“SEED POLYMORPHISM AND GERMINATION BEHAVIOUR OF *ACACIA MANGIUM* IN CHHATTISGARH”

M.Sc. (Forestry) THESIS

by

GUNJAN PATIL

DEPARTMENT OF FORESTRY
COLLEGE OF AGRICULTURE
INDIRA GANDHI KRISHI VISHWAVIDYALAYA
RAIPUR (C.G.) 492006

2007

"SEED POLYMORPHISM AND GERMINATION BEHAVIOUR OF *Acacia mangium* IN CHHATTISGARH"

Thesis

Submitted to the

Indira Gandhi Krishi Vishwavidyalaya, Raipur

By

GUNJAN PATIL

IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THE
DEGREE OF

Master of Science

in

FORESTRY

Roll No. 7415 **ID No. 120105020**

SEPTEMBER, 2007

CERTIFICATE - I

This is to certify that the thesis entitled **"SEED POLYMORPHISM AND GERMINATION BEHAVIOUR OF *Acacia mangium* IN CHHATTISGARH"** submitted in partial fulfillment of the requirements for the degree of **"MASTER OF SCIENCE IN FORESTRY"** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of the bonafide research work carried out by **GUNJAN PATIL** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma (certificate, award etc.) or has been published/published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by her.

Date: **(M.N. NAUGRAIYA)**
Chairman Advisory Committee

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

Chairman	**Dr. M. N. Naugraiya**	________________________
Member	**Dr. S. L. Swamy**	________________________
Member	**Dr. H. C. Nanda**	________________________
Member	**Dr. Ravi R. Saxena**	________________________

CERTIFICATE - II

This is to certify that the thesis entitled **"SEED POLYMORPHISM AND GERMINATION BEHAVIOUR OF *Acacia mangium* IN CHHATTISGARH"** submitted by **GUNJAN PATIL** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) in partial fulfillment of the requirements for the degree of **"M.Sc. (FORESTRY)"**, in the **Department of Forestry** has been approved by the Student's Advisory Committee after oral examination in collaboration with the external examiner.

Date: **EXTERNAL EXAMINER**

Major Advisor ___________________________

Head of the Department ___________________________

Dean/ Dean Faculty ___________________________

Director of Instructions ___________________________

Acknowledgement

First of all, I would like to thank and praise Almighty the most beneficial and merciful, for all his blessings conferred upon mankind.

In the inner course of my heart, I feel great pleasure in expressing my deep sense of gratitude to Dr. M.N. Naugraiya, Senior Scientist and Chairman of my Advisory Committee for his valuable guidance, constant encouragement and constructive throughout the tenure of this investigation and preparation of the manuscript.

I am highly greatful to Dr. B.S. Thakur, Dean and Head, department of Forestry, IGKV, Raipur for his most able guidance during my research work.

It gives me an immense please to extend sincere thank to the members of my Advisory Committee Dr. S. L. Swamy, Scientist, Dept. of Forestry, Dr. H.C. Nanda, Scientist, Department of Plant Breeding and Genetics and Dr. Ravi R. Saxena, Assoc. Professor, Dept. of Statistics and Computer Science, for their valuable advices and suggestions for improving this manuscript.

A special vote of thanks to Dr. Lalji Singh (ex head) Dept. of Forestry, Dr. R.K. Prajapati, Dr. S.S. Bargali, Scientist and Shri P. Toppo, Assistant Professor for their kind cooperation and help rendered during course of this investigation.

I wish to recorded my profound report and greateful thanks to Dr. C.R. Hazra, Hon'ble Vice Chancellor, Dr. R. B. Sharma, Director Research Services, IGAU for providing necessary facilities during the course of study and experimental period.

I also owe my greateful thanks to all those unmentioned teachers from my schooling life till now who directly or indirectly helped me to reach upto this level. My special thank to all staff members Shri U.S. Singh, Shri Motilal Sahu, Smt. Shilpa Kaushik, Smt. Amita Sharma, Shri Santosh Dhruve, Patel, Tiwariji, Dulari didi.

I express my thanks to my seniors, Mr. Tarun Thakur, Miss Lekha Ghosh, Vijay Laxmi Kog, Bardani, Alice, M. Veena, Sanjeewan, Satish, Sukhdeo, Dinesh, Dheeraj, my classmates Swati, Priyeta, Shaillendra and Vijay and my juniors Bharati, Shweta, Kiran, Vasha, Umakant, Manash, vinod, Vedprakash and Ashu.. My heartful thanks to my all friends Ekta, madhu, Manisha, Sita, Anamika, Chandu, Meena, Mitali, Mahima, Deepali, Mamta, Swati, Raju, Archu, Faizan, Yogesh, Pankaj, Uday and Vikas for their moral support.

Acknowledgements are also due to Mr. Ajay Kaushik for typing and giving shape to this manuscript.

Diction is not enough to express the heartful gratitude to my beloved father Shri A.R. Patil and my mother Smt. G.A. Patil, sister Smt Jyoti, Jijaji Shri D. J. Waikar, Brothers Amit, Ashish, Bhabhi Smt Archna, my beloved Nephew Shrankla, Prakriti, Shubhi, Diksha, Sankalp whose affection, encouragement, obstinate sacrifice, sincere prayer and love have always been the vital source of inspiration and raising me to the present position. They have always been beckon of light to me in my endeavour.

Department of Forestry
College of Agriculture **Gunjan Patil**
IGKV, Raipur (C.G.)

CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

Abbreviations	Description
&	And
Atm.	Atmospheric
°C	Degree Celsius
CD	Collar Diameter
CD	Critical difference
cm	Centimetre
DBH	Diameter at Breast Height
et al.	And others/ co-workers
Fig.	Figure
g	Gram
GA	Gibberellic Acid
ha	Hectare
hr	Hour
IAA	Indol Acitic Acid
i.e.	That is
kg	Kilogram
<	Less than
m	Metre
mm	Millimetre
mM	milli Mol
>	More than
NS	Non significant
%	Per cent
ppm	Part per million
SEm±	Standard error of mean
viz.	Namely

CHAPTER-I

INTRODUCTION

Seed is the primary unit of dispersal and propagation of plants Harper *et al.* (1970). The seed is a ripened ovule, which develops after the fusion of male and female gametes, containing an embryo in arrested state of development with a food reserve (in endosperm or cotyledons) and a protective layer (seed coat). In seeds Act, 1966, the seed has been is defined as the propagating material. The seed is a small living entity consisting of a dormant embryonic plant which develops into a new plant when favourable environmental conditions (moisture, temperature and oxygen) are available. Actually the seed is a miniature plant.

Seeds protect and nourish the embryo or baby plant. Seeds usually give a seedling a faster start than a sprouting from the spore because of the larger food reserves in the seed.

Seed germinate after a brief period of dormancy, when optimum environmental conditions like moisture, air temperature are conducible. In laboratory test, germination is defined as the emergence and development of the seed embryo from the seed, its ability to produce a normal plant under favourable conditions (A. O. S. A, 1991).

Seeds can be classified as Normal seeds – if germinate in normal course; Hard seeds –such as seeds of Leguminasae and malvaceae which remain hard do not absorb water due to there impermeable seed coat and insularly fail to germinate even under favourable conditions; (ISTA Rules Para 5.2.3). Fresh ungerminated seeds – unlike hard seeds, which remain firm and approximate viable after the appropriate pre treatment for dormancy are classified as fresh ungerminated seeds. (ISTA Rules. Para 5.2.4) and Dead seeds – seeds, which at the end of the first period are neither hard and do not have produced seedlings. They generally decayed, covered with fungi become soft or their embryo become soft or colour less.

On a globally forests occupies about one third of the world's land surface. However in India forest occupies nearly 64.01 million ha of land (FSI, 1989) constitute about 1/5th of the total land area of the country. With only about 2 percent of the total forest area of the world, India supports about 15 percent of the total human and 14 percent of the total cattle population of the world. (Khullar 1991)

Seeds of woody plants exhibit a great range of variation in shape, size, colour and seed coat surface. These are very often adapted to the conditions, in which the various species evolved. Knowledge of seed morphology is thus, advantageous for artificial regeneration as it can influence the collection, processing, storage and treatment of seeds. The external and internal morphological features of seeds are remarkably stable; therefore, they provide reliable criteria for positive identification of unknown seeds (Martin and Barkley, 1981; Gunn, 1972; Kozlowski, 1972). Seeds usually inhibits much greater variability in shape, size and position of seed coat surface and placement, shape, size and position of hilum in relation to lens, micropyle and raphe, presence and absence of associated parts such as arils, caruncles etc. (Troup, 1921; Bailwin, 1942)

The major environmental conditions essentially required for germination are water and air, a suitable range of temperatures, freedom from high concentrations of inorganic salts, freedom from inhibitors and in some species, exposure to light. All above factors are the causes of dormancy. Seed dormancy has been categories in to various types by different authors based on the manner in which it originated; Harper (1957) and Robert (1972) recognized three types of dormancy innate, induced and enforced. Nikolaeva, (1969) has used the physiological basis of classified the dormancy, seeds with morphologically immature embryos, seeds with internal dormancy and double dormancy.

Seeds of many species of Leguminasae family, such as species of *Cassia*, *Acacia*, *Albizias* etc, have impermeable seed coat. (Khullar, 1991) Seed coat imposed dormancy in a large majority of forestry species, though seed dormancy is also caused by the structures surrounding the embryo glumen, palea and lemmae, pericarp, testa and endosperm. In these cases, the embryo remains dormant while still enclosed in the seed coat but germinates soon if isolated and cultured on the appropriate medium or the seed is punctured by mechanical or chemical treatments. Which are scarification, hot water, soaking seeds in water, dry storage, light, moisture stress, salts and some growth hormones.(Bewley and Black, 1982)

The initial phase of germination is imbibitions when water enters the seed through the micropyle. Most seeds at maturity have a moisture content less than 20 percent, such as in species of *Acacias*, *Albizias* and *Dalbergia sissoo* etc. while an exception is *Azadirachta indica* where moisture content varies

(28-35%) from source to source and also place to place as well. ((Khullar, 1991))

Some woody species are now days found to be most suitable for commercialization, reforestation and environmental protection and *Acacia mangium* is one of them has become a major plantation species in the humid tropical lowlands of Asia due to its extremely fast growth and tolerance of very acidic and infertile soils. (Turnbull, 1996) It has also been sliced for veneer and at one time was used locally for house construction. (Francis, 2002)

Acacia mangium is native to Northern Queensland in Australia Papua New Guinea, Iran Jaya and the Moluccas Islands in Indonesia. (Turnbull 1996) It belongs to family Fabaceae and commonly known as Mangium, Mangium wattle, mange, forest mangrove. The species occurred throughout the humid tropics and it also naturalized in Puerto Rico. (Francis & Liogier, 1991) *Acacia mangium* is the fast growing, medium sized, evergreen with phyllodes a modified leaves acting as water given tree. Tree reaches 30 m in height and 60 cm in diameter in their native range. *Acacia mangium* grows best in warm climates with 1500 to 3000 mm annual rainfall. (Turnbull, 1996) The species grows in a wide Variety of soil type. It can be grown in light acid soil with medium to low fertility status having facilities of poor to moderate drain while soil with high pH is not tolerated. (Turnbull, 1996) Thus *Acacia mangium* is planted primarily for site rehabilitation. Its fast growth and dense shade make it an effective tool for Imperata grass swards and reducing fire risk (NFTA, 1987). Its ability to grow well in poor soils, especially those low in phosphorus, make it a favorite for rehabilitation of mine spoils and eroded sites. The tree also produces commercial wood, which is hard and has an air dry specific gravity of 0.69. The sapwood is cream coloured the heartwood is yellow-brown. It is suitable for furniture and resembles the better-known blackwood (*Acacia melanoxylon*) in appearance. The wood is suitable for particleboard, veneer, pulp, fence posts, firewood and charcoal. Plantations in Indonesia and Malaysia are the resource base for a paper industry. Its dense evergreen foliage makes this species a useful shade, screening and soil cover crop. *Acacia mangium* among the most important to fulfill all the type of requirement. (Francis, 2002)

The leaves can be used as a live stock fodder. It is successfully cultivated in tropical countries. In recent years intensive cultivation of this tree has been taken care in southern states of India like Kerala, Tamil Nadu, Karnataka and Chhattisgarh (Venkatesh, 2000).

Acacia mangium is widely accepted under Social forestry programme due to its fast growth and commercial value of timber by the existing cultivars in Chhattisgarh and for facilitating them initial studies in germination and seedling growth behaviour in respect to inherent dormancy as well as micro climatic influences has been conducted systematically.

Keeping in view the above facts the present investigation has been planned with the following objectives :

Objectives:-

1. To study the morphological behaviour of pod and seed in respect to location, Phenological impression and behaviour of trees.
2. To study the effect of various agents on germination and seedling growth attribute.

3. CHAPTER-II

4. Review of literature

5.

6. In this chapter an attempt has been made to review the work done on "Seed polymorphism and germination behaviour of *Acacia mangium* (Willd) in Chhattisgarh. The literature has been reviewed under the following major aspects.

7. 2.1 Morphological and phenological behaviour of the tree

8. 2.2 Morphology of fruit/pod and seeds

9. 2.3 Germination and seeding vigour

10. 2.1 Morphological and phenological behaviour of the tree

11. The morphological and phenological growth depends on the genetic potential of species, site characteristics and management practices adopted. The growth rates are higher when allow to grow in fertile site than degraded land.

12. Singh *et al.* (1994) reported the variation in growth performance of fodder tree species *viz; Dalbergia sissoo, Acacia tortolis, Albezzia qwara, Albizzia lebbeck* in three different soil types in Bundelkhand region. They also found the significant variation in growth, phenology and biomass production under different set of management of cultivation in IDRC silvopastoral operation research project for Bundelkhand region.

13. Gopichand (2005) studied nine MPTs for their vertical and radical growth performance as well as biomass production under influences of different irrigation practice in short rotation, high density plantation and get more biomass production in irrigated fields than without irrigated and soil working field of plantation at Himachal Pradesh.

14. Duguma *et al.* (1994) have studied the plant height and diameter of ten multipurpose tree species. They found that the height and growth of *Paraserianthes faccatoria*, was highest (12.11 m) as compared to the to the other species. In three year plantation stem diameter was found maximum of *A. mangium* (10.59 cm) followed by *A. auriculiformis* (8.43 m).

15. Singh and Singh (2000) studied the irrigated plantation of *Dalbagia sissoo* and observed significant variation in the plant height due to stand age. The height of the plants varied from 6.9 m in 4 year old to 16.0 m in 30 year stand and showed gradual increase with stand age. Height and stand age were positively correlated.

16. Bhumibhavon *et al.* (1994) recorded variation in flowering and seedling of *Acacia mangium* in Thailand among different provenance. All provenances flowered at the age of 28 months though wide variations were observed in flower production, flower distribution, flower development, seed characteristics and seed production among different provenances.

17. The variation in growth behaviour started in early growth stage of plant even at nursery stage when the plants were given different set of management in the cultivation in terms of soil moisture, nutrient and microclimatic application. In case of legume tree species soil moisture played important role for development of Rhizobium needs which do fulfil the requirement of nitrogen upto some extent very close and apparent results were observed in case of *Dalbergia sissoo* when grown in different soil nutrients application by Naugraiya (2007).

18. Pande *et al.* (1999) observed that *A. mangium* seedlings, planted at Chhindwara in Madhya Pradesh during July 1997, flowered at the age of seven months (February, 1998), when the plant height and girth was 1.9 m and 10 cm, respectively, which ultimately produced seeds of average 2.0-3.5 cm length and 1.0-1.5 cm width.

19. Yamada *et al.* (2000) observed that the flowering strength in a seed orchard of *A. mangium* was related with family variation and provenance variation. The flowering strength assigned visually was significantly different among families and provenances. The flowering strength in lower part of tree crown was less than that on the upper part of the tree crown.

20. Chhangani (2004) studied the phenology of flowers and fruits of dry deciduous forest in Aravalli hills of Rajasthan, India In all the seasons of a year. He reported that flower buds were available

throughout the year with an average 8.32 percent with minimum of 1.13 percent in November and maximum 14.77 percent in August. Availability of average mature flower throughout the year was 9.35 percent. Fruits were also available throughout the year on an average of 8.32 percent with minimum availability of 3.23 percent in February and maximum 15.21 percent in May.

21. Pande *et al.* (2004) studied on phonological behaviour of *Azadirecta indica A.* Juss (Neem) of different agro climatic zones viz. Narmada valley, Vainganga valley and Satpura plateau are described major leaf fall period between February, March except in Narmada valley where it was extended up to April. The significant variations among the quantitative, phenological parameters like leaf area, leaf let area and leaf weight for different climatic zones. These variations were non significantly created with growth parameters like gbh, tree height, crown diameter and crown height. Significant positive correlation between flower and fruit abundance was obtained which indicated that increasing flower abundance enhanced fruit production.

22. Singh and Sharma (2006) studied that the effect of micro-zonal variations on the different phenophases like flowering, fruiting, seed maturation and seed dispersal of four important multipurpose shrubs of Himachal Himalayas i.e. *Wood fordia*, *Carissa*, *Prinsepia* and *Debregeasia* species. Their results indicated that the climatic

conditions were greatly influenced the life cycle of the vegetal elements. Flowering phase was enhanced in Wood *forelia* and *Debregeasia* species of certain site due to minute temperature variations.

23. 2.2 Morphology of fruit/pod and seeds

24. Production of Fruit/pod/seeds in plant always found to be govern by genetic potentiality and environmental stress because there are the end production of standing plant generation in the life cycle and produce new generation. The morphological status of trail indicates the status of seed quality and available in fruits. Seed quality in relation to size colour, weight; reflect the germination ability, viability and longevity as well as production commercially valuable ingredients i.e. Food, oil, resin, medicine and dyes etc. thus the study of fruit/pod and seed morphology in essential for prediction of genetically and physiological commercial behaviour as well as value.

25. Siddiqi *et al.* (1991) studied that the seeds of sundry (*Heritiera femes* Buch. ham.) germination in relation to seed size and time an average of 62.32 % germination success was recorded. No significant difference was found in germination success among the small, medium and large sized seeds.

26. Naugraiya and Pathak (1983) studied the variation in seeds of *Atylosis scarabaeoides* Benth based on colour (light, brown and dark brown) as well as size (large, medium and small). The variation was

similar on different collection sources medium size and brown seeds were dominating in their group. While light brown and small seeds were shairing least populationin the respective group, however the variation in respect to the collection site.

27. Naugraiya and Pathak (1987) also studied that the seeds of *Indigofera glandulosa* Willd. for their colour wise polymorphic groups i.e. black, blackish green, red and yellowish green colour. Where the population of blakish green seeds was more than 90 percent with higher test weight as well as germination of seeds, while red and yellowish green seeds gave poor results even at both the collection sites.

28. Bagchi and Dabriyal (1990) studied twenty one provenances of *Acacia nilotica* for their seed morphology where the seed length width and thickness was varied from with statistically significant differences.

29. Srimathi *et al.* (1991) studied that the seeds dormancy in *Acacia melifera* Benth. was imposed by hard seed coat while seed size and colour affected the germination. Medium sized seeds recorded the highest germination and small one gave less than 15 percent though effect of seed colour in viability and vigour, green seeds possessed high viability and vigour.

30. Naugraiya and Pathak (1999) observed that seed polymorphism affected germination vigour in *Atylosia scurabaeoides*

Benth. Among colour groups, maximum seed germination was obtained more than 75 percent for dark brown seeds while it was minimum for light brown seeds (43.15 %). In case of three size group the medium size seeds gave maximum germination and minimum was recorded for larger size seeds.

31. Hedge *et al.* (2000) conducted studies on the variation in seed characteristics and seedling growth performance of *Acacia mangium* Willd. and *Acacia auriculiformis A.* Cunn ex Benth. in the field. *A. mangium* and *A. auriculiformis* had more or less similar morphology and difficult to identity. They found that *A. auriculiformis* had larger and heaviest seeds and also accumulating more seedling biomass than *A. mangium*.

32. Thakur *et al.* (2001) studied on germination behaviour in seeds of provenances of *A. mangium* collected from Australia, Papua New Guinea and round that overall germination was ranged 84.9 to 60.9 percent with mean germination of 71.98 percent.

33. Srimathi *et al.* (2001) evaluated the association of seed germination and seedling vigour with seed size of *Parkia biglobosa* seeds, their results indicated that decreasing the size of seeds the germination and seedling vigour.

34. Dar *et al.* (2002) found that the seed grading of different multipurpose tree species *viz;* Khair, Siris, Chir pine and Robinia affected the germination percentage. The seeds were in three graded

in to small, medium and large seeds based on their size and weight. Passing the seeds though sieves of different mesh sizes did the seed grading. Large size seeds were found heaver from medium and small size by two and three times.

35. Jenner *et al.* (2003) carried out experiments with a view to assess the variability in seeds of *Madhuca latifolia* Roxb Mcbrided from 23 sources. Results indicated distinct variation in seeds among the 23 sources in respect of seed characters like length, breadth of seeds, test weight of seeds and oil content.

36. Todaria *et al.* (2004) studied on variation in pod and seed characteristics of *Acacia catechu* Willd. in Garhwal Himalaya. They observed highest variation in pod length width, number of seeds per pod, healthy and damaged seeds, pods among sources, pod length, when seed collected from defferent attribute longitudes and latitudes in gradual range of Himalaya.

37. Lavania and Singh (2004) studied the effect of different seed sources on germination, survival and early seedling growth of *populus ciliate*. Their study revealed that the seed sources had statistically significant effect on seed germination and seedling growth, negative correlation between latitude and shoot length, while the seedling vigour index gave significant positive correlation with altitude.

38. Buhler *et al.* (2006) observed that the effect of different irrigation regimes growth and penology of 100 established *Tilia cordata* street trees was investigated during growth period of 2004. They found that relative stem increment increased significantly when irrigation of water though out the growth period. These results indicate that growth and growth period of street trees are augment by increase of amount water available to them.

39. 2.3 Germination and seeding vigour

40. Seed germination is an important event in the plant life history and its success depends on the micro-climate available around it and genetic potentiality of bearing seed dormancy, thus factors played equally important role in seed behaviour.

41. Doyan *et al.* (1996) conducted studies on germination on seven seed lots of *Acacia mangium*. They found that the seeds in light and total dark did not show any significant effect on germination. They also reported that the age of seed lots and temperature affected the seed viability.

42. Lima and Garcia (1996) studied different methods to overcome seed dormancy with substrate and temperature conditions to evaluate seed behaviour for *Acacia mangium*. They found that hot water treatment gave best germination and it was easiest, cheapest and safe methods to break seed dormancy with substrate of paper towel at 35 ^{0}C.

43. Rohayat *et al.* (1997) studied the effect of tree age on seed germination and seedling quality in *A. mangium*. Seeds of six and nine year's old trees gave significant variation in germination as well as in seedling vigour. The best germination was in seeds from nine year old trees (68 %) but the seedling vigour was reported in seeds from six year old trees.

44. Banerjee *et al.* (1998) studied that the *Melia azedarach* for its seed germination behaviour under different treatments of IAA, IBA, and GA_3 in 100, 200, 400 and 500 ppm concentrations presoaking hormones treatments. All concentrations of IAA were found promotive in comparison to control, but the germination increases with decreasing of concentrations in both the 24 and 48 hours soaking treatments. They reported that over all 200 ppm of IAA for 24 hours presoaking has been found better for germination.

45. Gehlot and Sen (1998) studied that effect of acid scarification on seed germination of *Cressa cretica.* Their observation revealed that seeds from all sites showed a significant variations and the germination increased linearly with scarification in order of 5 < 10 < 15 minutes.

46. Mandal and Hondoo (1998) studied that on seed germination of *Leuceana lucocephala* presoaking treatments under inorganic and organic chemicals, which control the effect of salinity on seed germination. The presoaked seeds were further placed in saline media

created by $CaCl_2$ and NaCl having salt stress of 4, 8, 12 and 10 ds m^{-1}. Their results showed the decline in germination in presence of higher concentrations of salts. Presoaking seed treatments with hydration dehydration, $CuSO_4$ (0.1 ppm) $ZnSO_4$ (0.1 ppm) and proline (50, 100 and 200 ppm) showed varied response in alleviating the salinity stress as exhibited various germination parameters.

47. Gehlot and Sen (1999) studied that the influence soil salinity on seeds of *Sueda fruticosa* for success or failure of seedling establishment. The different concentration of v*iz;* NaCl 1.9, 3.9, 7.8, 15.6 and 31.25 mM were used to test the germination behaviour and the result showed that germination increased up to 7.8 mM afterwards it was found decreasing.
48. Nautiyal *et al.* (2000) studied at the high altitude plant physiology research centre H. N.U. Garhwal University Shrinagar Garhwal (U.P.). Seeds of *Quercus leucocephora* A. Camus were collected from 7 places varying considerably in their longitude, latitude and altitude tested for their seed attributes, germinability of seeds and seedling growth. However difference were significant more in rate of germination than total germination percentage.
49. Thakur *et al.* (2001) reported that the variation in germination behaviour in different *Acacia mangium* provenances, where the over all germination was 71.9 percent, with the highest germination rate of

84.9 percent and lowest of 60.9 percent in Papua New Guinea seed source.

50. Kiran *et al.* (2000) observed that the seeds of *Givota rottleriformis* treated with various concentrations of GA_3 i.e. 500, 1000, 2000 ppm for 24 and 72 hours, showed the quicker and higher percent of germination at higher level of treatment exposed to seeds and at it was found to be decreased with lower concentration. They also reported the in absence of treatment germination was not estimated even after the 40 days of sowing.

51. Dar *et al.* (2002) also found that germination of multipurpose tree species *viz;* Khair, Siris, Chir pine and Robinia affected by the seed polymorphism. Germination was received higher in medium size seeds i.e. as compared to other large and small for all species.

52. Hashim and Wathern (2003) studied on moisture stress affected seed germination of *A. mangium*. Moisture stress created by using mannitol with different concentrations *viz*; (0, 0.3 and 0.5 Mpa). They found that the germination was decrease with increasing mannitol concentration.

53. Jenner *et al.* (2003) also studied on the seedling vigour of *Madhuca latifolia* Roxb Mcbrided from 23 sources. Results indicated that the significant variation found in seedling traits like shoot length, basal diameter, root length, number of leaves and total dry weight.

54. Kiran and Devar (2003) conducted studies on the fruits of *Scrpindus trifoliatus* Linn. collected from 40 individual trees from four climatic zones *viz*; dry deciduous, moist deciduous, evergreen and coastal zone in Uttar Kannada district of Karnataka, to understand the relationship of growth, fruit yield and germination trait, the morphometric characters *eg*. Crown diameter, bole height, fruit weight, fruit diameter, effected the germination. They round the large seed supported high germination.

55. Sharma and Kukadia (2003) studied that the effect of salinity created by NaCl, $CaCl_2$ H_2SO_4 and $MgSO_4$ on seed germination of MPTs *viz; Acacia nilotica, Azadirecta indica, Dalbergia sissoo, Gemelina arborea, Leucaena leucocephala, Prosopis cineraria, Prosopis juliflora*. At four different salt levels 0, 2.5, 3.5 and 6.5 ds m^{-1}. The results have clearly indicated that *Azadiracta indica and Dalbergia sissoo* tolerated salts up to higher salinity level (6.5 ds m^{-1}) at germination stage. Where as *Leucaena leucocephala* and *Gmelina arborea* appeared sensitive even at lower salinity level (3.5 ds m^{-1}). The reduction in the number of leaves/plant and shoot and root length was observed in saline media in linear fashion as compared to control condition.

56. Mutha *et al.* (2004) studied the effect of seed size and pretreatments on germination of *Albizia lebbeck*. They found that the bold seeds

gave high germination and good seedling quality and 15 minutes conc. H_2SO_4 scarification gave best germination.

57. Ghyare (2005) studied that the effect of GA_3 on the germination timber species *viz*; *Albizia lebbek, Bombax ceiba, Cassia siamea, Prosopis juliflora* and *Tamarindus indica*. The seeds were pretreated in with concentration 500, 400, 300, 200 and 100 ppm of GA_3 for 24 hours showed increment in germination up to 400 ppm in all the cases.

58. Hasnat and Thapliyal (2005) observed that leguminous species *Cassia fistula* have very hard seed coat and require to breaked by any stage techniques enhance germination and the found the scarification by conc. H_2SO_4 treatment (30 minutes) was most suitable than other method to get maximum and quick germination.
59. Sharma *et al.* (2005) also observed the requirement of presowing treatments on germination of *Ribe orientale* and out of different treatments *viz*; cold, Luke warm, boiling water, scarification by conc. H_2SO_4 for 1 and for 5 minutes, only 1 minute exposure found best to break seed dormancy and to get maximum germination.
60. Pandit and Jeetram (2006) observed that the seeds of *Pinus roxburghii* (Chir pine) were slightly affected by the pregermination treatments of H_2SO_4. Which was used in different concentrations for different time duration. The higher germination was found (94.25 %) at the 20 percent H_2SO_4 treatment for 20 minutes.
61. Sinhababu *et al.* (2007) studied the seed germination in seven fast growing fuelwood yielding leguminous trees, *viz; A. auriculiformis*,

A. holosericea, Albizia lebbek, Bahunia variegate, Cassia fistula, Cassia siamea and *Leucaena leucocephala*. To improve the low germination rate, seeds of these species were pretreated with hot water or phytohormones (200 ppm IAA and GA), KNO_3 (2.5 mM). Significant increase in germination over control was observed in all species with hot water pretreatment. Pretreatment with hormone and nitrogenous substances also improved in germination but it was limited in some cases.

62.

CHAPTER-III

MATERIALS AND METHODS

The present study conducted on the **"Seed polymorphism and germination behaviour of *Acacia mangium* in Chhattisgarh"** was carried out in the laboratory of Department of Forestry Indira Gandhi Krishi Vishwavidyalaya, (C.G.) during 2006-07. The details of material used, experimental procedures followed and techniques adopted in the study are described in this chapter.

3.1 Study area

The graphical situation, climates and soil of the experimental site are described below.

3.1.1 Geographical situation

The experiment was carried out at Raipur which is in the eastern part of Chhattisgarh situated between 21 ^{0} 33' to 21 ^{0} 76' north latitude and 81 ^{0} 30' to 81 ^{0} 36' east longitude having an altitude of 289.59 m above sea level.

3.1.2 Climate

The climatic condition of experimental site is sub-humid dry tropical. The region receives an average annual rainfall of 1250 mm, of which 80 per cent occurs during rainy season from June to end of September and occasional rainfall during October to February. May is the hottest and December is the coolest month of the year. The mean monthly maximum temperature ranges from 27^{0}C in December to 42^{0}C in May and minimum temperature varies from 13.2^{0}C in December to 28.3^{0}C in May. The maximum temperature sometime even rises as high as 46^{0}C in May and minimum as low as 6^{0}C in December. The relative humidity is high from July to August, which reaches up to 80 percent while minimum relative humidity of 29 percent is observed during April-May while velocity is high from May to August.

Monthly average meteorological data during the span of the study as recorded at meteorological observatory, Indira Gandhi Krishi Vishawavidyalaya, Raipur is presented in Figure 3.1.

3.1 3 Physiography

Chhattisgarh has three distinct agro climatic zone *viz*; Northern hills, Central plains and southern plateau of Baster. Plantation of suitable exotic species for commercial purposes are common practice in private sector of central plains of Chhattisgarh comprises of 10 districts *viz*., Bilaspur, Dhamtari, Durg, Janjgir, Kawardha, Korba, Mahasamund, Raigarh, Raipur and Rajnandgaon. This zone is also known as upper Mahanadi basin, which is a saucer, shaped. The longer part of the basin in undulating, flat terrain, gentle slope from west to east. The general geological feature of the zone comprises of laterites, alluvium capping over horizontally bedded sequence of sedimentary rocks of limestone and dolomite, on the top followed by limestone shale, quartzite sand stone, gneisses and metasediments of old age. These formations have very limited primary porosity and permeability to water.

3.1.4 Tree vegetation in Chhattisgarh

Chhattisgarh has 46 percent of forest cover of its total area, which is more than 33 percent of forest cover recommended by National Forest Policy (Jha *et al*., 1998) and is the second dense forest state of the country after

Assam. Further, the state is well known in the country for its sal forests, which occupy nearly 36 percent of total forest cover. Teak forests are also abundant here but mainly in western and southern parts of the state. Forest of Chhattisgarh belongs either tropical moist deciduous forests or tropical dry deciduous forests. The tropical moist deciduous forests are spread over as slightly moist peninsular sal forests and moist mixed deciduous forests. (Champion and Seth 1968). While, tropical dry deciduous forests are divided in to peninsular sal forests, northern dry mixed deciduous forests and montane subtropical forest (Jha *et al*., 1998).

3.2 Experimental details

The research studies were conducted at the laboratory of department of Forestry at Indira Gandhi Krishi Vishwavidyalaya, Raipur.

3.2.1 Plantation

Acacia mangium commonly known as mangium or Australian teak in India is a fast growing, nitrogen fixing and commercially valuable tree species. Looking to the suitable climatic conditions it is recently introduduced in Chhattisgarh. Two different sites *viz*; (i) Experimental field of department of Forestry at Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) and (ii) Energy Park, VIP road, Raipur having different soil management practice was selected for study of tree morphology, phenology and collection of pod and seeds site –I has black cotton soil (Vertisols) and while site – II has light soil (Inceptisols). The plantation of *Acacia mangium* was irrigated at site-I and rainfed at site-II.

3.2.2 Soil

Physico- chemical property of soil

S. No.	Character	Vertisol	Inceptisol
1.	**Textural fraction**		
	(a) Sand (%)	24.3	47.05
	(b) Silt (%)	21.4	22.3
	(c) Clay (%)	54.3	30.6
2.	pH	7.8	6.6
3.	E.C. (ds m^{-1})	0.22	0.18
4.	N (Kg ha^{-1})	218	220
5.	P (Kg ha^{-1})	15.0	17.0
6.	K (Kg ha^{-1})	302	280
7.	Organic carbon (%)	0.24	0.14
8.	CEC (c mol(p^+)Kg ha^{-1})	42.69	42.64
9.	Calcium Carbonate (%)	0.34	0.25

Source: Naugriaya (2001)

3.3 Morphological characteristics of tree

3.3.1 Tree age

The date of plantation of the both sites (1) Experimental field of Department of Forestry and (2) Energy Park was collected by plantation agencies to work out the age of trees.

3.3.2 Tree height

The total height of standing trees was measured either with the help of a standard graduated bamboo pole, and meter scale or with the help of Ravi multimeter and 30 meters long tape. The height was recorded from the base to tip of the tree.

3.3.3 Tree diameter (Collar Diameter, DBH)

The collar diameter (CD) and diameter at breast height of standing trees were recorded with the help of Venier caliper at 10 cm and 1.37 meters respectively from the ground level. Two consequents measurements of diameter were taken at two directions i.e. right angles to each other and the average of these two measurements was taken under consideration.

3.3.4 Crown diameter

Crown diameter was recorded by measuring the length between the two opposite outer edge of the canopy of tree. The two consequent measurements were taken at right angle to each other the help of average of these two records was taken under consideration.

3.3.4 Crown length

Crown length was measured vertically from the upper most tip of the tree to the lowest branches of green crown on the trunk. It can also be estimated by measuring total tree height and clean bole height. The measurement was done with the help of standard graduated bamboo and meter scale.

3.4 Phenological observations

3.4.1 Foliage

Weekly observations recorded for different stages of crown foliages and their intensity in respect to initiation, maturity and falling of leaves at two different sites.

3.4.2 Flowering and Fruiting

Different stages and intensity of flowering and fruiting were also recorded weekly right from the initiation of bud to the maturity of fruit.

3.5 Morphology of fruit / pod and seed

Collection of mature fruits were made in three phase i.e, early (collection period -1), middle/peak (collection period -2) and late (collection period -3) at both the plantations. Thus six pod/fruit lots were made, and ten pods were randomly taken from each lot in three replications. These pods were studied for their morphological characteristics and seed production biology.

3.5.1 Pod length

Coiled pod length was measured with the help of thread and centimeter scale. Thread was stretched along the length of pod from the one end to other end and this length of thread was measured by scale.

3.5.2 Pod width

Verneer calliper was used to measure the pod width. Two observations were made in each pod at the minimum and maximum width of the pod. The average value these two records were taken under consideration.

3.5.3 Pod thickness

Pod thickness was measured with the help of standard methods screw gauge.

3.5.4 Weight of pod

Each lot of pod was precisionaly weighted with the help of electronic Smadzu AEU – 210 top pan balance as per ISTA (1966) for their total pod and husk weighted.

3.5.5 Seeds in the pod

In each pod number of locule and seeds were counted. Number of seeds pod^{-1}, number of healthy seeds pod $^{-1}$ and number of damage seeds pod^{-1} were estimated each lots (treatments) collected from two location in three i.e. early, middle and late fruiting period.

3.5.6 Seed polymorphism and morphology

Collected matured fruits/pods from two locations in three different period i.e. early, middle and late were processed by hand to get cleaned seeds in bulk. Ten gram seeds in three replications were taken from each seed lots. Each lots of seeds were counted and separated in to three sizes v*iz;* large, medium and small and these size groups further were separated in to three colour group v*iz.*; black, brown and light, thus comprises of nine polymorphic group. The seeds of each polymorphic group were counted and weighted. The percentage distribution of seeds for each polymorphic group on the basis of number along with their test weight was worked out.

3.5.7 Seed dimension

The dimension parameters *viz;* length, breadth and thickness of the seed were measured with the help of standard methods of screw gauge.

3.6 Seed germination and seedling growth vigour

Cleaned uniform size and colour group of seeds were separated and dried in the air and kept in to seed box in the laboratory after proper labeling. Seed germination was tested in the seed germinator having facilities of controlling temperature and humidity in side the chamber under automatic and controlled programming. Chamber of germination was sterilized with use of mercuric chloride (0.2%) strength. Labeled pteriplates were used after proper cleaning with lab wash and sterilization with mercuric chloride. Whatman filter papers of petriplates size were used to keep seed moistened during the germination. Twenty five seeds were placed in each petriplates. Placements of labeled petriplates in the germinator were based on statistical design of experiments with three or four replications.

The emerging of redical in a seed was accounted as germination of seed. Alternative day's observations were made. Seed germinated on same days were grown in same media and environment up to ten days for measuring their plumule and redical length leaves number and total weight of seedlings. Cumulative germination of seeds were computed in percentage and presented in figures and tables. Angular transformation percentage values were used for analysis of variance to determine the significance level of each studies.

3.6.1 Scarification

There was hard seeds coat dormancy occurred in *A. mangium* , and there is necessity to break it for getting early germination. To break the hard seed coat dormancy, the scarification treatment of conc. Sulfuric acid was applied for the 7 different time duration v*iz;* 0.5, 1.0, 2.0, 3.0, 5.0, 10 and 15 minutes along with the control without scarification. Seeds were kept in conc. H_2SO_4 and mixed thoroughly by glass rod till the desired time period after which seeds were washed out thoroughly in tape water than by distilled water at 2-3 three times than put in to the distilled water for over night. Afterward seeds were placed on filter papers in sterilized petridishes, which were kept at 32 ^{0}C in seed germinator ISTA (1966). The optimum time of seed scarification by conc.

H_2SO_4 was to get early and maximum germination, used for all the seed germination studies.

3.6.2 Temperature

Germination of seeds was tested at seven temperature treatments *viz*; 16, 20, 24, 28, 32, 36 and 40 ^{0}C which were maintained constantly in INDOSAW seed germinator. Seeds scarified with conc. H_2SO_4 for 10 minutes and washed thoroughly with tape water and than distilled water were kept in distilled water for over night soaking. Scarified seeds were placed in moistened filter paper lined in to petriplates. The temperature suitable for getting best germination results was further used for the different germination studies.

3.6.3 Moisture stress

Seven moisture stress conditions viz. 0, 0.33 (Field capacity), 5.0, 7.5, 10.0, 12.0 and 15.0 (Permanent wilting point) atm were create by the using mannitol as per the method of Wiggam and Gardenar (1959).

= PVM/RT atm. (Unit)

Where -

P= Osmotic pressure

T= Absolute temperature (^{0}C + 273)

M= Molecular Wt. of mannitol (182.19)

V= Volume (Liter)

R= 0.08205 Lt./atm./degree

Scarified seeds were kept in these seven moisture conditions for over night than placed in petriplates lined with filter papers. The germination and seedling growth was observed at 32 ^{0}C in seed germination in the filter paper of each treatments were moistened by respective moisture stress solution of mannitol.

3.6.4 Collection period (early, middle and late)

Seeds collected in different three collection period were also tested for germination and seedling growth behaviour. After acid scarification and washing seeds were put in to distilled water for overnight. Soaked seeds were placed on moistened filter paper in side the sterilized petridishes. Seed germination and seedling growth was observed at 32 ^{0}C in INDOSAW seed germinator

3.6.5 Polymorphic group

The cleaned seeds of nine polymorphic group on the basis of sizes *viz*; large, medium and small and colour group *viz*; black, brown and light were tested for seed germination and seedling growth behaviour. After acid scarification, water washing and over night soaking in distilled water seeds were placed on moistened filter paper in side the sterilized petridishes than seed germination and seedling growth was observed at 32 ^{0}C in INDOSAW seed germinator.

3.6.6 Sodium Salts (NaCl, $NaHCO_3$ and Na_2CO_3)

The concentrations v*iz;* 0, 100, 200, 500, 700, 1000 and 2000 ppm of three sodium salts i.e. NaCl, $NaHCO_3$ and Na_2CO_3 were used to test the salinity tolerance of the *Acacia mangium.* Scarified seeds were put in to different concentrations of sodium salts for over night and than placed on filter paper in side the petriplates having moistened with respective concentrations of sodium salts. The germination and seedling growth was observed at 32 ^{0}C studies used in the seed germinator.

3.6.7 Gibberellic acid

Gibberellic acid used as the growth regulator. Different seven concentrations viz. 0, 250, 500, 750, 1000, 1250 and 1500 ppm, were made and kept in dark bottles because hormones are highly light sensitive. After acid scarification and water washing seeds were put in to these seven concentrations of gibberellic acid separately for over night and than soaked seeds were placed on moistened filter paper in pteriplates at 32 ^{0}C in germinator and finally to observed seed germination and seedling growth.

3.6.8 Ascorbic acid

The role of ascorbic acid on seed germination and seedling growth was also studied as ascorbic acid affected the seeds metabolic activity. There were seven different concentrations viz. 0, 0.25, 1, 1.5, 2, 2.5 and 3 % were used as the pregermination treatment. After acid scarification and water washing seeds were put in to these seven concentrations of ascorbic acid separately for over night and than soaked seeds were placed on moistened filter paper in petriplates at 32 ^{0}C in germinator and finally to observed seed germination and seedling growth.

3.7 Statistical analysis

Experiment was framed as per CRD and factorial RBD design. The data generated from the experiment was computed and tabulated for its statistical analysis as per the standard statistical/package (Panse and Sukhatme, 1967) suggested by statistical scientist of advisory committee. Spreadsheet based software of Lotus Smart suite–12 /MS office Excel was used for all the mathematical and statistical calculation.

3.8 Graphic presentation

Graphic presentations of the data were made by using MS Excel /Lotus Smart suite -123 software.

3.9 Photography

Colour photographic descriptions were also recorded for evidence of research work by using Sony digital camera with 30-70 mm zoom lens.

CHAPTER-IV

RESULTS AND DISCUSSION

The chapter deals with the results of the experiment entitled "Seed polymorphism and germination behaviour of *A. mangium* in C.G." and these results are critically discussed in the light of recent available literature. The experiment was carried out on *A. mangium* during 2006-07 in the laboratory of Department of Forestry, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). The observations were taken and data were analyzed statistically following the standard procedure. The salient findings of each experiment are presented in following sequence.

4.1 To study the morphological behaviour of pod and seed in respect to location, phenological impression and behaviour of trees.

Morphological characteristics of tree

4.1.1 Tree age

Tree age was workedout from the records of plantation of both the sites, one of them was Department of Forestry, Indira Gandhi Krishi Vishwavidyalaya, Raipur (Site-I) where the plantation was done 26.09.03 while other site located 2 km from IGKV, Raipur was Energy Park where Plantation was done 29.06.01 Thus plantations of *A. magium* was 4 year and 6 year old at IGKV and Energy park, respectively.

4.1.2 Tree height

Total tree height of *A. mangium* plantation recorded during the study period was 9.24 m at Energy Park and 5.76 m at IGKV, Raipur, with MAI of 1.54 m and 1.44 m respectively.

4.1.3 Tree diameter (Collar diameter, Diameter at breast height)

The collar diameter (CD) was 16.46 cm at energy park plantation and 12.78 cm at the IGKV. The tree growth in diameter at breast height was 12.14 cm at Energy park plantation and 10.64 cm at the IGKV plantation. But annual increment was 3.20 and 2.23 cm for collar diameter at site-I and site-II respectively similar trend was observed for DBH i.e. 2.66 and 2.02 cm at site-I and site-II respectively.

4.1.4 Crown diameter

The crown diameter was 2.71 m at energy park plantation and 2.05 m at experimental field of Department of Forestry, IGKV, Raipur.

4.1.5 Crown length

The crown length was 6.47 m at Energy park plantation and 3.77 m at Dept. of Forestry, IGKV, Raipur (C.G.).

Performance of *A. mangium* at two different plantation site and management showed variation in growth of trees parameters which was recorded maximum at site-II this might be due to age of plantation. But mean annual increment (MAI) was found at higher at site-I where the plantation was properly cared in terms of soil working, moisture and nutrients because the plantations are the part of Agroforestry system. While at site-II plantation was done for esthetic values. The variation in growth parameters of MPTs growth at different locations having varied soil- moisture and nutrient status, was observed by Singh *et al*. (1994) in central India, Gopichand similar results was also observed by many in different cultural management of trees (Singh *et al*., 1994, Nath, *et al*., 1990).

4.2 Phenological observations for foliage, flowering and fruiting

Phenological records were made by visual observations during 2006-07 from August to July presented in Table 4.1.

4.2.1 Foliage initiation, maturity, and leaf fall

A. mangium is evergreen tree so the phenomenon of foliage initiation, maturity and fall was not significantly differentiated. However foliage initiation maximum during winter season less in the summer month May at both the sites. Foliage gets matured after two week from their initiation. Leaf fall was observed in the September and February at the Experimental field of Forestry IGKV and October and March at the Energy park plantation respectively (Table-4.1).

4.2.2 Flowering initiation

The flowers formation started from the end of August and reached to peak flowering stage during 2nd to 3rd week of September afterward than flowering started to decline and finally stopped in at the second week of October at the IGKV, Raipur. In case of Energy Park plantation flowering started from the last week of September and peak flowering was recorded during the 3rd and 4th week of October than get declined and finally get stopped in the 2nd week of November (Table-4.1).

4.2.3 Fruit/ pod initiation and maturity

Pods formation started from the 1st week of October, which was gradually found to be increasing till the January when the fruiting intensity was at peak. The declining in fruiting was observed after the January and finally stopped in the April at experimental field of Department of Forestry, IGKV Raipur (Table-4.1).

In case of Energy park plantation, the pod formation started from the end week of October month and maximum fruiting was recorded in the February afterwards it's started to decline and finally stopped in May.

Variation in phenology at both sites this may be due to soil environmental conditions and genetic potential. Similarly Bhumibhavan *et al*. (1994) observed that the *A. mangium* provenances showed great variation in flowering pattern and their conversion in to trait along with significant variation in production and seed production and characteristics, Naugriaya and Pathak (1989). In case of *Azadiracta indica* the morphological and phenological parameters are pooled and correlated with tree height, girth at breast height, crown height and diameter. They found that climate affected growth and phenology of *Azadirchta indica*, lower temperature and high rainfall which may be probable cause of different growth parameters suggested by Pande *et al*. (2004). The variation in phenology pattern in the central part of India, probably due to climate like, rainfall, environmental conditions and geomorphological situation observed by Newton (1988).

Frankie *et al*. (1974) in their studies in the dry deciduous forest of Costa Rica observed fruiting peak during dry season. They provide the evidence that central American forests, the timing of leaf fall flush and flowering is largely depend on the tree water status. Pande *et al*. (1999) recorded early flowering in *A. mangium* at Chhindwara in M.P. in the year 1998 during February. Daniel and Rao (1987-88) found similar results in respect to some semi evergreen tree species. Peak flowering and fruiting in September-October. Yamada *et al*. (2000) reported that the flowering strength of *A. mangium* was less in lower part of crown and maximum at the upper part of the crown. This may be due to stand density and tree size.

4.3 Morphology of fruit/ pod

Morphological characters *viz;* length, width, thickness and test weight of pods collected from the two sites in three *viz;* early (CP-1), middle (CP-2) and late (CP-3) collection periods of their formation and maturities were presented in Table-4.2.

4.3.1 Pod length

The pod lengths were measured 16.47 cm at site-II and 15.28 cm at site-I with statistically significant difference (Table-4.2). Collection period also gave significant results where, the pod length was maximum (18.75 cm) and minimum (13.93 cm) when collected during the late CP-3 and early CP-1 season, respectively. The interaction of sites and collection periods was also showed significant difference with maximum pod length at site-II × CP-3 (20.52 cm) and followed by site-I × CP-3 (16.98 cm) than site-I × CP-2 (15.32 cm), while minimum pod length was at site-I × CP-1 (13.76). There were insignificant variations between CP-1 and CP-2 the both sites.

4.3.2 Pod width

The width of the pods was found statistically insignificant for collection sites with maximum at site-II (0.83 cm) and minimum at site-I (0.77 cm). But it was showed significant result for collection periods where the maximum width of pod was in late fruiting (0.89 cm) and minimum in early fruiting (0.75 cm). The insignificant difference was seen between CP-1 and CP-2 represented in (Table-4.2).

Interaction of sites and collection periods showed insignificant differences, with maximum width at site-II × CP-3 (0.91 cm) followed by site-I (0.88 cm) during the CP-3, while minimum width was at site-I during CP-1 (0.71 cm).

4.3.3 Pod thickness

Pod thickness was recorded maximum at the site-II (0.423 cm) and minimum at the site-I (0.33 cm) with insignificant result (Table-4.2). In case of collection period, the maximum thickness of pod was in CP-3 (0.55 cm) and minimum in CP-1 (0.26 cm) with statistically significant results. Overall interaction of site and collection periods was found insignificant where the maximum thickness was at site-II during CP-3 (0.56 cm) followed by site-I during CP-3 (0.54 cm). However, minimum was recorded in site-I during CP-1 (0.22 cm) (Table-4.2).

4.3.4 Test weight of pods

Test weight of 100 fresh pods and dry pods showed statistical significant results (Table-4.2). Pods collected from site-I and site-II were weighted for their test weight of fresh pods, which was maximum at site-II (33.72 g/100 pods) and minimum at site-I (26.54 g/100 pods). The collection periods also showed statistically significantly variations with maximum test weight of 50.07 g/100 pods during CP-3 and minimum 16.05 g/100 pods during CP-1 (Table- 4.2).

The interaction of sites and collection periods for test weight of fresh pod was found statistically insignificant, with maximum fresh pod test weight of at site-II during CP-3 (56.99 g/100 pods) followed by site-I during CP-3 (44.45 g/100 pods), while the minimum was at site-I during CP-1 (15.56 g/100 pods).

In case of test weight of dry pod similar trend was observed for sites where the maximum weight was at site-II (13.3 g/100 pods) and minimum at site-I (10.70 g/100 pods). Collection periods also showed significant variations with maximum during CP-3 (18.22 g/100 pods) and minimum during CP-1 (6.75 g/100 pods).

Interaction of sites and collection periods for test weight of dry pods also showed significant variation, with highest at site-II × CP-3 (18.99 g/100 pods) followed by site-I × CP-3 (17.10 g/100 pods) during the late collection period while the lowest was at site-I during early collection period (5.30 g/100 pods).

The variation in test weight at different sites and collection schedule was proportionate to dimensions of pods, which was further depended on availability of resources like nutrients, water, temperature etc. Similarly many workers in agricultural crops reported expression. Todaria *et al*. (2004) also found the variation in pod length width and total number of seeds/ pod, healthy and damage seed/ pod of *Acacia catechu* in different sources, and they advocated that this was due to genotypic and phenotypic variance.

4.4 Seed formation

In the fruit/pod seeds were formed after the successful pollination, fertilization and embryogenesis in due time and suitable environmental conditions and ultimately reflected in quality and quantity of seeds. The estimation of seed production and morphology parameters are presented in Table-4.3.

4.4.1 Number of locules pod^{-1}

Number of locules pod^{-1} significantly varied for sites and collection periods and these were (9.24 locules pod^{-1}) and (8.81 locules pod^{-1}) at site-II and site-I respectively. In case of collection periods the maximum number of locules pod^{-1} were found during the CP-3 (10.55 locules pod^{-1}) and minimum during CP-1 (8.025 locules pod^{-1}) (Table-4.3).

Interaction of sites and collection periods gave insignificant results. Whereas, the number of locules pod^{-1} were observed maximum at site-II × CP-3 (11.23 locules pod^{-1}) followed by at site-I × CP-3 (9.875 locules pod^{-1}) and minimum at the site-I × CP-1 (7.5 locules pod^{-1}) which is represented in Table-4.3.

4.4.2 Healthy seeds

Number of Healthy seeds pod^{-1} depends on length of pod, number of locules well as on fertilization and embryogenesis. Availability of healthy seeds ultimately reflected the successes of next generation. Pods collected from two sites during three collection periods were showed statistically significant variation for production of healthy seeds in a pod (Table-4.3). The maximum healthy seeds pod^{-1} was available at site-II (88.55%) and minimum at site-I (83.60%). In case of collection period healthy seeds were observed maximum during CP-3 (91.71%) and minimum during CP-1 (80.25%).

Interaction of sites and collection period were also found statistically significant, where the healthy seeds in a pod were maximum at site-I × CP-3 (92.15%) followed by site-II × CP-3 (91.31%) and minimum was in site-I × CP-2 (76.24%).

4.4.3 Undeveloped seeds

Number of undeveloped seeds available in a pod at both sites showed statistically insignificant difference with higher rate at site-I (10.99%) and lower rate at site-II (8.88%). Number of undeveloped seeds available in a pod showed statistically significant differences among the collection periods where maximum was during CP-1 (15.07%) and minimum during CP-3 (5.12 %).

There was also found statistically significant difference for the interaction of sites and collection periods, where the maximum undeveloped seeds were available at site-I during CP-1 (14.33%) followed by site-II × CP-I (8.77%) and minimum site-II × CP-3 (0.35%) (Table-4.3).

4.4.4 Empty locule

Empty locule in a pod showed the unsuccessful results of seed formation process at any of the stages and it was found in all collection periods and sites. The maximum empty locules were found at site-I (5.5%) and minimum at site-II (2.55 %) with statistically significant results. In case of collection periods maximum empty locules were available during CP-2 (9.83%) and minimum during CP-3 (3.17%) with significant variations (Table-4.3).

Interaction of sites and collection periods was also found statistically significant, where the maximum empty locules were found at site-I × CP-2 (18.50%) followed by site-II × CP-2 (16.44%) and minimum at site-I × CP-3 (0%).

Formation of seed in a pod trait was also depending on resource available and utilization by the plants as well as on environmental variation. The variations in pod and seed characteristics were also reported for *Acacia albida*

(Sniezko and Stewart, 1998) and *Prosopis cineraria* (Arya *et al*., 1992). The seed population dynamics of a plant in a set of environment was depending on seed biology and reproductive potential of the species and results of population ecology indicated the successes or failure of species in that vary natural habited or management of cultivation.

4.5 Seed dimensions

4.5.1 Seed length

The seed collected from two sites during three collection periods were found statistically insignificant in all the cases, for length of seeds with maximum at site-I (0.55 mm) and minimum at the site-II (0.52 mm), while in case of collection periods, maximum seed length was recorded during CP-2 (0.55 mm) and minimum during CP-1 (0.52 mm) (Table-4.4).

Interaction of sites and collection periods gave insignificant results with, maximum seed length at site-I × CP-3 (0.56 mm), while minimum at site-II × CP-3 (0.49 mm).

4.5.2 Seed width

The seed width gave the statistically insignificant results in respect to collection periods, sites and their interaction. The seed width was recorded more at site-I (0.39 mm) and less at site-II (0.38 mm), while seed width during different collection periods was found maximum in CP-3 (0.396 mm) and minimum in CP-1 (0.37 mm).

Interaction of sites and collection periods gave the maximum seed width at site-I × CP-3 (0.41 mm) and minimum in site-I × CP-1 (0.37 mm) with insignificant difference (Table-4.4).

4.5.3 Seed thickness

The seed thickness was found maximum at site-II (0.180 mm) and minimum at site-I (0.164 mm) with statistically significant difference. Collection periods also showed statistically significant variation with maximum thickness during CP-2 and CP-3 (0.177 mm) and minimum during early collection period (0.166 mm). Interaction of sites and collection periods was also found statistically significant variation where the maximum thickness was at site-II × CP-2 (0.194 mm), followed by site-II × CP-3 (0.184 mm) while minimum was at site-I × CP-1 (0.159 mm) (Table-4.4).

4.5.4 Test weight of seeds

The test weight of 1000 seeds was found maximum at site-II (27.57 g/1000 seeds) and minimum at site-I (21.48 g/1000 seeds) with the statistically significant variation. In respect to collection periods maximum test weight of seeds was weighted during CP-3 (30.20 g/1000 seeds) and minimum during CP-1 (14.56 g/1000 seeds).

Interaction of sites and collection periods also showed significant variation where the heaviest seeds were recorded maximum at site-II × CP-2 (34.50 g/1000 seeds) followed by site-II × CP-3 (32.50 g/1000 seeds), while the lighter seeds were found at site-I × CP-1 (13.60 g/1000 seeds).

Seed length, width and thickness are inherently correlated to various growth parameters of a species each other and showed significant variation as well as to the environment habitats. (Bagchi and Dobriyal, 1990) in case of *A. nilotica*. They suggested that the significant variation existed among the provenances and lower variation within the provenance; this might be due to environmental variation. Bagchi and Sharma (1989) again reported the positively significant correlations among length, breadth and test weight of seeds in *Santlum album*. A close relationship between seed size/weight and quality has been documented for many tropical tree species by many workers (Gupta *et al*., 1983; Ponnammal *et al*., 1993, Dar *et al*., 2002). Jenner *et al*. (2003) found that variation in seeds of *Madhuca latifolia* was attributed to differential selective pressure over the species range and random genetic drift in relation to genotypic, phenotypic and environmental variance, respectively. Todaria *et al*. (2006) also reported that seeds had most variable character in *Acacia catechu*, due to source variation. Raychowdhary (1961) showed that the genotypic association between length and breadth of rice grains was negative relation. Naugraiya and Pathak *et al.* (1999) also found the variability in seed length, breadth and thickness of *Atylosia scarabaceoides*. They indicated that in lower shape index from bolder seeds and higher from poor seeds. The inter site variability was also apparently indicated the role of various site factors on production of overall seed dimensions.

4.6 Seed polymorphism

Seeds were collected from two sites during three collection periods, early, middle and late collection periods. Collected seeds were divided in to three groups on the basis of their size (small, medium and large) and these groups were again divided in three groups on the basis of their colour (light, brown and black). Finally nine seed polymorphic groups were made and the share of seed in each group was estimated on the basis of number and weight presented for percentage distribution.

4.6.1 Seed distribution in Polymorphic group

The overall mean population of different size of seed, was found statistically significant where the maximum population of seeds were found in medium (63.40%) followed by small (24.56%) and minimum large seed (12.24%) at site-I. The seeds from different collection period showed more or less similar trend, where it was 66.3, 64.8 and 57.2 percent from medium seeds during late, early and middle collection respectively. The contribution of small group of seed was ranged 29.09 to 20.7 percent in early to late collection period shared large seed group was varied in all the collection period at site-I (Fig-4.1).

In case of site-II the overall population of different seed size was found insignificant with highest in medium size (48.5 %) followed by small (32.55 %) and lowest in large seeds (18.56). The role of collection periods in a seed lot for the size of seeds followed more or less trend of site-I but population of medium size seeds decreased from 62.3 percent to 37.64 percent from early collection to late collection period, while the share of small sized was found to be increased from 15.4 percent in early collection to 43.08 percent in late collection period.

In case of colour wise population of seeds in a lot at site-I, the maximum seed were found in black colour (86.44 %) followed by brown colour (8.45 %) and light colour (3.34 %). In consideration of collection period the black colour seeds share was increased from 80.34 to 91.72 percent with increasing the collection time of seeds, while population of brown and light colour seeds were declined from 10.36 to 4.80 percent and 9.24 to 3.31 percent respectively early to late collection time of seeds at site-I.

Seed population in colour groups showed significant variation and their maximum strength was for brown seeds (74.28 %) followed by black seeds (13.81 %) at site-II. In case of different collection period the share of brown colour seeds were found to be increased as the collection period increased from 70.4 to 79.64 percent while share of black seed was found to be decreased three times from early collection (18.09 %) to late collection (6.15 %). The share of light colour seeds was found to be varied and it was 10.86 percent during early collection, which decreased by 1 percent in middle peak collection period and further increased up to 13.75 percent in late collection period.

The overall contribution of nine polymorphic group of seed at site-I showed maximum number seeds in medium black group (56.05 %) followed by small black group (20.69 %) and large black group (9.75 %) while rest of group possessed less than 5 percent seeds, with minimal in large light group (0.75 %). In case of site-II the over all contribution of nine polymorphic groups of seeds showed maximum number of seeds in medium brown group (38. 4 %) followed by small brown group (26.42 %) and rest of the size and colour possessed less than 10 percent seeds, where the minimum number of seeds was in small and black colour (1.9 %).

4.6.2 Test weight of seeds in polymorphic group

Test weight of different polymorphic groups of seed was taken on precessions analytical balance (Table 4.5 & 4.6).

The seeds from different collection period at site-I showed that the heavier seeds were received during late collection (25.61 g/1000 seeds) followed by middle collection (20.91 g/1000 seeds) and early collection (20.38 g/1000 seeds) (Table 4.5).

The overall mean test weight of different size of seed was found statistically significant where the maximum test weight of seeds was found in large seeds (28.64 g/1000 seeds) followed by medium (22.16 g/1000 seeds) and minimum in small seed (16.09 g/1000 seeds) at site-I (Table 4.5). During early collection there were 26.65, 17.56 and 16.93 g/1000 seeds in large medium and small seeds respectively and it increased up to late collection in all size group accept in small seed which decreased in middle collection by 2.96 percent. Overall size and collection period interaction showed that large seed of late collection was heavier seeds (31.0 g/1000 seeds) followed by middle size seeds, while the lightest seed were observed in small size during middle collection (13.97 g/1000 seeds).

In case of colour wise test weight of seeds at site-I, the maximum weight was found in brown colour seeds (23.8 g/1000 seeds) followed by light (23.29 g/1000 seeds) and black colour seeds (19.81 g/1000 seeds) with insignificant variation. In consideration of collection period the test weight of black colour seeds was increased from 17.52 to 22.48 g/1000 seeds with the increasing the collection time of seeds. Similar trend was observed in light colour seeds where test weight was also found to be increased from 19.35 to 28.43 g/1000 seeds, which were heaviest group in respective collection period i.e. early to late collection. While test weight of brown colour seeds were declined from early collection (24.94 g/1000 seeds) to middle collection (21.2 g/1000 seeds) and further increased in late collection (25.94 g/1000 seeds).

The overall nine polymorphic group of seed size and colour at site-I showed maximum test weight of seeds in large light colour group (32.21 g/1000 seeds) followed by large brown (29.02 g/1000 seeds) and large black group (24.69 g/1000 seeds) while small group possessed least test weight of seeds, with black colour (14.17 g/1000 seeds) and light colour group (14.97 g/1000 seeds). (Table 4.5)

In case of site-I the overall test weight of nine polymorphic group of seeds in three collection periods showed maximum test weight of seeds in large light colour group of late collection (34.46 g/1000 seeds) followed by medium light colour group of late collection (33.6 g/1000 seeds). In case of site-II the role of collection period on the seed test weight showed that heavier seed weigh in early collection (21.45 g/1000 seeds) followed by late collection (19.46 g/1000 seeds) and middle collection (18.57 g/1000 seeds) respectively. (Table 4.5)

In case of site –II size group of seed test weight was found statistically significant with highest in large seeds (22.45 g/1000 seeds) followed by medium size (17.7 g/1000 seeds) and small seeds (15.82 g/1000 seeds) respectively (Table-4.6).

The test weight of different size of seeds in early collection period showed that test weight of 23.44, 18.47 and 13.47 g/1000 seeds was recorded in larger, medium and small seeds respectively and decreased to 21.68 and 12.99 g/1000 seeds in larger and medium class seed during middle collection period., while the test weight of small seed was found to be increased to 19.65 g/1000 seeds. In late collection period the test weight of larger and medium class seed was increased while decreased in small seed which was over all minimum (14.56 g/1000 seeds) in 9 group size and collection period (Table-4.6).

Seed test weight in colour groups of site-II showed insignificant variation and there maximum test weight was recorded for light colour seeds (20.90 g/1000 seeds) followed by brown seeds (18.55 g/1000 seeds) and minimum in black seeds (17.82 g/1000 seeds). In case of different collection period and colour group, the test weight of black colour seeds were maximum during late collection and minimum in middle collection period (15.65 g/1000 seeds) which was lowest among all nine group of colour × collection periods. In brown colour group the heaviest seed was recorded during middle collection (20.33 g/1000 seeds) while least seed weight was recorded in late collection (17.06 g/1000 seeds). The test weight of light colour seeds was found 20.60 ± 0.73 g/1000 seeds during three collection periods (Table-4.6).

Among the interaction of size and colour seed group the heaviest seeds were weighed in large and light colour seeds (25.2 g/1000 seeds) followed by medium black (23.1 g/1000 seeds) and minimum recorded in small and black seeds (11.57 g/1000 seeds) at site-II.

In case of Size x colour x collection period at site-II the insignificant lower ranged of test weight was recorded in black and small seeds during all the collection period (11.42 to 11.71 g/1000 seeds) and also in light and small seed of middle collection (11.6 g/1000 seeds). Maximum test weight was recorded in medium and black seeds (31.20 g/1000 seeds) during late collection followed by large and light colour seed of early and late collection period (27.45 ± 0.03 g/1000 seeds) (Table-4.6).

The inter site variability was apparently indicated the role of various site factors on distribution pattern of polymorphic group. Such behaviour of polymorphic seeds has been found in many species Harper (1977). A close relationship between seed size/ weight and quality has been documented for many tropical tree species (Gupta *et al*., 1983; Ponnammal *et al*., 1993). Pathak *et al*. (1974) also reported polymorphism behaviour in respect to seeds in *L. leucocephala* and found significant variation in seeds due to habitats of growing trees. Seed coat colour variations had also been reported in *Abizia procera* where the yellow colour seeds proved superior to black and brown seeds (Kandya, 1989), while dark colour of the seed was found to be associated with incomplete development of embryo in *Albizia lebbek* as well as in *Acacia catechu* (Babeley and Kandya, 1984). Similar results reported by Naugriaya and Pathak (1987) in rangeland legumes *Indigofera gladulosa* where the blackish green seeds had maximum test weight but showed insignificant results between other colour group while seed from moist sites gave heavier seeds due to presence of moisture. Similarly, Naugraiya (1999) reported that variation in different polymorphic group *Atylosia scarabaeoides* L. maximum distribution of brown medium colour over the brown large and brown small in respect to all sites, while in respect to seed test weight, Naugraiya and Pathak (1999) also reported the higher test weight for larger x dark brown seeds at site-II and minimum in the small x light brown seeds at site-III, this may be due to the variation in soil properties and field moisture level. This indicated that there was a natural adjustment between available resources and production of polymorphic quality of seeds as it was apparently in present case of *A. mangium*.

4.7 Seed germination and seedling vigour

Seed germination and initial growth always found to be an important phase of the plant for establishing them in an environment to lead a successful life. In nature seeds always react with various climatic stress as per their genetically and physiological potential and finally reflected in germination and seedling vigour. Here results are presented on seed germination and seedling vigour of *Acacia mangium* after conduction of series of experiments in the standard laboratory condition.

4.7.1 Effect of chemical scarification

Scarification is the one method breaking hard seed coat dormancy. Here the chemical method was used for breaking the hard seed coat dormancy by using the conc. H_2SO_4 at eight different time period *viz*., 0.0 (T_1), 0.5 (T_2), 1.0 (T_3), 2.0 (T_4), 3.0 (T_5), 5.0 (T_6), 10.0 (T_7) and 15.0 (T_8) minutes (Table-4.7 & Fig-4.2).

Germination: There was significant variation in all treatments. Germination percentage was received maximum in at the T_7 (90.67%) i.e., 10 minutes scarification followed by T_6 (89.33%) and T_5 (82.67%) The minimum germination was in without scarified seed T_1 (6.67%).

Seedling vigour: Seedlings vigour observed at 10 days after germination for all the growth parameters *viz*.; plumule length, radical length, leaves number and total dry weight of seedling showed statistically significant results for various treatments of scarification.

The growth in plumule length was recorded maximum in the T_7 (7.2 cm) followed by T_6 (6.85 cm) and T_5 (6.5 cm), while the minimum was observed in the not scarified/control condition T_1 (2.2 cm).

Radical length was received maximum in T_7 (4.58 cm) followed by T_6 (4.45 cm) and T_5 (3.63 cm), though the minimum was recorded in control T_1 (1.59 cm). The leaves number was maximum in T_7 (10 leaves/seedling) followed by T_6 (9.67 leaves/seedling) and T_5 (9.65 leaves/seedling), while minimum was recorded in the control T_1 (6.0 leaves/seedling).

Total dry weight of seedling was received maximum in T_7 (0.0159 g) followed by T_6 (0.0155 g) and T_5 (0.0141 g) with minimum in control condition i.e. T_1 (0.0068 g).

Leguminous seeds bear hard seed coat dormancy and required treated to break it. These lot of work have been done on breaking the hard seed coat by many workers for number of tree species (Mutha *et al*., 2004, Pandit and Ram, 2006 and Bhatacharya and Sahu, 1990) observed that disintegration of the seed coat as well as the microphyler plug was the reason for increase in imbition and subsequent germination in *Cassia fistula, Albizia labbeckand* and *Pinus roxburghii,* seeds. In leguminous tree species the best germination was observed after acid treatment which results from the break down of the seed coat, permitting unrestricted inflow of water into the seed and the expansion of the embryonic parts (Bebari and Mohammed, 1985). Softening seed coat by acid treatment induced water absorption and gaseous exchange resulting in quick and early emergence of radical (Eviritt, 1983, Kissock and Hafferkamp 1983). A similar result was also reported by the Gehlot and David (1998) germination, seedling vigour and germination rate showed close association, which increased linearly with, increases linearly duration of acid scarification. The treatment of acid scarification was also found more effective and significant over hard seed coat dormancy and enhance germination of *A. mangium*.

4.7.2 Effect of Temperature

Temperature is the most essential factor activating the seed physiological activities for germination. The most suitable temperature available to the seeds always resulted fast and maximum germination. Temperature actively supported to the seed germination and seedling growth in *A. mangium* where seven ranges of temperature were used for germination and seedling growth *viz;* 16°C (T_1), 20°C (T_2), 24°C (T_3), 28°C (T_4), 32°C (T_5), 35°C (T_6) and 40°C (T_7). The results of observations are presented in Table-4.8 & Fig-4.2.

Germination: Germination under different treatments of temperatures was found statistically significant with maximum at 32 ^{0}C i.e., T_5 (97.33%) followed by T_4 (76.0%) and T_3 (70.67%), respectively while the minimum was recorded at 40 ^{0}C i.e., T_7 (36.0%).

Seedling vigour: Seedling growth was measured for different parameters. All parameters *viz;* plumule and radical length, leaves number and total dry weight were found statistically significant under various temperatures.

Plumule length was received maximum at 32 ^{0}C T_5 (9.02 cm) followed by 28 ^{0}C (7.520 cm) and 24 ^{0}C (5.85 cm) while minimum at the 16 ^{0}C T_1 (1.99 cm). Radical length was also maximum at the 32 ^{0}C (4.35 cm) followed by 28 ^{0}C (3.18 cm) and 24 ^{0}C (2.81 cm) and minimum at the 40 ^{0}C (0.65 cm). Leaves numbers were found the maximum at 32 ^{0}C (11.50 leaves/seedling) followed by

28 ^{0}C (11.38 leaves/seedling), 24 ^{0}C (9.88 leaves/seedling) and minimum at the 16 ^{0}C (6.88 leaves/seedling). Total dry weight of seedling was received maximum at 32 ^{0}C (0.0153 g/seedling) followed by 28 ^{0}C (0.0129 g/seedling) and minimum at 16 ^{0}C T_1 (0.0075 g/seedling).

Similar results observed by Khamane and Bhosle (2002) in case of 12 wood species were germination was decreased with an increase in temperature upto 40°C. Dayan and Reaviler (1996) also found the temperature affected the seed viability and germination of *A. mangium*. Lima and Garcia (1996) reported that the most suitable temperature for germination and seedling growth in *A. mangium* was up to 35°C.

4.7.3 Effect of Moisture stress

Moisture play vital role in seed germination and to determine the response of *A. mangium* in various moisture stress condition studied conducted in laboratory. The moisture stress was created by the using mannitol its seven ranges viz. 0 (T_1), 0.33 (T_2), 5.0 (T_3), 7.5 (T_4), 10.0 (T_5), 12.0 (T_6) and 15.0 (T_7) atm., where the T_2 and T_7 was field capacity and wilting point respectively for plants. The results are presented in Table-4.9 & Fig-4.2.

Germination: Germination was more at lower concentration and at decline with increasing the concentration. Germination was found statistically significant with maximum at the T_1 (0 atm) i.e. without applying moisture stress (97.33%) followed by T_2 (41.33%) i.e. field stress condition and T_3 (28.0%). While the lowest germination was recorded in T_5 (5.33 %) seeds did not germinate at T_6 and T_7.

Seedling vigour: Moisture stress also affected the seedling growth. Growth in seedlings was found statistically significant for all parameters *viz*.; plumule and radical length, leaves number and total dry weight.

Plumule length of seedlings was received maximum in control T_1 (12.43 cm) followed by T_2 (8.13 cm) and minimum at the 10 atm. T_5 (2.40 cm). Radical length was also received maximum in control T_1 (3.44 cm) followed by T_2 (3.09 cm) and minimum at T_5 (0.82 cm).

Leaves numbers were found maximum under control T_1 (11.0 leaves/seedling) followed by T_2 (8.8 leaves/seedling) and minimum 10 atm. T_5 (6.0 leaves/seedling). Total dry weight of seedlings was recorded maximum in the control T_1 (0.0121 g/seedling) and minimum in the T_5 (0.0045 g/seedling) while T_3 and T_4 was showed insignificant difference, with 0.0073 and 0.0063 g/seedlings respectively.

Similar results were observed by Hashim and Wathern (2003) when moisture stress created by mannitol concentrations caused decline in seed germination and growth of seedlings in *A. mangium* with increasing the concentration.

4.7.4 Collection period

Seeds collected during the three collection periods *viz*.; early, middle and late at site-I and site-II were tested for their germination and seedling growth vigour are presented in Table-4.10 & Fig-4.3.

Germination: The role of collection periods, sites and their interactions on germination of seeds were found statistically significant. Seeds were received from the site-II gave maximum germination (89.20%) and than the site-I (72.60%).

In case of collection periods the germination was found maximum in late collection (95.00%) and minimum in the early collection period (49.40%). Interaction of sites and collection periods gave maximum germination at the site-II CP-3 (99.50%) followed by site-I CP-2 (95.20%) and site-II CP-2 (84.90%) while minimum was in site-I CP-1 (24.90%).

Seedling vigour: Plumule length of seedling was 8.32 and 6.60 cm recorded, at the site-II at site-I respectively with significant variation (Table-4.10). The collection periods showed significant impact on growth of plumule with maximum length in late collection (8.71 cm) followed by middle collection (7.29 cm) and minimum in early collection (6.44 cm). Interaction of site and collection period gave maximum in site-II CP-3 (9.75 cm) followed by site-II CP-2 (8.55 cm) and site-I CP-3 (7.67 cm) and minimum at the site-I CP-2 (5.94 cm).

Growth in radical length was significantly varied in sites with maximum at site-II (4.36 cm) and minimum at site-I (3.17 cm). Collection periods were also showed significant variation for growth of radical which was maximum in CP-3 (5.12 cm) followed by CP-2 (4.12 cm) and minimum in CP-1 (2.05 cm). Interaction among the sites and collection periods for growth was showed significant variation with maximum at site - II CP-3 (5.56 cm) followed by site - II CP-2 (4.75 cm) and site - I CP-3 (4.66 cm) while minimum at site - I CP-1 (1.35 cm).

Formation of leaves in seedlings was recorded 8.67 and 8.0 leaves/seedlings in site-II and site-I respectively with significant difference. Though the effect of collection period was found insignificant leaf formation with maximum in CP-3 (9.0 leaves/seedling). Middle and early collection (8.0 leaves/seedling).

Interaction of sites and seed collection periods was found statistically insignificant with maximum in site-II CP-3 (10.0 leaves/seedling) and minimum (8.0 leaves/seedling) in rest of the other interactions.

Total dry weight was found insignificant for sites, collection period and their interaction. However it was maximum at site-II (0.0078 g/seedling) and minimum at site-I (0.0067 g/seedling). Collection period maximum dry weight was found in late collection period (0.0106 g) and minimum in CP-1 (0.0046 g/seedling).

Interaction of sites and collection periods gave maximum dry weight in site-I CP-3 (0.0114 g/seedling) and minimum in site-I CP-1 (0.0037 g/seedling).

Khullar *et al*. (1991) reported that the collection period was affected the seed germination. The maximum germination in peak period (middle) in comparison to initial and end phases in case of *Hardwickia binnata* and similar phenomenon observed in *Albizia labback*. These observations indicate the importance of timing of the collection period. Rahayat and Minclowati (1997) found that the germination and germination value of *A. mangium* differed between tree ages. Seedling height and diameter growth, dry weight and root length received maximum in six year old tree and germination fond maximum in nine year old trees. Suresh *et al*. (2001) found that the higher germination values in seeds of old age trees of *A. nilotica* and decreased in seeds of young trees, but in respect to seedling vigour they received maximum growth in seeds of old age tree.

4.7.5 Effect of seed polymorphism

Seeds collected from two sites in three collection periods were separated in nine groups on the basis of three sizes (Large, Middle and Small) and three colour (Black, Brown and Light). Thus nine seed polymorphic groups were tested for germination and seedling growth for site-I and site-II as well as three collection periods are presented in Table-4.11 & 4.12.

Over all the seed germination of *A. mangium* showed insignificant variation for their collection periods at site-I and site-II. At the site-I seed germination was recorded in order of middle > late >early collection, while at site-II it was in order of late> middle > early collection of seeds.

4.7.5.1 Effect of Size

Seed germination was found insignificant in respect to their size for both site-I and site-II. The maximum germination was observed in large seeds (70.61 %) followed by medium (61.08 %) and minimum was in the small (60.28 %) at site-I, while in case of site-II, the maximum seed germination was recorded in small seed (62.99 %) followed by medium (62.73 %) and minimum was observed in the large seeds (59.72 %) (Table-4.11 & 4.12) (Fig-4.4 & 4.5).

4.7.5.2 Effect of Colour

Seed colours played statistically significant role in germination for site-I and Site-II. A site-I, maximum germination was counted in black colour seed (83.43 %) followed by brown colour (66.86 %) and minimum in light colour (30.31 %). In case of site-II the maximum germination was recorded in brown colour seed (82.86 %) followed by black colour (66.95 %) and minimum in light colour (35.67 %).

4.7.5.3 Effect of Interactions of Size, Colour and Collection period

***Size x Colour*:** Interaction of size and colour seeds was found statistically insignificant for germination at both the sites. The maximum seed germination was showed by large and black seeds (89.11 %) and followed by medium and black seeds (81.04 %) and minimum was in small and light colour seeds (21.51 %) at site-I. In case of site-II the maximum germination was observed in medium and brown seed (83.19 %) and minimum in large and light colour seed (28.14 %).

Size x Collection period: Interaction of size and collection periods showed insignificant variation in germination at ether sites. The maximum germination for seeds at site-I was recorded in large size seeds of late collection (84.10 %) and minimum in small size seeds of late collection (50.77 %). In case of site-II the maximum germination was found in the small late collection seed (64.79 %) and minimum in medium seed of late collection (58.50 %) (Table-4.11 & 4.12).

Colour x Collection period: Interaction of seed colours and collection periods were found statistically insignificant in respect to germination for the site-I and site-II (Table- 4.11 & 4.12). It was maximum in seeds of black colour and middle collection (86.36 %) and minimum in seeds of light colour middle collection (27.64 %) for site-I. Seeds of site-II gave maximum germination in brown colour seeds of middle collection (88.12 %) and minimum in light colour seeds of middle collection (31.68 %).

***Size x Colour x Collection period*:** The interaction of the sizes, colours and collection periods for seed germination were not found significant in site-I and site-II (Table- 4.11 & 4.12). However the maximum germination was observed in large and black colour seeds of early and middle collection (92.31%) and minimum in small light colour seeds of late collection (4.70%) at site-I. In site-II it was maximum in medium, brown colour seeds of middle collection (90.83 %) and minimum in large, light colour seeds of middle collection (21.72 %).

Seedling vigour: Early collection of seed showed statistically significant difference among the polymorphic group in respect to all growth parameters of seedlings *viz;* plumule and radical length, leaves number and total dry weight at the both sites (Table-4.13 & 4.14).

Seedling growth behaviour of seeds collected from site-I during three seed collection period are presented Table 4.13 presented showed that in early collection seeds plumule length was observed maximum in medium black (9.20 cm) and minimum in large light seed (1.37 cm). In case of radical length maximum was received by medium black (3.33 cm) followed by large black seed (2.99 cm) and minimum by large light (0.81 cm). Number of leaves maximum in medium black and large black (11.33 leaves / seedling) followed in small brown (10 leaves/ seedling) and minimum in the small light (5.33 leaves/ seedling). In case of total dry weight of seedling maximum was recorded in small black (0.019 g/seedling) followed by medium and large black seeds (0.018 g/seedling) and minimum by small light colour seeds (0.005 g/seedling). Middle collection there period was found insignificant difference among all seedling parameters except in total dry weight at site-I. Plumule length was received maximum by the medium black (8.53 cm) and minimum by large light colour seeds (3.5 cm). In case of radical length maximum growth was found in medium black seeds (2.53 cm) and minimum in large light colour seeds (0.96 cm). Leaves numbers were found maximum in medium black seeds (11.33 leaves/ seedling) and minimum in the large light colour seeds (5.5 leaves/ seedling). Total dry weight of seedling was observed maximum in medium black seeds (0.018 g/seedling) and minimum in small black (0.004 g/ seedling) at site-I. Late collection period was showed significant difference in all seedling parameters but insignificant difference was found in number of leaves/ seedling. (Table-4.13) Plumule length was found maximum in medium black (8.8 cm) followed by large black (8.23 cm) and lowest in small light seeds (2.77 cm). Radical length was received maximum by the large black seeds (2.93 cm) and minimum by small light seeds (1.04 cm). Number of leaves was found maximum in large brown seeds (10 leaves/seedling) and minimum in small and medium light colour seeds (5.33 leaves/seedling) but there were insignificant relations. Total dry weight of seedling was found maximum in large black seeds (0.019 g/ seedling) and minimum in small and medium light colour seeds (0.006 g/ seedling).

In case of site-II and early collection of seeds the plumule length was received maximum by the large black seeds (9.07 cm) and minimum by the small light (6.0 cm) (Table-4.14). The growth in radical length of seedling was found maximum in large black (2.8 cm) and minimum in small light colour seeds (1.51 cm). Number of leaves was found maximum in large black and medium black seeds (11.3 leaves/seedling) and minimum in large light colour seeds (6.67 leaves/seedling). Total dry weight of seedling was found maximum in seedling of medium black seeds (0.017 g/seedling) and minimum in small light colour seeds (0.008 g/seedling). There was found statistically significant results for all the growth parameters. Seedlings of middle collection seeds showed were found significant difference for all the growth parameters of seedling. Plumule length was found maximum in medium black seeds (9.43 cm) and minimum in small light seeds (5.10 cm). Radical length was found maximum in large black seeds (2.8 cm) and minimum in small light seeds (1.39 cm). Leaves numbers were found maximum in large black seeds (11.33 leaves/seedling) with insignificant difference to large and medium brown seeds, while minimum leaves were recorded in small light colour seeds (8.00 leaves/ seedling). Total dry weight of seedling was found maximum in large black and brown seeds (0.019 g/seedling) and minimum in small light (0.008 g/seedling).

In case of late collection of seeds the plumule and radical length was maximum in large black (8.8 cm) and large brown seed (2.93 cm) respectively, though minimum length in plumule and radical was recorded in small light colour seeds 7.07 and 1.10 cm, respectively. Number of leaves was maximum in large brown seeds (10 leaves/seedling) and minimum in small light colour seed (8.17 leaves/seedling). Total dry weight of seedling was found with statistically insignificant maximum in large brown seeds (0.019 g/seedling) and minimum in medium light colour seeds (0.004 g/seedling) at site-II (Table-4.14).

Kiran *et al*. (2003) also found that the germination rate was positively significant with seed weight and large seeds were found to be encouraged high germination and successful production of seedlings because large sized seeds provide greater food reserves, which sequential resulted in more rapid germination reported by Brown (1970). Srimanthi *et al*. (2001), Bagchi *et al*. (1989) and Shivkumar and Banerjee (1989) also reported the role of large size fruits or seeds for encouraging the high germination and better seedlings.

In case of of *Grewia optiva*, Tyagi *et al*. (1999) workedout the positive correlation of germination with all the seed characters studied *viz*.; seed length, width, thickness, and 100 seed weight.

In *A. mangium*, size and colour showed significant variation among sites and collection period. Where the large and late collection seed gave comparatively better results because bigger seeds from trees more than eight years of age had large endocarp and with sufficient nutrients to enhance better and fast growth in Neem. Ponnuswamy *et al*. (1991). Similar results reported by Naugriaya and Pathak (1987) in *Indigorea gladulosa*, blackish green seeds had maximum test weight but showed insignificant results between other colour group and weight. Moist sites gave heavier seeds due to presence of moisture. Similarly, Naugriaya and Pathak (1983) found the highest germination achieved by large dark brown in *Atylosia scarabacoides* be the result of genetic set up. Srimathi *et al*. (1991) also reported that the medium size seed obtained highest germination *Acacia mellifera* and seedling vigour also received superior. Naugraiya and Pathak (1999) also found that the germination behaviour of polymorphic seeds showed different germination peak for dark brown and medium seeds from different sites. Ghosh *et al*. (1976) also reported that the medium, sized seeds of *Prinus roxbarghii* gave significantly higher initial germination, total germination and germination value. Dar *et al*. (2002) also found that the bold seeds recorded higher germination and germination value with high seedling vigour. Heavier seed produce more seedling and total dry weight, to greater nutrient reserve in larger seeds (Kathju *et al.*, 1978). Similar trend was also reported by Gonzales (1993) *Virola koschyni*, Pannamal *et al*., (1993) for *Hardwickia binata* and Roy (1985) for.*A. lebbek*

4.7.6 Effect of Sodium salts

Sodium salts were caused salinity and inhibited the plant growth and seed germination. Hence the seven concentrations (ppm) *viz;* 0 (T_1), 100 (T_2), 200 (T_3), 500 (T_4), 700 (T_5), 1000 (T_6) and 2000 ppm (T_7) of sodium carbonate, bicarbonate and chloride were used to test of germination, seedling growth and behaviour.

4.7.6.1 Sodium carbonate

Effect of sodium carbonate and seed germination and seedling growth was presented in Table-4.15 & Fig-4.6.

Germination: Germination was varied significantly for different concentrations with maximum in the control T_1 (94.67%) and reduced to 85.33 percent at 100 ppm $T_{2.}$ Germination gradually decreased minimum at concentration 2000 ppm 69.33 percent.

Seedling vigour: Seedling growth was also affected significantly by the different concentrations of sodium carbonate. Plumule length of seedling showed statistically significant maximum growth in the control - T_1 (11.4 cm) followed by T_2 (8.98 cm) and T_3 (8.51 cm) while minimum at the T_7 (6.93 cm). But there was insignificant variation among the all the concentration of sodium carbonate.

Growth of radical was also found statistically significant under different treatments. The maximum length was recorded in the T_1 (2.76 cm) followed by T_2 (2.53 cm) with insignificant variation. It was further decreased up to 2000 ppm (0.79 cm).

Leaves number was recorded statistically significant with maximum in control - T_1 (11.67 leaves/seedling) followed by T_2 (9.50 leaves/seedling). The decreasing trend of leaves quantity showed the insignificant difference form 100 ppm to 1000 ppm. The minimum number of leaves was produced at T_7 2000 ppm the T_7 (7.51 leaves/seedling).

Total dry weight accumulated in the seedling was found insignificant with maximum in control T_1 (0.0109 g/seedlings) and minimum at 2000 ppm (0.0091 g/seedlings).

4.7.6.2 Sodium bicarbonate

Sodium bi carbonate was also influenced the germination and seedling growth vigour and the results are presented in Table- 4.16 & Fig-4.6.

Germination : Germination of seeds was observed statistically significant, where it was found maximum in the control T_1 (90.67%) but in presence of sodium bi carbonate it was maximum at lower concentration i.e. 100 ppm (85.33 %) which further insignificantly droped up to 500 ppm T_3 (82.67%). The minimum seed germination was recorded at 2000 ppm T_7 (58.66%).

Seedling vigour : Seedling growth was showed significant variation in plumule length, which was obtained, maximum by the T_1 (11.6 cm) followed by T_2 (9.96 cm) and minimum by the T_7 (5.81 cm).

Growth of radical length was showed insignificant variation with maximum in T_1 (2.99 cm) followed by T_2 (2.48 cm) and minimum in T_7 (1.77 cm). Number of Leaves in seedling was found significant for seven concentrations of $NaHCO_3$. The leaves were found maximum in control T_1 (11.27 leaves/seedling). Number of leaves in a seedling were decreased in presence of $NaHCO_3$ where it had insignificant from 100 ppm to 700 ppm (9.5 leaves/seedling) & (8.17 leaves/seedling) presence of leaves was recorded at 2000 ppm minimum T_7 (7.67 leaves/seedling).

Total dry weight accumulated the seedling growth in different concentrations of $NaHCO_3$ was recorded statistically significant with maximum dry weight in control - T_1 (0.0107 g/seedling) followed by T_2 (0.0094 g/ seedling) and T_3 (0.0085 g/seedling) and it further decreased minimum in T_7 (0.0073 g/seedling).

4.7.6.3 Sodium chloride

Effect of different concentrations of sodium chloride on seed germination and seedling growth vigour was presented in Table-4.17 & Fig-4.6.

Germination : Germination percentage was varied with different concentrations of sodium chloride. The sodium chloride was showed significant reduction in seed germination after the control - T_1 (93.33%). At 100 ppm of NaCl. The germination was T_2 86.67 percent, 78.67 percent in T_3 and 66 percent in T_6. The minimum germination was recorded at 2000 ppm - T_7 (54.67%).

Seedling vigour **:** Seedling growth was showed significant variation in case of plumule length, which was recorded, maximum in the control - T_1 (12.03 cm), insignificantly followed by T_2 (11.52 cm), T_3 (10.08 cm) T_4 (9.8 cm) and T_5 (9.29 cm) and minimum in T_7 (7.11 cm).

In case of radical length, it was recorded statistically insignificant with maximum in T_1 (3.2 cm) followed by T_2 (3.02 cm) and T_3 (2.99 cm) and minimum in T_7 (1.18 cm). Leaves numbers in the seedlings were found statistically significant and the maximum number of leaves were recorded in control - T_1 (11.67 leaves/seedling) followed by T_2 (10.17 leaves/seedling) with significant relation. The minimum number of leaves was recorded at 2000 ppm T_7 (7.67 leaves/seedling) which showed insignificant variation up to 2000 ppm concentrations. Total dry weight of seedling was recorded insignificant variation under various concentration treatments of sodium chloride. However it was recorded maximum in control - T_1 (0.0093 g/seedling) and minimum in higher concentration of NaCl T_7 (0.0062 g/seedling).

Overall the seed germination of *A. mangium* was reduced with increasing salt concentration though at lower concentrations species was seems to tolerant. Similar trend was found by Gehlot and David (1991) on *Suaeda fruticosa*, they observed that the higher concentrations were retarding the germination, germination rate and seedling viguor because of osmotic effect. Similar declines in seed germination of rangeland legumems was seen by Pathak and Naugraiya (1987) and Naugraiya (2001) where higher concentration of salts absorbed by seeds might be caused toxic effect on tissues and reduced the germinability and growth vigour. Seeds germinate under lower salinity stress because weaker concentration of salts easily enter the seed tissues, it decrease water potentiality in seeds and promoted the water up take. This start the mechanism to germinate rapidly when the salt stress is received but excess time as well as concentration under saline condition, Indol acid, oxide activities attributed to delay in germination and stunting of seedling growth (Shukla and Baizal, 1977) similar trend Tomar and Yadav (1980) was also observed that initial seed germination was significantly decreased with increasing salinity levels. Sharma *et al*. (1996) reported that the increase in salinity levels resulted significant declining trend for all the growth parameters of various forest species.

4.7.7 Gibberellic acid

Gibberellic acid is the growth regulator hormone and also induced the seed germination and seedling growth. Different seven concentrations (ppm) of viz; 0 (T_1), 250 (T_2), 500 (T_3), 750 (T_4), 1000 (T_5), 1250 (T_6) and 1500 (T_7) were used as per sowing treatments. The results of the germination and growth vigour of seedlings are presented in Table-4.18 & Fig-4.7.

Germination : Gibberellic acid sensitive to light highly and also stimulate the seed germination. Germination of treated seed with different concentrations of gibberellic acid showed significant variation. Maximum germination was found in both control - T_1 and T_2 (90.67%) followed by T_3 (80.0%) and T_4 (74.67%) while minimum was found by T_7 (60.0%).

Seedling vigour : Growth in seedlings was found to be highly sensitive in presence of different concentrations of Gibberellic acid. All seedling parameters like, plumule length, radical length, leaves number and total dry weight was recorded with statistically significant differences (Table -4.18).

Length of plumule was found maximum in control T_1 (11.71 cm) followed by T_2 (7.41 cm) and T_3 (7.39 cm) and minimum in T_7 (3.71 cm).

Growth in radical length of seedling was found maximum in T_1 (3.91 cm) followed by T_2 (3.83 cm) and T_3 (2.70 cm) and minimum in T_7 (1.04 cm). Leaves numbers were found maximum in T_1 (11.5 leaves/seedlings) followed by T_2 (9.00 leaves/seedling) and T_3 (8.50 leaves/seedling) and minimum in the T_7 (6.58). Total dry weight of seedling was found again maximum in control T_1 (0.0135 g/seedling) followed by T_2 (0.010 g/seedling) and T_3 (0.0085 g/seedling) and minimum in T_7 (0.004 g/seedling).

Khullar *et al*. (1991) remarked that the GA3 increased seed germination due to the increases the activity of isocitrate lyure, which is a enzyme of glyoxylate cycle in the cotyledons for mobilizing the stored lipids, which is essential for growth of embryo resulting roster growth in growing tissues.(Brain and Groove, 1957). Gibberellic acid induced growth activities in the plant at lower concentration while at higher concentration gave depressing effect Naugraiya and Pathak (1987) studied the various growth and ecophysiological (RGR, NAR and LAR) parameters in *Atylosia scarbaeoidos* and recorded more or less similar trends as it was in present study of *A. mangium*. Robert and Smith (1977) reported similarly results of Gibberellic acid in case of germination of dormant seeds of 23 tree species. Ghyare (2005) also observed that the germination was increased the upto 400 ppm concentration of Gibberellic acid. Shinhababu *et al*. (2007) also find out that the growth the role of regulators (GA_3, IAA) for improvement of earlier seed germination in a number of woody plants.

4.7.8 Ascorbic acid

Ascorbic acid or vitamin ‘C’ also affected the seed metabolic activities and to understand it effect on seed germination and seedling growth, different concentrations in (%) of ascorbic acid *viz*; 0 (T_1), 0.25 (T_2), 1.0 (T_3), 1.5 (T_4), 2.0 (T_5), 2.5 (T_6) and 5.0% (T_7) were used and the results are presented in Table –4.19 & Fig-4.7.

Germination : Ascorbic acid affected the germination of *A. mangium* With statistically significant variation. The maximum germination was observed in control T_1 (93.33%), which dropped by 60 percent in T_2 (29.33%) and further decreased T_3 (13.33%) and T_4 (12.00%). The minimum germination observed in T_5 (2.00%) afterwards no germination was recorded in higher concentration of T_6 and T_7.

Seedling vigour : There was found statistically significant differences in all the growth parameters *viz*; plumule and radical length, leaves number and total dry weight.

Plumule length of seedling was observed maximum in control -T_1 (12.25 cm) followed by T_2 (4.4 cm) and T_3 (3.33 cm) while minimum was recorded in T_5 (2.00 cm).

Growth in radical length of seedling was also received maximum in control - T_1 (2.3 cm) followed by T_2 (2.07 cm), which reduce by half in T_3 (1.33 cm) and by one fourth in T_4 (0.68 cm). The minimum radical growth was recorded in T_5 (0.57 cm).

Number Leaves in a seedling was found maximum again in control T_1 (10.0 leaves/seedling) followed by T_2 (7.83 leaves/seedling) and T_3 (6.67

leaves/seedling) with minimum in T_4 and T_5 (6.0 leaves/seedling). Total dry weight of seedling was ultimately found maximum in T_1 (0.0108 g/seedling) in presence of Ascorbic acid it was (0.0074 g/seedling) and (0.0056 g/seedling) in T_2 and T_3 respectively. The minimum total dry weight was recorded in higher concentration of Ascorbic acid -T_5 (0.0037 g/seedling).

Ascorbic acid decreases the seed germination with increasing concentration similar results were observed by Naurgraiya and Pathak (1989) in *Atylosia scarbaueoides* in which germination and seedling growth reduced with increasing concentrations of Ascorbic acid. Ascorbic acid played an important physiological role in metabolism of growing plant (Chenoy, 1967) but its biosynthesis has importance in germinating seeds as well as other growing parts of seed. In case of *A. mangium* the results were found more or less similar to many workers (Abraham *et al.*, 1968 a, Agrawal and Govind, 1978 and Chenoy, 1967).

CHAPTER-V

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FUTURE RESEARCH WORK

The study on “Seed polymorphism and germination behaviour of *A. mangium* in Chhattisgarh was carried out in laboratory of Department of Forestry, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) during 2006-07. Experimental material was collected from two sites. Experimental field of Department of Forestry, IGKV, Raipur and Energy park plantation, Raipur in the three collection periods.

The highlights of the finding are as follows:

Tree characteristics

1. Four years old plantation at site-I was found average of height 5.76m, CD 12.78cm, DBH 10.64cm, crown diameter 2.05m and crown length 3.77m.
2. Six years old plantation at site-II was found average of height 9.24m, CD 16.46cm, DBH 12.14cm, crown diameter 2.71m and crown length 6.47m.

Tree Phenology

1. Peak period of leaf initiation was winter season and leaf fall was found maximum in the summer season.
2. Flowering was initiated in August at site-I and September at site-II.

3. Pod formation was started in first week of October at site-I and in last week of October at site-II.

Morphology of pods and seeds

1. Pod length was measured maximum at site-II (16.47 cm) and (15.28 cm) at site-I showed significant difference, while it was found maximum during late collection (18.75 cm) and minimum during early collection (13.93 cm).
2. Pod width was ranged 0.71 to 0.91 cm with maximum at site-II during late collection (0.91 cm) and minimum at site-I during early collection (0.71 cm) with insignificant difference.
3. Pod thickness was found maximum at site-II during late collection (0. 56 mm) and minimum at site-I during early collection (0.22 cm).
4. Test weight of fresh and dry pod was found maximum at site-II during late collection (56.99 g/100 pods) and (18.99 g/ 100 pods) respectively. The minimum test weight of fresh and dry pods was found at site-I during early collection (15.56 g/100 pods) and (5.30 g/100 pods) respectively.
5. The number of locule pod^{-1} was found highest at site-II during late collection (11.23 locule/pod) and minimum at site-I during early collection (7.5 locules/pod) with insignificant difference.
6. Healthy seeds pod^{-1} was found maximum at site-I during late collection (92.15%) and minimum at site-I during middle collection (76.24%) with significant difference.

7. Undeveloped seeds pod^{-1} was found maximum at site-I during early collection (14.33%) and minimum at site-II during late collection (0.35%) with significant difference.

8. Empty locule pod^{-1} was found maximum at site-I during middle collection (18.5%) and minimum at site-I during late collection (0%) with significant difference.

9. Seed length was found maximum at site-I during late collection (0.56 mm) and minimum at site-II during late collection (0.49 mm) with insignificant difference.

10. Seed width was recorded maximum at site-I during late collection (0.41 mm) and minimum at site-I during early collection (0.37 mm).

11. Seed thickness was found maximum as site-II during middle collection (0.194 mm) and minimum at site-I in during early collection (0.159 mm) with significant difference.

12. Test weight of seeds was found maximum at site-II during middle collection (34.50 g/1000 seed) and minimum at site-I during early collection (13.60 g/1000 seed).

13. Population of seeds in a lot showed nine polymorphic groups i. e. large, medium and small size seeds having light, brown and black coloured seeds. Where maximum number of seed was medium black at site-I and brown in site-II and minimum number of seed was large and light seeds at both sites.

14. At site-I late collection period gave maximum share of medium seeds (66.3%) and minimum share of large (12.88%), while in respect to

colour the maximum was received by black seeds colour (91.72%) and minimum by light colour seeds (3.31%).

15. At site-II the share of medium size was maximum (62.3%) during early collection and minimum in large (14.8%) during middle collection. Where as colour wise seed found maximum (79.64%) during late collection brown and minimum (6.15%) during late collection light.

16. Test weight of seeds of different polymorphic group in three collection periods showed heavier seeds in late collection at site-I and in early collection at site-II.

17. Large seeds were found to be bold and heavier than small at both sites while in colour least test weight of seed was found in black at both sites.

18. Test weight of colour x size group showed maximum value in large and light colour seeds at site-I (32.2 g/1000 seeds) and at site-II (25.2 g/1000 seeds) and minimum found in small seeds in order of black (14.17 g/1000 seeds) < range of test weight of light (14.97 g/1000 seeds) < brown (19.12 g/1000 seeds) at site-I while at site-II it was in order of black (11.57 g/1000 seeds) < brown (14.23 g/1000 seeds) < light colour (14.99 g/1000 seeds) in small seeds.

Seed germination and seedling vigour

1. Concentrate H_2SO_4 was received maximum germination in 10 minutes scarification (90.67%) and also high growth of seedling in respect to all parameters.

2. Most suitable temperature was found for germination 32°C (97.33%) and poor germination at the 40°C (36.0%).

3. Moisture stress was showed germination decrease with increase concentrations and poor growth in seedlings Maximum in control (97.33 %) and minimum in 10 atm (5.33 %).

4. Germination as found maximum in late collection period (95.00%) and minimum in early collection (49.40%) with significant difference. Seedling vigour was found maximum in late collection period.

5. Large size seeds were found maximum germination (70.61%) and minimum in small (60.28%) at site-I while at site-II maximum in small (62.99 %) and minimum in large (59.72 %).

6. Black colour was found maximum germination (83.43 %) minimum in light colour (30.31 %) at site-I in case of site-II brown colour (82.86 %) and minimum in light colour (35.67 %).

7. Interaction of size x colour was found maximum in large and black (89.11 %) and minimum in small and light (21.51 %) at site I. In site-II maximum in small brown (84.06 %) and minimum in large light (28.14 %).

8. Interaction of size and collection period was found in case of site-I maximum germination was found in large and late collection (84.10 %) and minimum in small and late collection (50.77 %). In case of site-II maximum in medium and middle collection (69.65 %) and minimum in large and early collection (55.90 %).

9. Interaction of colour and collection period was found maximum germination in black and late collection (84.10 %) and minimum in light and late collection (27.64 %) for site-I. In case of site-II maximum

germination in brown colour seed and middle collection (88.12 %) and minimum in light colour and middle collection (31.68 %).

10. Interaction of all characters *viz;* colour, size and collection period gave maximum germination by large black colour of early and middle collection (92.31 %) at site-I and minimum found in small light and late collection (4.70 %). In case of site-II maximum germination was found in medium brown and middle collection (90.83 %) and minimum in large light and middle collection (21.72 %).
11. Seedling vigour was found maximum by the large black and late collection at site-I and medium brown and middle collection at site-II.
12. Sodium salts (Na_2CO_3, $NaHCO_3$ and NaCl) decreased germination with increasing concentrations.
13. Gibberellic acid and Ascorbic acid was showed poor germination with increasing concentration.
14. Seedling growth vigour was found maximum in respect to best germination.

Conclusion

The study on seed polymorphism and germination behaviour of *Acacia mangium* in Chhattisgarh was found energy park the most suitable site for growing *Acacia mangium* tree compared to experimental field at Department of Forestry, IGKV, Raipur. Peak period of flowering of *A. mangium* was end of rainy season and pods formation maximum in January. Healthy pods heath seeds were collected from site-II in late collection.

The germination behaviour in different seed groups of *A mangium* was received germination in order of large > medium > small seeds at site-I, while it was reversed at site-II, while it was also varied at both the sites in colour group. Overall collection period of seeds at site-I and site-II did not show any significant difference.

Seeds were found heavy and bold during early collection at site-II while during late collection at site-I. Population of seed on the basis of size and colour group was found maximum in light and large group at both site-I and site-II. These might be due to effect of site and tree age.

All the treatments imposed on germination influenced the germination percentage and there was found that 10 minutes scarification with H_2SO_4, gave better results at 32 °C temperature, moisture stress created by mannitol from field capacity level to wilting point reduces the germination. Late collection getting maximum germination compared to early and middle collection period. Large and black colour seeds was received maximum germination at site-I and medium and brown colour at site-II. Application of Gibberellic acid and ascorbic acid also reduced germination but it was nonsignificant upto 250 ppm in GA. Salinity created by sodium salts caused depression in seed germination and seedling growth with increasing concentrations. Similar trend was seen in seedling growth of *A. mangium* in almost of the cases.

Suggestions for future work

1. Seed production behaviour of *A. mangium* need to be further correlated with reproductive biology in relation to field condition.

2. Germination and seedlings growth should be studied for all growth parameters with eco physiological expressions.
3. Analysis of chemical changes in seed due to the treatments need to be carried out to determine the physiochemicals regions.

SEED POLYMORPHISM AND GERMINATION BEHAVIOUR OF *ACACIA MANGIUM* IN CHHATTISGARH

By

Gunjan Patil

ABSTRACT

The present study entitled "Seed polymorphism and germination behaviour of *Acacia mangium* in Chhattisgarh" was conducted at laboratory of Department of Forestry, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) during 2006-2007. Seed material was collected from Experimental field of Department of Forestry, IGKV, Raipur site-I and Energy park plantation, Raipur site-II. The experiment was aimed to determine the suitable collection period and site for getting healthy and viable seeds and germination index under different treatments. The experiment was laid out in Complete Randomized Design (CRD) with three replications and Factorial Randomized Block Design with four replications.

The most suitable site was found site-II (Energy park plantation) and late collection period. Site-II and late collection was found healthy pod and seed. Seeds were found heavy and bold during early collection at site-II while during late collection at site-I. Population of seed on the basis of size and colour group was found maximum in light and large group at both site-I and site-II. These might be due to effect of site and tree age.

Seed scarification with conc. H_2SO_4, for 10 minutes was suitable for germination and gave 90.67 percent in compare to control 6.67 percent seed without any treatments. In respect to temperature was found statistically significant, maximum germination obtained at 32°C (97.33%) and minimum at 40°C (36.0%).

Moisture stress was decreased the germination by 45 percent at 0.33 atm. field capacity and seeds could not germinate beyond 12.0 atm. Collection periods showed maximum germination in seeds of late collection for the both sites.

Seed belongs to large size, black colour and late collection found responsible for maximum germination site-I and while at site-II small , brown and late collection seeds gave maximum.

Seedling growth vigour in different polymorphic seed group showed the over all growth results in black colour seeds at the both sites and three collection periods was comparatively superior.

Sodium salts *viz*.; Na_2CO_3, $NaHCO_3$ and NaCl caused toxic for germination at lower concentration (100 ppm) and gave 85.33 percent ,85.33 percent and 86.67percent respectively.

Gibberellic acid Ascorbic acid showed decreasing order of germination with increasing the concentrations.

Seedling growth vigour in respect to plumule and radical length, leaves number and total dry weight was also followed the trend of seed germination and different treatments.

Department of Forestry
College of Agriculture,
Raipur (C.G.)

(M.N. Nagauriaya)
Major Advisor

REFERENCE

Abraham, P. G., Dare, I. C . and Sexena, O.P. (1968). Studies in the physiology of seed germination ascorbic acid metabolism in germination of wheat under influence of lights of different wavelengths. Abst. 37 th session National *Acad Sci*. (India) p.- 45.

Agrawal, P. K. and Govind, P. (1978). Control on seed germination in some Indian trees. *Trop.col*. **19**.(2) : 174-177.

Ahmad, M., Gupta, B.K. and Bhandari, R.S. (1991). Efficacy of some plant extracts against Ailanthus web worm. *Atteva fabriciella*. *Indian Journal of Forestry* **14**(1) : 5-7.

Arya, C. and Arya, A. (2006). Effect of storage on seed viability and germination of certain leguminous trees. *Indian Forester* **132**(5) : 601-603.

Arya, S., Toky, R., Bisht, R.P. and Harris, P.J.C. (1992). Provenance variation in seed and pod characteristics of *Prosopis cineraria* (L.) Druce in Arid India. *J. Tree Sci*. **11**(2) : 86-94.

Babeley, G.S. and Kandya, A.K. (1984). Preliminary note on the new report of Bruchus hole disease of the seed of *Albizia lebbek* and *Acacia catechu*. *Indian J. Pl. Sci*. 2 : 25-30.

Bagchi, S.K. and Dobriyal, N.D. (1990). Provenance variation in seed parameter of *Acacia nilotica*. *Indian Forester*. **116**(12) : 958-961.

Banargee, V.K. (1998). Germination of *Melia azadirach* seeds with IAA, IBA and GA_3. *Indian Forester*. **124**(3) : 220-223.

Bhumibhamon, S., Lawskew, S., Jaiying, Thavrn, D.W. and Kanchanakantika, S. (1994). Flower and seed production of *Acacia mangium* in Thailand. Proceedings International symposium on genetic conservation and production of Tropical Forest Tree Seed : 68-77.

Bingeding, N.B., Ishibashi, N. and Wilangue, M.N. (2000). *Acacia mangium* seedlings. *Photosynthesis.* **41**(3) : 349-355.

Brain, P.W. and Groove, J. F. (1957). Gibberellic acid. *Endeavour*. **16** : 161-171.

Chacko, K.C. and Pillai, P.K.C. (1996). Effect of some presowing treatments on germination of *Acacia mangium* seeds. Bangladesh *Journal of Forest Science*. **24**(1) : 70-73.

Chaturvedi, O. P. and Das, D. K. (2004) Effect of seed drying, storage and pretreatments on the germination and growth of *Acacia ariculiformis* and *Acacia nilotica* seedlings. *Indian Journal of Forestry*. **27**(1):75-81.

Chenoy, J. J. (1967). Role of ascorbic acid in crop production. *Poona Agric. College Mag.* 57:1-6.

Chhangani, A.K. (2003). Flowering and fruiting phenology of plants of a dry deciduous forest in the Aravali hills of Rajasthan, India. *Indian Forester.* **130**(7) : 771-784.

Das, F.A., Gera, M. and Gera, N. (2002). Effect of seed grading on germination pattern of some multipurpose tree species of Jammu region. *Indian Forester*. **128**(5) : 509-512.

Dayan, M.P. and Reaviles, R.S. (1996). Germination test standard for *Acacia mangium*. *Sylvatrop*. **4**(2) : 1-6.

Gehlot, A.K. and Sen, N. (1998). Effect of acid scarification on percent germination, vigour index and germination rate in *Cressa cretica* (Linn.). *Journal of Ecophysiology*. **1**(3-4) : 79-82.

Gehlot, A.K. and Sen, N. (1999). Effect of NaCl on percent germination, vigour index and germination rate in *Suaeda fruticosa* (Linn.) Falsk, a halophye of Indian and zone. *Journal of Ecophysiology*. **2**(1) : 9-14.

Ghyare, B.P. (2005). Effect of gibberellic acid on germination of fine timber species. *Indian Forester*. **131**(6) : 844-846.

Girase, U. S. Jambhale, N. D. and Suryawanshi, Y. B. (2002) Germination and seed dormancy studies in *Acacia* species . *Seed Research.* **30**(1): 39-42.

Gopichand (2005). Influence of irrigation on growth and biomass production of some short rotation high density energy plantation in North Western Himachal Himalaya (H.P.). In. Verma *et al*.(Eds) *Short rotation forestry for Industrial and rural development*. Pub. ISTS, Solan 17:72-78.

Harper, J.L (1977). *Population Biology of Plants*. Academic Press, London.

Hasim M. N. and Wathern, P. (2003) Germination characteristics of selected tropical pioneer tree species. Part I: Effects of light and stimulated moisture stress. *Malaysian Forester*. **66**(3/4): 228-234.

Hasnat, S.M. and Thapliyal, R.C. (2005). Enhancement of seed germination in hard coated seeds of *Cassia fistula*. *Journal of Non-Timber Forest Products*. **12**(4) : 229-300.

Hegde, R., Varghese, M., Padmini, S. and Jayaraj, R.S.C. (2000). Variation in seed and seedling characteristics of *Acacia mangium* Willd. and *Acacia auriculiformis*. A. Curr. Ex Benth. *Indian Fotester* **126**(4) : 382-388.

Jenner, V.G., Dasthagir, M.G., Parthiban, K.T. and Sudhagar, R. (2003). Variability studies on seed and seedling attributes in Mahua (*Madhuca latifolia* Rax.) Macbride. *Indian Forester*. **4**(12) : 509-515.

Khan, M.A. and Unger, I.A. (1984). Seed polymorphism and germination responses to salt stress in *Atriplex triangularis* Willd. *Botanical Gazette*, 145 : 487-494.

Khomane, B.V. and Bhosle, L.J. (2002) Effect of constant temperature treatment on seed germination in some fuelwood species. *International journal of Forest Usufrudts Management.* **3**(1/2):91-105.

Khullar, P., Thapliya, R.C., Beniwal, B.S., Vakshasya, R.K. and Sharma, A. (1991) *Forest Seed* publishing by the editor, directorial Board FRI Dehradun.pp-450.

Kiran, A.K. and Devar, K.V. (2003). Correlation of morphometric, fruits seed and germination traits in Soapnut (*Sapindus trifoliatus* Linn.). *Indian Forester* **11**(2) :1386-1390.

Kiran, D.J.S., Rao, P.S., Venkaidh, K. and Saibabu, A. (2001). Effect of Gebberallic acid (GA_3) on germination of *Givotia rottleriformis* Griff seeds. *Indian Forester*. **127**(8) : 944-946.

Kundya, S. (1989). Investigations into the seed biology of *Albizia procera*. Proc. National Seminar on Forest Seed Technology. Inst. Of Forest Genetics and Tree Breeding, Coimbatore, Nov. 29-30.

Lavania, S.K. and Singh, V. (2004). Effect of seed source on germination and early seedling growth in Himalayan poplar (*Populus ciliata* Wall. Ex. Poyle). *Indian Journal of Forestry*. **27**(1) : 15-18.

Lima, D de and Careia, L.C. (1996). Evaluation of methods for germination testing in *Acacia mangium* Willd. Seeds. *Revista-Brasileila de Sementes*. **18**(2) : 180-185.

Mandal, M.P. and Handood, J.K. (1998). Presowing seed treatments for alleviation of salinity stress in subabul (*Leucaena leucocephala* (Lam, Dewit) during germination. *Indian Journal of Forestry*. **2**(3) : 204-207.

Mikhiel, G.S., Mayer, S.G. and Pondleton, R. (1992). Variation in germination response to temperature and salinity in shrubby Atriplex species. *Journal of Arid Environments.* **22** : 39-49.

Mutha, N., Bohra, M.D., Burman, U. and Harsh, I.N. (2004). Effect of seed size and pre-treatments on germination of *Albizia lebbeck* (L.) Bonth.

Naugraiya, M. N. (1985) Population Ecology of *Atylosia scarabaeoidos* in the rangelands of Jhansi U P Ph. D. Thesis. Bundelkhand University Jhansi. pp-410

Nath, S., Das, P.K., Gangopadhyay, S.K., singh, B. and Banarjee, S.K. (1990). Suitability of different forest species for social forestry programme under different soil conditions. Part II. Lateritic soil. *Indian Forester*. 116: 564-573.

Naugraiya, M. N. and Pathak, P. S. (1987). Effect of Gibberellic acid on growth of *Atylosia scarabaeoidos* Benth. *Indian J. Range Mgmt.* P (1) : 55-57.

Naugraiya, M.N. (1999). Germination vigour effected by seed polymorphism in *Atylosia scarabaeoides* Benth. *Range Mgmt. and Agroforestry* **20**(1) : 19-25.

Naugraiya, M.N. (2001). Effect of sodium salts in seed germination and seedling growth of *Atylosia scarabaeoides* Benth. *J. Agril. Issues* **6** (2) : 19-23.

Naugraiya, M.N.(2001). Plus tree collection, evaluation and mass propagation of plus tree stands of *Dalbegia sissoo* in south –eastern region of M.P. Final research report of ICFRE-world bank research project of forestry , IGKV, Raipur . pp-56.

Naugraiya, M.N. (2007). Effect of soil types and fertilizer application on nursery crop of *Dalbergia sissoo* Roxb. *Indian J. Agroforestry* **9**(2): 97-101.

Naugraiya, M.N. and Pathak, P.S. (1983). Study of seed size and germination of *Atylosia scarabaeoides* Benth. *Adv. Biol. Res*. **1** (1) : 22-25.

Naugraiya, M.N. and Pathak, P.S. (1987). Seed polymorphism and germination in *Indigofera glandulosa* Willd. *Indian Journal of Ecology*. **14**(2) : 283-285.

Naugraiya, M.N. and Pathak, P.S. (1989). Effect of temperature and light on germination of *Indigofera glandulosa* Willd. *Indian Journal of Ecology*. **16**(1): 88-90.

Naugraiya, M.N. and Pathak, P.S. (1989). Germination response of *A. scarabaeoides* Benth to growth regulators. *Indian Journal of Ecology and Environmental Science*. **15** : 187-195.

Nautiyal, A.R., Rawat, D.C.S. and Prasad, P. (2000). Physiological aspects of seed source variation in seed germination of *Quercus leueotrichophora* A. camus. *Indian Forester*. **131**(4) : 269-273.

Newman, V. (1989). Occasional technical and scientific notes : Effect of pretreatments on germination of *Acacia mangium* (Willd.) in Sabah. *FRC-Publication*. **54** : vi + 21

Pande, P.K., Singh, J., Meshram, P.B. and Pal, M. (2004). Phenological studies on *A. indica* A. Juss (Neem) of Satpura and adjacent agroclimatic zones of Madhya Pradesh (India). *Indian Forester* **130**(3) : 272-281.

Pandey, P.K., Bisaria, A.K. and Pandey, A.K. (1999). Early flowering and seed setting in *Acacia mangium* Willd. *Indian Forester*. **125**(3) : 329-330.

Pandit, A. and Ram. J. (2006). Effect of pre-treatment on germination of *Pinus roxburghii* Sarg. In Uttaranchal, Himalaya, India. *Indian Forester*. **132**(11) : 1477-1484.

Pathak, P.S. and Naugraiya (1984). Effect of salts and moisture stress on seed germination of *Indigofera glandulosa* (Willd). *Adv. Biol. Res*. **2** (1) :1-5.

Pathak, P.S., Roy, P.D. and Rai, P. (1979). Autoecology of *Leucaena leucocephalal* (Lam) seed polymorphism and germination. *Trop. Ecol*. **15** (182) : 1-10.

Ray choudhary (1961). Biometrical studies on grain size of paddy. *Science and Culture*. 27 : 455-456.

Rohayat, N. and Minduwati, N. (1997). Seed germination capacity and seedling quality using seeds harvested from some different aged *Acacia mangium*. *Bulletin enelition-Hutun*. 610 : 51-58.

Sagta, H.C. and Nautiyal (2001). Variation in germination of *Dalbergia sissoo* Roxb. Seeds under different media and osmo-conditions. *Indian Forester*. **127**(12) : 1371:1376.

Sharma, A. and Kukadia, M.U. (2003). Effect of salinity levels on germination, number of leaves and shoot and root length of different tree species. *Indian Journal of Forestry* **26**(2) : 135-142.

Sharma, A., Kukkadia, M.V., Jadeja, P.B. and Vashi, B.G. (1996). Effect of different salinity levels on germination and initial growth parameters of different agro-forestry tree species in nursery stage. *Indian Journal of forestry*. **21**(2) : 156-159.

Sharma, S., Takar, K.S., Kumar, S. and Negi, P.S. (2005). Study on effect of pre-sowing treatments on germination of *Ribes orientale* Dasf seeds. *Indian Forester*. **131**(5) : 667-672.

Sharma, S.D., Prasad, .G. and Singh, H.B. (1992). Salinity and alkalinity tolerance of some leguminous tree seedlings *Van Vigayan*. **30**(2) : 86-94.

Singh, A.K., Meena, S.L., Williams, A.J., Banergee, S.K. and Gupta, B.N. (1994). Effect of mulching and watering interval on growth of *Albizia procera* in skeletal soil. *Environ. & Eco*. 12:93-98.

Singh, B. and Sarma, S. (2006). Effect of microsize variations in the phenological studies of Himalayan shrubs- Wood farad, *Carissa prinsepia* and *Debregeasia*. *Indian Forester* **132**(2) : 211-220.

Singh, P., Pathak, P. S., Gupta, S. K., Naugraiya, M. N., Parihar, R. S. and Srivastava, A. K. (1994). IDRC- silvipasture operation research project for Bundelkhand region. Second phase Annual Report, Pub. IGFRI, Jhansi- pp-50.

Shukla, A.K. and Baizal, B.D. (1977). Effect of salinity on IAA oxidase activity. *Ind. J.Pl. Physio*. **20** (2): 157-160.

Siddiqi, N.A., Shahidullah, M. and Shahjalal, M.A.H. (1991). Studies on the size, viability and germination of seeds of Sundri (*Heritiera fomes* Buch- Ham.) *Indian Journal of Forestry* **14**(2) : 119-124.

Smiderle, O.J., Mowrao, J.M. and Seusa, R.C.P. (2005). Pre-germination treatments in acacia seeds. *Revista-Brasileria-de Sementes*. **27**(1) : 78-85.

Sniezko, R.A. and Stewart, H.T.L.(1989). Range wide provenance variation in growth and nutrition of *Acacia albida* seedlings propagated in Zimbabwe. *For. Ecol. Mgmt*. 27 : 179-197.

Srimathi, P., Malarkodi, K. and Sundaralingam, K. (2001). Influence of seed size grading and seed testing media on expression of seed quality in *Parkia biglobosa*. *Journal of Non Timber Forest Product*. **8**(3/4) : 196-199.

Srimathi, P., Vinaya Rai, R.S. and Surendran, C. (1991). Studied on the effect of seed coat colour and seed size on seed germination in *Acacia mellifera* (Vahl.) Benth. *Indian Journal of Forestry*. **14**(1) : 1-4.

Suresh, K.K., Mambulingam,R. and Sekar, I. (2001). Effect of tree age on seed and seedling quality in *Acacia nilotica*. *Indian Forester*. **127**(6) ; 685-689.

Susilawat, S. and Setieveli, D. (2003). Preliminary research on natural hybrid of *Acacian mangium* and *Acacia auriculiformis* in Wonogiri central Jawa. Proceedings of the International Conference on advance genetic improvement of tropical tree species, Yogyakarta, Indonesia. 153-156.

Swaminathan, C. and Swarnapiria, R. (2001). Improving germination in two Australian *acacias*. *Journal of Tropical Forest Science* **13**(2) : 364-368.

Thakur A., Sharma P. and Mahanta N. (2001) Study on germination variation is seeds of different provenances of *Acacia mangium. Indian Forester*. **127**(11) : 1294-1296.

Todaria, N.P., Saklani, K.P. and Sachan, M.S. (2004). Variation in pod and seed characteristics of *Acacia catechu* (Willd) in Garwal Himalayas. *Indian Forester*. **130**(3) : 53-61.

Tomata, B.P., Verma, S.K. and Choudhary, N. (2001). Effect of moist pre chilling on the viability germination of *Cupressus torulosa* Don. seed. *Indian Forester*. **127**(2) : 1405-1407.

Venkatesh M., Shivakumar K. V. and Sheshagiri (2000) Germination and initial growth studies in *Acacia mangium. Indian Forester.* **126**(4) : 427-529.

Wiggam, S. C. and Gardenar, P. F. (1959) The effectiveness of various solution for simulating drought condition as measured by germination and seedling growth. *Agron. J.* **51** : 315 – 18.

Yomada, H., Hendrati, R.L., Tambunan, P. and Kawasaki, H. (2000). Preliminary observation of flowering strength in seedlings, seed orchard of *Acacia mangium* in Wonogiri, Central Jawa. *Bulletin of the National Forest Tree Breeding Centre*, 17 ;1-8.

Yu Hua and Ong Beelian (2003) Effect of radiation quality on growth and photosynthesis of *Acacia mangtium* seedlings. International Institute for Earth System Science Najing, China. *Photosynthetica.* **41**(3):349-355.

Appendix I: Weekly meteorological data during the study period (2006 to 2007)

Weeks	Temperature (^oC)		Rainfall (mm)	Relative humidity (%)	
	Maximum	Minimum		I	II
31	28.9	24.2	45.3	92	79
32	29.5	24.2	7.0	89	75
33	29.1	24.2	266.8	93	80
34	29.2	24.6	30.8	93	81
35	28.4	23.7	60.1	92	75
36	31.3	25.1	114.4	94	71
37	32.0	24.6	72.2	94	77
38	30.9	24.4	11.6	90	70
39	31.5	23.1	34.0	90	64
40	31.8	23.7	5.9	94	63
41	33.7	23.0	0.0	91	43
42	33.3	20.8	0.0	93	46
43	31.3	18.8	0.0	90	47
44	27.8	20.8	1.6	93	65
45	29.6	18.3	0.0	92	43
46	29.4	14.6	0.0	91	35
47	31.0	15.2	0.0	89	31
48	30.7	18.0	0.0	87	41
49	30.8	15.0	0.0	88	32
50	29.4	12.2	0.0	88	29
51	26.9	10.6	0.0	90	35
52	28.1	11.9	0.0	88	36
01	26.7	9.6	0.0	88	30
02	28.8	10.6	0.0	89	32
03	28.4	11.5	0.0	83	30
04	29.8	10.4	0.0	83	22
05	31.6	15.6	0.0	80	32
06	31.3	16.4	0.0	85	37
07	27.6	15.0	22.4	87	43
08	30.4	13.0	0.0	81	21
09	32.0	16.6	0.0	78	27
10	31.9	17.0	0.0	74	30
11	32.6	17.8	2.5	80	30
12	37.3	21.2	0.0	67	22
13	35.7	18.7	0.0	58	14
14	39.7	21.3	0.0	52	18
15	39.6	23.7	3.2	56	22
16	37.1	24.1	0.0	63	28
17	41.7	24.3	0.0	34	11
18	41.0	25.6	0.0	52	24
19	41.5	26.0	11.0	62	21
20	42.0	26.9	1.2	54	20
21	42.6	28.9	0.0	40	16
22	41.6	27.9	6.8	45	21
23	42.5	30.0	6.8	48	27
24	37.6	26.3	29.4	73	44
25	34.2	25.0	17.3	90	67
26	30.5	23.9	79.6	93	77
27	29.9	24.9	11.5	85	76
28	30.2	24.8	10.7	92	78
29	31.9	25.5	1.5	89	69
30	32.1	24.5	13.6	92	68
31	31.8	25.3	1.5	90	68
32	29.7	24.9	15.8	92	83
33	29.4	24.6	0.7	90	72
34	30.3	24.5	9.6	94	79

Table 4.2: Effect of site and collection period on behaviour of pods of *A. mangium*

Treatments	Pod length (cm)	Pod width (cm)	Pod thickness (cm)	Test weight of 100 pods (g)	
				Fresh	Dry
Site (S)					
S_1	15.28	0.774	0.373	26.54	10.70
S_2	16.47	0.827	0.423	33.72	13.39
SEm±	0.37	0.021	0.022	2.25	0.37
CD (P=0.05)	1.12	NS	NS	6.77	1.11
Collection period (CP)					
CP_1 - Early	13.93	0.748	0.263	16.05	6.76
CP_2 - Middle	14.94	0.759	0.378	23.77	11.08
CP_3 - Late	18.75	0.897	0.553	50.07	18.22
SEm±	0.30	0.017	0.018	1.834	0.30
CD (P=0.05)	0.91	0.052	0.055	5.530	0.90
Interaction of Site (S) x Collection period (CP)					
S_1CP_1	13.76	0.705	0.220	15.56	5.30
S_1CP_2	15.315	0.736	0.355	19.91	9.20
S_1CP_3	16.98	0.881	0.543	44.45	17.10
S_2CP_1	14.11	0.790	0.305	16.53	8.20
S_2CP_2	14.79	0.781	0.400	27.63	12.99
S_2CP_3	20.52	0.910	0.564	56.99	18.90
SEm±	0.52	0.028	0.032	3.177	0.46
CD (P=0.05)	1.57	NS	NS	NS	1.38

S_1 : Site of Department of Forestry, S_2 : Site of Energy park

CP_1 : Early collection period,CP_2 : Middle collection period
CP_3 : Late collection period

Table 4.3 : Effect of site and collection period on seed formation in *A. mangium*

Treatments	Number of locules pod^{-1}	Number of seeds pod^{-1}		
		Healthy	Undeveloped	Empty locule pod^{-1}
Site (S)				
S_1	8.810	7.37 (83.60)	0.96 (10.99)	0.48 (5.50)
S_2	9.237	8.18 (88.55)	0.82 (8.88)	0.24 (2.57)
SEm±	0.139	0.11	0.09	0.02
CD (P=0.05)	0.420	0.32	NS	0.06
Collection period (CP)				
CP_1 - Early	8.025	6.44 (80.25)	1.21 (15.07)	0.38 (4.67)
CP_2 - Middle	9.240	7.42 (80.30)	0.91 (9.87)	0.91 (9.83)
CP_3 - Late	10.550	9.68 (91.71)	0.54 (5.12)	0.34 (3.17)
SEm±	0.114	0.09	0.07	0.02
CD (P=0.05)	0.343	0.26	0.22	NS
Interaction of Site x Collection period (S x CP)				
S_1CP_1	7.500	6.10 (81.33)	1.08 (14.33)	0.325 (4.33)
S_1CP_2	9.050	6.90 (76.24)	0.48 (5.25)	1.675 (18.50)
S_1CP_3	9.875	9.10 (92.15)	0.73 (7.34)	0.05 (0.00)
S_2CP_1	8.550	6.78 (79.29)	0.75 (8.77)	1.02 (11.92)
S_2CP_2	9.425	7.525 (79.84)	0.35 (3.71)	1.55 (16.44)
S_2CP_3	11.225	10.25 (91.31)	0.35 (3.12)	0.625 (5.57)
SEm±	0.197	0.15	0.12	0.026
CD (P=0.05)	NS	0.45	0.37	0.077

Note – Data in parenthesis is percentage of corresponding values.
S_1 : Site of Department of Forestry S_2 : Site of Energy park
CP_1 : Early collection period, CP_2 : Middle collection period,
CP_3 : Late collection period

Table 4.4 : Effect of site and collection period on seed polymorphism in *A. mangium*

Treatments	Seed length (mm)	Seed width (mm)	Seed thickness (mm)	Test weight (g)/ 1000 seeds
Site (S)				
S_1	0.550	0.390	0.164	21.48
S_2	0.520	0.380	0.180	27.57
SEm±	0.015	0.006	0.002	0.81
CD (P=0.05)	NS	NS	0.007	2.40
Collection period (CP)				
CP_1 - Early	0.523	0.373	0.166	14.56
CP_2 - Middle	0.550	0.380	0.177	28.74
CP_3 - Late	0.530	0.396	0.177	30.20
SEm±	0.012	0.005	0.002	0.66
CD (P=0.05)	NS	NS	0.006	1.98
Interaction of Site x Collection period (S x CP)				
S_1CP_1	0.524	0.370	0.159	13.60
S_1CP_2	0.550	0.380	0.162	23.00
S_1CP_3	0.560	0.410	0.171	27.80
S_2CP_1	0.520	0.380	0.173	15.68
S_2CP_2	0.550	0.371	0.194	34.50
S_2CP_3	0.490	0.390	0.184	32.50
SEm±	0.021	0.008	0.003	1.14
CD (P=0.05)	NS	NS	0.009	3.44

S_1 : Site of Department of Forestry, S_2 : Site of Energy park

CP_1 : Early collection period, CP_2 : Middle collection period
CP_3 : Late collection period

Table 4.7 : Effect of scarification on seed germination and seedling growth in *A. mangium*

Treatments (minutes)	Germi-nation %	Plumule length (cm)	Radical length (cm)	Leaves number (Plant^{-1})	Total dry weight (g)
T_1 (0)	6.67	2.20	1.59	6.00	0.0680
	(15.00)				
T_2 (0.5)	42.67	3.98	2.43	7.33	0.0087
	(40.80)				
T_3 (1.0)	58.67	4.83	2.62	8.83	0.0104
	(50.01)				
T_4 (2.0)	63.84	5.03	2.82	9.33	0.0130
	(53.01)				
T_5 (3.0)	82.67	6.50	3.63	9.65	0.0141
	(65.42)				
T_6 (5.0)	89.33	6.85	4.45	9.67	0.0155
	(70.91)				
T_7 (10.0)	90.67	7.20	4.58	10.00	0.0159
	(72.24)				
T_8 (15.0)	58.67	4.77	2.74	8.83	0.0105
	(50.01)				
SEm±	3.92	0.51	0.63	0.48	0.0014
CD (5%)	11.76	1.53	1.89	1.42	0.0034

Note : Values in parenthesis are angular transformation

Table 4.8 : Effect of temperature (°C) on seed germination and seedling growth in *A. mangium*

Treatments	Germi-nation %	Plumule length (cm)	Radical length (cm)	Leaves number ($plant^{-1}$)	Total dry weight (g)
T_1 (16°C)	43.33 (41.15)	1.986	0.73	6.88	0.0115
T_2 (20°C)	53.00 (46.72)	5.84	2.57	9.88	0.0088
T_3 (24°C)	70.67 (57.26)	5.85	2.81	9.13	0.0103
T_4 (28°C)	76.00 (60.72)	7.52	3.18	11.38	0.0129
T_5 (32°C)	97.33 (80.54)	9.02	4.35	11.50	0.0153
T_6 (36°C)	50.67 (45.39)	5.87	1.74	9.00	0.0118
T_7 (40°C)	36.00 (36.87)	4.43	0.65	8.63	0.0108
SEm±	2.21	0.24	0.23	0.29	0.0006
CD (5%)	6.71	0.71	0.64	0.88	0.0018

Note : Values in parenthesis are angular transformation

Table 4.9 : Effect of moisture stress on seed germination and seed germination and seedling growth in *A. mangium*

Treatments (moisture stress Atm.)	**Germi-nation %**	**Plumule length (cm)**	**Radical length (cm)**	**Leaves number ($plant^{-1}$)**	**Total dry weight (g)**
T_1 (0)	97.33 (80.54)	12.43	3.44	11.00	0.0121
T_2 (0.33)	41.33 (39.99)	8.13	3.09	8.83	0.0105
T_3 (5.0)	28.0 (31.95)	6.53	2.03	8.00	0.0073
T_4 (07.5)	13.33 (21.37)	3.70	1.48	7.33	0.0063
T_5 (10.0)	5.33 (13.31)	2.40	0.82	6.00	0.0045
T_6 (12.0)	0	0	0	0	0
T_7 (15.0)	0	0	0	0	0
SEm±	1.56	0.22	0.19	0.39	0.0005
CD (5%)	4.73	0.66	0.59	1.18	0.0014

Note : Values in parenthesis are angular transformation

Table 4.10 : Effect of collection period on seed germination and seed germination and seedling growth in *A. mangium*

Treatments	Germi-nation %	Plumule length (cm)	Radical length (cm)	Leaves number ($plant^{-1}$)	Total dry weight (g)
Site (S)					
S_1	72.60 (58.46)	6.6	3.17	8.000	0.0067
S_2	89.20 (70.86)	8.32	4.36	8.670	0.0078
SEm±	0.75	0.19	0.04	0.048	0.0002
CD (P=0.05)	2.22	0.56	0.13	0.150	NS
Collection period (CP)					
CP_1 - Early	49.40 (44.69)	6.44	2.05	8.000	0.0046
CP_2 - Middle	90.70 (72.25)	7.24	4.12	8.000	0.0065
CP_3 - Late	95.0 (77.05)	8.71	5.12	9.000	0.0106
SEm±	0.61	0.23	0.52	0.059	0.0002
CD (P=0.05)	1.82	0.69	1.60	NS	NS
Interaction of site (S) x Collection period (CP)					
S_1CP_1	24.90 (29.99)	6.2	1.35	8.000	0.0037
S_1CP_2	95.20 (77.24)	5.94	3.49	8.000	0.0052
S_1CP_3	86.20 (68.16)	7.67	4.66	8.000	0.0114
S_2CP_1	74.20 (59.39)	6.67	2.75	8.000	0.0056
S_2CP_2	84.90 (67.25)	8.55	4.75	8.000	0.0078
S_2CP_3	99.50 (85.95)	9.75	5.56	10.000	0.0099
SEm±	1.06	0.32	0.74	0.083	0.0030
CD (P=0.05)	3.14	0.98	2.20	NS	NS

Note- Values in parenthesis are angular transformation.

Table 4.15 : Effect of sodium carbonate on seed germination and seedling growth in *A. mangium*

Treatments (ppm)	Germination %	Plumule length (cm)	Radical length (cm)	Leaves number (plant^{-1})	Total dry weight (g)
T_1 (0)	94.67	11.41	2.76	11.67	0.0109
	(79.16)				
T_2 (100)	85.33	8.98	2.53	9.50	0.0106
	(67.49)				
T_3 (200)	84	8.51	2.35	9.17	0.0106
	(66.50)				
T_4 (500)	82.67	8.25	1.44	8.83	0.0104
	(65.51)				
T_5 (700)	76	7.13	1.41	8.33	0.0096
	(60.86)				
T_6 (1000)	72	7.03	1.39	8.17	0.0094
	(58.07)				
T_7 (2000)	69.33	6.93	0.79	7.51	0.0091
	(56.36)				
SEm±	2.78	0.69	0.20	0.51	0.0081
CD (5%)	8.43	2.12	0.61	1.54	NS

Note : Values in parenthesis are angular transformation

Table 4.16 : Effect of sodium bicorbonate on seed germination and seedling growth in *A. mangium*

Treatments (ppm)	Germi-nation %	Plumule length (cm)	Radical length (cm)	Leaves number ($plant^{-1}$)	Total dry weight (g)
T_1 (0)	90.67 (72.26)	11.6	2.99	11.27	0.0107
T_2 (100)	85.33 (67.49)	9.96	2.48	9.50	0.0094
T_3 (200)	82.67 (65.42)	8.75	2.25	9.00	0.0085
T_4 (500)	78.97 (62.49)	8.75	2.10	9.00	0.0081
T_5 (700)	73.33 (58.90)	8.75	2.10	8.17	0.0079
T_6 (1000)	66.67 (54.75)	6.96	1.99	8.00	0.0079
T_7 (2000)	58.66 (49.97)	5.81	1.77	7.67	0.0073
SEm±	1.07	0.57	0.33	0.45	0.0005
CD (5%)	3.24	1.73	NS	1.38	0.0016

Note : Values in parenthesis are angular transformation

Table 4.17 : Effect of sodium chloride on and seed germination and seedling growth in *A. mangium*

Treatments (ppm)	Germi-nation %	Plumule length (cm)	Radical length (cm)	Leaves number ($plant^{-1}$)	Total dry weight (g)
T_1 (0)	93.33 (75.07)	12.03	3.20	11.67	0.0093
T_2 (100)	86.67 (68.61)	11.52	3.02	10.17	0.0089
T_3 (200)	78.67 (62.51)	10.08	2.99	8.67	0.0089
T_4 (500)	77.33 (61.56)	9.80	2.45	8.67	0.0083
T_5 (700)	69.33 (56.36)	9.29	2.22	8.33	0.0080
T_6 (1000)	60 (50.75)	7.20	1.93	8.33	0.0079
T_7 (2000)	54.67 (47.66)	7.11	1.18	7.67	0.0062
SEm±	0.99	0.89	0.46	0.60	0.0120
CD (5%)	3.0	2.69	NS	1.82	NS

Note : Values in parenthesis are angular transformation

Table 4.18 : Effect of Gibberellic acid on seed germination and seedling growth in *A. mangium*

Treatments (ppm)	Germi-nation %	Plumule length (cm)	Radical length (cm)	Leaves number (plant^{-1})	Total dry weight (g)
T_1 (0)	90.67 (72.24)	11.71	3.91	11.5	0.0135
T_2 (250)	90.67 (72.24)	7.41	3.83	9.00	0.0100
T_3 (500)	80.0 (64.43)	7.39	2.70	8.50	0.0085
T_4 (750)	74.67 (59.80)	7.08	2.10	8.33	0.0059
T_5 (1000)	64.00 (53.18)	7.03	2.00	8.17	0.0054
T_6 (1250)	62.67 (52.37)	4.45	1.74	7.67	0.0050
T_7 (1500)	60.0 (50.77)	3.71	1.04	6.58	0.0040
SEm±	4.286	0.64	0.48	0.495	0.0004
CD (5%)	13.000	1.93	1.45	1.500	0.0011

Note : Values in parenthesis are angular transformation

Table 4.19 : Effect of ascorbic acid on seed germination and seedling growth in *A. mangium*

Treatments	Germi-nation %	Plumule length (cm)	Radical length (cm)	Leaves number ($plant^{-1}$)	Total dry weight (g)
T_1 (0%)	93.33 (75.0)	12.25	2.30	10.00	0.0108
T_2 (0.25%)	29.33 (32.77)	4.40	2.067	7.83	0.0074
T_3 (1.00%)	13.33 (21.39)	3.33	1.33	6.67	0.0056
T_4 (1.50%)	12.00 (21.19)	2.33	0.68	6.00	0.0053
T_5 (2.0%)	8.00 (16.43)	2.00	0.57	6.00	0.0037
T_6 (2.5%)	0	0	0	0	0
T_7 (5.0%)	0	0	0	0	0
SEm±	2.88	0.26	0.12	0.013	0.0134
CD (5%)	8.76	0.79	0.35	0.041	0.0405

Note : Values in parenthesis are angular transformation

Table 4.1 : Phenological observations of *A. mangium* of two different sites 2006-07

Site	Weeks	August				September				October				November				December				January			
		LI	LF	FL	FR	LI	LF	FL	FR	LI	LF	FL	FR	LI	LF	FL	FR	LI	LF	FL	FR	LI	LF	FL	FR
S-I	1	**	*	-	-	**	-	**	-	***	-	**	*	****	-	-	**	***	-	-	***	**	-	-	****
	2	**	*	-	-	**	-	***	-	***	-	*	**	****	-	-	**	***	-	-	***	**	-	-	****
	3	**	*	-	-	**	-	***	-	***	-	-	**	****	-	-	**	***	-	-	***	**	-	-	****
	4	**	*	-	-	**	-	****	-	***	-	-	***	****	-	-	**	***	-	-	***	**	-	-	****
	5	**	*	-	-	**	-	****	-	***	-	-	***	****	-	-	**	***	-	-	***	**	-	-	****
S-II	1	*	**	-	-	**	***	-	-	*	-	**	-	**	-	**	*	***	-	-	**	****	-	-	***
	2	*	**	-	-	**	***	-	-	*	-	***	-	**	-	*	*	***	-	-	**	****	-	-	***
	3	*	**	-	-	**	****	-	-	*	-	****	-	**	-	-	**	***	-	-	***	****	-	-	***
	4	*	**	-	-	**	****	-	-	*	-	****	-	**	-	-	-	***	-	-	***	****	-	-	***
	5	*	**	-	-	**	****	-	-	*	-	***	*	**	-	-	**	***	-	-	***	****	-	-	***

Site	Weeks	February				March				April				May				June				July			
		LI	LF	FL	FR	LI	LF	FL	FR	LI	LF	FL	FR	LI	LF	FL	FR	LI	LF	FL	FR	LI	LF	FL	FR
S-I	1	*	****	-	**	**	-	-	*	***	*	*	*	****	-	**	-	***	****	****	-	**	**	-	-
	2	*	****	-	**	**	-	-	*	***	*	*	*	****	-	**	-	***	****	****	-	**	**	-	-
	3	*	****	-	**	**	-	-	*	***	*	*	*	****	-	***	-	***	****	****	-	**	**	-	-
	4	*	****	-	**	**	-	-	*	***	*	*	*	****	-	***	-	***	****	**	-	**	**	-	-
	5	*	****	-	**	**	-	-	*	***	*	*	*	****	-	***	-	***	****	**	-	**	**	-	-
S-II	1	*	**	-	****	**	-	-	***	*	-	-	**	*	****	-	*	**	-	-	-	***	*	-	-
	2	*	**	-	****	**	-	-	***	*	-	-	**	*	****	-	*	**	-	-	-	***	*	-	-
	3	*	**	-	****	**	-	-	***	*	-	-	**	*	****	-	*	**	-	-	-	****	*	-	-
	4	*	**	-	****	**	-	-	***	*	-	-	**	*	****	-	*	**	-	-	-	****	*	-	-
	5	*	**	-	****	**	-	-	***	*	-	-	**	*	****	-	*	**	-	-	-	****	*	-	-

LI = Leaf initiation; LF = Leaf fall; FL = Flowering; FR = Fruiting; S-I=Experimental field of Forestry; S-II=Plantation of Energy Park

* : Low; **, *** : Moderate; **** : Peak

Table 4.13 : Effect of different seed polymorphic group on seedling growth behaviour of *A. mangium* at site-I

Treatments	Early				Middle				Late			
	Plumule length (cm)	Radical length (cm)	Leaves number plant^{-1}	Total Dry weight (g)	Plumule length (cm)	Radical length (cm)	Leaves number plant^{-1}	Total Dry weight (g)	Plumule length (cm)	Radical length (cm)	Leaves number plant^{-1}	Total Dry weight (g)
T_1 (Small light)	2.30	0.97	5.33	0.005	5.30	1.79	8.67	0.012	2.77	1.04	5.33	0.006
T_2 (Small brown)	7.20	2.33	8.67	0.017	5.50	1.43	5.67	0.006	6.17	2.43	9.0	0.009
T_3 (Small black)	7.63	2.70	10.0	0.019	7.73	2.30	9.0	0.004	6.40	2.50	9.33	0.017
T_4 (Medium light)	7.17	2.00	8.0	0.010	4.20	1.26	5.33	0.007	3.43	1.29	5.33	0.006
T_5 (Medium brown)	8.13	2.10	8.67	0.012	7.93	2.40	10.0	0.012	6.20	2.10	8.33	0.009
T_6 (Medium black)	9.20	3.33	11.33	0.018	8.53	2.53	11.33	0.018	8.80	2.63	9.33	0.012
T_7 (Large light)	1.37	0.81	5.33	0.006	3.50	0.96	5.50	0.005	7.10	2.20	9.67	0.013
T_8 (Large brown)	6.23	2.47	9.0	0.012	7.60	2.13	10.0	0.014	7.33	2.60	10.0	0.018
T_9 (Large black)	7.20	2.99	11.33	0.018	8.27	2.40	9.83	0.017	8.23	2.93	9.67	0.019
SEm±	0.60	0.25	1.32	0.002	1.31	0.37	1.63	0.002	0.74	0.29	1.29	0.001
CD (5%)	1.79	0.75	3.93	0.005	NS	NS	NS	0.010	2.20	0.87	NS	0.004

Table 4.14 : Effect of different seed polymorphic group on seedling growth behaviour of *A. mangium* at site-II

Treatments	Early				Middle				Late			
	Plumule length (cm)	**Radical length (cm)**	**Leaves number plant^{-1}**	**Total Dry weight (g)**	**Plumule length (cm)**	**Radical length (cm)**	**Leaves number plant^{-1}**	**Total Dry weight (g)**	**Plumule length (cm)**	**Radical length (cm)**	**Leaves number plant^{-1}**	**Total Dry weight (g)**
T_1 (Small light)	6.0	1.51	7.33	0.008	5.10	1.39	8.00	0.008	7.10	1.79	8.17	0.009
T_2 (Small brown)	7.10	2.30	9.33	0.010	7.03	1.84	9.33	0.010	7.43	1.86	9.33	0.010
T_3 (Small black)	7.50	2.77	10.67	0.012	7.30	2.20	9.33	0.013	7.70	2.21	9.33	0.009
T_4 (Medium light)	6.67	2.17	8.00	0.009	5.27	1.23	8.00	0.009	7.07	1.10	8.33	0.040
T_5 (Medium brown)	7.20	2.30	9.33	0.010	8.27	2.50	10.00	0.014	7.90	2.10	9.50	0.018
T_6 (Medium black)	7.80	2.60	11.33	0.017	9.43	2.73	9.67	0.018	8.00	2.13	9.67	0.012
T_7 (Large light)	6.33	1.70	6.67	0.009	7.57	2.07	8.67	0.016	7.63	1.84	10.00	0.014
T_8 (Large brown)	6.87	2.37	8.67	0.012	8.80	2.80	10.67	0.019	8.47	2.39	11.50	0.019
T_9 (Large black)	9.07	2.8	11.33	0.014	9.13	3.27	11.33	0.019	8.83	1.97	9.17	0.014
SEm±	0.06	0.07	0.63	0.0002	0.15	0.05	0.47	0.0002	0.17	0.08	0.36	0.009
CD (5%)	0.19	0.22	1.87	0.0006	0.44	0.16	1.40	0.0006	0.49	0.24	1.07	-

Table 4.5 : Test weight of different polymorphic group at site-I

Collection period	Black			Brown			Light			Mean	Size			Colour		
	Large	Medium	Small	Large	Medium	Small	Large	Medium	Small		Large	Medium	Small	Black	Brown	Light
CP-1	22.54	18.59	11.44	26.66	19.99	26.12	30.74	14.10	13.22	20.38	26.65	17.56	16.93	17.52	24.26	19.39
CP-2	24.03	20.52	13.78	29.38	20.63	13.59	31.42	20.27	14.54	20.91	28.28	20.47	13.97	19.44	21.20	22.08
CP-3	27.52	22.62	17.29	31.02	29.16	17.64	34.46	33.66	17.16	25.61	31.00	28.64	17.36	22.48	25.94	28.43
Mean	24.69	20.57	14.17	29.02	23.26	19.12	32.21	22.66	14.97		28.64	22.16	16.09	19.81	23.80	23.29

	Collection period	Size	Colour	Size x Collection period	Colour x Collection period	Size x Colour	Size x Colour x Collection period
SEm±	1.63	1.63	1.63	2.83	2.83	2.83	4.9
CD	NS	4.79	NS	NS	NS	NS	NS

Table 4.6 : Test weight of different polymorphic group at site-II

Collection period	Black			Brown			Light			Mean	Size			Colour		
	Large	Medium	Small	Large	Medium	Small	Large	Medium	Small		Large	Medium	Small	Black	Brown	Light
CP-1	19.90	20.54	11.71	23.14	17.28	14.22	27.43	17.58	13.78	21.45	23.49	18.47	13.24	17.38	18.21	19.59
CP-2	17.81	17.56	11.58	24.63	20.72	15.79	20.69	26.76	11.60	18.57	21.68	12.99	19.65	15.65	20.38	19.68
CP-3	18.63	31.20	11.42	20.43	18.09	12.67	27.48	15.64	19.58	19.46	22.18	21.64	14.56	20.42	17.06	20.09
Mean	18.78	23.10	11.57	22.73	18.69	14.23	25.20	19.99	14.99		22.45	17.70	15.82	17.82	18.55	20.06

	Collection period	Size	Colour	Size x Collection period	Colour x Collection period	Size x Colour	Size x Colour x Collection period
SEm±	2.04	2.04	2.04	3.53	3.53	3.53	6.12
CD	NS	5.98	NS	NS	NS	NS	NS

CP-1 Early collection; CP-2 Middle collection; CP-3 Late collection

Table 4.11 : Effect of seed polymorphism on germination (%) in *A. mangium* at site-I

Collection period	Black			Brown			Light			Mean	Size			Colour		
	Large	Medium	Small	Large	Medium	Small	Large	Medium	Small		Large	Medium	Small	Black	Brown	Light
CP-1	92.31	68.31	78.84	61.5	66.83	45.72	26.21	34.72	35.93	56.71	60.00	56.62	63.97	79.82	58.02	32.29
	(73.92)	(55.72)	(62.63)	(51.65)	(54.84)	(42.53)	(23.77)	(29.67)	(32.42)		(50.77)	(48.79)	(53.07)	(62.73)	(49.72)	(34.45)
CP-2	92.31	85.42	81.4	76.3	77.3	66.8	34.60	34.50	23.91	60.96	67.74	65.74	66.10	86.38	73.46	31.00
	(73.92)	(67.52)	(64.43)	(60.80)	(61.59)	(54.79)	(36.06)	(36.02)	(29.28)		(55.37)	(54.25)	(54.39)	(68.36)	(59.02)	(33.21)
CP-3	82.7	89.4	80.2	73.31	66.6	67.4	35.90	42.31	4.70	60.28	84.10	60.89	50.77	84.10	69.10	27.64
	(65.42)	(71.01)	(63.51)	(59.01)	(54.79)	(56.27)	(36.85)	(40.58)	(12.52)		(66.50)	(53.30)	(45.46)	(66.50)	(56.23)	(31.69)
Mean	89.11	81.04	80.15	70.44	70.44	59.97	32.23	37.21	21.51		70.61	61.08	60.28	83.43	66.86	30.31
	(71.09)	(64.16)	(64.23)	(57.04)	(56.91)	(50.71)	(30.98)	(35.06)	(27.62)		(57.27)	(50.83)	(50.94)	(65.80)	(54.88)	(33.40)

	Colour	Size	Collection period	Colour x size	Colour x collection period	Size x collection period	Colour x size x collection period
SEm±	5.62	5.62	5.62	9.73	.9.73	9.73	16.86
CD	16.48	NS	NS	NS	NS	NS	NS

CP-1 Early collection, CP-2 Middle collection & CP-3 Late collection
Note : Value in parentheses are angular transformation

Table 4.12 : Effect of seed polymorphism on germination (%) in *A. mangium* at site-II

Collection period	Black			Brown			Light			Mean	Size			Colour		
	Large	Medium	Small	Large	Medium	Small	Large	Medium	Small		Large	Medium	Small	Black	Brown	Light
CP-1	62.80	53.42	70.43	70.43	86.74	78.71	34.71	40.00	54.65	61.24	55.90	60.05	67.93	62.22	78.62	43.12
	(52.41)	(46.92)	(57.01)	(57.01)	(68.63)	(62.51)	(36.06)	(39.22)	(47.68)		(48.39)	(50.83)	(55.49)	(52.06)	(62.44)	(41.03)
CP-2	70.34	71.50	55.31	86.75	90.83	86.74	21.72	46.62	26.71	61.83	59.60	69.65	56.25	65.78	88.12	31.68
	(57.01)	(55.77)	(48.00)	(68.62)	(72.32)	(68.63)	(27.75)	(43.08)	(31.08)		(50.53)	(56.60)	(48.62)	(54.27)	(69.82)	(34.20)
CP-3	76.00	70.51	72.00	86.74	72.00	86.74	28.00	33.00	35.62	62.29	63.58	58.50	64.79	72.84	81.83	32.21
	(60.67)	(57.22)	(58.09)	(68.63)	(58.09)	(68.63)	(31.91)	(35.03)	(36.65)		(53.07)	(49.89)	(53.63)	(58.63)	(64.75)	(34.57)
Mean	69.37	65.14	65.91	81.29	83.19	84.06	28.14	40.01	38.99		59.72	62.73	62.99	66.95	82.86	35.67
	(36.42)	(53.79)	(54.27)	(64.38)	(65.80)	(66.50)	(32.20)	(39.23)	(38.59)		(50.59)	(52.36)	(52.43)	(54.88)	(65.57)	(36.75)

	Colour	Size	Collection period	Colour x size	Colour x collection period	Size x collection period	Colour x size x collection period
SEm±	4.21	4.21	4.21	7.29	7.29	7.29	12.62
CD	12.34	NS	NS	NS	NS	NS	NS

CP-1 Early collection, CP-2 Middle collection & CP-3 Late collection
Note : Value in parentheses are angular transformation

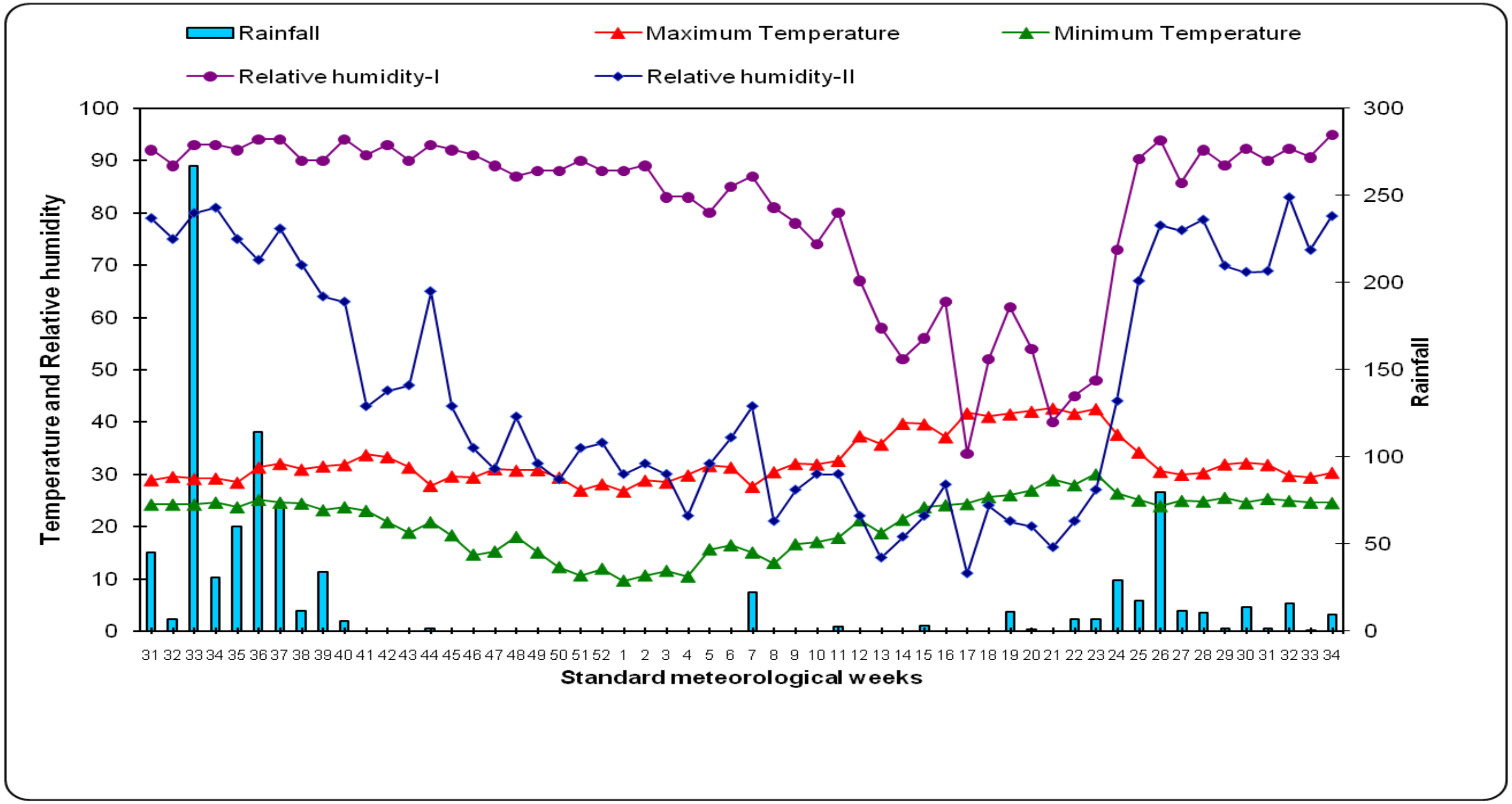


Fig. 3.1: Weekly meteorological parameters during the study period

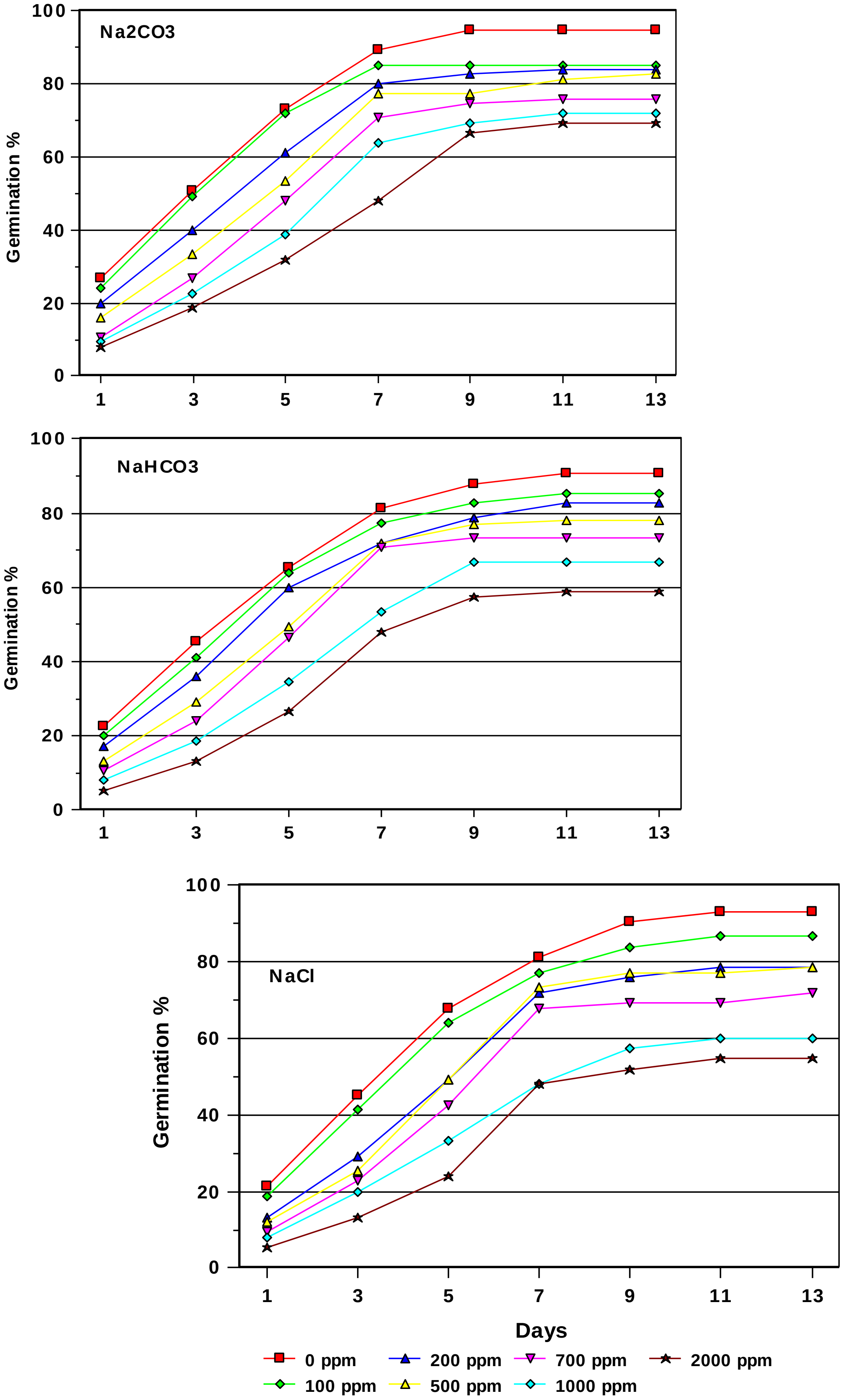
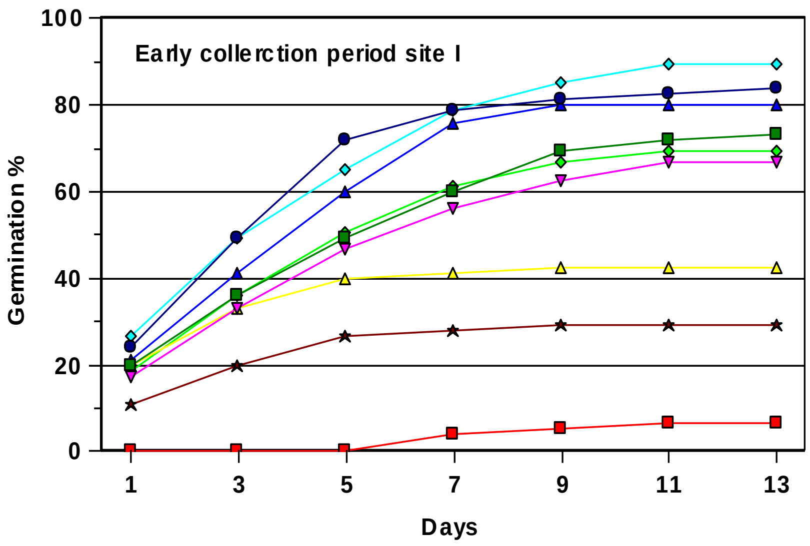
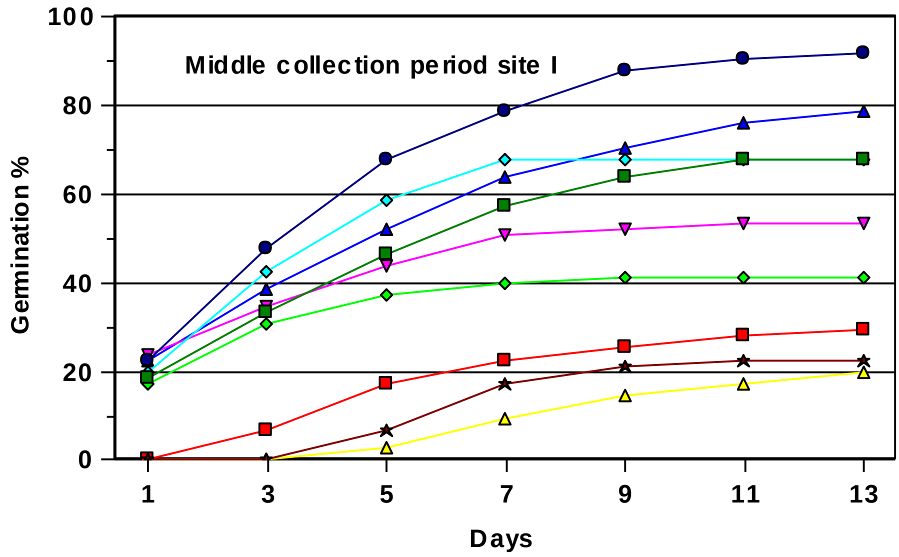


Fig.No 4.6 Effect of Sodium salts (Na_2CO_3, $NaHCO_3$ & NaCl) on seed germination in *A. mangium*


Early collerction period site I
Germination %
Days
100
80
60
40
20
0
1
3
5
7
9
11
13


Middle collection period site I
Germination %
Days
100
80
60
40
20
0
1
3
5
7
9
11
13

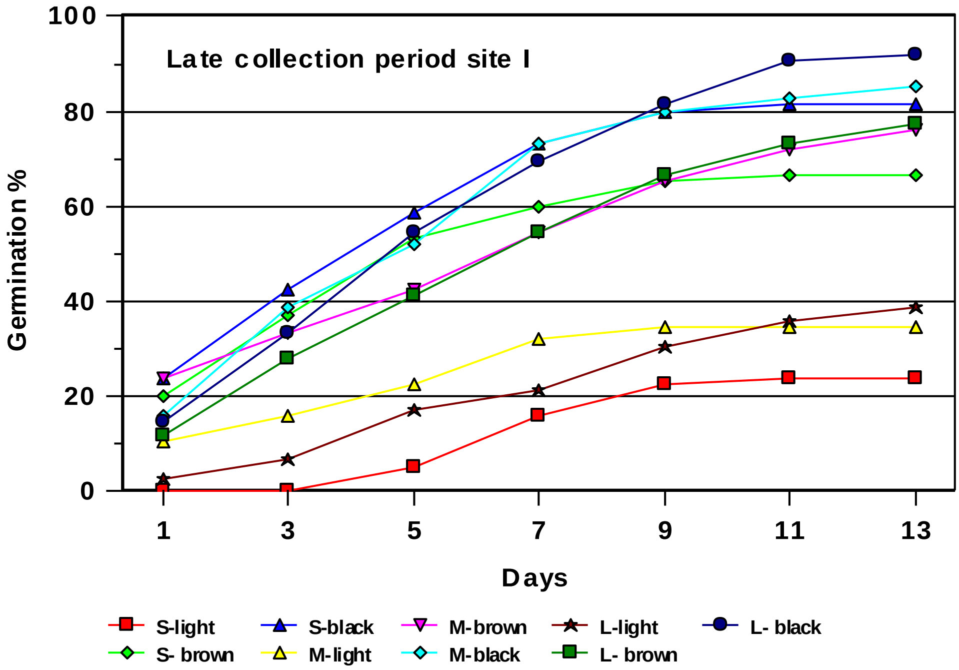
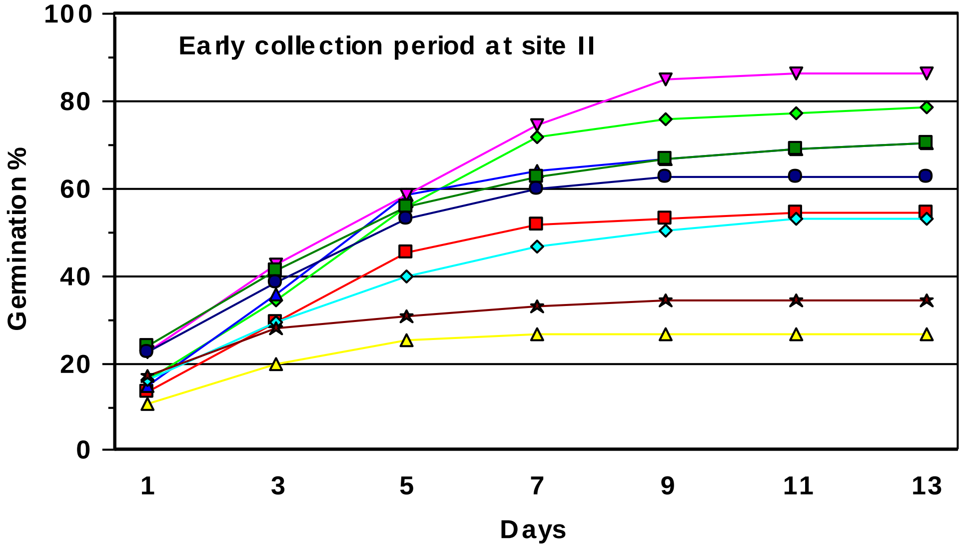


Fig.No 4.4 Effect of polymorphic group on seed germination in *A.mangium* Site



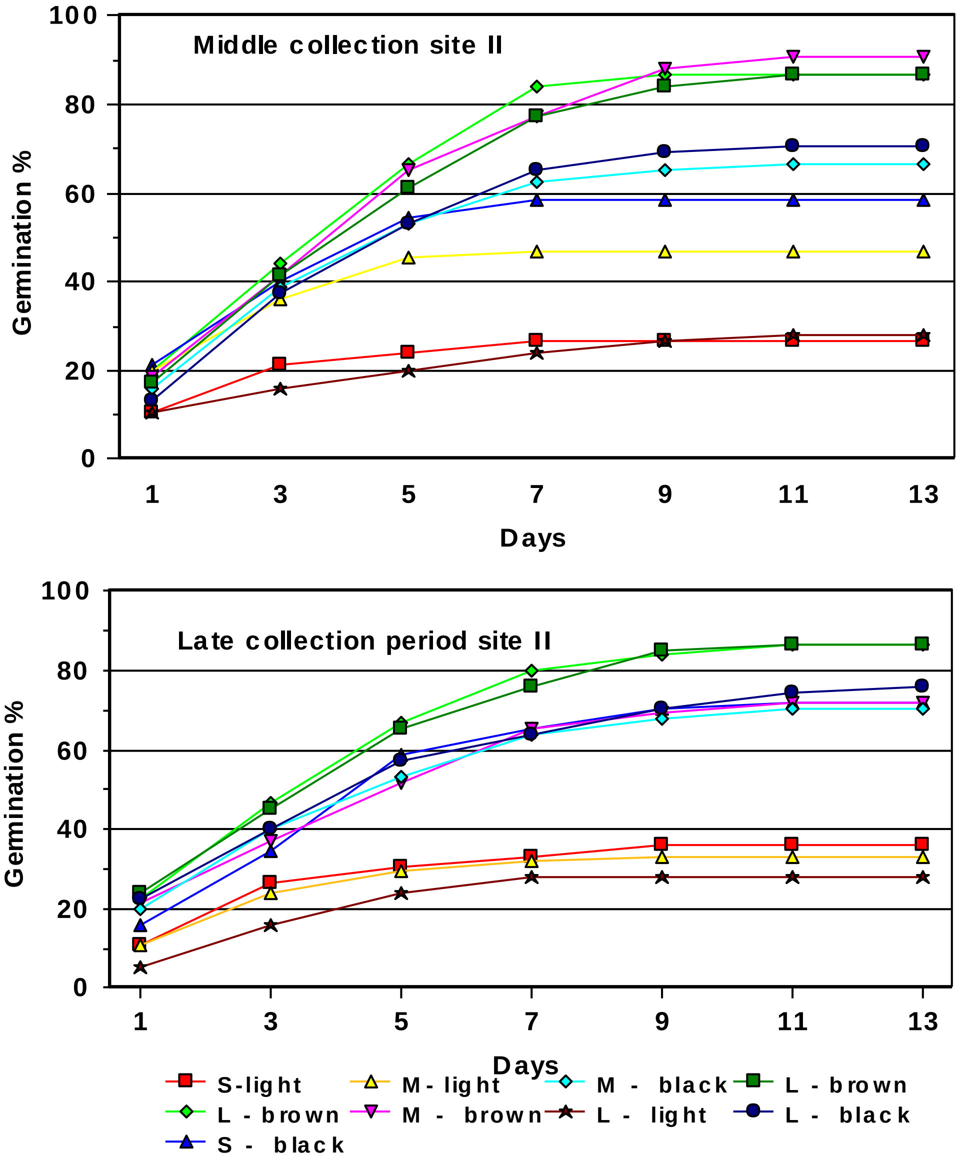
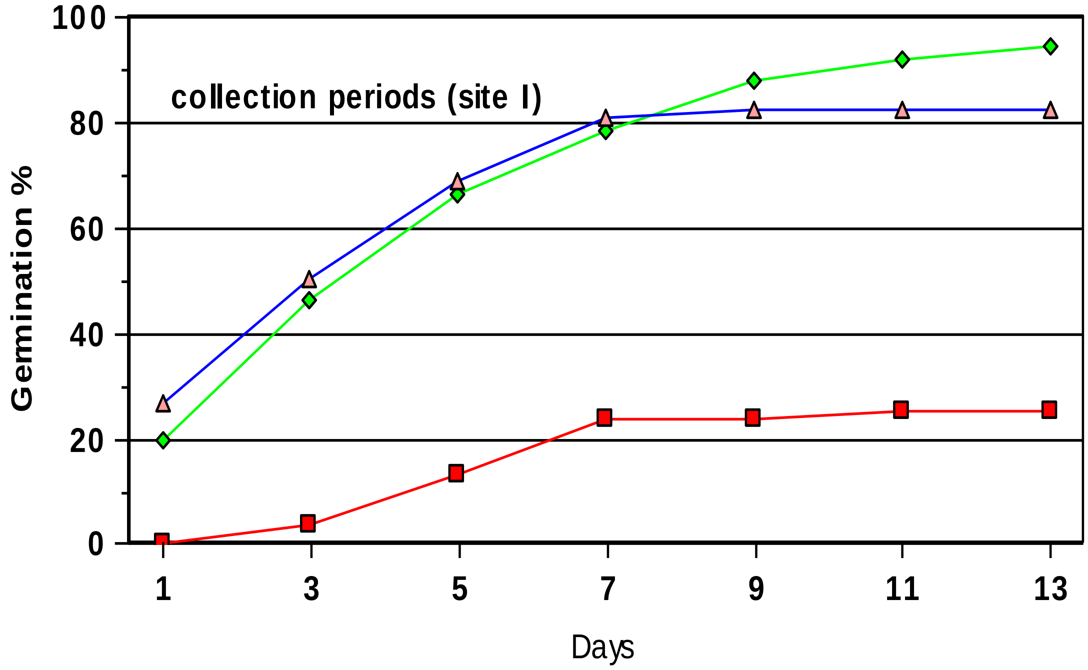


Fig.No. - 4.5 Effect of polymorphic group on seed germination in *A.mangium* Site-II



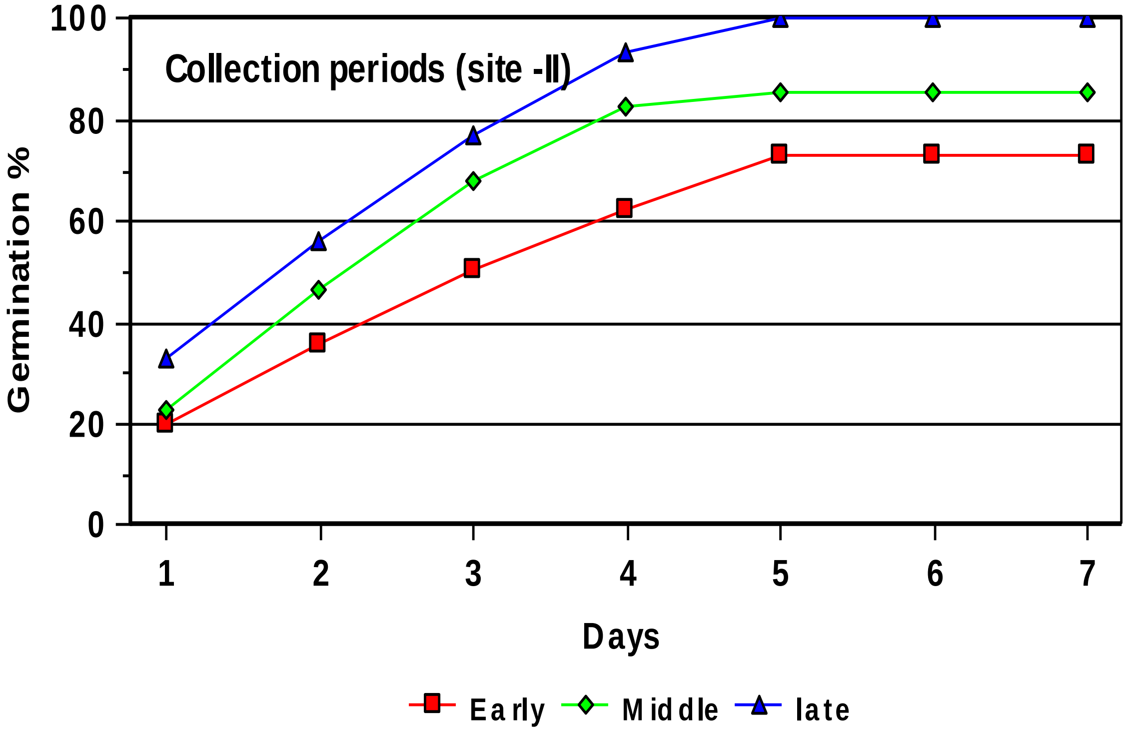
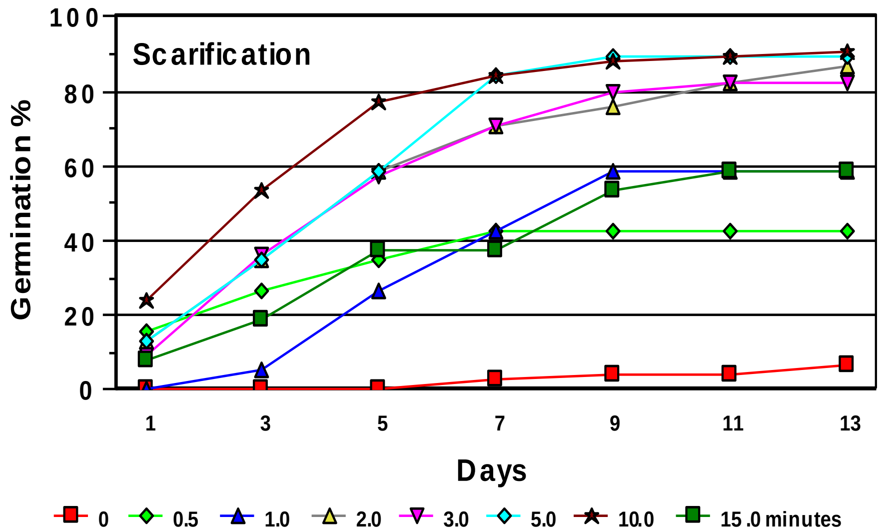
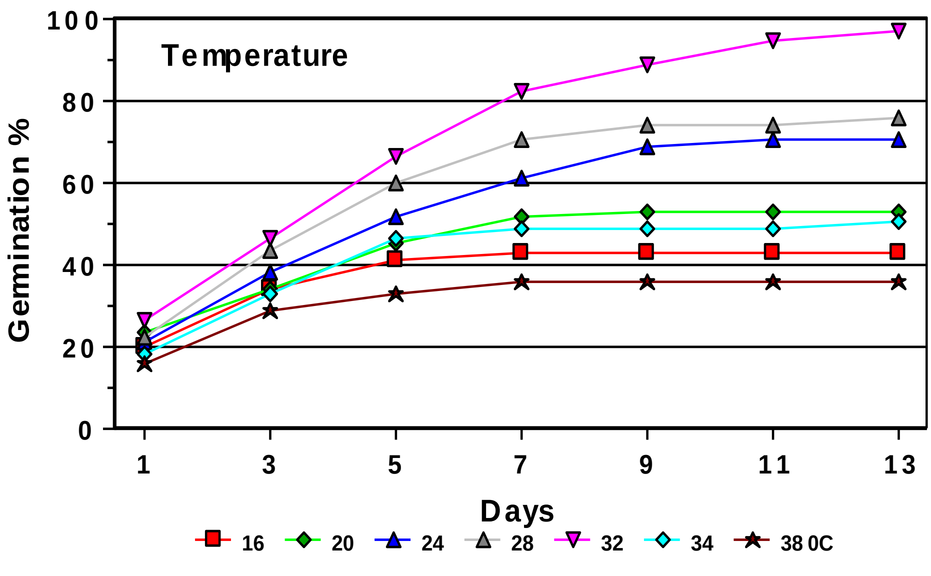


Fig.No. – 4.3 Effect of collection periods (early, middle, late) on se

in

*A. mangium*at site- I and site- II





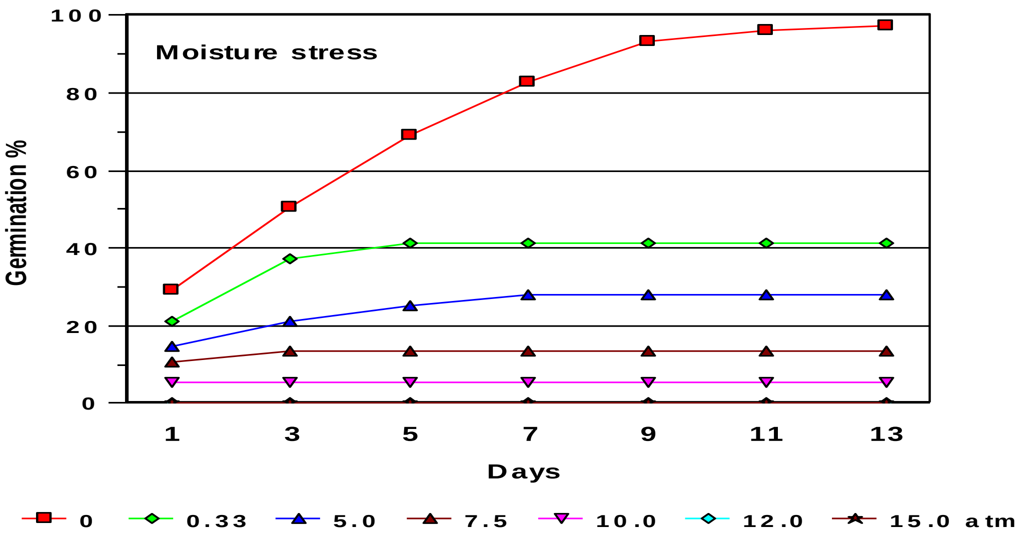
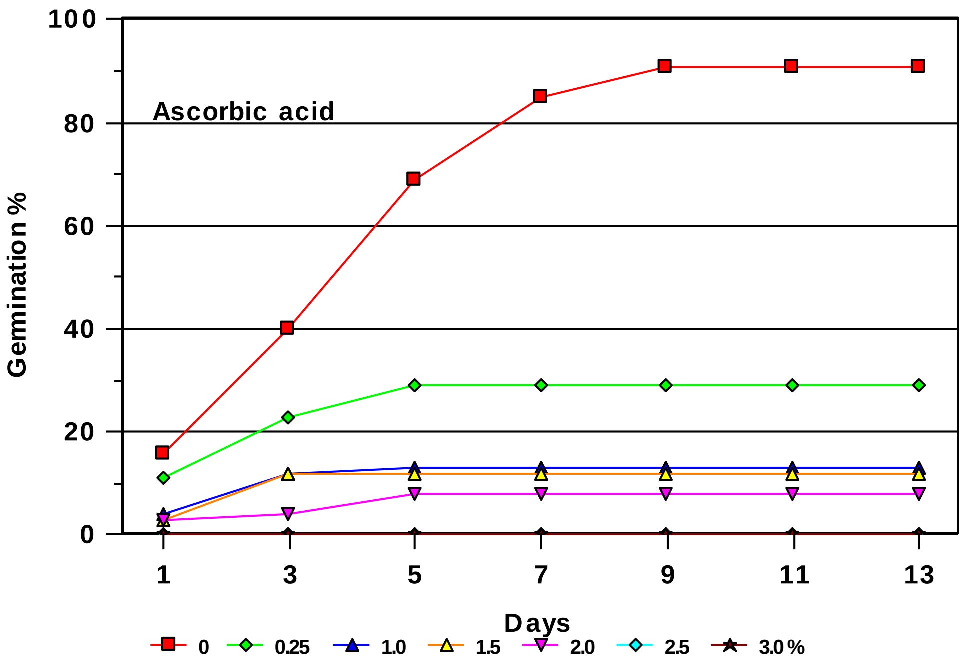


Fig.No. – 4.2 Effect of different treatments on seed germination in *A.mangium*



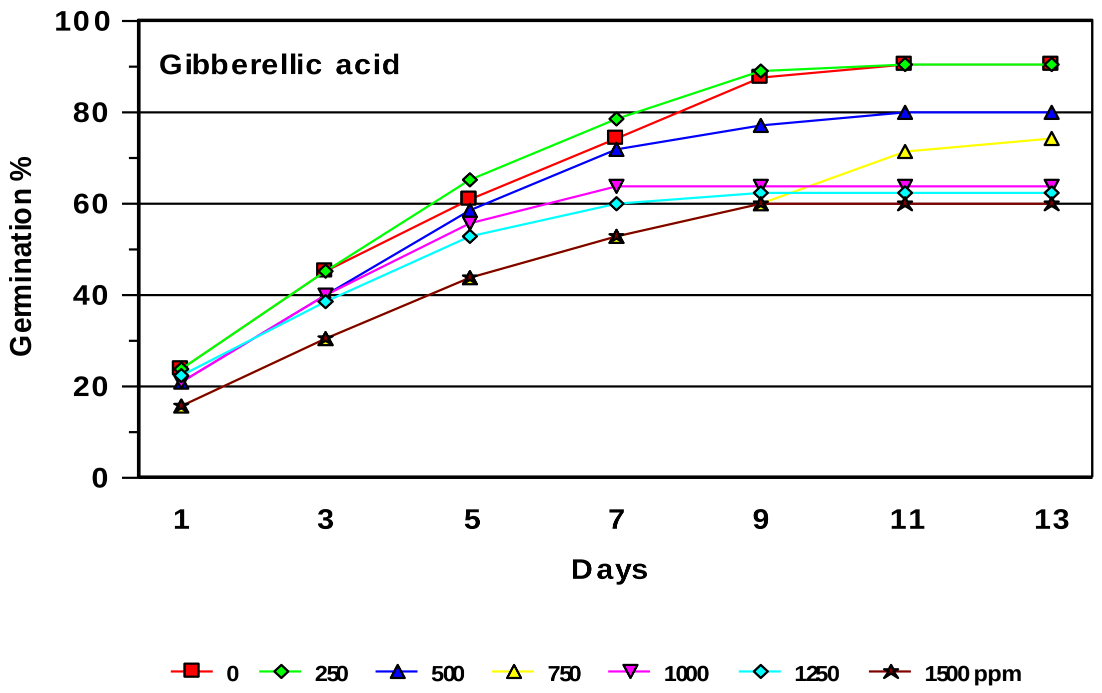


Fig.No.-4.7 Effect of growth regulator (GA) and vitamin on seed germination in *A.mangium*

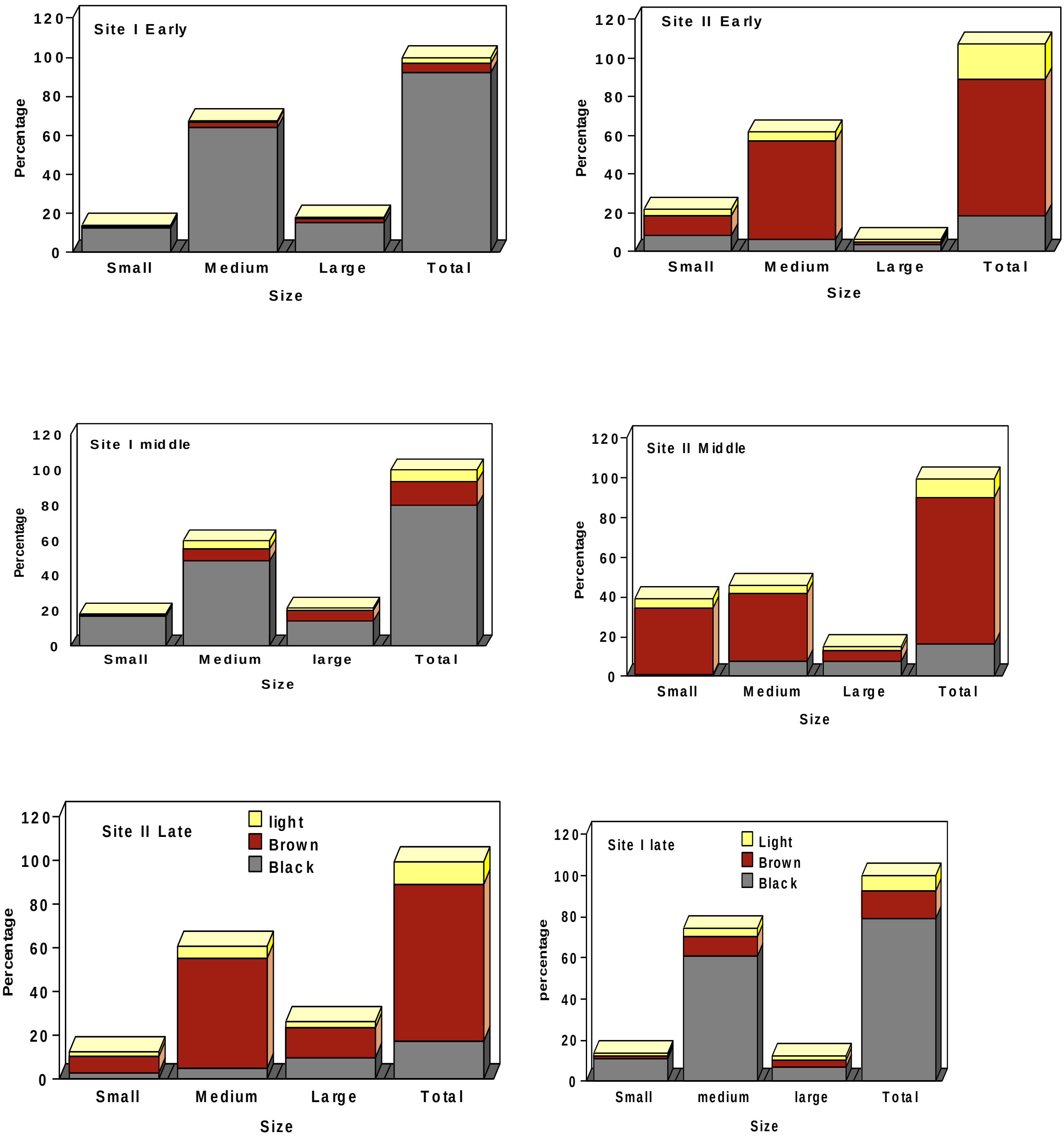


Fig.4.1 – Percentage distribution of different polymorphic group at site-I and site-II

Plate No.   1 :Plantation site-I at Field of Forestry Department, IGKV, Raipur.

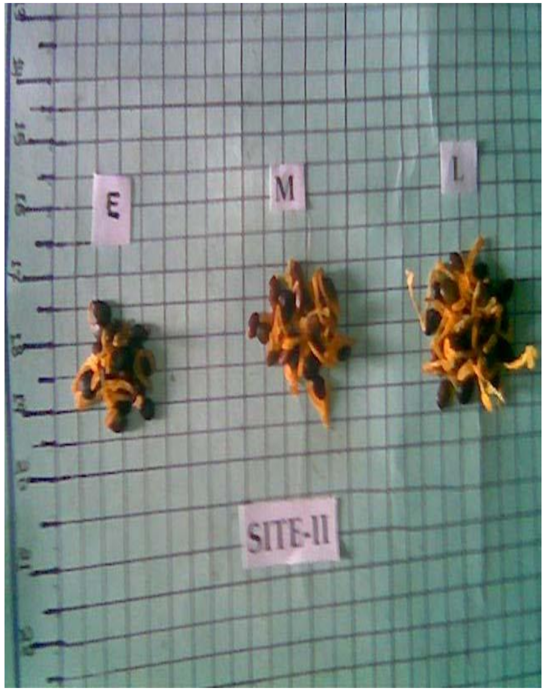
Plate No. 2: Plantation site-II at Energy Park

A view of plantation of *A.mangium*

Plate No. 4 : Phenological impression of *A.mangium*

Plate No. 5 : Pod Morphology at Experimental field of Forestry & Plantation of Energy park


E
M
L
SITE-I


E
M
L
SITE-II

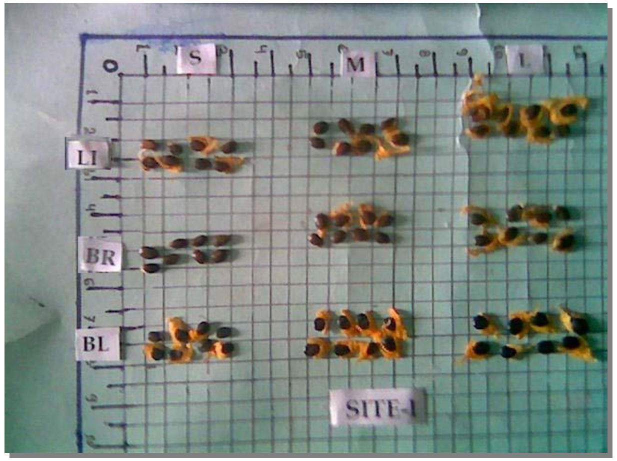
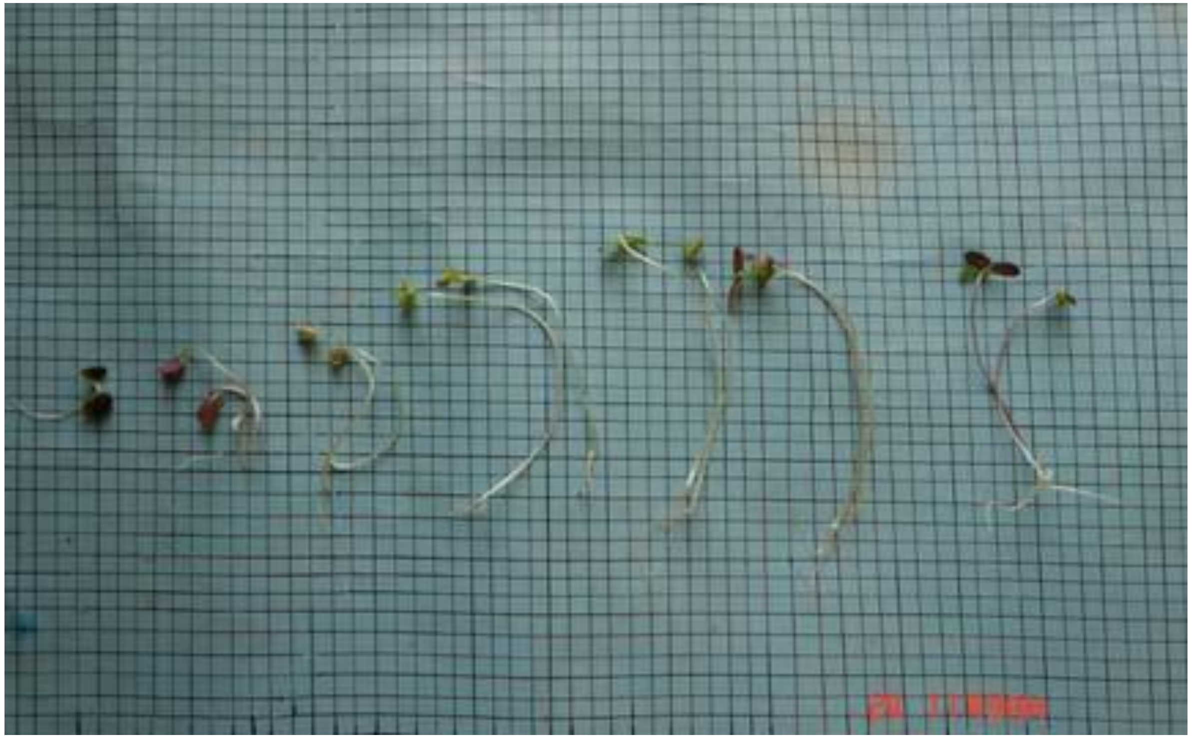


Plate No. 6 : Seed polymorphism in *A. mangium* at different site in different collection period

Collection period: E- Early, M- Middle, L- Late; Seed Size- S-Small, M-Midium, L-Large;
Seed Colour: LI- Light, BR- Brown, BL- Black

P late No. 7 : Seed germination & Seedling growth in *A. mangium*

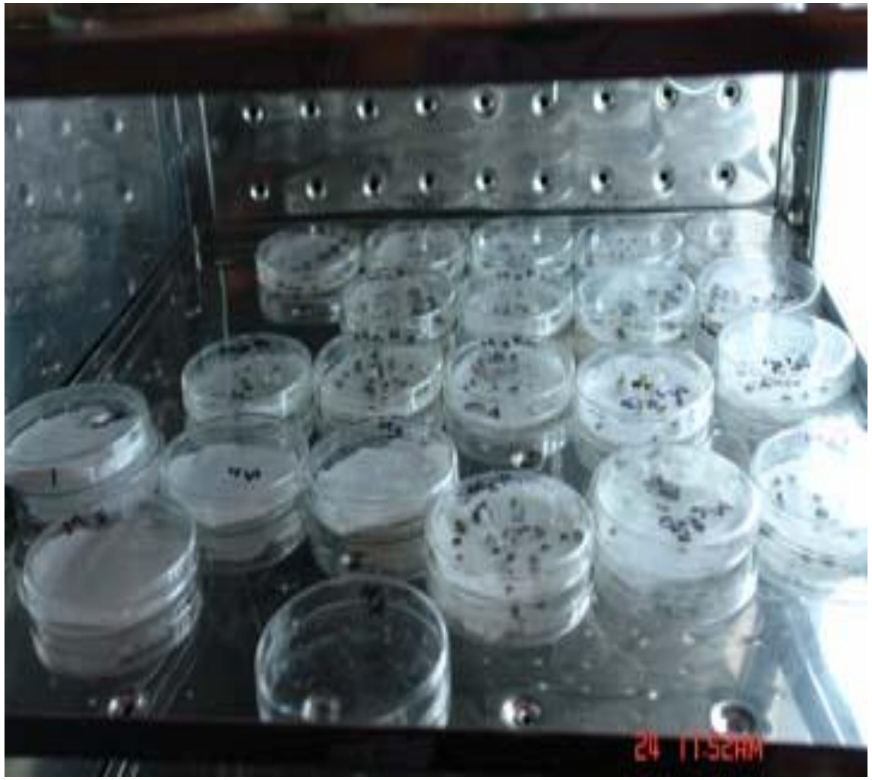


Plate No. 3 : A view of Seed Germinator