	0.346
	Richards Model	y=12.194/(1+exp(1.998-0.430x))^(1/1.718)	0.983**	0.412	0.364
	Gompertz Relation	y=13.09*exp(-exp(0.372-0.245x))	0.982	0.397	0.375
	Rational Function	y=(3.440+0.635x)/(1-0.072x+0.006x^2)	0.984**	0.395	0.449
S_4F_2	MMF Model	y=(4.4*108.14+15.4*x^3.2)/(108.14+x^3.1)	0.985**	0.565	0.499
	Weibul Model	y=14.841-10.999*exp(-0.039*x^2.017)	0.981**	0.645	0.571
	Richards Model	y=14.980/(1+exp(2.662-0.592x))^(1/1.682)	0.980**	0.657	0.582
	Logistic Model	y=15.283/(1+4.590*exp(-0.478x))	0.980**	0.623	0.590
S_4F_3	MMF Model	y=(2.75*119.8+188.8*x^0.9)/(119.8+x^0.8)	0.984**	0.529	0.466
	Weibul Model	y=50.765-47.834*exp(-0.029*x^0.947)	0.984**	0.533	0.478
	Gompertz Model	y=21.584*exp(-exp(0.585-0.141x))	0.981**	0.532	0.501
	Polynomial Model	y=3.03+1.13x+0.102x^2-0.02x^3+0.001x^4	0.986**	0.527	1.528

** Significant at 1 percent
Y is the height increment,
X is the age

Table 4.1.4(a):Selected Models for 4x1m(SP_1)xNo fertilizer(F_0);4x1m(SP_1)x50:100:50(F_1); 4x2m(SP_2) x No fertilizer (F_0) for dbh.

Combi nation	Name of the Model	Model Equations	R^2	SE	RMSE
SP_1F_0	MMF Model	y=(2.96*70.5+127.4*x^0.75)/(70.5)+x^0.75	0.994**	0.211	0.172
	Weibul Model	y=33.438-30.299*exp(-0.053*x^0.818)	0.994**	0.217	0.177
	Gompertz Relation	y=14.907*exp(-exp(0.299-0.178x))	0.991**	0.236	0.215
	Logistic Model	y=13.26/(1+2.29*exp(-0.286x))	0.989**	0.260	0.237
SP_1F_1	Weibul Model	y=10.272-4.660*exp(-0.003*x^3.597)	0.987**	0.287	0.254
	Richards Model	y=10.11/(1+exp(94.65-14.26x))^(1/119.718)	0.984**	0.327	0.266
	MMF Model	y=(5.63*848.9+10.9*x^4.26)/(848.9+x^4.3)	0.983**	0.334	0.271
	Logistic Model	y=15.16/(1+2.399*exp(-0.211x))	0.959**	0.460	0.419
SP_2F_0	MMF Model	y=(3.03*26.95+67.5*x^0.74)/(26.95+x^0.7)	0.975**	0.534	0.434
	Weibul Model	y=38.22-35.14*exp(-0.067*x^0.749)	0.975**	0.535	0.436
	Gompertz Model	y=16.416*exp(-exp(0.290-0.203x))	0.971**	0.510	0.465
	Logistic Model	y=14.89/(1+2.288*exp(-0.314x))	0.969**	0.528	0.481

** Significant at 1 percent
Y is the height increment,
X is the age

Table 4.1.4(b): Selected Models for 4x2m (SP_2) x 50:100:50(F_1); 4x3m (SP_3) x No fertilizer (F_0); 4x3m (SP_3) x50:100:50 (F_1) for dbh.

Combination	Name of the Model	Model Equations	R^2	SE	RMSE
SP_2F_1	Rational Function	y=(0.259+5.571x)/(1+0.397x-0.007x^2)	0.985**	0.439	0.358
	Weibul Model	y=22.121-25.774*exp(-0.363*x^0.456)	0.985**	0.440	0.359
	MMF Model	y=(2.76*3.6+29.3*x^0.54)/(3.612+x^0.54)	0.985**	0.440	0.359
	Logarithm Model	y=3.971+3.795*ln(x)	0.982**	0.393	0.392
SP_3F_0	MMF Model	y=(3.7*20.98+12.5*x^2.39)/(20.98+x^2.4)	0.998**	0.172	0.140
	Weibul Model	y=11.689-8.378*exp(-0.096*x^1.703)	0.997**	0.204	0.166
	Richards Model	y=11.802/(1+exp(1.53-0.585x))^(1/1.196)	0.997**	0.210	0.171
	Logistic Model	y=11.875/(1+3.373*exp(-0.552x))	0.997**	0.189	0.172
SP_3F_1	Weibul Model	y=12.746-9.450*exp(-0.092*x^1.858)	0.998**	0.192	0.157
	MMF Model	y=(3.76*22.8+13.49*x^2.7)/(22.8+x^2.68)	0.998**	0.195	0.159
	Richards Model	y=12.827/(1+exp(2.281-0.76x))^(1/1.512)	0.998**	0.196	0.161
	Logistic Model	y=12.97/(1+4.25*exp(-0.657x))	0.998**	0.185	0.169

** Significant at 1 percent
Y is the height increment,
X is the age

For the third spacing and their combination, 4x3m(SP_3) xNo fertilizer(F_0), out of different Models tried MMF Model (R^2 = 0.998, SE=0.172 and RMSE=0.140) was proved better followed by Weibul Model (R^2 =0.997, SE=0.204 and RMSE=0.166), Richards Model (R^2 =0.997, SE=0.210 and RMSE=0.171) and Logistic Model (R^2 =0.997, SE= 0.189 and RMSE=0.172), and for the second combination 4x3m(SP_3) x50:100:50 (F_1), out of different Models tried Weibul Model (R^2 =0.998, SE=0.192 and RMSE=0.157) was proved better followed by MMF Model (R^2 =0.998, SE= 0.195 and RMSE=0.159), Richards Model (R^2 =0.998, SE=0.196 and RMSE=0.161) and Logistic Model (R^2 = 0.998, SE=0.185 and RMSE=0.169). (Table4.1.4 (b)).

4.1.1.1 Models predicting the future Height growth with corresponding error terms in case of Sources and fertilizer level:

Among different Models tried in predicting the Height growth, the treatment combinations, Polynomial, Gaussian, Sinusoidal, Richards, Weibul, Rational, MMF, Logistic, Logarithm, and Gompertz Model was found to be the best Model with highest R^2 value and lowest SE and RMSE. Therefore, these Models are considered for predicting the height at different years and comparing the same with the actual values. In case of first source and their combination, Kerala (S_1) x25:50:25(F_1) the best Model obtained was Rational Function and the estimated Model obtained was y= (-370.216+512.827x)/ (1+70.015x-1.866x^2), Based on this Model the prediction was made for the 11 years and then compared with the actual values .It was noticed the errors between observed and expected values varies from 0.03m (1998) to 0.27m (2008) and the error values are presented in the (Table 4.1.1.1a(I)). The second best Model obtained was Weibul Model and the estimated Model obtained was y=14.747-61.633*exp (-1.594*x^0.177), Based on this Model the prediction was made for the 11 years and then compared with the actual values .It was noticed the errors between observed and expected values varies from -0.14m (1998) to 0.58m (2008) and the error values are presented in the (Table 4.1.1.1a(II)). The third best Model obtained was MMF Model and the estimated Model obtained was y= (19.772*0.632+16.132*x^0.416)/ (0.632+x^0.416), Based on this Model the prediction was made for the 11 years and then compared with the actual values .It was noticed the errors between observed and expected values varies from -0.14m (1998) and 0.59m (2008) the error values are presented in the (Table 4.1.1.1a (III)). The fourth best Model obtained was Logarithm Model and the estimated Model obtained was y=2.481+2.943*ln(x).Based on this Model the prediction was made for the 11 years and then compared with the actual values .It was noticed the errors between observed and expected values varies from -0.39m (1998) to 0.40m (2008) and the error values are presented in the (Table 4.1.1.1a (IV)).

In case of second combination Kerala (S_1) x50:100:50(F_2), the best Model obtained was Rational Function and the estimated Model obtained was y=(60818031.41+ 83856448.89 x) / (1+11024498.96x+223011.0063x^2), Based on this Model the prediction was made for the 11 years and then compared with the actual values .It was noticed the errors between observed and expected values varies from -0.13m (1998) to 0.37m (2008) and the error values are presented in the (Table 4.1.1.1b(I)). The second best Model obtained was MMF Model and the estimated Model obtained was y= (26.425*0.321+11.371*x^0.624)/ (0.321+x^0.624).Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was

Noticed the error between observed and expected values varies from -0.18m (1998) to 0.67m (2008) and the error values are presented in the (Table 4.1.1.1b (II)). The third best Model was Weibul Model and the estimated Model obtained was y=10.9-179.6*exp(-3.1*x^0.16), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.21m (1998) to 0.67m (2008) and the error values are presented in the (Table 4.1.1.1b (III)). The fourth best Model obtained was Logarithm Model and the estimated Model obtained was y=2.797+2.681 * ln (x).Based on this Model the prediction was made for the 11 years and then compared with the actual values .It was noticed the errors between observed and expected values varies from -0.79m (1998) to 0.28m (2008) and the error values are presented in the (Table 4.1.1.1b (IV)).

Table 4.1.1.1(a): Table showing the actual values and predicted values Kerala (S_1) x 25:50:25(F_1) for height (m).

I. Rational Function: y=(-370.216+512.827x)/(1+70.015x-1.866x^2).

II. Weibul Model: y=14.747-61.633*exp(-1.594*x^0.177)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		2.09	2.06	0.03		2.09	2.23	-0.14
1998-1999		4.68	4.91	-0.22		4.68	4.58	0.10
1999-2000		6.15	6.01	0.14		6.15	5.86	0.30
2000-2001		7.01	6.69	0.32		7.01	6.71	0.30
2001-2002		7.33	7.21	0.12		7.33	7.34	-0.01
2002-2003		7.37	7.65	-0.28		7.37	7.84	-0.47
2003-2004		7.84	8.06	-0.21		7.84	8.25	-0.40
2004-2005		8.67	8.45	0.22		8.67	8.59	0.09
2005-2006		8.75	8.84	-0.10		8.75	8.88	-0.13
2006-2007		8.97	9.25	-0.28		8.97	9.13	-0.17
2007-2008		9.94	9.66	0.27		9.94	9.36	0.58

III. MMF Model: y=(19.772*0.632+16.132*x^0.416)/(0.632+x^0.416)

IV. Logarithm Model: y=2.481+2.943*ln(x)

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
1997-1998		2.09	2.23	-0.14		2.09	2.48	-0.39
1998-1999		4.68	4.59	0.09		4.68	4.52	0.16
1999-2000		6.15	5.87	0.28		6.15	5.71	0.44
2000-2001		7.01	6.72	0.29		7.01	6.56	0.45
2001-2002		7.33	7.35	-0.02		7.33	7.22	0.11
2002-2003		7.37	7.85	-0.48		7.37	7.75	-0.38
2003-2004		7.84	8.25	-0.41		7.84	8.21	-0.36
2004-2005		8.67	8.59	0.09		8.67	8.60	0.07
2005-2006		8.75	8.87	-0.13		8.75	8.95	-0.20
2006-2007		8.97	9.12	-0.16		8.97	9.26	-0.29
2007-2008		9.94	9.35	0.59		9.94	9.54	0.40

Table 4.1.1.1(b): Table showing the actual values and predicted values of Kerala (S_1) x 50:100:50(F_2) for height (m).

I. RationalFunction:y=(60818031.41+83856448.89x)/(1+11024498.96x+223011.01x2)

II. MMF Model: y=(26.425*0.321+11.371*x^0.624)/(0.321+x^0.624)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		2.01	2.13	-0.13		2.01	2.19	-0.18
1998-1999		5.28	5.05	0.23		5.28	4.86	0.43
1999-2000		6.05	6.14	-0.09		6.05	6.11	-0.06
2000-2001		7.27	6.78	0.50		7.27	6.87	0.40
2001-2002		7.28	7.23	0.04		7.28	7.39	-0.12
2002-2003		7.44	7.61	-0.17		7.44	7.78	-0.34
2003-2004		7.56	7.94	-0.38		7.56	8.08	-0.52
2004-2005		7.94	8.25	-0.32		7.94	8.32	-0.39
2005-2006		8.58	8.55	0.03		8.58	8.52	0.06
2006-2007		8.76	8.84	-0.08		8.76	8.69	0.07
2007-2008		9.51	9.14	0.37		9.51	8.84	0.67

III. Weibul Model: y=10.901-179.632*exp(-3.029*x^0.162)

IV. Logarithm Model: y=2.797+2.681*ln(x)

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
1997-1998		2.01	2.21	-0.21		2.01	2.80	-0.79
1998-1999		5.28	4.84	0.44		5.28	4.66	0.63
1999-2000		6.05	6.09	-0.03		6.05	5.74	0.31
2000-2001		7.27	6.85	0.42		7.27	6.51	0.76
2001-2002		7.28	7.38	-0.10		7.28	7.11	0.16
2002-2003		7.44	7.77	-0.33		7.44	7.60	-0.16
2003-2004		7.56	8.07	-0.51		7.56	8.01	-0.45
2004-2005		7.94	8.32	-0.38		7.94	8.37	-0.44
2005-2006		8.58	8.52	0.06		8.58	8.69	-0.10
2006-2007		8.76	8.69	0.07		8.76	8.97	-0.21
2007-2008		9.51	8.84	0.672		9.51	9.23	0.284

Table 4.1.1.1(c): Table showing the actual values and predicted values Kerala (S_1) x75:150:75(F_3) for height (m)

I. Rational Function: y=(-59.410+85.149x)/(1+10.892x-0.234x^2)

II. Weibul Model: y=12.361-77.427*exp(-2.044*x^0.189)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		2.21	2.21	0.01		2.21	2.33	-0.12
1998-1999		5.16	5.08	0.08		5.16	4.83	0.33
1999-2000		5.75	6.21	-0.46		5.75	6.10	-0.36
2000-2001		7.21	6.89	0.32		7.21	6.92	0.29
2001-2002		7.60	7.38	0.22		7.60	7.51	0.09
2002-2003		8.04	7.79	0.24		8.04	7.96	0.08
2003-2004		8.11	8.16	-0.05		8.11	8.32	-0.21
2004-2005		8.28	8.50	-0.22		8.28	8.61	-0.33
2005-2006		8.56	8.83	-0.27		8.56	8.86	-0.30
2006-2007		8.83	9.15	-0.32		8.83	9.07	-0.24
2007-2008		9.94	9.48	0.46		9.94	9.25	0.69

III. Logarithm Model: y=2.744+2.829*ln(x)

IV. Richards Model: y=8.961/(1+exp(-2.322-0.524x))^(1/0.048)

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
1997-1998		2.21	2.74	-0.53		2.21	2.80	-0.58
1998-1999		5.16	4.70	0.45		5.16	4.46	0.70
1999-2000		5.75	5.85	-0.11		5.75	5.91	-0.17
2000-2001		7.21	6.67	0.54		7.21	7.00	0.21
2001-2002		7.60	7.30	0.31		7.60	7.74	-0.13
2002-2003		8.04	7.81	0.22		8.04	8.21	-0.18
2003-2004		8.11	8.25	-0.14		8.11	8.51	-0.40
2004-2005		8.28	8.63	-0.34		8.28	8.69	-0.41
2005-2006		8.56	8.96	-0.40		8.56	8.80	-0.24
2006-2007		8.83	9.26	-0.43		8.83	8.87	-0.04
2007-2008		9.94	9.53	0.41		9.94	8.90	1.04

In case third combination Kerala (S_1) x75:150:75(F_3), the best Model obtained was Rational Function and the estimated Model obtained was y= (-59.410+85.149x)/ (1+10.892x-0.234x^2), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.01m (1998) to 0.46m (2008) and the error values are presented in the (Table 4.1.1.1c (I)). The second best Model obtained was Weibul Model and the estimated Model obtained was 12.361-77.427*exp (-2.044*x^0.189), Based on this Model the prediction was made for the 11 years and then compared with the actual values .It was noticed the errors between observed and expected values varies from -0.12m (1998) to 0.69m (2008) and the error values are presented in the (Table 4.1.1.1c (II)). The third best Model obtained was Logarithm Model and the estimated Model obtained was y=2.744+2.829*ln(x), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.53m (1998) to 0.41m (2008) and the error values are presented in the (Table 4.1.1.1c (III)).The fourth best Model obtained was Richards Model and the estimated Model obtained was y=8.961/(1+exp(-2.322-0.524x))^ (1/0.048), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.58m (1998) to 1.04 m (2008) and the error values are presented in the (Table 4.1.1.1c (IV)).

In case of second source and their combination, Bangalore (S_2) x25:50:25(F_1) the best Model obtained was Rational Function and the estimated Model obtained was y= (-12.715+22.488x)/(1+3.149x-0.076x^2), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.03m (1998) to -0.21 m (2008) and the error values are presented in the (Table 4.1.1.1d (I)). The second best Model obtained was MMF Model and the estimated Model obtained was y= (-49.542 *0.424 +24.593*x^0.183)/ (0.424+x^0.183), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.09m (1998) to -0.01m (2008) and the error values are presented in the (Table 4.1.1.1d (II)). The third best Model obtained was Weibul Model and estimated Model obtained was y=15.05-37.7*exp (-1.1*x^0.2), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.0981m (1998) to -0.006m (2008) and the error values are presented in the (Table 4.1.1.1d(III)) and the fourth best Model obtained was Logarithm Model and the estimated Model obtained was y=2.621+2.555*ln(x), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.19m (1998) to -0.07m (2008) and the error values are presented in the (Table 4.1.1.1d (IV)).

In case of second combination Bangalore (S_2) x50:100:50(F_2), the best Model obtained was Weibul Model and the estimated Model obtained was y=16.66-24.88*exp (-0.594*x^0.26), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.06m (1998) to -0.14m (2008) and the error values are presented in the (Table 4.1.1.1e (I)). The second best Model obtained was MMF Model and the estimated Model obtained was y= (-7.852*1.964+24.086*x^0.297)/ (1.964+x^0.297), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.06m (1998) to -0.13m (2008) and the error values are presented in the (Table 4.1.1.1e (II)). The third best Model obtained was Logarithm Model and the estimated Model obtained was y=2.866+2.305*ln(x), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.01m (1998) to -0.11m (2008) and the error values are presented in the (Table 4.1.1.1e (III)).

And the fourth best Model obtained was Rational Function and the estimated Model obtained was y= (-0.197+4.686x)/ (1+0.548x-0.008x^2), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.05m (1998) to -0.19m (2008) and the error values are presented in the (Table 4.1.1.1e (IV)).

Table 4.1.1.1(d): Table showing actual and predicted values Bangalore (S_2) x25:50:25(F_1) height (m)

I. Rational Function: y=(-12.715+22.488x)/(1+3.149x-0.076x^2)

II. MMF Model: y=(-49.542*0.424+24.593*x^0.183)/(0.424+x^0.183)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		2.43	2.40	0.03		2.43	2.52	-0.09
1998-1999		4.32	4.61	-0.29		4.32	4.43	-0.11
1999-2000		6.08	5.61	0.48		6.08	5.50	0.58
2000-2001		6.39	6.24	0.15		6.39	6.24	0.15
2001-2002		6.50	6.72	-0.22		6.50	6.80	-0.30
2002-2003		6.81	7.12	-0.31		6.81	7.25	-0.43
2003-2004		7.04	7.49	-0.45		7.04	7.62	-0.58
2004-2005		8.31	7.84	0.47		8.31	7.94	0.37
2005-2006		8.46	8.18	0.28		8.46	8.21	0.25
2006-2007		8.53	8.52	0.00		8.53	8.46	0.07
2007-2008		8.67	8.87	-0.21		8.67	8.68	-0.01

III. Weibul Model: y=15.050-37.721*exp(-1.103*x^0.199)

IV. Logarithm Model: y=2.621+2.555*ln(x)

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
1997-1998		2.43	2.53	-0.098		2.43	2.62	-0.19
1998-1999		4.32	4.42	-0.096		4.32	4.39	-0.07
1999-2000		6.08	5.49	0.594		6.08	5.42	0.66
2000-2001		6.39	6.23	0.162		6.39	6.16	0.24
2001-2002		6.50	6.79	-0.298		6.50	6.73	-0.23
2002-2003		6.81	7.25	-0.432		6.81	7.19	-0.38
2003-2004		7.04	7.62	-0.583		7.04	7.58	-0.55
2004-2005		8.31	7.94	0.373		8.31	7.92	0.39
2005-2006		8.46	8.21	0.247		8.46	8.22	0.24
2006-2007		8.53	8.46	0.070		8.53	8.49	0.03
2007-2008		8.67	8.67	-0.006		8.67	8.74	-0.07

Table 4.1.1.1(e): Table showing the actual values and predicted values Bangalore (S_2) x 50:100:50(F_2) for height (m)

I. Weibul Model: y=16.661-24.877*exp(-0.594*x^0.259)

II. MMF Model: y=(-7.852*1.964+24.086*x^0.297)/(1.964+x^0.297)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		2.86	2.93	-0.06		2.86	2.92	-0.06
1998-1999		4.64	4.44	0.20		4.64	4.44	0.20
1999-2000		5.31	5.37	-0.05		5.31	5.36	-0.05
2000-2001		5.94	6.03	-0.09		5.94	6.03	-0.09
2001-2002		6.50	6.56	-0.06		6.50	6.55	-0.05
2002-2003		7.00	6.99	0.01		7.00	6.98	0.02
2003-2004		7.07	7.35	-0.28		7.07	7.34	-0.27
2004-2005		7.97	7.67	0.30		7.97	7.66	0.31
2005-2006		8.06	7.95	0.11		8.06	7.94	0.12
2006-2007		8.23	8.20	0.03		8.23	8.19	0.04
2007-2008		8.28	8.42	-0.14		8.28	8.41	-0.13

III. Logarithm Model: y=2.866+2.305*ln(x)

IV. Rational Function: y=(-0.197+4.686x)/(1+0.548x-0.008x^2)

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
1997-1998		2.86	2.87	-0.01		2.86	2.91	-0.05
1998-1999		4.64	4.46	0.18		4.64	4.45	0.19
1999-2000		5.31	5.40	-0.08		5.31	5.39	-0.08
2000-2001		5.94	6.06	-0.12		5.94	6.05	-0.11
2001-2002		6.50	6.58	-0.08		6.50	6.56	-0.06
2002-2003		7.00	7.00	0.01		7.00	6.98	0.02
2003-2004		7.07	7.35	-0.28		7.07	7.34	-0.26
2004-2005		7.97	7.66	0.31		7.97	7.65	0.32
2005-2006		8.06	7.93	0.13		8.06	7.94	0.12
2006-2007		8.23	8.17	0.06		8.23	8.22	0.01
2007-2008		8.28	8.39	-0.11		8.28	8.47	-0.19

Table 4.1.1.1(f): Table showing the actual values and predicted values Bangalore (S_2) x75:150:75(F_3) for height (m)

I. Rational Function: y=(-1.628+7.057x)/(1+0.931x-0.022x^2)

II. Weibul Model: y=20.544-26.585*exp(-0.410*x^0.282)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		2.84	2.84	-0.01		2.84	2.90	-0.06
1998-1999		4.53	4.50	0.02		4.53	4.40	0.13
1999-2000		5.27	5.44	-0.16		5.27	5.34	-0.07
2000-2001		6.28	6.08	0.20		6.28	6.04	0.24
2001-2002		6.75	6.59	0.16		6.75	6.60	0.15
2002-2003		6.82	7.03	-0.21		6.82	7.07	-0.25
2003-2004		6.83	7.42	-0.59		6.83	7.47	-0.64
2004-2005		8.19	7.79	0.40		8.19	7.82	0.37
2005-2006		8.32	8.15	0.17		8.32	8.13	0.18
2006-2007		8.38	8.50	-0.12		8.38	8.42	-0.04
2007-2008		8.72	8.86	-0.14		8.72	8.67	0.05

III. MMF Model: y=(5.356*3.144+28.890*x^0.325)/(3.144+x^0.325)

IV. Logarithm Model: y=2.765+2.429*ln(x)

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
1997-1998		2.84	2.91	-0.07		2.84	2.77	0.07
1998-1999		4.53	4.40	0.12		4.53	4.45	0.08
1999-2000		5.27	5.35	-0.07		5.27	5.43	-0.16
2000-2001		6.28	6.05	0.23		6.28	6.13	0.15
2001-2002		6.75	6.60	0.15		6.75	6.67	0.08
2002-2003		6.82	7.07	-0.25		6.82	7.12	-0.30
2003-2004		6.83	7.47	-0.63		6.83	7.49	-0.66
2004-2005		8.19	7.82	0.37		8.19	7.82	0.37
2005-2006		8.32	8.13	0.19		8.32	8.10	0.21
2006-2007		8.38	8.41	-0.03		8.38	8.36	0.02
2007-2008		8.72	8.67	0.06		8.72	8.59	0.13

In case third combination Bangalore (S_2) x75:150:75(F_3), the best Model obtained was Rational Function and the estimated Model obtained was y= (-1.628+7.1x)/(1+0.931x-0.022x^2), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed value and expected values varies from -0.01m (1998) to -0.14m (2008) and the error values are presented in the (Table 4.1.1.1f (I)). The second best Model obtained was Weibul Model and the estimated Model obtained was y=20.544-26.58*exp (-0.410*x^0.28), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.06m (1998) to 0.05m (2008) and the error values are presented in the (Table 4.1.1.1f (II)). The third best Model obtained was MMF Model and the estimated Model obtained was y= (5.356*3.144+28.890*x^0.325)/ (3.144+x^0.325), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.07m (1998) to 0.06 m (2008) and the error values are presented in the (Table 4.1.1.1f (III)) and fourth best Model obtained was Logarithm Model and the estimated Model obtained was y=2.765+2.429*ln(x), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.07m (1998) to 0.13m (2008) and error values are presented in (Table 4.1.1.1f (IV)).

In case of third source and their combination, Chikkamangalore (S_3) x25:50:25(F_1) the best Model obtained was MMF Mode and the estimated Model obtained was y= (2.203*34.772+9.268 *x^3.846)/ (34.772+x^3.846), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.04m (1998) to 0.40m (2008) and the error values are presented in the (Table 4.1.1.1g (I)). The second best Model obtained was Richards Model and the estimated Model obtained was y=9.17/ (1+exp (3.37-1.28x)) ^ (1/1.60), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.01m (1998) to 0.48m (2008) and the error values are presented in the (Table 4.1.1.1g (II)).

The third best Model obtained was Logistic Model and the estimated Model obtained was y=9.205/ (1+9.032*exp (-1.076x)), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.18m (1998) to 0.044 m (2008) and the error values are presented in the (Table 4.1.1.1g (III)). The fourth best Model obtained was Weibul Model and the estimated Model obtained was y=9.128-7.308 *exp (-0.079*x^2.432), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.06m (1998) to 0.52m (2008) and the error values are presented in the (Table 4.1.1.1g (IV)).

In case of second combination Chikkamangalore (S_3) x50:100:50(F_2), the best Model was MMF and the estimated Model obtained was y= (2.4*31.27+9.5*x^3.6)/ (31.3 +x^3.6), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.11m (1998) to 0.55m (2008) and the error values are presented in the (Table 4.1.1.1h (I)). The second best Model obtained was Logistic Model and the estimated Model obtained was y=9.384/ (1+7.260 *exp (-0.968x)), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.21m (1998) to 0.59m (2008) and the error values are presented in the (Table 4.1.1.1h (II)). The third best Model obtained was Richards Model and the estimated Model obtained was y=9.401/ (1+exp (1.608-0.915x)) ^ (1/0.824), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.22m (1998) to 0.57m (2008) and the error values are presented in the (Table 4.1.1.1h(III)) and fourth best Model obtained was Gompertz Model and the estimated Model obtained was y=9.510*exp (-exp (1.001-0.684x)), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from0.29m (1998) to 0.47m (2008) and the error values are presented in the (Table 4.1.1.1h (IV)).

Table 4.1.1.1(g): Table showing the actual values and predicted values Chikkamangalore (S_3) x 25:50:25(F_1) for height (m)

I. MMF Model: y=(2.203*34.772+9.268*x^3.846)/(34.772+x^3.846)
II. Richards Model :y=9.167/(1+exp(3.367-1.284x))^(1/1.600)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		2.44	2.40	0.04		2.44	2.32	0.12
1998-1999		4.17	4.27	-0.10		4.17	4.41	-0.25
1999-2000		6.97	6.89	0.08		6.97	6.79	0.18
2000-2001		8.46	8.25	0.21		8.46	8.31	0.16
2001-2002		8.55	8.80	-0.25		8.55	8.91	-0.36
2002-2003		8.86	9.03	-0.17		8.86	9.09	-0.24
2003-2004		8.89	9.13	-0.25		8.89	9.15	-0.26
2004-2005		9.03	9.19	-0.16		9.03	9.16	-0.13
2005-2006		9.13	9.22	-0.09		9.13	9.17	-0.04
2006-2007		9.50	9.23	0.27		9.50	9.17	0.33
2007-2008		9.64	9.24	0.40		9.64	9.17	0.48

III. Logistic Model: y=9.205/(1+9.032*exp(-1.076x))
IV. Weibul Model: y=9.128-7.308 *exp(-0.079*x^2.432)

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
1997-1998		2.44	2.26	0.18		2.44	2.38	0.06
1998-1999		4.17	4.49	-0.33		4.17	4.36	-0.19
1999-2000		6.97	6.78	0.19		6.97	6.80	0.17
2000-2001		8.46	8.20	0.26		8.46	8.40	0.07
2001-2002		8.55	8.84	-0.29		8.55	8.99	-0.44
2002-2003		8.86	9.08	-0.22		8.86	9.11	-0.26
2003-2004		8.89	9.16	-0.27		8.89	9.13	-0.24
2004-2005		9.03	9.19	-0.16		9.03	9.13	-0.10
2005-2006		9.13	9.20	-0.07		9.13	9.13	0.00
2006-2007		9.50	9.20	0.30		9.50	9.13	0.37
2007-2008		9.64	9.20	0.44		9.64	9.13	0.52

Table 4.1.1.1(h): Table showing the actual values and predicted values Chikkamangalore (S_3) x 50:100:50(F_2) for height (m).

I. MMF Model: y=(2.371*31.274+9.459 *x^3.612)/(31.274 +x^3.612)

II. Logistic Model: y=9.384/(1+7.260 *exp(-0.968x))

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		2.70	2.59	0.11		2.70	2.50	0.21
1998-1999		4.06	4.36	-0.31		4.06	4.58	-0.53
1999-2000		7.23	6.83	0.41		7.23	6.71	0.52
2000-2001		8.25	8.23	0.02		8.25	8.15	0.10
2001-2002		8.55	8.85	-0.31		8.55	8.87	-0.33
2002-2003		8.84	9.13	-0.29		8.84	9.18	-0.34
2003-2004		9.07	9.27	-0.19		9.07	9.31	-0.23
2004-2005		9.30	9.34	-0.04		9.30	9.35	-0.05
2005-2006		9.32	9.38	-0.06		9.32	9.37	-0.06
2006-2007		9.52	9.41	0.12		9.52	9.38	0.14
2007-2008		9.97	9.42	0.55		9.97	9.38	0.59

III. RichardS Model: y=9.401/(1+exp(1.608-0.915x))^(1/0.824)

IV. Gompertz Model: y=9.510*exp(-exp(1.001-0.684x))

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
1997-1998		2.70	2.48	0.22		2.70	2.41	0.29
1998-1999		4.06	4.60	-0.55		4.06	4.76	-0.70
1999-2000		7.23	6.71	0.53		7.23	6.70	0.53
2000-2001		8.25	8.12	0.13		8.25	7.97	0.28
2001-2002		8.55	8.85	-0.30		8.55	8.70	-0.15
2002-2003		8.84	9.17	-0.33		8.84	9.09	-0.25
2003-2004		9.07	9.31	-0.23		9.07	9.30	-0.22
2004-2005		9.30	9.36	-0.06		9.30	9.40	-0.10
2005-2006		9.32	9.39	-0.07		9.32	9.46	-0.14
2006-2007		9.52	9.39	0.13		9.52	9.48	0.04
2007-2008		9.97	9.40	0.57		9.97	9.50	0.47

In case third combination Chikkamangalore (S_3) x75:150:75(F_3), the best Model obtained was MMF Model and the estimated Model obtained was y= (2.487*29.420 +9.847 *x^3.469)/ (29.420+x^3.469), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.12m (1998) to 0.49m (2008) and the error values are presented in the (Table 4.1.1.1i (I)).

The second best Model obtained was Richards Model and the estimated Model obtained was y=9.784/(1+exp(1.246-0.836x))^(1/0.696), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.24m (1998) to 0.5 m (2008) and the error values are presented in the (Table 4.1.1.1i (II)). The third best Model obtained was Logistic Model and the estimated Model obtained was y=9.749/ (1+6.743 *exp (-0.921x)), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.2m (1998) to 0.54m (2008) and the error values are presented in the (Table 4.1.1.1i(III)) and fourth best Model obtained was Gompertz Model and the estimated Model obtained was y=9.888*exp(-exp(0.957-0.653x)), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.30m (1998) to 0.41m (2008) and the error values are presented in the (Table 4.1.1.1i (IV)).

In case of fourth source and their combination, Thirthahalli (S_4) x25:50:25(F_1) the best Model obtained was Rational Function and the estimated Model obtained was y= (-2.791 +6.964x)/(1+0.792x-0.019x^2), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.12m (1998) to 0.38 m (2008) and the error values are presented in the (Table 4.1.1.1j (I)). The second best Model obtained was Weibul Model and the estimated Model obtained was y=22.002 -32.158*exp (-0.495*x^0.277), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.07m (1998) to 0.63m (2008) and the error values are presented in the (Table 4.1.1.1j (II)). The third best Model obtained was MMF Model and the estimated Model obtained was y=(7.68*2.5+27.47*x^0.37)/ (2.49+x^0.37), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values from 0.07m (1998) to 0.63m (2008) and the error values are presented in the (Table 4.1.1.1j (III)) and fourth best Model obtained was Logarithm Model and the estimated Model obtained was y=2.269 +3.076*ln(x), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from0.20m (1998) to 0.70m (2008) and the error values are presented in the (Table 4.1.1.1j (IV)).

In case of second combination Thirthahalli (S_4) x50:100:50(F_2), the best Model obtained was MMF Model and the estimated Model obtained was y= (1.5*7.89+9.5*x^2.1)/ (7.89+x^2.1), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.11m (1998) to 1.26m (2008) and the error values are presented in the (Table 4.1.1.1k(I)). The second best Model obtained was Rational Function and the estimated Model obtained was y= (-2.574+6.145x)/ (1+0.555x-0.001x^2), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.19m (1998) to 0.98m (2008) and the error values are presented in the (Table 4.1.1.1k(II)).The third best Model obtained was Weibul Model and the estimated Model obtained was y=9.688-12.179 *exp(-0.502*x^0.779), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.17m (1998) to 1.07m (2008) and the error values are presented in the (Table 4.1.1.1k(III)) and fourth best Model obtained was Gompertz Model and the estimated Model obtained was y=8.983*exp (-exp(0.829-0.561x)), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.06m (1998) to 1.35m (2008) and the error values are presented in the (Table 4.1.1.1k(IV)).

Table 4.1.1.1(i): Table showing the actual values and predicted values Chikkamangalore (S_3) x75:150:75(F_3) for height (m)

I. MMF Model: y=(2.487*29.420 +9.847 *x^3.469)/(29.420 +x^3.469)

II. RichardS Model: y=9.784/(1+exp(1.246-0.836x))^(1/0.696)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		2.85	2.73	0.12		2.85	2.61	0.24
1998-1999		4.17	4.50	-0.33		4.17	4.75	-0.59
1999-2000		7.33	6.95	0.38		7.33	6.84	0.49
2000-2001		8.55	8.42	0.13		8.55	8.29	0.26
2001-2002		8.76	9.11	-0.35		8.76	9.08	-0.32
2002-2003		9.17	9.44	-0.27		9.17	9.47	-0.30
2003-2004		9.32	9.60	-0.29		9.32	9.65	-0.33
2004-2005		9.69	9.69	0.00		9.69	9.72	-0.04
2005-2006		9.70	9.74	-0.04		9.70	9.76	-0.05
2006-2007		9.93	9.77	0.15		9.93	9.77	0.15
2007-2008		10.28	9.79	0.49		10.28	9.78	0.50

III. Logistic Model: y=9.749/(1+6.743 *exp(-0.921x))

IV. Gompertz Model: y=9.888*exp(-exp(0.957-0.653x))

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
1997-1998		2.85	2.65	0.20		2.85	2.55	0.30
1998-1999		4.17	4.71	-0.55		4.17	4.88	-0.72
1999-2000		7.33	6.84	0.49		7.33	6.85	0.48
2000-2001		8.55	8.34	0.21		8.55	8.17	0.38
2001-2002		8.76	9.13	-0.37		8.76	8.95	-0.19
2002-2003		9.17	9.49	-0.33		9.17	9.39	-0.22
2003-2004		9.32	9.65	-0.33		9.32	9.63	-0.31
2004-2005		9.69	9.71	-0.02		9.69	9.75	-0.06
2005-2006		9.70	9.73	-0.03		9.70	9.82	-0.11
2006-2007		9.93	9.74	0.18		9.93	9.85	0.08
2007-2008		10.28	9.75	0.54		10.28	9.87	0.41

Table 4.1.1.1(j): Table showing the actual values and predicted values Thirthahalli (S_4) x25:50:25(F_1) for height (m).

I. Rational Function: y=(-2.791 +6.964x)/(1+0.792x-0.019x^2)

II. Weibul Model: y=22.002 -32.158*exp(-0.495*x^0.277)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		2.47	2.35	0.12		2.47	2.40	0.07
1998-1999		4.01	4.44	-0.43		4.01	4.35	-0.34
1999-2000		5.54	5.65	-0.10		5.54	5.56	-0.02
2000-2001		7.17	6.49	0.68		7.17	6.45	0.72
2001-2002		7.27	7.14	0.13		7.27	7.16	0.11
2002-2003		7.70	7.69	0.01		7.70	7.74	-0.04
2003-2004		7.76	8.19	-0.43		7.76	8.24	-0.48
2004-2005		8.59	8.65	-0.06		8.59	8.67	-0.08
2005-2006		8.86	9.09	-0.23		8.86	9.05	-0.20
2006-2007		9.09	9.52	-0.43		9.09	9.40	-0.31
2007-2008		10.34	9.96	0.38		10.34	9.71	0.63

III. MMF Model: y=(7.679*2.486+27.466*x^0.371)/(2.486+x^0.371)

IV. Logarithm Model: y=2.269 +3.076*ln(x)

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
1997-1998		2.47	2.40	0.07		2.47	2.27	0.20
1998-1999		4.01	4.35	-0.34		4.01	4.40	-0.39
1999-2000		5.54	5.56	-0.02		5.54	5.65	-0.10
2000-2001		7.17	6.46	0.71		7.17	6.53	0.64
2001-2002		7.27	7.16	0.11		7.27	7.22	0.05
2002-2003		7.70	7.74	-0.04		7.70	7.78	-0.08
2003-2004		7.76	8.24	-0.48		7.76	8.25	-0.50
2004-2005		8.59	8.67	-0.08		8.59	8.67	-0.08
2005-2006		8.86	9.06	-0.20		8.86	9.03	-0.17
2006-2007		9.09	9.40	-0.31		9.09	9.35	-0.26
2007-2008		10.34	9.71	0.63		10.34	9.64	0.70

Table 4.1.1.1(k): Table showing the actual values and predicted values Thirthahalli (S_4) x50:100:50(F_2) for height (m).

I. MMF Model: y=(1.486*7.889+9.472*x^2.087)/(7.889+x^2.087)

II. Rational Function: y=(-2.574+6.145x)/(1+0.555x-0.001x^2)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		2.49	2.38	0.11		2.49	2.30	0.19
1998-1999		3.94	4.27	-0.32		3.94	4.61	-0.67
1999-2000		6.12	5.91	0.21		6.12	5.97	0.14
2000-2001		7.26	7.01	0.25		7.26	6.87	0.40
2001-2002		8.10	7.72	0.38		8.10	7.51	0.59
2002-2003		8.10	8.17	-0.07		8.10	7.99	0.11
2003-2004		8.11	8.48	-0.37		8.11	8.36	-0.26
2004-2005		8.34	8.69	-0.35		8.34	8.67	-0.33
2005-2006		8.47	8.84	-0.37		8.47	8.92	-0.45
2006-2007		8.56	8.95	-0.39		8.56	9.13	-0.57
2007-2008		10.29	9.03	1.26		10.29	9.31	0.98

III. Weibul Model: y=9.688-12.179 *exp(-0.502*x^0.779)

IV. Gompertz Model : y=8.983*exp(-exp(0.829-0.561x))

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
1997-1998		2.49	2.32	0.17		2.49	2.43	0.06
1998-1999		3.94	4.54	-0.60		3.94	4.26	-0.32
1999-2000		6.12	5.95	0.17		6.12	5.87	0.25
2000-2001		7.26	6.91	0.35		7.26	7.05	0.22
2001-2002		8.10	7.59	0.51		8.10	7.82	0.28
2002-2003		8.10	8.08	0.02		8.10	8.30	-0.20
2003-2004		8.11	8.45	-0.34		8.11	8.59	-0.48
2004-2005		8.34	8.72	-0.38		8.34	8.75	-0.41
2005-2006		8.47	8.93	-0.47		8.47	8.85	-0.39
2006-2007		8.56	9.09	-0.53		8.56	8.91	-0.35
2007-2008		10.29	9.22	1.07		10.29	8.94	1.35

In case third combination Thirthahalli (S_4) x75:150:75(F_3), the best Model obtained was MMF Model and the estimated Model obtained was y= (4.8*9.3+70.24*x^0.34)/ (9.32+x^0.339), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.17m (1998) to 1.24m (2008) and the error values are presented in the (Table 4.1.1.1l (I)). The second best Model obtained was Weibul Model and the estimated Model obtained was y=34.109-38.422*exp (-0.193*x^0.359), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.17m (1998) to 1.26m (2008) and the error values are presented in the (Table 4.1.1.1l (II)). The third best Model obtained was Logarithm Model and the estimated Model obtained was y=2.065+3.112*ln(x), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.2m (1998) to 1.5m (2008) and the error values are presented in the (Table 4.1.1.1l (III)). The fourth best Model obtained was sinusoidal Model and the estimated Model obtained was y=-18.537+29.318*cos (0.050x+5.493), Based on this Model the prediction was made for the 11 years and compared with the actual values.

It was noticed errors between observed and expected values varies from -0.84m(1998) to 1.08 m(2008) and the error values are presented in the (Table 4.1.1.1l(IV)).

4.1.1.2. Models predicting the future Height growth with corresponding error terms in case of spacing and fertilizer level.

Among different Models tried in predicting the Height growth, the treatment combinations, Polynomial, Gaussian, Sinusoidal, Richards, Weibul, Rational, MMF, Logistic, Logarithm, and Gompertz Model was found to be the best Model with highest R^2 values and lowestnSE and RMSE. Therefore, these Models are considered for predicting the height at different years and comparing the same with the actual values.

In case of first spacing and their combination, 4x1m(SP_1) x No fertilizer(F_0) the best Model obtained was Rational Function and the estimated Model obtained was y=(4919929.327+ 15045079.70x) / (1+2308948.462x+45656.128x^2), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.10m (2001) to 0.00m (2008) and the error values are presented in the (Table 4.1.1.2a (I)). The second best Model obtained was Weibul Model and the estimated Model obtained was y=9.569-44.816*exp (-2.182*x^0.153), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.16m (2001) to 0.07m (2008) and the error values are presented in the (Table 4.1.1.2a (II)). The third best Model obtained was MMF Model and the estimated Model obtained was y= (-5.1*0.54 +9.69*x^0.5)/(0.54 +x^0.5), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.14m (2001) to 0.09m (2008) and the error values are presented in the (Table 4.1.1.2a (III)). And fourth best Model obtained was Logarithm Model and the estimated Model obtained was y=4.611+1.350*ln(x), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.24m (2001) to 0.01m (2008) and the error values are presented in the (Table 4.1.1.2a (IV)).

In case of second combination 4x1m (SP_1) x50:100:50(F_1), the best Model obtained was Rational Function and the estimated Model obtained was y= (975187.722+7228255.648x)/ (1+1280154.543x+ 43226.362x^2), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from-0.05m (2001) to -0.09m (2008) and the error values are presented in the (Table 4.1.1.2b (I)). The second best Model obtained was MMF Model and the estimated Model obtained was y= (4.497*180.619+118.985*x^0.770)/ (180.619+x^0.770), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from-0.12m (2001) to -0.04m (2008) and the error values are presented in the (Table 4.1.1.2b(II)).

Table 4.1.1.1(I): Table showing the actual values and predicted values Thirthahalli (S_4) x75:150:75(F_3) for height (m).

I. MMF Model: y=(4.844*9.319+70.243*x^0.339)/(9.319+x^0.339)

II. Weibul Model: y=34.109-38.422*exp(-0.193*x^0.359)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		2.26	2.43	-0.17		2.26	2.43	-0.17
1998-1999		4.03	4.13	-0.10		4.03	4.11	-0.09
1999-2000		5.83	5.27	0.56		5.83	5.25	0.58
2000-2001		6.67	6.16	0.52		6.67	6.14	0.54
2001-2002		6.84	6.89	-0.05		6.84	6.87	-0.03
2002-2003		7.05	7.51	-0.46		7.05	7.50	-0.45
2003-2004		7.82	8.06	-0.24		7.82	8.05	-0.23
2004-2005		8.29	8.55	-0.27		8.29	8.54	-0.25
2005-2006		8.38	9.00	-0.62		8.38	8.98	-0.60
2006-2007		8.99	9.41	-0.42		8.99	9.39	-0.40
2007-2008		11.02	9.78	1.24		11.02	9.77	1.26

III. Logarithm Model: y=2.065+3.112*ln(x)

IV. Sinusoidal Model: y=-18.537+29.318*cos(0.050x+5.493)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		2.26	2.07	0.20		2.26	3.11	-0.84
1998-1999		4.03	4.22	-0.20		4.03	4.07	-0.04
1999-2000		5.83	5.48	0.35		5.83	4.98	0.86
2000-2001		6.67	6.38	0.29		6.67	5.82	0.85
2001-2002		6.84	7.07	-0.24		6.84	6.61	0.23
2002-2003		7.05	7.64	-0.59		7.05	7.33	-0.28
2003-2004		7.82	8.12	-0.30		7.82	7.99	-0.17
2004-2005		8.29	8.54	-0.25		8.29	8.58	-0.29
2005-2006		8.38	8.90	-0.52		8.38	9.10	-0.72
2006-2007		8.99	9.23	-0.24		8.99	9.56	-0.57
2007-2008		11.02	9.53	1.50		11.02	9.94	1.08

Table 4.1.1.2(a): Table showing the actual values and predicted values for 4x1m(SP_1) x No fertilizer(F_0) for height(m).

I. Rational function: y= (4919929.33 +15045079.7x)/(1+2308948.5x+45656.1 x^2)
II. Weibul Model: y=9.569-44.816*exp(-2.182*x^0.153)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
2000-2001		4.37	4.47	-0.10		4.37	4.54	-0.16
2001-2002		6.00	5.68	0.33		6.00	5.63	0.37
2002-2003		6.23	6.17	0.06		6.23	6.20	0.04
2003-2004		6.27	6.50	-0.22		6.27	6.57	-0.30
2004-2005		6.46	6.76	-0.29		6.46	6.84	-0.37
2005-2006		7.11	6.99	0.12		7.11	7.05	0.06
2006-2007		7.34	7.21	0.13		7.34	7.21	0.13
2007-2008		7.42	7.42	0.00		7.42	7.35	0.07

III. MMF Model: y=(-5.106 *0.539 +9.693 *x^0.501)/(0.539 +x^0.501)
IV. Logarithm Model: y=4.611+1.350*ln(x)

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
2000-2001		4.37	4.51	-0.14		4.37	4.61	-0.24
2001-2002		6.00	5.61	0.39		6.00	5.55	0.46
2002-2003		6.23	6.18	0.05		6.23	6.09	0.14
2003-2004		6.27	6.55	-0.28		6.27	6.48	-0.21
2004-2005		6.46	6.82	-0.36		6.46	6.78	-0.32
2005-2006		7.11	7.03	0.08		7.11	7.03	0.08
2006-2007		7.34	7.19	0.15		7.34	7.24	0.10
2007-2008		7.42	7.33	0.09		7.42	7.42	0.01

Table 4.1.1.2(b): Table showing the actual values and predicted values for 4x1m (SP_1) x 50:100:50(F_1) for height (m).

I. RationalFunction:y=(975187.722+7228255.648x)/(1+1280154.543x+43226.362x^2)
II. MMF Model: y=(4.497*180.619+118.985*x^0.770)/(180.619+x^0.770)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
2000-2001		5.00	5.06	-0.05		5.00	5.13	-0.12
2001-2002		5.87	5.65	0.22		5.87	5.57	0.30
2002-2003		5.88	6.00	-0.12		5.88	5.96	-0.08
2003-2004		6.29	6.31	-0.02		6.29	6.31	-0.02
2004-2005		6.39	6.61	-0.22		6.39	6.64	-0.25
2005-2006		7.06	6.92	0.14		7.06	6.96	0.10
2006-2007		7.39	7.25	0.14		7.39	7.26	0.13
2007-2008		7.52	7.61	-0.09		7.52	7.56	-0.04

III. Weibul Model: y=17.750-13.170*exp(-0.043*x^0.860)
IV. Richards Model: y=7.520/(1+exp(49.771-6.832x))^(1/119.099)

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
2000-2001		5.00	5.13	-0.13		5.00	5.24	-0.24
2001-2002		5.87	5.57	0.30		5.87	5.55	0.32
2002-2003		5.88	5.96	-0.08		5.88	5.88	0.00
2003-2004		6.29	6.32	-0.03		6.29	6.23	0.06
2004-2005		6.39	6.66	-0.27		6.39	6.60	-0.21
2005-2006		7.06	6.98	0.09		7.06	6.99	0.08
2006-2007		7.39	7.28	0.11		7.39	7.39	0.00
2007-2008		7.52	7.57	-0.05		7.52	7.52	0.00

The third best Model obtained was Weibul Model and the estimated Model obtained was y=17.750-13.170*exp(-0.043*x^0.860), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.13m (2001) to -0.05m (2008) and the error values are presented in the (Table 4.1.1.2b (III)). The fourth best Model obtained was Richards Model and the estimated Model obtained was y=7.520/ (1+exp (49.771-6.832x)) ^ (1/119.099).Based on this Model the prediction was made for the 8 years and then compared with the actual values .It was noticed the errors between observed and expected values varies from -0.24m (2001) to 0.00m (2008) and the error values are presented in the (Table 4.1.1.2b (IV)).

In case third combination 4x2m(SP_2) x No fertilizer (F_0), the best Model obtained was Rational Function and the estimated Model obtained was y=(16012204.327+ 47230914.5x) / (1+7154710.82x+241494.77x^2), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.13m (2001) to 0.23m (2008) and the error values are presented in the (Table 4.1.1.2c (I)). The second best Model obtained was Weibul Model and the estimated Model obtained was y=22.200-24.844*exp (-0.344*x^0.263), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.20m (2001) to 0.04m (2008) and the error values are presented in the (Table 4.1.1.2c (II)). The third best Model obtained was MMF Model and the estimated Model obtained was y=(2.242*3.487+28.360*x^0.304)/(3.487+x^0.304), Based on this Model the prediction was made for the 8 years and then compared with the actual values .

It was noticed the errors between observed and expected values varies from-0.19m (2001) to 0.41m (2008) and the error values are presented in the (Table 4.1.1.2c(III)) and fourth best Model was Logarithm Model and the estimated Model obtained was y=4.49+1.9 *ln(x). Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.11m (2001) to 0.47m (2008) and the error values are presented in the (Table 4.1.1.2c (IV)).

In case of fourth spacing and their combination, 4x2m (SP_2) x 50:100:50(F_1) the best Model was Weibul Model and the estimated Model obtained was y=11.004-35.99*exp (-1.7*x^0.2), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.13m (2001) to 0.32m (2008) and the error values are presented in the (Table 4.1.1.2d (I)). The second best Model obtained was MMF Model and the estimated Model obtained was y= (-7.926*0.576+11.536*x^0.400)/(0.576+ x^0.4), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.32m (2001) and -0.13m (2008) the error values are presented in the (Table 4.1.1.2d (II)). The third best Model obtained was Logarithm Model and the estimated Model obtained was y=4.501+1.543*ln(x), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.2m (2001) to 0.32m (2008) and the error values are presented in the (Table 4.1.1.2d (III)) and fourth best Model obtained was Gompertz Model and the estimated Model obtained was Gompertz Model: y=7.771*exp (-exp(0.197-0.431x)), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.77m (2001) to 0.48m (2008) and the error values are presented in the (Table 4.1.1.2d (IV)).

In case of fifth combination 4x3m(SP_3) xNo fertilizer(F_0), the best Model obtained was Rational Function and the estimated Model obtained was y=(0.045+6.971x)/(1+0.996x-0.019x^2), Based on this Model the prediction was made for the 8 years and then compared with the actual values .It was noticed the errors between observed and expected values varies from -0.01m (2001) to -0.02m (2008) and the error values are presented in the (Table 4.1.1.2e(I)). The second best Model obtained was Logarithm Model and the estimated Model obtained was y=3.567+1.734*ln(x), Based on this Model the prediction was made for the 8 years and then compared with the actual values.

Table 4.1.1.3(c): Table showing actual and predicted values Kerala(S_1) x 75:150:75(F_3) for dbh (cm)

I. Rational Function: y=(-1.551+9.291x)/(1+0.886x-0.031x^2)
II. Weibul Model: y=44.247-44.153*exp(-0.102*x^0.545)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		4.20	4.17	0.02		4.20	4.38	-0.18
1998-1999		6.42	6.43	-0.01		6.42	6.20	0.22
1999-2000		7.42	7.79	-0.37		7.42	7.57	-0.15
2000-2001		9.08	8.80	0.29		9.08	8.71	0.37
2001-2002		10.03	9.65	0.38		10.03	9.70	0.33
2002-2003		10.28	10.42	-0.14		10.28	10.57	-0.29
2003-2004		10.98	11.17	-0.19		10.98	11.36	-0.38
2004-2005		11.79	11.92	-0.14		11.79	12.08	-0.30
2005-2006		12.77	12.70	0.07		12.77	12.75	0.02
2006-2007		13.02	13.51	-0.50		13.02	13.37	-0.36
2007-2008		14.58	14.39	0.19		14.58	13.96	0.62

III. MMF Model: y=(0.176*14.855+66.540*x^0.566)/(14.855+x^0.566)
IV. Sinusoidal Model : y=-12.831+27.742*cos(0.062x+5.342)

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
1997-1998		4.20	4.36	-0.17		4.20	4.86	-0.67
1998-1999		6.42	6.19	0.23		6.42	6.15	0.27
1999-2000		7.42	7.57	-0.15		7.42	7.37	0.05
2000-2001		9.08	8.71	0.38		9.08	8.51	0.57
2001-2002		10.03	9.69	0.34		10.03	9.57	0.46
2002-2003		10.28	10.56	-0.28		10.28	10.54	-0.26
2003-2004		10.98	11.35	-0.38		10.98	11.42	-0.44
2004-2005		11.79	12.07	-0.29		11.79	12.21	-0.42
2005-2006		12.77	12.74	0.03		12.77	12.90	-0.13
2006-2007		13.02	13.36	-0.34		13.02	13.49	-0.48
2007-2008		14.58	13.93	0.64		14.58	13.98	0.59

Table 4.1.1.3(d): Table showing the actual values and predicted values Bangalore (S_2) x25:50:25(F_1) for dbh (cm)

I. Rational Function: y=(-0.694+5.741x)/(1+0.443x-0.009x^2)
II. Weibul Model: y=30.342-35.344*exp(-0.277*x^0.395)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		3.62	3.52	0.10		3.62	3.55	0.07
1998-1999		5.52	5.83	-0.31		5.52	5.79	-0.27
1999-2000		7.39	7.35	0.03		7.39	7.29	0.09
2000-2001		8.68	8.47	0.21		8.68	8.45	0.23
2001-2002		9.65	9.37	0.28		9.65	9.39	0.26
2002-2003		10.38	10.12	0.26		10.38	10.20	0.19
2003-2004		10.56	10.79	-0.23		10.56	10.90	-0.33
2004-2005		10.89	11.40	-0.51		10.89	11.51	-0.63
2005-2006		12.14	11.97	0.17		12.14	12.07	0.07
2006-2007		12.91	12.52	0.39		12.91	12.58	0.33
2007-2008		13.11	13.06	0.05		13.11	13.04	0.07

III. MMF Model: y=(3.853*4.792+39.095*x^0.473)/(4.792+x^0.473)
IV. Logarithm Model: y=3.138+4.018*ln(x)

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
1997-1998		3.62	3.56	0.05		3.62	3.14	0.48
1998-1999		5.52	5.79	-0.27		5.52	5.92	-0.40
1999-2000		7.39	7.30	0.08		7.39	7.55	-0.17
2000-2001		8.68	8.46	0.22		8.68	8.71	-0.03
2001-2002		9.65	9.41	0.24		9.65	9.60	0.05
2002-2003		10.38	10.21	0.17		10.38	10.34	0.05
2003-2004		10.56	10.91	-0.35		10.56	10.96	-0.39
2004-2005		10.89	11.53	-0.64		10.89	11.49	-0.61
2005-2006		12.14	12.08	0.05		12.14	11.97	0.17
2006-2007		12.91	12.59	0.32		12.91	12.39	0.52
2007-2008		13.11	13.05	0.06		13.11	12.77	0.34

Table 4.1.1.3(e) : Table showing the actual values and predicted values Bangalore(S_2) x50:100:50(F_2) for dbh (cm)

I. MMF Model: y=(3.180*7.612+13.581*x^1.599)/(7.612+x^1.599)

II. Weibul Model: y=12.635-10.441*exp(-0.232*x^1.060)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		4.37	4.39	-0.02		4.37	4.36	0.01
1998-1999		6.29	6.14	0.15		6.29	6.20	0.09
1999-2000		7.27	7.67	-0.40		7.27	7.67	-0.40
2000-2001		9.21	8.87	0.34		9.21	8.83	0.38
2001-2002		9.81	9.76	0.05		9.81	9.73	0.08
2002-2003		10.48	10.43	0.04		10.48	10.42	0.06
2003-2004		10.71	10.95	-0.24		10.71	10.95	-0.24
2004-2005		11.38	11.35	0.03		11.38	11.36	0.02
2005-2006		11.72	11.66	0.06		11.72	11.67	0.05
2006-2007		11.72	11.91	-0.19		11.72	11.91	-0.19
2007-2008		12.28	12.11	0.17		12.28	12.09	0.19

III. Gompertz Relation: y=12.307*exp(-exp(0.385-0.371x))

IV. Rational Function: y=(1.846+3.119x)/(1+0.141x+0.004x^2)

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
1997-1998		4.37	4.46	-0.09		4.37	4.34	0.03
1998-1999		6.29	6.11	0.18		6.29	6.23	0.06
1999-2000		7.27	7.59	-0.32		7.27	7.68	-0.41
2000-2001		9.21	8.82	0.39		9.21	8.80	0.41
2001-2002		9.81	9.78	0.03		9.81	9.66	0.15
2002-2003		10.48	10.50	-0.02		10.48	10.33	0.15
2003-2004		10.71	11.03	-0.32		10.71	10.85	-0.14
2004-2005		11.38	11.41	-0.03		11.38	11.24	0.14
2005-2006		11.72	11.68	0.03		11.72	11.54	0.18
2006-2007		11.72	11.87	-0.16		11.72	11.76	-0.04
2007-2008		12.28	12.01	0.27		12.28	11.91	0.37

Table 4.1.1.2(f) :Table showing the actual values and predicted values of 4x3m(SP_3) x 50:100:50 (F_1) for height(m).

I. Rational Function: y=(-4.072+16.418x)/(1+2.176x-0.040x^2)
II. MMF Model: y=(10.565*0.589+12.518*x^0.424)/(0.589+x^0.424)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
2000-2001		3.93	3.94	-0.01		3.93	3.96	-0.03
2001-2002		5.60	5.54	0.06		5.60	5.48	0.12
2002-2003		6.22	6.30	-0.09		6.22	6.29	-0.07
2003-2004		6.88	6.80	0.09		6.88	6.83	0.06
2004-2005		6.97	7.17	-0.20		6.97	7.22	-0.25
2005-2006		7.69	7.49	0.20		7.69	7.53	0.16
2006-2007		7.84	7.77	0.07		7.84	7.78	0.06
2007-2008		7.96	8.03	-0.07		7.96	7.99	-0.03

III. Weibul Model: y=10.718-25.819*exp(-1.342*x^0.248)
IV. Logarithm Model: y=4.079+1.930*ln(x)

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
2000-2001		3.93	3.97	-0.04		3.93	4.08	-0.15
2001-2002		5.60	5.47	0.12		5.60	5.42	0.18
2002-2003		6.22	6.29	-0.07		6.22	6.20	0.02
2003-2004		6.88	6.83	0.06		6.88	6.75	0.13
2004-2005		6.97	7.22	-0.25		6.97	7.19	-0.22
2005-2006		7.69	7.53	0.16		7.69	7.54	0.15
2006-2007		7.84	7.78	0.06		7.84	7.83	0.01
2007-2008		7.96	7.99	-0.03		7.96	8.09	-0.13

It was noticed the errors between observed and expected values varies from -0.03m (2001) to 0.01m (2008) and the error values are presented in the (Table 4.1.1.2e (II)).

The third best Model obtained was MMF Model and the estimated Model obtained was y= (7.361*1.248+17.195*x^0.285)/(1.248 + x^0.285). Based on this Model the prediction was made for the 8 years and then compared with the actual values . It was noticed the errors between observed and expected values varies from -0.03m (2001) to 0.01m (2008) and the error values are presented in the (Table 4.1.1.2e (III)) and fourth best Model obtained was Weibul Model and the estimated Model obtained was y=12.707-20.725*exp (-0.818*x^0.229), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.02m (2001) to 0.02m (2008) and the error values are presented in the (Table 4.1.1.2e (IV)).

In case of sixth combination 4x3m (SP_3) x50:100:50 (F_1), the best Model obtained was Rational Function and the estimated Model obtained was y= (-4.072+16.418x)/(1+2.176x-0.040x^2), Based on this Model the prediction was made for the 8 years and then compared with the actual values . It was noticed the errors between observed and expected values varies from -0.01m (2001) to -0.07m (2008) and the error values are presented in the (Table 4.1.1.2f (I)). The second best Model obtained was MMF Model and the estimated Model obtained was y=(10.565*0.589+12.518*x^0.424)/ (0.589+x^0.424), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.03m (2001) to -0.03m (2008) and the error values are presented in the (Table 4.1.1.2f (II)). The third best Model obtained was Weibul Model and the estimated Model obtained was y=10.718-25.819*exp (-1.342*x^0.248), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.04m (2001) to -0.03m (2008) and the error values are presented in the (Table 4.1.1.2f(III)) and fourth best Model obtained was Logarithm Model and the estimated Model obtained was y=4.079+1.930*ln(x), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.15m (2001) to -0.13m (2008) and the error values are presented in the (Table 4.1.1.2f (IV)).

4.1.1.3 Models predicting the future DBH growth with corresponding error terms in case of Sources and fertilizer level:

Among different Models tried in predicting the Height growth, the treatment combinations, Polynomial, Gaussian, Sinusoidal, Richards, Weibul, Rational, MMF, Logistic, Logarithm, and Gompertz Model was found to be the best Model with highest R^2 value and lower SE and RMSE. Therefore these Models are considered for predicting the height at different years and comparing the same with the actual values.

In case of first source and their combination, Kerala (S_1) x25:50:25(F_1) the best Model obtained was MMF Model and the estimated Model obtained was y= (1.223*20.725+ 64.040*x^0.729) /(20.725+x^0.729), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.02cm (1998) to 0.28cm (2008) and the error values are presented in the (Table 4.1.1.3a (I)). The second best Model obtained was Weibul Model and the estimated Model obtained was y=37.048-35.788*exp (-0.083*x^0.728), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.02cm (1998) to 0.33cm (2008) and the error values are presented in the (Table 4.1.1.3a (II)). The third best Model obtained was Polynomial Model and the estimated Model obtained y=2.098+2.175x-0.166x^2+0.008x^3-0.0001x ^4, Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.03cm (1998) to 0.09cm (2008) and the error values are presented in the (Table 4.1.1.3a(III)) and fourth best Model obtained was Rational Function and the estimated Model obtained was y=(1.797+2.916x)/(1+0.156x-0.004x^2), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies fromc0.00m (1998) to -0.05cm (2008) and the error values are presented in the (Table 4.1.1.3a (IV)).

Table 4.1.1.3(a): Table showing the actual values and predicted values Kerala (S_1) x 25:50:25(F_1) for dbh (cm)

I. MMF Model: y=(1.223*20.725+64.040*x^0.729)/(20.725+x^0.729)

II. Weibul Model: y=37.048-35.788*exp(-0.083*x^0.728)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		4.09	4.11	-0.02		4.09	4.11	-0.02
1998-1999		5.98	5.87	0.11		5.98	5.86	0.12
1999-2000		6.99	7.32	-0.33		6.99	7.29	-0.31
2000-2001		8.91	8.58	0.33		8.91	8.55	0.36
2001-2002		10.02	9.70	0.32		10.02	9.67	0.35
2002-2003		10.36	10.72	-0.36		10.36	10.69	-0.33
2003-2004		11.02	11.66	-0.65		11.02	11.63	-0.62
2004-2005		13.32	12.54	0.78		13.32	12.50	0.82
2005-2006		13.40	13.36	0.04		13.40	13.32	0.08
2006-2007		13.58	14.13	-0.54		13.58	14.08	-0.50
2007-2008		15.13	14.85	0.28		15.13	14.80	0.33

III. Polynomial Model: y=2.098+2.175x-0.166x^2+0.008x^3-0.0001x ^4

IV. Rational Function: y=(1.797+2.916x)/(1+0.156x-0.004x^2).

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
1997-1998		4.09	4.11	-0.06		4.09	4.09	0.00
1998-1999		5.98	5.85	0.13		5.98	5.89	0.09
1999-2000		6.99	7.34	-0.35		6.99	7.36	-0.38
2000-2001		8.91	8.63	0.28		8.91	8.63	0.28
2001-2002		10.02	9.76	0.26		10.02	9.75	0.27
2002-2003		10.36	10.77	-0.41		10.36	10.77	-0.41
2003-2004		11.02	11.69	-0.68		11.02	11.71	-0.70
2004-2005		13.32	12.56	0.76		13.32	12.61	0.71
2005-2006		13.40	13.40	-0.00		13.40	13.48	-0.08
2006-2007		13.58	14.25	-0.66		13.58	14.33	-0.75
2007-2008		15.13	15.12	0.01		15.13	15.18	-0.05

In case of second combination Kerala (S_1) x50:100:50(F_2), the best Model obtained was Rational Function and the estimated Model obtained was y= (-8.56+20.27x)/ (1+2.01x - 0.07x^2), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.01cm (1998) to 0.55cm (2008) and the error values are presented in the (Table 4.1.1.3b (I)).

The second best Model obtained was MMF Model and the estimated Model obtained was y= (-3.642*10.286+84.996*x^0.392)/(10.286+x^0.392), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from-0.23cm (1998) to 1.04cm (2008) and the error values are presented in the (Table 4.1.1.3b (II)). The third best Model obtained was Weibul Model and the estimated Model obtained was y=43.473-46.689*exp (-0.174*x^0.407), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.25cm (1998) to 1.01cm (2008) and the error values are presented in the (Table 4.1.1.3b (III)). The fourth best Model obtained was Logarithm Model and the estimated Model obtained was y=3.644+4.163*ln(x), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.34cm (1998) to 1.43cm (2008) and the error values are presented in the (Table 4.1.1.3b (IV)).

In case third combination Kerala (S_1) x75:150:75(F_3), the best Model obtained was The second best Model obtained was Rational Function and the estimated Model obtained was y=(-1.551+9.291x)/(1+0.886x-0.031x^2), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.02cm (1998) to 0.19cm (2008) and the error values are presented in the (Table 4.1.1.3c (I)). The second best Model obtained was Weibul Model and the estimated Model obtained was y=44.247-44.153*exp (-0.102*x^0.545), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.18cm (1998) to 0.62cm (2008) and the error values are presented in the (Table 4.1.1.3c(II)), The third best Model obtained was MMF Model and the estimated Model obtained was y=(0.176*14.855+66.540*x^0.566)/ (14.855+ x^ 0.56 6), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.17cm (1998) to 0.64 cm (2008) and the error values are presented in the (Table 4.1.1.3c (III)) and fourth best Model obtained was sinsoidol Model and the estimated Model obtained was y=-12.831+27.742*cos(0.062x+5.342), Based on this Model the prediction was made for the 11 years and then compared with the actual values . It was noticed the errors between observed and expected values varies from -0.67cm (1998) to 0.590cm (2008) and the error values are presented in the (Table 4.1.1.3c (IV)).

In case of second source and their combination, Bangalore (S_2) x25:50:25(F_1) the best Model obtained was Rational Function and the estimated Model obtained was y= (-0.694+ 5.741x)/(1+0.443x-0.009x^2), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.10cm (1998) to 0.05cm (2008) and the error values are presented in the (Table 4.1.1.3d(I)). The second best Model obtained was Weibul Model and the estimated Model obtained was y=30.342-35.344*exp (-0.277*x^0.395), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from0.07cm (1998) to 0.07cm (2008) and the error values are presented in the (Table 4.1.1.3d (II)). The third best Model obtained was MMF Model and the estimated Model obtained was y=(3.853*4.792+39.095*x ^0.473 4.792+x^0.473), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from0.05cm (1998) to 0.06cm (2008) and the error values are presented in the (Table 4.1.1.3d(III)), The fourth best Model obtained was Logarithm Model and the estimated Model obtained was y=3.138+4.018*ln(x), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.48cm (1998) to 0.34cm (2008) and the error values are presented in the (Table 4.1.1.3d (IV)).

Table 4.1.1.3(b): Table showing the actual value and predicted values of Kerala (S_1) x50:100:50(F_2) for dbh (cm)

I. RationalFunction: y=(-8.560+20.272x)/(1+2.012x-0.069x^2)

II. MMF Model: y=(-3.642*10.286+84.996*x^0.392)/(10.286+x^0.392)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		3.99	3.98	0.01		3.99	4.21	-0.23
1998-1999		6.78	6.74	0.04		6.78	6.39	0.39
1999-2000		7.80	8.15	-0.34		7.80	7.89	-0.09
2000-2001		9.23	9.13	0.10		9.23	9.07	0.16
2001-2002		10.33	9.94	0.39		10.33	10.05	0.28
2002-2003		10.74	10.68	0.06		10.74	10.90	-0.16
2003-2004		11.16	11.39	-0.23		11.16	11.65	-0.49
2004-2005		12.45	12.11	0.34		12.45	12.32	0.13
2005-2006		12.60	12.86	-0.27		12.60	12.94	-0.34
2006-2007		12.81	13.65	-0.84		12.81	13.50	-0.69
2007-2008		15.06	14.51	0.55		15.06	14.02	1.04

III. Weibul Model : y=43.473-46.689*exp(-0.174*x^0.407)

IV. Logarithm Model : y=3.644+4.163*ln(x)

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
1997-1998		3.99	4.24	-0.25		3.99	3.64	0.34
1998-1999		6.78	6.40	0.38		6.78	6.53	0.25
1999-2000		7.80	7.91	-0.10		7.80	8.22	-0.41
2000-2001		9.23	9.09	0.14		9.23	9.42	-0.19
2001-2002		10.33	10.07	0.25		10.33	10.34	-0.02
2002-2003		10.74	10.92	-0.19		10.74	11.10	-0.37
2003-2004		11.16	11.68	-0.51		11.16	11.74	-0.58
2004-2005		12.45	12.35	0.10		12.45	12.30	0.15
2005-2006		12.60	12.97	-0.37		12.60	12.79	-0.19
2006-2007		12.81	13.53	-0.72		12.81	13.23	-0.42
2007-2008		15.06	14.05	1.01		15.06	13.63	1.43

Table 4.1.1.3(c): Table showing actual and predicted values Kerala(S_1) x 75:150:75(F_3) for dbh (cm)

V. Rational Function: y=(-1.551+9.291x)/(1+0.886x-0.031x^2)

VI. Weibul Model: y=44.247-44.153*exp(-0.102*x^0.545)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		4.20	4.17	0.02		4.20	4.38	-0.18
1998-1999		6.42	6.43	-0.01		6.42	6.20	0.22
1999-2000		7.42	7.79	-0.37		7.42	7.57	-0.15
2000-2001		9.08	8.80	0.29		9.08	8.71	0.37
2001-2002		10.03	9.65	0.38		10.03	9.70	0.33
2002-2003		10.28	10.42	-0.14		10.28	10.57	-0.29
2003-2004		10.98	11.17	-0.19		10.98	11.36	-0.38
2004-2005		11.79	11.92	-0.14		11.79	12.08	-0.30
2005-2006		12.77	12.70	0.07		12.77	12.75	0.02
2006-2007		13.02	13.51	-0.50		13.02	13.37	-0.36
2007-2008		14.58	14.39	0.19		14.58	13.96	0.62

VII. MMF Model: y=(0.176*14.855+66.540*x^0.566)/(14.855+x^0.566)

VIII. Sinusoidal Model : y=-12.831+27.742*cos(0.062x+5.342)

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
1997-1998		4.20	4.36	-0.17		4.20	4.86	-0.67
1998-1999		6.42	6.19	0.23		6.42	6.15	0.27
1999-2000		7.42	7.57	-0.15		7.42	7.37	0.05
2000-2001		9.08	8.71	0.38		9.08	8.51	0.57
2001-2002		10.03	9.69	0.34		10.03	9.57	0.46
2002-2003		10.28	10.56	-0.28		10.28	10.54	-0.26
2003-2004		10.98	11.35	-0.38		10.98	11.42	-0.44
2004-2005		11.79	12.07	-0.29		11.79	12.21	-0.42
2005-2006		12.77	12.74	0.03		12.77	12.90	-0.13
2006-2007		13.02	13.36	-0.34		13.02	13.49	-0.48
2007-2008		14.58	13.93	0.64		14.58	13.98	0.59

Table 4.1.1.3(d): Table showing the actual values and predicted values Bangalore (S_2) x25:50:25(F_1) for dbh (cm)

V. Rational Function: y=(-0.694+5.741x)/(1+0.443x-0.009x^2)

VI. Weibul Model: y=30.342-35.344*exp(-0.277*x^0.395)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		3.62	3.52	0.10		3.62	3.55	0.07
1998-1999		5.52	5.83	-0.31		5.52	5.79	-0.27
1999-2000		7.39	7.35	0.03		7.39	7.29	0.09
2000-2001		8.68	8.47	0.21		8.68	8.45	0.23
2001-2002		9.65	9.37	0.28		9.65	9.39	0.26
2002-2003		10.38	10.12	0.26		10.38	10.20	0.19
2003-2004		10.56	10.79	-0.23		10.56	10.90	-0.33
2004-2005		10.89	11.40	-0.51		10.89	11.51	-0.63
2005-2006		12.14	11.97	0.17		12.14	12.07	0.07
2006-2007		12.91	12.52	0.39		12.91	12.58	0.33
2007-2008		13.11	13.06	0.05		13.11	13.04	0.07

VII. MMF Model: y=(3.853*4.792+39.095*x^0.473)/(4.792+x^0.473)

VIII. Logarithm Model: y=3.138+4.018*ln(x)

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
1997-1998		3.62	3.56	0.05		3.62	3.14	0.48
1998-1999		5.52	5.79	-0.27		5.52	5.92	-0.40
1999-2000		7.39	7.30	0.08		7.39	7.55	-0.17
2000-2001		8.68	8.46	0.22		8.68	8.71	-0.03
2001-2002		9.65	9.41	0.24		9.65	9.60	0.05
2002-2003		10.38	10.21	0.17		10.38	10.34	0.05
2003-2004		10.56	10.91	-0.35		10.56	10.96	-0.39
2004-2005		10.89	11.53	-0.64		10.89	11.49	-0.61
2005-2006		12.14	12.08	0.05		12.14	11.97	0.17
2006-2007		12.91	12.59	0.32		12.91	12.39	0.52
2007-2008		13.11	13.05	0.06		13.11	12.77	0.34

In case of second combination Bangalore (S_2) x50:100:50(F_2), the best Model obtained was MMF Model and the estimated Model obtained was y=(3.180*7.612+13.581*x^1.599)/ (7.612+x^1.599), Based on this Model the prediction was made for the 11 years and then compared with the actual values . It was noticed the errors between observed and expected values varies from -0.02cm (1998) 0.17cm (2008) and the error values are presented in the (Table 4.1.1.3e (I)). The second best Model obtained was Weibul Model: and the estimated Model obtained was y=12.635-10.441*exp (-0.232*x^1.060), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.19cm (2008) and 0.01cm (1998) the error values are presented in the (Table 4.1.1.3e(II)), The third best Model obtained was Gompertz Relation and the estimated Model obtained was y=12.307*exp(-exp(0.385-0.371x)), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.09cm (1998) to 0.27cm (2008) and the error values are presented in the (Table 4.1.1.3e(III)) and fourth best Model was Rational Function ,the estimated Model was y=(1.8+3.15x)/(1+0.14x+ 0.004x^2) .

Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.03cm (1998) to 0.37cm (2008) and the error values are presented in the (Table 4.1.1.3e (IV)).

In case third combination Bangalore (S_2) x75:150:75(F_3), the best Model obtained was Weibul Model and the estimated Model obtained was y=19.758-20.532*exp (-0.294*x^0.525), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.04cm (1998) to -0.07cm (2008) and the error values are presented in the (Table 4.1.1.3f (I)). The second best Model obtained was MMF Model and the estimated Model obtained was y=(0.155*4.609+24.306*x^0.653)/(4.609+x^0.653), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.04cm (1998) to -0.06cm (2008) and the error values are presented in the (Table 4.1.1.3f (II)), The third best Model obtained was Rational Function and the estimated Model obtained was y=(1.616+4.107x)/(1+0.288x-0.004x^2), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed value and expected values varies from 0.04cm (1998) to -0.30cm (2008) and the error values are presented in the (Table 4.1.1.3f (III)). The fourth best Model obtained was Gompertz Relation and the estimated Model obtained was y=12.964*exp (-exp (0.291-0.288x)), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.25cm (1998) to 0.15cm (2008) and the error values are presented in the (Table 4.1.1.3f (IV)).

In case of third source and their combination, Chikkamangalore (S_3) x25:50:25(F_1), the best Model obtained was MMF Model and the estimated Model obtained was y=(1.138*4.039+ 15.197*x^1.186)/(4.039+x^1.186), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.06cm (1998) to 0.28 cm (2008) and the error values are presented in the (Table 4.1.1.3g (I)). The second best Model obtained was Rational Function and the estimated Model obtained was y=(-0.286+5.592x)/(1+0.369x-0.002x^2), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.10cm (1998) to 0.09cm (2008) and the error values are presented in the (Table 4.1.1.3g (II)). The third best Model obtained was Weibul Model and the estimated Model obtained y=14.43-16.3*exp(-0.44*x^0.67).

Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.08cm (1998) to 0.24cm (2008) and the error values are presented in the (Table 4.1.1.3g (III)). The fourth best was Logarithm and the estimated Model obtained was y=3.86+3.7*ln(x), Based on this Model the prediction was made for the 11 years and then compared with the actual values.

Table 4.1.1.3(e) : Table showing the actual values and predicted values Bangalore(S_2) x50:100:50(F_2) for dbh (cm)

V. MMF Model: y=(3.180*7.612+13.581*x^1.599)/(7.612+x^1.599)

VI. Weibul Model: y=12.635-10.441*exp(-0.232*x^1.060)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		4.37	4.39	-0.02		4.37	4.36	0.01
1998-1999		6.29	6.14	0.15		6.29	6.20	0.09
1999-2000		7.27	7.67	-0.40		7.27	7.67	-0.40
2000-2001		9.21	8.87	0.34		9.21	8.83	0.38
2001-2002		9.81	9.76	0.05		9.81	9.73	0.08
2002-2003		10.48	10.43	0.04		10.48	10.42	0.06
2003-2004		10.71	10.95	-0.24		10.71	10.95	-0.24
2004-2005		11.38	11.35	0.03		11.38	11.36	0.02
2005-2006		11.72	11.66	0.06		11.72	11.67	0.05
2006-2007		11.72	11.91	-0.19		11.72	11.91	-0.19
2007-2008		12.28	12.11	0.17		12.28	12.09	0.19

VII. Gompertz Relation: y=12.307*exp(-exp(0.385-0.371x))

VIII. Rational Function: y=(1.846+3.119x)/(1+0.141x+0.004x^2)

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
1997-1998		4.37	4.46	-0.09		4.37	4.34	0.03
1998-1999		6.29	6.11	0.18		6.29	6.23	0.06
1999-2000		7.27	7.59	-0.32		7.27	7.68	-0.41
2000-2001		9.21	8.82	0.39		9.21	8.80	0.41
2001-2002		9.81	9.78	0.03		9.81	9.66	0.15
2002-2003		10.48	10.50	-0.02		10.48	10.33	0.15
2003-2004		10.71	11.03	-0.32		10.71	10.85	-0.14
2004-2005		11.38	11.41	-0.03		11.38	11.24	0.14
2005-2006		11.72	11.68	0.03		11.72	11.54	0.18
2006-2007		11.72	11.87	-0.16		11.72	11.76	-0.04
2007-2008		12.28	12.01	0.27		12.28	11.91	0.37

Table 4.1.1.3(f): Table showing the actual values and predicted values Bangalore (S_2) x75:150:75(F_3) for dbh (cm)

I. Weibul Model: y=19.758-20.532*exp(-0.294*x^0.525)

II. MMF Model: y=(0.155*4.609+24.306*x^0.653)/(4.609+x^0.653)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		4.50	4.46	0.04		4.50	4.46	0.04
1998-1999		6.17	6.31	-0.14		6.17	6.30	-0.13
1999-2000		7.50	7.59	-0.09		7.50	7.59	-0.08
2000-2001		8.93	8.59	0.34		8.93	8.59	0.34
2001-2002		9.50	9.40	0.10		9.50	9.40	0.10
2002-2003		10.03	10.09	-0.06		10.03	10.09	-0.07
2003-2004		10.14	10.68	-0.54		10.14	10.69	-0.54
2004-2005		11.43	11.21	0.23		11.43	11.21	0.23
2005-2006		11.77	11.67	0.10		11.77	11.67	0.10
2006-2007		12.16	12.09	0.07		12.16	12.08	0.08
2007-2008		12.40	12.47	-0.07		12.40	12.46	-0.06

III. Rational Function: y=(1.616+4.107x)/(1+0.288x-0.004x^2)

IV. Gompertz Relation: y=12.964*exp(-exp(0.291-0.288x))

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
1997-1998		4.50	4.46	0.04		4.50	4.75	-0.25
1998-1999		6.17	6.30	-0.13		6.17	6.11	0.06
1999-2000		7.50	7.62	-0.12		7.50	7.38	0.13
2000-2001		8.93	8.64	0.29		8.93	8.49	0.44
2001-2002		9.50	9.47	0.03		9.50	9.44	0.06
2002-2003		10.03	10.16	-0.14		10.03	10.22	-0.20
2003-2004		10.14	10.77	-0.62		10.14	10.85	-0.70
2004-2005		11.43	11.31	0.12		11.43	11.34	0.09
2005-2006		11.77	11.81	-0.04		11.77	11.73	0.04
2006-2007		12.16	12.27	-0.10		12.16	12.03	0.14
2007-2008		12.40	12.70	-0.30		12.40	12.25	0.15

Table 4.1.1.3(g): Table showing the actual values and predicted values Chikkamangalore(S_3) x 25:50:25(F_1) for dbh(cm).

I. MMF Model: y=(1.138*4.039+15.197*x^1.186)/(4.039+x^1.186)

II. Rational Function: y=(-0.286+5.592x)/(1+0.369x-0.002x^2)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		3.98	3.93	0.06		3.98	3.88	0.10
1998-1999		6.09	6.20	-0.11		6.09	6.30	-0.21
1999-2000		7.67	7.84	-0.17		7.67	7.89	-0.22
2000-2001		9.15	9.04	0.12		9.15	9.04	0.12
2001-2002		10.42	9.93	0.49		10.42	9.90	0.52
2002-2003		10.84	10.62	0.21		10.84	10.59	0.25
2003-2004		10.84	11.17	-0.33		10.84	11.15	-0.31
2004-2005		11.00	11.61	-0.61		11.00	11.62	-0.62
2005-2006		11.76	11.97	-0.21		11.76	12.03	-0.27
2006-2007		12.52	12.27	0.25		12.52	12.39	0.13
2007-2008		12.80	12.52	0.28		12.80	12.71	0.09

III. Weibul Model: y=14.431-16.303*exp(-0.437*x^0.667)

IV. Logarithm Model: y=3.861+3.691*ln(x)

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
1997-1998		3.98	3.90	0.08		3.98	3.86	0.12
1998-1999		6.09	6.29	-0.20		6.09	6.42	-0.33
1999-2000		7.67	7.86	-0.19		7.67	7.92	-0.24
2000-2001		9.15	9.01	0.14		9.15	8.98	0.18
2001-2002		10.42	9.89	0.53		10.42	9.80	0.62
2002-2003		10.84	10.58	0.25		10.84	10.47	0.36
2003-2004		10.84	11.14	-0.30		10.84	11.04	-0.20
2004-2005		11.00	11.60	-0.60		11.00	11.54	-0.54
2005-2006		11.76	11.97	-0.21		11.76	11.97	-0.21
2006-2007		12.52	12.29	0.23		12.52	12.36	0.16
2007-2008		12.80	12.56	0.24		12.80	12.71	0.09

Table 4.1.1.3(h): Table showing the actual values and predicted values hikkamangalore (S_3) x 50:100:50(F_2) for dbh (cm).

I. MMF Model: y=(3.459*16.250+14.792*x^2.293)/(16.250+x^2.293)

II. Gompertz Relation: y=14.312*exp(-exp(0.672-0.433x))

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		4.25	4.12	0.14		4.25	4.02	0.23
1998-1999		5.73	6.08	-0.36		5.73	6.28	-0.56
1999-2000		8.54	8.37	0.17		8.54	8.39	0.15
2000-2001		10.54	10.22	0.32		10.54	10.12	0.42
2001-2002		11.60	11.52	0.08		11.60	11.43	0.17
2002-2003		11.97	12.40	-0.43		11.97	12.37	-0.40
2003-2004		12.66	13.00	-0.34		12.66	13.02	-0.36
2004-2005		13.66	13.42	0.24		13.66	13.46	0.20
2005-2006		13.77	13.71	0.06		13.77	13.75	0.01
2006-2007		13.95	13.93	0.02		13.95	13.95	0.00
2007-2008		14.19	14.09	0.10		14.19	14.07	0.12

III. Weibul Model: y=14.218-11.881*exp(-0.154*x^1.388)

IV. Logistic Model: y=13.99/(1+4.16*exp(-0.53x))

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
1997-1998		4.25	4.03	0.22		4.25	4.06	0.20
1998-1999		5.73	6.28	-0.55		5.73	5.73	-0.01
1999-2000		8.54	8.36	0.17		8.54	7.57	0.97
2000-2001		10.54	10.08	0.46		10.54	9.33	1.21
2001-2002		11.60	11.40	0.21		11.60	10.81	0.79
2002-2003		11.97	12.35	-0.38		11.97	11.93	0.05
2003-2004		12.66	13.02	-0.36		12.66	12.70	-0.04
2004-2005		13.66	13.47	0.19		13.66	13.20	0.46
2005-2006		13.77	13.76	0.01		13.77	13.51	0.25
2006-2007		13.95	13.94	0.01		13.95	13.71	0.24
2007-2008		14.19	14.06	0.13		14.19	13.82	0.37

It was noticed the errors between observed and expected values varies from0.12cm (1998) to 0.09cm (2008) and the error values are presented in the (Table 4.1.1.3g (IV)).

In case of second combination Chikkamangalore (S_3) x50:100:50(F_2), the best Model obtained was MMF Model and the estimated Model obtained was y=(3.459*16.250+14.792*x ^2.293)/(16.250+x^2.293), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.14cm (1998) to 0.10cm (2008) and the error values are presented in the (Table 4.1.1.3h (I)). The second best Model obtained was Gompertz Relation and the estimated Model obtained was y=14.312*exp (-exp (0.672-0.433x)), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.23cm (1998) to 0.12cm (2008) and the error values are presented in the (Table 4.1.1.3h (II)). The third best Model obtained was Weibul Model and the estimated Model obtained was y=14.218-11.881*exp (-0.154*x^1.388), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.22cm (1998) to 0.13cm (2008) and the error values are presented in the (Table 4.1.1.3h(III)) and fourth best Model obtained was Logistic Model and the estimated Model obtained was y=13.99/(1+4.16*exp(-0.53x)), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.20cm (1998) to 0.37cm (2008) and the error values are presented in the (Table 4.1.1.3h (IV)).

In case third combination Chikkamangalore (S_3)) x75:150:75(F_3), the best Model obtained was Rational Function and the estimated Model obtained was y= (-0.892+6.729x)/(1+ 0.411x -0.007x^2), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.30cm (1998) to 0.98cm (2008) and the error values are presented in the (Table 4.1.1.3i (I)).

The second best Model obtained was MMF Model and the estimated Model obtained was y= (0.480*4.595+21.451*x^1.002)/ (4.595+x^1.002).Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.23cm (1998) to 1.33cm (2008) and the error values are presented in the (Table 4.1.1.3i (II)). The third best Model obtained was Weibul Model and the estimated Model obtained was y=22.955-27.247*exp (-0.373*x^0.515), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.27cm (1998) to 1.23cm (2008) and the error values are presented in the (Table 4.1.1.3i(III)), The fourth best Model obtained was Richards Model and the estimated Model obtained was y=15.349/(1+exp(-1.508-0.377x))^(1/0.117), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.13cm (1998) to 1.73 cm (2008) and the error values are presented in the (Table 4.1.1.3i (IV)).

In case of fourth source and their combination, Thirthahalli (S_4) x25:50:25(F_1) the best Model was Sinusoidal Model and the estimated Model obtained was y=5.9+5.7* cos (0.2x+4.2), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.24cm (1998) to -0.03cm (2008) and the error values are presented in the (Table 4.1.1.3j (I)). The second best Model obtained was Richards Model and the estimated Model obtained was y=12.194/ (1+exp (1.998-0.430x)) ^ (1/1.718), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.31cm (1998) to 0.14cm (2008) and the error values are presented in the (Table 4.1.1.3j (II)). The third best Model obtained was Gompertz Model and the estimated Model obtained was y=13.09*exp (-exp (0.372-0.245x)), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.13cm (1998) to -0.25cm (2008) and the error values are presented in the (Table 4.1.1.3j (III)). The fourth best Model obtained was Rational Function and the estimated Model obtained was y= (-2.79+6.964x)/ (1+0.792x-0.019x^2), Based on this Model the prediction was made for the 11 years and then compared with the actual values.

Table 4.1.1.3(i): Table showing the actual values and predicted values Chikkamangalore (S_3) x75:150:75(F_3) for dbh (cm).

I. Rational Function: y=(-0.892+6.729x)/(1+0.411x-0.007x^2)
II. MMF Model: y=(0.480*4.595+21.451*x^1.002)/(4.595+x^1.002)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		4.46	4.16	0.30		4.46	4.23	0.23
1998-1999		6.11	7.00	-0.89		6.11	6.85	-0.74
1999-2000		8.98	8.89	0.09		8.98	8.77	0.21
2000-2001		10.37	10.28	0.09		10.37	10.25	0.11
2001-2002		12.42	11.37	1.05		12.42	11.42	1.00
2002-2003		12.63	12.28	0.35		12.63	12.37	0.26
2003-2004		12.68	13.08	-0.40		12.68	13.16	-0.48
2004-2005		13.11	13.79	-0.67		13.11	13.82	-0.71
2005-2006		13.94	14.44	-0.50		13.94	14.38	-0.45
2006-2007		14.13	15.06	-0.92		14.13	14.87	-0.74
2007-2008		16.63	15.65	0.98		16.63	15.29	1.33

III. Weibul Model: y=22.955-27.247*exp(-0.373*x^0.515)
IV. Richards Model: y=15.349/(1+exp(-1.508-0.377x))^(1/0.117)

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
1997-1998		4.46	4.19	0.27		4.46	4.59	-0.13
1998-1999		6.11	6.97	-0.86		6.11	6.58	-0.47
1999-2000		8.98	8.83	0.15		8.98	8.51	0.47
2000-2001		10.37	10.23	0.13		10.37	10.20	0.17
2001-2002		12.42	11.36	1.06		12.42	11.57	0.85
2002-2003		12.63	12.30	0.33		12.63	12.63	0.00
2003-2004		12.68	13.09	-0.41		12.68	13.42	-0.74
2004-2005		13.11	13.78	-0.67		13.11	14.00	-0.88
2005-2006		13.94	14.38	-0.45		13.94	14.41	-0.47
2006-2007		14.13	14.92	-0.79		14.13	14.70	-0.56
2007-2008		16.63	15.40	1.23		16.63	14.90	1.73

Table 4.1.1.3(j): Table showing the actual values and predicted values Thirthahalli(S_4) x25:50:25(F_1) for dbh(cm)

I. Sinusoidal Model: y=5.908+5.740*cos(0.187x+4.244)

II. Richards Model: y=12.194/(1+exp(1.998-0.430x))^(1/1.718)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		4.07	4.31	-0.24		4.07	4.38	-0.31
1998-1999		5.93	5.37	0.57		5.93	5.35	0.59
1999-2000		6.05	6.44	-0.39		6.05	6.40	-0.35
2000-2001		7.63	7.49	0.14		7.63	7.47	0.16
2001-2002		8.60	8.49	0.11		8.60	8.50	0.10
2002-2003		9.13	9.40	-0.27		9.13	9.42	-0.29
2003-2004		9.80	10.18	-0.38		9.80	10.18	-0.38
2004-2005		11.34	10.82	0.52		11.34	10.78	0.56
2005-2006		11.37	11.29	0.09		11.37	11.22	0.15
2006-2007		11.43	11.57	-0.14		11.43	11.54	-0.11
2007-2008		11.62	11.65	-0.03		11.62	11.75	-0.14

III. Gompertz Relation: y=13.09*exp(-exp(0.372-0.245x))

IV. Rational Function: y=(-2.791 +6.964x)/(1+0.792x-0.019x^2)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		4.07	4.21	-0.13		4.07	4.36	-0.29
1998-1999		5.93	5.38	0.55		5.93	5.35	0.58
1999-2000		6.05	6.53	-0.48		6.05	6.38	-0.33
2000-2001		7.63	7.59	0.04		7.63	7.40	0.23
2001-2002		8.60	8.55	0.05		8.60	8.37	0.23
2002-2003		9.13	9.38	-0.25		9.13	9.25	-0.12
2003-2004		9.80	10.08	-0.28		9.80	9.98	-0.18
2004-2005		11.34	10.67	0.67		11.34	10.54	0.80
2005-2006		11.37	11.16	0.22		11.37	10.92	0.45
2006-2007		11.43	11.55	-0.12		11.43	11.13	0.31
2007-2008		11.62	11.87	-0.25		11.62	11.16	0.46

Table 4.1.1.3(k): Table showing the actual values and predicted values Thirthahalli (S_4) x 50:100:50(F_2) for dbh (cm).

I. MMF Model: y=(4.388*108.136+15.401*x^3.149)/(108.136+x^3.149)

II. Weibul Model: y=14.841-10.999*exp(-0.039*x^2.017)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		4.46	4.49	-0.03		4.46	4.26	0.20
1998-1999		5.42	5.22	0.20		5.42	5.45	-0.03
1999-2000		6.68	6.89	-0.21		6.68	7.15	-0.47
2000-2001		8.63	9.03	-0.40		8.63	9.03	-0.41
2001-2002		11.64	10.94	0.70		11.64	10.80	0.84
2002-2003		12.73	12.35	0.38		12.73	12.25	0.48
2003-2004		12.93	13.30	-0.37		12.93	13.32	-0.38
2004-2005		12.96	13.92	-0.97		12.96	14.01	-1.06
2005-2006		14.56	14.34	0.22		14.56	14.43	0.13
2006-2007		14.58	14.62	-0.03		14.58	14.65	-0.07
2007-2008		15.30	14.81	0.49		15.30	14.76	0.54

III. Richards Model: y=14.980/(1+exp(2.662-0.592x))^(1/1.682)

IV. Logistic Model: y=15.283/(1+4.590*exp(-0.478x))

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		4.46	4.08	0.38		4.46	3.97	0.49
1998-1999		5.42	5.51	-0.09		5.42	5.53	-0.11
1999-2000		6.68	7.20	-0.53		6.68	7.30	-0.62
2000-2001		8.63	9.03	-0.41		8.63	9.11	-0.48
2001-2002		11.64	10.77	0.87		11.64	10.76	0.89
2002-2003		12.73	12.21	0.52		12.73	12.12	0.61
2003-2004		12.93	13.26	-0.33		12.93	13.16	-0.22
2004-2005		12.96	13.96	-1.01		12.96	13.89	-0.93
2005-2006		14.56	14.39	0.16		14.56	14.39	0.17
2006-2007		14.58	14.65	-0.06		14.58	14.72	-0.13
2007-2008		15.30	14.79	0.51		15.30	14.93	0.37

It was noticed the errors between observed and expected values varies from -0.29cm (1998) to 0.46 cm (2008) and the error values are presented in the (Table 4.1.1.3j (II)).

In case of second combination Thirthahalli (S_4) x50:100:50(F_2), the best Model obtained was MMF Model and the estimated Model obtained was y= (4.388*108.136+ 15.401*x^3.149) / (108.136+x^3.149), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed that the errors between observed and expected values varies from -0.03cm (1998) to 0.49cm (2008) and the error values are presented in the (Table 4.1.1.3k(I)). The second best Model obtained was Weibul Model and the estimated Model obtained was y=14.841-10.999*exp (-0.039*x^2.017), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.20cm (1998) to 0.54cm (2008) and the error values are presented in the (Table 4.1.1.3k(II)), The third best Model obtained was Richards Model and the estimated Model obtained was y=14.980/(1+exp(2.662-0.592x))^(1/1.682), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed that the errors between observed and expected values varies from 0.38cm (1998) to 0.51cm (2008) and the error values are presented in the (Table 4.1.1.3k(III)), fourth best Model was Logistic Model and the estimated Model obtained was y=15.283/(1+4.590*exp(-0.478x)), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from0.49cm (1998) to 0.37cm (2008) and the error values are presented in the (Table 4.1.1.3k(IV)).

In case third combination Thirthahalli (S_4) x75:150:75(F_3), the best Model obtained was MMF Model and the estimated eqation was y= (2.7*119.8+188.8*x^0.9)/(119.8 +x^0.9), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.11cm (1998) to 0.45cm (2008) and the error values are presented in the (Table 4.1.1.3l (I)). The second best Model obtained was Weibul Model and the estimated Model obtained was y=50.765-47.834*exp (-0.029*x^0.947), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed that the errors between observed and expected values varies from -0.12cm (1998) to 0.57cm (2008) and the error values are presented in the (Table 4.1.1.3l (II)). The third best Model obtained was Gompertz model and the estimated Model obtained was y=21.584*exp (-exp (0.585-0.141x)), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.36cm (1998) to 0.47 cm (2008) and the error values are presented in the (Table 4.1.1.3l (III)).

And fourth best Model was Polynomial Model and the estimated Model obtained was y=3.032+1.129x+0.102x^2-0.023x^3+0.001x ^4, Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.06cm (1998) to 3.39cm (2008) and the error values are presented in the (Table 4.1.1.3l (I)).

4.1.1.4. Models predicting the future DBH growth with corresponding error terms in case of spacing and fertilizer level.

Among different Models tried in predicting the Height growth, the treatment combinations, Polynomial, Gaussian, Sinusoidal, Richards, Weibul, Rational, MMF, Logistic, Logarithm, and Gompertz Model was found to be the best Model with highest R^2 value. Therefore, these Models are considered for predicting the height at different years and comparing the same with the actual values.

In case of first spacing and their combination, 4x1m(SP_1) x No fertilizer(F_0) the best Model obtained was MMF Model and the estimated Model obtained was y=(2.956*70.525 +127.392*x^0.748) /(70.525+ x^0.748), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed that the errors between observed and expected values varies from -0.12cm (2001) to 0.23cm (2008) and the error values are presented in the (Table 4.1.1.4a (I)). The second best Model obtained was Weibul Model and the estimated Model obtained was y=33.438-30.299 *exp (-0.053*x^0.818), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.12cm (2001) to 0.24cm (2008) and the error values are presented in the (Table 4.1.1.4a (II)).

Table 4.1.1.3(l): Table showing the actual values and predicted values Thirthahalli (S_4) x 75:150:75(F_3) for dbh (cm)

I. MMF Model: y=(2.754*119.810+188.822*x^0.881)/(119.810+x^0.881)

II. Weibul Model: y=50.765-47.834*exp(-0.029*x^0.947)

Year	**I**	**Actual value**	**Predicted value**	**Error**	**II**	**Actual value**	**Predicted value**	**Error**
1997-1998		4.18	4.29	-0.11		4.18	4.30	-0.12
1998-1999		5.88	5.57	0.31		5.88	5.53	0.34
1999-2000		6.22	6.75	-0.53		6.22	6.70	-0.48
2000-2001		8.05	7.88	0.17		8.05	7.82	0.23
2001-2002		9.74	8.95	0.78		9.74	8.89	0.84
2002-2003		9.97	9.99	-0.02		9.97	9.93	0.04
2003-2004		10.28	11.00	-0.72		10.28	10.93	-0.65
2004-2005		12.03	11.97	0.06		12.03	11.91	0.13
2005-2006		13.10	12.93	0.17		13.10	12.85	0.25
2006-2007		13.45	13.86	-0.41		13.45	13.76	-0.31
2007-2008		15.22	14.77	0.45		15.22	14.65	0.57

III. Gompertz Relation: y=21.584*exp(-exp(0.585-0.141x))

IV. Polynomial Model: y=3.032+1.129x+0.102x^2-0.023x^3+0.001x ^4

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
1997-1998		4.18	4.54	-0.36		4.18	4.24	-0.06
1998-1999		5.88	5.57	0.30		5.88	5.53	0.35
1999-2000		6.22	6.66	-0.44		6.22	6.80	-0.58
2000-2001		8.05	7.77	0.27		8.05	7.96	0.08
2001-2002		9.74	8.89	0.85		9.74	8.98	0.76
2002-2003		9.97	9.99	-0.02		9.97	9.81	0.16
2003-2004		10.28	11.06	-0.78		10.28	10.45	-0.16
2004-2005		12.03	12.07	-0.04		12.03	10.91	1.12
2005-2006		13.10	13.03	0.07		13.10	11.25	1.85
2006-2007		13.45	13.93	-0.48		13.45	11.52	1.93
2007-2008		15.22	14.75	0.47		15.22	11.82	3.39

The third best Model obtained was Gompertz Model and the estimated Model obtained was y=14.91*exp (-exp (0.3-0.178x)), Based on this Model the prediction was made for the 8 years and then compared with the actual values .It was noticed that the errors between observed and expected values varies from-0.24cm (2001) to 0.25cm (2008) and the error values are presented in the (Table 4.1.1.2a (III)). And fourth best Model was Logistic Model and the estimated Model obtained was y=13.3/(1+2.3*exp (-0.286x)), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed that the errors between observed and expected values varies from -0.29cm (2001) to 0.26cm (2008) and the error values are presented in the (Table 4.1.1.4a (IV)).

In case of second combination 4x1m (SP_1) x50:100:50(F_1), the best Model obtained was Weibul Model and the estimated Model obtained was y=10.272-4.660*exp (-0.003*x^3.597), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.15cm (2001) to -0.21cm (2008) and the error values are presented in the (Table 4.1.1.2b (I)). The second best Model obtained was Richards Model and the estimated Model obtained was y=10.11/(1+exp(94.654-14.262x))^(1/119.718), Based on this Model the prediction was made for the 11 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.31cm (2001) to 0.01cm (2008) and the error values are presented in the (Table 4.1.1.4b(II)), The third best Model obtained was MMF Model and the estimated Model obtained was y=(5.628*848.945+10.897*x^4.256)/(848.945 x^4.256), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.16cm (2001) to -0.21cm (2008) and the error values are presented in the (Table 4.1.1.4b (III)). And fourth best Model was Logistic Model and the estimated Model obtained was y=15.16/(1+2.399*exp(-0.211x)), Based on this Model the prediction was made for the 8 years and then compared with the actual values .It was noticed the errors between observed and expected values varies from 0.32cm (2001) to -0.36cm (2008) and the error values are presented in the (Table 4.1.1.4b(IV)).

In case third combination 4x2m (SP_2) x No fertilizer (F_0), the best Model obtained was MMF Model and the estimated Model obtained was y= (3.033*26.953+67.528*x^0.744) /(26.953+x^0.744), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.20cm (2001) to 0.37cm (2008) and the error values are presented in the (Table 4.1.1.4c (I)). The second best Model obtained was Weibul Model and the estimated Model obtained was y=38.221-35.140*exp (-0.067*x^0.749), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.22cm (2001) to 0.32cm (2008) and the error values are presented in the (Table 4.1.1.4c (II)). The third best Model obtained was Gompertz Relation and the estimated Model obtained was y=16.416*exp (-exp (0.290-0.203x)), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.37cm (2001) to 0.36cm (2008) and the error values are presented in the (Table 4.1.1.4c (III)).

And fourth best Model was Logistic Model and the estimated Model obtained was 14.89/ (1+2.288*exp (-0.314x)), Based on This Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.43cm (2001) to 0.42cm (2008) and the error values are presented in the (Table 4.1.1.4c (IV)).

In case of fourth spacing and their combination, 4x2m (SP_2) x 50:100:50(F_1) the best Model obtained was Rational Function and the estimated Model obtained was y= (0.259+ 5.571 x)/(1+0.397x-0.007x^2), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.01cm (2001) to 0.27cm (2008) and the error values are presented in the (Table 4.1.1.4d (I)). The second best Model obtained was Weibul Model and the estimated Model obtained was y=22.121-25.774*exp (-0.363*x^0.456), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.01cm (2001) to 0.27cm (2008) and the error values are presented in the (Table 4.1.1.4d (II)).

Table 4.1.1.4(a): Table showing the actual values and predicted values for 4x1m (SP_1)x No fertilizer(F_0) for dbh(cm).

I. MMF Model: y=(2.956*70.525+127.392*x^0.748)/(70.525+x^0.748)
II. Weibul Model: y=33.438-30.299*exp(-0.053*x^0.818)

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
2000-2001		4.58	4.70	-0.12		4.58	4.70	-0.12
2001-2002		6.08	5.85	0.23		6.08	5.84	0.24
2002-2003		6.84	6.84	-0.01		6.84	6.84	0.00
2003-2004		7.68	7.74	-0.06		7.68	7.74	-0.06
2004-2005		8.63	8.57	0.06		8.63	8.57	0.06
2005-2006		9.24	9.35	-0.11		9.24	9.35	-0.11
2006-2007		9.89	10.09	-0.19		9.89	10.08	-0.19
2007-2008		11.02	10.79	0.23		11.02	10.78	0.24

III. Gompertz Relation:- y=14.907*exp(-exp(0.299-0.178x))
IV. Logistic Model: y=13.26/(1+2.29*exp(-0.286x))

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
2000-2001		4.58	4.82	-0.24		4.58	4.87	-0.29
2001-2002		6.08	5.80	0.29		6.08	5.78	0.30
2002-2003		6.84	6.76	0.08		6.84	6.73	0.11
2003-2004		7.68	7.69	-0.01		7.68	7.67	0.02
2004-2005		8.63	8.57	0.07		8.63	8.57	0.07
2005-2006		9.24	9.38	-0.13		9.24	9.39	-0.15
2006-2007		9.89	10.11	-0.22		9.89	10.13	-0.23
2007-2008		11.02	10.77	0.25		11.02	10.76	0.26

Table 4.1.1.4(b): Table showing the actual values and predicted values for 4x1m (SP_1) x 50:100:50(F_1) for dbh (cm).

I. Weibul Model: y=10.272-4.660*exp(-0.003*x^3.597)

II. Richards Model: y=10.110/(1+exp(94.654-14.262x))^(1/119.718)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
2000-2001		5.48	5.63	-0.15		5.48	5.17	0.31
2001-2002		5.86	5.78	0.08		5.86	5.82	0.04
2002-2003		6.28	6.29	-0.01		6.28	6.56	-0.28
2003-2004		7.34	7.27	0.07		7.34	7.38	-0.04
2004-2005		7.96	8.52	-0.56		7.96	8.32	-0.36
2005-2006		9.72	9.57	0.15		9.72	9.37	0.35
2006-2007		10.10	10.10	0.00		10.10	10.11	-0.01
2007-2008		10.12	10.25	-0.13		10.12	10.11	0.01

III. MMF Model: y=(5.628*848.945+10.897*x^4.256)/(848.945+x^4.256)

IV. Logistic Model:- y=15.16/(1+2.399*exp(-0.211x))

Year		Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
2000-2001		5.48	5.63	-0.16		5.48	5.15	0.32
2001-2002		5.86	5.74	0.11		5.86	5.89	-0.04
2002-2003		6.28	6.22	0.06		6.28	6.67	-0.39
2003-2004		7.34	7.21	0.13		7.34	7.46	-0.12
2004-2005		7.96	8.40	-0.44		7.96	8.26	-0.30
2005-2006		9.72	9.35	0.36		9.72	9.04	0.67
2006-2007		10.10	9.97	0.13		10.10	9.79	0.31
2007-2008		10.12	10.33	-0.21		10.12	10.50	-0.38

Table 4.1.1.4(c): Table showing the actual values and predicted values of 4x2m (SP_2)xNo fertilizer (F_0) for dbh(cm).

I. MMF Model: y=(3.033*26.953+67.528*x^0.744)/(26.953+x^0.744)
II. Weibul Model: y=38.221-35.140*exp(-0.067*x^0.749)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
2000-2001		5.14	5.34	-0.20		5.14	5.36	-0.22
2001-2002		7.36	6.81	0.55		7.36	6.82	0.54
2002-2003		7.79	8.03	-0.24		7.79	8.05	-0.26
2003-2004		8.74	9.11	-0.37		8.74	9.14	-0.40
2004-2005		10.54	10.09	0.45		10.54	10.12	0.42
2005-2006		10.96	10.99	-0.03		10.96	11.03	-0.07
2006-2007		11.32	11.82	-0.50		11.32	11.87	-0.55
2007-2008		12.98	12.61	0.37		12.98	12.65	0.32

III. Gompertz Relation: y=16.416*exp(-exp(0.290-0.203x))
IV. Logistic Model: y=14.89/(1+2.288*exp(-0.314x))

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
2000-2001		5.14	5.51	-0.37		5.14	5.57	-0.43
2001-2002		7.36	6.74	0.62		7.36	6.70	0.66
2002-2003		7.79	7.94	-0.14		7.79	7.87	-0.08
2003-2004		8.74	9.07	-0.33		8.74	9.02	-0.27
2004-2005		10.54	10.11	0.43		10.54	10.09	0.45
2005-2006		10.96	11.06	-0.10		10.96	11.05	-0.09
2006-2007		11.32	11.89	-0.56		11.32	11.87	-0.55
2007-2008		12.98	12.61	0.36		12.98	12.56	0.42

Table 4.1.1.4(d): Table showing the actual values and predicted values of 4x2m (SP_2) x50:100:50 (F_1) for dbh (cm)

I. Rational Function: y=(0.259+5.571x)/(1+0.397x-0.007x^2)

II. Weibul Model: y=22.121-25.774*exp(-0.363*x^0.456)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
2000-2001		4.18	4.19	-0.01		4.18	4.19	-0.01
2001-2002		6.57	6.46	0.12		6.57	6.46	0.12
2002-2003		7.78	7.98	-0.19		7.78	7.96	-0.18
2003-2004		8.92	9.10	-0.19		8.92	9.10	-0.19
2004-2005		10.62	10.00	0.61		10.62	10.02	0.60
2005-2006		10.69	10.76	-0.08		10.69	10.79	-0.10
2006-2007		10.95	11.42	-0.48		10.95	11.45	-0.50
2007-2008		12.30	12.02	0.27		12.30	12.02	0.27

III. MMF Model: y=(2.764*3.612+29.332*x^0.542)/(3.612+x^0.542)

IV. Logarithm Model: y=3.971+3.795*ln(x)

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
2000-2001		4.18	4.20	-0.02		4.18	3.97	0.21
2001-2002		6.57	6.46	0.12		6.57	6.60	-0.03
2002-2003		7.78	7.97	-0.18		7.78	8.14	-0.36
2003-2004		8.92	9.11	-0.19		8.92	9.23	-0.32
2004-2005		10.62	10.02	0.59		10.62	10.08	0.54
2005-2006		10.69	10.79	-0.11		10.69	10.77	-0.08
2006-2007		10.95	11.45	-0.50		10.95	11.36	-0.41
2007-2008		12.30	12.03	0.27		12.30	11.86	0.43

The third best Model obtained was MMF Model and the estimated Model obtained was y=(2.764*3.612+29.332* x^0.542) /(3.612+x^0.542), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from -0.02cm (2001) to 0.27cm (2008) and the error values are presented in the (Table 4.1.1.4d (III)). The fourth best Model obtained was Logarithm Model and the estimated Model obtained was y=3.97+3.8*ln(x), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.21cm (2001) to 0.43cm (2008) and the error values are presented in the (Table 4.1.1.4d (IV)).

In case of fifth combination 4x3m(SP_3) xNo fertilizer(F_0), the best Model obtained was MMF Model and the estimated Model obtained was y=(3.7*20.99+12.52 *x^2.4)/(20.99 +x^2.4), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.03cm (2001) to 0.11cm (2008) and the error values are presented in the (Table 4.1.1.4e (I)). The second best Model obtained was Weibul Model and the estimated Model obtained was y=11.689-8.378*exp(-0.096*x^1.703), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.07cm (2001) to 0.14cm (2008) and the error values are presented in the (Table 4.1.1.4e (II)).

The third best Model obtained was Richards Model and the estimated Model obtained was y=11.802/ (1+exp (1.537-0.585x)) ^ (1/1.196), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.09cm (2001) to 0.13cm (2008) and the error values are presented in the (Table 4.1.1.4e (III)). And fourth best Model was Logistic Model and the estimated Model obtained was y=11.875/(1+3.373*exp(-0.552x)), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.11cm (2001) to 0.12cm (2008) and the error values are presented in the (Table 4.1.1.4e (IV)).

In case of sixth combination 4x3m (SP_3) x50:100:50 (F_1), the best Model obtained was Weibul Model and the estimated Model obtained was y=12.75-9.45*exp (-0.092*x^ 1.858), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from 0.02cm (2001) to 0.03cm (2008) and the error values are presented in the (Table 4.1.1.4f (I)). The second best Model obtained was MMF Model and the estimated Model obtained was y=(3.758*22.797+13.495*x^2.675)/(22.797+x^2.675), Based on this Model the prediction was made for the 8 years and then compared with the actual values. It was noticed the errors between observed and expected values varies from-0.02cm (2001) to -0.06cm (2008) and the error values are presented in the (Table 4.1.1.4f(II)).The third best Model obtained was Richards Model and the estimated Model obtained was y=12.827/(1+exp(2.281-0.759x)) ^ (1/1.512), Based on this Model the prediction was made for the 8 years and then compared with the actual values .It was noticed the errors between observed and expected values varies from 0.04cm (2001) to 0.01cm (2008) and the error values are presented in the (Table 4.1.1.2f(III)) and fourth best Model was Logistic model and the estimated Model obtained was y=12.97/(1+4.25*exp(-0.657x)).Based on this Model the prediction was made for the 8 years and then compared with the actual values .It was noticed the errors between observed and expected values varies from 0.10cm (2001) to -0.04cm (2008) and the error values are presented in the (Table 4.1.1.4f(IV)).

4.2.1 Best suited Models with their predicted height values of *Acacia mangium* for next 5 years corresponding to incremental values (Sources and fertilizer level).

Based on spacing and treatment combinations the best Fitted top four Models based on their R^2 values and lower standard error and RMSE values are selected and the prediction of height for the next 5 years is made based on the best selected Models.

In case of first combination Kerala (S_1) x25:50:25(F_1), the best selected Models are Rational Function, Weibul Model, MMF Model and Logarithm Model.

Table 4.1.1.4(e) :Table showing the actual values and predicted values of 4x3m (SP_3) x No fertilizer (F_0) for dbh(cm).

I. MMF Model: y=(3.714*20.985+12.523*x^2.395)/(20.985+x^2.395)

II. Weibul Model: y=11.689-8.378*exp(-0.096*x^1.703)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
2000-2001		4.14	4.11	0.03		4.14	4.08	0.07
2001-2002		5.42	5.48	-0.06		5.42	5.56	-0.14
2002-2003		7.23	7.22	0.00		7.23	7.20	0.03
2003-2004		8.87	8.72	0.15		8.87	8.66	0.21
2004-2005		9.63	9.81	-0.18		9.63	9.80	-0.17
2005-2006		10.68	10.56	0.13		10.68	10.59	0.09
2006-2007		10.89	11.06	-0.17		10.89	11.09	-0.20
2007-2008		11.53	11.41	0.11		11.53	11.38	0.14

III. Richards Model: y=11.802/(1+exp(1.537-0.585x))^(1/1.196)

IV. Logistic Model: y=11.875/(1+3.373*exp(-0.552x))

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
2000-2001		4.14	4.05	0.09		4.14	4.04	0.11
2001-2002		5.42	5.59	-0.17		5.42	5.61	-0.18
2002-2003		7.23	7.21	0.02		7.23	7.22	0.00
2003-2004		8.87	8.66	0.21		8.87	8.66	0.21
2004-2005		9.63	9.80	-0.17		9.63	9.79	-0.16
2005-2006		10.68	10.58	0.10		10.68	10.58	0.11
2006-2007		10.89	11.09	-0.19		10.89	11.09	-0.20
2007-2008		11.53	11.39	0.13		11.53	11.41	0.12

Table 4.1.1.4(f) :Table showing the actual values and predicted values of 4x3m(SP_3) x 50:100:50 (F_1) for dbh(cm).

I. Weibul Model: y=12.746-9.450*exp(-0.092*x^1.858)

II. MMF Model: y=(3.758*22.797+13.495*x^2.675)/(22.797+x^2.675)

Year	I	Actual value	Predicted value	Error	II	Actual value	Predicted value	Error
2000-2001		4.15	4.13	0.02		4.15	4.17	-0.02
2001-2002		5.94	5.98	-0.03		5.94	5.89	0.05
2002-2003		8.09	8.09	-0.01		8.09	8.17	-0.08
2003-2004		10.12	9.93	0.19		10.12	10.00	0.12
2004-2005		10.97	11.23	-0.26		10.97	11.20	-0.24
2005-2006		12.21	12.02	0.19		12.21	11.95	0.26
2006-2007		12.37	12.44	-0.07		12.37	12.41	-0.05
2007-2008		12.65	12.63	0.03		12.65	12.71	-0.06

III. Richards Model: y=12.827/(1+exp(2.281-0.759x))^(1/1.512)

IV. Logistic Model: y=12.97/(1+4.25*exp(-0.657x))

Year	III	Actual value	Predicted value	Error	IV	Actual value	Predicted value	Error
2000-2001		4.15	4.11	0.04		4.15	4.05	0.10
2001-2002		5.94	6.01	-0.07		5.94	6.05	-0.11
2002-2003		8.09	8.10	-0.01		8.09	8.15	-0.06
2003-2004		10.12	9.94	0.18		10.12	9.92	0.20
2004-2005		10.97	11.25	-0.28		10.97	11.19	-0.22
2005-2006		12.21	12.02	0.18		12.21	11.98	0.23
2006-2007		12.37	12.43	-0.07		12.37	12.44	-0.07
2007-2008		12.65	12.64	0.01		12.65	12.69	-0.04

In case of Rational Function, the increment seen in height between12th to 16th year ranges between 10.10m to 12.17m, whereas in case of Weibul Model it ranges from 9.56m to 10.19 m, MMF Model ranges between 9.54m to 10.16m and Logarithm Model ranges from 9.76m to 10.64m. (Table 4.2.1a).

In case of second combination Kerala (S_1) x50:100:50(F_2), the best selected Models are Rational Function, MMF Model, Weibul Model, and Logarithm Model. In case of Rational Function, the increment seen in height between12th to 16th year ranges between 9.44m to 10.74m, whereas in case of MMF Model it ranges between 8.96m to 9.34m, Weibul Model it ranges between 8.97m to 9.34 m, and Logarithm Model ranges from 9.46m to 10.23m.(Table 4.2.1b).

In case of third combination Kerala (S_1) x75:150:75(F_3), the best selected Models are Rational Function, Weibul Model, Logarithm Model and Richards Model. In case of Rational Function, the increment seen in height 12th to 16th year ranges between 9.82m to 11.29m, where as in case of Weibul Model it ranges between 9.42m to 9.91m, Logarithm Model it ranges between 9.77m to 10.59m and Richards Model it ranges between 8.93m to 8.96m.(Table 4.2.1c).

In case of fourth combination Bangalore(S_2) x25:50:25(F_1), the best selected Models are Rational Function, MMF Model , Weibul Model and Logarithm Model. In case of Rational Function it ranges between 9.24m to 10.87m, whereas in case of MMF Model it ranges between 8.87m to 9.52m, Weibul Model it ranges between 8.87m to 9.49m and Logarithm Model the increment seen in height between12th to 16th year ranges between 8.96m to 9.69m.(Table 4.2.1d).

In case of fifth combination Bangalore (S_2) x50:100:50(F_2), the best selected Models are Weibul Model, MMF Model, Logarithm Model and Rational Function. In case of Weibul Model it ranges between 8.63m to 9.30m, whereas in case of MMF Model Model it ranges between 8.62m to 9.30m, Logarithm Model, the increment seen in height between12th to 16th year ranges between 8.59m to 9.26m, and Rational Function it ranges between 8.72m to 9.69m. (Table 4.2.1e).

In case of sixth combination Bangalore (S_2) x75:150:75(F_3),the best selected Models are Rational Function,Weibul Model, MMF Model and Logarithm Model. In case of Rational Function the increment seen in height between12th to 16th year ranges between 9.22m to 10.84m whereas in case of, Weibul Model it ranges between 8.91m to 9.69m, MMF Model it ranges between 8.90m to 9.68m and Logarithm Model ranges between 8.80m to 9.50m. (Table 4.2.1f).

In case of seventh combination Chikkamangalore (S_3) x 25:50:25(F_1), the best selected Models are MMF Model, Richards Model, Logistic Model and Weibul Model. In case of MMF Model, the increment seen in height between12th to 16th year ranges between 9.25m to 9.26m the results showed that tree was stagnant after 12 years it means after 12 years we can go for cutting of a tree, whereas in case of Logistic Model it ranges between 9.20m to 9.20m. In this case the tree was stagnant after 9 years it means after 9 years we can go for cutting of a tree, Richards Model it ranges between 9.17m to 9.17m, the results showed that tree was stagnant after 9 years it means after 9 years we can go for cutting of a tree, and Weibul Model it ranges between 9.13m to 9.13m, the results showed that tree was stagnant after 9 years it means after 9 years we can go for cutting of a tree.(Table 4.2.1g).

In case of eighth combination Chikkamangalore (S_3) x 50:100:50 (F_2), the best selected Models are MMF Model Logistic Model, Gompertz Model and Richards Model. In case of MMF Model, the increment seen in height between12th to 16th year ranges between 9.43m to 9.45m, the results showed that tree was stagnant after 13 years it means after 13years we can go for cutting of a tree, whereas in case of Logistic Model it ranges between 9.38m to 9.38m, the results showed that tree was stagnant after 10 years it means after 10 years we can go for cutting of a tree, Gompertz Model it ranges between 9.50m to 9.51m the results showed that tree was stagnant after 13 years it means after 13 years we can go for cutting of a tree,and Richards Model it ranges between 9.40m to 9.40m the results showed that tree was stagnant after 11 years it means after 11 years we can go for cutting of a tree, (Table 4.2.1h).

Table 4.2.1(a) : Table showing Predicted Values for next 5 years of Kerala(S_1) x 25:50:25(F_1)for height.

combination	Name of the Model	Model Eqations	X(yrs)	Y(m)
S_1F_1	Rational Function	y=(-370.216+512.827x)/(1+70.015x-1.866x^2)	12	10.10
			13	10.57
			14	11.06
			15	11.60
			16	12.17
	Weibul Model	y=14.747-61.633*exp(-1.594*x^0.177)	12	9.56
			13	9.74
			14	9.90
			15	10.05
			16	10.19
	MMF Model	y=(19.772*0.632+16.132*x^0.416)/(0.632+x^0.416)	12	9.54
			13	9.72
			14	9.88
			15	10.03
			16	10.16
	Logarithm Model	y=2.481+2.943*ln(x)	12	9.79
			13	10.03
			14	10.25
			15	10.45
			16	10.64

Y is the height increment, X is the age

Table 4.2.1(b) : Table showing Predicted Values for next 5 years of Kerala(S_1) x 50:100:50(F_2) for height.

combination	Name of the Model	Model Eqations	X(yrs)	Y(m)
S_1F_2	Rational Function	y=(60818031.41+83856448.89x)/(1+11024498.96x-223011.0063x^2)	12	9.44
			13	9.74
			14	10.06
			15	10.39
			16	10.74
	Weibul Model	y=10.901-179.632*exp(-3.029*x^0.162)	12	8.97
			13	9.08
			14	9.17
			15	9.26
			16	9.34
	MMF Model	y=(26.425*0.321+11.371*x^0.624)/(0.321+x^0.624)	12	8.96
			13	9.07
			14	9.17
			15	9.26
			16	9.34
	Logarithm Model	y=2.797+2.681*ln(x)	12	9.46
			13	9.67
			14	9.87
			15	10.06
			16	10.23

Y is the height increment, X is the age

Table 4.2.1(c) : Table showing Predicted Values for next 5 years of Kerala(S_1) x 75:150:75(F_3) for height.

combination	Name of the Model	Model Eqations	X(yrs)	Y(m)
S_1F_3	Rational Function	y=(-59.410+85.149x)/(1+10.892x-0.234x^2)	12	9.82
			13	10.17
			14	10.52
			15	10.90
			16	11.29
	Weibul Model	y=12.361-77.427*exp(-2.044*x^0.189)	12	9.42
			13	9.56
			14	9.69
			15	9.80
			16	9.91
	Richards Model	y=8.961/(1+exp(-2.322-0.524x))^(1/0.048)	12	8.93
			13	8.94
			14	8.95
			15	8.95
			16	8.96
	Logarithm Model	y=2.744+2.829*ln(x)	12	9.77
			13	10.00
			14	10.21
			15	10.41
			16	10.59

Y is the height increment, X is the age

Table 4.2.1(d) : Table showing Predicted Values for next 5 years of Bangalore(S_2) x 25:50:25(F_1) for height.

combination	Name of the Model	Model Eqations	X(yrs)	Y(m)
S_2F_1	Rational Function	y=(-12.715+22.488x)/(1+3.149x-0.076x^2)	12	9.24
			13	9.61
			14	10.01
			15	10.43
			16	10.87
	Weibul Model	y=15.050-37.721*exp(-1.103*x^0.199)	12	8.87
			13	9.04
			14	9.21
			15	9.36
			16	9.49
	MMF Model	y=(49.542*0.424+24.593*x^0.183)/(0.424+x^0.183)	12	8.87
			13	9.06
			14	9.22
			15	9.37
			16	9.52
	Logarithm Model	y=2.621+2.555*ln(x)	12	8.96
			13	9.16
			14	9.35
			15	9.53
			16	9.69

Y is the height increment, X is the age

Table 4.2.1(e): Table showing Predicted Values for next 5 years of Bangalore(S_2) x 50:100:50(F_2)for height.

combination	Name of the Model	Model Eqations	X (yrs)	Y(m)
S_2F_2	Rational Function	y=(-0.197+4.686x)/(1+0.548x-0.008x^2)	12	8.72
			13	8.97
			14	9.21
			15	9.45
			16	9.69
	Weibul Model	y=16.661-24.877*exp(-0.594*x^0.259)	12	8.63
			13	8.82
			14	8.99
			15	9.15
			16	9.30
	MMF Model	y=(-7.852*1.964+24.086*x^0.297)/(1.964+x^0.297)	12	8.62
			13	8.81
			14	8.98
			15	9.15
			16	9.30
	Logarithm Model	y=2.866+2.305*ln(x)	12	8.59
			13	8.78
			14	8.95
			15	9.11
			16	9.26

Y is the height increment, X is the age

Table 4.2.1(f) :Table showing Predicted Values for next 5 years of Bangalore(S_2) x75:150:75(F_3)for height.

combination	Name of the Model	MODEL	X (yrs)	Y(m)
S_2F_3	Rational Function	y=(-1.628+7.057x)/(1+0.931x-0.022x^2)	12	9.22
			13	9.60
			14	9.99
			15	10.41
			16	10.84
	Weibul Model	y=20.544-26.585*exp(-0.410*x^0.282)	12	8.91
			13	9.13
			14	9.33
			15	9.52
			16	9.69
	MMF Model	y=(5.356*3.144+28.890*x^0.325)/(3.144+x^0 .325)	12	8.90
			13	9.12
			14	9.32
			15	9.51
			16	9.68
	Logarithm Model	y=2.765+2.429*ln(x)	12	8.80
			13	9.00
			14	9.18
			15	9.34
			16	9.50

Y is the height increment, X is the age

Table 4.2.1(g) : Predicted Values for next 5 years of Chikkamangalore(S_3) x 25:50:25(F_1) for height.

combination	Name of the Model	Model Eqations	X(yrs)	Y(m)
S_3F_1	Richards Model	y=9.167/(1+exp(3.367-1.284x))^(1/1.600)	12 13 14 15 16	9.17 9.17 9.17 9.17 9.17
	Weibul Model	y=9.128-7.308 *exp(-0.079*x^2.432)	12 13 14 15 16	9.13 9.13 9.13 9.13 9.13
	MMF Model	y=(2.203*34.772+9.268*x^3.846)/(34.772+x^3.846)	12 13 14 15 16	9.25 9.26 9.26 9.26 9.26
	Logistic Model	y=9.205/(1+9.032*exp(-1.076x))	12 13 14 15 16	9.20 9.20 9.20 9.20 9.20

Y is the height increment, X is the age

Table 4.2.1(h) : Predicted Values for next 5 years of Chikkamangalore(S_3) x 50:100:50(F_2) for height.

combination	Name of the Model	MODEL	X(yrs)	Y(m)
S_3F_2	Gompertz Model	y=9.510*exp(-exp(1.001-0.684x))	12 13 14 15 16	9.50 9.51 9.51 9.51 9.51
	Richards Model	y=9.401/(1+exp(1.608-0.915x))^(1/0.824)	12 13 14 15 16	9.40 9.40 9.40 9.40 9.40
	MMF Model	y=(2.371*31.274+9.459*x^3.612)/(31.274 +x^3.612)	12 13 14 15 16	9.43 9.44 9.44 9.45 9.45
	Logistic Model	y=9.384/(1+7.260 *exp(-0.968x))	12 13 14 15 16	9.38 9.38 9.38 9.38 9.38

Y is the height increment, X is the age'

Table 4.2.1(i) : Predicted Values for next 5 years of Chikkamangalore(S_3) x 75:150:75(F_3) for height.

combination	Name of the Model	Model Eqations	X(yrs)	Y(m)
S_3F_3	Gompertz Model	y=9.888*exp(-exp(0.957-0.653x))	12 13 14 15 16	9.88 9.88 9.89 9.89 9.89
	Richards Model	y=9.784/(1+exp(1.246-0.836x))^(1/0.696)	12 13 14 15 16	9.78 9.78 9.78 9.78 9.78
	MMF Model	y=(2.487*29.420+9.847*x^3.469)/(29.420 +x^3.469)	12 13 14 15 16	9.81 9.82 9.82 9.83 9.83
	Logistic Model	y=9.749/(1+6.743 *exp(-0.921x))	12 13 14 15 16	9.75 9.75 9.75 9.75 9.75

Y is the height increment, X is the age

Table 4.2.1(j): Predicted Values for next 5 years of Thirthahalli (S_4) x 25:50:25(F_1) for height.

combination	Name of the Model	Model Eqations	X(yrs)	Y(m)
S_4F_1	Rational Function	y=(-2.791 +6.964x)/(1+0.792x-0.019x^2)	12 13 14 15 16	10.40 10.85 11.32 11.82 12.33
	Weibul Model	y=22.002 -32.158*exp(-0.495*x^0.277)	12 13 14 15 16	10.00 10.26 10.50 10.73 10.94
	MMF Model	y=(7.679*2.486+27.466*x^0.371)/(2.486+x^0.371)	12 13 14 15 16	9.99 10.25 10.49 10.72 10.93
	Logarithm Model	y=2.269 +3.076*ln(x)	12 13 14 15 16	9.91 10.16 10.39 10.60 10.80

Y is the height increment, X is the age

Table 4.2.1(k): Predicted Values for next 5 years of Thirthahalli (S_4) x 50:100:50(F_2) for height.

combination	Name of the Model	Model Eqations	X (yrs)	Y(m)
S_4F_2	Rational Function	y=(-2.574+6.145x)/(1+0.555x-0.001x^2)	12 13 14 15 16	9.47 9.61 9.73 9.85 9.95
	Weibul Model	y=9.688-12.179 *exp(-0.502*x^0.779)	12 13 14 15 16	9.31 9.39 9.45 9.49 9.53
	MMF Model	y=(1.486*7.889+9.472*x^2.087)/(7.889+x^2.087)	12 13 14 15 16	9.09 9.14 9.18 9.21 9.24
	Gompertz Model	y=8.983*exp(-exp(0.829-0.561x))	12 13 14 15 16	8.96 8.97 8.98 8.98 8.98

Y is the height increment, X is the age

Table 4.2.1(l) : Predicted Values for next 5 years of Thirthahalli(S_4) x 75:150:75(F_3) for height.

combination	Name of the Model	Model Eqations	X (yrs)	Y(m)
S_4F_3	Sinusoidal Model	y=-18.537+29.318*cos(0.050x+5.493)	12 13 14 15 16	10.25 10.49 10.66 10.76 10.78
	Weibul Model	y=34.109-38.422*exp(-0.193*x^0.359)	12 13 14 15 16	10.12 10.45 10.75 11.04 11.32
	MMF Model	y=(4.844*9.319+70.243*x^0.339)/(9.319+x ^0.339)	12 13 14 15 16	10.13 10.46 10.77 11.06 11.34
	Logarithm Model	y=2.065+3.112*ln(x)	12 13 14 15 16	9.80 10.05 10.28 10.49 10.69

Y is the height increment, X is the age

In case of ninth combination Chikkamangalore (S_3) x75:150:75(F_3), the best selected Models are MMF Model, Logistic Model, Gompertz Model, and Richards Model. In case of MMF Model, the increment seen in height between12th to 16th year ranges between 9.81m to 9.83m the results showed that tree was stagnant after 13 years it means after 13 years we can go for cutting of a tree, whereas in case of Logistic Model it ranges between 9.75m to 9.75m the results showed that tree was stagnant after 11years it means after 11years we can go for cutting of a tree, Gompertz Model it ranges between 9.88m to 9.89m the results showed that tree was stagnant after 12 years it means after 12 years we can go for cutting of a tree.

And Richards Model it ranges between 9.78m to 9.78m the results showed that tree was stagnant after 11 years it means after 11 years we can go for cutting of a tree. (Table 4.2.1i).

In case of tenth combination Thirthahalli (S_4) x 25:50:25(F_1), the best selected Models are Logarithm Model, Rational Function, Weibul Model and MMF Model. In case of Logarithm Model, the increment seen in height between12th to 16th year ranges between 9.91m to 10.80m, whereas in case of Rational Function it ranges between 10.40m to 12.33m, Weibul Model it ranges between 10.00m to 10.94m and MMF Model it ranges between 9.99m to 10.94m. (Table 4.2.1j).

In case of eleventh combination Thirthahalli (S_4) x 50:100:50(F_2), the best selected Models are MMF Model, Gompertz Model, Rational Function and Weibul Model. In case of MMF Model, the increment seen in height between12th to 16th year ranges between 9.09m to 9.24m, whereas in case of Gompertz Model it ranges between 8.96m to 8.98m, Rational Function it ranges between 9.47m to 9.95m and Weibul Model it ranges between 9.31m to 9.53m. (Table 4.2.1j).

In case of twelth combination Thirthahalli (S_4) x 75:150:75(F_3), the best selected Models are Logarithm Model, MMF Model, Weibul Model, and sinusoidal Model. In case of Logarithm Model, the increment seen in height between12th to 16th year ranges between 9.80m to 10.69m, whereas in case of MMF Model it ranges between 10.13m to 11.34m, Weibul Model it ranges between 10.12m to 11.32m and sinusoidal Model it ranges between 10.25m to 10.78m. (Table 4.2.1k).

4.2.2 Best suited Models with their predicted height values of *Acacia mangium* for next 5 years corresponding to incremental values (spacing and fertilizer level).

In case of first combination 4x1m (SP_1) xNo fertilizer (F_0), the best selected Models are Rational Function, Logarithm Model, Weibul Model and MMF Model. In case of Rational Function, the increment in height between12th to 16th year ranges between 7.64m to 8.55m, where as in case of Logarithm Model it ranges between 7.58m to 8.07m, Weibul Model ranges between 7.47m to 7.81m and MMF Model it ranges between 7.44m to 7.77m.(Table 4.2.2a).

In case of second combination 4x1m (SP_1) x 50:100:50(F_1), the best selected Models are Rational Function, MMF Model, Weibul Model and Richards Model. In case of Rational Function, the increment seen in height between12th to 16th year ranges between 7.99m to 9.96m, where as in case of MMF Model it ranges from 7.84m to 8.89m, Weibul Model it ranges 7.84m to 8.84m and Richards it ranges between 7.52m to 7.52m, the results showed that tree was stagnant after 9 years it means after 9 years we can go for Cutting of a tree, (Table 4.2.2b).

In case of third combination 4x2m (SP_2) x No fertilizer (F_0), the best selected Models are Rational Function, Logarithm Model, Weibul Model and MMF Model. In case of Rational Function, the increment seen in height between12th to 16th year ranges between 9.12m to 11.46m, where as in case of Logarithm Model it ranges between 8.65m to 9.34m, Weibul Model it ranges between 8.74m to 9.55m and MMF Model it ranges between 8.73m to 9.53m. (Table 4.2.2c).

In case of fourth combination 4x2m (SP_2) x 50:100:50(F_1), the best selected Models are Logarithm Model, Weibul Model, MMF Model and Gompertz Model.

Table 4.2.2(a) : Predicted Values for next 5 years of 4x1 m(SP_1) x No ferilizer(F_0) for height.

combination	Name of the Model	Model Eqations	X(yrs)	Y(m)
SP_1F_0	Rational function	y=(4919929.327+15045079.703x)/(1+2308948.462x-45656.128x^2)	9 10 11 12 13	7.64 7.86 8.08 8.31 8.55
	Weibul Model	y=9.569-44.816*exp(-2.182*x^0.153)	9 10 11 12 13	7.47 7.57 7.66 7.74 7.81
	MMF Model	y=(-5.106*0.539+9.693 *x^0.501)/(0.539 +x^0.501)	9 10 11 12 13	7.44 7.54 7.63 7.70 7.77
	Logarithm Model	y=4.611+1.350*ln(x)	9 10 11 12 13	7.58 7.72 7.85 7.97 8.07

Y is the height increment, X is the age

Table 4.2.2(b): Predicted Values for next 5 years of 4x1 m(SP_1) x x50:100:50 (F_1) for height.

combination	Name of the Model	MODEL	X(yrs)	Y(m)
SP_1F_1	Rational Function	y=(975187.722+7228255.648x)/(1+1280154.543x-43226.362x^2)	9 10 11 12 13	7.99 8.41 8.87 9.39 9.96
	Weibul Model	y=17.750-13.170*exp(-0.043*x^0.860)	9 10 11 12 13	7.84 8.11 8.36 8.60 8.84
	MMF Model	y=(4.497*180.619+118.985*x^0.770)/(180.619+x^0.77)	9 10 11 12 13	7.84 8.11 8.38 8.64 8.89
	Richards Model	y=7.520/(1+exp(49.771-6.832x))^(1/119.099)	9 10 11 12 13	7.52 7.52 7.52 7.52 7.52

Y is the height increment, X is the age

Table 4.2.2(c) : Predicted Values for next 5 years of 4x2m(SP_2) x No ferilizer (F_0) for height.

combination	Name of the Model	Model Eqations	X (yrs)	Y(m)
SP_2F_0	Rational Function	y=(16012204.327+47230914.500x)/(1+7154710.820x-241494.770x^2)	9	9.12
			10	9.63
			11	10.18
			12	10.78
			13	11.46
	Weibul Model	y=22.200-24.844*exp(-0.344*x^0.263)	9	8.74
			10	8.97
			11	9.18
			12	9.38
			13	9.55
	MMF Model	y=(2.242*3.487+28.360*x^0.304)/(3.487+x^0.304)	9	8.73
			10	8.96
			11	9.17
			12	9.36
			13	9.53
	Logarithm Model	y=4.497+1.888 *ln(x)	9	8.65
			10	8.84
			11	9.02
			12	9.19
			13	9.34

Y is the height increment, X is the age

Table 4.2.2(d) : Predicted Values for next 5 years of 4x2m(SP_2) x x50:100:50 (F_1) for height.

combination	Name of the Model	Model Eqations	X(yrs)	Y(m)
SP_2F_1	Gompertz	y=7.771*exp(-exp(0.197-0.431x))	9	7.58
			10	7.64
			11	7.69
			12	7.72
			13	7.74
	Weibul Model	y=11.004-35.985*exp(-1.699*x^0.160)	9	7.79
			10	7.92
			11	8.03
			12	8.13
			13	8.23
	MMF Model	y=(-7.926*0.576+11.536*x^0.400)/(0.576+x^0.400)	9	7.78
			10	7.91
			11	8.02
			12	8.12
			13	8.21
	Logarithm Model	y=4.501+1.543*ln(x)	9	7.89
			10	8.05
			11	8.20
			12	8.34
			13	8.46

Y is the height increment, X is the age

Table 4.2.2(e) : Predicted Values for next 5 years of 4x3m(SP_3) x No ferilizer (F_0) for height.

combination	Name of the Model	Model Eqations	X (yrs)	Y(m)
SP_3F_0	Rational Function	y=(0.045+6.971x)/(1+0.996x-0.019x^2)	9	7.45
			10	7.70
			11	7.95
			12	8.19
			13	8.44
	Weibul Model	y=12.707-20.725*exp(-0.818*x^0.229)	9	7.35
			10	7.52
			11	7.68
			12	7.82
			13	7.95
	MMF Model	y=(7.361*1.248+17.195*x^0.285)/(1.248+x^0.285)	9	7.37
			10	7.54
			11	7.70
			12	7.85
			13	7.98
	Logarithm Model	y=3.567+1.734*ln(x)	9	7.38
			10	7.56
			11	7.72
			12	7.88
			13	8.01

Y is the height increment, X is the age

Table 4.2.2(f) : Predicted Values for next 5 years of 4x3m(SP_3) x x50:100:50 (F_1) for height.

combination	Name of the Model	Model Eqations	X (yrs)	Y(m)
SP_3F_1	Rational Function	y=(-4.072+16.418x)/(1+2.176x-0.040x^2)	9	8.28
			10	8.53
			11	8.78
			12	9.04
			13	9.29
	Weibul Model	y=10.718-25.819*exp(-1.342*x^0.248)	9	8.17
			10	8.32
			11	8.45
			12	8.57
			13	8.67
	MMF Model	y=(10.565*0.589+12.518*x^0.424)/(0.589+x^0.424)	9	8.17
			10	8.33
			11	8.46
			12	8.59
			13	8.69
	Logarithm Model	y=4.079+1.930*ln(x)	9	8.32
			10	8.52
			11	8.71
			12	8.87
			13	9.03

Y is the height increment, X is the age

In case of Logarithm Model, the increment seen in height between12th to 16th year ranges between 7.89m to 8.46m, where as in case of Weibul Model it ranges between 7.79m to 8.23m, MMF Model it ranges between 7.78m to 8.21m and Gompertz Model it ranges between 7.58m to 7.74m.(Table 4.2.2d).

In case of fifth combination 4x3m(SP_3) xNo fertilizer(F_0), the best selected Models are Logarithm Model ,Rational function, Weibul Model and MMF Model. In case of Logarithm Model, the increment seen in height between12th to 16th year ranges between 7.38m to 8.01m, where as in case of Rational function it ranges between 7.45m to 8.44m, Weibul Model it ranges between 7.35m to 7.95m and MMF Model it ranges between 7.37m to 7.98m.(Table 4.2.2e).

In case of sixth combination 4x3m(SP_3) x50:100:50 (F_1), the best selected Models are Rational Function, Logarithm Model, Weibul Model and MMF Model. In case of Rational Function, the increment seen in height between12th to 16th year ranges between 8.28m to 9.29m, where as in case of Logarithm Model it ranges between 8.32m to 9.03m, Weibul Model it ranges between 8.17m to 8.67m and MMF Model it ranges between 8.17m to 8.69m.(Table 4.2.2e).

4.2.3 Best suited Models with their predicted dbh values of *Acacia mangium* for next 5 years corresponding to incremental values (Sources and fertilizer level).

In case of first combination Kerala (S_1) x25:50:25(F_1), the best selected Models are Rational Function, Weibul Model, MMF Model and polynomial Model. In case of Rational Function, the increment seen in height between12th to 16th year ranges between 16.02cm to 19.60cm, where as in case of Weibul Model it ranges between 15.49cm to 17.89cm, MMF Model it ranges between 15.54cm to 17.99cm and, polynomial Model it ranges between 16.04cm to 20.62cm.(Table 4.2.3a).

In case of second combination Kerala (S_1) x50:100:50(F_2), the best selected Models are Rational Function, MMF Model, Weibul Model and Logarithm Model. In case of Rational Function, the increment seen in height between12th to 16th year ranges between 15.43cm to 20.34cm, where as in case of MMF Model it ranges between 14.51cm to 16.19cm, Weibul Model it ranges between 14.54cm to 16.21cm and, Logarithm Model it ranges between 13.99cm to 15.19cm.(Table 4.2.3b).

In case of third combination Kerala (S_1) x75:150:75(F_3), the best selected Models are Rational function, Weibul Model and MMF Model and sinusoidal Model. In case of Rational function it ranges between 15.34cm to 20.32cm, where as in case of Weibul Model it ranges between 14.51cm to 16.44cm and, MMF Model it ranges between 14.48cm to 16.39cm.and in sinusoidal Model it ranges from 14.37cm to 14.88 cms.(Table 4.2.3c).

In case of fourth combination Bangalore (S_2) x25:50:25(F_1), the best selected Models are Rational function, Weibul Model, MMF Model and Logarithm Model. In case of Rational function, the increment seen in height between12th to 16th year ranges between 13.59cm to 15.76cm, where as in case of Weibul Model it ranges between 13.47cm to 14.90cm, MMF Model it ranges between 13.47cm to 14.89cm and, Logarithm Model it ranges between 13.12cm to 14.28cm.(Table 4.2.3d).

In case of fifth combination Bangalore (S_2) x50:100:50(F_2), the best selected Models are MMF Model, Gompertz Model, Weibul Model and Rational Function. In case of MMF Model, the increment seen in height between12th to 16th year ranges between 12.28cm to 12.72cm, where as in case of Gompertz Model it ranges between 12.10cm to 12.26cm Weibul Model it ranges between 12.22cm to 12.50cm and, Rational Function it ranges between 12.02cm to 12.09cm. (Table 4.2.3e).

In case of sixth combination Bangalore (S_2) x75:150:75(F_3), the best selected Models are Rational function, Weibul Model, MMF Model and Gompertz Model. In case of Rational function, the increment seen in height between12th to 16th year ranges between 13.12m to 14.69m, where as in case of Weibul Model it ranges between 12.81m to 13.94m MMF Model, it ranges between 12.80m to 13.92m and Gompertz Model it ranges between 12.43m to 12.79m.(Table 4.2.3f).

Table 4.2.3(a) : Predicted Values for next 5 years of 4x3m(SP_3) x x50:100:50 (F_1) for height.

combination	Name of the Model	Model Eqations	X(yrs)	Y(m)
S_1F_1	Polynomial Model	y=2.098+2.175x-0.166x^2+0.008x^3-0.0001x ^4	12	16.04
			13	17.04
			14	18.12
			15	19.31
			16	20.62
	Rational Function	y=(1.797+2.916x)/(1+0.156x-0.004x^2)	12	16.02
			13	16.88
			14	17.76
			15	18.66
			16	19.60
	Weibul Model	y=37.048-35.788*exp(-0.083*x^0.728)	12	15.49
			13	16.13
			14	16.74
			15	17.33
			16	17.89
	MMF Model	y=(1.223*20.725+64.040*x^0.729)/(20.725+x^0.729)	12	15.54
			13	16.20
			14	16.82
			15	17.42
			16	17.99

Y is the height increment, X is the age

Table 4.2.3(b) : Predicted Values for next 5 years of Kerala(S_1) x 50:100:50(F_2) for dbh.

combination	Name of the Model	MODEL	X(yrs)	Y(cm)
S_1F_2	Rational Function	y=(-8.560+20.272x)/(1+2.012x-0.069x^2)	12	15.43
			13	16.46
			14	17.59
			15	18.88
			16	20.34
	Weibul Model	y=43.473-46.689*exp(-0.174*x^0.407)	12	14.54
			13	14.99
			14	15.42
			15	15.82
			16	16.21
	MMF Model	y=(3.642*10.286+84.996*x^0.392)/(10.286+x^0.392)	12	14.51
			13	14.97
			14	15.40
			15	15.80
			16	16.19
	Logarithm Model	y=3.644+4.163*ln(x)	12	13.99
			13	14.32
			14	14.63
			15	14.92
			16	15.19

Y is the height increment, X is the age

Table 4.2.3(c): Predicted Values for next 5 years of Kerala (S_1) x 75:150:75(F_3) for dbh.

combination	Name of the Model	Model Eqations	X(yrs)	Y(m)
S_1F_3	Sinusoidal Model	y=-12.831+27.742*cos(0.062x+5.342)	12	14.37
			13	14.66
			14	14.84
			15	14.88
			16	14.91
	Rational Function:	y=(-1.551+9.291x)/(1+0.886x-0.031x^2)	12	15.34
			13	16.38
			14	17.54
			15	18.84
			16	20.32
	Weibul Model:	y=44.247-44.153*exp(-0.102*x^0.545)	12	14.51
			13	15.03
			14	15.52
			15	15.99
			16	16.44
	MMF Model:	y=(0.176*14.855+66.540*x^0.566)/(14.855+x^0.566)	12	14.48
			13	14.99
			14	15.48
			15	15.95
			16	16.39

Y is the height increment, X is the age

Table 4.2.3(d) : Predicted Values for next 5 years of Bangalore(S_2) x 25:50:25(F_1) for dbh.

combination	Name of the Model	MODEL	X(yrs)	Y(cm)
S_2F_1	Rational Function	y=(-0.694+5.741x)/(1+0.443x-0.009x^2)	12	13.59
			13	14.12
			14	14.65
			15	15.20
			16	15.76
	Weibul Model	y=30.342-35.344*exp(-0.277*x^0.395)	12	13.47
			13	13.86
			14	14.23
			15	14.58
			16	14.90
	MMF Model	y=(3.853*4.792+39.095*x^0.473)/(4.792+x^0.473)	12	13.47
			13	13.86
			14	14.23
			15	14.57
			16	14.89
	Logarithm Model	y=3.138+4.018*ln(x)	12	13.12
			13	13.44
			14	13.74
			15	14.02
			16	14.28

Y is the height increment, X is the age

Table 4.2.3(e) : Predicted Values for next 5 years of Bangalore(S_2) x 50:100:50(F_2) for dbh.

combination	Name of the Model	Model Eqations	X(yrs)	Y(m)
S_2F_2	Rational Function	y=(1.846+3.119x)/(1+0.141x+0.004x^2)	12	12.02
			13	12.08
			14	12.11
			15	12.11
			16	12.09
	Weibul Model	y=12.635-10.441*exp(-0.232*x^1.060)	12	12.22
			13	12.33
			14	12.40
			15	12.46
			16	12.50
	MMF Model	y=(3.180*7.612+13.581*x^1.599)/(7.612+x^1.599)	12	12.28
			13	12.42
			14	12.53
			15	12.63
			16	12.72
	Gompertz Relation	y=12.307*exp(-exp(0.385-0.371x))	12	12.10
			13	12.16
			14	12.21
			15	12.24
			16	12.26

Y is the height increment, X is the age

Table 4.2.3(f) : Predicted Values for next 5 years of Bangalore(S_2) x 75:150:75(F_3) for dbh.

combination	Name of the Model	Model Eqations	X(yrs)	Y(m)
S_2F_3	Rational Function	y=(1.616+4.107x)/(1+0.288x-0.004x^2)	12 13 14 15 16	13.12 13.52 13.92 14.30 14.69
	Weibul Model	y=19.758-20.532*exp(-0.294*x^0.525)	12 13 14 15 16	12.81 13.13 13.42 13.69 13.94
	MMF Model	y=(0.155*4.609+24.306*x^0.653)/(4.609+x^0.653)	12 13 14 15 16	12.80 13.12 13.41 13.67 13.92
	Gompertz Relation	y=12.964*exp(-exp(0.291-0.288x))	12 13 14 15 16	12.43 12.56 12.66 12.74 12.79

Y is the height increment, X is the age

Table 4.2.3(g) : Predicted Values for next 5 years of Chikkamangalore(S_3) x 25:50:25(F_1) for dbh.

combination	Name of the Model	Model Eqations	X(yrs)	Y(m)
S_3F_1	Rational Function	y=(-0.286+5.592x)/(1+0.369x-0.002x^2)	12 13 14 15 16	13.00 13.26 13.51 13.74 13.95
	Weibul Model	y=14.431-16.303*exp(-0.437*x^0.667)	12 13 14 15 16	12.78 12.98 13.15 13.29 13.42
	MMF Model	y=(1.138*4.039+15.197*x^1.186)/(4.039+x^1.186)	12 13 14 15 16	12.74 12.92 13.09 13.23 13.36
	Logarithm Model	y=3.861+3.691*ln(x)	12 13 14 15 16	13.03 13.33 13.60 13.86 14.09

Y is the height increment, X is the age

Table 4.2.3(h) : Predicted Values for next 5 years of Chikkamangalore(S_3) x 50:100:50(F_2) for dbh.

combination	Name of the Model	Model Eqations	X(yrs)	Y(m)
S_3F_2	Logistic Model	y=13.99/(1+4.16*exp(-0.53x))	12 13 14 15 16	13.89 13.93 13.96 13.97 13.98
	Weibul Model	y=14.218-11.881*exp(-0.154*x^1.388)	12 13 14 15 16	14.12 14.17 14.19 14.20 14.21
	MMF Model	y=(3.459*16.250+14.792*x^2.293)/(16.250+x^2.293)	12 13 14 15 16	14.21 14.30 14.37 14.43 14.48
	Gompertz Relation	y=14.312*exp(-exp(0.672-0.433x))	12 13 14 15 16	14.16 14.21 14.25 14.27 14.28

Y is the height increment, X is the age

Table 4.2.3(i): Predicted Values for next 5 years of Chikkamangalore(S_3) x 75:150:75(F_3) for dbh.

combination	Name of the Model	Model Eqations	X(yrs)	Y(m)
S_3F_3	Rational Function	y=(-0.892+6.729x)/(1+0.411x-0.007x^2)	12 13 14 15 16	16.22 16.78 17.34 17.90 18.46
	Weibul Model	y=22.955-27.247*exp(-0.373*x^0.515)	12 13 14 15 16	15.83 16.22 16.58 16.90 17.20
	MMF Model	y=(0.480*4.595+21.451*x^1.002)/(4.595+x^1.002)	12 13 14 15 16	15.67 16.00 16.29 16.55 16.79
	Richards Model	y=15.349/(1+exp(-1.508-0.377x))^(1/0.117)	12 13 14 15 16	15.04 15.13 15.20 15.25 15.28

Y is the height increment, X is the age

Table 4.2.3(j): Predicted Values for next 5 years of Thirthahalli (S_4) x 25:50:25(F_1) for dbh.

combination	Name of the Model	Model Eqations	X(yrs)	Y(m)
S_4F_1	Gompertz Relation	y=13.09*exp(-exp(0.372-0.245x))	12 13 14 15 16	12.12 12.33 12.49 12.62 12.72
	Rational Function	y=(3.440+0.635x)/(1-0.072x+0.006x^2)	12 13 14 15 16	11.25 11.40 11.47 11.50 11.51
	Sinusoidal Model	y=5.908+5.740*cos(0.187x+4.244)	12 13 14 15 16	11.73 11.76 11.78 11.78 11.79
	Richards Model	y=12.194/(1+exp(1.998-0.430x))^(1/1.718)	12 13 14 15 16	11.90 12.00 12.07 12.11 12.14

Y is the height increment, X is the age

Table 4.2.3(k) : Predicted Values for next 5 years of Thirthahalli(S_4) x 50:100:50(F_2) for dbh.

combination	Name of the Model	Model Eqations	X(yrs)	Y(m)
S_4F_2	Richards Model	y=14.980/(1+exp(2.662-0.592x))^(1/1.682)	12 13 14 15 16	14.88 14.92 14.95 14.96 14.97
	Weibul Model	y=14.841-10.999*exp(-0.039*x^2.017)	12 13 14 15 16	14.81 14.83 14.837 14.840 14.841
	MMF Model	y=(4.388*108.136+15.401*x^3.149)/(108.136+x^3.149)	12 13 14 15 16	14.94 15.04 15.12 15.17 15.21
	Logistic Model	y=15.283/(1+4.590*exp(-0.478x))	12 13 14 15 16	15.06 15.14 15.20 15.23 15.25

Y is the height increment, X is the age

Table 4.2.3(l) : Predicted Values for next 5 years of Thirthahalli(S_4) x 75:150:75(F_3) for dbh.

combination	Name of the Model	Model Eqations	X(yrs)	Y(m)
S_4F_3	Polynomial Model	y=3.032+1.129x+0.102x^2-0.023x^3+0.001x^4	12	12.26
			13	12.98
			14	14.13
			15	15.92
			16	18.54
	Weibul Model	y=50.765-47.834*exp(-0.029*x^0.947)	12	15.51
			13	16.34
			14	17.16
			15	17.95
			16	18.72
	MMF Model	y=(2.754*119.81+188.822*x^0.881)/(119.810+x^0.881)	12	15.66
			13	16.53
			14	17.39
			15	18.23
			16	19.05
	Gompertz Relation	y=21.584*exp(-exp(0.585-0.141x))	12	15.51
			13	16.20
			14	16.82
			15	17.38
			16	17.88

Y is the height increment, X is the age

In case of seventh combination Chikkamangalore (S_3) x 25:50:25(F_1), the best selected Models are Rational function, MMF Model, Weibul Model and Logarithm Model. In case of Rational function, the increment seen in height between12th to 16th year ranges between 13.00m to 13.95m, where as in case of MMF Model it ranges between 12.74m to 13.36m Weibul Model it ranges between 12.78m to 13.42m and Logarithm Model it ranges between 13.03m to 14.09m.(Table 4.2.3g).

In case of eighth combination Chikkamangalore (S_3) x 50:100:50 (F_2), the best selected Models are MMF Model, Gompertz Model, Weibul Model and Logistic Model. In case of MMF Model, the increment seen in height between12th to 16th year ranges between 13.00m to 13.95m, where as in case of Gompertz Model it ranges between 12.74m to 13.36m, Weibul Model it ranges between 12.78m to 13.42m and Logistic Model it ranges between 13.89m to 13.98m.(Table 4.2.3h).

In case of ninth combination Chikkamangalore (S_3) x75:150:75(F_3), the best selected Models are Rational function, MMF Model, Weibul Model, and Richards Model. In case of Rational function, the increment seen in height between12th to 16th year ranges between 16.22m to 18.46m, where as in case of MMF Model it ranges between 15.67m to 16.79m, Weibul Model it ranges between 15.83m to 17.20m and richards Model it ranges between 15.04m to 15.28m.(Table 4.2.3i).

In case of tenth combination Thirthahalli (S_4) x 25:50:25(F_1), the best selected Models are Rational Function, Sinusoidal Model and Richards Modeland Gompertz Model. In case of, Rational Function it ranges between 11.25m to 11.51m, where as in case of Sinusoidal Model it ranges between 11.73m to 11.79m, Richards Model it ranges between 11.90m to 12.14m. And in Gompertz Model it ranges between 12.12m to 12.72m (Table 4.2.3j).

In case of eleventh combination Thirthahalli (S_4) x50:100:50(F_2), the best selected Models are MMF Model, Logistic Model, Weibul Model and Richards Model. In case of MMF Model, the increment seen in height between12th to 16th year ranges between 14.94m to 15.21m, where as in case of Logistic Model it ranges between 15.06m to 15.25m, Weibul Model it ranges between 14.81m to 14.841m and Richards Model it ranges between 14.88m to 14.97m.(Table 4.2.3k).

In case of twelth Thirthahalli (S_4) x 75:150:75(F_3), the best selected Models are polynomial Model, MMF Model, Weibul Model, and Gompertz Model. In case of polynomial Model, the increment seen in height between12th to 16th year ranges between 12.26m to 18.54m, where as in case of MMF Model it ranges between 15.66m to 19.05m, Weibul Model it ranges between 15.51m to 18.72m and Gompertz Model it ranges between 15.51m to 17.88m. (Table 4.2.3l).

4.2.4 Best suited Models with their predicted dbh values of *Acacia mangium* for next 5 years corresponding to incremental values (spacing and fertilizer level).

In case of first combination 4x1m (SP_1) x No fertilizer (F_0), the best selected Models are MMF Model, Weibul Model, Gompertz and Logistic Model. In case of MMF Model the increment seen in height between 9th to 13th year's ranges between 11.46m to 13.92m, where as in case of Weibul Model it ranges between 11.43m to 13.77m, Gompertz Model, it ranges between 11.36cm to 13.05cm, and in case of Logistic Model it ranges between 11.29cm to 12.73cm, (Table 4.2.4a).

In case of second combination 4x1m (SP_1) x50:100:50(F_1), the best selected Models are Weibul Model, Richards Model, and MMF Model. In case of Weibul Model, the increment seen in height between 9th to 13th year ranges between 10.27m to 10.27m the results showed that tree was stagnant after 9 years it means after 9 years we can go for cutting of a tree, where as in case of Richards Model it ranges between 10.11m to 10.11m the results showed that tree was stagnant after 7 years it means after 7 years we can go for cutting of a tree and MMF Model it ranges between 10.54m to 10.82m.and in Logistic Model it ranges from 11.15cm to 13.13 cms.(Table 4.2.4b).

Table 4.2.4(a) : Predicted Values for next 5 years of 4x1 m(SP_1) x No ferilizer(F_0) for dbh.

combination	Name of the Model	Model Eqations	X (yrs)	Y(m)
SP_1F_0	Logistic Model	y=13.26/(1+2.29*exp(-0.286x))	9 10 11 12 13	11.29 11.72 12.07 12.35 12.56
	Gompertz Relation	y=14.907*exp(-exp(0.299-0.178x))	9 10 11 12 13	11.36 11.87 12.32 12.71 13.05
	Weibul Model	y=33.438-30.299*exp(-0.053*x^0.818)	9 10 11 12 13	11.43 12.06 12.65 13.22 13.77
	MMF Model	y=(2.956*70.525+127.392*x^0.748)/(70.525 +x^0.748)	9 10 11 12 13	11.46 12.11 12.73 13.33 13.92

Y is the height increment, X is the age

Table 4.2.4(b) : Predicted Values for next 5 years of 4x1 m(SP_1) x x50:100:50 (F_1) for dbh.

combination	Name of the Model	Model Eqations	X(yrs)	Y(m)
SP_1F_1	Weibul Model	y=10.272-4.660*exp(-0.003*x^3.597)	9 10 11 12 13	10.27 10.27 10.27 10.27 10.27
	MMF Model	y=(5.628*848.945+10.897*x^4.256)/(848.945+x^4.256)	9 10 11 12 13	10.54 10.66 10.74 10.79 10.82
	Richards Model	y=10.110/(1+exp(94.654-14.262x))^(1/119.718)	9 10 11 12 13	10.11 10.11 10.11 10.11 10.11
	Logistic Model	y=15.16/(1+2.399*exp(-0.211x))	9 10 11 12 13	11.15 11.74 12.27 12.73 13.13

Y is the height increment, X is the age

Table 4.2.4(c) : Predicted Values for next 5 years of 4x2m(SP_2) x No ferilizer (F_0) for dbh.

combination	Name of the Model	Model Eqations	X(yrs)	Y(m)
SP_2F_0	Logistic Model	y=14.89/(1+2.288*exp(-0.314x))	9 10 11 12 13	13.11 13.55 13.89 14.14 14.34
	Weibul Model	y=38.221-35.140*exp(-0.067*x^0.749)	9 10 11 12 13	13.39 14.09 14.75 15.38 15.98
	MMF Model	y=(3.033*26.953+67.528*x^0.744)/(26.953 +x^0.744)	9 10 11 12 13	13.34 14.04 14.70 15.33 15.94
	Gompertz Relation	y=16.416*exp(-exp(0.290-0.203x))	9 10 11 12 13	13.24 13.77 14.22 14.60 14.92

Y is the height increment, X is the age

Table 4.2.4(d) : Predicted Values for next 5 years of 4x2m(SP_2) x x50:100:50 (F_1) for dbh.

combination	Name of the Model	Model Eqations	X(yrs)	Y(m)
SP_2F_1	Rational Function	y=(0.259+5.571x)/(1+0.397x-0.007x^2)	9 10 11 12 13	12.58 13.11 13.62 14.11 14.60
	Weibul Model	y=22.121-25.774*exp(-0.363*x^0.456)	9 10 11 12 13	12.53 12.99 13.40 13.77 14.11
	MMF Model	y=(2.764*3.612+29.332*x^0.542)/(3.612+x^0.542)	9 10 11 12 13	12.54 12.99 13.41 13.79 14.13
	Logarithm Model	y=3.971+3.795*ln(x)	9 10 11 12 13	12.31 12.71 13.07 13.40 13.70

Y is the height increment, X is the age

Table 4.2.4(e) : Predicted Values for next 5 years of 4x3m(SP_3) x No ferilizer (F_0) for dbh.

combination	Name of the Model	Model Eqations	X(yrs)	Y(m)
SP_3F_0	Richards Model	y=11.802/(1+exp(1.537-0.585x))^(1/1.196)	9 10 11 12 13	11.57 11.67 11.73 11.76 11.78
	Weibul Model	y=11.689-8.378*exp(-0.096*x^1.703)	9 10 11 12 13	11.54 11.62 11.66 11.68 11.69
	MMF Model	y=(3.714*20.985+12.523*x^2.395)/(20.985+x^2.395)	9 10 11 12 13	11.66 11.84 11.97 12.07 12.14
	Logistic Model	y=11.875/(1+3.373*exp(-0.552x))	9 10 11 12 13	11.60 11.72 11.78 11.82 11.84

Y is the height increment, X is the age

Table 4.2.4(f) : Predicted Values for next 5 years of 4x3m(SP_3) x x50:100:50 (F_1) for dbh.

combination	Name of the Model	MODEL	X(yrs)	Y(cm)
SP_3F_1	Logistic Model	y=12.97/(1+4.25*exp(-0.657x))	9 10 11 12 13	12.82 12.89 12.93 12.95 12.96
	Weibul Model	y=12.746-9.450*exp(-0.092*x^1.858)	9 10 11 12 13	12.71 12.73 12.74 12.74 12.75
	MMF Model	y=(3.758*22.797+13.495*x^2.675)/(22.797+x^2.675)	9 10 11 12 13	12.91 13.05 13.14 13.22 13.27
	Richards Model	y=12.827/(1+exp(2.281-0.759x))^(1/1.512)	9 10 11 12 13	12.74 12.79 12.80 12.82 12.83

Y is the height increment, X is the age

In case of third combination 4x2m (SP_2) x No fertilizer (F_0), the best selected Models are, MMF Model, Weibul Model, Gompertz Model and Logistic Model. In case of, MMF Model the increment seen in height between 9th to 13th year ranges between 13.34m to 15.94m , where as in case of Weibul Model it ranges between 13.39m to 15.98m , Gompertz Model it ranges between 13.24m to 14.92m.and in Logistic Model it ranges from13.11 cm to 14.34 cm.(Table 4.2.4c).

In case of fourth combination 4x2m (SP_2) x 50:100:50(F_1), the best selected Models are Rational function, Weibul Model, MMF Model and Logarithm Model. In case of Rational Function, the increment seen in height between 9th to 13th year ranges between 12.58m to 14.60m, where as in case of Weibul Model it ranges between 12.53m to 14.11m, MMF Model it ranges between 15.43m to 16.75m and Logarithm Model it ranges between 12.31m to 13.70m.(Table 4.2.4d).

In case of fifth combination 4x3m (SP_3) xNo fertilizer (F_0), the best selected Models are MMF Model, Logistic Model, Weibul Model and Richards Model. In case of MMF Model, the increment seen in height between 9th to 13th year ranges between 11.66m to 12.14m, where as in case of Logistic Model it ranges between 11.60m to 11.84m, Weibul Model it ranges between 11.54m to 11.685m and Richards Model it ranges between 11.57m to 11.78m.(Table 4.2.4e).

In case of sixth combination 4x3m (SP_3) x50:100:50 (F_1), the best selected Models are Weibul Model, MMF Model, Richards Model and Logistic Model. In case of Weibul Model, the increment seen in height between 9th to 13th year ranges between 12.71m to 12.746m, where as in case of MMF Model it ranges between 12.91m to 13.27m, Richards Model it ranges between 12.74m to 12.823m and Logistic Model it ranges between 12.82cm to 12.96cm. (Table 4.2.4f).

4.3 Growth curves

4.3.1 Height growth curves (Sources and fertilizer level)

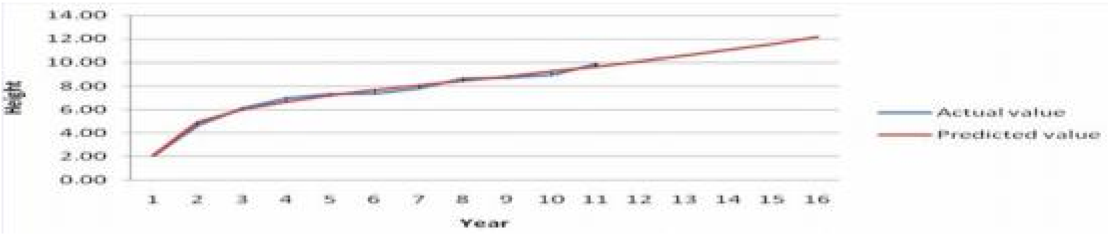
The pattern followed by the height growth of *Acacia mangium* in different combination over the years is of vital most important in developing prediction Models; as a result the pattern followed by the growth also gains much importance. So an attempt is made to Model the height growth curves, Based on the R^2, SE and RMSE the best Fitted Model is selected and the curve pattern is studied.

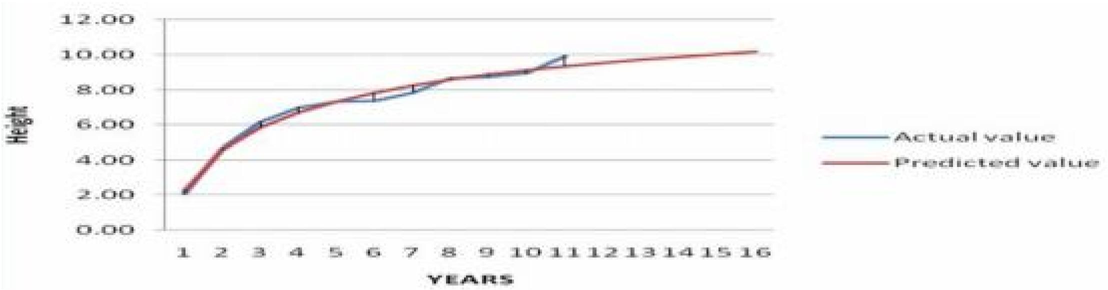
In case of first source and their combinations, Kerala (S_1) x25:50:25(F_1), the best selected Models are Rational Function, Weibul Model, MMF Model and Logarithm Model. The curve is increasing as shown in fig 4.3.1a. In case of Kerala (S_1) x50:100:50(F_2), the best selected Models are Rational Function, Weibul Model, MMF Model and Logarithm Model. The curve is increasing as shown in fig 4.3.1b.and in case of Kerala (S_1) x75:150:75(F_3), the best selected Models are Rational Function, Weibul Model, Logarithm Model and Richards Model. The curve is increasing as shown in fig 4.3.1c.

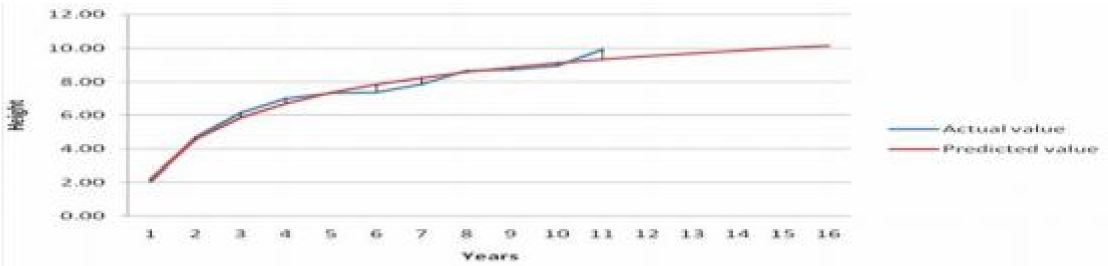
In case of second source and their combinations, Bangalore (S_2) x25:50:25(F_1), the best selected Models are Logarithm Model, Rational Function, MMF Model and Weibul Model. The curve is increasing as shown in fig 4.3.1d. In case of Bangalore (S_2) x50:100:50(F_2), the best selected Models are Logarithm Model, Weibul Model, MMF Model and Rational Function. The curve is increasing as shown in fig 4.3.1e. and in case of Bangalore(S_2) x75:150:75(F_3), the best selected Models are Logarithm Model, Rational Function, Weibul Model, and MMF Model. The curve is increasing as shown in fig 4.3.1f.

In case of third source and their Combinations, Chikkamangalore (S_3) x 25:50:25(F_1), the best selected Models are MMF Model, Logistic Model, Richards Model and Weibul Model. The curve is increasing as shown in fig 4.3.1g. In case of Chikkamangalore (S_3) x 50:100:50 (F_2),the best selected Models are MMF Model, Logistic Model, Gompertz Model and Richards Model. The curve is incrasing as shown in fig 4.3.1h.and in case of Chikkamangalore (S_3) x75:150:75(F_3), the best selected Models are MMF Model, Logistic Model, Gompertz Model, and Richards Model. The curve is incrasing as shown in fig 4.3.1i.

Fig 4.3.1a. Graph showing the actual values and predicted values of Kerala(S1) x 25:50:25 (F1) for height growth of *Acacia mangium*.







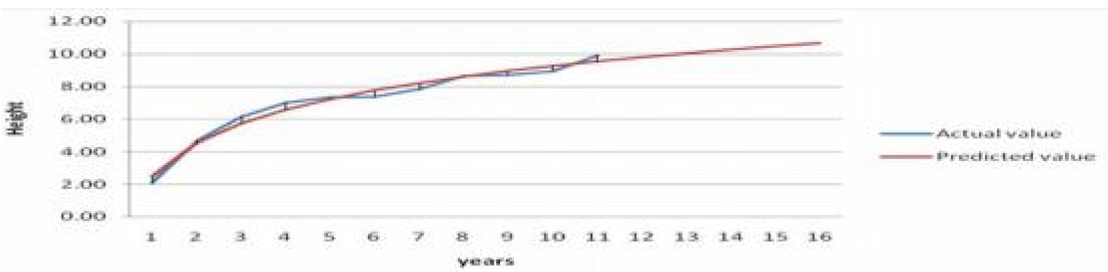
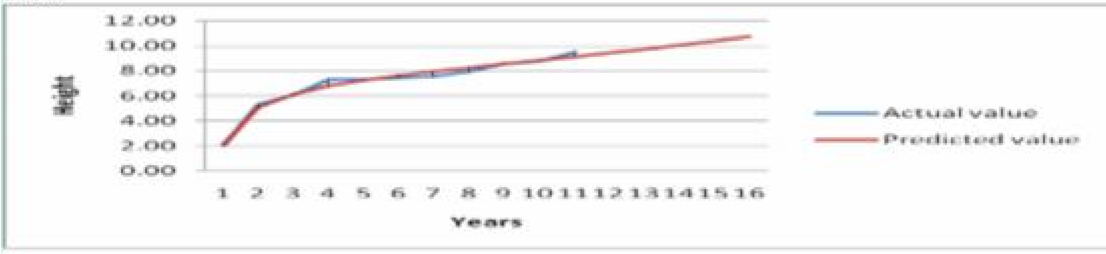


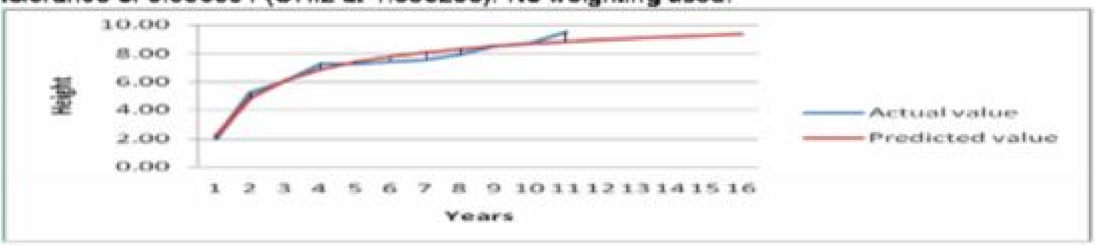
Fig 4.31b: Graph showing the actual values and predicted values of Kerala(S1)x50:100:50 (F2) for height growth of *Acacia mangium*.

I. RationalFunction: y=(60818031.41+83856448.89x)/(1+11024498.96x+223011.0063x^2)
Comment: The Model converged to a tolerance of 0.000001in 20 iterations. No weighting used.



II Weibul Model: y=10.901-179.632*exp(-3.029*x^0.162)
Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 1.396533).No weighting used.

III MMF Model: y=(26.425*0.321+11.371*x^0.624)/(0.321+x^0.624)
Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 1.385285). No weighting used.



IV Logarithm Model: y=2.797+2.681*ln(x)
Comment: The Model converged to a tolerance of 0.000001in 3 iterations. No weighting used.

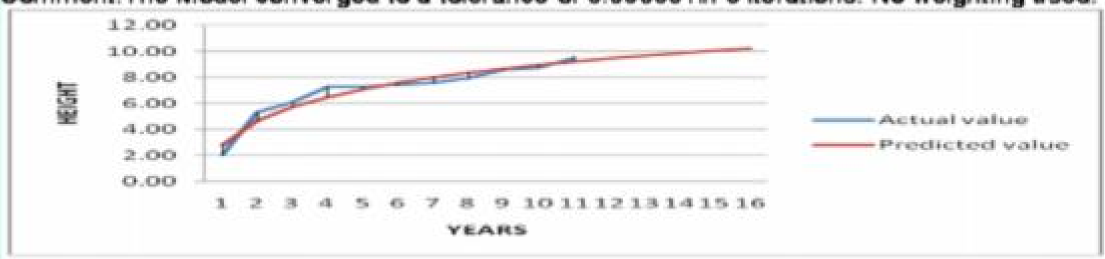


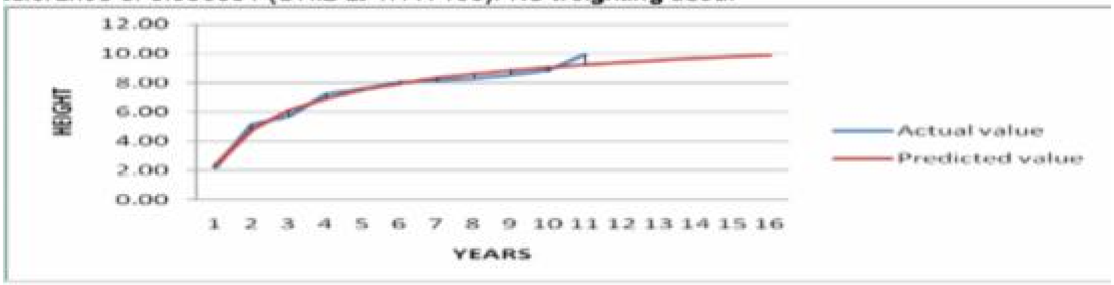
Fig 4.3.1c: Graph showing the actual values and predicted values of Kerala(S1) x 75:150:75 (F3) for height growth of *Acacia mangium*.

I. Rational Function: y=(-59.410+85.149x)/(1+10.892x-0.234x^2)

Comment: The Model converged to a tolerance of 0.000001 in 9 iterations. No weighting used.

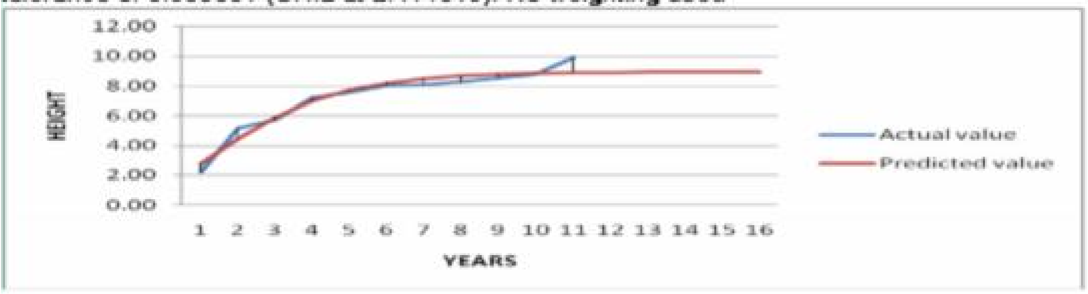
II Weibul Model: y=12.361-77.427*exp(-2.044*x^0.189)

Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 1.117139). No weighting used.



III Richards Model: y=8.961/(1+exp(-2.322-0.524x))^(1/0.048)

Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 2.411010). No weighting used



IV Logarithm Model: y=2.744+2.829*ln(x)

Comment: The Model converged to a tolerance of 0.000001 in 3 iterations. No weighting used.

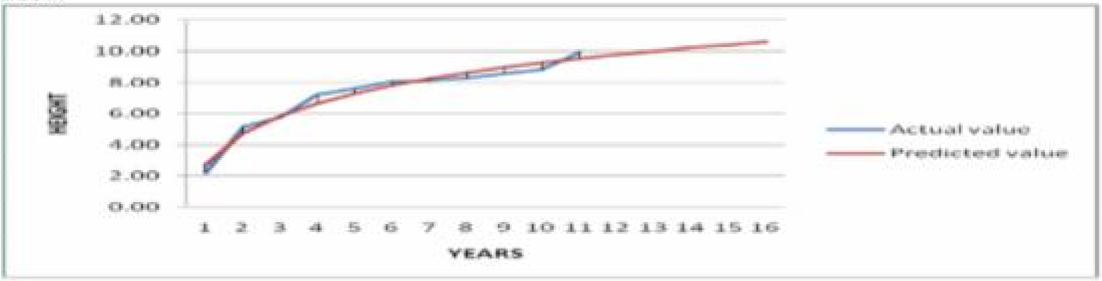
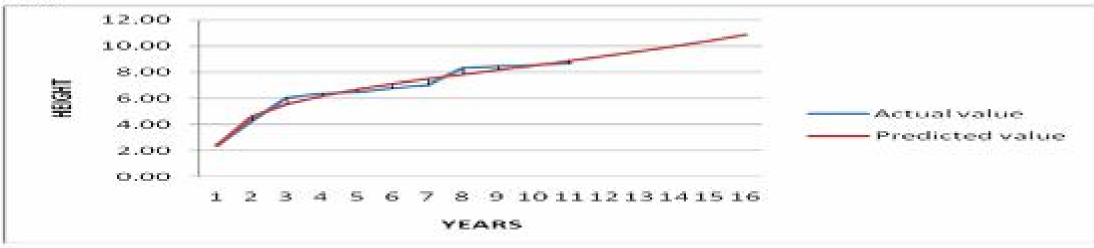


Fig 4.3.1d: Graph showing the actual values and predicted values of Bangalore (S2) x 25:50:25 (F1) for height growth of *Acacia mangium*.

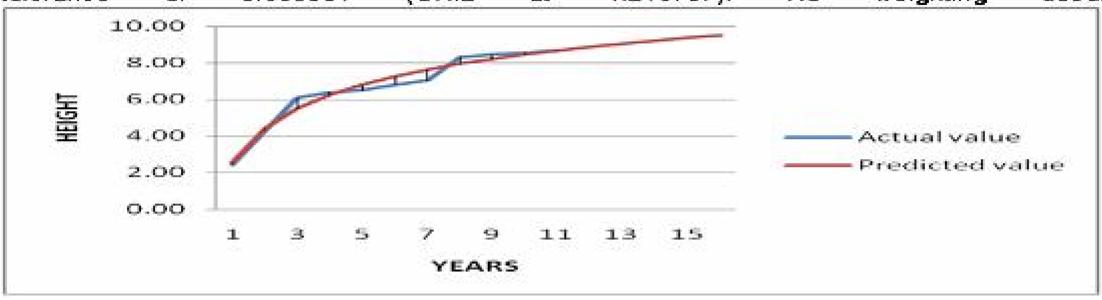
I. Rational Function: y=(-12.715+22.488x)/(1+3.149x-0.076x^2)

Comment: The Model converged to a tolerance of 0.000001 in 8 iterations. No weighting used.



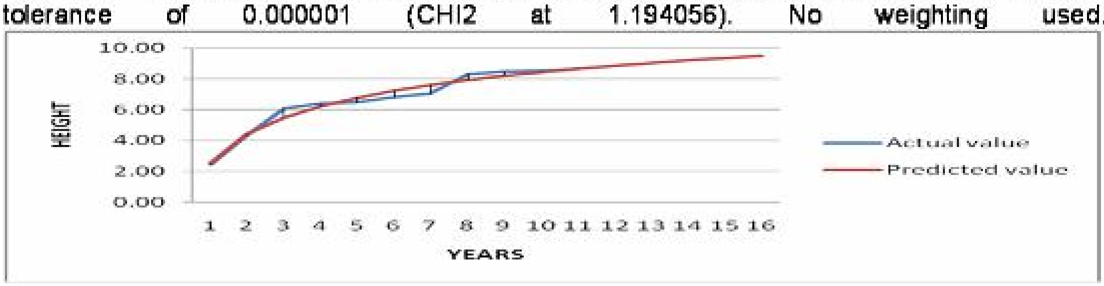
II Weibul Model: y=15.050-37.721*exp(-1.103*x^0.199)

Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 1.210737). No weighting used.



III MMF Model: y=(-49.542*0.424+24.593*x^0.183)/(0.424+x^0.183)

Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 1.194056). No weighting used.



IV Logarithm Model: y=2.621+2.555*ln(x)

Comment: The Model converged to a tolerance of 0.000001 in 3 iterations. No weighting used.

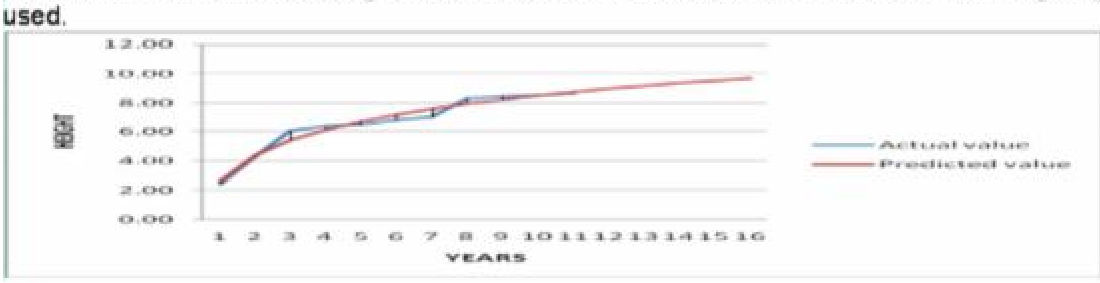
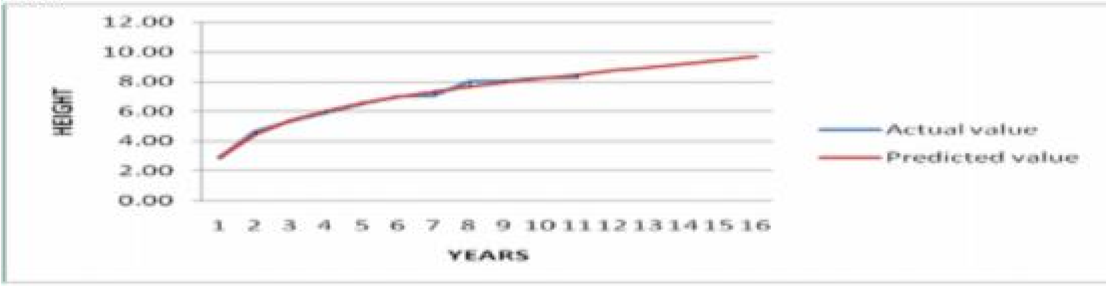


Fig 4.3.1e: Graph showing the actual values and predicted values of Bangalore (S2) x50:100:50 (F2) for height growth of *Acacia mangium*.

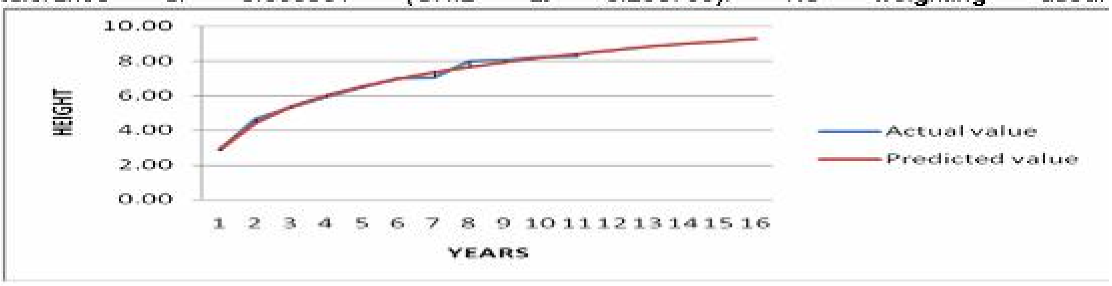
I. Rational Function: y=(-0.197+4.686x)/(1+0.548x-0.008x^2)

Comment: The Model converged to a tolerance of 0.000001 in 8 iterations. No weighting used.



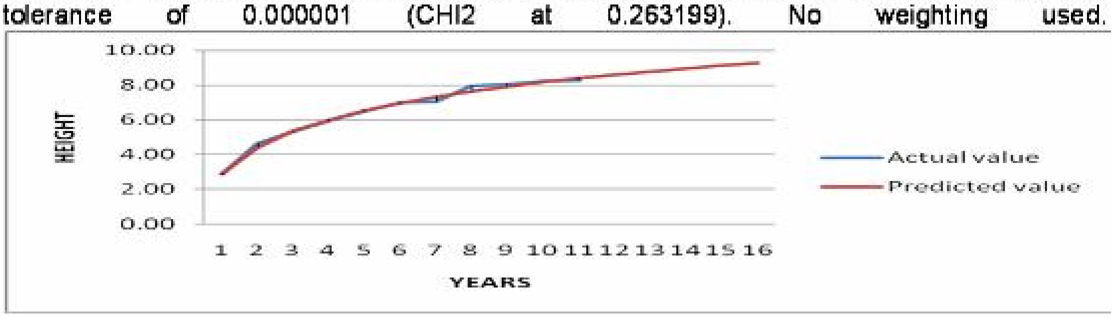
II Weibul Model: y=16.661-24.877*exp(-0.594*x^0.259)

Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 0.263700). No weighting used.



III MMF Model: y=(-7.852*1.964+24.086*x^0.297)/(1.964+x^0.297)

Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 0.263199). No weighting used.



IV Logarithm Model: y=2.866+2.305*ln(x)

Comment: The Model converged to a tolerance of 0.000001 in 2 iterations. No weighting used.

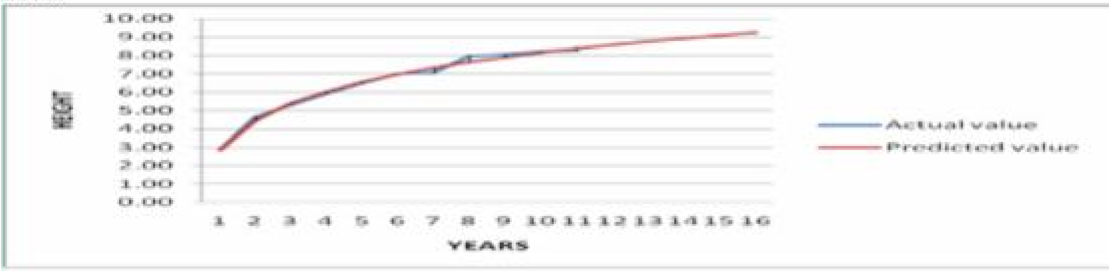
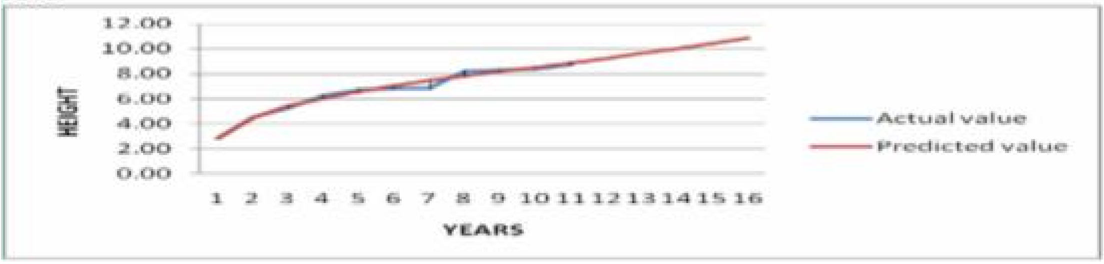
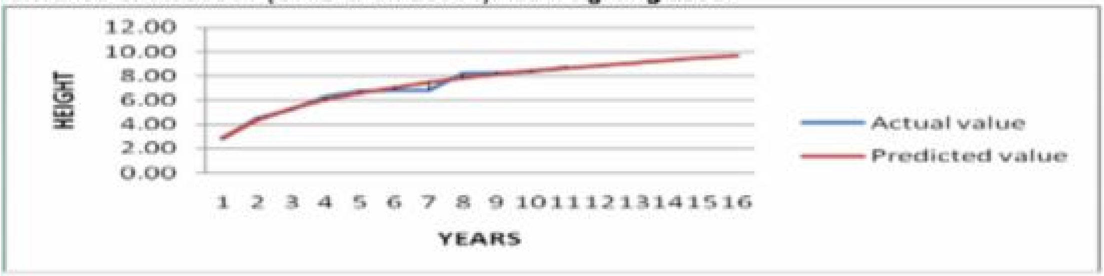


Fig 4.3.1f: Graph showing the actual values and predicted values of Bangalore (S2) x75:150:75 (F3) for height growth of *Acacia mangium*.

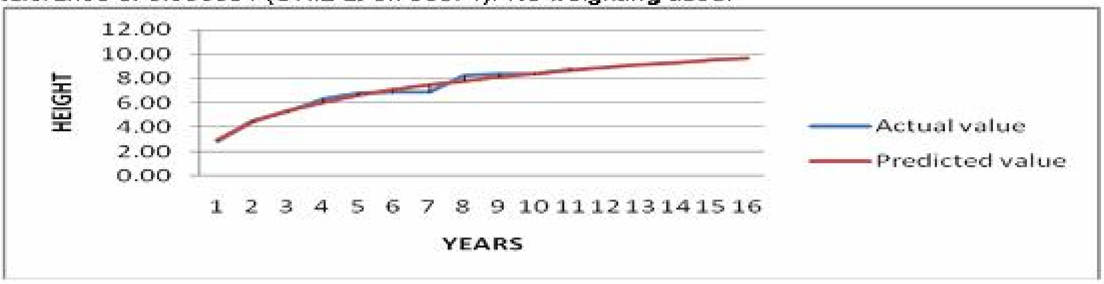
I. Rational Function: y=(-1.628+7.057x)/(1+0.931x-0.022x^2)
Comment: The Model converged to a tolerance of 0.000001 in 7 iterations. No weighting used.



II Weibul Model: y=20.544-26.585*exp(-0.410*x^0.282)
Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 0.750501). No weighting used.



III MMF Model: y=(5.356*3.144+28.890*x^0.325)/(3.144+x^0.325)
Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 0.750371). No weighting used.



IV Logarithm Model: y=2.765+2.429*ln(x)
Comment: The Model converged to a tolerance of 0.000001 in 2 iterations. No weighting used.

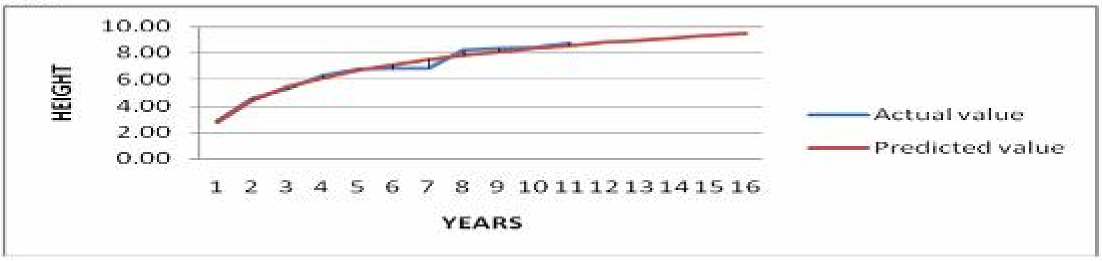
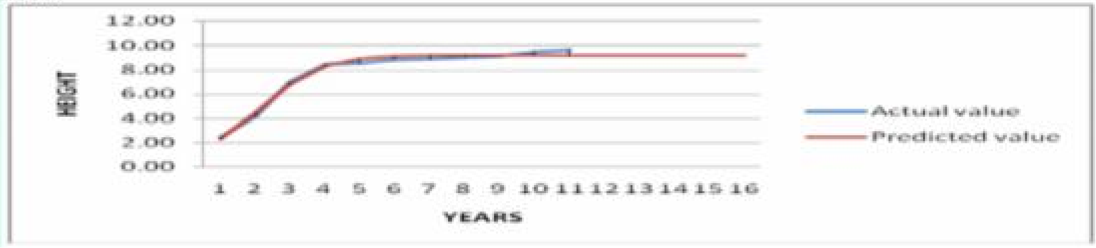


Fig 4.3.1g: Graph showing the actual values and predicted values of Chikkamangalore (S3) x25:50:25(F1) for height growth of Acacia mangium.

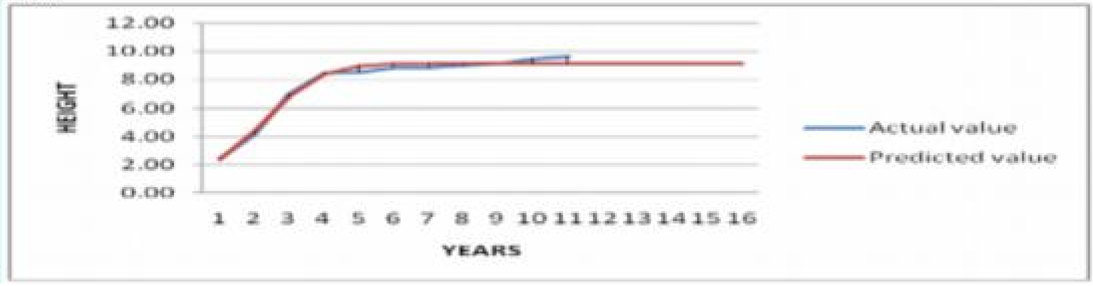
I. RichardS Model :y=9.167/(1+exp(3.367-1.284x))^(1/1.600)

Comment:The Model converged to a tolerance of 0.000001in 14 iterations. No weighting used.



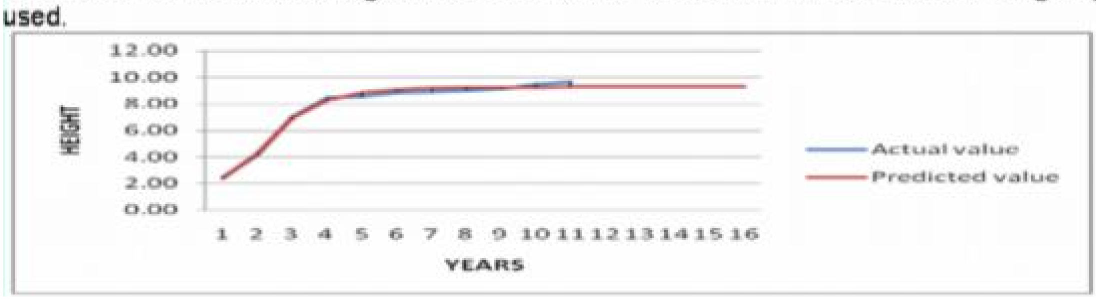
II Weibul Model: y=9.128-7.308 *exp(-0.079*x^2.432)

Comment: The Model converged to a tolerance of 0.000001in 24 iterations.No weighting used.



III MMF Model: y=(2.203*34.772+9.268*x^3.846)/(34.772+x^3.846)

Comment: The Model converged to a tolerance of 0.000001in 17 iterations.No weighting used.



IV Logistic Model: y=9.205/(1+9.032*exp(-1.076x))

Comment: The Model converged to a tolerance of 0.000001in 4 iterations. No weighting used.

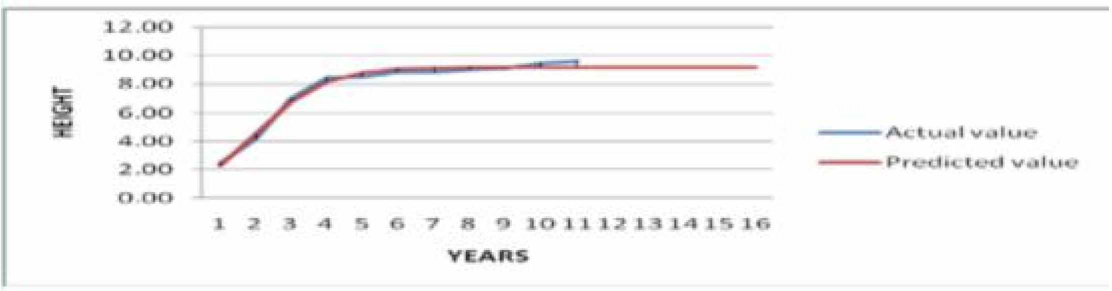
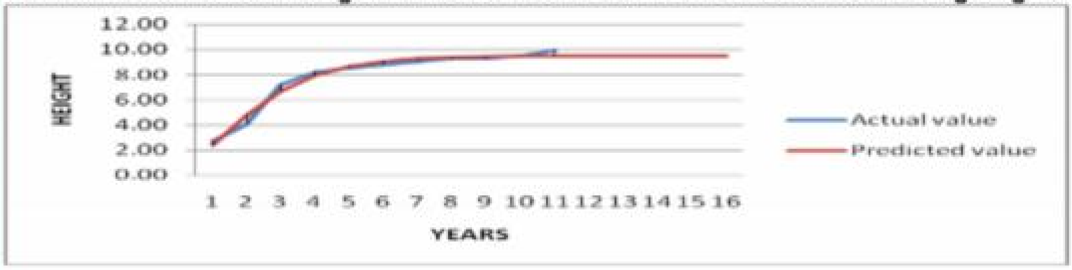


Fig 4.3.1h: Graph showing the actual values and predicted values of Chikkamangalore (S3) x 50:100:50(F2) for height growrh of Acacia mangium.

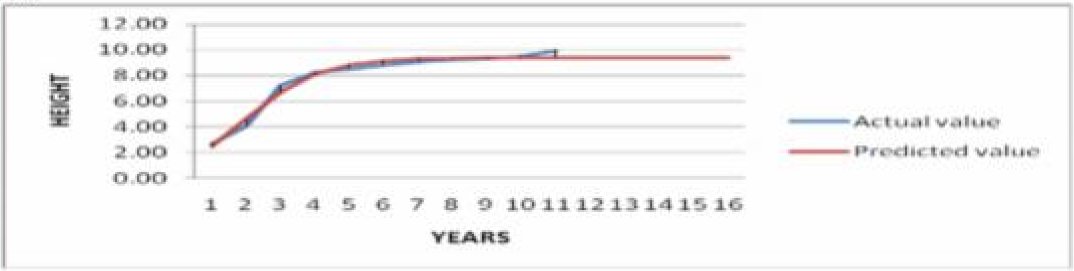
I. Gompertz Model: y=9.510*exp(-exp(1.001-0.684x))

Comment: The Model converged to a tolerance of 0.000001in 4 iterations. No weighting used.



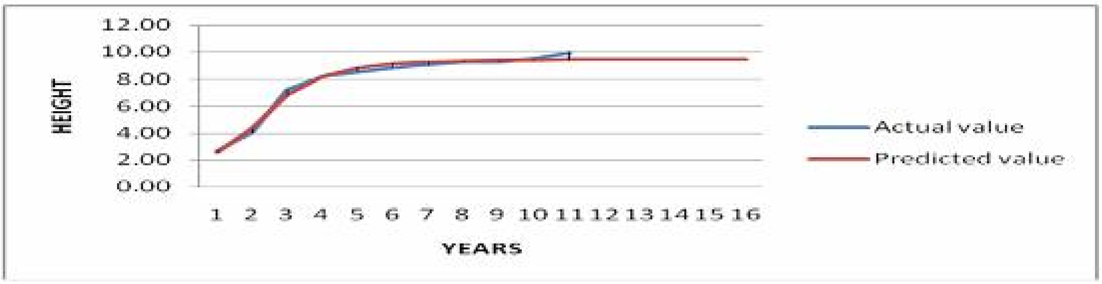
II RichardS Model: y=9.401/(1+exp(1.608-0.915x))^(1/0.824)

Comment:The Model converged to a tolerance of 0.000001in 19 iterations. No weighting used.



III MMF Model: y=(2.371*31.274+9.459 *x^3.612)/(31.274 +x^3.612)

Comment:The Model converged to a tolerance of 0.000001 in 19 iterations.No weighting used.



IV .Logistic Model: y=9.384/(1+7.260 *exp(-0.968x))

Comment: The Model converged to a tolerance of 0.000001 in 5 iterations. No weighting used.

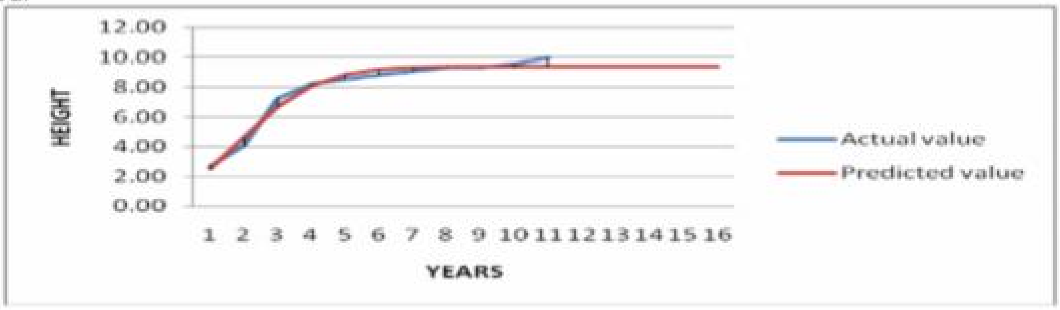
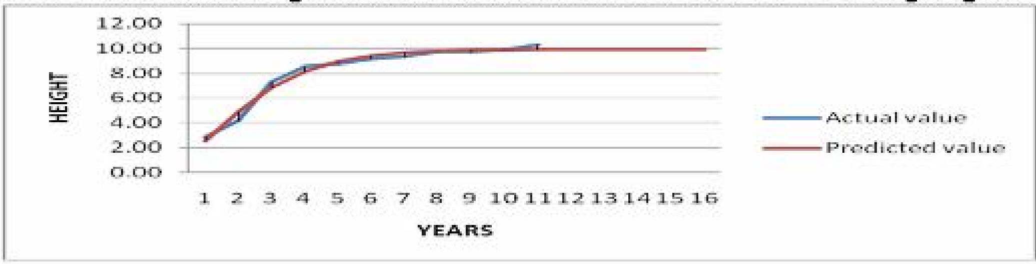


Fig 4.3.1i: Graph showing the actual values and predicted values of Chikkamangalore (S3) x 75:150:75(F3) for height growth of Acacia mangium.

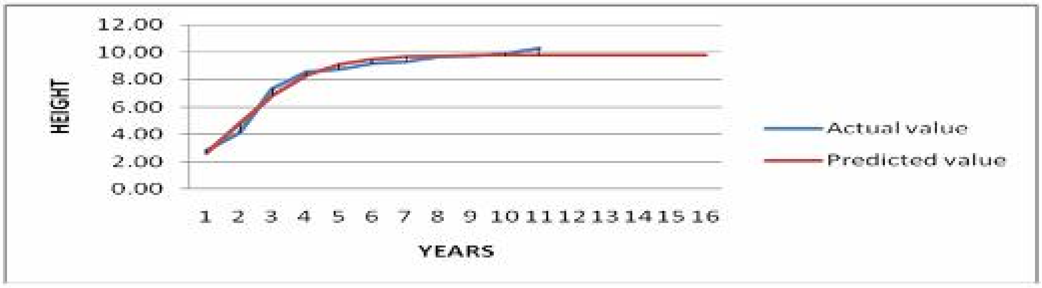
I. Gompertz Model: y=9.888*exp(-exp(0.957-0.653x))

Comment:The Model converged to a tolerance of 0.000001 in 4 iterations.No weighting used.



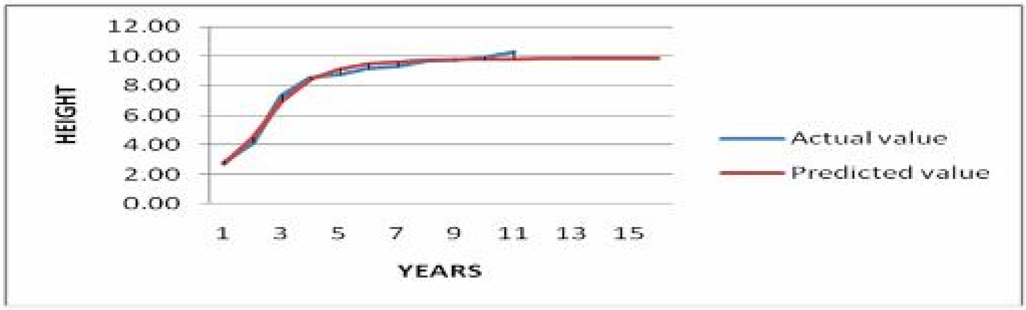
II RichardS Model: y=9.784/(1+exp(1.246-0.836x))^(1/0.696)

Comment: The Model converged to a tolerance of 0.000001in 29 iterations.No weighting used.



III MMF Model: y=(2.487*29.420 +9.847 *x^3.469)/(29.420 +x^3.469)

Comment:The Model converged to a tolerance of 0.000001 in 19 iterations.No weighting used.



IV Logistic Model: y=9.749/(1+6.743 *exp(-0.921x))

Comment: The Model converged to a tolerance of 0.000001 in 5 iterations. No weighting used.

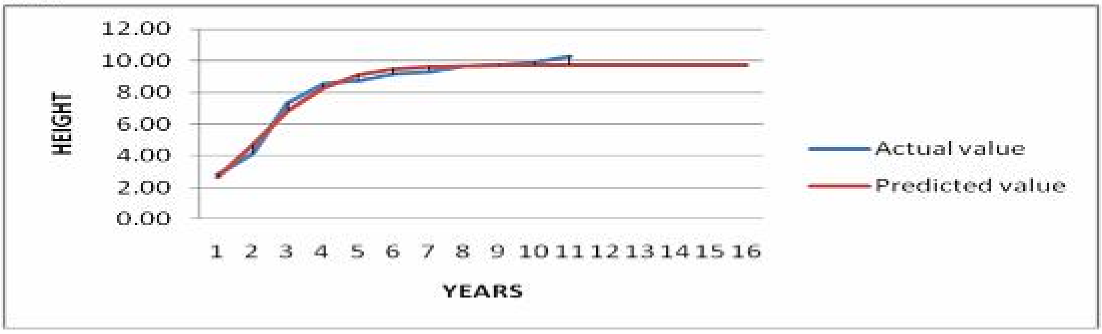
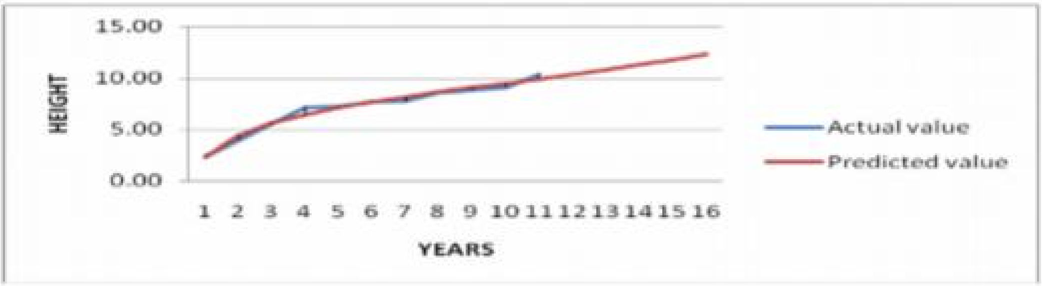
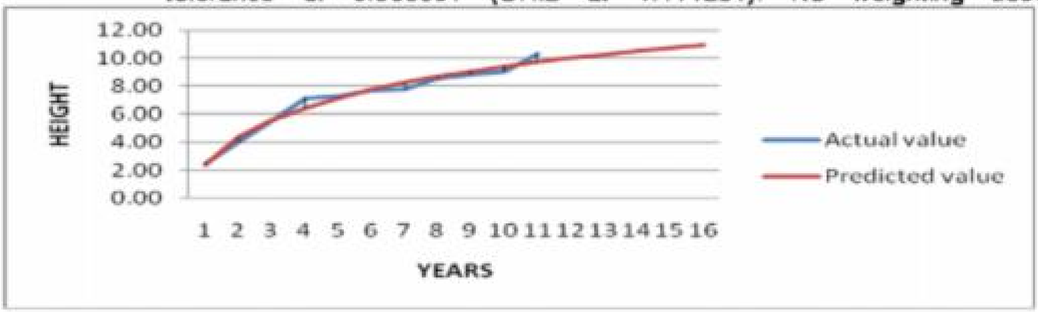


Fig 4.3.1j: Graph showing the actual values and predicted values of Thirthahalli (S4) x 25:50:25(F1) for height growth of *Acacia mangium*..

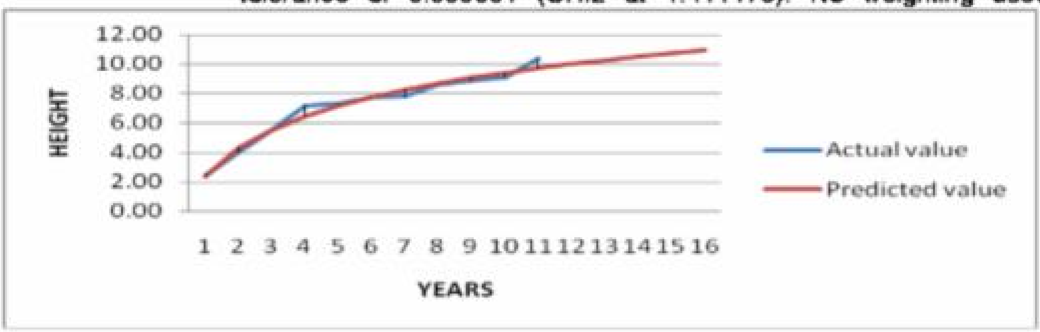
I. Rational Function: y=(-2.791 +6.964x)/(1+0.792x-0.019x^2)
Comment: The Model converged to a tolerance of 0.000001 in 8 iterations. No weighting used.



II Weibul Model: y=22.002 -32.158*exp(-0.495*x^0.277)
Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 1.411231). No weighting used.



III MMF Model: y=(7.679*2.486+27.466*x^0.371)/(2.486+x^0.371)
Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 1.411478). No weighting used.



IV Logarithm Model: y=2.269 +3.076*ln(x)
Comment: The Model converged to a tolerance of 0.000001 in 3 iterations. No weighting used.

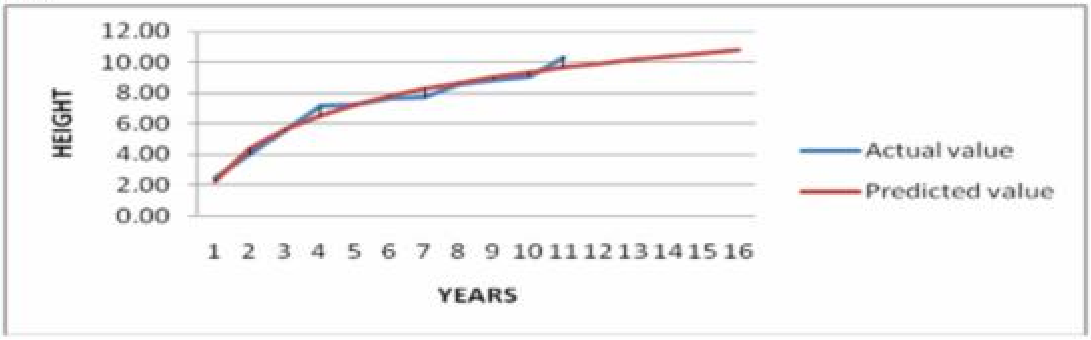
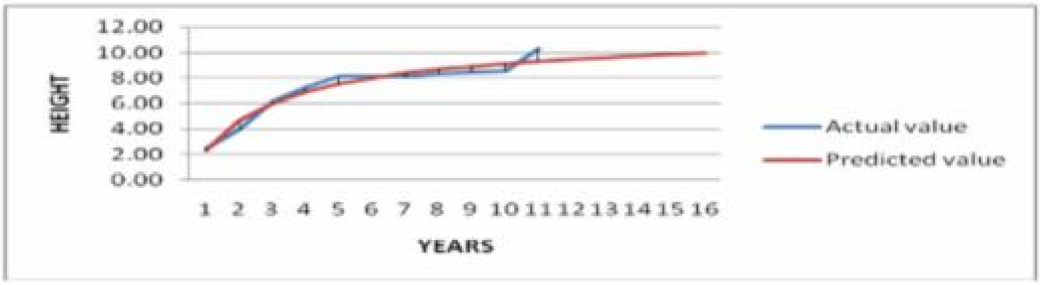
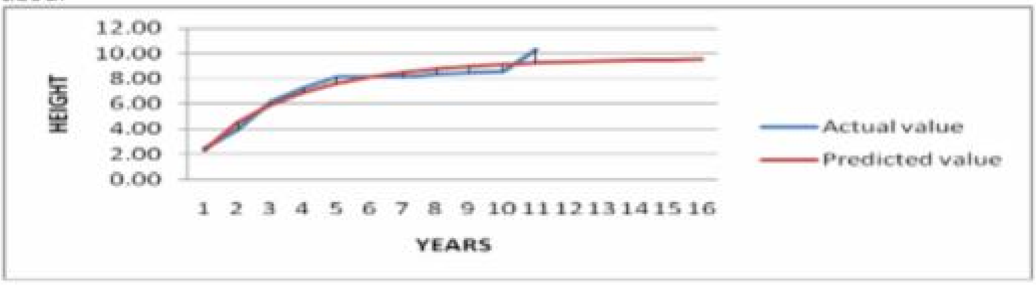


Fig 4.3.1k: Graph showing the actual values and predicted values of Thirthahalli (S4) x 50:100:50(F2) for height growth of *Acacia mangium*.

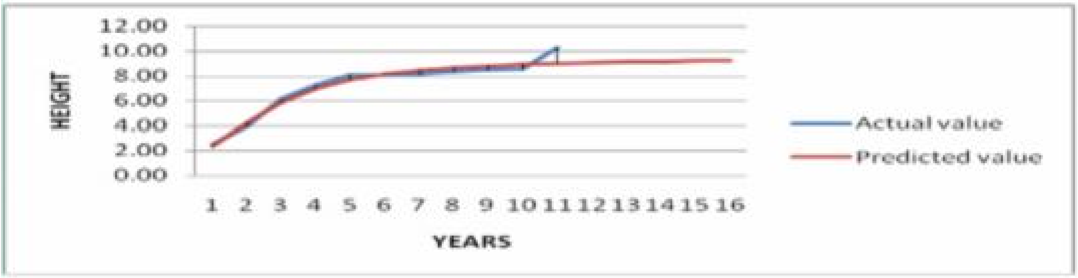
I. Rational Function: y=(-2.574+6.145x)/(1+0.555x-0.001x^2)
Comment:The Model converged to a tolerance of 0.000001 in 10 iterations.No weighting used.



II Weibul Model: y=9.688-12.179 *exp(-0.502*x^0.779)
Comment: The Model converged tolerance of 0.000001 in 14 iterations.No weighting used.



III MMF Model: y=(1.486*7.889+9.472*x^2.087)/(7.889+x^2.087)
Comment: The Model converged to a tolerance of 0.000001 in 8 iterations. No weighting used.



IV Gompertz: y=8.983*exp(-exp(0.829-0.561x))
Comment: The Model converged to a tolerance of 0.000001 in 4 iterations. No weighting used.

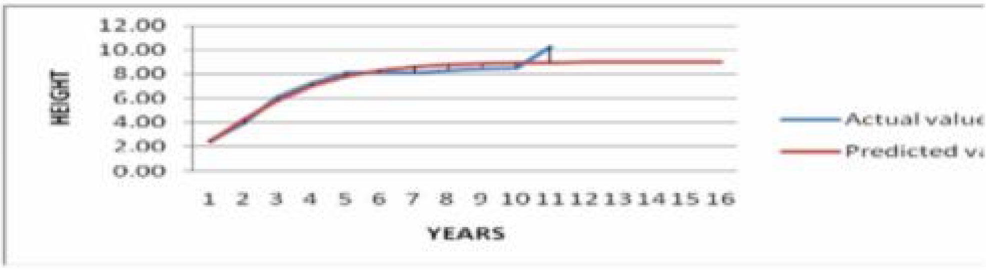
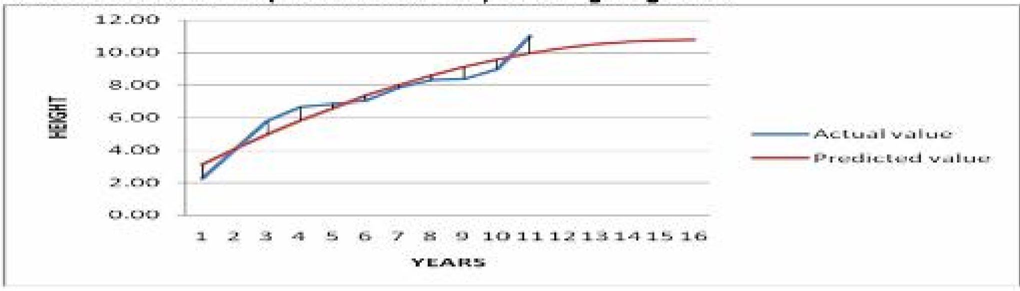


Fig 4.3.1l: Graph showing the actual values and predicted values of Thirthahalli (S4) x 75:150:75(F3) for height growth of *Acacia mangium*.

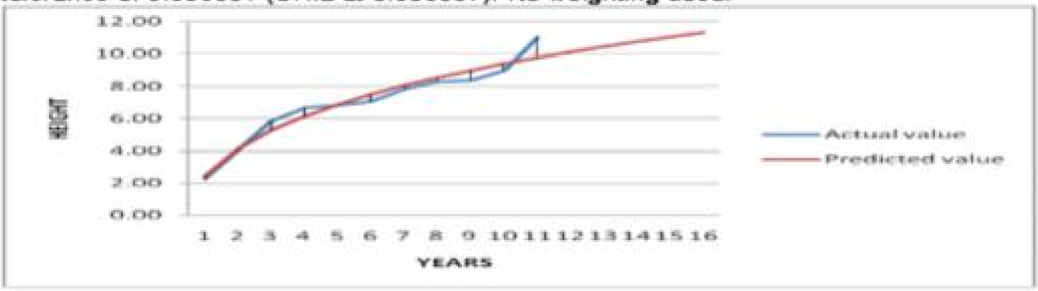
I. Sinusoidal Model: y=-18.537+29.318*cos(0.050x+5.493)

Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 4.421928). No weighting used.



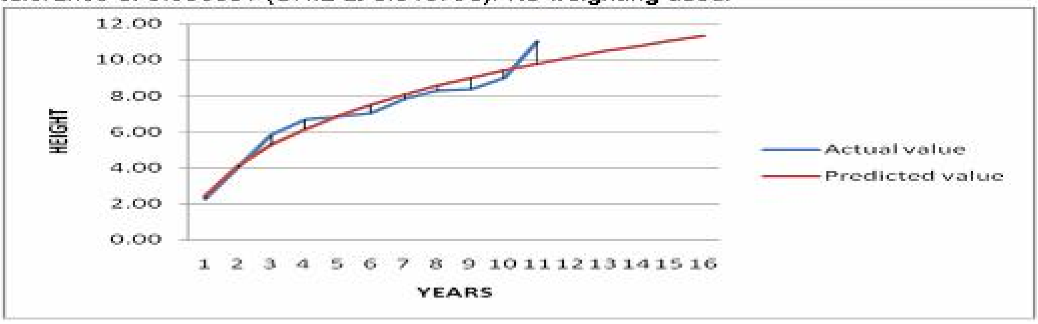
II Weibul Model: y=34.109-38.422*exp(-0.193*x^0.359)

Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 3.053657). No weighting used.



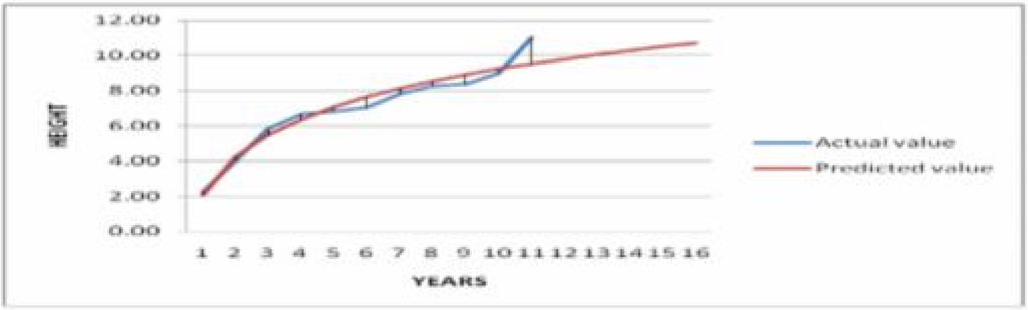
III MMF Model: y=(4.844*9.319+70.243*x^0.339)/(9.319+x^0.339)

Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 3.040798). No weighting used.



IV Logarithm Model: y=2.065+3.112*ln(x)

Comment: The Model converged to a tolerance of 1e-006 in 3 iterations. No weighting used.



n case of fourth source and their combinations, Thirthahalli (S_4) x 25:50:25(F_1), the best selected Models are Logarithm Model, Rational Function, Weibul Model and MMF Model. The curve is incrasing as shown in (fig 4.3.1j). In case of Thirthahalli (S_4) x50:100:50(F_2), the best selected Models are MMF Model, Gompertz Model, Rational Function and Weibul Model the curve is incrasing as shown in fig 4.3.1j.and in case of Thirthahalli(S_4) x 75:150:75(F_3), the best selected Models are Logarithm Model, MMF Model ,Weibul Model, and sinusoidal Model. The curve is incrasing as shown in fig 4.3.1k.

4.3.2 Height growth curves (spacing and fertilizer level).

In case of first spacing and their combination, 4x1m (SP_1) xNo fertilizer (F_0), the best selected Models are Rational Function, Logarithm Model, Weibul Model and MMF Model. The curve is incrasing as shown in fig 4.3.2a.and in case of 4x1m(SP_1) x 50:100:50(F_1), the best selected Models are Rational Function, MMF Model, Weibul Model and Richards Model. The curve is incrasing as shown in fig 4.3.2b.

In case of second spacing and their combination, 4x2m (SP_2) x No fertilizer (F_0), the best selected Models are Rational Function, Logarithm Model, Weibul Model and MMF Model. The curve is incrasing as shown in fig 4.3.2c.and in case of 4x2m (SP_2) x 50:100:50(F_1), the best selected Models are Logarithm Model, Weibul Model, MMF Model and Gompertz Model. The curve is incrasing as shown in fig 4.3.2d.

In case of third spacing and their combination, 4x3m(SP_3) xNo fertilizer(F_0), the best selected Models are Logarithm Model ,Rational function, Weibul Model and MMF Model. The curve is incrasing as shown in fig 4.3.2e.and in case of 4x3m(SP_3) x50:100:50 (F_1), the best selected Models are Rational Function, Logarithm Model, Weibul Model and MMF Model. The curve is incrasing as shown in fig 4.3.2e.

4.3.3 Dbh growth curves (Sources and fertilizer level)

In case of first source and their combinations Kerala (S_1) x25:50:25(F_1), the best selected Models are Rational Function, Weibul Model, MMF Model and polynomial Model. The curve is incrasing as shown in fig 4.3.3a. In case of second combination Kerala (S_1) x50:100:50(F_2), the best selected Models are Rational Function, MMF Model, Weibul Model and Logarithm Model. The curve is incrasing as shown in fig 4.3.3b. And In case of third combination Kerala (S_1) x75:150:75(F_3), the best selected Models are sinusoidal Model, Rational function, Weibul Model and MMF Model. The curve is incrasing as shown in fig 4.3.3c.

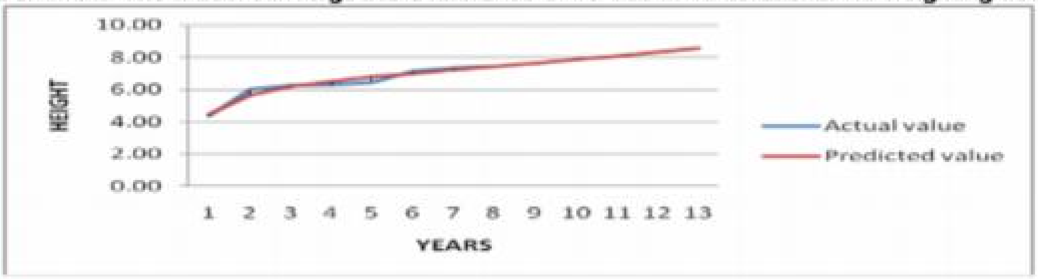
In case of fourth combination Bangalore (S_2) x25:50:25(F_1), the best selected Models are Rational function, Weibul Model, MMF Model and Logarithm Model. The curve is incrasing as shown in fig 4.3.3d.In case of fifth combination Bangalore(S_2) x50:100:50(F_2), the best selected Models are MMF Model, Gompertz Model, Weibul Model and Rational Function. The curve is incrasing as shown in fig 4.3.3e.In case of sixth combination Bangalore(S_2) x75:150:75(F_3), the best selected Models are Rational function, Weibul Model, MMF Model and Gompertz Model. The curve is incrasing as shown in fig 4.3.3f.

In case of seventh combination Chikkamangalore (S_3) x 25:50:25(F_1), the best selected Models are Rational function, MMF Model, Weibul Model and Logarithm Model. The curve is incrasing as shown in fig 4.3.3g. In case of eighth combination Chikkamangalore (S_3) x 50:100:50 (F_2), the best selected Models are MMF Model, Gompertz Model, Weibul Model and Logistic Model. The curve is incrasing as shown in fig 4.3.3h. In case of ninth combination Chikkamangalore (S_3) x75:150:75(F_3), the best selected Models are Rational function, MMF Model, Weibul Model, and Richards Model. The curve is incrasing as shown in fig 4.3.3i.

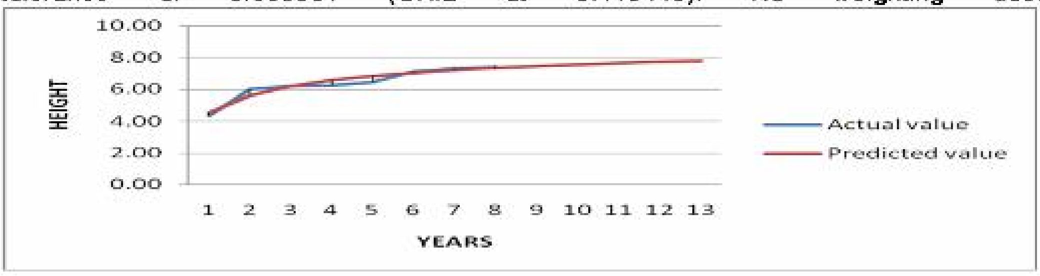
In case of tenth combination Thirthahalli (S_4) x 25:50:25(F_1), the best selected Models are Gompertz Model, Rational Function, Sinusoidal Model and Richards Model. The curve is increasing as shown in fig 4.3.3j. In case of eleventh combination Thirthahalli (S_4) x50:100:50(F_2), the best selected Models are MMF Model, Logistic Model, Weibul Model and Richards Model. The curve is increasing as shown in fig 4.3.3k. In case of twelth Thirthahalli(S_4) x 75:150:75(F_3), the best selected Models are polynomial Model, MMF Model , Weibul Model, and Gompertz Model. The curve is increasing as shown in fig 4.3.3l.

Fig 4.3.2a: Graph showing the actual values and predicted values for of 4x1m(SP1) x No fertilizer(F0) for height growth of *Acacia mangium*.

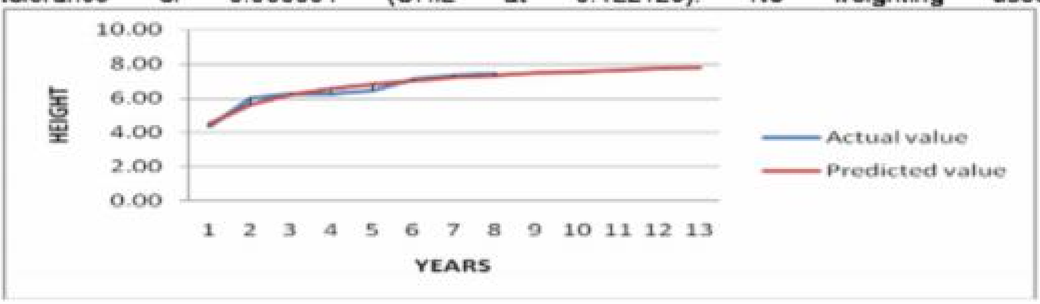
I. Rationalfunction: y=(4919929.327+15045079.70x)/(1+2308948.462x+45656.128x^2)
Comment: The Model converged to a tolerance of 1e-006 in 16 iterations. No weighting used.



II Weibul Model: y=9.569-44.816*exp(-2.182*x^0.153)
Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 0.418446). No weighting used.



III MMF Model: y=(-5.106 *0.539 +9.693 *x^0.501)/(0.539 +x^0.501)
Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 0.422129). No weighting used.



IV Logarithm Model: y=4.611+1.350*ln(x)
Comment: The Model converged to a tolerance of 1e-006 in 3 iterations. No weighting used.

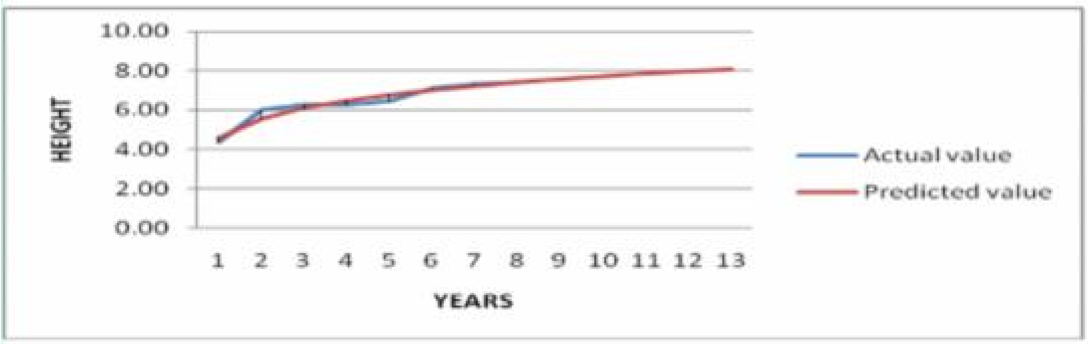
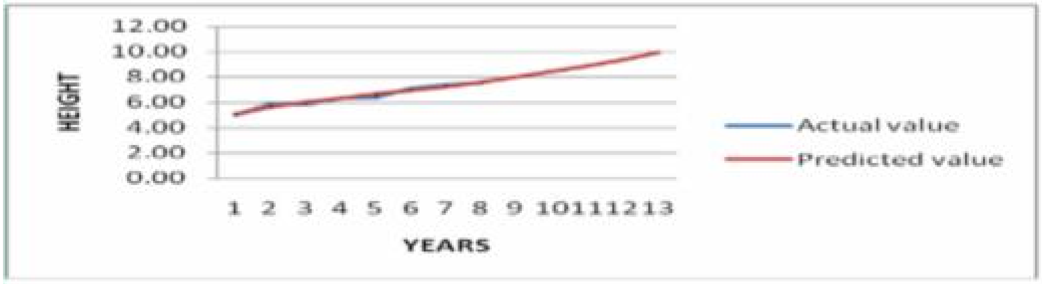
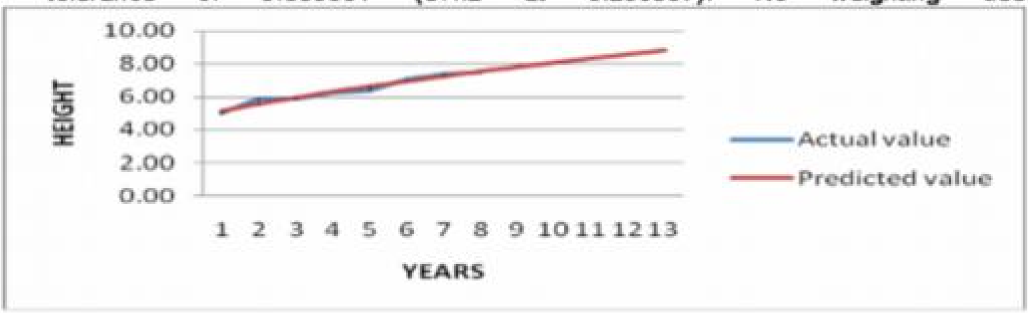


Fig 4.3.2b: Graph showing the actual values and predicted values for of 4x1m (SP1) x 50:100:50(F1) for height growth of *Acacia mangium*.

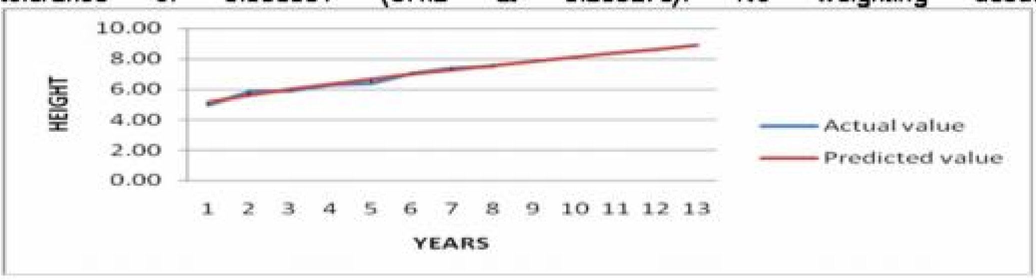
I. Rational Function: $y=(975187.72+7228255.65x)/(1+1280154.54x+43226.36x^2)$
Comment: The Model converged to a tolerance of 1e-006 in 14 iterations. No weighting used.



II Weibul Model: $y=17.750-13.170*\exp(-0.043*x^{0.860})$
Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 0.208507). No weighting used.



III MMF Model: $y=(4.497*180.619+118.985*x^{0.770})/(180.619+x^{0.770})$
Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 0.205270). No weighting used.



IV Richards Model: $y=7.520/(1+\exp(49.771-6.832x))^{(1/119.099)}$
Comment: The Model converged to a tolerance of 1e-006 in 30 iterations. No weighting used.

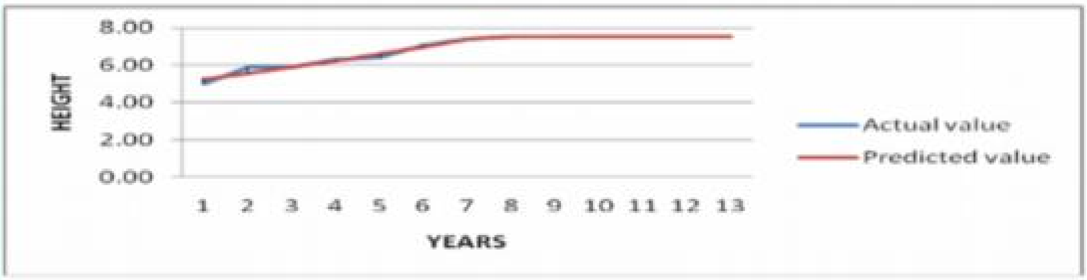
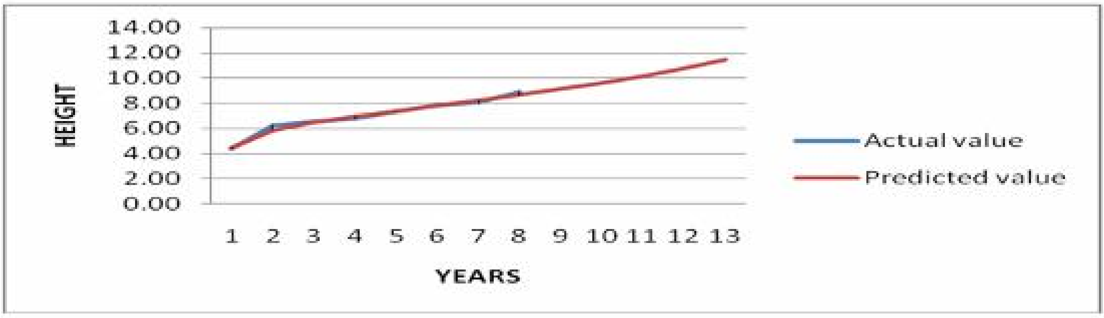


Fig 4.3.2c: Graph showing the actual values and predicted values for 4x2m (SP2) x No fertilizer (F0) for height growth of *Acacia mangium*.

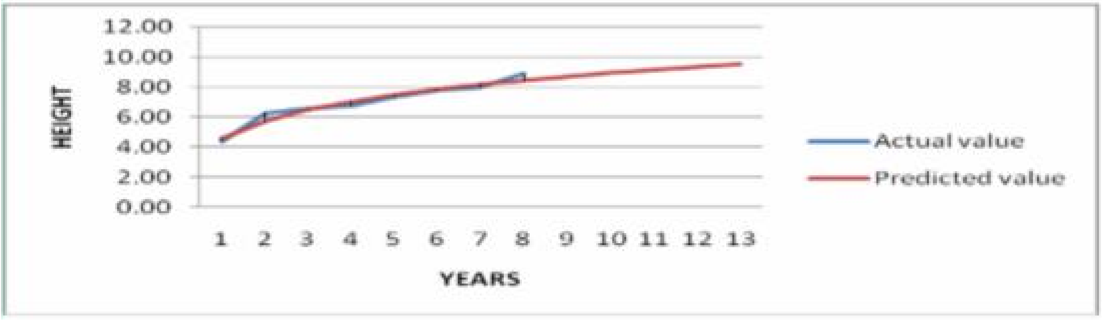
I. RationalFunction:y=(16012204.33+47230914.5x)/(1+7154710.82x+241494.77x^2

Comment: The Model converged to a tolerance of 1e-006 in 16 iterations. No weighting used.



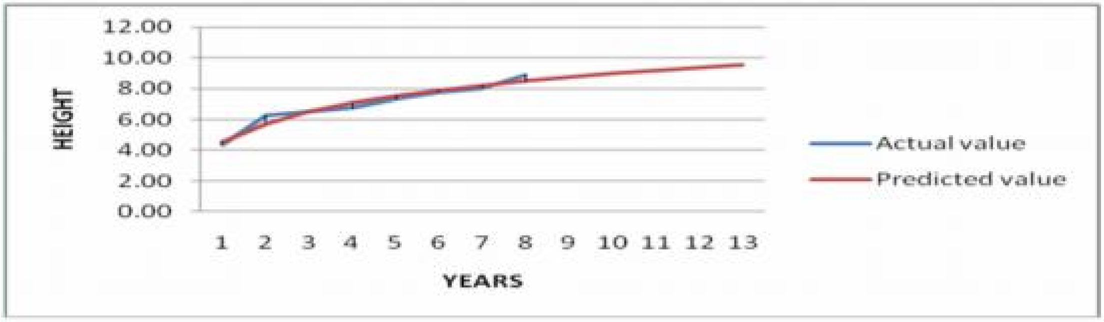
II Weibul Model: y=22.200-24.844*exp(-0.344*x^0.263)

Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 0.638097). No weighting used.



III MMF Model: y=(2.242*3.487+28.360*x^0.304)/(3.487+x^0.304)

Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 0.640083). No weighting used.



IV Logarithm Model: y=4.497+1.888 *ln(x)

Comment: The Model converged to a tolerance of 1e-006 in 3 iterations. No weighting used

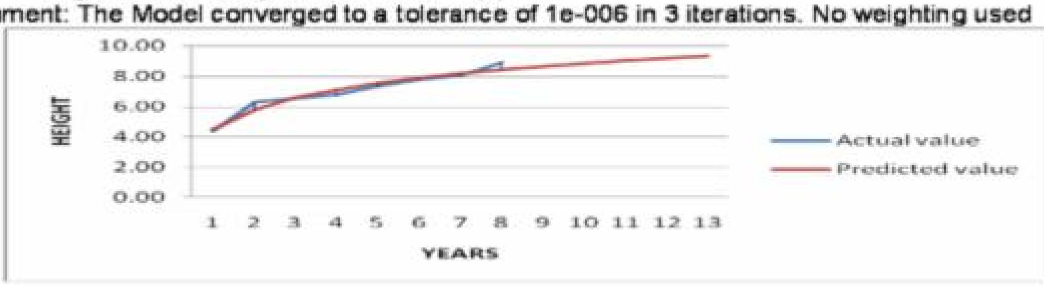
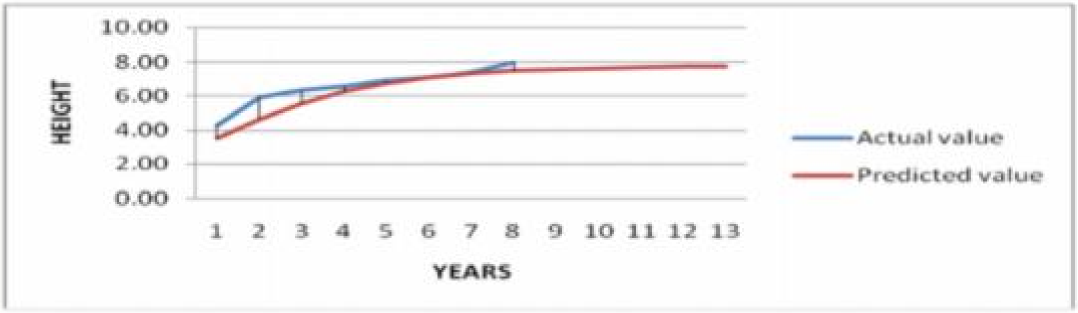


Fig 4.3.2d: Graph showing the actual values and predicted values for 4x2m (SP2) x 50:100:50 (F1) for height growth of *Acacia mangium*.

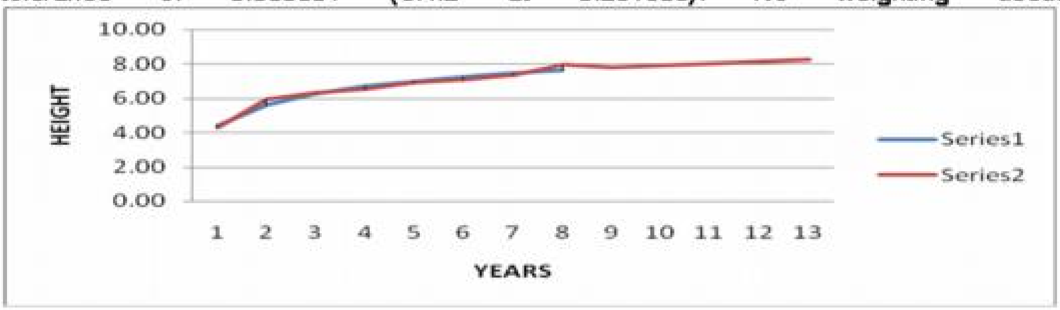
I. Gompertz Model: y=7.771*exp(-exp(0.197-0.431x))

Comment: The Model converged to a tolerance of 1e-006 in 7 iterations. No weighting used.



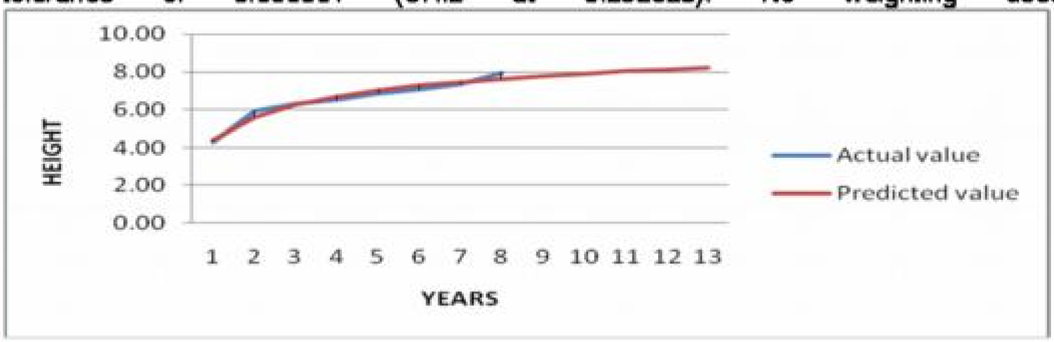
II Weibul Model: y=11.004-35.985*exp(-1.699*x^0.160)

Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 0.291585). No weighting used.



III MMF Model: y=(-7.926*0.576+11.536*x^0.400)/(0.576+x^0.400)

Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 0.292528). No weighting used.



IV Logarithm Model: y=4.501+1.543*ln(x)

Comment: The Model converged to a tolerance of 1e-006 in 3 iterations. No weighting used.

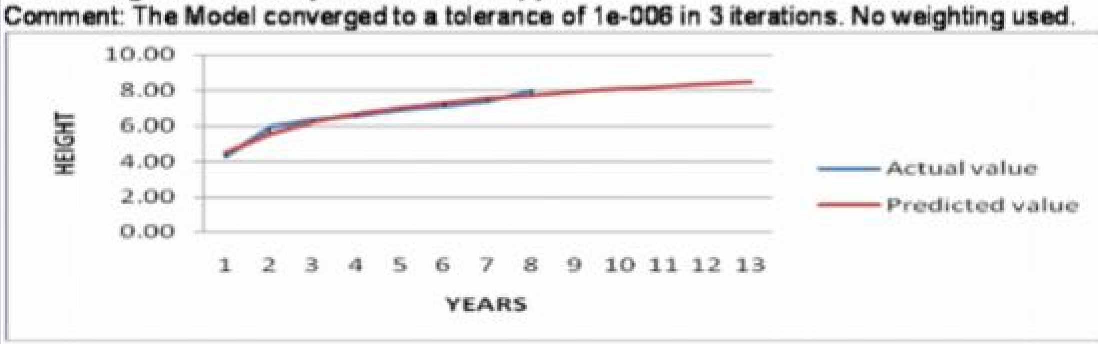
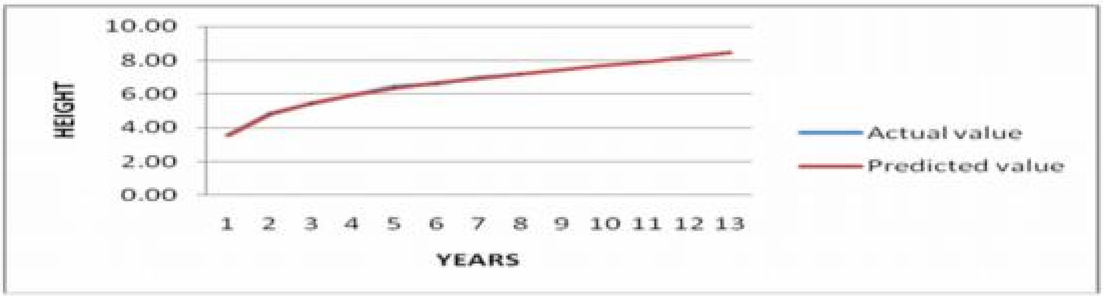
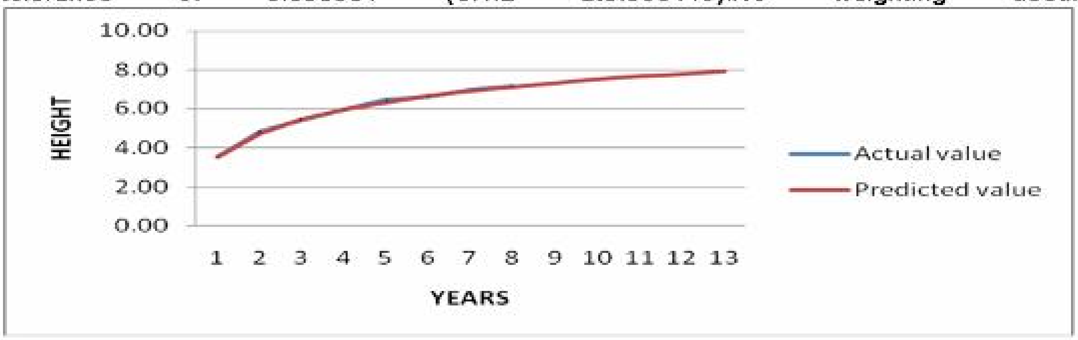


Fig 4.3.2e: Graph showing the actual values and predicted values for 4x3m(SP3) x No fertilizer (F0) for height growth of *Acacia mangium*.

I. Rational Function: y=(0.045+6.971x)/(1+0.996x-0.019x^2)
Comment: The Model converged to a tolerance of 1e-006 in 7 iterations. No weighting used.



II Weibul Model: y=12.707-20.725*exp(-0.818*x^0.229)
Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at0.030448).No weighting used.



III MMF Model: y=(7.361*1.248+17.195*x^0.285)/(1.248+x^0.285)
Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 0.030164). No weighting used.

IV Logarithm Model: y=3.567+1.734*ln(x)
Comment: The Model converged to a tolerance of 1e-006 in 2 iterations. No weighting used.

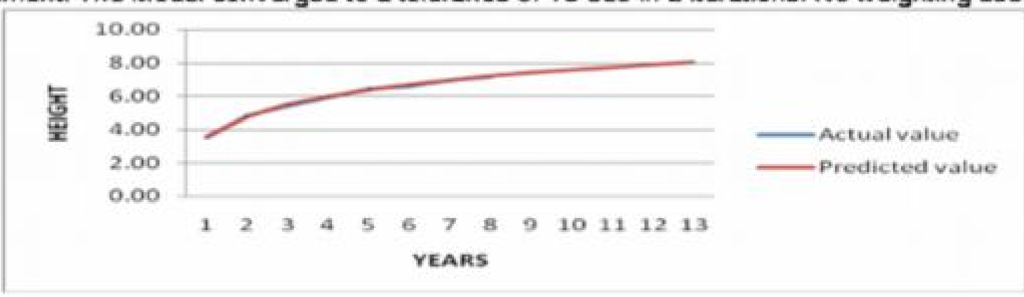
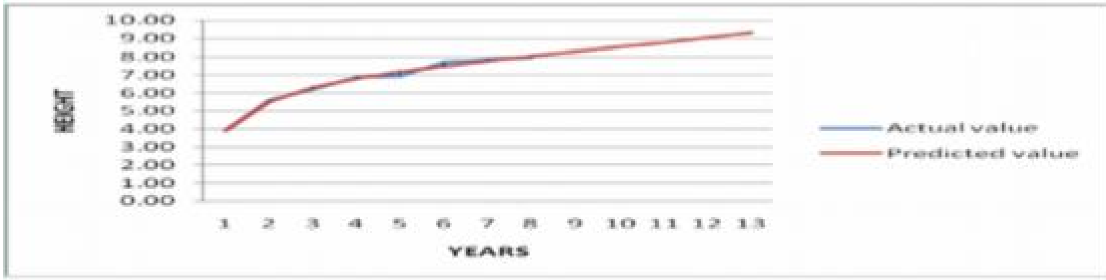
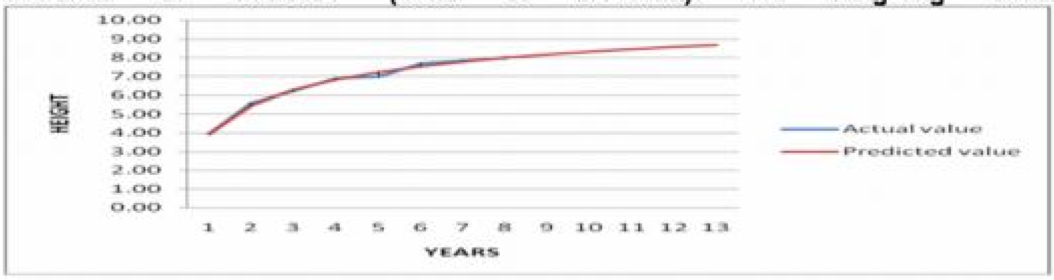


Fig 4.3.2f: Graph showing the actual values and predicted values for 4x3m(SP3) x 50:100:50 (F1) for height growth of *Acacia mangium*.

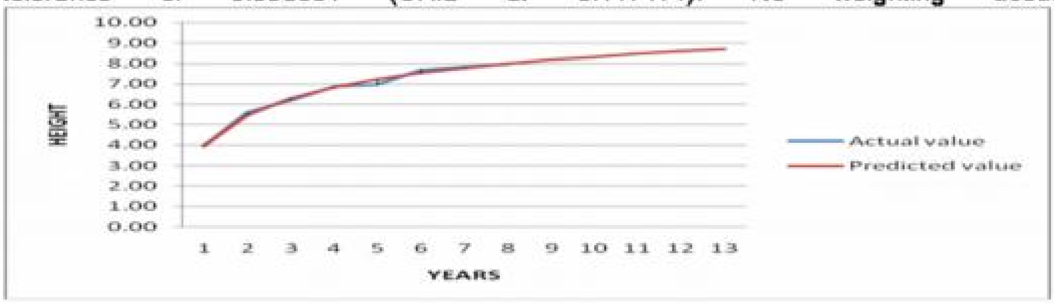
I. Rational Function: $y=(-4.072+16.418x)/(1+2.176x-0.040x^2)$
Comment: The Model converged to a tolerance of 1e-006 in 8 iterations. No weighting used.



II Weibul Model: $y=10.718-25.819*\exp(-1.342*x^{0.248})$
Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 0.118682). No weighting used.



III MMF Model: $y=(10.565*0.589+12.518*x^{0.424})/(0.589+x^{0.424})$
mment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 0.117174). No weighting used.



IV Logarithm Model: $y=4.079+1.930*\ln(x)$
Comment: The Model converged to a tolerance of 1e-006 in 3 iterations. No weighting used.

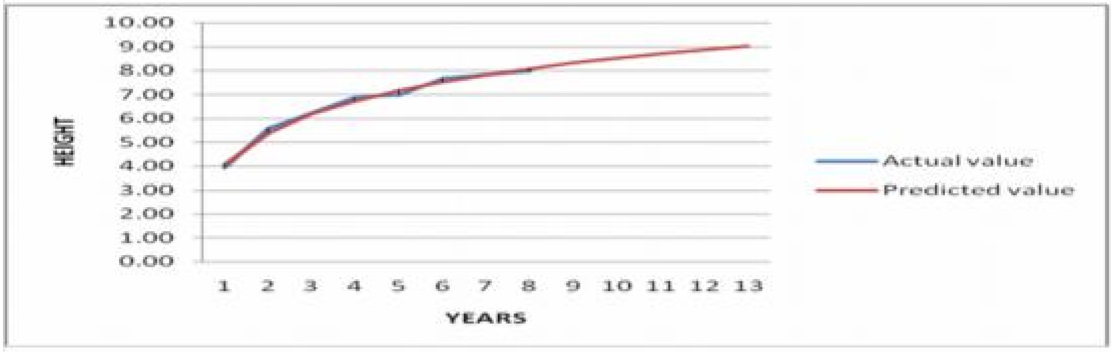
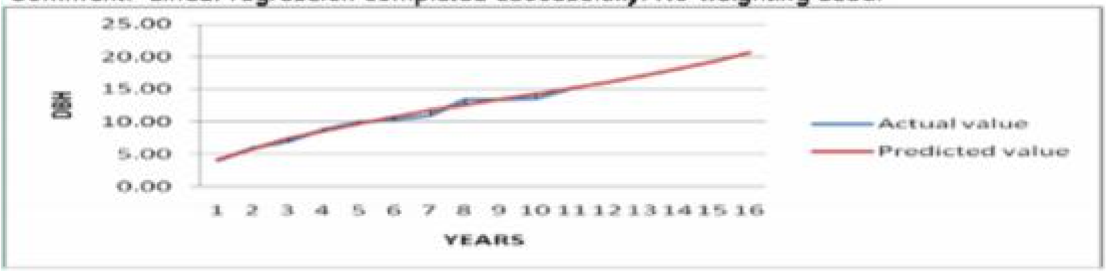
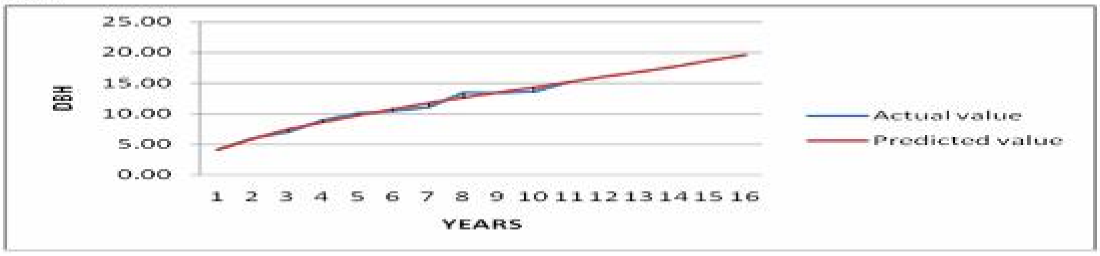


Fig 4.3.3a: Graph showing the actual values and predicted values of Kerala(S1) x 25:50:25(F1) for dbh growth of *Acacia mangium*.

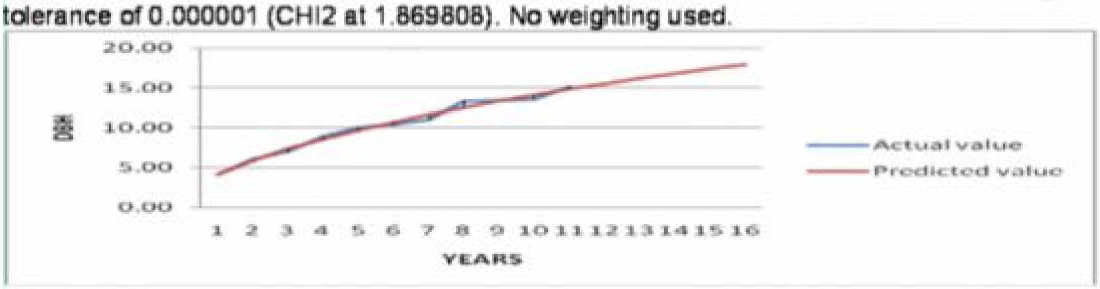
I. Polynomial Model: $y=2.098+2.175x-0.166x^2+0.008x^3-0.0001x^4$
Comment:- Linear regression completed successfully. No weighting used.



II Rational Function: $y=(1.797+2.916x)/(1+0.156x-0.004x^2)$
Comment:- The Model converged to a tolerance of 1e-006 in 13 iterations. No weighting used.



III Weibul Model: $y=37.048-35.788*\exp(-0.083*x^{0.728})$
Comment:- The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 1.869808). No weighting used.



IV MMF Model: $y=(1.223*20.725+64.040*x^{0.729})/(20.725+x^{0.729})$
Comment:- The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 1.867495). No weighting used.

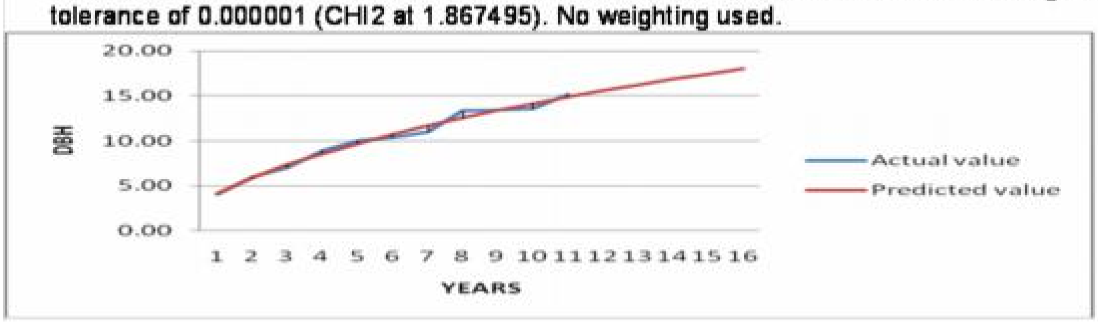
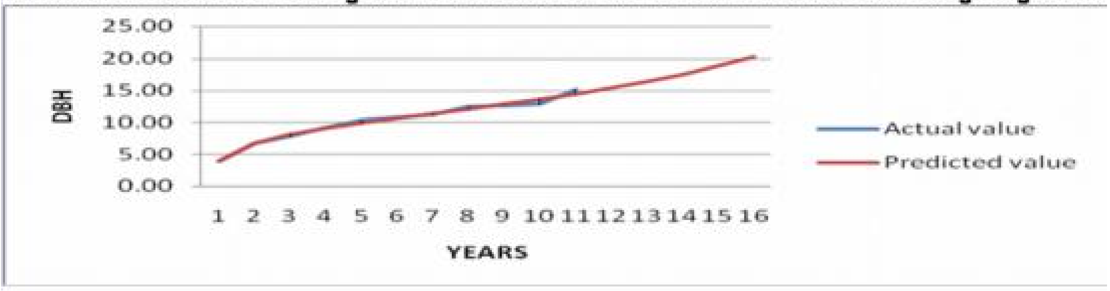
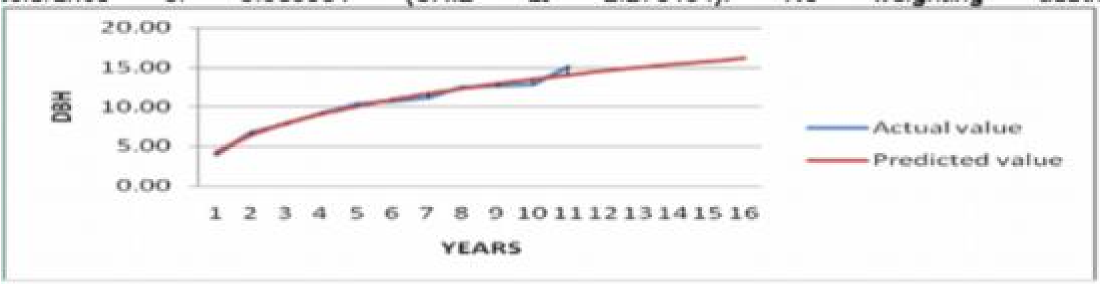


Fig 4.3.3b: Graph showing the actual values and predicted values of Kerala(S1)x 50:100:50 (F2) for dbh growth of *Acacia mangium*.

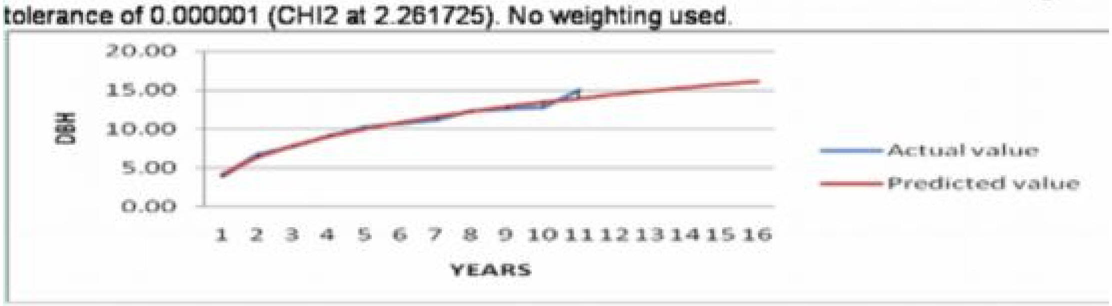
I. Rational Function: y=(-8.560+20.272x)/(1+2.012x-0.069x^2)
Comment:-The Model converged to a tolerance of 0.000001 in 7 iterations.No weighting used.



II Weibul Model : y=43.473-46.689*exp(-0.174*x^0.407)
Comment:- The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 2.275404). No weighting used.



III MMF Model: y=(-3.642*10.286+84.996*x^0.392)/(10.286+x^0.392)
Comment:- The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 2.261725). No weighting used.



IV Logarithm Model : y=3.644+4.163*ln(x)
Comment:- The Model converged to a tolerance of 0.000001in 3 iterations. No weighting used.

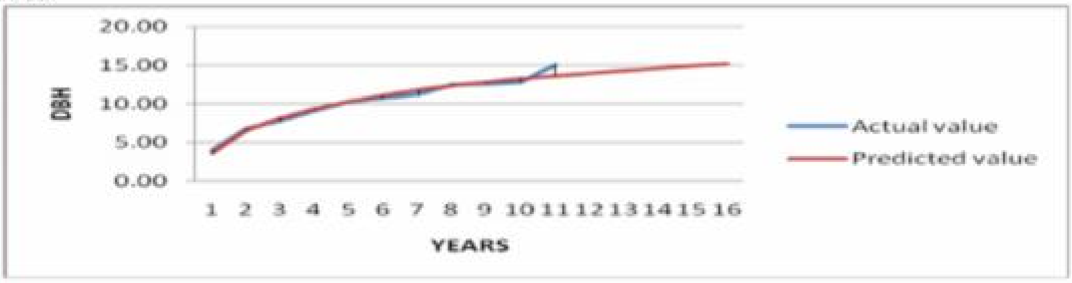
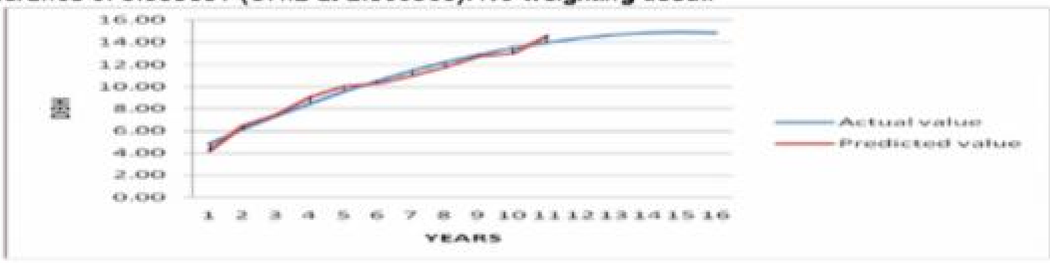


Fig 4.3.3c: Graph showing the actual values and predicted values of Kerala(S1) x 75:150:75 (F3) for dbh growth of *Acacia mangium*.

I. Sinusoidal Model: y=-12.831+27.742*cos(0.062x+5.342)

Comment:- The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 2.066530). No weighting used..

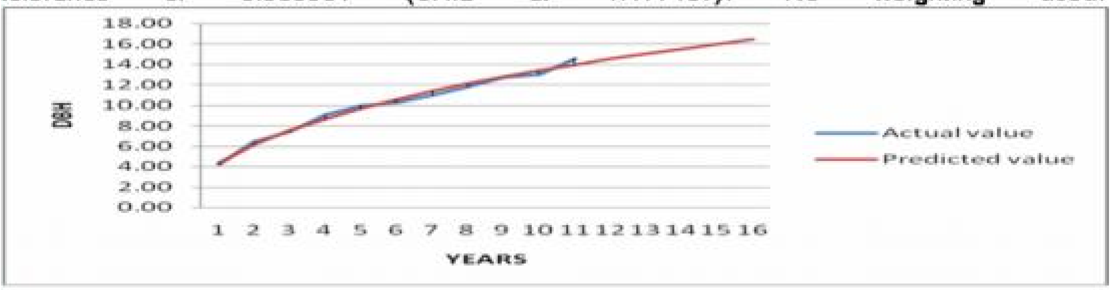


II Rational Function: y=(-1.551+9.291x)/(1+0.886x-0.031x^2)

Comment:- The Model converged to a tolerance of 1e-006 in 7 iterations. No weighting used.

III Weibul Model: y=44.247-44.153*exp(-0.102*x^0.545)

Comment:- The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 1.177107). No weighting used.



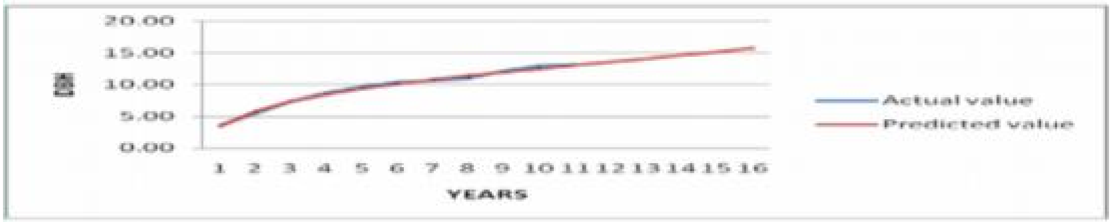
IV MMF Model: y=(0.176*14.855+66.540*x^0.566)/(14.855+x^0.566)

Comment:- The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 1.182770). No weighting used.

Fig 4.3.3d: Graph showing the actual values and predicted values of Bangalore (S2)x 25:50:25 (F1) for dbh growth of *Acacia mangium*.

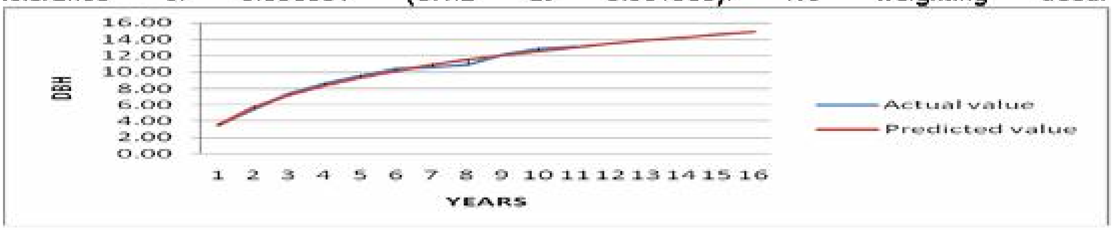
I. Rational Function: y=(-0.694+5.741x)/(1+0.443x-0.009x^2)

Comment:-The Model converged to a tolerance of 0.000001 in 5 iterations. No weighting used.



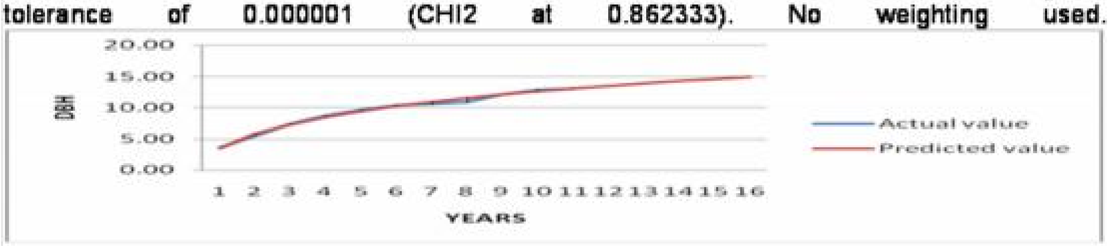
II Weibul Model: y=30.342-35.344*exp(-0.277*x^0.395)

Comment:- The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 0.861590). No weighting used.



III MMF Model: y=(3.853*4.792+39.095*x^0.473)/(4.792+x^0.473)

Comment:- The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 0.862333). No weighting used.



IV Logarithm Model: y=3.138+4.018*ln(x)

Comment:-The Model converged to a tolerance of 0.000001 in 3 iterations. No weighting used.

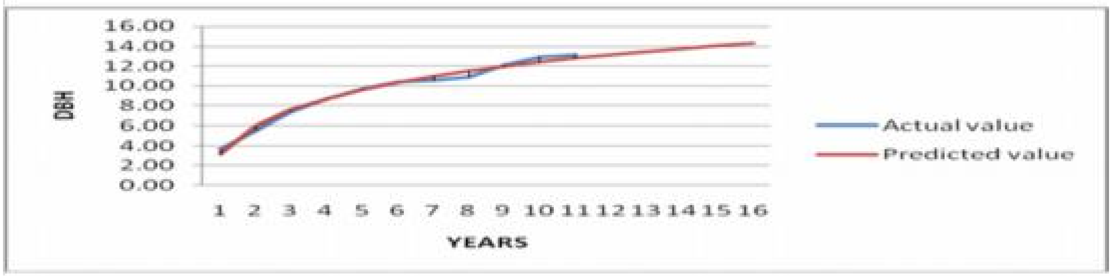
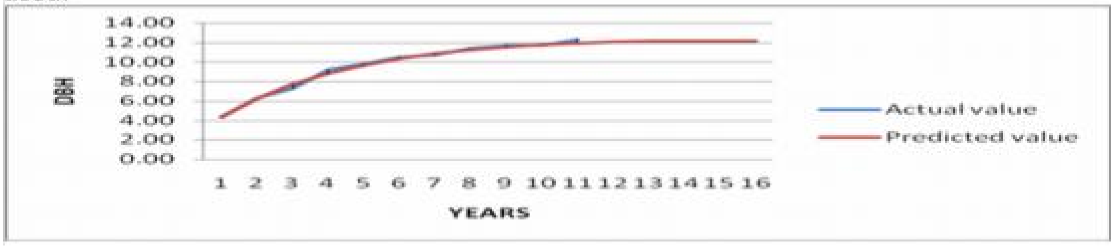


Fig 4.3.3e: Graph showing the actual values and predicted values of Bangalore (S2)x50:100:50 (F2) for dbh growth of *Acacia mangium*.

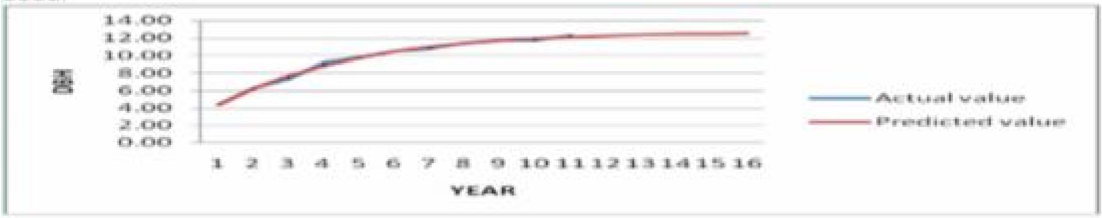
I. Rational Function: $y=(1.846+3.119x)/(1+0.141x+0.004x^2)$

Comment:-The Model converged to a tolerance of 0.000001 in 6 iterations. No weighting used.



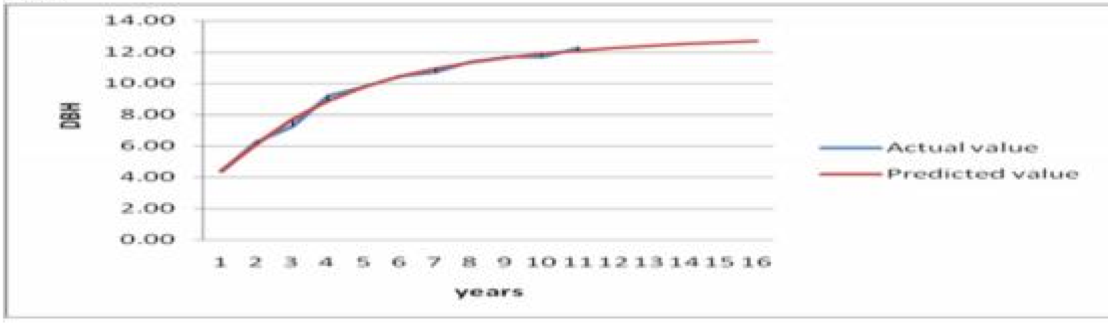
II Weibul Model: $y=12.635-10.441*\exp(-0.232*x^{1.060})$

Comment:-The Model converged to a tolerance of 0.000001 in 6 iterations. No weighting used.



III MMF Model: $y=(3.180*7.612+13.581*x^{1.599})/(7.612+x^{1.599})$

Comment:- The Model converged to a tolerance of 0.000001in 6 iterations. No weighting used.



IV Gompertz Relation: $y=12.307*\exp(-\exp(0.385-0.371x))$

Comment:-The Model converged to a tolerance of 0.000001 in 3 iterations. No weighting used.

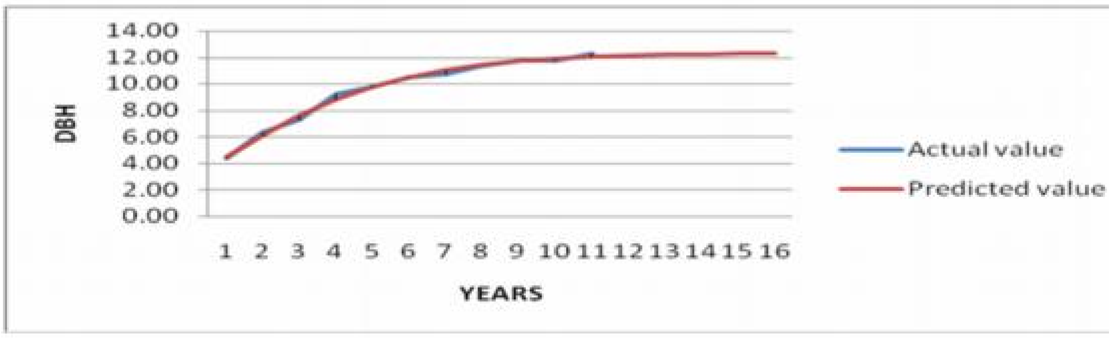
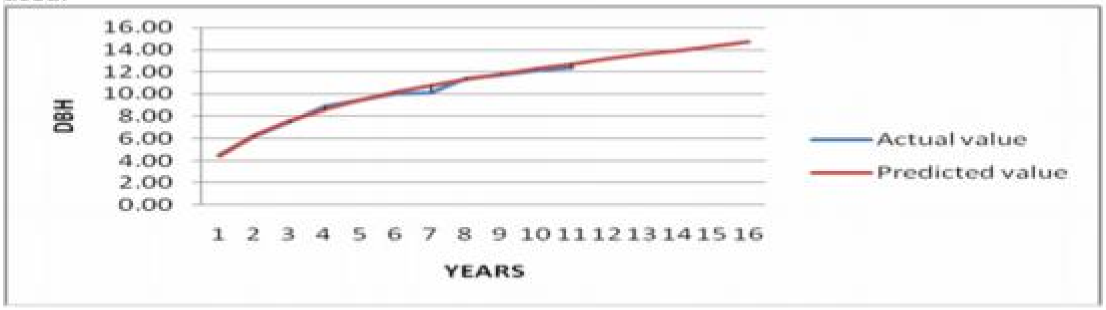


Fig 4.3.3f: Graph showing the actual values and predicted values of Bangalore (S2)x75:150:75 (F3) for dbh growth of *Acacia mangium*.

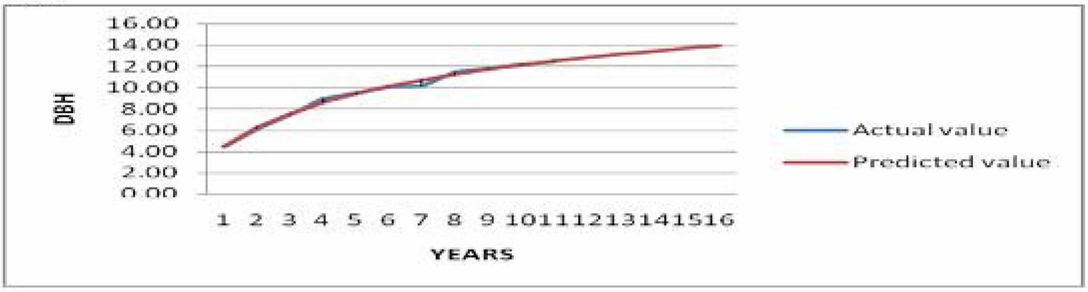
I. Rational Function: $y=(1.616+4.107x)/(1+0.288x-0.004x^2)$

Comment:-The Model converged to a tolerance of 0.000001 in 6 iterations.No weighting used.



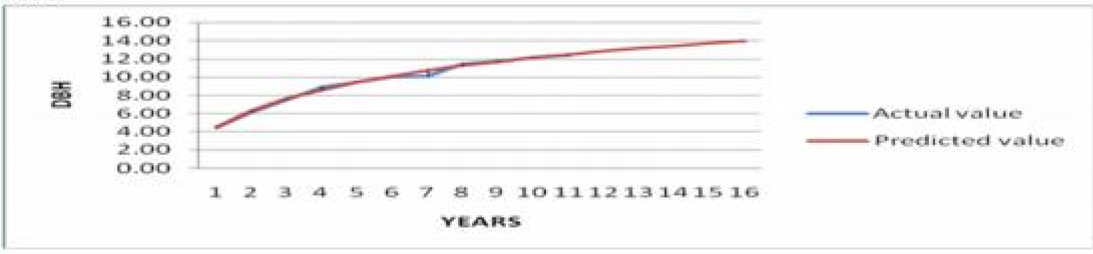
II Weibul Model: $y=19.758-20.532*\exp(-0.294*x^{0.525})$

Comment:The Model converged to a tolerance of 0.000001 in 68 iterations.No weighting used.



III MMF Model: $y=(0.155*4.609+24.306*x^{0.653})/(4.609+x^{0.653})$

Comment:The Model converged to a tolerance of 0.000001 in 53 iterations.No weighting used.



IV Gompertz Relation: $y=12.964*\exp(-\exp(0.291-0.288x))$

Comment:- The Model converged to a tolerance of 0.000001 in 4 iterations.No weighting used.

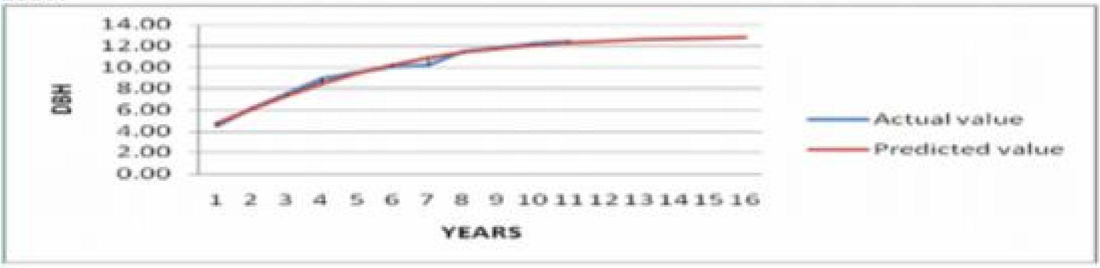
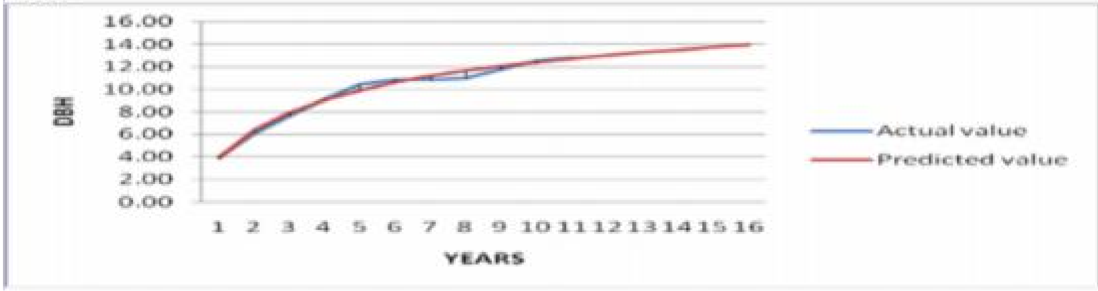


Fig 4.3.3g: **Graph showing the actual values and predicted values of Chikkamangalore (S3) x 25:50:25(F1) for dbh growth.**

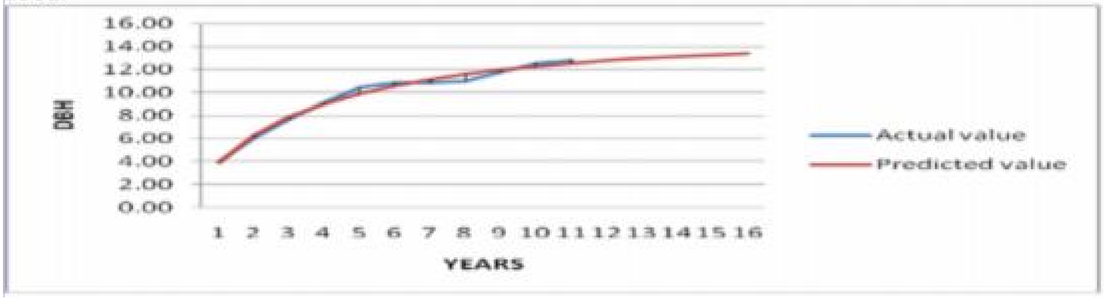
I. Rational Function: y=(-0.286+5.592x)/(1+0.369x-0.002x^2)

Comment:-The Model converged to a tolerance of 0.000001 in 7 iterations. No weighting used.



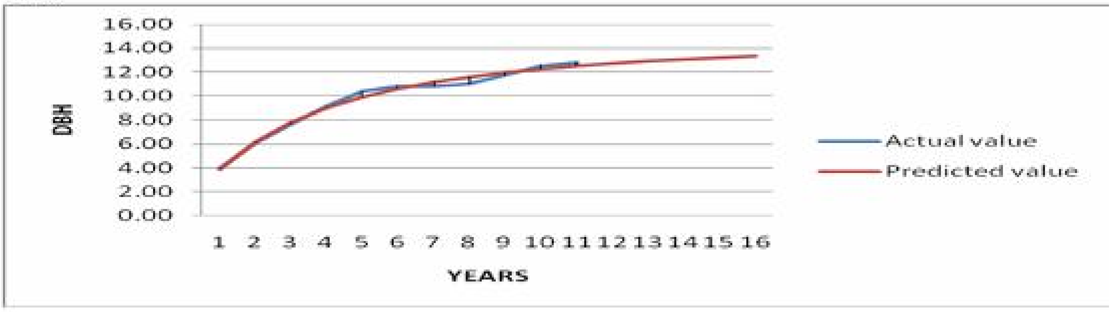
II Weibul Model: y=14.431-16.303*exp(-0.437*x^0.667)

Comment:-The Model converged to a tolerance of 0.000001 in 5 iterations. No weighting used.



III MMF Model: y=(1.138*4.039+15.197*x^1.186)/(4.039+x^1.186)

Comment:-The Model converged to a tolerance of 0.000001 in 7 iterations. No weighting used.



IV Logarithm Model: y=3.861+3.691*ln(x)

Comment:-The Model converged to a tolerance of 0.000001 in 3 iterations. No weighting used.

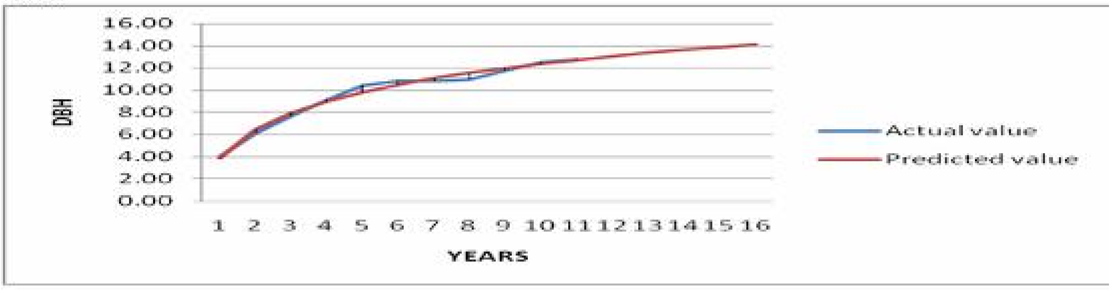
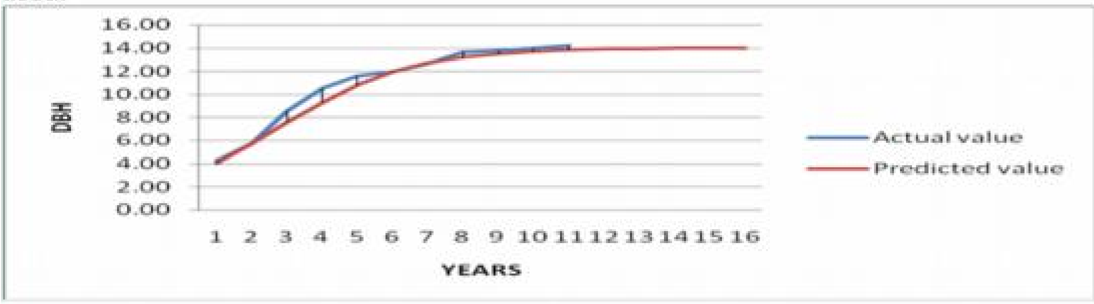


Fig 4.3.3h: **Graph showing the actual values and predicted values of Chikkamangalore (S3) x 50:100:50(F2) for dbh growth.**

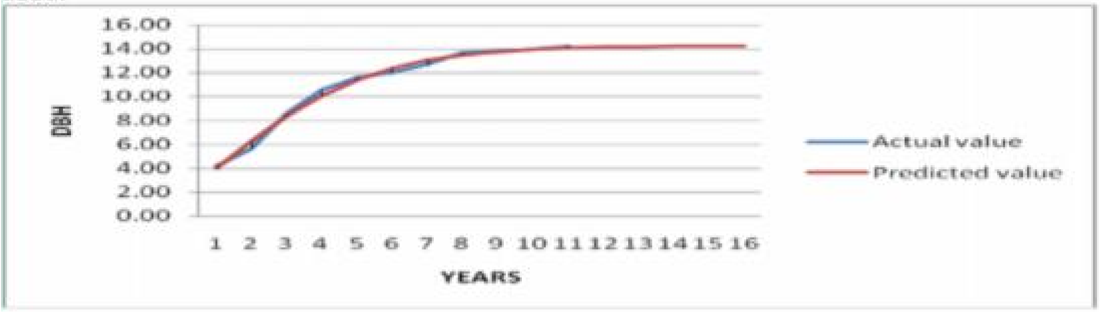
I. Logistic Model: y=13.99/(1+4.16*exp(-0.53x))

Comment:-The Model converged to a tolerance of 0.000001 in 5 iterations. No weighting used.



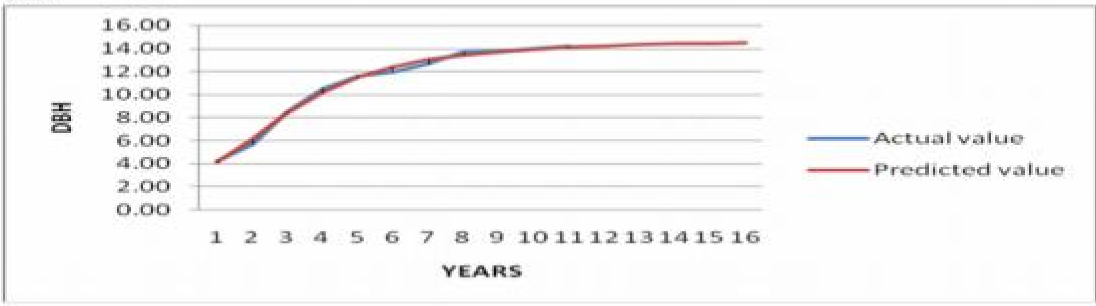
II Weibul Model: y=14.218-11.881*exp(-0.154*x^1.388)

Comment:-The Model converged to a tolerance of 0.000001in 14 iterations.No weighting used.



III MMF Model: y=(3.459*16.250+14.792*x^2.293)/(16.250+x^2.293)

Comment:The Model converged to a tolerance of 0.000001 in 21 iterations.No weighting used.



IV Gompertz Relation: y=14.312*exp(-exp(0.672-0.433x))

Comment:-The Model converged to a tolerance of 0.000001 in 4 iterations. No weighting used.

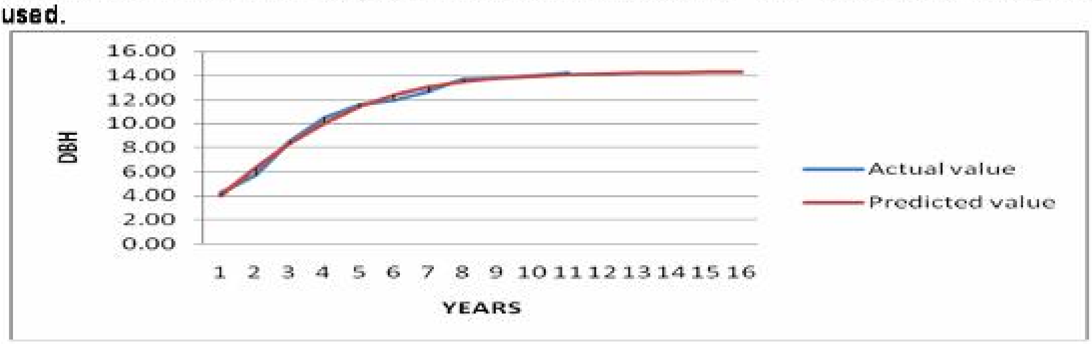
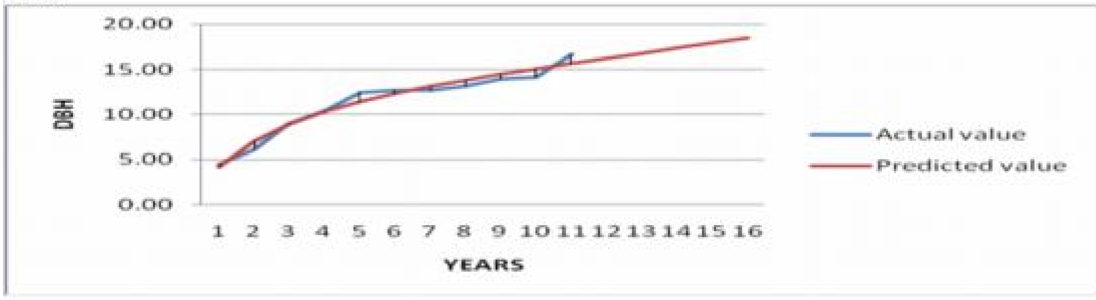


Fig 4.3.3i: Graph showing the actual values and predicted values of Chikkamangalore (S3) x 75:150:75(F3) for dbh growth.

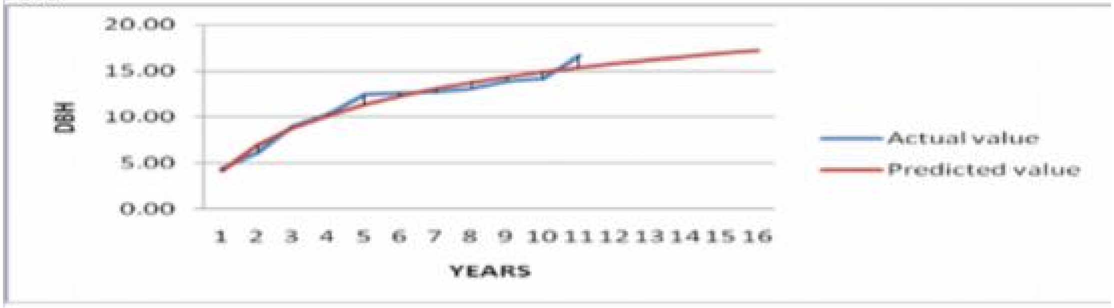
I. Rational Function: y=(-0.892+6.729x)/(1+0.411x-0.007x^2)

Comment:-The Model converged to a tolerance of 0.000001in 10 iterations.No weighting used.



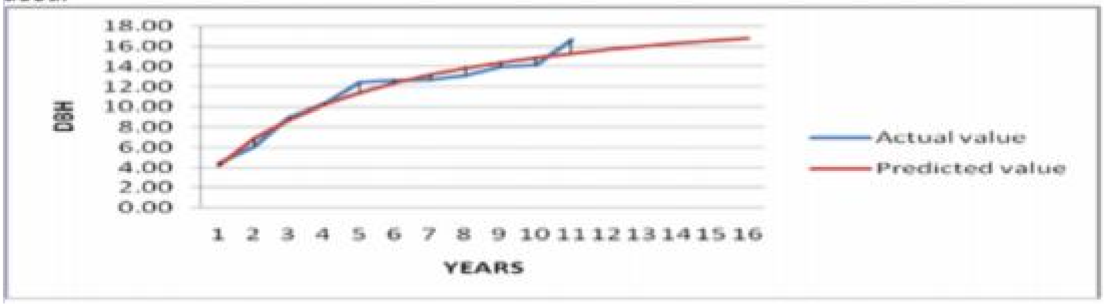
II Weibul Model: y=22.955-27.247*exp(-0.373*x^0.515)

Comment:-The Model converged to a tolerance of 0.000001in 45 iterations.No weighting used.



III MMF Model: y=(0.480*4.595+21.451*x^1.002)/(4.595+x^1.002)

Comment:-The Model converged to a tolerance of 0.000001 in 9 iterations. No weighting used.



IV Richards Model: y=15.349/(1+exp(-1.508-0.377x))^(1/0.117)

Comment:-The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 6.086976). No weighting used.

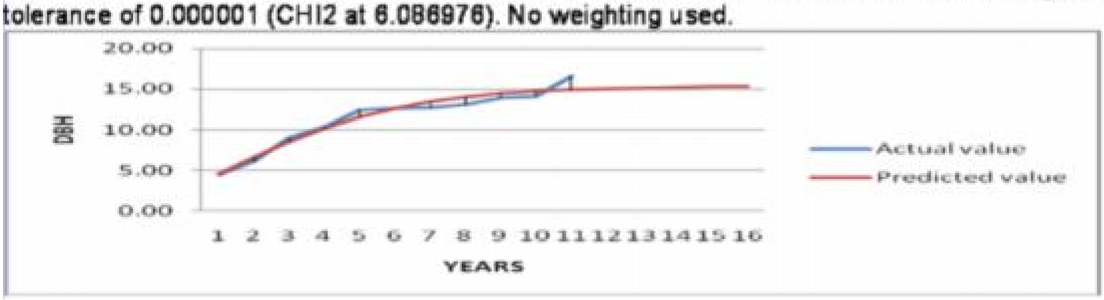
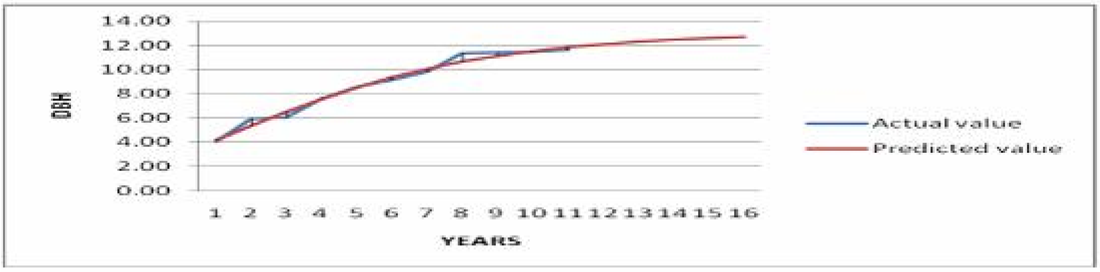
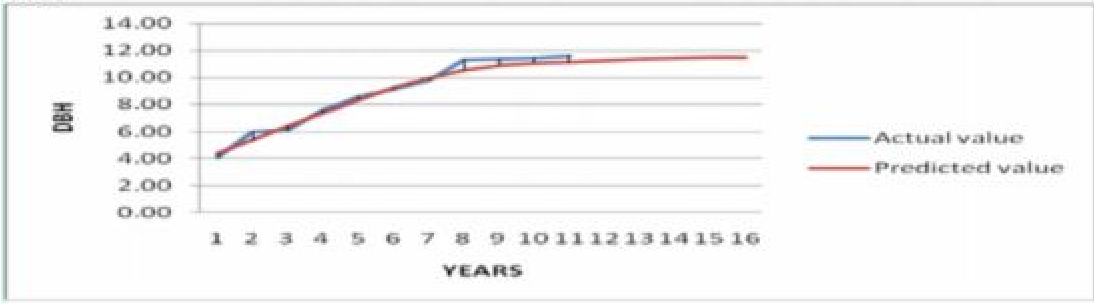


Fig 4.3.3j: Graph showing the actual values and predicted values of Thirthahalli (S4)x25:50:25(F1) for dbh growth of *Acacia mangium*.

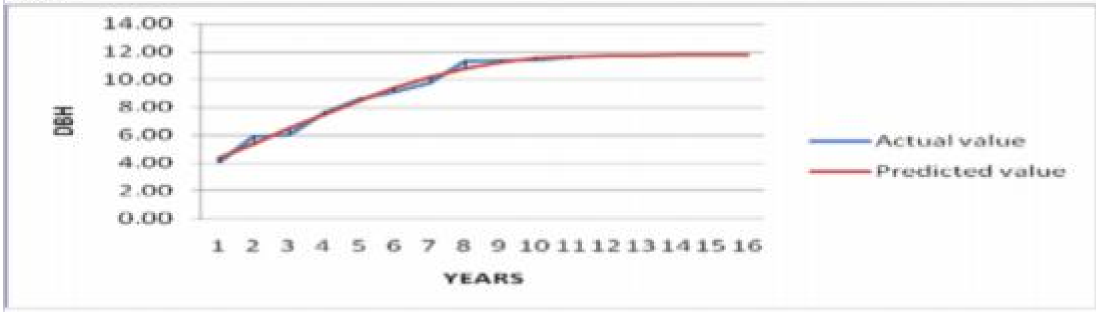
I. Gompertz Relation: y=13.09*exp(-exp(0.372-0.245x))
Comment:-The Model converged to a tolerance of 0.000001 in 3 iterations.No weighting used.



II Rational Function: y=(3.440+0.635x)/(1-0.072x+0.006x^2)
Comment:-The Model converged to a tolerance of 0.000001 in 7 iterations.No weighting used.



III Sinusoidal Model: y=5.908+5.740*cos(0.187x+4.244)
Comment:-The Model converged to a tolerance of 0.000001 in 7 iterations. No weighting used.



IV Richards Model: y=12.194/(1+exp(1.998-0.430x))^(1/1.718)
Comment:-The Model converged to a tolerance of 0.000001 in 21 iteration.No weighting used.

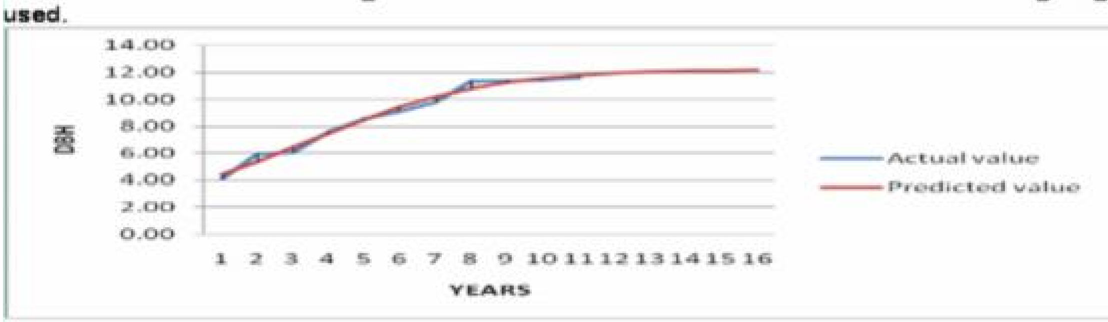
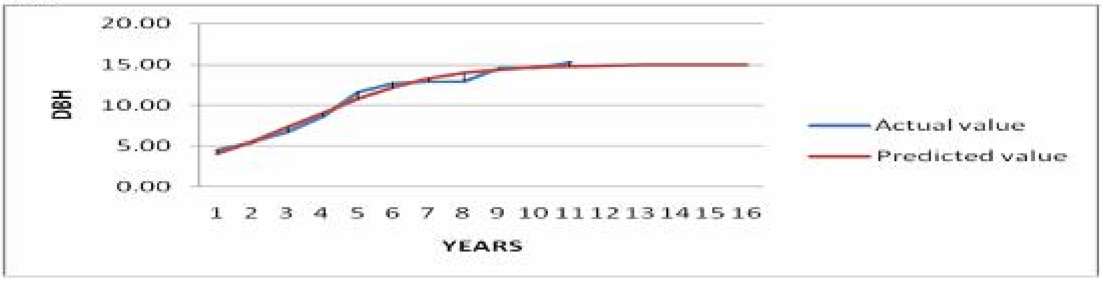


Fig 4.3.3k: Graph showing the actual values and predicted values of Thirthahalli (S4)x50:100:50(F2) for dbh growth of *Acacia mangium*..

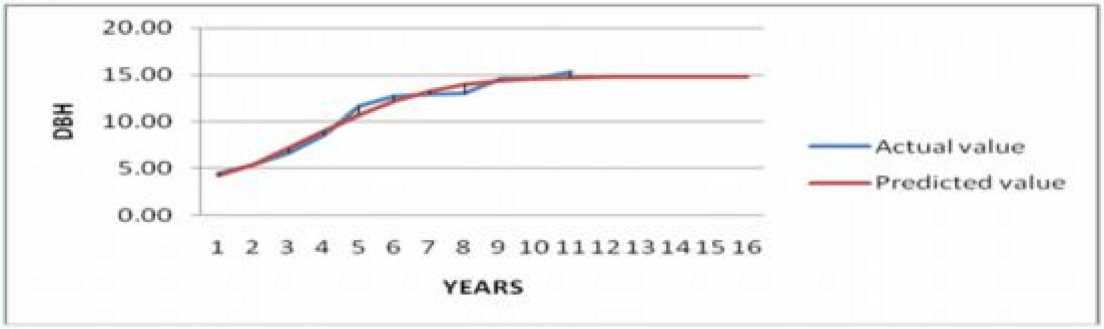
I. Richards Model: $y=14.980/(1+\exp(2.662-0.592x))^{(1/1.682)}$

Comment:The Model converged to a tolerance of 0.000001 in 14 iterations.No weighting used.



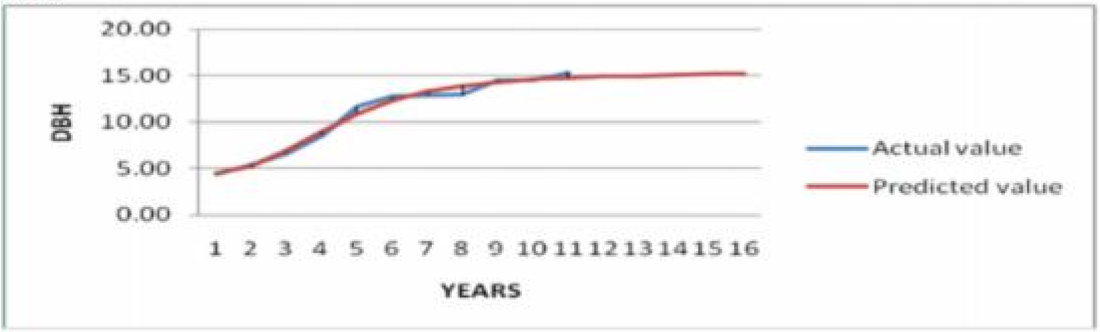
II Weibul Model: $y=14.841-10.999*\exp(-0.039*x^{2.017})$

Comment:The Model converged to a tolerance of 0.000001 in 21 iterations.No weighting used.



III MMF Model: $y=(4.388*108.136+15.401*x^{3.149})/(108.136+x^{3.149})$

Comment:The Model converged to a tolerance of 0.000001 in 31 iterations.No weighting used.



IV Logistic Model: $y=15.283/(1+4.590*\exp(-0.478x))$

Comment:-The Model converged to a tolerance of 0.000001 in 4 iterations. No weighting used.

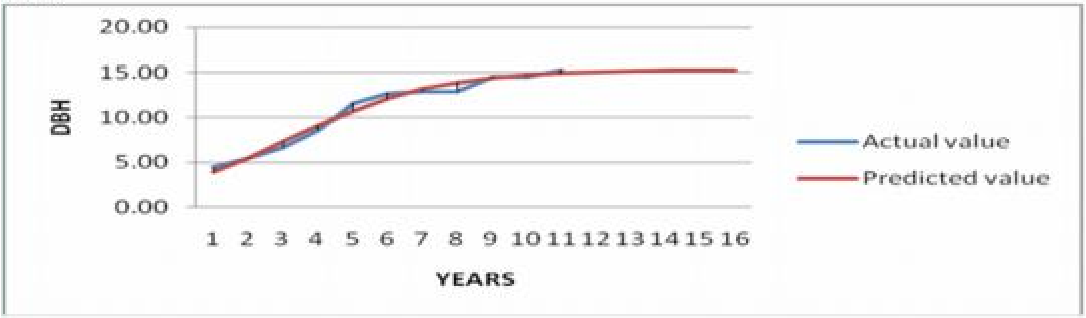
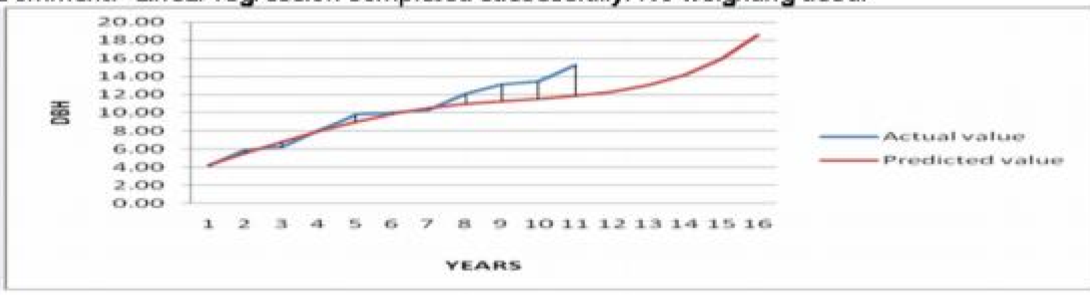


Fig 4.3.3l: Graph showing the actual values and predicted values of Thirthahalli (S4)x75:150:75(F3) for dbh growth of *Acacia mangium*.

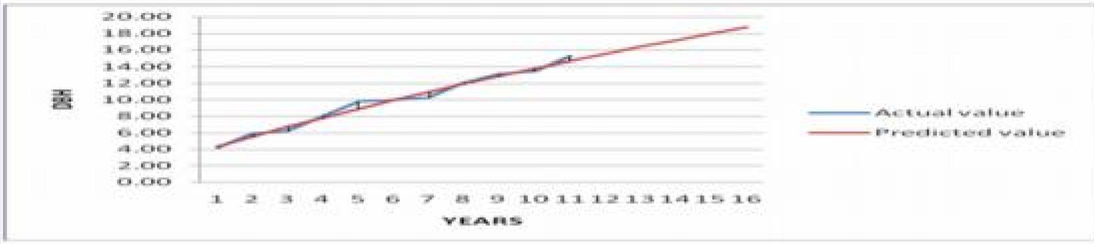
I. Polynomial Model: y=3.032+1.129x+0.102x^2-0.023x^3+0.001x ^4

Comment:- Linear regression completed successfully. No weighting used.



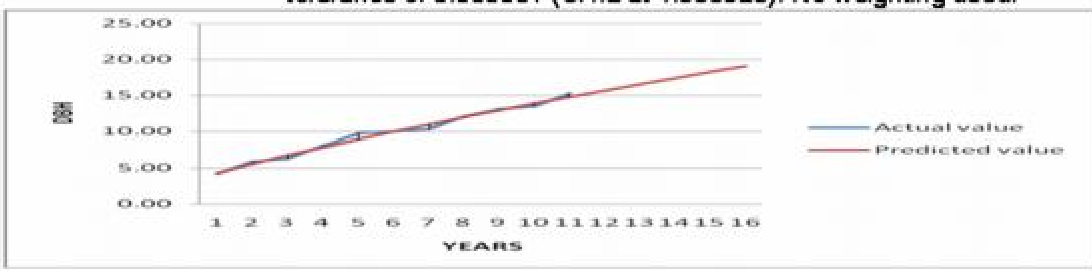
II Weibul Model: y=50.765-47.834*exp(-0.029*x^0.947)

Comment:- The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 1.989755). No weighting used.



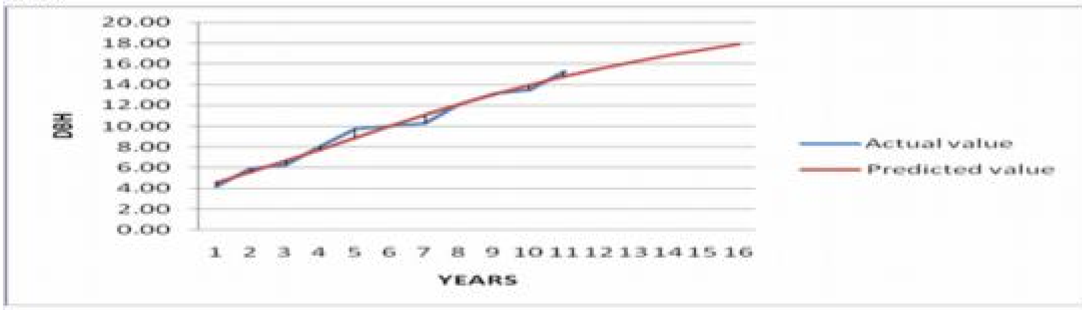
III MMF Model: y=(2.754*119.810+188.822*x^0.881)/(119.810+x^0.881)

Comment: The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 1.959929). No weighting used.



IV Gompertz Relation: y=21.584*exp(-exp(0.585-0.141x))

Comment:The Model converged to a tolerance of 0.000001in 7 iterations. No weighting used.



4.3.1 Growth Models for dbh (spacing and fertilizer level).

In case of first spacing and their combination, 4x1m (SP_1) x No fertilizer (F_0), the best selected Models are Gompertz Model, Logistic Model, MMF Model and Weibul Model. The curve is increasing as shown in fig 4.3.4a.and in case of second combination 4x1m(SP_1) x50:100:50(F_1), the best selected Models are Weibul Model, Richards Model, MMF Model and Logistic Model. The curve is increasing as shown in (fig 4.3.4b).

In case of second spacing and their combination 4x2m (SP_2) x No fertilizer (F_0), the best selected Models are Logistic Model, MMF Model, Weibul Model and Gompertz Model. The curve is increasing as shown in fig 4.3.4c.and in case of fourth combination 4x2m (SP_2) x 50:100:50(F_1), the best selected Models are Rational function, Weibul Model,MMF Model and Logarithm Model. The curve is increasing as shown in fig 4.3.4d.

In case of third spacing and their combination 4x3m (SP_3) xNo fertilizer (F_0), the best selected Models are MMF Model, Logistic Model, Weibul Model and Richards Model. The curve is increasing as shown in fig 4.3.4e.and in case of sixth combination 4x3m(SP_3) x50:100:50 (F_1), the best selected Models are Weibul Model ,MMF Model, Richards Model and Logistic Model. The curve is increasing as shown in fig 4.3.4f.

4.4 Weibul distribution

4.4.1 Weibul distribution for height (Sources, Spacing and Fertilizer level).

For fitting the Weibul distribution for the height, the parameters were estimated using MLE procedure in which the gamma value was estimated using the trial and error method $\left(\frac{\sum_1^n x_i^{\gamma} \ln x_i}{\sum_1^n x_i^{\gamma}} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i = 0$ by substituting the values of x_i (height) and $^{\gamma}$ (it is a value at which the above equation becomes zero) and n is the total no observation, and θ value was obtained using the $\hat{\theta} = \sum_1^n x_i^{\hat{\gamma}}/n$. Where, xi (height) and $\hat{\gamma}$. (estimated gamma value) and n is total no of observation , the obatained parameter values and form of Weibul distribution for all the Sources, spacing and fertilizer level combinations are showed in the tables below.

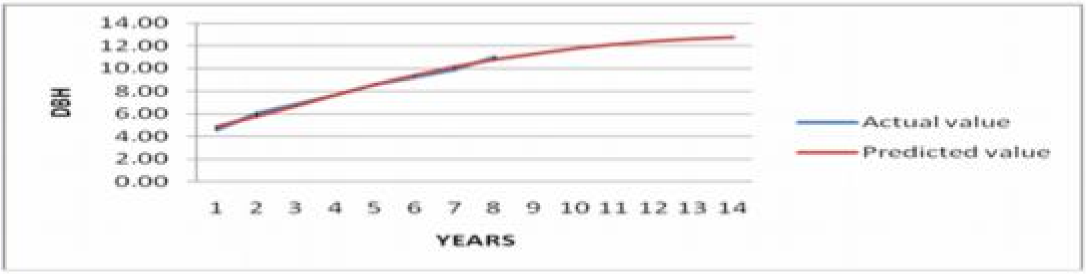
4.4.2 Weibul distribution for dbh (Sources, spacing and fertilizer level).

For Modelting the Weibul distribution for the dbh, the parameters were estimated using MLE procedure in which the gamma value was estimated using the trial and error method $\left(\frac{\sum_1^n x_i^{\gamma} \ln x_i}{\sum_1^n x_i^{\gamma}} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i = 0$ by substituting the values of x_i (height) and $^{\gamma}$ (it is a value at which the equation becomes zero) and n is total no observation , and θ value was obtained using the $\hat{\theta} = \sum_1^n x_i^{\hat{\gamma}}/n$. . where ,$x_i$ (height) and $\hat{\gamma}$ (estimated gamma value) and n is the total no observation , the obatained parameter values and form of Weibul distribution for all the Sources , spacing and fertilizer level combinations are showed in the tables below.

Fig 4.3.4a: Graph showing the actual values and predicted values for of 4x1m(SP1)x No fertilizer(F0) for dbh. growth of *Acacia mangium*.

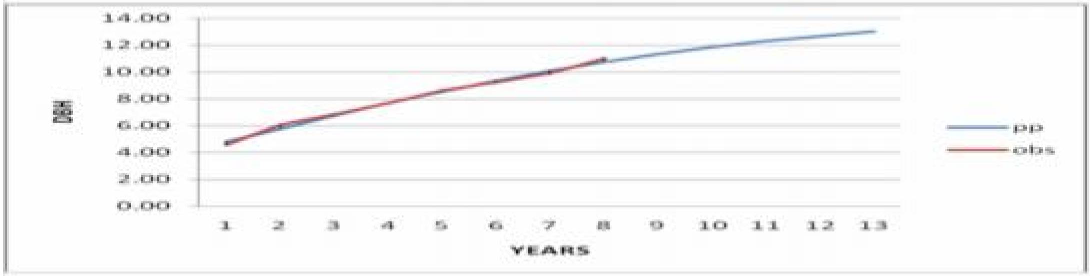
I. Logistic Model: y=13.26/(1+2.29*exp(-0.286x))

Comment:- The Model converged to a tolerance of 0.000001 in 4 iterations. No weighting used.



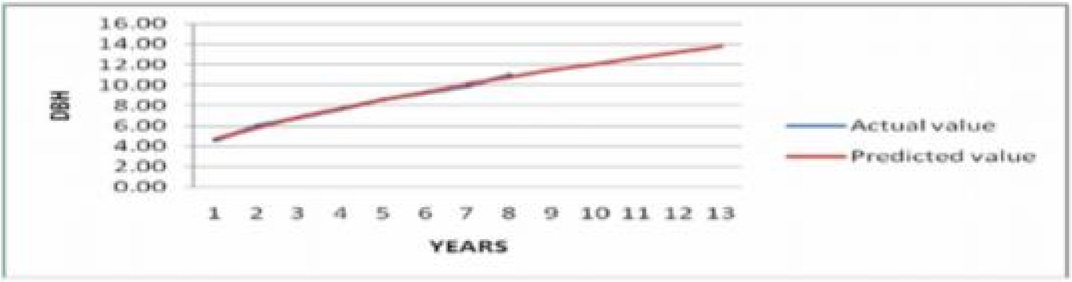
II Gompertz Relation:- y=14.907*exp(-exp(0.299-0.178x))

Comment:-The Model converged to a tolerance of 0.000001 in 4 iterations. No weighting used.



III Weibul Model: y=33.438-30.298*exp(-0.053*x^0.818)

Comment:- The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 0.188426). No weighting used.



IV MMF Model: y=(2.956*70.525+127.392*x^0.748)/(70.525+x^0.748)

Comment:- The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 0.177686). No weighting used.

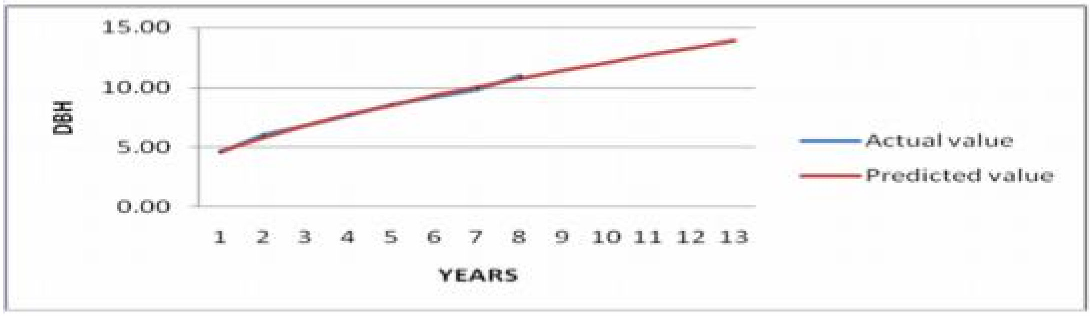
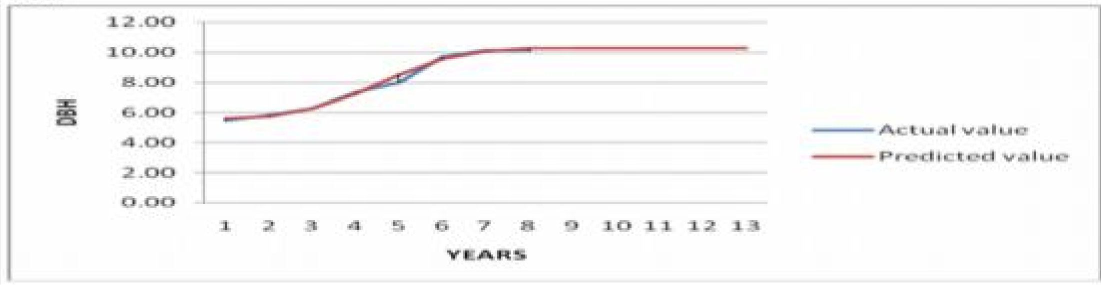


Fig 4.34b: Graph showing the actual values and predicted values for of 4x1m (SP1) x 50:100:50(F1) for dbh growth of *Acacia mangium*.

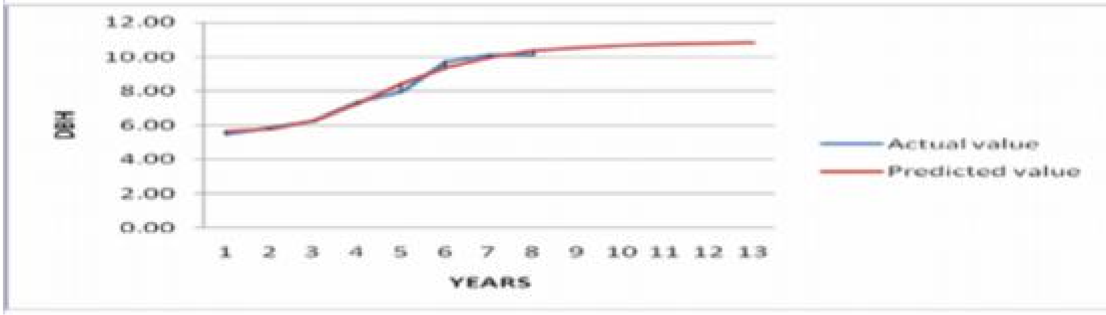
I. Weibul Model: $y=10.272-4.660*\exp(-0.003*x^{3.597})$

Comment:-The Model converged to a tolerance of 0.000001 in 54 iteration.No weighting used.



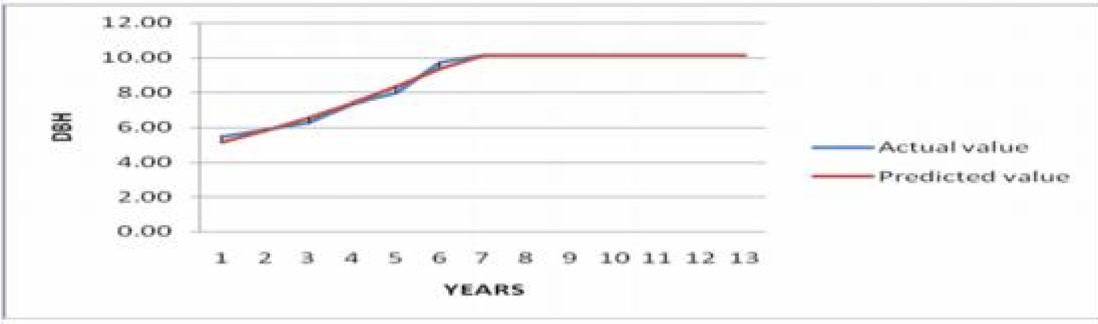
II MMF Model: $y=(5.628*848.945+10.897*x^{4.256})/(848.945+x^{4.256})$

Comment:-The Model converged a tolerance of 0.000001 in 41 iterations.No weighting used.



III Richards Model: $y=10.110/(1+\exp(94.654-14.262x))^{(1/119.718)}$

Comment:The Model converged to a tolerance of 0.000001 in 15 iterations.No weighting used.



IV Logistic Model: $y=15.16/(1+2.399*\exp(-0.211x))$

Comment:- The Model converged to a tolerance of 0.000001 in 15 iterations. No weighting used.

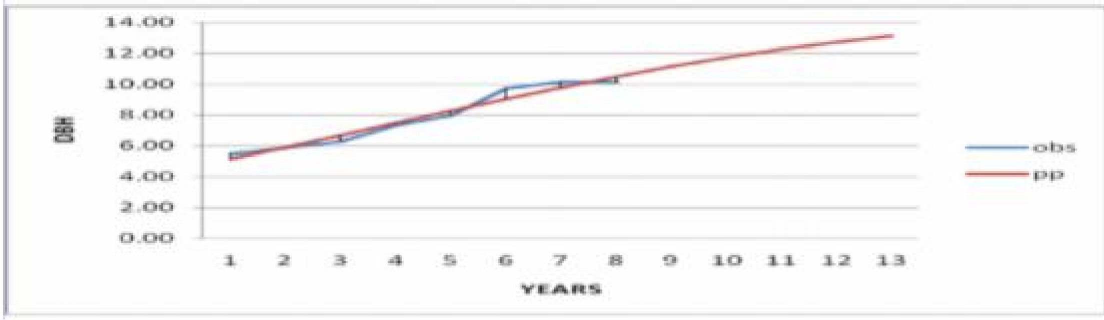
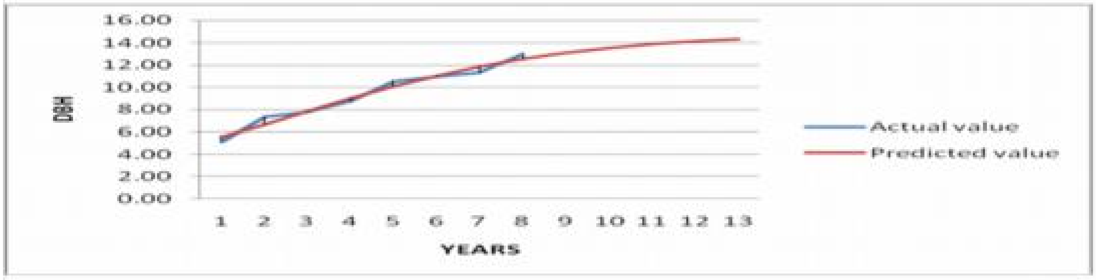


Fig 4.3.4c: Graph showing the actual values and predicted values for 4x2m (SP2) x No fertilizer (F0) for dbh growth of *Acacia mangium*.

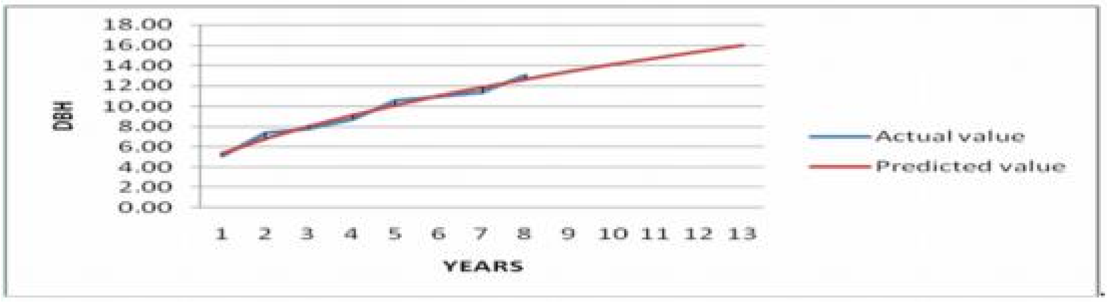
I. Logistic Model: y=14.89/(1+2.288*exp(-0.314x))

Comment:-The Model converged to a tolerance of 0.000001 in 5 iterations. No weighting used.



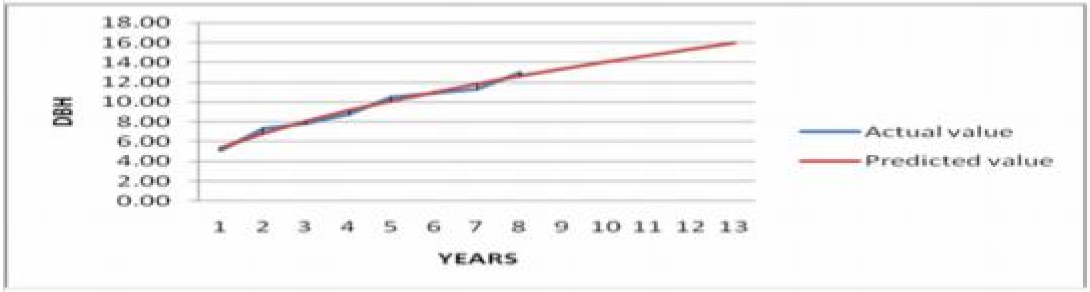
II Weibul Model: y=38.221-35.140*exp(-0.067*x^0.749)

Comment:- The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 1.142952). No weighting used



III MMF Model: y=(3.033*26.953+67.528*x^0.744)/(26.953+x^0.744)

Comment:- The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 1.140932). No weighting used.



IV Gompertz Relation: y=16.416*exp(-exp(0.290-0.203x))

Comment:-The Model converged to a tolerance of 0.000001 in 6 iterations. No weighting used.

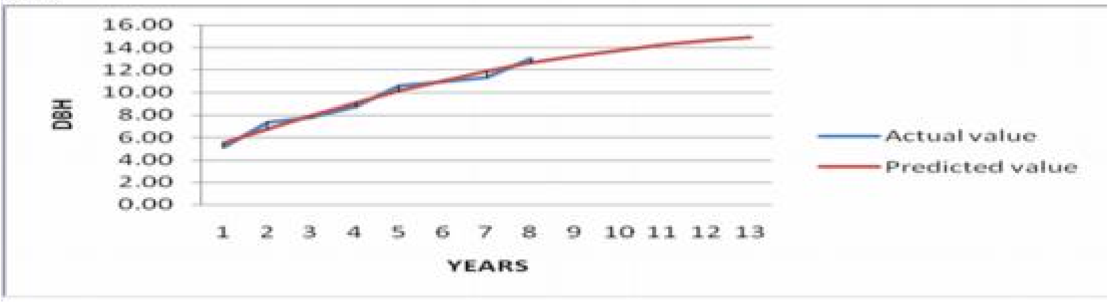
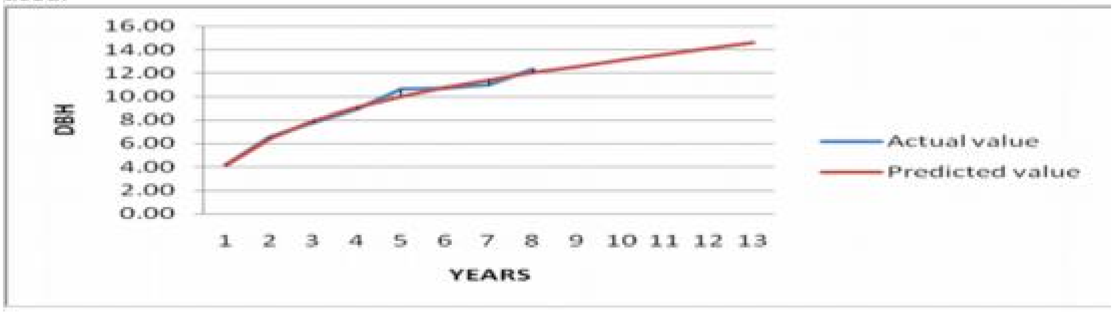


Fig 4.3.4d: Graph showing the actual values and predicted values for 4x2m (SP2) x 50:100:50 (F1) for dbh growth of *Acacia mangium*.

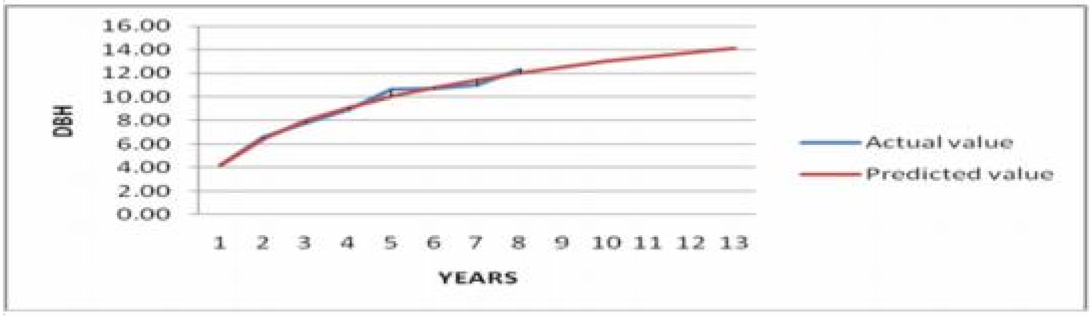
I. Rational Function: $y=(0.259+5.571x)/(1+0.397x-0.007x^2)$

Comment:-The Model converged to a tolerance of 0.000001 in 6 iterations. No weighting used.



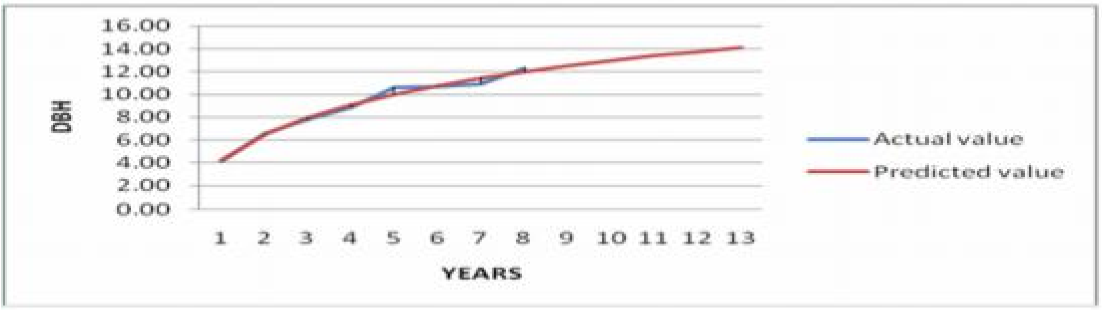
II Weibul Model: $y=22.121-25.774*\exp(-0.363*x^{0.456})$

Comment:- The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 0.772761). No weighting used.



III MMF Model: $y=(2.764*3.612+29.332*x^{0.542})/(3.612+x^{0.542})$

Comment:- The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 0.772652). No weighting used.



IV Logarithm Model: $y=3.971+3.795*\ln(x)$

Comment:-The Model converged to a tolerance of 0.000001 in 2 iterations.No weighting used.

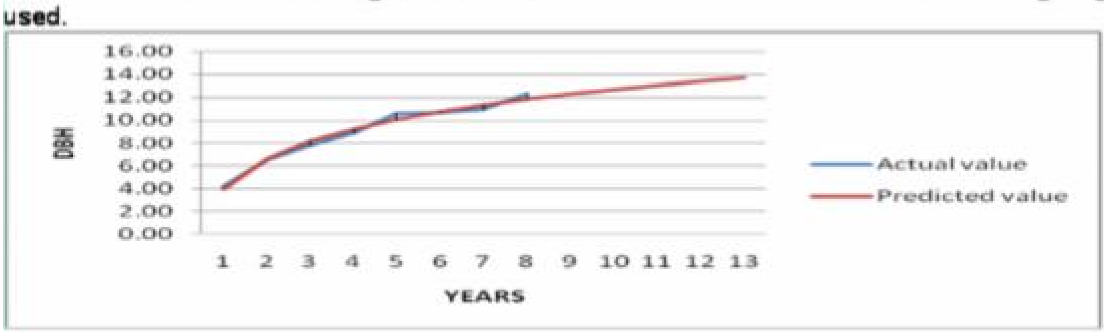
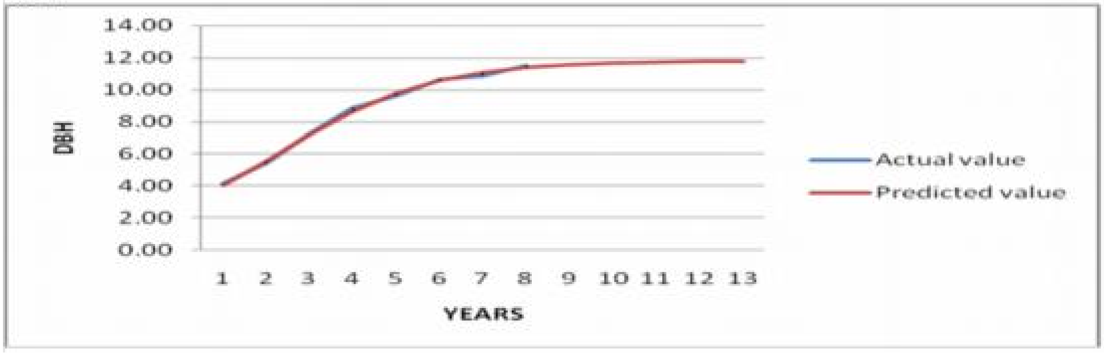


Fig 4.3.4e: Graph showing the actual values and predicted values for 4x3m(SP3) x No fertilizer (F0) for dbh growth of *Acacia mangium*.

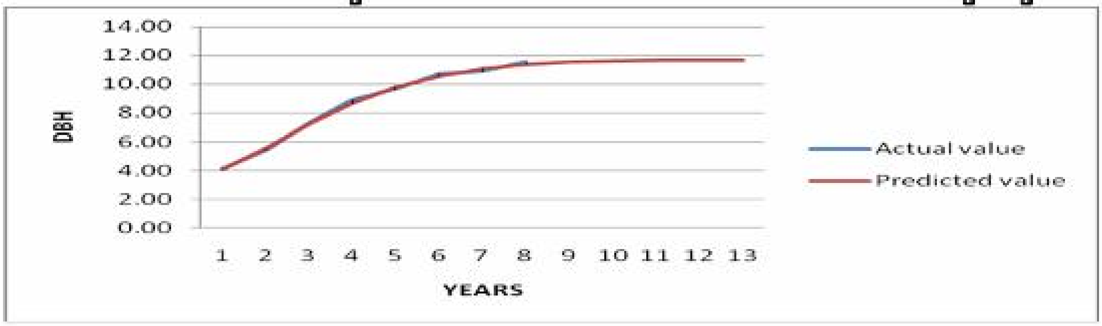
I. Richards Model: y=11.802/(1+exp(1.537-0.585x))^(1/1.196)

Comment:-The Model converged to a tolerance of 0.000001 in 6 iterations.No weighting used.



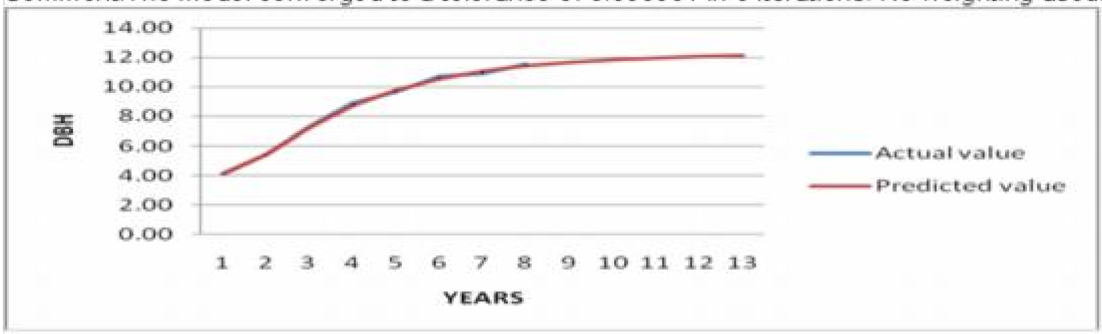
II Weibul Model: y=11.689-8.378*exp(-0.096*x^1.703)

Comment:-The Model converged a tolerance of 0.000001 in 16 iterations.No weighting used.



III MMF Model: y=(3.714*20.985+12.523*x^2.395)/(20.985+x^2.395)

Comment:The Model converged to a tolerance of 0.000001 in 8 iterations. No weighting used.



IV Logistic Model: y=11.875/(1+3.373*exp(-0.552x))

Comment:-The Model converged to a tolerance of 0.000001 in 2 iterations. No weighting used.

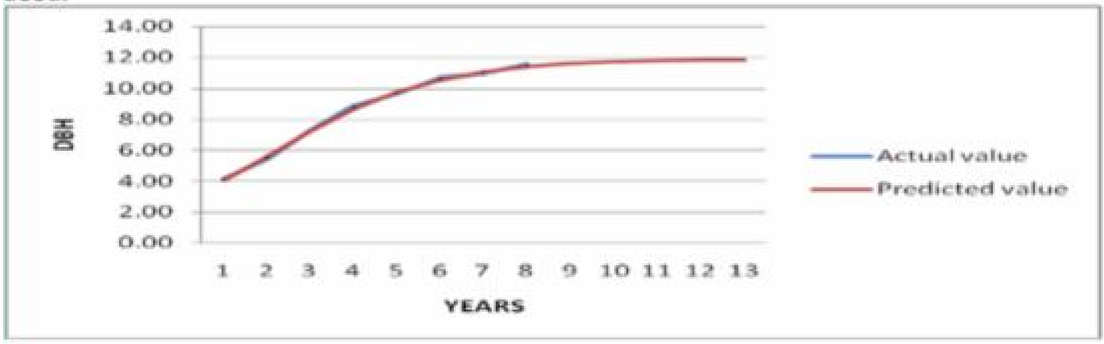
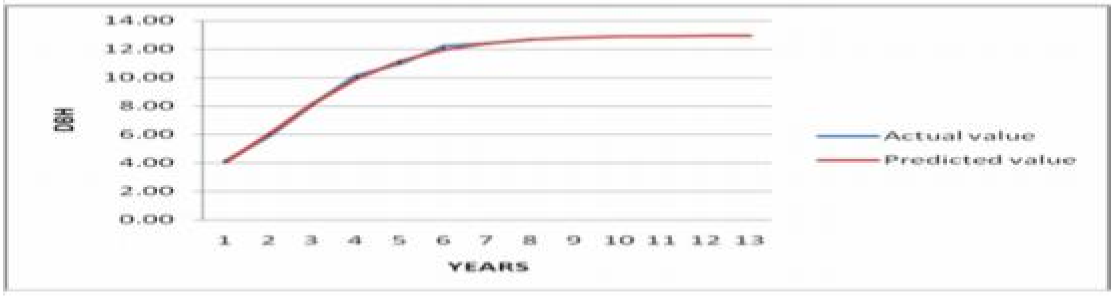


Fig 4.3.4f: Graph showing the actual values and predicted values for 4x3m(SP3) x 50:100:50 (F1) for dbh growth of *Acacia mangium.*

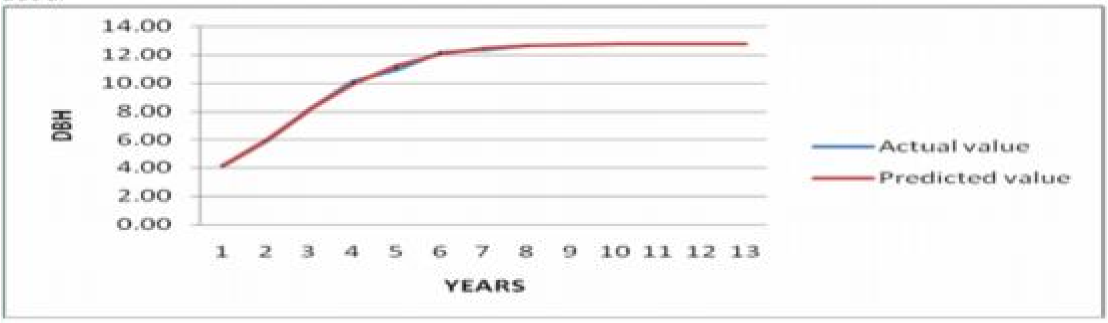
I. Logistic Model: y=12.97/(1+4.25*exp(-0.657x))

Comment:- The Model converged to a tolerance of 0.000001 in 3 iterations. No weighting used..



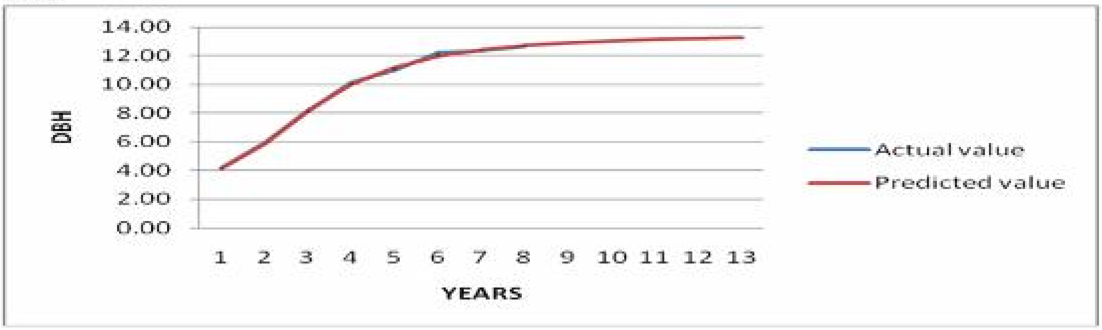
II Weibul Model: y=12.746-9.450*exp(-0.092*x^1.858)

Comment:- The Model converged to a tolerance of 0.000001in 12 iterations. No weighting used.



III MMF Model: y=(3.758*22.797+13.495*x^2.675)/(22.797+x^2.675)

Comment:- The Model converged to a tolerance of 0.000001in 7 iterations. No weighting used.



IV Richards Model: y=12.827/(1+exp(2.281-0.759x))^(1/1.512)

Comment:- The Model converged to a tolerance of 0.000001in 5 iterations. No weighting used.

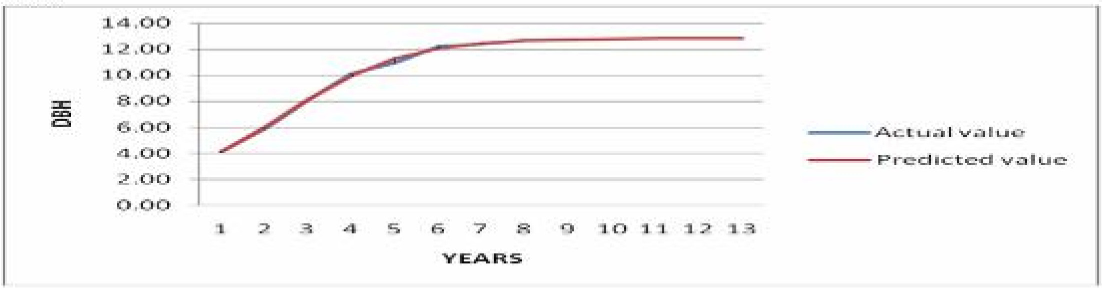


Table 4.4.1. Table showing parameter values and form of Weibul distribution for height

combination	γ	θ	γ/θ	Form: $f(x) = (\gamma/\theta)x_i^{\gamma-1} exp(-x_i^{\gamma}/\theta)$
S_1F_1	4.2	5810.93	0.0007	$f(x) = (0.0007)x_i^{3.2} exp(-x_i^{4.2}/5810.93)$
S_1F_2	4.6	12042.31	0.0004	$f(x) = (0.0004)x_i^{3.6} exp(-x_i^{4.6}/12042.31)$
S_1F_3	4.5	11179.39	0.0004	$f(x) = (0.0004)x_i^{3.5} exp(-x_i^{4.5}/11179.39)$
S_2F_1	4.6	9581.39	0.0005	$f(x) = (0.0005)x_i^{3.6} exp(-x_i^{4.6}/9581.39)$
S_2F_2	5	18465.77	0.0003	$f(x) = (0.0003)x_i^{4} exp(-x_i^{5}/17465.77)$
S_2F_3	4.7	11173.74	0.0004	$f(x) = (0.0004)x_i^{3.7} exp(-x_i^{4.7}/11173.74)$
S_3F_1	4.8	29366.52	0.0002	$f(x) = (0.0002)x_i^{3.8} exp(-x_i^{4.8}/29366.52)$
S_3F_2	4.8	31369.24	0.0002	$f(x) = (0.0002)x_i^{3.8} exp(-x_i^{4.8}/31369.24)$
S_3F_3	4.8	36975.48	0.0001	$f(x) = (0.0001)x_i^{3.8} exp(-x_i^{4.8}/36975.48)$
S_4F_1	3.9	3199.50	0.0012	$f(x) = (0.0012)x_i^{2.9} exp(-x_i^{3.9}/3199.50)$
S_4F_2	4.3	7612.55	0.0006	$f(x) = (0.0006)x_i^{3.3} exp(-x_i^{4.3}/7612.55)$
S_4F_3	3.5	1314.85	0.0027	$f(x) = (0.0027)x_i^{2.5} exp(-x_i^{3.5}/1314.85)$
SP_1F_0	9.2	43645488.25	0.00000021	$f(x)=(0.00000021)x_i^{8.2}exp(x_i^{9.2}/43645488.25)$
SP_1F_1	9.1	36203820.78	0.00000025	$f(x)=(0.00000025)x_i^{8.1}exp(x_i^{9.1}/36203820.78)$
SP_2F_0	6.7	736937.32	0.00000909	$f(x) = (0.0000091)x_i^{5.7} exp(-x_i^{\gamma 6.7}/736937.32)$
SP_2F_1	8.3	9882851.68	0.00000084	$f(x) = (0.00000084)x_i^{7.3}exp(x_i^{8.3}/9882851.68)$
SP_3F_0	6.8	277647.41	0.00002449	$f(x) = (0.0000245)x_i^{5.8} exp(-x_i^{6.8}/277647.41)$
SP_3F_1	6.8	628279.90	0.00001082	$f(x) = (0.0000108)x_i^{5.8} exp(-x_i^{6.8}/628279.9)$

Table 4.4.2. Table showing parameter values and form of Weibul Distribution For dbh

combination	γ	θ	γ/θ	Form
S_1F_1	3.6	6449.62	0.0006	$f(x) = (0.006)x_i^{2.6} exp(-x_i^{3.6}/6449.62)$
S_1F_2	4	16467.93	0.0002	$f(x) = (0.0002)x_i^{3} exp(-x_i^{4}/16467.93)$
S_1F_3	4	15216.61	0.0003	$f(x) = (0.0003)x_i^{3} exp(-x_i^{4}/15216.61)$
S_2F_1	4	12323.79	0.0003	$f(x) = (0.0003)x_i^{3} exp(-x_i^{4}/12323.79)$
S_2F_2	5.1	158188.39	0.00003	$f(x)=(0.00003)x_i^{4.1}exp(x_i^{5.1}/158188.39)$
S_2F_3	4.8	76144.81	0.0001	$f(x) = (0.0001)x_i^{3.8} exp(x_i^{4.8}/76144.81)$
S_3F_1	4.8	87024.75	0.0001	$f(x) = (0.0001)x_i^{3.8} exp(x_i^{4.8}/87024.75)$
S_3F_2	4.3	45635.17	0.0001	$f(x) = (0.0001)x_i^{3.3} exp(x_i^{4.3}/45635.17)$
S_3F_3	4	25322.89	0.0002	$f(x) = (0.0002)x_i^{3} exp(-x_i^{4}/25322.89)$
S_4F_1	4.3	17791.96	0.0002	$f(x) = (0.0002)x_i^{3.3} exp(x_i^{4.3}/17791.96)$
S_4F_2	3.5	6290.65	0.0006	$f(x) = (0.0006)x_i^{2.5} exp(-x_i^{3.5}/6290.65)$
S_4F_3	3.4	3466.25	0.0010	$f(x) = (0.0010)x_i^{2.4} exp(-x_i^{3.4}/3466.25)$
SP_1F_0	4.7	26944.17	0.0002	$f(x) = (0.0002)x_i^{3.7} exp(x_i^{4.7}/26944.17)$
SP_1F_1	5	46593.59	0.0001	$f(x) = (0.0001)x_i^{4} exp(-x_i^{\gamma 5}/46593.59)$
SP_2F_0	4.6	44939.28	0.0001	$f(x) = (0.0001)x_i^{3.6} exp(x_i^{4.6}/44939.28)$
SP_2F_1	4.4	24265.12	0.0002	$f(x) = (0.0002)x_i^{3.4} exp(x_i^{4.4}/24265.12)$
SP_3F_0	4.1	10014.43	0.0004	$f(x) = (0.0004)x_i^{3.1} exp(x_i^{4.1}/10014.43)$
SP_3F_1	3.9	9979.77	0.0004	$f(x) = (0.0004)x_i^{2.9} exp(-x_i^{3.9}/9979.77)$

5. DISCUSSION

The present investigation performed on agroforestry based systems is subjected to some of the statistical analysis viz., Model Modelting, and growth curve Modelting and Modelting of probability distribution. The results of the analysis which is presented in the previous chapter with cross references done under review of literature. The major trends observed and some of the reasons responsible for findings have been discussed in this chapter under following headings.

5.1 Growth curves and growth Models

Models were built in order to predict the height growth and diameter growth of *Acacia mangium* for different Sources, Spacing and fertilizer levels with the help of previous year's growth parameters. Best Models were selected on the basis of higher R^2 (coefficient of determination) values and lower standard error, RMSE. The height and diameter Models developed in this study can be used to predict tree heights and dbh of *Acacia mangium* without measuring in the field. The total variations explained by the generated Models are between 0.923-0.997. This indicated that age is highly influencing on the height/diameter growth. R^2 values were high as 0.997 indicating the significant and larger contribution from age. Non linear growth Models of *Gmelina.Mahoganey and Acacia mangium willd*. Were fitted for height and dbh. The results showed that the total variation explained by generated Models ranges from 81 percent to 99.5 percent (Roscinto lan c. lumbers et al., 2011).

5.1a Growth curves and growth Models for height (Sources and fertilizer level)

For predicting the height for different Sources and fertilizer combination, four Models were initially examined to determine the best height Model for *Acacia mangium plantations*. All the four Models provided very similar results in term of higher R^2 values and lower standard error, RMSE (R^2 value ranged from 0.923 to 0.991, SE ranged from 0.173 to 0.795 and RMSE ranged from 0.171 to 0.702). This indicated that age is highly influencing on the height growth. R^2 values were high as 0.997 indicating the significant and larger contribution from age .This result was found in accordance with (Du ji shan (1998)), where in he fitted the different Models for the basal area prediction and found that the Richards Model is best Model.

For first source and their combinations, for Kerala (S_1) x25:50:25(F_1), Rational Function in which the Model converged to a tolerance of 0.000001 in 11 iterations is being better than other three Models (Weibul Model,MMF Model and Logarithm Model). For the second combination Kerala (S_1) x50:100:50(F_2).

Rational Function in which the Model converged to a tolerance of 0.000001 in 20 iterations is being better than other three Models (Weibul Model, MMF Model and Logarithm Model) and for the third combination Kerala (S_1) x75:150:75(F_3), Rational Function in which the Model converged to a tolerance of 0.000001 in 9 iterations is being better than other three Models (Weibul Model ,Logarithm Model and Richards Model).

For the second source and their combination, Bangalore (S_2) x25:50:25(F_1) Rational Function in which the the Model converged to a tolerance of 0.000001 in 8 iterations is being better than other three Models (Logarithmic Model, MMF Model and Weibul Model), For the second combination Bangalore (S_2) x50:100:50(F_2), Weibul Model in which the iteration count of 100 was exceeded.

The Model failed to converge to tolerance of 0.000001 (CHI2 at 0.263700) is being better than other three Models (Logarithm Model, MMF Model and Rational Function) and for the third combination Bangalore (S_2) x75:150:75(F_3), Rational Function in which the Model converged to a tolerance of 0.000001 in 7 iterations is being better than other three Models (Logarithm Model, Weibul Model, and MMF Model).

For the third source and their combination, Chikkamangalore(S_3) x 25:50:25(F_1) MMF Model in which the Model converged to a tolerance of 0.000001 in 17 iterations is being better than other three Models (Logistic Model, Richards Model and Weibul Model).

For the second combination Chikkamangalore(S_3) x 50:100:50 (F_2), MMF Model in which the Model converged to a tolerance of 0.000001 in 19 iterations is being better than other three Models (Logistic Model, Gompertz Model and Richards Model)and for the third combination Chikkamangalore(S_3) x75:150:75(F_3), MMF Model in which the Model converged to a tolerance of 0.000001 in 19 iterations is being better than other three Models (Logistic Model, Gompertz Model and Richards Model).

For the fourth source and their combination, Thirthahalli(S_4) x 25:50:25(F_1) Rational Function in which the Model converged to a tolerance of 0.000001 in 8 iterations being better than other three Models (Logarithm Model, Weibul Model and MMF Model). For the second combination Thirthahalli(S_4) x50:100:50(F_2), MMF Model in which the Model converged to a tolerance of 0.000001 in 8 iterations is being better than other three Models (Gompertz Model, Rational Function and Weibul Model) and for the third combination Thirthahalli(S_4) x 75:150:75(F_3), MMF Model in which the iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 3.040798) being better than other three Models (Logarithm Model, Weibul Model, and sinusoidal Model).

5.1b Growth curves and growth Models for height (spacing and fertilizer level)

For predicting the height with respect to spacing and fertilizer combination, four Models were initially examined to determine the best height Model for *Acacia mangium plantations*. All the four Models provided very similar results in term of higher R^2 values and lower standard error and RMSE.(R^2 value ranged from 0.934 to 0.997 , SE from 0.07 to 0.4 and RMSE ranged from0.068 to 0.720). This indicated that age is highly influencing on the height growth. R^2 values were high as 0.997 indicating the significant and larger contribution from age.

For first combination,4x1m(SP_1)xNo fertilizer(F_0) Rational Function in which the Model converged to a tolerance of 0.000001 in 16 iterations is better than other three Models (Logarithm Model, Weibul Model and MMF Model) and for combination 4x1m(SP_1) x50:100:50(F_1), Rational Function in which the Model converged to a tolerance of 0.000001 in 14 iterations is being better than other three Models (MMF Model, Weibul Model and Richards Model).

For the second combination 4x2m(SP_2) x No fertilizer (F_0), Rational Function in which the Model converged to a tolerance of 0.000001 in 16 iterations is better than other three Models (Logarithm Model, Weibul Model and MMF Model) and for combination, 4x2m(SP_2) x 50:100:50(F_1) Weibul Model in which The iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 0.291585) is being better than other three Models (Logarithm Model, MMF Model and Gompertz Model).

For the third combination 4x3m (SP_3) xNo fertilizer (F_0), Rational function The Model converged to a tolerance of 0.000001 in 7 iterations is being better than other three Models (Logarithm Model , Weibul Model and MMF Model) and for combination 4x3m(SP_3) x50:100:50 (F_1), Rational Function in which the Model converged to a tolerance of 0.000001 in 8 iterations is being better than other three Models (Logarithm Model, Weibul Model and MMF Model).

5.1c Growth curves and growth Models for dbh (Sources and fertilizer level)

For predicting the dbh growth with respect to Sources and fertilizer level combination, four Models were initially examined to determine the best dbh growth Model for *Acacia mangium plantations*. All the four Models provided very similar results in term of higher R^2 values and lower standard error (R^2 value ranged from 0.923 to 0.991, SE from 0.173 to 0.795 and RMSE ranged from 0.220 to 0.821). This indicated that age is highly influencing on the diameter growth. R^2 values were high as 0.991 indicating the significant and larger contribution from age .This result was found in accordance with (Du ji shan (1998)), where in he fitted the different Models for the basal area prediction and found that the Richards Model is best Model.

For first source and their combination, Kerala (S_1) x25:50:25(F_1), MMF Model in which the iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 1.867495) is being better than other three Models (Rational Function, Weibul Model, and polynomial Model). For the second combination Kerala (S_1) x50:100:50(F_2), Rational Function in which the Model converged to a tolerance of 0.000001 in 7 iterations is being better than other three Models (MMF Model, Weibul Model and Logarithm Model) and for the third combination Kerala (S_1) x75:150:75(F_3), Rational function in which the Model converged to a tolerance of 0.000001 in 7 iterations being better than other three Models (Sinsoidol Model, Weibul Model and MMF Model).

For the second source and their combination,Bangalore(S_2) x25:50:25(F_1) Rational function in which the Model converged to a tolerance of 0.000001 in 5 iterations is being better than other three Models (Weibul Model, MMF Model and Logarithm Model),For the second combination Bangalore(S_2)x50:100 :50 (F_2), MMF Model in which the Model converged to a tolerance of 0.000001 in 6 iterations is being better than other three Models (Gompertz Model, Weibul Model and Rational Function) and for the third combination Bangalore(S_2) x75:150:75(F_3), Weibul Model in which the Model converged to a tolerance of 0.000001 in 6 iterations is being better than other three Models (Rational function, MMF Model and Gompertz Model).

For the third source and their combination, Chikkamangalore (S_3) x 25:50:25(F_1), MMF Model in which the the Model converged to a tolerance of 0.000001 in 7 iterations is being better than other three Models (Rational function, Weibul Model and Logarithm Model), For the second combination Chikkamangalore(S_3) x 50:100:50 (F_2) , MMF Model in which the Model converged to a tolerance of 0.000001 in 21 iterations is being better than other three Models (Gompertz Model, Weibul Model and Rational function) and for the third combination Chikkamangalore (S_3)x75:150:75(F_3) , Rational function in which the Model converged to a tolerance of 0.000001 in 10 iterations is being better than other three Models (MMF Model , Weibul Model and Rational function).

For the fourth source and their combination, Thirthahalli(S_4) x 25:50:25(F_1), Sinusoidal Model in which the Model converged to a tolerance of 0.000001 in 7 iterations is being better than other three Models (Gompertz Model, Rational function and Richards Model), For the second combination Thirthahalli(S_4) x50:100:50(F_2), MMF Model in which the Model converged to a tolerance of 0.000001 in 31 iterations is being better than other three Models (Logistic Model, Weibul Model and Richards Model)and for the third combination Thirthahalli(S_4) x 75:150:75(F_3), MMF Model in which the iteration count of 100 was exceeded and the Model failed to converge to tolerance of 0.000001 (CHI2 at 1.959929) being better than other three Models (polynomial Model, Weibul Model, and Gompertz Model).

5.1d Growth curves and growth Models for dbh (spacing and fertilizer level)

For predicting the dbh with respect to different spacing and the fertilizer level combination, four Models were initially examined to determine the best dbh growth Model for *Acacia mangium plantations*. All the four Models provided very similar results in term of higher R^2 values and lower standard error (R^2 value ranged from 0.934 to 0.997, SE from 0.07 to 0.4 and RMSE ranged from 0.161 to 0.465). This indicated that age is highly influencing on the diameter growth. R^2 values were high as 0.997 indicating the significant and larger contribution from age .This result was found in accordance with (Du ji shan (1998)), where in he fitted the different Models for the basal area prediction and found that the Richards Model is best Model.

For first combination, 4x1m (SP_1) xNo fertilizer (F_0), MMF Model in which the Model the iteration counts of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 0.177686) is being better than other three Models (Gompertz Model, Logistic Model and Weibul Model) and for combination 4x1m(SP_1)x50:100:50(F_1), Weibul Model in which the Model converged to a tolerance of 0.000001 in 54 iterations is being better than other three Models (Richards and MMF Model) .

For the second combination 4x2m (SP_2) x No fertilizer (F_0), MMF Model in which the the iteration count of 100 was exceeded. The Model failed to converge to tolerance of 0.000001 (CHI2 at 1.140932) is being better than other three Models (Logistic Model, Weibul Model and Gompertz Model) and for combination, 4x2m (SP_2) x 50:100: 50 (F_1), Rational function in which the Model converged to a tolerance of 0.000001 in 6 iterations is being better than other three Models (Weibul Model, MMF Model and Logarithm Model).

For the third combination 4x3m(SP_3) xNo fertilizer(F_0), MMF Model in which the Model converged to a tolerance of 0.000001 in 8 iterations is being better than other three Models (Logistic Model, Weibul Model and Richards Model) and for the combination 4x3m(SP_3) x50:100:50 (F_1), Weibul Model in which the Model converged to a tolerance of 0.000001 in 12 iterations is being better than other three Models (MMF, Richards and polynomial Model).

5.2 Probability Distribution.

The Weibul distribution, has been applied extensively in forestry due to its ability to describe a wide range of unimodal distributions and the relative simplicity of parameter estimation, and its closed cumulative density functional form (e.g. Bailey, Dell 1973; Schreuder, Swank 1974; Schreuder et al. 1979; Little 1983; Rennolls et al. 1985; Mabvurira et al. 2002), and its previous success in describing diameter frequency distributions within different stand types (e.g. Bailey, Dell 1973; Little 1983; Kilkki et al. 1989; Liu et al. 2004; Newton et al. 2004, 2005).the parameters were estimated using the Maximum likelihood equation (MLE) through the trial and error method and than the Weibul distribution was Fitted for both height and dbh.

5.2a Weibul distribution for height (Sources, spacing and fertilizer level)

The Weibul distribution was also Fitted for height with respect to Sources, spacing and fertilizer level combination, the parameters were estimated using Maximum likelihood equation (MLE) . In case of first source and their combinations, Kerala (S_1) x25:50:25(F_1), the gamma value was obtained trial and error method, the value started from 0.01 to 4.2. At 4.2 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 4.2. The second parameter teta was obtained using the gamma value as $\hat{\theta} = \sum_1^n x_i^{\hat{\gamma}}/n$ and obtained θ value was 5810.93. For Kerala (S_1) x50:100:50 (F_2), the gamma value started from 0.01 to 4.6. At 4.6 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 4.6. The second parameter θ was obtained using the gamma value as $\hat{\theta} = \sum_1^n x_i^{\hat{\gamma}}/n$ and obtained θ value was 12042.31.and in case of Kerala (S_1) x75:150:75(F_3), the gamma value started from 0.01 to 4.5. At 4.5 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 4.5. The second parameter θ was obtained using the gamma value as $\hat{\theta} = \sum_1^n x_i^{\hat{\gamma}}/n$ and obtained θ value was 11179.39.

In case of second source and their combination, Bangalore (S_2) x25:50:25(F_1), the gamma value started from 0.01 to 4.6. At 4.6 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$, tends to zero hence the gamma value was 4.6. And using the γ value. The obtained θ value was 9581.39. In case of Bangalore (S_2) x 50:100:50(F_2), the gamma value started from 0.01 to 5. At 5 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 5. And using the γ value the obtained θ value was 17465. And for Bangalore (S_2) x75:150:75(F_3), the gamma value started from 0.01 to 4.7. At 4.7 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 4.7. And using the γ value the obtained θ value was 11173.74.

In case of third source and their combination, Chikkamangalore (S_3) x 25:50:25(F_1), the gamma value started from 0.01 to 4.8. At 4.8 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 4.8. And using the γ value the obtained θ value was 29366.52. In case of Chikkamangalore (S_3) x 50:100:50 (F_2), the gamma value started from 0.01 to 4.8. At 4.8 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 4.8. And using the γ value the obtained θ value was 31369 and in case of Chikkamangalore(S_3) x 75:150:75(F_3) , the gamma value started from 0.01 to 4.8. At 4.8 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 4.8. And using the γ value the obtained θ value was 36975.

In case of fourth source and their combination, Thirthahalli (S_4) x 25:50:25(F_1), the gamma value started from 0.01 to 4.2. At 4.2 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 4.2. And using the γ value the obtained θ value was 3199. In case of Thirthahalli (S_4) x50:100:50(F_2), the gamma value started from 0.01 to 4.3. At 4.3 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 4.3. And using the γ value the obtained θ value was 7612.55. And for Thirthahalli (S_4) x 75:150:75(F_3), the gamma value started from 0.01 to 3.5. At 3.5 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 3.5. And using the γ value the obtained θ value was 1314.85.

In case of spacing and fertilizer level combinations for height. For 4x1m (SP_1) x No fertilizer(F_0),the gamma value started from 0.01 to 9.2. At 9.2 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 9.2. And using the γ value the obtained θ value was 43645488. And in case of 4x1m (SP_1) x 50:100:50(F_1), the gamma value started from 0.01 to 9.1. At 9.1 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 9.1. And using the γ value the obtained θ value was 36203820.

In case of second spacing and their combination, 4x2m (SP_2) x No fertilizer (F_0), the gamma value started from 0.01 to 6.7. At 6.7 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 6.7. And using the γ value the obtained θ value was 736937. And in case of 4x2m (SP_2) x 50:100:50(F_1), the gamma value started from 0.01 to 8.3. At 8.3 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 8.3. and using the γ value the obtained θ value was 9882851.68.

In case of third spacing and their combination 4x3m (SP_3) xNo fertilizer (F_0) the gamma value started from 0.01 to 6.8. At 6.8 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 4.8. And using the γ value the obtained θ value was 277647 and in case of 4x3m(SP_3) x50:100:50 (F_1), the gamma value started from 0.01 to 6.8. At 6.8 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 6.8. And using the γ value the obtained θ value was 628279.

5.2b. Weibul distribution for dbh (Sources, spacing and fertilizer level).

The Weibul distribution was also Fitted for dbh with respect to Sources, spacing and fertilizer level combination, the parameters were estimated using Maximum likelihood equation (MLE) .

In case of first source and their combinations, Kerala (S_1) x 25:50:25(F_1) the gamma value started from 0.01 to 3.6. At 3.6 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 3.6. And using the γ value the obtained θ value was 6449. In case of Kerala (S_1) x50:100:50(F_2), the gamma value started from 0.01 to 4. At 4 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 4. And using the γ value the obtained θ value was 16467. And in case of Kerala (S_1) x75:150:75(F_3), the gamma value started from 0.01 to 4. At 4 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 4. And using the γ value the obtained θ value was 15216.61.

In case of second source and their combination, Bangalore (S_2) x25:50:25(F_1), the gamma value started from 0.01 to 4. At 4 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 4. And using the γ value the obtained θ value was 12323.79. In case of Bangalore (S_2) x50:100:50(F_2), the gamma value started from 0.01 to 5.1. At 5.1 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 5.1. And using the γ value the obtained θ value was 158188. And in case of Bangalore (S_2) x75:150:75(F_3), the gamma value started from 0.01 to 4.8. At 4.8 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 4.8. And using the γ value the obtained θ value was 76144.81.

In case of third source and their combination, Chikkamangalore (S_3) x 25:50:25(F_1), the gamma value started from 0.01 to 4.8. At 4.8 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 4.8. And using the γ value the obtained θ value was 87024 . In case of Chikkamangalore (S_3) x 50:100:50 (F_2), the gamma value started from 0.01 to 4.3. At 4.3 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 4.3. And using the γ value the obtained θ value was 45635.and in case of Chikkamangalore(S_3) x75:150:75(F_3), the gamma value started from 0.01 to 4. At 4 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 4. And using the γ value the obtained θ value was 25322.

In case of fourth source and their combination, Thirthahalli (S_4) x 25:50:25(F_1), the gamma value started from 0.01 to 4.3. At 4.3 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 4.3. And using the γ value the obtained θ value was 17791.96. In case of Thirthahalli (S_4)x 50:100:50(F_2), the gamma value started from 0.01 to 3.5. At 3.5 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 3.5. And using the γ value the obtained θ value was 6290.65. And in case of Thirthahalli (S_4) x 75:150:75(F_3), the gamma value started from 0.01 to 3.4. At 3.4 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 3.4. And using the γ value the obtained θ value was 3466.

In case of spacing and fertilizer, for first spacing and their combination 4x1m (SP_1) xNo fertilizer (F_0), the gamma value started from 0.01 to 4.7. At 4.7 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 4.7 And using the γ value the obtained θ value was 26944. And in case of combination 4x1m (SP_1) x 50:100:50(F_1).

The gamma value started from 0.01 to 5. At 5 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 5. And using the γ value the obtained θ value was 46593.59.

In case of second spacing and their combination 4x2m (SP_2) x No fertilizer (F_0), the gamma value started from 0.01 to 4.6. At 4.6 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 4.6. And using the γ value the obtained θ value was 44939.28. And in case of combination 4x2m (SP_2) x 50:100:50(F_1), the gamma value started from 0.01 to 4.4. At 4.4 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 4.4. And using the γ value the obtained θ value was 24265.12.

In case of third spacing and their combination 4x3m (SP_3) xNo fertilizer (F_0), the gamma value started from 0.01 to 4.1. At 4.1 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 4.1. And using the γ value the obtained θ value was 10014.43. And in case of combination 4x3m (SP_3) x50:100:50 (F_1), the gamma value started from 0.01 to 3.9. At 3.9 this equation $\left(\frac{\sum_1^n x_i^\gamma \ln x_i}{\sum_1^n x_i^\gamma} - \frac{1}{\gamma}\right) - \frac{1}{n}\sum_1^n \ln x_i$ tends to zero hence the gamma value was 3.9. And using the γ value the obtained θ value was 9979.77.

6. SUMMARY AND CONCLUSIONS

Agroforestry is one of the most widely practiced land-use system in the world, in which woody perennials are grown in association with herbaceous plants and /or livestock in spatial and temporal arrangement. Thus the term 'agroforestry' encompasses a diverse set of integrated land use practices employed for variety of purposes. To increase interest in agroforestry practices, reliable predictive tools are needed to forecast system outcomes with reasonable accuracy. Therefore a statistical study has been made in order to reveal the relationship of different combinations on height and diameter of *Acacia mangium*. The data on different Sources, spacing and fertilizer level combinations was collected from AICRP on Agroforestry, University of Agricultural Sciences, Dharwad.

Different prediction Models namely polynomial, Gaussian, Sinusoidal, Richards, Weibul, Rational, MMF, Logistic, Logarithm, and Gompertz Model, etc., have been tried to predict the height and diameter growth of different trees.

Out of different Models were tried for predicting height growth of *Acacia mangium* with different Sources and fertilizer levels, for first source and their combination, Kerala (S_1) x25:50:25(F_1), Kerala (S_1) x50:100:50(F_2) and Kerala (S_1) x75:150:75(F_3), Rational function is the best Model fallowed by Weibul Model. This indicates that we can use above Models to predict the height. Among these three combinations S_1F_1 is the best combination fallowed by S_1F_2 and S_1F_3 (based on highest R^2 value and lower RMSE, SE). For the second source and their combination, Bangalore (S_2) x25:50:25(F_1) and Bangalore (S_2) x75:150:75(F_3), Rational function and for Bangalore (S_2) x50:100:50(F_2), Weibul Model is the best Model. This indicates that we can use above Models to predict the height. Among these three combinations S_2F_2 is the best combination fallowed by S_2F_3 and S_2F_1 (based on highest R^2 value and lower RMSE, SE). For the third source and their combination, Chikkamangalore (S_3) x 25:50:25(F_1), Chikkamangalore (S_3) x 50:100:50 (F_2) and Chikkamangalore (S_3) x75:150:75(F_3), MMF Model was the best Model. This indicates that we can use above Model to predict the height. Among these three combinations S_3F_1 is the best combination fallowed by S_3F_2 and S_3F_3 (based on highest R^2 value and lower RMSE, SE). For the fourth source and their combination, Thirthahalli (S_4) x50:100:50(F_2), and Thirthahalli (S_4) x 75:150:75(F_3), MMF Model was the best Model and Thirthahalli (S_4) x 25:50:25(F_1) for Rational function is the best Model. This indicates that we can use above Models to predict the height. Among these three combinations S_4F_1 is the best combination fallowed by S_4F_2 and S_4F_3 (based on highest R^2 value and lower RMSE, SE). Among all the Sources S_2F_2 is the best source for height.

For spacing and fertilizer levels, for first combination, 4x1m(SP_1)xNo fertilizer(F_0) and 4x1m(SP_1)x50:100:50(F_1) Rational Function is the best Model. This indicates that we can use Rational function to predict the height. Among these two combinations SP_1F_1 is the best combination fallowed by SP_1F_O (based on highest R^2 value and lower RMSE, SE). For the second spacing and combinations 4x2m (SP_2) x No fertilizer (F_0), Rational function and for 4x2m (SP_2) x 50:100:50(F_1), Weibul Models is the best Model. This indicates that we can use above Model to predict the height. Among these two combinations SP_2F_1 is the best combination fallowed by SP_2F_0 (based on highest R^2 value and lower RMSE, SE). For the third spacing and combination 4x3m (SP_3) xNo fertilizer (F_0), and for 4x3m (SP_3) x50:100:50 (F_1), Rational Function is the best Model. This indicates that we can use the Rational function to predict the height. Among these two combinations SP_3F_0 is the best combination fallowed by SP_3F_1 (based on highest R^2 value and lower RMSE, SE). Among all the spacing SP_3F_0 is the best spacing for height.

For dbh growth of *Acacia mangium* with different Sources and fertilizer levels, for first source and their combination, Kerala (S_1) x50:100:50 (F_2) and Kerala (S_1) x75:150:75(F_3), Rational function is the best Model and for Kerala (S_1) x25:50:25(F_1), MMF Model is the best Model. This indicates that we can use above Models to predict the dbh. Among these three combinations S_1F_3 is the best combination fallowed by S_1F_2 and S_1F_1 (based on highest R^2 value and lower RMSE, SE). For the second source and their combinations, for Bangalore (S_2) x25:50:25(F_1) Rational function is the best Model and for Bangalore (S_2) x50:100:50(F_2), MMF Model is the best Model and Bangalore (S_2) x75:150:75(F_3) Weibul Model is the best Model.This indicates that we can use above Models to predict the height.

Among these three combinations S2F2 is the best combination fallowed by S_2F_3 and S_2F_1 (based on highest R^2 value and lower RMSE, SE). For the third source and their combination, Chikkamangalore (S_3) x 25:50:25(F_1) and Chikkamangalore (S_3) x 50:100:50 (F_2), MMF Model is the best Model and for Chikkamangalore (S_3) x75:150:75(F_3) Rational function is the best Model. This indicates that we can use above Models to predict the height. Among this three combinations S_3F_2 is the best combination fallowed by S_3F_1 and S_3F_3 (based on highest R^2 value and lower RMSE , SE).For the fourth source and their combination, Thirthahalli (S_4) x 25:50:25(F_1) sinusoidal Model is the best Model and for Thirthahalli(S_4) x50:100:50(F_2), and Thirthahalli(S_4) x 75:150:75(F_3) MMF Model is the best Model. This indicates that we can use above Models to predict the height. Among these three combinations S_4F_1 is the best combination fallowed by S_4F_3 and S_4F_2 (based on highest R^2 value and lower RMSE, SE). Among all the Sources S_2F_2 is the best sourcefor dbh.

For first spacing and combination, 4x1m (SP_1) xNo fertilizer (F_0) MMF Model is the best Model and for 4x1m (SP_1) x50:100:50(F_1), Weibul Model is the best Model. This indicates that we can use above Models to predict the dbh. Among these two combinations SP_1F_0 is the best combination fallowed by SP_1F_1 (based on highest R^2 value and lower RMSE, SE). For the second spacing and their combination 4x2m (SP_2) x No fertilizer (F_0) MMF Model and for 4x2m (SP_2) x 50:100:50(F_1) Rational Function is the best Model. This indicates that we can use above Models to predict the dbh. Among these two combinations SP_2F_1 is the best combination fallowed by SP_2F_0 (based on highest R^2 value and lower RMSE, SE). For the third spacing and their combination, 4x3m (SP_3) xNo fertilizer (F_0), MMF Model is the best Model and for 4x3m (SP_3) x50:100:50 (F_1), Weibul Model is the best Model. This indicates that we can use above Models to predict the dbh. Among these two combinations SP_3F_0 is the best combination fallowed by SP_3F_1 (based on highest R^2 value and lower RMSE, SE). Among all the spacing SP_3F_0 is the best spacing for dbh.

The Weibul distribution was fitted well for all the Sources, spacing and fertilizer level combinations for dbh than the height values.

Important findings of this research

1. For height among all the Sources, Bangalore (S_2) x 50:100:50(F_2)[Weibul Model (R^2 =0.991 , SE=0.194,and RMSE=0.171)] is the best source and 4x3m(SP_3) xNo fertilizer (F_0) [Rational function (R^2 =0.997 , SE=0.085,and RMSE=0.068)]is the best spacing, for *Acacica mangium* plantation.
2. For dbh among all the Sources, Bangalore (S_2) x 50:100:50(F_2) [MMF Model (R^2 =0.993, SE=0.249, and RMSE=0.220)] is the best source and 4x3m (SP_3) xNo fertilizer (F_0) [MMF Model (R^2 =0.998 , SE=0.172,and RMSE=0.140)] is the best spacing for *Acacia mangium* plantation.
3. The Weibul distribution was fitted well for the dbh values than the height values.

Future line of work

- Prediction Models can be developed for predicting the economic returns from the agroforestry systems
- The Models can be built using the weather parameters and canopy cover for estimating the yield of *Acacica mangium*.
- Studies on agroforestry Models for different agro-climatic zones are required.

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APPLICATION OF PROBABILITY DISTRIBUTIONS AND STATISTICAL MODELS FOR PRODUCTIVITY OF *Acacia mangium*

SHILPA V. **2013** **Dr. S.N. MEGERI**
MAJOR ADVISOR

ABSTRACT

Acacia mangium is very good, short rotation forestry species, good for pulp wood purpose and adopts well to high rain fall areas. The study was conducted based on secondary data collected from All India Coordinated Research Project on Agroforestry (AICRP), UAS Dharwad. The main objectives of the study were to identify suitable statistical models for estimating the productivity (height/diameter at breast height (dbh)) of *Acacia mangium* in respect of different sources, fertilizer level and spacing and to fit the suitable probability distribution for growth.(Sources:- Kerala, Bangalore, Chikkamangalore, Thirthahalli; Fertilizer combination :-25:50:25, 50:100:50, 75:150:75 NPK gm/tree; Spacing:- 4x1 m, 4x2m, 4x3m).The data pertaining to height and dbh of different sourses,spacing and their fertilizer combination were collected.

In predicting the height growth of *Acacia mangium*, among all the sources, Bangalore (S_2) x 50:100:50(F_2) is the best sourse and weibul model is the best model with higher coefficient of determination (R^2) value and lower Standard Error(SE) and Root Mean Square Error (RMSE).(R^2 =0.991 , SE=0.194,and RMSE=0.171)] and for spacing combination, 4x3m(SP3) x No fertilizer (F0) is the best spacing and rational function is the best model with higher R^2 value and lower SE and RMSE. [(R^2 =0.997, SE=0.085, and RMSE=0.068)] for *Acacia mangium* plantation. In case of Diameter at breast height (dbh), among all the sources, Bangalore (S2) x 50:100:50(F2) is the best sourse and MMF model is the best model with higher R^2 value and lower SE and RMSE[(R^2 =0.993, SE=0.249, and RMSE=0.220)] and for spacing combination, 4x3m (SP3) xNo fertilizer (F0) is the best spacing and MMF model is the best model with higher R^2 value and lower SE and RMSE (R^2 =0.998 , SE=0.172,and RMSE=0.140) is the best spacing for *Acacia mangium* plantation. For fitting the probability distribution, the weibul distribution was fitted well for the dbh values than the height values.