INVESTIGATIONS ON THE PRODUCTION OF HEALTHY SEEDLINGS OF TEAK (*Tectona grandis* Linn f) IN THE NURSERY

By

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THESIS

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Dedicated to

My parents

DECLARATION

I hereby declare that the thesis entitled Investigations on the production of healthy seedlings of teak (*Tectona grandis* Linn.f) in the nursery is a bonafide record of research work done by me during the course of research and this thesis has not previously formed the basis for the award of any degree, diploma associateship fellowship or other similar title of any other University or Society

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CERTIFICATE

Certified that the thesis entitled Investigations on the production of healthy seedlings of teak (Tectona grandis Linn f) is a record of research work done independently by Shri Syam V College of Forestry Vellanikkara under our guidance and supervision and that it has not previously formed the basis for the award of any degree fellowship or associateship to him

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Introduction

INTRODUCTION

Teak (Tectona grandis Linn.f) is a valuable timber species belonging to the family Verbenaceae. It is naturally distributed within South East Asia, the Indian sub continent, Burma, Thailand and western part of Laos. In its natural habitat teak forms a part of the moist and dry deciduous forest, in different associations, normally constituting a small percentage of the total number of individuals, but occasionally in almost pure stands.

In India, teak extends from Western Aravallis in Rajasthan through Central India and south wards upto Tirunelveli and Trivandrum district in Kerala. Areas with an annual rainfall of 1250-3000 mm with a marked dry season of 3-5 months, a maximum shade temperature ranging from 36°-38°C and a minimum shade temperature ranging from 12°-14°C and an altitude of about 700 meters above msl with deep well drained sandy loam soils are ideal for the best growth of teak in India.

Being a large deciduous tree teak attains a height of 30-40 mts with a clean bole upto 15-20 mts under favourable conditions. It is one of the most versatile timber trees used for both heavy and light construction work, house building, carpentry, furniture wood carving etc. The commercial value of teak was well recognized by the Britishers in India, and they took an active interest in its artificial regeneration on a large scale to meet their timber requirements. Teak has been artificially introduced in many localities outside its natural zone in the states of Uttar Pradesh, West Bengal, Assam, Bihar and Orissa in India. It has also been raised successfully in countries like Ceylon, Jamaica, Malaysia, Nigeria, Trinidad and Tobago

Teak plantations were established in the erstwhile states of Travancore, Cochin and Malabar in Kerala after clearing fresh forest land. Attempts to establish teak plantations in Travancore dates back to the second half of the 19th century with the raising of plantations in Konni and Malayattur. The oldest existing teak plantation in India, the Conolly's Permanent Preservation Plot (1842), which has attained world wide fame is at Nilambur (Malabar). Teak plantations were also extensively raised in Machad, Trichur and Chalakudy in Cochin State. The total area under teak in Kerala State is 78583.4 ha (Anon, 1988) The present supply of teak is such that, it is hardly sufficient to meet even the domestic requirements Hence the need to bring more areas under teak to ensure supply on a regular sustained basis is of atmost importance.

The methods of regeneration of forest crops include both natural as well as artificial methods. Natural regeneration in teak depends on a number of biotic factors which are often beyond the control of the silviculturist. Artificial regeneration is resorted to get quick and uniform germination which is very important in establishing teak plantations. The main constraints in the artificial regeneration of teak have been the irregular fruiting habits, poor seed setting, loss of viability of seeds in storage and the various problems associated with seed dormancy. In its natural habitat teak may start flowering at the age of 6-8 years beginning in about a month after the first rains in June August The flowers are small, whitish bisexual and appear in large panicles containing thousands of flower buds which open only a few at a time, during the flowering period of 2 4 weeks. From flowering it takes about 50 days for the green fruits to develop to full size and afterwards about 120-200 days to become fully ripe (Hedegart 1973). During this period, maximum number of premature fruit shedding occurs. The fruit is a hard irregularly rounded drupe. The size varies from 5 to 20 mm in diameter containing four seed chambers. It is surrounded from the inside by a stony endocarp, a thick felty brown mesocarp and a thin papery exocarp formed from the persistent calyx. The oval shaped seeds are about 6 mm long and 4 mm wide, tapering towards the radicle Only rarely have all the four seed chambers fully developed seeds, with the number of seeds per fruit varying between 0-4 the normal being 1-2 (Kamra, 1973). Due to difficulty in extracting the seeds, the unit for handling a teak fruit which for practical and conventional reasons is termed 'seed' if nothing else is specified (Keiding, 1985). The fruits are usually collected from the ground after sweeping the floor beneath the crown of the mother trees during the time of fruitfall from December to March Since the viability of the seed is generally found to decrease on storage, the collected fruits are normally sown in the same year at the start of the premonsoon showers.

Dormancy of the teak fruit is an important factor to be considered in the artificial regeneration of teak and appears to manifest itself in the form of poor germination results. Various reasons regarding the cause for dormancy have been put forth by different workers (Eidmann, 1934, Joshi and Kelkar, 1971, Gupta et al., 1975, Bhumibhamon et al., 1980). In general, dormancy in teak fruits appears to be a mixture of exogenous dormancy (both physical and chemical) as well as endogenous physiological dormancy. As teak fruits are normally broadcasted in the nursery in standard seed beds of size 12 x 1.2 x 0.3 meters (Khanna, 1977) the immediate effect of dormancy is uneven germination. Besides as teak plants are sensitive to shade, the late germinating plants are suppressed by the earlier germinating ones resulting in low plant percentage.

Due to the various types of dormancy operating in teak, finding out a suitable pretreatment for the teak fruits has been a century old problem. Most of the conventional methods aim at hastening the process of weathering of the impermeable stony endocarp and the felty mesocarp and include methods like alternate wetting and drying, use of acids, alkalies etc. These methods have been only partially successful although in some localities encouraging results have been obtained. At present the conventional method of alternate wetting and drying at 12 hour intervals for three consecutive days is being followed as a pretreatment for teak fruits by the Kerala

State Forest Department. Percentage of germination in this method range from 30-50 per cent But none of the various pretreatments described are in fact applicable for all types of teak seed and very often different seed sources have been found to require different pretreatments (eidi g, 9) The problem is all the more complicated since the knowledge of the seed with respect to its physiological state and dormancy is still very limited. The ideal solution would be to go in for a pretreatment that has been developed locally and perfected over the years using seeds from more or less the same source.

Grading of the teak fruits, is another important practice which will help in reducing the wastage of teak fruits in the nursery The influence of seed size on germination and growth of seedlings has been investigated by various workers (Eidmann, 1934, Joshi and Kelkar 1971 Kumar, 1979) though in general, bigger sized fruits have been found to germinate faster than small sized fruits, the effect of grading has not been really proven. Moreover, seed source or locality, also seems to have an influence on germination results of graded fruits (kumar, 1976)

The effect of media on germination and growth of seedlings have also been studied by various workers

The International Seed Testing Association has recommended the use of sand as a medium for teak seed germination (ISTA, 1976). However, detailed studies regarding the effectiveness of various media like vermiculite have not been done so far.

The present study was undertaken with the following objectives

1. To estimate the various fruit characters, average emptiness per fruit and viability percentage of teak fruits by cutting test.

2 To study the germination and seedling growth characteristics of graded teak fruits

3. To study the effect of various pretreatments on seed germination and seedling growth characteristics.

4. To study the effect of germination media on seed germination and seedling growth characteristics

Review of Literature

REVIEW OF LITERATURE

Teak being a commercially important species, has attracted the attention of wood users all over the world. Attempts at artificial regeneration of teak dates to far back as the mid nineteenth century Various methods to break the dormancy of teak seeds have been attempted by numerous workers. But none of these are effectively applicable for all types of teak seeds and in fact different seed sources require different pretreatments (Keiding, 1985) Past works regarding the various aspects of teak fruits, grading, dormancy breaking and viability testing have been briefly reviewed in this chapter

2.1 Effect of fruit characters

Fruiting in teak is affected by various factors like fertility index of site, locality factors, age and condition of mother trees, incidence of pests and diseases etc. Kadambi (1945) has stressed the importance of climate, edaphic and biotic factors on the natural reproduction of teak in India.

2.1.1 Seed source

The source of seed has an important bearing on the germination and development of teak plants. It is recommended to collect teak fruits from middle aged trees having well developed compact crowns, straight stem free from excessive buttressing and free from severe pest and disease attack (George 1961, Kedarnath and Mathews, 1962). Khayankit (1967) found that when teak fruits from 10, 15, 20 and 24 years old stands were tested for germination, those from 20 years old stands exhibited the maximum percentage of germination (49.2 per cent) and those from 10 year old plantations had the lowest percentage of germination (29.6 per cent). Keiding (1985) has commented that wherever possible, phenotypically good stands of teak plantations between the age of 15-45 years should be chosen as seed collection units. Prasad and Jalil (1986)studied the emptiness and germination percentage of teak fruits collected from natural stands in Madhya Pradesh and seed orchards from four localities in Uttar Pradesh. He observed that germination varied from 4.20 to 37.81 per cent in orchards and 13.93 to 54.42 per cent in natural stands, although there was no significant difference in emptiness among the fruits of different origins

The climate and precipitation of a seed collection area has also been found to exert considerable influence on fruit characters by various workers. Seth and Khan (1958) have identified 3 types of teak forests namely dry, semi-moist and moist types. The seed characters of teak fruits from these 3 types were found to vary considerably. Joshi and Kelkar (1971) found high temperature as a predisposing factor in accelerating the process of lignification of teak fruits from dry areas. This was pointed out to be an important reason for the poor seed development and consequently lesser germination percentage of the dry teak. Teak fruits from high rainfall areas also require less pre-treatment than seeds from dry hot areas (F.A.O , 1974). Gupta et al. (1975) in a study on the factors affecting the germination behaviour of teak fruits from 18 origins covering 6 states in India concluded that the fertility index of the site had a more pronounced effect on seed behaviour than precipitation. They also observed that teak fruits from dry areas were in some cases easier to germinate than those from moist areas

2.1.2 Method of teak fruit collection

In seed orchards, beating and shaking of trees followed by collection of fruits from the ground after spreading plastic sheets is practised and this has been found to be very effective (Apichart, 1981). In teak plantations as well as in natural stands, collection is done effectively by sweeping the forest floor of debris and other leaf litter after giving a light burning to destroy undergrowth, and the fruits are then handpicked at periodic intervals from the ground (Keiding, 1985).

2.1.3 Time of teak fruit collection

In India, seedfall in teak is usually from December end to March (Troup, 1921). The first fallen fruits requires more after ripening and a longer period of drying than the later collected ones to give better germination and hence if the fruits are to be collected from a particular area only, to obtain the highest degree of utilization, the fruits should be collected at least in two rounds (Eidmann, 1934). Hedegart (1973) has reported highest germination and least damage for the fruits collected towards the end of the fruit fall season.

2.1.4 Emptiness in teak fruits

Although teak fruits are described as tetra locular generally the seeds in all the four loculi do not develop equally. On an average only one out of four is fully developed (Joshi and Kelkar, 1971). Gupta and Kumar (1976) in a study on teak fruits collected from 23 different sources found that the emptiness varied from one source to another. The number of seeds in teak fruits ranged from 0 to 4 with one seeded fruits showing the highest frequency of distribution. Dabral (1976) pointed out that the emptiness in teak fruits was not in any way related to the size of the loculi, but the site factor which determines the availability of food was exerting a significant effect on it Since usually only one seed per fruit manages to develop into a plant in practice the number of fruits and seeds are considered the same (Keiding, 1985).

2.2 Effect of grading

Environmental influences during the development of the seed and genetic variability can result in variation in seed dimensions within the same species. It has been suggested that larger seeds have greater advantage over smaller seeds in germination and seedling growth, possibly due to larger embryo or gametophytic tissue, more cotyledons or greater initial leaf area (Farmer, 1980) Grading of seeds in this respect should be a relatively simple operation but, to get the full benefit of grading proper processing of the seed should be done before hand (Willan, 1985).

Grading has been practised in the case of teak by some earlier workers. Eidman (1934) in his investigations on the influence of fruit size on germination and early growth of teak seedlings, found that bigger seeds (greater than 14 mm diameter) germinated faster or had a better speed of germination than smaller seeds and hence showed better growth performance during the first year. But Anon (1955) found no significant difference in the mean height of seedlings raised from teak fruits of different sizes, Sarowart (1964) also did not obtain any correlation between the fruit size and size of stump.

Pakdee (1961) in a comparison of germination of teak fruits of different size classes found that 11-14 mm diameter class was best and 8-11 mm class and 14-17 mm class were moderate in germination, while 5-8 mm diameter class proved to be poorest in germination. Kumar (1979) graded teak fruits according to size into 5 diameter classes viz. 5.0 - 7.5 mm, 7.5-10.0 mm, 10.0-12.5 mm. 12.5-15.0 mm, 15.0 - 17.6 mm and 17.5-20 mm respectively. The class 10.0-12 5 mm produced the maximum number of seedlings (13 per cent) while the 12.5-15.0 mm class recorded the minimum number (3.4 per cent). The 17.5-20 mm, 15.0-17.5 mm and 7.5-10.0 mm diameter size classes recorded 11.7 per cent, 10 per cent and 7.5 per cent respectively.

The effect of size grading of seeds on germination and further growth, of tree species other than teak have also been studied by various workers. Ghosh et al. (1976) in a nursery study on three pine species Pinus roxburghii, P. caribaea and P. oocarpa found that the medium sized seeds gave significantly higher germination percentage and plant percentage as compared to large or small sized seeds. The medium sized seeds also gave higher mean daily germination, peak value of germination, germination value, total biomass, height growth and root/shoot ratio of the seedlings as compared to other two grades. Basada (1979) found that there was significant correlation of seed size on germination and seedling height growth in Shorea contorta. Chauhan and Raina (1980) also found that seed size had a significant effect on size of seedling in the case of Pinus roxburghii. The effect of seed size on germination and seedling growth of loblolly pine (Pinus tarda) was also found to be significant (Dunlap and Barnett, 1983). Bonner (1987) found that seed size was positively correlated with germination rate in Liquidamber styraciflua L., but was completely insignificant in <u>Pinus echinata</u> while it was varying in significance among three seed lots of <u>Pinus elliotii</u>.

2.3 Seed dormancy in teak

Teak exhibits dormancy and this is mainly due to a number of complex, possibly inter related factors. Keiding (1985) has reported that this dormancy period varies from 4-6 weeks even upto a maximum of three years in the case of seed lots coming from the same source Attempts have been made to find out the correlation between the climate of the seed source and the degree of dormancy of the teak seeds. Though in general, seeds from drier regions of teaks natural distribution seemed to have a higher degree of dormancy, the exact correlation between annual rainfall and dormancy has not been really proven. Other factors also seems to have considerable influence on dormancy of teak seeds.

Eidmann (1934) has pointed out that delay in germination would be due to the process of after ripening phenomenon operating in teak seeds. Joshi and Kelkar (1975) have stated that the lignification of pericarp and endocarp before fruit drop which limited gaseous exchange is an important factor resulting in prolongation of seed dormancy.

This was also attributed to be the reason behind the very poor or negative response of teak seeds to quick viability tests. Gupta et al. (1975) hinted that the physiological condition in the form of nutrient imbalance could be an important cause for the dormancy of teak seeds. The presence of water soluble germination inhibitors in the mesocarp was believed to play an important role in teak seed dormancy by him. Bhumibhamon et al. (1980) noticed that an aqueous or alcohol extract of the teak fruit mesocarp inhibited the germination of rice grains and pine seeds thereby indicating the presence of a phytocide.

2.4 Breaking dormancy of teak seeds

Considerable variation exists in the fruit characteristics of teak between seed lots from different sources and also quite often within seed lots from the same source (Krishnamurthy,1973). This was one of the main reasons for attempting a number of different pretreatments by many earlier workers in this field to obtain uniform germination of teak seeds. A brief account of the important pretreatments are presented below.

2.4.1 Weathering treatment

Most of the conventional approaches aim at hastening the process of weathering of the impermeable woody endocarp and felty mesocarp. Such approaches include methods like alternate wetting and drying, Bengal pit method, treatment with hot sand, treating the fruits with a mixture of lime water and cow dung slurry etc. Hodgson (19 0) described a method of soaking the teak fruits in lukewarm water for 12-24 hours prior to sowing. Another weathering treatment was by exposing teak fruits to the heat of the sun for two months (Damale, 1901). The method of mixing teak fruits with cowdung slurry or earth in pits for varying periods before sowing has been described by various workers (Osmaston, 1908; Gamble, 1921)

Yet another successful method of germination was reported by Singh (1925). In this method teak fruits were taken in pits of size 3 x 3 x 2 ft., covered with straw and leaves and kept for one year The use of straw prevented the removal of the mesocarp by white ants and enhanced germination when the fruits were taken out and sown after soaking in water for 24 hours Tuggerse (1926) has commented on this method and recommended over ground treatment of teak fruits to prevent seed rotting especially in high rainfall areas. Wimbush (1927) has recommended a presoaking treatment in gunny bags for 24 hours in cold water before sowing. According to Banerjee (1942) soaking the teak fruits in a pond for 36 hours before spreading on bamboo mats, followed by watering at 12 hour intervals for a period of 3-4 weeks is a sure method to guarantee at least 50 per cent germination. Wijesinghe (1963) in his experiments on teak seed germination in Sri Lanka; tried different periods of soaking and reported that good germination could be obtained when the fruits were soaked for 48 hours in water. Muttiah (1975) concluded that in the case of teak fruits of dry origin, a 48 hours soaking in stagnant water followed by alternate soaking and drying for four days was the best pretreatment method in Sri Lanka. Nglube (1988) has recommended the soaking of teak fruits in water for 48 hours followed by alternate soaking and drying for 12 hour periods for 21 days. This method has been found successful in Africa ensuring at least 50 per cent germination in teak nurseries

2.4.2 Hot water treatment

This treatment has been found to be relatively easy, safe to practice and effective. The proper relationship between the volume of water to the volume of seeds as well as the temperature requirement, duration of treatment etc. vary from species to species and is determined by experiments (Bonner, 1974) Usually the seeds are placed into boiling water which is immediately removed from the heat source and left to cool gradually with the seeds remaining in the water, for about 12 hours (Willan, 1985).

Hot water treatment has been practised in the case of teak fruits by several workers. Panjamanodth (1962) has reported that teak fruits when sown immediately after soaking for five minutes in hot water at 40°C, 60°C, 80°C, 80°C and 100°C gave 0.9, 0.75, 0.05 and 0.00 per cent germination respectively. The control treatment gave a germination of 1.35 per cent and was found to be highly significant over the other treatments. Thaninpong (1963) observed that teak fruits immersed in hot water at 50°C for different periods and soaking in cold water for a fixed period of four hours gave germination results ranging from 28.5 to 34.5 per cent, but these were not significantly different from control (33.5 per cent).

Hot water treatment has been practiced successfully in the case of other tree seeds by various workers. Larsen (1964) claimed that 60 per cent germination could be achieved in *Acasia sieberiana*, an exceptionally resistant species, by boiling the seeds in water for 60 minutes. Singh (1987) has reported that soaking the seeds of *Cassia fistula* L. in hot water at 95°C for one minute resulted in 70 per cent germination

2.4.3 Acid treatment

The chemical which is most commonly used to break seed coat dormancy is concentrated sulphuric acid. Though this treatment has been found to be more effective than hot water treatment in some species, the main disadvantage is that great care is needed for handling of the acid and is not at all safe for use by unskilled workers. Since the toughness of the seedcoat is found to vary between seed lots from different sources and sometimes even between individual trees in the same species, the optimum period of immersion in the acid as well as strength of the acid to be used is determined only by experiment (Willan,1985).

Teak fruits soaked in sulphuric acid having concentration of 5%, 10% and 20% yielded good germination results although the treatments did not differ significantly from control (Chakobkai, 1962, Savinthoru, 1963). Shintorn (1963) in a comparative study on teak seed germination by soaking the fruits in varying concentrations of sulphuric acid for a specific time period of 30 minutes, found that there was no significant difference between the treatments and the control In his study 5%, 10% 15% and 20% concentration of the acid recorded germination percentages of 16.5, 18.7, 16.7, 16.25 and 18.25 respectively Boonyasirikul (1964) and Bumrungrach (1964) also reported that the germination of teak seeds was not influenced by the concentration of the acid, but lower concentration gave better germination results though not significant from control. Ngulube (1986) after conducting experiments in Malawi (Africa) has reported that 3.8 per cent germination in teak fruits after immersing the seeds in 98 per cent concentrated sulphuric acid for 2 hours.

Sulphuric acid treatment has also been tried out in other tree species by various workers. Sniezko and Gwaze (1987) found that treating the seeds of Acasia albida with sulphuric acid gave excellent germination results. Babb and Kandya (1988), after screening 25 pretreatments on Cassia fistula seeds reported that 98 per cent concentration of sulphuric acid for 90 and 45 minutes gave 84 per cent and 75 per cent germination respectively.

2.4.4 Gibberellic acid treatment

A wide range of chemicals including Gibberellic acid have been tested experimentally in an attempt to overcome the internal of endogenous dormancy of seeds of many tree species. Bachelard (1967) found that the germination of dormant seeds of Eucalyptus delegatensis E. fastiga and E. regnans could be improved by treatment with Gibberellic acid. Shafiq (1980) observed that in Nothofagus sp. complete and quick germination could be effected when gibberellic acid was used instead of the normal stratification method to break the physiological dormancy in that species. 200 ppm GA_3 gave 100 per cent germination in 8 days and 50 ppm GA_3 gave 100 per cent germination in 12 days thereby proving that higher concentration of GA_3 in fact helped to quicken the process of germination. Soaking seeds in GA_3 solution to break dormancy and to promote seed germination in many other species has been tried out by several workers in recent years (Shatat 1985, Zaitoun 1986, Holloway, 1987, Maithani et al.,(1987).

GA_3 has been used previously to break dormancy and promote seedling growth in teak also. Somabutra (1964) found that the growth of teak seedlings showed a marked improvement over control when GA_3 was used. Maximum growth of seedlings were recorded in 50 ppm and 100 ppm treatments. Dharncaai (1965) stated that teak seeds treated with 100 ppm GA_3 increased height growth even though it was not significantly different from control. Thanchai (1965) in his experiments on teak seed germination using GA_3 observed that when the height growth of one year old teak seedlings were considered, the treatment with GA_3 at 100 ppm showed significant difference from control and GA_3 at 75 ppm and 50 ppm were insignificant. Leadem (1987) confirmed the role of exogenous application of gibberellic acid in breaking the dormancy of tree seeds. He found that the germination of seeds was to be frequently associated with increased gibberellic acid levels.

Gibberellic acid has also been found to promote height growth in many species when it was used as a spray in fully emerged seedlings. The application of 1 per cent GA_3 in the form of lanolin paste on one week old teak shoots arising from stumps resulted in a clear increase in height growth (Seth and Mathuada, 1959). Mishra and Mishra (1984) noticed that the spraying of GA_3 on one month old seedlings of teak at 10 ppm and 15 ppm respectively induced a promotive effect on growth and dry weights of shoot and root. The effect of GA_3 at 100 ppm was suppressive. Ananthapadmanabha (1987) has also reported that the regular spraying of growth hormones especially GA_3 has promoted the height growth and biomass production in the case of seedlings of 12 tree species.

Several direct biochemical studies have been made on the effects of gibberellic acid on protein and nucleic acid synthesis during germination. Application of gibberellic acid (GA_3) released Coryllus avellana seeds from dormancy and stimulated DNA synthesis (Jarvis et al., 1968). It was suggested that GA_3 induced germination in that species was due to the depression of certain specific genes, allowing the production of RNAs for proteins which are essential for germination.

Paley (1960) has described the mode of action of gibberellic acid on the germination of cereal grains. The embryo and endosperm were the site of action of gibberellic acid. The GA produced in the growing embryo was transported to the aleurone layer where it stimulated the synthesis of hydrolytic enzymes which in turn acted on the starchy endosperm. The sugars and amino acids thus released were absorbed by the embryonic axis through the scutellum thereby enabling the embryo to grow heterotrophically until its establishment by photosynthesis.

Rowe and Gordon (1981) concluded that the responses to GA treatment were dependent upon experimental conditions and could vary considerably with the type of GA and test environment.

2.5 Seed Testing

The main objective of seed testing is determine the quality of the seed sample accurately and to relate the laboratory results to the planting value to the extend possible (Justice, 1972). ISTA (1976) has given standard prescriptions regarding the seed testing methods appropriate for 61 different genera of plants.

2.5.1 Importance of sampling in seed testing

Sampling is an important prerequisite in seed testing. One of the objective in sampling is to obtain a sample size suitable for tests in which the probability of a constituent being present is determined only by its level of occurrence in the seed lot (ISTA, 1976). Seed lots of the same species should not be mixed if they come from different origins/provenances, differ greatly in age or, if they come from plantations growing on very different site types (Willan, 1985).

Bonner (1974) has stated that when seed sampling is done correctly the primary samples will be distributed in proportion to the volume of different parts of the seed lot Weight of the working sample depends on the seed size of the species in question. ISTA (1976) has prescribed a minimum size of the working sample for teak as one kilogram.

2.5.2 Importance of seed weight in seed testing

The measurement of seed weight is made on the pure seed component separated by purity test and is normally expressed as the weight of 1000 pure seeds. Seed weight may be determined simply by counting out 1000 seeds and weighing them (Bonner, 1974).

Very often the number of teak fruits per kilogram collected from 2 different sources may differ considerably Dabral (1976) found that two samples of teak fruits collected from two different seed collection areas gave results of 2290 fruits/kg and 2646 fruits/kg respectively. The first sample yielded 2542 seeds but from the second sample only 2287 seeds could be extracted. Kumar (1979) in a study on teak fruits from five sources in Andhra Pradesh found that the number of teak fruits per kilogram varied from 1538 to 2417. The average weight of 1000 fruits also showed considerable difference between the sources.

2 6 Viability test for teak seeds

Viability tests indicate the potential for germination of a seed lot. It also indicates the germination percentage provided, that the germination potential is properly utilised by applying the right pretreatment and sowing techniques (Keiding, 1985). The testing methods for seed viability are broadly classified into direct and indirect methods.

2.6.1 Germination test

This is a very reliable, direct method for testing the viability of seeds. Of all the quality measurements of seed lots, none is more important than the potential germination of fresh, firm and possibly viable seeds (Bonner, 1974). The ISTA rules (ISTA, 1976) have recognized four groups of abnormal seedlings, viz., damaged, deformed, decayed and seedlings with unusual hypocotyl movement. The assessment of many of the doubtful and abnormal seedlings are normally left till the end of the test period to ensure that slower growing but otherwise normal seedlings are not incorrectly classified (Willan, 1985).

Although the methods for conducting germination tests are fairly well standardized, the interpretation of results is often too subjective. Czabator (1962) has presented a formulae for objectively evaluating results of germination results. The concept of germination value

(G.V) put forth by him, is a composite expression of both speed and completeness of germination. This concept aims to combine in a single figure, an expression total germination at the end of the test period with an expression of germination energy. This concept of germination value has been used by several workers in India for many tree species like Pinus sp. (Ghosh et al.,1976), Albizzia procera and Eucalyptus sp. (Bahuguna et al., 1987 a & b), and for Albezzia lebbek (Singh and Paliwal,1987).

Normally one germination test consists of 400 seeds in four replicates of 100 seeds each, provided they do not overcrowd the test substrate (Bonner, 1974). A spacing of 1.5 to 5 times the normal seed diameter between seeds, to discourage spread of fungal moulds, is also recommended by him. Gupta et al. (1975) has given standard guidelines for conducting germination tests of teak seeds under Indian conditions. Sand as a germination medium, a temperature requirement of 30°C, a light requirement of 8 hours per day and an observation period of 16 days stating from the 14th day since the start of the test till the 30th day have been suggested by him. Two pretreatments namely (1) soaking the teak fruits in water for 24 hrs before sowing (2) soaking in Sach's nutrient solution for 4 hours before sowing has also been recommended. ISTA (1976) have also given standard prescriptions for conducting germination test of teak seeds, which also almost identical to those mentioned above. They have recommended a 14 day observation period instead of 16 days and an additional pretreatments of teak seeds consisting of alternate wetting and drying of the seeds.

Proper evaluation of the germination results is as important as conducting a germination test successfully In laboratory tests the majority of the normal seedlings are removed at interim counts. At the end of the test period all the remaining ungerminated seeds are usually cut and examined to record the number of fresh, firm and possibly viable seeds (Bonner, 1974). Very often the results obtained under ideal conditions in the laboratory are not directly applicable in the field nursery where only limited control over environmental conditions is possible. Hence, a correction factor based on experience should be applied to convert the germination potential of a seed lot as determined from laboratory tests, to actual germination expected under field conditions (Willan, 1985)

2.6.2 Cutting test

This is an indirect method of testing viability of seeds. Here the seeds are cut open with a knife or scalpel and directly inspected visually. The cutting test can be performed before the start of a germination test to get an idea about the probable germination percentage of a seed lot by estimating the size and maturity of the seed samples The cutting test is also done at the end of the germination test to determine the apparent viability of ungerminated seeds (Bonner, 1974).

In an estimation of the potential germiability of teak fruits from 23 different sources by cutting test (Gupta and Kumar, 1976) it was found that the frequency of distribution of one seeded fruits was the highest followed by fruits with two seeds. The number of fruits with three seeds were still less frequent and four seeded fruits, very rare.

Seeber and Agpoa (1976) have found good correlation between cutting and germination tests in fairly large seeded species like Leucaena leucocephala, Intsia bijuga and Lagerstroemia speciosa in Philippines. But the germination percentage was consistently 10-20 per cent less than the percentage of sound seeds obtained by cutting test. In another cutting test on teak fruits from 54 sources (Keiding, 1985) the per cent of sound, viable seeds varied from 44-100 with an average of 78. The actual germination per cent was not found to be consistent with the figures of cutting test.

2.6.3 Tetrazolium test

This is now an accepted bio-chemical test developed for seed testing. In this method the living cells are stained red by the reduction of a colourless tetrazolium salt to form a red formazon. Justice (1972) has stated that, while the tetrozolium procedure was good in principle, its practical use in routine testing is limited due to many problems including difficulty in staining of some seeds, need for cutting or dissecting seeds to permit observation of stained parts, poor agreement with germination tests especially in the case of seeds with low germination capacity, lack of uniformity in staining and difficulty in interpreting the significance of different degrees of staining. Gupta and Raturi (1975) have attempted the standardisation of viability test by tetrazolium staining in the case of six Indian tree species viz., *Albizzia lebbeck*, *Albizzia procera*, Albizzia chinensis, Cassia fistula, Cassia nodosa and Pinus roxburghii. They have found that tetrazolium staining is a dependable biochemical method for testing the inherent germination capacity of a seed lot, more so in the case of forest seeds which take much larger time to germinate or exhibit various types of dormancy. ISTA (1976) has recommended tetrazolium test especially in the case of some species of hardwoods and conifers which germinate slowly by regular germination methods. Keiding (1985) cencluded that the estimation of viability percentage in the case of teak seeds by tetrazolium staining was in correlation with the results obtained by cutting test.

2.7 Effect of media on germination and seedling growth

The choice of media on which the seeds are placed for germination depends on the equipment used, the species, the working conditions as well as the experience of the operator. The main requirements of a substrate are nontoxicity to germinating seedlings, freedom from fungi and other microorganisms, a porous nature of the media which is essential for adequate aeration and moisture for the germinating seeds (Justice, 1972).

Various media have been tried out in the case of teak seeds with the main objective of increasing germination per cent, seedling growth and survival by different workers. Rujakom (1962) found that there was no significant difference in germination per cent between teak fruits sown in sand and sand supplemented with $CaCO_3$ at various levels. Tanukit (1966) observed that when sand was used as a covering medium for germinating teak fruits, smaller sized stumps were obtained compared to rice shell covering which gave larger sized stumps. However, the survival per cent and seedling height were better in sand. Sukcharoen (1968) did not observe any significant difference in the germination per cent of teak seedlings obtained from different germination media.

Gupta, *et al*. (1975) in framing seed testing rules for conducting germination tests for some common Indian tree seeds, sand was recommended as an ideal medium for large seeds and paper, for small seeds. ISTA (1976) has recommended the use of sand as a substrate for teak fruits in germination trials. Yadav, *et al*. (1982) in a study on the growth performance of teak seedlings in different pot culture media found that the overall growth was best in natural black soil.

Materials and Methods

MATERIALS AND METHODS

The present investigations on the production of healthy seedlings of teak (Tectona grandis Linn.f) in the nursery were conducted from the month of April to August 1988, after collecting the teak fruits from seven middle aged teak plantations in Trichur Forest Division

3.1 Seed Collection

3.1.1 Identification of seed collection areas

The fruits of teak start to shed during the early part of the year from January to March. As far as possible, stress with clean straight bole free from excessive fluting and branching with rounded crown and bearing abundant fruits were selected as seed mother trees Seven middle aged teak plantations (Plate 1 and 2) in Trichur Forest Division were identified and promising seed mother trees in these plantations were selected and marked for seed collection. These plantations were situated more or less adjacent to reserve forests and were in the first rotation period. The details of the selected teak plantations are presented in Table 1.

Fig 1 Forest map of Trichur Forest Division sho ing the administra ive blocks(Forest Ranges) and location of the selected Teak Plant tions

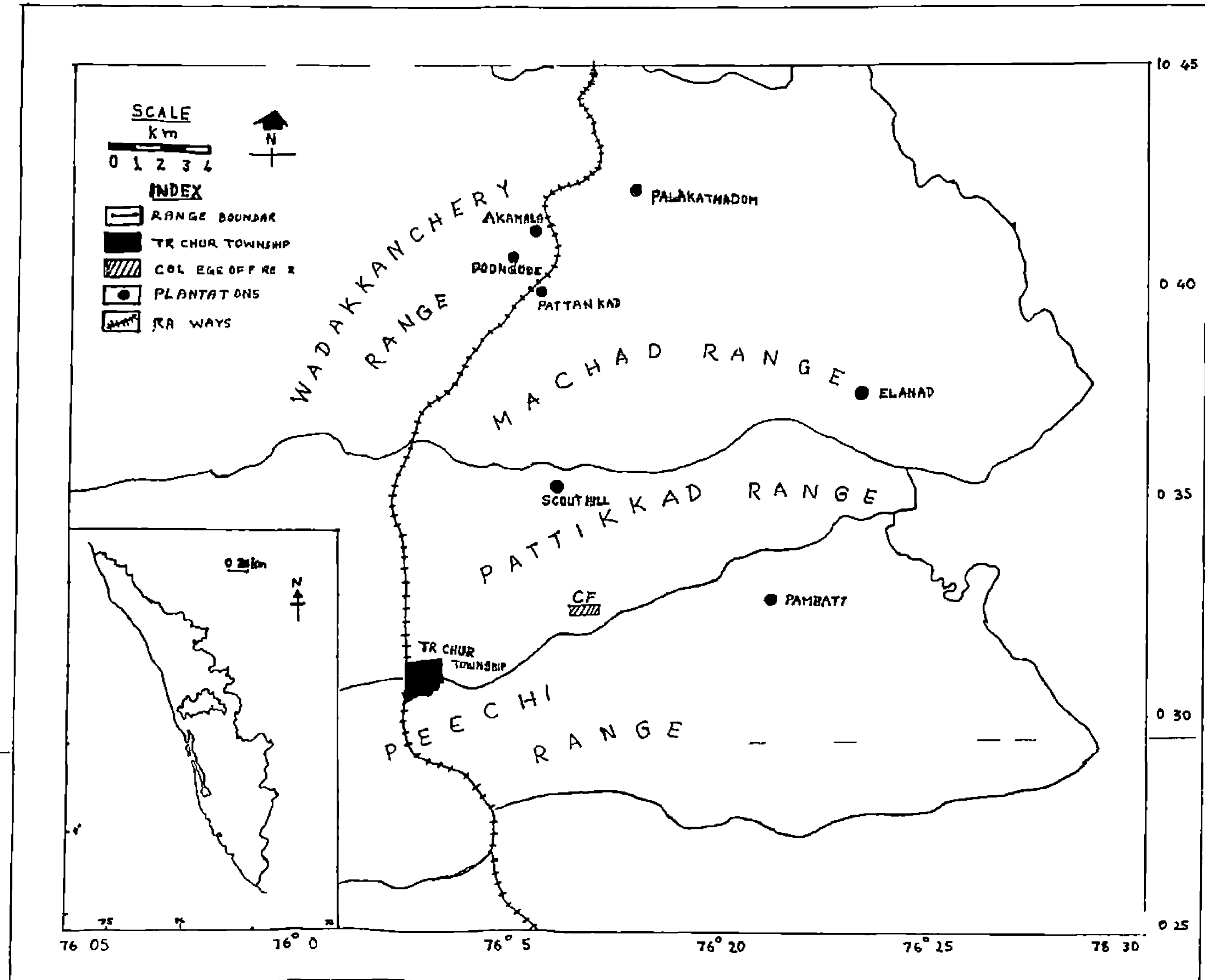


Table 1 Details of teak plantations selected for seed collection

Sl No	Name of plantation	Forest range	Year of planting	Area in ha	Escapement (M)	Average girth (cm)	Average height (M)	Month of collection	Mean annual rainfall (mm)
1	Pattanikad	Machad	1943-44	18.21	2 x 2	60	12	Feb	2700-3000
2	Palakathadom	Machad	1952-53	32 39	2 x 2	50	10	Feb	2700-3000
3	Elanad	Machad	1945-46	31 97	2 x 2	80	13	Feb	2700-3000
4	Pambatti	Peechi	1928-29	30 99	2 x 2	125	20	Feb.	2700-3000
5	Akamala	Wadakkan-cherry	1942-43	8 09	2 x 2	100	15	Feb	2700-3000
6	Poongode	Wadakkan-cherry	1945-46	30 73	2 x 2	100	15	Feb	2700-3000
7	Scout Hill	Pattikad	1946-47	32 00	8 x 8	125	12	Mar	2700-3000

Plate 1 & 2. A view of the selected middle aged teak plantations (Poongode and Elanad plantations).

3 1.2 Method of teak fruit collection

The floor under the selected seed mother trees was cleared of weeds leaf litter and such other undergrowth during the first and second week of January coinciding with the onset of fruit fall. The fruits were collected in four to five rounds at weekly intervals They were spread out and dried under sun as and when collected and stored in gunny bags at room temperature About 40 kg of fruits could thus be obtained

3.2 Processing

3.2.1 Cleaning and purity analysis

The teak fruits collected were mixed throughly and beaten with sticks before winnowing to remove the outer thin papery exocarp. The composite sample containing all the impurities like inert material broken fruits, damaged fruits etc was then weighed and the weight of the fruit lot noted Winnowing was done to remove the impurities and the weight of pure fruits of teak was noted The pure fruits of teak included peices resulting from breakage that are more than half their original size in addition to mature undamaged ones (ISTA 1976) The percentage of pure fruits was calculated using the formulae

$$\text{Purity \%} = \frac{\text{Weight of pure fruits (g)}}{\text{Total weight of original sample (g)}} \times 100$$

and only those samples whose purity per cent exceeded 94 per cent were taken for further trials (ISTA 1976)

3.2.2 Sampling of teak fruits

The fruit lots collected from different teak plantations were thoroughly mixed by hand to improve its homogeneity before taking samples The entire fruit lot was spread out on a smooth surface and mixed by scooping the fruits from side to side and from top to bottom After thorough mixing the fruits were spread out evenly and the whole lot was divided into four equal parts and poured simultaneously into a large container to ensure thoroughness in mixing. The spreading quartering and mixing was done twice as per ISTA rules for seed sampling

3.2.3 Grading of teak fruits

The primary fruit lots after sampling were then seived to get less than 12 mm diameter, 12-15 mm diameter and greater than 15 mm diameter teak fruits A portion of the primary fruit lot was also left ungraded The four primary fruit lots thus obtained were designated as G_0 (ungraded) G_1 (less than 12 mm diameter) G_2 (12-15 mm diameter) and G_3(greater than 15 mm diameter) grades and kept separately in containers (Plate 3)

From the G_0 grade six random samples of one kilogram each were taken and the number of G_1 grade G_2 grade and G_3 grade fruits in each of the sample was recorded. The total number of teak fruits per kilogram of the ungraded sample as well as the 100 fruit weight of each grade in the respective sample was also noted

3.3 Observations on fruit characters by cutting test

Three replicates of one kilogram each of teak fruits were drawn by hand from each of the four graded fruit lot using sampling techniques and the number of teak fruits per kilogram was recorded. From each replicate of the respective fruit grade, the average weight of 100 fruits picked out at random was also determined by weighing them out separately using an electronic balance The seeds from these 100 fruits of each replicate were extracted using a modified teak seed cutter (Dabral 1976) and the number of small seeds and large seeds were recorded. The number of one seeded two seeded three seeded four seeded and empty

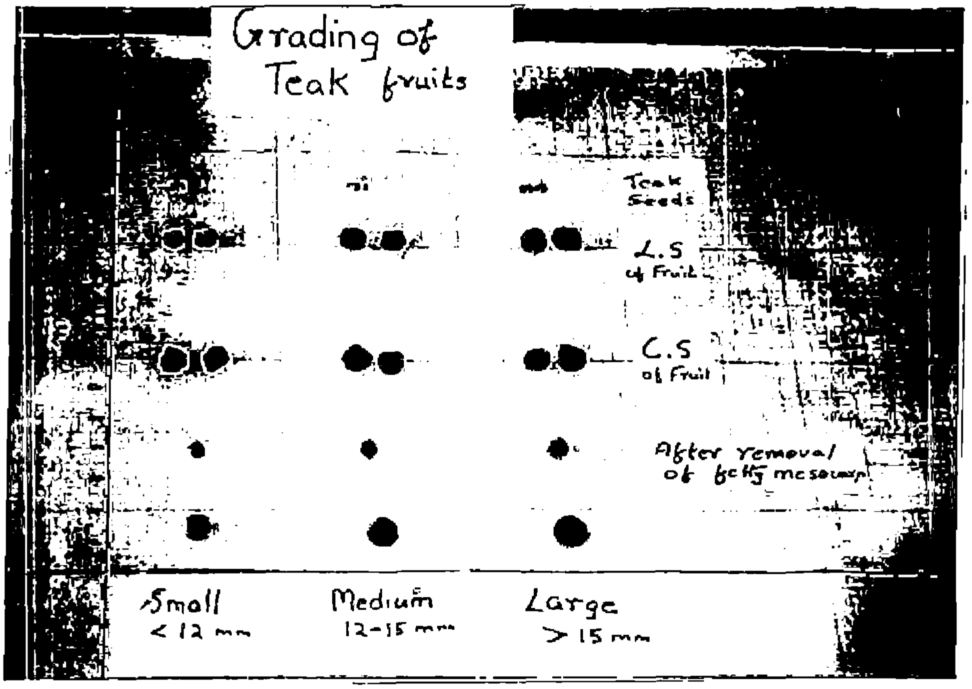


Plate 3. Grading of teak fruits based on fruit diameter.

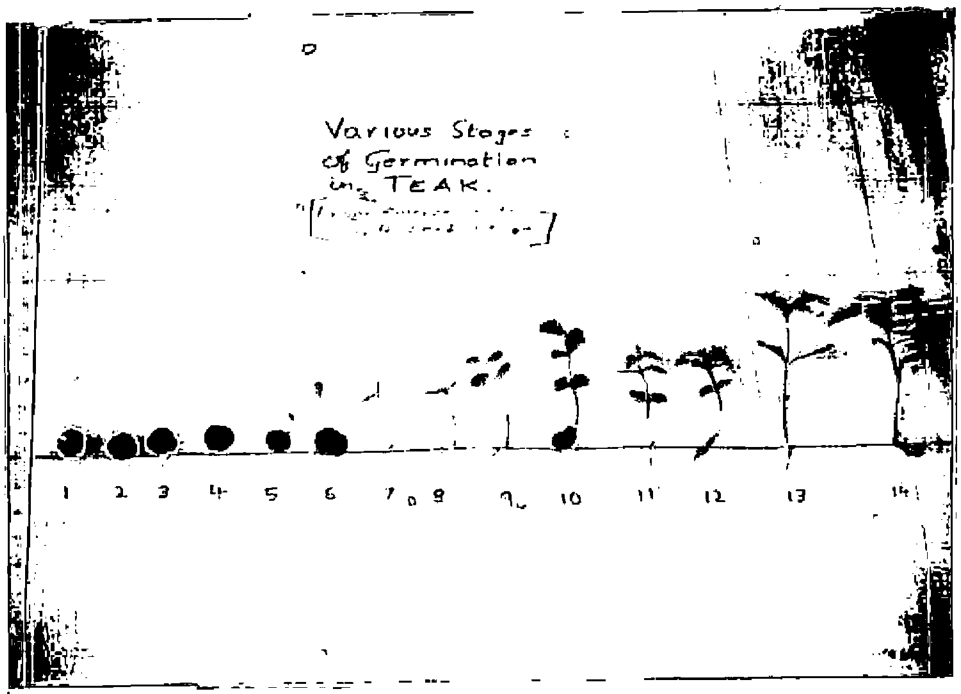


Plate 4. Various stages of germination of teak fruit (seed) upto one month old seedling.

fruits for each fruit grade were also noted From this data the average emptiness per fruit was calculated using the formulae

$$\text{Average emptiness per fruit} = \frac{\text{Total empty loculi}}{\text{Total number of fruits taken} \times 4}$$

where 4 is the total number of loculi per fruit

The viability per cent was also determined from the cutting test. The number of fully developed healthy seeds, whitish in colour and filling the seed chambers was counted In the case of more than one such good seed per fruit, only one was counted and the viability per cent calculated by expressing the number of these fruits with 1-4 viable seeds as a percentage of all the fruits examined (Keiding 1985) The data was then subjected to R B D. analysis

3 4 Details of the experiment

3 4.1 <u>Design and lay out</u>

Design - 2 x 4 x 5 Factorial R.B D.

Number of factors - Three

1 Germination media

M_1 - Sand

M_2 - Vermiculite

2 Fruit grade

G_0 = Ungraded

G_1 - less than 12 mm diameter

G_2 - 12 - 15 mm diameter

G_3 - greater than 15 mm diameter

3 Pretreatments

T_0 - Untreated (control)

T_1 - Alternate wetting and drying/weathering

T_2 - Hot water treatment

T_3 - Sulphuric acid treatment

T_4 - Gibberellic acid treatment

Number of replications - 3

Number of treatment combinations - 40

3.4.2 Pretreatment of seeds

Samples were drawn from the four composite graded fruit lots, G_0 G_1, G_2 and G_3 seeds by thrusting the hand into the lot and removing small portions The samples were then placed on a clean surface and thoroughly mixed by hand. It was then divided into quarters with a sharp edged object and opposite quarters discarded The process was repeated until a final sample of the approximate weight of 2 5 kg required for 40 germination trays was obtained for each grade The 2.5 kg working samples of each grade were then divided into 5 equal fractions for pretreatment of seeds and kept separately in polythene bags

T_0 - Control

The untreated fruits of G_0 G_1, G_2 and G_3 grades served as the control set for checking the effect of treatments in the experiment

T_1 - Alternate wetting and drying

This method is the normal procedure followed by the Forest Department in Kerala for raising teak seedlings in the nursery For this experiment teak fruits from the working sample of each grade kept in the polythene bags were taken out and placed in cloth bags which were then secured firmly and immersed completely in water taken in plastic buckets This immersion process was done at room temperature in the evening In the morning the cloth bags containing the soaked fruits were taken out and left to dry in the hot sun throughout the day without opening the bags In the evening the unopened bags were again immersed in fresh water in the buckets This procedure was repeated for three consecutive days and on the fourth day morning the bags were opened and the fruits taken out and sown directly in 24 germination trays at the rate of 100 fruits per tray

T_2 - Hot water treatment

Around 500 gms of the teak fruits of each grade were taken separately in cloth bags which were then tied and immersed in boiling water taken in a trough for 5 minutes Immediately after this time interval the trough was removed from the heat source and the water allowed to cool After 12 hours the cloth bags were taken out and the soaked fruits sown directly in the germination trays at the rate of 100 fruits per tray as in the previous treatment

T_3 - Acid treatment

About 500 gms of the teak fruits from each grade were taken separately in four one litre glass beakers Sulphuric acid having a strength of 20 per cent was poured into the glass beakers and stirred well using a glass rod so that the fruits were completely immersed in the acid About 400 ml of the acid was sufficient to immerse the fruits in each case The beakers were then kept at room temperature for 12 hours To ensure uniform mixing the fruits were stirred occasionally using a glass rod. After 12 hours the acid was drained away and the fruits were washed thoroughly in distilled water 3 to 4 times before sowing directly in germination trays as done in previous treatments

T_4 - Gibberellic acid treatment

Stock solution of gibberellic acid (GA_3 supplied by Loba-Chemie Bombay) was prepared by weighing out 1 gm of GA_3 and disolving it in 10 ml of ethyl alcohol (90%) and diluting it to one litre by adding distilled water From the stock solution 10 litres of GA_3 solution having a concentration of 100 ppm was prepared The prepared solution was then taken in plastic treatment trays The graded teak fruits were taken separately in these trays and kept fully immersed for 24 hours before sowing directly in the germination trays

3 4 3 Germination trial

120 Plastic trays of size 40 cm x 33 cm x 8 cm were used for conducting the germination trial out of which 60 trays were filled with finely seived sand as germination medium and for the remaining 60 trays exfoliated vermiculite (Vermiculate supplied by M/s Dugar Vermiculite Pvt Ltd) was taken as the germination medium The trays were numbered serially using code numbers corresponding to the pretreatment grade and media The media was filled in the trays upto one centimeter below the edge of trays and well moistened The timing of the seed pretreatments were adjusted so that the correspon- ding teak fruits in each treatments were sown on the same day The fruits were sown at a depth of one centimeter below the surface of the media and at a spacing of 2 x 1 5 cm in 10 rows and 10 columns so that each tray contained 100 fruits The media was moistened uniformly on alternate days using a hand sprayer Daily germination counts were recorded for a period of 30 days from the start of the germination trial If more than one seedling per teak fruit had emerged for the purpose of germination count it was taken as one The germination trial was conducted under laboratory conditions and the weather

data recorded during those months is presented in Table 2 The date of first seedling emergence the number of seedlings emerging on each day the number of seedling casualities during the course of the observation period were recorded From this data the germination per cent plant per cent and germination value and speed of germination were computed

The germination value (Czabator 1962) was calculated from the formulae Germination value (G.V.) = final mean daily germination (M.D G) x Peak value of germination (P V) The M.D G is calculated as the cumulative per cent of full seed germination at the end of the germination test, divided by the number of days from sowing to the end of the test P V actually denotes the speed of germination, which is the maximum mean daily germination recorded at any time during the period of the test

The speed of germination index is calculated by adding the quotients of the daily germination counts divided by the number of days of the germination observation period The speed of germination, which gives a measure of the seedling vigour is based on the principle that seed lots which produce the largest number of germinated seeds at the preliminary counts will produce the fastest stand establishment

Table 2 Climatic data for the period of the experiment

Month	Mean maximum Temp °C	Mean min temp °C	Highest Max temp°C	Lowest Min temp	Mean R H %	Total rainfall (mm)	No of rainy days
April	35 06	24 28	38 0	21 5	70	145 4	9
May	33 70	25 40	35 1	22 0	76	242 6	6

The plant per cent was calculated by counting the number of seedlings actually obtained at the end of the period of observation of the test The germination per cent was calculated by counting the number of seedlings actually germinated during the period of observation

To check the spread of collar rot of seedlings two rounds of spraying using a 1 per cent fungicidal solution of Areestan (Carbendazim) 50 per cent W P was given The dead seedlings were removed as and when observed and the number recorded

3.4.4 Tetrazolium test for viability

The ungerminated fruits were taken out after the period of observation and split open using the modified teak seed cutter and the seeds extracted The number of dead damaged and whole seeds were noted The whole seeds were subjected to Tetrazolium test using a 1 per cent solution of tetrazolium chloride and the number of completely stained partially stained and unstained seeds was recorded From this the percentage of ungerminated viable seeds was found out and the actual viability percentage of the graded teak fruits was calculated

3.5 Field planting

3 5.1 Preparation of polythene bags for potting

Sand, soil and powdered cowdung were taken in the ratio 1 1:1 and mixed well before filling the polythene bags (250 guage) of size 35 x 18 cm The bags were provided with sufficient number of holes at the bottom to facilitate drainage The bags were then filled upto about 5 cm below the surface and kept ready for potting the teak seedlings. The bags were serially numbered corresponding to the source, grade and seed treatment as done in the case of germination trays. The polythene bags were kept ready in the shade in this manner for potting the seedlings from the germination trays

3 5 2 Preparation of seedlings for potting

The normal seedlings were carefully removed from the germination trays as soon as one pair of fully emerged leaves were put forth. The seedlings were then transferred to polythene bags kept in the shade for this purpose. Initially two seedlings per polythene bag were planted which was subsequently thinned down to one per bag as soon as the seedlings had fully established This ensured seedlings in all the polythene bags.

3.5 3 Shifting the seedlings

Once the seedlings had established in the poly bags they were gradually transferred to the open At least ten seedlings from each of the 40 treatment combinations were finally retained in the polythene bags for recording biometric observations The bags were kept in the field for a period of three months The weather data during this period is presented in Table 3.

3.5.4 Watering

The seedlings were watered regularly using a rose can except on rainy days.

3.5 5 Plant protection

Three rounds of Nuvacron (Monocrotophos) 0 1 per cent spraying was resorted to at periodic intervals coinciding with new flush emergence to control aphid attack The attack was particularly noticeable at the time of each new flush emergence.

3.6 Biometric observations

After a period of three months the polythene bags were carefully split open using a pen knife and the seedlings taken out with the root system intact The mud,

Table 3 Weather data during the growth phase of seedlings in the nursery

Month	Mean Max temp°C	Mean Min temp°C	Highest max temp °C	Lowest Min temp°C	Mean R H %	Total rainfall (mm)	No of rainy days
June	30 0	23 7	33 0	21.4	86	632.1	25
July	29 0	23.2	31.7	21 9	88	545.0	26
August	29 2	24.3	31.5	22 5	86	507.8	25

debris etc. sticking on to the roots were carefully removed by repeatedly washing in running water. The seedlings were then spread out for a brief period of drying and sorted according to the respective grade and seed treatment and the following observations were recorded.

3.6.1 Seedling height

The seedlings were spread on the floor and the length of the shoot was measured from the tip of the growing point to the collar regions using a measuring tape and the mean height in centimeters worked out.

3 6.2 Collar diameter

The collar diameter of the seedlings was measured using a vernier callipers and the two diametrically opposite readings were noted and the mean recorded in millimeters

3 6.3 Tap root length

The length of the tap root was measured from the collar region to the tip of the main tap root using a measuring tape and the mean length recorded in centimeters

3.6.4 Diameter at the point of maximum girth of the tap root

The diameter at the maximum girth of the tap root was measured using a vernier callipers and recorded in millimeters

3.6.5 Number of secondary/lateral roots

The numbar of secondary/lateral roots were counted for each seedling and recorded. From this the mean number was worked out.

3 6 6 Length of the longest secondary/lateral root

The main tap root with the lateral root attached to it were spread out on a table and the longest lateral root was identified. The length was then measured in centimeters using a tape, from the tip of the root to the point of attachment on the main tap root. The mean length was then worked out

3 6 7 Dry matter production per seedling

The leaves were first detached from the shoot and the fresh weight noted The stem was detached from the tap root at the collar region and its fresh weight was also recorded The lateral roots were also detached from the main tap root and its fresh weight recorded after recording the fresh weight of the main tap root minus the lateral roots. The leaves stem lateral roots and main tap root were then kept separately in a hot air oven maintained at 80 ± 2°C for 48 hours and dried to constant weight The weight was then determined using an electronic balance. The dry weight of stem leaves, tap root and lateral roots were added together to obtain the total dry weight of a single seedling.

3.7 Statistical analysis

The data relating to each character observed were analysed by analysis of variance technique and their significance tested by 'F' test (Snedecor and Cochran, 1967)

Results

RESULTS

The results of the investigations are presented in four main sections as fruit characters germination characters, biometric and biomass observations

4.1 Fruit characters

Various characters of graded teak fruits and the results of the cutting test are presented in Tables 4 and 5. The analysis of variance is presented in Appendix I.

4 1.1 Grading

The number of ungraded fruits per kg together with the proportion and weight of the different size grades are presented in Table 4. The total number of fruits per kilogram obtained from six samples of upgraded teak fruits showed a mean value of 1961.5 $\pm$ 2.22. The grading done on the basis of fruit diameter showed that the maximum number of teak fruits fall in the G_2 grade having a diameter range of 12-15 mm, followed by G_1 grade ($<$12 mm diameter) and the minimum in G_3 grade ($>$15 mm diameter)

The weight of 100 fruits in the three grades showed a gradual increase from G_1 to G_3 grade. The mean values obtained in the various samples analysed were 43.59 ± 0.68, 59.31 ± 0.46, 77.55 ± 0.58 gms respectively for G_1, G_2 and G_3 grade (Table 4).

4.1.2 Mean number of fruits per kilogram

Grading of teak fruits had a significant effect on the mean number of fruits recorded per kilogram. Fruits having a diameter less than 12 mm were more in number per kilogram than the ungraded lot, while fruits having a diameter greater than 15 mm were least in number per kilogram (Table 5). The difference in the total number of fruits per kg between G_0 and G_1 grade was more or less equal to the difference between G_0 grade and G_2 grade. The maximum variation recorded in the number of fruits/kg was between G_1 and G_3 grade (947.33) and the minimum was between G_0 and G_2 grade (280.00)

4 1.3 Mean weight of 100 fruits

Graded fruits showed significant variation in weight. The G_1 grade recorded the lowest mean weight (44.88 g) while the ungraded lot G_0 recorded a slight increase over G_1 grade (Table 5). The highest value

Table 4. Proportion and weight of different grades of teak fruits (seeds)

Sample No	Total No. of ungraded fruit per kg	Number of graded fruits in one kg of ungraded sample			Weight of 100 fruits in various grades (g)		
		G_1 (less than 12 mm diameter)	G_2 (12-15 mm diameter)	G_3 (greater than 15 mm diameter)	G_1	G_2	G_3
1	1960	628	843	489	44.43	59.68	76.83
2	1958	626	842	490	43 65	58 64	77 52
3	1961	628	840	493	42 55	59.95	78.45
4	1963	630	845	488	44 10	58.82	76.92
5	1962	631	841	490	43.96	59.24	77 46
6	1965	633	840	492	42.84	59 52	78.10
Mean	1961 5	629.3	841.8	490.3	43 59	54 31	77.55
SEm ±	2 22	2.29	1 77	1.69	0.68	0.46	0.58

(77.06 g) was for G_3 grade which showed an increase of 33 g/100 fruits over G_1 grade

4.1.4 Number of seeds extracted from 100 fruits

The effect of grading was significant on the number of seeds extracted. The grades differed significantly in the number of large seeds as well as the total number of seeds The maximum number of seeds extracted was from G_3 (129.66) and the minimum was from G_1 (71.66). The number of large seeds in G_3 was twice that in G_1 but, this difference was not observed in the case of small seeds in which G_1, G_2 and G_3 grades were statistically on par (Table 5).

4.1.5 Number of one, two, three, four and empty seeded fruits in 100 numbers

The fruit grades varied significantly in the number of one, two, three and empty seeded fruits that could be obtained from 100 fruits. The effect of grading was insignificant on the number of four seeded fruits that could be obtained

Very little variation was observed in the number of one seeded fruits between G_2 and G_1 grades as well as between G_2 and G_0 grades G_2 was on par with G_1 and G_0 but inferior to G_3, which recorded the highest number (50.00).

The variation between G_2 grade and G_1 grade as well as between G_2 grade and G_3 grade was equal in the case of the number of two seeded fruits per 100 The G_0 grade was on par with G_1 and G_2 grades The G_3 grade again recorded the maximum number (26.00).

The maximum number of three seeded fruits per 100 were obtained in G_3 grade, which was on par with G_2 grade. The minimum number (0.33) was recorded by G_1 grade

There was no significant difference between the different grades with respect to four seeded fruits per 100 numbers.

The number of empty seeded fruits per 100 was minimum (15 00) in G_3 grade while it was maximum (41.66) in G_1 grade (Table 5).

4.1.6 <u>Average emptiness per fruit</u>

Grading had a significant influence on the average emptiness per fruit recorded The average emptiness

Table 5. Fruit characters of teak

Sl. No.	Fruit characters		G_0 grade (ungraded)	G_1 grade (12 mm diameter)	G_2 grade (12-15 mm diameter)	G_3 grade (15 mm diameter)	CD (5%)
1	Mean number of fruits per kilogram		1950.33	3250.33	1670.33	1303 00	3.890
2	Mean weight of 100 fruits (g)		51 22	44 88	59 45	77 06	1 113
3	Number of seeds extracted from 100 fruits						
	(i)	Large seeds	57.33	51 00	80.33	106 00	2.246
	(ii)	Small seeds	29 00	20 66	22.33	23.66	2 568
	(iii)	Total	86 33	71 66	102.66	129.66	4 310
4	Number of 1, 2, 3, 4 and empty seeded fruits in 100 numbers						
	(i)	One seeded	38 00	43 60	41.33	50 00	3 645
	(ii)	Two seeded	17 66	14.66	20.00	26.00	3 661
	(iii)	Three seeded	4 33	0.33	7.33	8.33	1 202
	(iv)	Four seeded	0 66	0.33	1 00	1.33	NS
	(v)	Empty seeded	40 00	41.66	31 33	15.00	3.311
5	Average emptiness per fruit		0 79	0.82	0 74	0 67	0 009
6	Viability per cent by cutting test		51.33	44 73	62 66	74 88	1 453

* CD has been given wherever the grades have been found significantly different with respect to the particular character

per fruit was minimum in G_3 grade (0.67) while it was maximum in G_1 grade (0.82).

4.1.7 Viability percentage

Grading had a significant influence on the viability percentage of teak seeds determined by cutting test. The maximum viability percentage (74.88 per cent) was recorded in G_3 followed by G_2 (62.66 per cent) and G_1 grades (51.33 per cent) and minimum (44.73 per cent) in G_1 grade The teak fruits irrespective of fruit grade gave a mean average viability percentage of 51 33 per cent as estimated by cutting test performed on them (Table 5).

4.2 Germination characters

The data obtained on germination characters of teak fruits are presented in Table 6 and their analysis of variance in Appendix II.

4 2.1 Speed of germination

Grading of teak fruits had a significant influence on the speed of germination. The G_3 grade recorded the maximum speed of germination (2 30) and the minimum (1.74) was by the G_1 grade

Table 6. Effect of grading pretreatments and germination media on germination characters of teak fruits

Treatments	Speed of germination	Germination value G V	Germination percentage	Plant percentage	Viability percentage
Fruit grade					
G_0	2.05	1 60	22.40	20 07	34.87
G_1	1.74	1.13	18.93	17 20	27.40
G_2	2.26	1.88	24.73	22.20	38 20
G_3	2.30	1.98	25.43	22 83	39 83
CD (5%)	0 037	0 065	0.364	0 285	1.457
Pretreatment					
T_0	0.29	0 06	7.21	6.96	50.54
T_1	2.46	1 54	27.08	24.17	32.79
T_2	2.33	1 69	30 83	29 75	37 88
T_3	0 39	0 10	8.58	8 29	9 92
T_4	4.96	4.84	40.67	33.71	44.25
CD (5%)	0.042	0.073	0.407	0 319	1 625
Media M_1	2.07	1 62	22.68	20 22	35.27
M_2	2.11	1 67	23 07	20.93	34.88
CD (5%)	0.026	0.046	0 258	0.202	NS
Interaction					
CD (5%)					
G x T	0.084	0.103	0.814	0 638	3 257
T x M	0.059	0.145	NS	0 451	NS
M x G	NS	NS	0 515	0 403	NS
G x T x M	NS	NS	NS	0 902	NS

The pretreatments also influenced the speed of germination significantly The highest value (4.96) was recorded by T_4 (Gibberellic acid treatment) and the lowest value (0.29) by T_0 control.

The germination media also significantly affected the speed of germination The medium M_2 (vermiculite) recorded a higher speed of germination (2.11) than in M_1 medium (2.07).

The interaction of the three factors viz fruit grade, pretreatment and media (G x T x M) did not turn significant on the speed of germination, even though the two factor interaction of G x T was significant. The treatment combination G_3 T_4 recorded the highest value (5 64) while the lowest (0.21) was by the G_1T_0 combination (Table 6.a).

In the two factor interaction of T x M which was also found significant on the speed of germination (Table 6.b), the treatment combination M_2T_4 recorded the highest speed of germination (5 05) while the lowest (0 29) was by the treatment combination M_1T_0 which was on par with M_2T_0 (0.30).

Table 6(a) Speed of germination of different size grades of teak seeds subjected to different presowing treatments (G x T interaction)

Fruit grades	Pretreatments T_0	T_1	T_2	T_3	T_4	Mean
G_0	0.29	2.39	2.26	0.39	4.95	2.05
G_1	0.21	2 22	2 17	0.33	3.74	1.74
G_2	0.33	2.60	2.43	0.41	5 53	2.26
G_3	0.34	2 62	2.48	0.44	5.64	2.30
Mean	0.29	2.46	2.33	0.39	4 96	
SEm ±	0.042					
CD (5%)						

Table 6(b) Speed of germination of teak seeds in T x M interaction

Germination Media	Pretreatments T_0	T_1	T_2	T_3	T_4	Mean
M_1	0 29	2.47	2 32	0 38	4 88	2.07
M_2	0 30	2 45	2.35	0.41	5 05	2.11
Mean	0.29	2.46	2.33	0 39	4.96	
SEm ±	0.027					
CD (5%)	0.053					

4.2.2 Germination value (GV)

The germination values were significantly affected by the grading of teak fruits. Germination value was low in G_1 (1.13) and maximum in G_3 grade (1.98).

The pretreatments also had a significant influence on the germination values recorded The highest germination value (4.84) was obtained in the fruits treated with GA_3 (T_4) while the lowest (0.06) was in the control (T_0).

The effect of media was also found to be statistically significant in the case of germination value Vermiculite (M_2) registered a higher value than sand (M_1)

In the interaction of the two factors, fruit grade and pretreatment (G x T) which was significant on the germination value recorded the highest value (6.05) was obtained in the treatment combination G_3T_4 while the lowest value (0 03) was in the treatment combination G_1T_0 (Table 6.d)

The interaction of pretreatment x media (T x M) which was also significant on the germination value (Table 6.d) the treatment combination M_2T_4 recorded the

Table 6(c) Interaction of fruit grade and pretreatment (G x T) on the germination value (G V.) of teak seeds

Fruit grades	Pretreatments					Mean
	T_0	T_1	T_2	T_3	T_4	
G_0	0.06	1 45	1.57	0.09	4.84	1.60
G_1	0.03	1.28	1.48	0.07	2.79	1.13
G_2	0.08	1.70	1.84	0.10	5 67	1.88
G_3	0.08	1.74	1.89	0 13	6 05	1.98
Mean	0 06	1.54	1 69	0.10	4 84	
SEm ±	0.073					
CD (5%)						

Table 6(d) Interaction of pretreatment and germination media (T x M) on the germination value (G V) of teak seeds.

Germination Media	Pretreatments					Mean
	T_0	T_1	T_2	T_3	T_4	
M_1	0 06	1 53	1.69	0.09	4 72	1 62
M_2	0.07	1 55	1.69	0 10	4.95	1 67
Mean	0.06	1.54	1.69	0.10	4 84	
SEm ±	0.052					
CD (5%)	0.103					

highest value (4.95) and the M_1T_0 combination recorded the lowest value (0.06).

The interaction of the three factors viz. fruit grade, pretreatment and media (G x T x M) did not turn significant on the germination value recorded.

4.2.3 <u>Germination percentage</u>

The four grades of teak fruits showed significant difference in germination percentages. The variation in germination percentage between G_1 and G_2 was more than the variation between G_1 and G_0 grades. The maximum variation (6.5 per cent) was between G_1 and G_3 grades and the least variation (0.70 per cent) was between G_3 and G_2 grades. Larger diameter fruits recorded higher germination percentages with a maximum (25.43 per cent) in the case of G_0 (Fig. 2)

The pretreatments also differed significantly with values ranging from 7.21 per cent in T_0 (control) to 40.67 per cent in T_4 (GA_3 treatment), recording a variation of 33.46 per cent between them. The minimum variation (1.37 per cent) was between T_0 (control) and T_3 (hot water treatment)

The germination media also differed significantly with M_2 medium recording a higher germination percentage (23.07 per cent) over M_1 medium (22.68 per cent)

The three factors interaction (G x M x T)was not significant on the germination percentages of teak seeds. But the two factor interaction of fruit grade and pretreatment (G x T) was found to be significant on the germination percentage (Table 6 e). The highest value (46.17 per cent) was recorded by the treatment combination G_3T_4 and the lowest value (5.33 per cent) by the G_1T_0 combination.

The interaction of germination media and fruit grade (M x G) was also significant on the germination percentage recorded (Table 6.f) The treatment combination M_2T_4 gave the highest value (25 87 per cent) and the lowest value (18.80 per cent) was recorded by the combination M_1T_1 which was on par with M_2T_1 (19 07 per cent)

4.2.4 <u>Plant percentage</u>

Grading pretreatments and germination media significantly influenced the plant percentage recorded at the end of the 30 day observation period of teak seed germination.

Table 6(e) Interaction of fruit grade and pretreatment (G x T) on the germination percentage of teak seeds

Fruit grades	Pretreatments					Mean
	T_0	T_1	T_2	T_3	T_4	
G_0	7.00	25 50	29.67	8.50	41 33	22.40
G_1	5.33	23.67	27.83	7.33	30.50	18 93
G_2	8.17	29.17	32.67	9.00	44 67	24 73
G_3	8.33	30.00	33 17	9.50	46.17	25.43
Mean	7.21	27.08	30.83	8 58	40.67	
SEm ±	0.409					
CD (5%)	0.814					

Table 6(f) Interaction of fruit grade and germination media (M x G) on the germination percentage of teak seeds

Germination media	Fruit grades				Mean
	G_0	G_1	G_2	G_3	
M_1	22 60	18 80	24 33	25 00	22 68
M_2	22.20	19.07	25 13	25 87	23 07
Mean	22 40	18 93	24 73	25.43	
SEm ±	0 259				
CD (5%)	0.515				

The fruit grades differed significantly with values of plant percentage rainging from 17.20 per cent in G_1 grade to 22.83 per cent in G_3 grade The maximum difference in plant percentage (5.63 per cent) was between G_3 and G_1 grades

The various pretreatments differed significantly in the case of plant percentage. The T_4 pretreatment gave the maximum plant percentage (33.71 per cent) while T_0 recorded the lowest (6.96 per cent).

The germination media also differed significantly in the plant percentage. The M_2 media gave significantly better results (20.93 per cent) over M_1 media (20.22 per cent)

The two factor interaction between G x T, T x M and M x G as well as the three factor interaction between G x T x M were found statistically significant.

In the G x T (Grade x pretreatment) interaction (Table 6.g) the highest value (39.00 per cent) was recorded by the treatment combination G_3T_4 and the lowest value (5 17 per cent) by the G_1T_0 combination.

The treatment combination M_2T_4 gave the highest plant per cent (35.25 per cent) in the T x M (pretreatment x

Table 6(g) Interaction of fruit grade and pretreatment (G x T) on the plant percentage of teak

Fruit grades	Pretreatments					Mean
	T_0	T_1	T_2	T_3	T_4	
G_o	6.67	23 00	28 67	8.33	33 67	20.07
G_1	5 17	21 67	27.33	7.00	24.83	17 20
G_2	7.83	26.00	31.17	8 67	37 33	22.20
G_3	8 17	26.00	31.83	9.17	39.00	22.83
Mean	6.96	24 17	29 75	8.29	33.71	
SEm ±	0.320					
CD (5%)	0 638					

Table 6(h) Interaction of pretreatments and germination media (T x M) on the plant percentage of teak

Germination media	Pretreatments					Mean
	T_0	T_1	T_2	T_3	T_4	
M_1	6.92	24.08	29.83	8 08	32.17	20.22
M_2	7.00	24.25	29.67	8.50	35 25	20 93
Mean	6.96	24.17	29.75	8.29		
SEm ±	0.226					
CD (5%)	0.451					

media) interaction (Table 6 h) and the lowest value (6 92 per cent) was recorded by M_1T_0 combination.

In the M x G (media x grade) interaction, the maximum value for plant percentage (23.40 per cent) was recorded by M_2G_3 treatment combination (Table 6 i) and the minimum value (17.07 per cent) was recorded by the treatment combination M_1G_1, which was on par with M_2G_1 combination (17.33 per cent).

In the G x T x M interaction, the highest recorded value (40.33 per cent) was by the treatment combination $G_3T_4M_2$ and the lowest value (5.00 per cent) was by the $G_1T_0M_1$ treatment combination (Table 6.j)

4 2.5 Viability percentage

Grading as well as pretreatments had a significant influence on the viability percentage of teak seeds recorded at the end of the 30 day observation period. The effect of germination media was not significant

The fruit grades differed significantly the highest value (39.83 per cent) was recorded by G_3 grade and the lowest value(27.40 per cent) was by G_1 grade. The maximum difference in viability percentage (12.43 per cent)

Table 6(i) Interaction of germination media and fruit grade (M x G) on the plant percentage of teak

Germination media	Fruit grades				Mean
	G_0	G_1	G_2	G_3	
M_1	19.87	17.07	21.67	22.27	20.22
M_2	20.27	17.33	22.73	23.40	20 93
Mean	20.07	17.20	22.20	22.83	
SEm ±	0 202				
CD (5%)	0.403				

Table 6(j) Interaction of fruit grade, pretreatment and germination media (G x T x M) on the plant percentage of teak

Pre-treat-ments / Fruit grades	M_1 medium						M_2 medium					
	T_0	T_1	T_2	T_3	T_4	Mean	T_0	T_1	T_2	T_3	T_4	Mean
G_0	7 00	24.00	28 00	8 67	31.67	19 87	6 33	22 00	29.33	8.00	35 67	20 26
G_1	5 00	21 67	28.00	6 87	24 00	17.11	5.33	21 67	26 67	7.33	25 61	17 32
G_2	7.67	25.33	31 67	8.33	35 33	21.67	8.00	26 67	30.67	9.00	39.33	22.73
G_3	8.00	25 33	31.67	8 67	37 67	22 67	8.33	26 67	32.00	9 67	40 33	23.40
Mean	6 92	24.08	29.83	8.08	32.17		7.00	24.25	29 67	8 50	35.25	
SEm ±	0 453											
CD (5%)	0.902											

was between G_3 & G while the minimum (1.63 per cent) was between G_3 and G_2 fruit grade The variation between G_1 and G_2 grades was greater than the variation between G_1 and G_0 grade.

The pretreatments also differed significantly The control (T_0) recorded the maximum viability percentage (50.54 per cent) followed by GA_3 treatment (T_4), while the acid treatment (T_3) gave the minimum value (9.92 per cent) The interaction of the two factors, grade x pretreatment (GxT) was significant on the viability percentage recorded (Table 6.k). The highest value (55.83 per cent) was recorded by the treatment combination G_3T_0, which was on par with G_2T_0 (53.83 per cent). The lowest recorded value (7.83 per cent), was by the treatment combination G_1T_3 which was on par with G_0T_3 (10.00 per cent) and G_2T_3 (10.67 per cent).

The interaction of the two factors pretreatment x media (T x M) as well as media x grade (M x G) and the three factor interaction of grade, pretreatment and media (Gx T x M) was not significant on the viability percentage

Table 6(k). Interaction of fruit grade and pretreatment (G x T) on the viability percentage of teak seeds

Treat-ments	T_0	T_1	T_2	T_3	T_4	Mean
G_0	51.00	32.83	35.33	10.00	45.17	34.87
G_1	41.50	23.33	31.33	7.83	33.00	27.40
G_2	53.83	36.67	41.33	10.67	48.50	38.20
G_3	35 83	38.33	43 50	11.17	50.33	39 83
Mean	50 54	32.79	37 88	9.92	44.25	
SEm ±	1 637					
CD (5%)	3.257					

Fig (2) Effect of grading on the germination characters of teak seeds

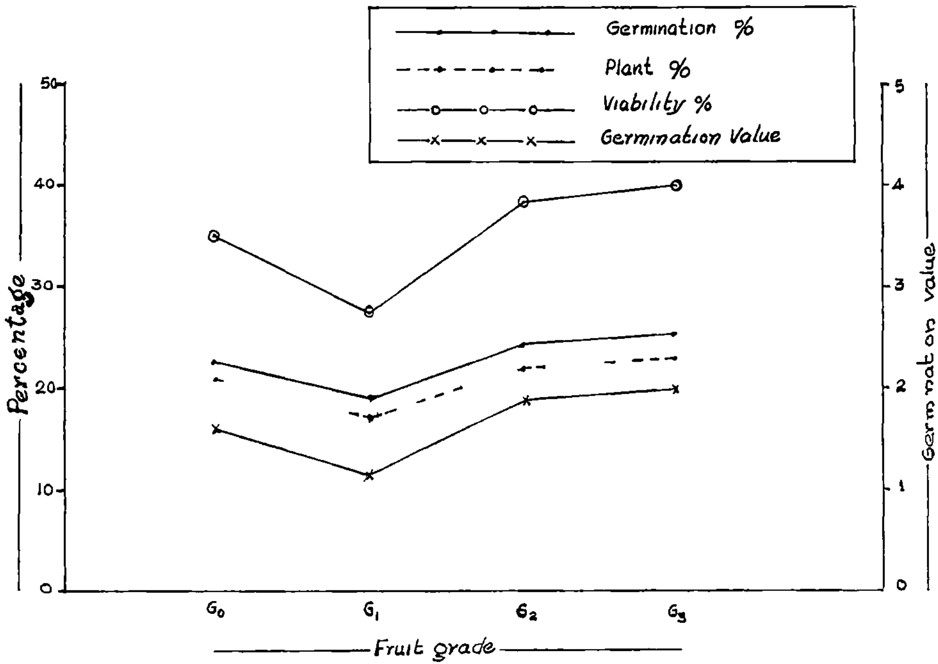


Fig 3 Effect of pretreatments on the germination characters of teak seeds

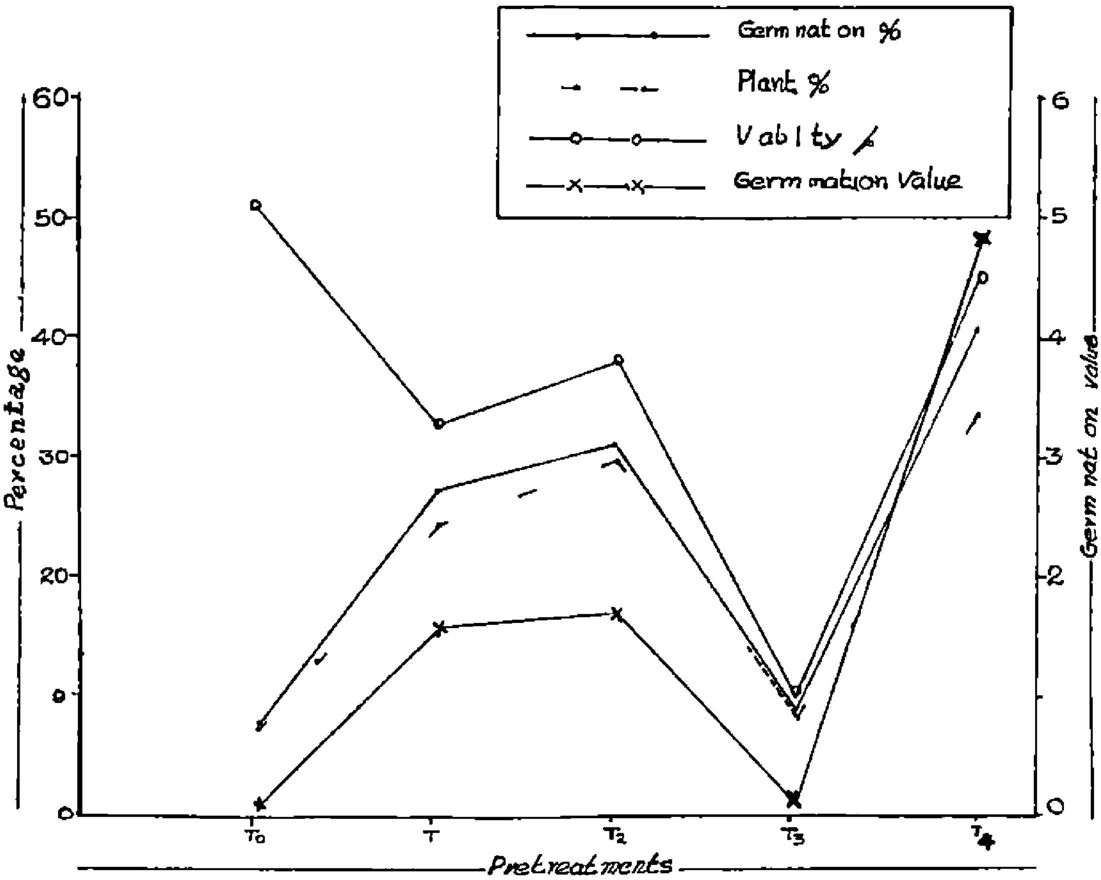
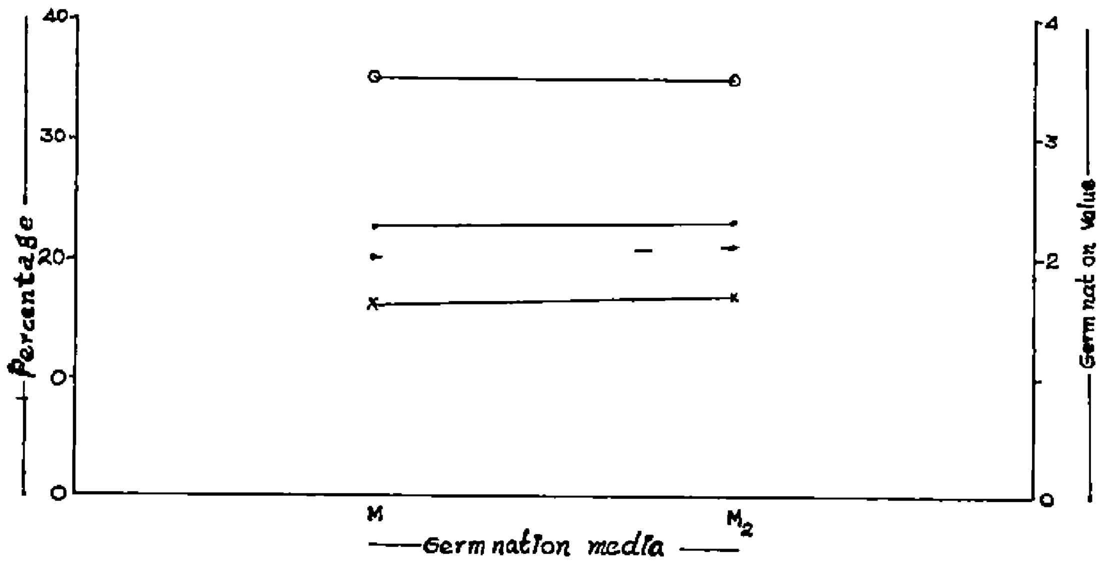


Fig 4 Effect of germination media on the germination characters of teak seeds



4 3 Biometric observations

The results of the biometric observations on the three month old teak seedlings are presented in Table 7 and their analysis of variance in Appendix III

4.3.1 Mean height of seedlings

Grading and pretreatment had a significant influence on the height of teak seedlings, but the effect of different germination media was insignificant.

The different grades of teak fruits showed significant difference with a value ranging from 34.02 cm in G_1 grade tp 37.29 cm in G_3 grade with respect to mean height.

Statistically significant difference was also observed between different pretreatments with regard to the mean height of seedlings The highest value (40.53 cm) was recorded by T_4 pretreatment followed by T_2, T_1 and T_0 (control). The T_3 pretreatment gave the lowest value (29 19 cm) for the mean height of seedlings

The interaction of fruit grade and pretreatment (G x T) as well as the interaction of pretreatment and germination media (T x M) was significant on the mean

Table 7 Effect of grading pretreatments and germination media on biometric observations of teak seedlings

Treatments	Mean height of seedling (cm)	Mean collar diameter (mm)	Mean length of taproot (cm)	Mean diameter at maximum girth of taproot (mm)	Number of lateral roots	Mean length of largest lateral root (cm)
Fruit grade						
G_0	36.17	8.29	32.14	11.32	27 27	26.11
G_1	34 02	7.20	31 21	10 33	26 13	25.83
G_2	36 46	8.43	32.28	11 57	27 33	26.06
G_3	37.29	8.52	33.18	11.78	27 53	26 71
CD (5%)	0 332	0.114	0.474	0 132	0 624	NS
Pretreatment						
T_0	35 55	7.21	29.12	10 16	25 13	24 11
T_1	38.31	8.91	33.36	12 45	29.04	25 65
T_2	39 33	8.26	32 58	11.34	25 50	24.03
T_3	26.19	6.04	31.73	8 91	25 29	26 67
T_4	40.53	10.13	34.23	13.45	30.38	30 43
CD(5%)	0.371	0.127	0 530	0.147	0 698	1.228
Media						
M_1	36.10	8.12	25.87	11.27	37.57	26.12
M_2	35.87	8.10	38 54	11.26	16.57	26.24
CD (5%)	NS	NS	0.335	NS	0 442	NS
Interaction						
CD(5%)						
G x T	0.742	0.255	NS	0.294	NS	NS
T x M	0 525	NS	0 750	NS	0 987	1 736
M x G	NS	NS	NS	NS	NS	NS
G x T x M	NS	NS	NS	NS	NS	NS

height of seedlings (Table 7.a and 7 b). In the G x T interaction, the treatment combination G_3T_4 recorded the maximum height (41.52 cm) and the minimum height (24 72 cm) was by the treatment combination G_1T_3. In the M x T interaction, the treatment combination M_1T_4 gave the maximum mean height (40.67 cm) while M_2T_3 gave the minimum value (25.25 cm).

The interaction between media and grade M x G and the three factor interaction (M x G x T) did not turn statistically significant for the mean height of seedlings

4.3.2 Mean collar diameter

The mean collar diameter recorded for the different fruit grades ranged from 7.20 mm in G_1 grade to 8.52 mm in G_3 grade. The collar diameter of seedlings increased with an increase in fruit diameter (Fig.5). The G_3 grade and G_2 grade were statistically on par but superior over G_0 and G_1 grade.

The different pretreatments differed significantly with values recorded ranging from 6.04 mm in T_3 to 10 13 mm in T_4.

Table 7(a) Interaction of fruit grade and pretreatment (G x T) on the mean height of teak seedlings (cm)

Fruit grade	Pretreatments					Mean
	T_0	T_1	T_2	T_3	T_4	
G_0	35.93	38.16	39.52	26 87	40.38	36.17
G_1	34.05	34.52	37.27	24.72	39 55	34 02
G_2	36.00	39.68	39 98	25 93	40.68	36 46
G_3	36.23	40 90	40.57	27.23	41.52	37.29
Mean	35.55	38.31	39.33	26.19	40.53	
SEm ±	0.373					
CD (5%)	0.742					

Table 7(b) Interaction of pretreatment and germination media (T x M) on the mean height of teak seedlings (cm)

Germination	Pretreatments					Mean
	T_0	T_1	T_2	T_3	T_4	
M_1	35 53	37.98	39.18	27 13	40.67	36.10
M_2	35 58	38.65	39 48	25.25	40 40	35 87
Mean	35 55	38.31	39.33	26 19	40.53	
SEm ±	0 264					
CD (5%)	0 525					

Table 7(c) Interaction of fruit grade and pretreatment (G x T) on the mean collar diameter of teak seedlings (mm)

Fruit grades	Pretreatments					Mean
	T_0	T_1	T_2	T_3	T_4	
G_0	7.44	9.14	8.48	6.17	10.23	8.29
G_1	6.10	8.14	7 47	5.40	8.92	7.20
G_2	7 59	9.18	8.54	6.23	10.59	8 43
G_3	7.72	9.18	8 57	6.38	10.78	8 53
Mean	7 21	8 91	8 26	6 04	10.13	
SEm ±	0.128					
CD (5%)	0.255					

The interaction of the three factors viz , grade, media and pretreatment (G x M x T) as well as T x M interaction and M x G interaction failed to evoke any significant influence on the mean collar diameter of seedlings However, when the interaction G x T alone was considered it was significant on the mean collar diameter recorded. The maximum diameter (10.78 mm) was recorded with the treatment combination G_3T_4 (Table 7.c) and the minimum value (5.40 mm) was by the G_1T_3 combination

4.3 3 Mean length of tap root

The maximum value for mean tap root length (33.18 cm) was produced by the G_3 grade teak fruits and this was superior over G_2, G_0 and G_1 grades. The values obtained for G_2 grade (32.28 cm) and G_0 grade (32.14 cm) were on par but was slightly more than that of G_1 grade (31.21 cm).

Of the various pretreatments tried, T_4 gave the maximum mean length of tap root (34.24 cm) while T_0 gave the minimum value (29.12 cm) and the increase over other treatments was statistically significant also.

When the two germination media used was considered M_2 medium differed significantly with M_1 medium The former

Table 7(d) Interaction of pretreatment and germination media (T x M) on the mean length of taproot (cm)

Germination media	Pretreatments					Mean
	T_0	T_1	T_2	T_3	T_4	
M_1	21.88	27.48	25.05	26.10	28.83	25.87
M_2	36.36	39.23	40.11	37 35	39 63	38.54
Mean	29.12	33 36	32 58	31 73	34.23	
SEm ±	0.377					
CD (5%)	0 750					

gave a value of 34.23 cm while the latter recorded 25.87 cm only.

The interaction G x T and M x G has non-significant for this character. But the interaction of treatment and media (T x M) was significant on the mean tap root length produced (Table 7 d). The treatment combination M_2T_2 gave the maximum length of tap root (40.11 cm) which was on par with M_2T_4 (39.63 cm) while the minimum length of tap root (21.88 cm) was obtained by the treatment combination M_1T_0.

The three factor interaction (M x G x T) did not turn statistically significant. However the maximum taproot length (40.40 cm) was recorded by the treatment combination $T_4M_2G_3$ (Table 9).

4.3.4 Mean diameter of the taproot

The effect of grading and pretreatments was significant on the mean diameter at the maximum girth point of the tap root.

The fruit grades differed significantly with values of 10.38 mm in G_1 grade and 11.78 mm in G_3 grade. Larger diameter fruits gave higher values for this character also (Fig.5).

The pretreatments also differed significantly with a maximum value of 13.44 mm in T_4 pretreatment and a minimumoof 8.91 mm in T_3

The effect of different germination media was not significant on the mean diameter of the tap root at the maximum girth point.

The interaction of fruit grade and pretreatment (G x T) was significant on the mean diameter of the tap root at the point of maximum girth (Table 7.e). The maximum value for this character (35.18 mm) was recorded by G_3T_4 combination.

4.3.5 Number of lateral roots

Grading had a significant effect on the number of lateral roots produced by the teak seedlings The G_3 grade was with the maximum number of lateral roots (27 53) but was on par with G_2 (27.33) and G_0 grade (27 27). These three grades were significantly superior to G_1 (26.13)

Pretreatment also significantly inflenced the number of lateral roots produced in the seedlings. The T_4 pretreatment was with significantly higher value (30.38)

Table 7(e) Interaction of fruit grade and pretreatment (G x T) on the mean diameter at maximum girth of taproot (mm)

Fruit grade	Pretreatments					Mean
	T_0	T_1	T_2	T_3	T_4	
G_0	29.18	33.33	33.18	31.27	33.73	32 14
G_1	28.50	31.60	31.73	30.68	33.55	31 21
G_2	29.33	33.60	32.45	31 57	34.45	32.28
G_3	29.47	34.90	32 95	33.38	35.18	33 18
Mean	29.12	33.36	32.58	31.75	34.23	
SEm ±	0.533					
CD (5%)	0.294					

than other treatments T_1 treatment with the lowest value (25.13) was not significantly different from T_3 (25 29).

The effect of media was highly significant on the number of lateral roots produced The M_1 medium was with a mean number of 37.57, while the M_2 medium was with only 16.57.

The interaction G x T as well as the M x G interaction was not significant. But the T x M interaction was found significant on the mean number of lateral roots produced (Table 7.f). The maximum number (40.67) was obtained in the treatment combination M_1T_4 which was on par with M_1T_1 (39.17). The lowest number (13.83) was obtained in the treatment combination M_2T_0 which was on par with M_2T_3 (14.17). The interaction of these three factors G x T x M was non-significant.

4.3.6 Mean length of the longest lateral root

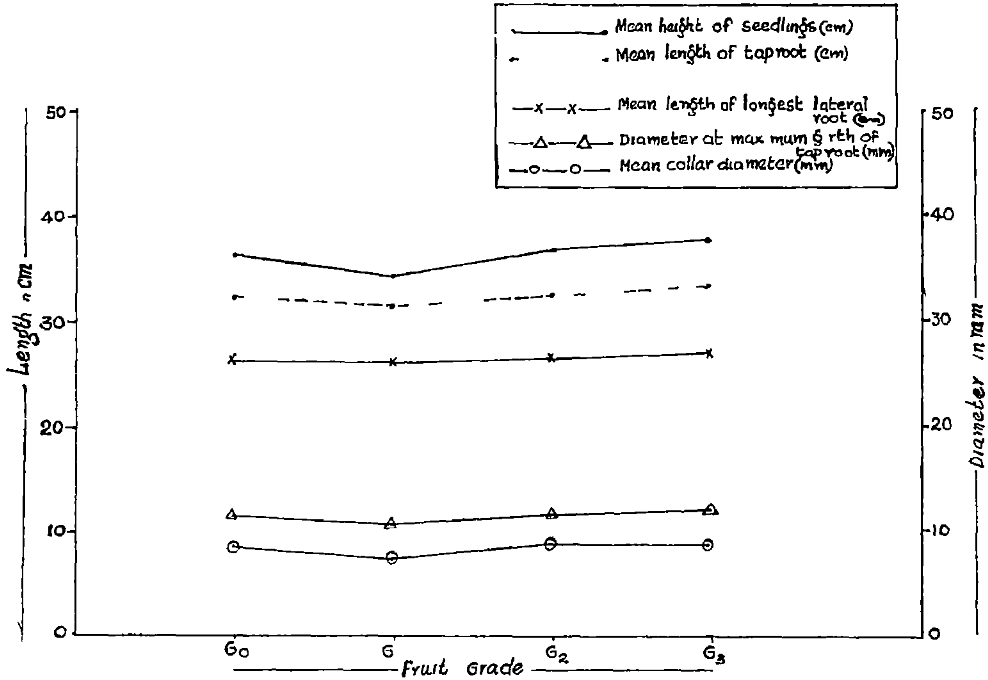
The effect of grading and germination media was nonsignificant on the mean length of the longest lateral root produced by the teak seedlings

The effect of pretreatments was significant on this character T_4 pretreatment recorded the highest value (30.43) and as superior over the rest of the pretreatments

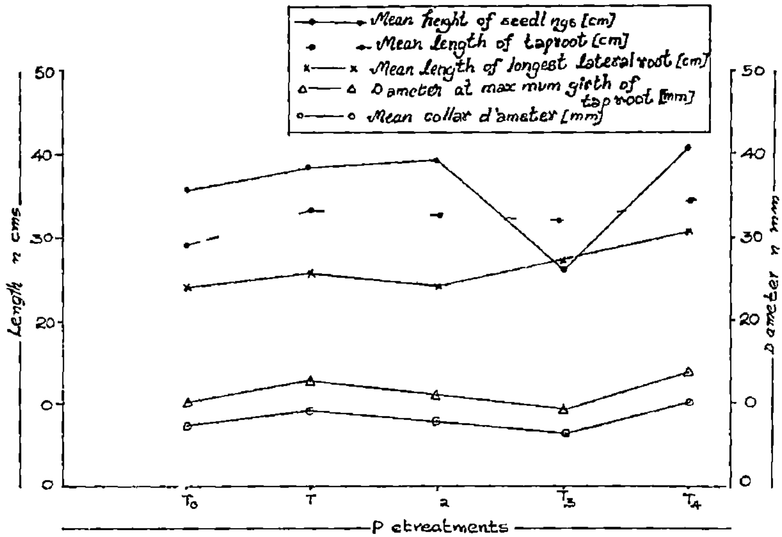
Table 7( ). Interaction of pretreatment and germination media (T x M) on the mean number of lateral roots produced by the teak seedlings

Germination media	Pretreatments					Mean
	T_0	T_1	T_2	T_3	T_4	
M_1	36.42	39.17	35.17	36.42	40.67	37.57
M_2	13.83	18.92	16.83	14.17	20.08	16 57
Mean	25.13	29.04	25.50	25 29	30.38	
SEm ±	0 497					
CD (5%)	0 987					

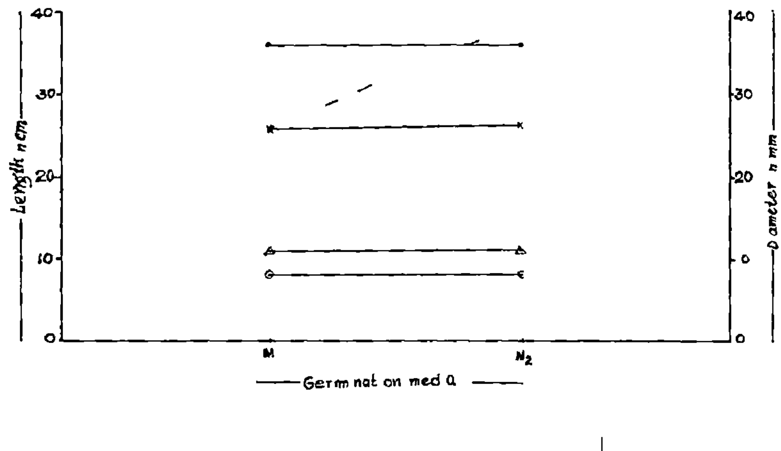
Fig. 5 Effect of Grading on biometric Observations of teak seedlings



F G (6) Effect of pretreatments on biometric observations of teak seedlings



F G 7 E cct c of ge m nat on m d a on biomet ic O ser ations of teak seed ngs



T_3 amd T_1 were on par but superior over T_0 and T_2 which was also statistically on par

4.4 Biomass observations

The results obtained on the biomass observations of the three month old seedlings are presented in Table 8. The analysis of variance is presented in Appendix IV.

4.4.1 Mean dry weight of stem

Different grades of fruits and pretreatments significantly influenced the mean dry weight of stem of the teak seedlings while the different germination media did not influence this character.

The fruit grades differed significantly with 1.93 g in G_1 grade to 2.60 g in G_3 grade.

The various pretreatments also differed significantly. The highest value (3.46 g) was obtained with T_4 pretreatment and the lowest (1.12 g) with T_3 pretreatment.

The interaction of grade and pretreatment (GxT) was significant on this character and the highest value

Table 8 Effect of grading, pretreatments and germination media on biomass of teak seedling

Treatments	Shoot biomass (g)			Root biomass (g)			Total biomass of seedling (g)
	Mean dry weight of stem	Mean dry weight of leaves	Total shoot biomass	Mean dry weight of taproot	Mean dry weight of lateral roots	Total root biomass	
Fruit grade							
G_0	2.42	4.40	6.82	1.68	1.00	2 67	9 49
G_1	1.93	3 79	5 72	1.35	0.70	2.05	7 77
G_2	2.53	4.50	7.03	1.80	1 00	2.79	9.82
G_3	2.60	4.62	7.23	1.84	1 03	2 87	10 10
CD (5%)	0.031	0.021	0.039	0.019	0.018	0 033	0 044
Pretreatment							
T_0	2.16	3.09	5.25	1.09	0 58	1 67	6 92
T_1	2.65	5.87	8.51	2.25	1.15	3.40	11.91
T_2	2.47	4.01	6.48	1.63	0.68	2.31	8 80
T_3	1.12	1.81	2 93	0 74	0.45	1.19	4.11
T_4	3.46	6.86	10.32	2.62	1.72	4.42	14 43
CD (5%)	0.034	0.024	0.044	0.021	0 029	0 037	0.049
Media							
M_1	2.36	4.29	6.66	1.65	0.92	2.57	9.22
M_2	2.38	4 36	6.74	1.68	0.94	2 63	9.37
CD (5%)	NS	0.015	0.020	0.013	0 018	0.023	0.031
Interaction CD (5%)							
G x T	0.069	0.047	0.087	0 041	0 057	0 074	0 099
T x M	0.049	0 033	0.062	0 029	0 036	NS	0 070
M x G	NS	0.030	0.055	0 026	NS	0 047	0 063
G x T x M	NS	0 067	0.123	0 059	NS	0 104	0.140

(2.86 g) was recorded by the treatment combination M_2T_4 (Table 8.a) and the lowest value (0.63 g) by the treatment combination G_1T_3.

The interaction of pretreatment and media (TxM) was also significant on the mean dry weight of stem (Table 8 b) The treatment combination M_2T_4 recorded the maximum value of 2.66 g and the minimum value of 0 74 g was recorded by M_1T_3 combination

The interaction M x G as well as the three factor interaction M x G x T were not significant on the mean dry weight of stem.

4.4.2 Mean dry weight of leaves

The fruit grades, pretreatment as well as germination media significantly influenced the mean dry weight of leaves.

Significant difference was observed between the different grades of fruits used A maximum of 4 62 g in G_3 grade and a minimum dry weight of 3 79 g in G_1 grade was noticed

The pretreatments differed significantly in the mean dry weight of leaves The highest mean value (6 86 g)

Table 8(a). Interaction of fruit grade and pretreatment (G x T) on the mean dry weight of stem (g)

Fruit grades	Pretreatments					Mean
	T_0	T_1	T_2	T_3	T_4	
G_0	1.09	2.29	1 65	0.71	2 63	1 68
G_1	0 85	1 83	1.32	0 63	2.15	1.35
G_2	1 21	2 42	1 70	0 80	2.85	1.80
G_3	1.22	2.46	1.85	0 82	2.86	1 84
Mean	1 09	2 25	1 63	0 74	2 62	
SEm ±	0.021					
CD (5%)	0.041					

Table 8(b) Interaction of pretreatment and media (T x M) on the mean dry weight of stem (g)

Germination media	Pretreatments					Mean
	T_0	T_1	T_2	T_3	T_4	
M_1	1.07	2.23	1 62	0.74	2.59	1.65
M_2	1.11	2.26	1.64	0 75	2.66	1.68
Mean	1.09	2.25	1 63	0.74	2 62	
SEm ±	0.015					
CD (5%)	0.029					

was recorded by T_4 pretreatment and the lowest mean dry weight of leaves (1.81 g) by the T_3 pretreatment.

The germination media also differed significantly The value recorded in M_2 (vermiculite) medium was significantly higher (4.36 g) than that obtained in M_1 (sand) with 4.29 g.

In the interaction between the grade and pretreatment (G x T) which was significant, the maximum value (7.32 g) was recorded in the treatment combination G_3T_4 and the minimum value of 1.64 g was as the G_1T_3 combination (Table 8.c).

In the T x M interaction which was significant the highest value was given by M_2T_4 (6 96 g) and the lowest (1.75 g) by M_1T_3 treatment combination (Table 8 d).

In the M x G interaction which was also significant the maximum value was obtained in the treatment combination M_2G_4 (4.72 g) and the minimum value (3.75 g) by M_1G_1 which was on par with M_2G_1 (3 81 g) treatment combination (Table 8 e).

The interaction of the three factors G x T x M was also significant on the mean dry weight of leaves

Table 8(c). Interaction of fruit grade and pretreatment (G x T) on mean dry weight of leaves (g)

Fruit grades	Pretreatments					Mean
	T_0	T_1	T_2	T_3	T_4	
G_0	3.14	5 95	4.26	1.91	6.73	4.40
G_1	2.77	4 44	3.21	1 64	6.41	3 79
G_2	3.22	6.27	4.28	1 75	6 99	4 50
G_3	3.25	6 35	4.31	1.93	7.32	4 62
Mean	3.09	5 87	4.01	1.81	6.86	
SEm ±	0.024					
CD (5%)	0.047					

Table 8(d) Interaction of pretreatment and media (T x M) on mean dry weight of leaves (g)

Germination media	Pretreatments					Mean
	T_0	T_1	T_2	T_3	T_4	
M_1	3 08	5 86	4 01	1.75	6 77	4 29
M_2	3 10	5 87	4 02	1 87	6 96	4 36
Mean	3 09	5 87	4 01	1 81	6 86	
SEm ±	0.017					
CD (5%)	0 033					

Table 8(e) Interaction of germination media and fruit grade (M x G) on mean dry weight of leaves (g)

Germination media	Fruit grades				Mean
	G_0	G_1	G_2	G_3	
M_1	4 38	3.78	4.49	4.53	4.29
M_2	4.41	3 81	4.51	4.72	4.36
Mean	4.40	3.79	4.50	4 62	
SEm ±	0.015				
CD (5%)	0.030				

Table 8(f). Interaction of fruit grade, pretreatment and germination media (G x T x M) on mean dry weight of leaves (g)

Pre-treatment / Fruit graded	M_1 medium						M_2 medium					
	T_0	T_1	T_2	T_3	T_4	Mean	T_0	T_1	T_2	T_3	T_4	Mean
G_0	3.13	5.96	4.25	1.90	6.67	4.38	3.15	5.94	4.27	1.92	6.79	4.41
G_1	2.76	4.93	3.21	1.57	6.41	3.77	2.77	4.94	3.21	1.72	6.41	3.81
G_2	3.21	6.28	4.27	1.71	6.97	4.49	3.23	6.26	4.28	1.79	7.00	4.51
G_3	3.24	6.28	4.30	1.82	7.03	4.53	3.26	6.35	4.32	2.04	7.62	4 72
Mean	3.08	5 86	4.01	1.75	6.77		3.10	5.87	4.02	1.87	6.96	
SEm ±	0.034											
CD (5%)	0.067											

(Table 8.f). The maximum value (7.62 g) obtained was in the treatment combination $G_3T_4M_2$ and the minimum value (1.57 g) in the $G_1T_3M_1$ combination.

4.4.3 Mean dry weight of tap root

Grading of teak fruits had significantly affected the mean dry weight of taproot of the three month old teak seedlings. The grades differed significantly with values ranging from a minimum of 1.35 g in G_1 grade to a maximum of 1.84 g in G_3 grade.

The pretreatments exerted a significant influence on the mean dry weight of tap root produced T_4 pretreatment gave the maximum dry weight (2.62 g) and the T_3 pretreatment gave the minimum (0.74 g)

The generation media also had a significant effect on the mean dry weight of tap root. The vermiculite medium (M_1) (1.68 g) was significantly superior over sand (M_1) (1.65 g) for this character

In the G x T interaction the highest value (2.86 g) was recorded by the T_3T_4 combination which was on par with G_2T_4 (2.88 g) The lowest value (0.63 g) was recorded in the G_1T_3 combination (Table 8.g).

The treatment combination M_2T_4 gave the highest value (2.66 g) in the (TxM) interaction (Table 8.h). The lowest values (0.74 g) was in the M_1T_3 which was on par with M_2T_3 (0 75 g) combination

In the M x G interaction, the treatment combination M_2G_3 gave the maximum (1.86 g) dry weight of tap root. The lowest value (1.32 g) was obtained in the treatment combination M_1G_1 (Table 8.i).

In the G x T x M interaction the maximum dry weight of tap root recorded (2.88 g) was in the treatment combination $G_3T_4M_2$ (Table 8.j) The lowest (0.62 g) in $G_0T_3M_2$ which was statistically on par with $G_1G_3M_1$ (0.63 g) and $G_1T_3M_2$ (0.64 g).

4.4.4 Mean dry weight of lateral roots

The effect of grading, pretreatments and germination media was significant on the mean dry weight of the lateral roots produced in teak seedlings

The seedlings obtained from G_3 grade teak fruits were with the maximum dry weight (1.03 g) of lateral roots and was significant over the other three grades. G_2 (1.00 g) and G_0 (1.00 g) were on par but superior over G_1 grade (0 70 g)

Table 8(g). Interaction of fruit grade and pretreatment (G x T) on the mean dry weight of the tap root (g)

Fruit grades	Pretreatments					Mean
	T_0	T_1	T_2	T_3	T_4	
G_0	1.09	2 29	1.65	0.71	2 65	1 68
G_1	1.09	1.83	1.32	0 63	2 15	1.35
G_2	1.21	2 42	1 70	0 80	2 85	1 80
G_3	1.22	2 46	1.85	0 82	2.86	1 84
Mean	1.09	2.25	1.63	0.74	2 62	
SEm ±	0.021					
CD (5%)	0.041					

Table 8(h) Interaction of pretreatment and germination media (T x M) on the dry weight of tap root (g)

Germination media	Pretreatments					Mean
	T_0	T_1	T_2	T_3	T_4	
M_1	1.07	2 23	1 62	0 74	2 59	1.65
M_2	1 11	2 26	1 64	0 75	2 66	1 68
Mean	1 09	2 25	1 63	0 74	2 62	
SEm ±	0 015					
CD (5%)	0 029					

Table 8(i) Interaction of germination media and fruit grade (M x G) on the mean dry weight of tap root (g)

Germination media	Fruit grades				Mean
	G_0	G_1	G_2	G_3	
M_1	1.69	1 32	1 77	1 82	1 65
M_2	1.66	1 38	1 82	1.86	1 68
Mean	1.68	1.35	1 80	1 84	
SEm ±	0.013				
CD (5%)	0 026				

Table 8 (j) Interaction of fruit grade pretreatment and germination media (G x T x M) on the mean dry weight of tap root (g)

Pretreat- ments / Fruit grades	M_1 medium						M_2 medium					
	T_0	T_1	T_2	T_3	T_4	Mean	T_0	T_1	T_2	T_3	T_4	Mean
G_0	1 09	2 29	1 64	0 80	2.61	1 68	1 09	2 28	1 67	0.62	2 66	1 66
G_1	0 50	1 78	1.31	0 63	2 09	1.26	0 89	1 87	1 32	0 64	2 20	1 38
G_2	1.19	2.41	1 70	0 73	2 81	1.77	1.23	2 42	1 70	0 87	2 90	1 82
G_3	1 20	2.44	1 84	0 79	2 83	1.82	1.24	2 48	1 87	0 85	2 88	1 86
Mean	1.07	2.23	1.62	0 74	2 59		1.11	2 26	1 64	0 75	2 66	
SEm ±	0 029											
CD(5%)	0 059											

The pretreatments differed significantly with values ranging from a minimum of 0.45 g in T_3 pretreatment to a maximum of 1.79 g in T_4 pretreatment The M_2 medium (vermiculite) was statistically superior to M_1 medium (sand) in the mean dry weight of lateral roots giving values of 0 94 g and 0.92 g respectively

The interaction G x T was found to be significant on the mean dry weight of lateral roots of the teak seedlings (Table 8 k). The maximum dry weight (2.03 g) was recorded in the treatment G_3T_4 which was on par with G_2T_4 (2.02 g) and the lowest (0 30 g) was in the treatment combination G_1T_3.

The interaction (T x M) which was also significant (Table 8 1) The maximum value (1.79 g) was recorded by M_1T_4 and M_2T_4 and the minimum value (0.40 g) by M_1T_3 combination.

4 4.5 <u>Total biomass of seedlings</u>

The teak fruit grading, pretreatment and germination media had significant effect on the total biomass of the three month old teak seedling

Table 8(k) Interaction of fruit grade and pretreatment (G x T) on the mean dry weight of lateral roots (g)

Fruit grades	Pretreatments					Mean
	T_0	T_1	T_2	T_3	T_4	
G_0	0 60	1 20	0.71	0.47	1.99	1.00
G_1	0.50	0 98	0 61	0.30	1.13	0 70
G_2	0.61	1.21	0 68	0.47	2 02	1 00
G_3	0.62	1.22	0.72	0.54	2.03	1.03
Mean	0.58	1.15	0.68	0.45	1.79	
SEm ±	0.029					
CD (5%)	0.05					

Table 8(1) Interaction of pretreatment and media (T x M) on the mean dry weight of lateral roots (g)

Germination media	Pretreatments					Mean
	T_0	T_1	T_2	T_3	T_4	
M_1	0 57	1.16	0.67	0 40	1.79	0.92
M_2	0 59	1 15	0 70	0.44	1 79	0 94
Mean	0 58	1 15	0 68	0.45	1 79	
SEm ±	0.20					
CD (5%)	0 040					

The grades of fruit differed significantly in the total biomass. The G_3 grade with 1.10 g recorded the maximum dry weight. The minimum dry weight of seedlings (7.77 g) was given by the G_1 grade teak fruits

The pretreatments had significant difference among themselves. The values ranged from 4.11 g in T_3 pretreatment to a maximum of 14.73 g in T_4 pretreatment.

The germination media also differed significantly The M_2 medium was with statistically higher biomass value (9.37 g) over M_1 medium (9.22 g).

In the G x T interaction which was significant the maximum biomass of seedling (16.00 g) was in the treatment combination G_3T_4 and the minimum (3.22 g) in G_1T_3 combination (Table 8.m).

In the interaction T x M which was significant, the highest value (14.88 g) was obtained in T_4M_2 and the lowest value (4.03 g) in T_3M_1 combination (Table 8.n)

When statistically significant M x G interaction was considered, the treatment combination M_2G_3 was with the highest seedling biomass (10.24 g) and the treatment

Table 8 (m). Interaction of fruit grade and pretreatment (G x T) on the total biomass of teak seedlings (g)

Fruit grades	Pretreatments					Mean
	T_0	T_1	T_2	T_3	T_4	
G_0	6.93	12.13	9.23	4.33	14.82	9.40
G_1	6.01	9.44	7.15	3.22	12.55	7 77
G_2	7.33	12.64	9.29	4.27	15.57	9.82
G_3	7.42	12.93	9 51	4 64	16.00	10.00
Mean	6.92	11.91	8 80	4 11	14.73	
SEm ±	0.049					
CD (5%)	0.099					

Table 8(n) Interaction of pretreatment and germination media (T x M) on the total biomass of teak seedlings (g)

Germination media	Pretreatments					Mean
	T_0	T_1	T_2	T_3	T_4	
M_1	6 87	11.88	8 75	4.03	14 59	9.22
M_2	6.98	11.94	8.84	4 20	14 88	9 37
Mean	6 92	11.91	8.80	4 11	14.73	
SEm ±	0.049					
CD (5%)	0 099					

combination M_1G_1 was with the lowest (7.73 g) seedling biomass values (Table 8.o).

The three factor interaction was also significant. In the G x T x M interaction (Table 8.p) the maximum seedling biomass (16.32 g) was recorded in the $G_3T_4M_2$ treatment combination and the minimum biomass (3.19 g) in $G_1T_3M_1$ treatment combination which was statistically on par with $G_1T_3M_2$ (3.26 g).

Table 8(o). Interaction of germination media and fruit grade (M x G) on the total biomass of teak seedling (g)

Germination media	Fruit grades				Mean
	G_0	G_1	G_2	G_3	
M_1	9 47	7 73	9.72	9 96	9 22
M_2	9 50	7 82	9.92	10.24	9 37
Mean	9.49	7 77	9.82	10 10	
SEm ±	0 031				
CD (5%)	0.063				

Table 8(p). Interaction of fruit grade, pretreatment and germination media (G x T x M) on the total biomass of teak seedlings (g)

Pretre-atment / Fruit grades	M_1 medium						M_2 medium					
	T_0	T_1	T_2	T_3	T_4	Mean	T_0	T_1	T_2	T_3	T_4	Mean
G_0	6.90	12.15	9.18	9.41	14 71	10.47	6 96	12 11	9.27	4 25	14 93	9 50
G_1	5 97	9 88	7.14	3 19	12 47	7 73	6 06	10 00	7 17	3.26	12 62	7 82
G_2	7 25	12.63	9.22	4.01	15 50	9.72	7 41	12 66	9 35	4 52	15 64	9 92
G_3	7 36	12.85	9.44	4 49	15 67	9 96	7 49	13 01	9 58	4 79	16 32	10 24
Mean	6 87	11.18	8.75	4 03	14.59		6 98	11.94	8.84	4.70	14 88	
SEm ±	0 070											
CD (5%)	0 140											

Fig 8 Effect of Grading Pretreatments and germination media on the shoot and root biomass of teak seedlings

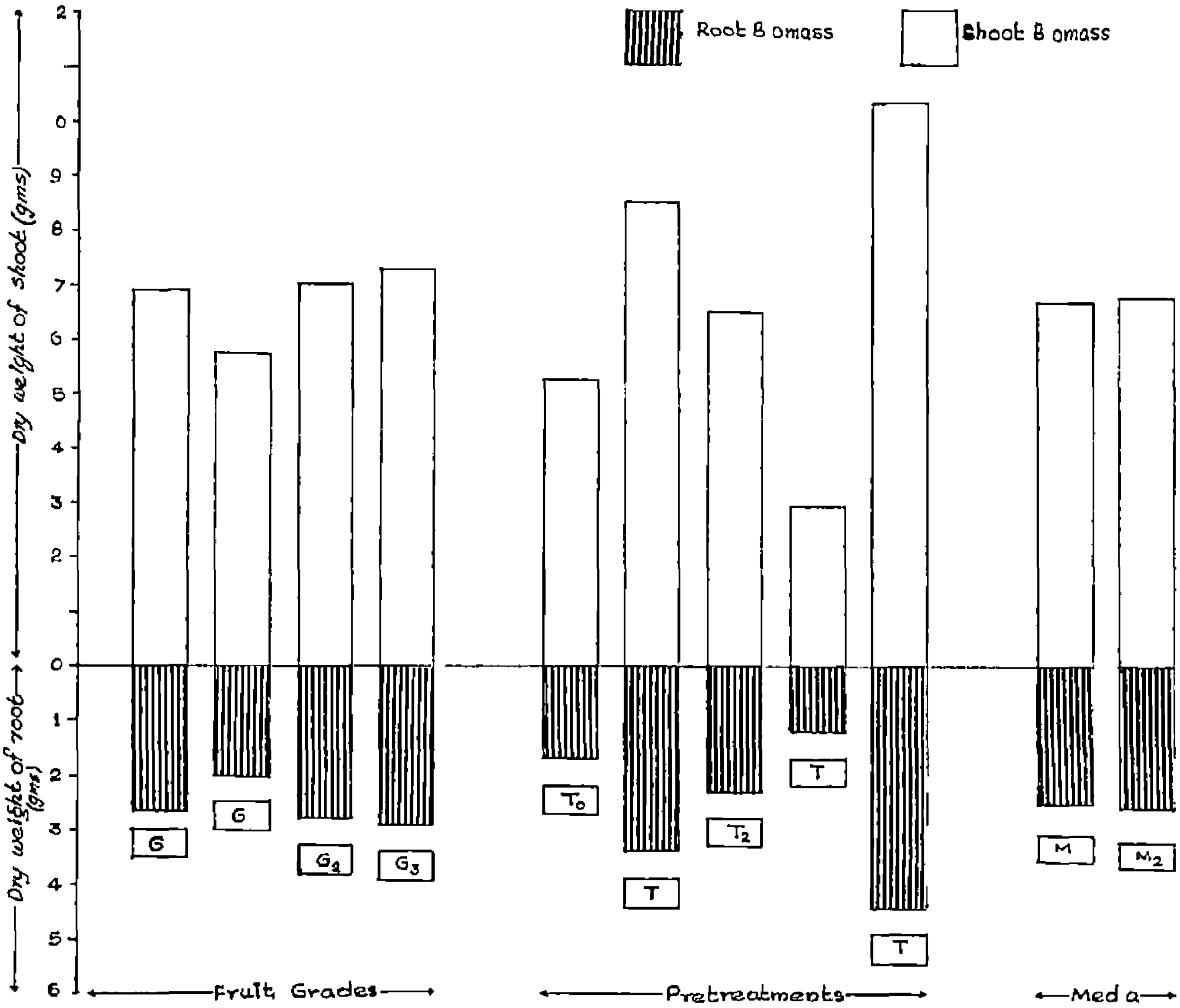


Table 9 Table showing the treatment combinations which recorded the highest and lowest values for germination characters biometric and biomass observations of teak

Parameters/observations		Highest/maximum values		Lowest/minimum values	
Germination characters of teak seeds	1. Speed of germination	5 75	$(G_3T_4M_2)$	0.20	$(G_1T_0M_1)$
	2. Germination under (GV)	6 15	$(G_3T_4M_2)$	0 03	$(G_1T_0M_1)$
	3 Germination percentage	46 67	$(G_3T_4M_2)$	5.00	$(G_1T_0M_1)$
	4 Plant percentage	40 33	$(G_3T_4M_2)$	5 00	$(G_1T_0M_1)$
	5. Viability percentage	56 00	$(G_3T_0M_1)$	7 67	$(G_1T_3M_1)$
Biometric observations of 3 month old teak seedlings	1. Mean height of seedling (cm)	41 57	$(G_3T_4M_2)$	23 07	$(G_3T_4M_2)$
	2 Mean collar diameter (mm)	10 80	$(G_3T_4M_2)$	5.17	$(G_1T_3M_2)$
	3. Mean length of taproot (cm)	41 00	$(G_3T_1M_2)$	21 40	$(G_1T_0M_1)$
	4 Mean diameter of taproot (mm)	13.90	$(G_3T_4M_1)$	7.96	$(G_1T_3M_2)$
	5. Number of lateral roots	41 33	$(G_3T_4M_1)$	13.33	$(G_1T_3M_2)$
	6. Mean length of largest lateral root (cm)	31 87	$(G_2T_4M_2)$	21.50	$(G_0T_0M_1)$
Biomass observations of 3 month old teak seedlings	1. Mean dry weight of stem	3 80	$(G_3T_4M_2)$	0 62	$(G_1T_3M_2)$
	2. Mean dry weight of leaves	7 62	$(G_3T_4M_2)$	1 57	$(G_1T_3M_1)$
	3 Total shoot biomass (g)	11 42	$(G_3T_4M_2)$	2.24	$(G_1T_3M_1)$
	4 Mean dry weight of taproot (g)	2.90	$(G_2T_4M_2)$	0.63	$(G_1T_3M_1)$
	5. Mean dry weight of lateral roots (g)	2 04	$(G_3T_4M_1)$	0 28	$(G_1T_3M_2)$
	6 Total root biomass (g)	4 92	$(G_2T_4M_2)$	0.91	$(G_1T_3M_2)$
	7 Total biomass of seedling (g)	16 32	$(G_3T_4M_2)$	3.19	$(G_1T_3M_1)$

Discussion

DISCUSSION

The results of the investigations on the production of healthy seedlings of teak (*Tectona grandis* Linn.f) in the nursery, which were presented in the previous chapter are briefly discussed in this chapter.

5.1 Estimation of fruit characters by cutting test

The cutting test is a simple viability testing method involving the direct eye inspection of seeds obtained from teak fruits. In this trial a modified teak seed cutter as described by Dabral (1976) has been used for breaking the hard endocarp of teak fruits and extracting the seeds. The cutting test, if performed before the start of a germination test is useful in getting an idea of the probable germination per cent. This may be helpful in deciding the approximate quantity of fruits actually needed for raising a nursery stock for planting in the main field (Willan, 1985).

Eventhough teak fruits are tetralocular, in the cutting test performed on them in this experiment, it was found that the distribution of one seeded fruits was the highest followed by fruits with two seeds. The number of fruits with three seeds was still less and the number of four seeded fruits, very rare. This observation is in confirmation with the results of the cutting test performed by Gupta and Kumar (1976) on teak fruits from 23 different sources.

Emptiness of teak fruits is reported as a common phenomenon by Dabral (1976). Prasad and Jalil (1986) in a cutting test performed on teak fruit from seven sources, found that the average emptiness per fruit varied from 0.698 to as high as 0.768. The teak fruits gave a mean average emptiness value per fruit as 0.750 in this experiment. Dabral (1976) had found that the average emptiness of teak fruits collected from 20 year old stands from four localities in Maharashtra, varied from 0.426 to 0.741, thereby indicating that locality has a significant influence on the average emptiness. The emptiness of teak fruits has been attributed to the fertility index of site by Gupta and Pattanath (1976). Hence site factor should be taken into account while collecting fruits (seeds) for raising teak nurseries Higher average emptiness is an indication of lesser number of available seeds and hence a seed rate slightly higher than the normal recommended, should be used in the nursery bed.

Since teak fruits are tetralocular and can have a maximum of four seeds per fruit, for practical purposes one fruit is counted as one seed especially for the calculation of viability per cent, eventhough more than one seedling may actually emerge out of a single fruit In a cutting test by Keiding (1985) on teak fruits 54 sources, a mean average viability percentage of 78 per cent was recorded. But the average viability percentage of teak seeds obtained in this experiment by cutting test was 58 65 per cent (Table 5).

Since it is not possible to distinguish between moribund, recently dead or recently injured seeds from sound ones, the actual germination percentage will always be lower than the estimated viability percentage by cutting test (Bonner, 1974). The actual germination percentage of teak seeds in this experiment ranged from 5 67 per cent to 46.67 per cent with a mean value of 22.87 per cent. Seeber and Agpoa (1976) found that the germination percentage was consistently 10-20 per cent less than the percentage of sound seeds from cutting test on _Leucaena_, _Intsia bijuga_ and _Lagerstroemia speciosa_.

The cutting test along with Tetrazolium test is performed at the end of the germination test to determine the apparent viability of ungerminated seeds (Willan, 1985). This procedure adopted in this trial gave values ranging from 7.67 per cent to 56.00 per cent with a mean of 35.07 per cent viability after taking into account only the number of fully stained teak seeds and was more or less in confirmation with the actual germination per cent (22.87 per cent) of the teak seeds Keiding (1985) has attributed this difference to various other factors among which the dormancy of the seed was the most influential factor. Justice (1972) has observed that while the tetrazolium testing procedure was good in principle, its practical use in routine testing was limited by many problems like difficulty in staining of the seeds, need for cutting and dissecting seeds to permit observation of stained parts, poor agreement with germination results, lack of uniform interpretation of staining and difficulty in interpreting the significance of different degrees of staining. Although Gupta and Raturi (1975) have standardised the procedure for tetrazolium test in the case of six Indian tree species, there is no standard procedure for teak seeds. Hence for computing the viability percentage of teak seeds only fully stained ones have been taken into account in this experiment.

5.2 Effect of grading

Environmental influences during the development of the seed counted with genetic variability can result in variations in seed diamensions according to Willan (1985). This appears to be true in the case of teak seeds also.

In the observation of fruit characters of graded teak fruits it was observed that fruits greater than 15 mm diameter (G_3 grade) recorded the highest mean weight of 100 fruits and the lowest number of fruits per kg. The maximum number of seeds that could be extracted per 100 fruits from G_3 grade was more compared to the lesser diameter fruits. However a larger number of fruits per kilogram does not necessarily indicate a greater number of extractable seeds Dabral (1976) while examining two fruit samples of one kilogram each, from two different sources, found that the number of seeds and fruits were almost the same in both the samples

Sample I with 2290 fruits/kg yielded 2542 seeds (av. 110.00 seeds/100 fruits) and Sample II with 2646 fruits/kg yielded only 2287 seeds (av. 86.43 seeds/100 fruits). A higher fruit weight on weight per 100 fruit generally is an indication of better seed filling in the case of teak The higher seed weight could be due to better seed filling in the G_3 grade and not due to bigger sized mesocarp and stony endocarp. The number of large seeds in the total number of extracted seeds was higher in G_3 grade but in the number of small seeds there was not much significant difference between the different grades. The occurrence of one, two, three and four seeded fruits per 100 numbers followed a general trend in all the four grades and was in agreement with the earlier observation of Gupta and Kumar (1976) However a relative increase in the trend was noticed as the diameter of fruits increased. The percentage of empty fruits decreased ffom 41.66 per cent in G_1 grade to 15.00 per cent in G_3 grade. The average emptiness values also showed a corresponding decrease. The viability percentage computed by occular estimate of seeds in the cutting test indicated that G_3 grade had at least 75 full sound apparently viable seeds per 100 fruit numbers.

The ungraded teak fruits (G_0 grade) showed intermediate values between G_1 and G_2 grade for all the observations. This may be due to the fact that 43 per cent of the teak fruits used in this experiment in the ungraded fruit lot were in the 12-15 mm diameter class, 32 per cent were in the less than 12 mm diameter class and about 25 per cent in the greater than 15 mm diameter size class (Table 4).

Teak fruits having a diameter greater than 15 mm (G_3 grade) recorded significantly higher speed of germination, germination value, germination percentage plant percentage and viability percentage. It also recorded significantly higher biometric values at the end of three months. The mean seedling biomass in G_3 grade fruits was 10.10 g, followed by 9 82 g in G_2 grade and 7.77 g in G_1 grade. For ungraded teak fruits (G_0) the mean seedling biomass was 9 49 g.

The higher values obtained in the G_3 grade seedlings with respect to the overall growth performance may be due to a relatively higher speed of germination and germination value giving these seedlings an increased initial vigour over the others. Eidmann (1934) in his investigations on the influence of fruit size on germination and early growth of teak seedlings found that bigger fruits (greater than 14 mm diameter) germinated faster or had a better speed of germination than smaller ones and hence the growth performance during the first year was better. This is in agreement with the observations of this experiment where the seedlings from G_3 grade (> 15 mm diameter) have shown a better overall growth performance

Farmer (1980) has suggested that generally larger seeds have greater advantage over smaller seeds in germination and seedling growth, possibly due to larger embryo or gametophytic tissue, more cotyledons or greater initial leaf area. This could be true in the case of teak fruits since the percentage of large seeds in the total number of available/extractable seeds per 100 fruit numbers was more (81.7 per cent) in fruits greater than 15 mm size (G_3 grade) and 71.1 per cent (G_1 grade) as observed from cutting test data (Table 5)

Kumar (1976) in his study on size graded teak fruits from five sources in Andhra Pradesh found that, larger the fruit diameter the better the germination percentage except in the case of fruits from a particular source where the 17.5 - 20 mm fruit size class recorded a germination percentage which was lower than 7.5-10.00 mm 10.0-12.5 mm and 15 0-17.5 mm size classes. Banik (1977) in his germination study on teak fruits from five sources in Bangladesh also reported that teak fruits greater than 14 mm size should be used in the nursery as smaller fruits were found to have a higher degree of emptiness.

A lack of uniformity in nursery beds of teak due to sowing of ungraded teak fruits often makes it imperative to pull stumps in two consecution years resulting in reduced utilization of seeds and seedling The greatest advantage of size grading of teak fruits before sowing would be in the development of the young plants in the sowing beds. Bigger fruits/seeds will generally germinate faster and more evenly thereby producing teak seedlings of uniform size. Hence in order to produce a crop of seedlings which will emerge and grow evenly in the nursery, size grading of teak fruits should be a useful practice.

However, due to the great variation in average fruit size from different sources, it may be difficult to state the exact limit within which the fruits should be size graded. Moreover the behaviour of teak fruits as far as their correlation of size with germination is concerned varies from source to source mainly due to differential seed filling based on locality/site factors. But grading, if properly applied and combined with cutting test can definitely increase the seed utilization and reduce wastage to a great extend.

5.3 Effect of pretreatments

Due to the special fruit characteristics of teak (Joshi and Kelkar, 1975), the various types of dormancy in teak (Keiding, 1985), the physiological condition of the teak fruit (Gupta et al., 1975), the presence of water soluble inhibitor in teak fruit mesocarp (Bhumibhaman et al., 1980) as well as the after ripening phenomenon operating in teak as reported by Eidmann (1934), teak fruits require pretreatment for germination But due to considerable variation in these characters between seedlots from different sources and also within the seed lots from the same source, a number of different pretreatments have been developed

In this experiment out of the five pretreatments tested, the pretreatment (T_1) consisting of alternate wetting and drying has been developed over the years in this locality and practised by the Kerala State Forest Department for raising teek nurseries (Plate 5). The T_4 pretreatment using GA_3 at 100 ppm was however, found better than this pretreatment.

The T_1 pretreatment was comparable to the hotwater (T_2) pretreatment. Slightly higher though significant values were obtained by the T_1 pretreatment seedlings over T_2 pretreatment seedlings for some of the germination characters, biometric and biomass observations. However the T_2 pretreatment gave higher germination percentage, plant percentage, viability percentage as well as germination value. It appears that hot water treatment T_2 is more helpful to soften the hard stony endocarp of the fruits more quickly than the time consuming process of alternate wetting and drying. In general the essential systems of most seeds are inactivated by the time they reach maturity and some of these systems such as soluble enzymes on mitochondria are easily reactivated by water during imbition to start celluar metabolism such as protein synthesis, solute and ion transport and respiration (Ching, 1973). The treatments T_1 and T_2 and to a certain extend T_3 (Acid pretreatment using 20 per cent conc. H_2SO_4) seem to have helped in absorbtion of water more quickly and easily by softening the fruit endocarp.

The alternate wetting and drying method of pretreatment in teak fruits has been practised with certain modifications to suit prevailing local situations by earlier workers (Hodgson, 1900; Damale, 1901; Osmaston, 1908; Singh, 1925, Tuggerse, 1926; Wimbush, 1927; Muttiah, 1975, Ngulube, 1988). The main advantage of this method is that it is relatively easy and can be practised even by unskilled workers. Moreover it ensures satisfactory germination percentage. The drawback is that, it is very cumbersome and takes longer time for satisfactory weathering of the teak fruits before they could be sown in nursery beds. There are chances for seed rot and damping off of the seedling also in this method.

The hot water treatment does not have the above disadvantages. But this method requires some skill and the time interval during which the teak fruits have to be immersed in the boiling water have to be standardised and strictly adhered to prevent the killing of the seeds

Further the hot water treatment is not suitable for treating the teak fruits in bulk quantities especially in a large scale planting programme. Even though treatment has been practised in teak fruits with fairly good results by Panjamanodth (1962) and also by Thaninpong (1963) in teak and in other tree species by Larsen (1964), it appears that the suitability is limited to small scale trials due to difficulty in handling the swollen seeds.

The acid pretreatment (T_3) recorded the poorest performance with respect to the growth characteristic of the seedlings and subsequent biomass observations at the end of three months. The mean viability percentage of 9.92 per cent (which was inclusive of the actual germination percentage of 8.58 per cent) was the lowest among the pretreatments tried in this experiment. This indicated that only 1.63 per cent of seeds under this pretreatment on an average had the potential for germination and such seeds could be identified through Tetrazolium test. Savinthoru (1963) and Saengdech (1964) have claimed fairly good results in germination of teak seeds using lower concentrations of the acid for pretreatment, though the results were not significantly different from control. Shintorn (1963) had also claimed 18.25 per cent germination of teak seeds by soaking the fruits is 20 per cent concentration of H_2SO_4 for 30 minutes. Boonyasirikul (1964) as well as Bumrungrach (1964) were of the opinion that germination of teak seeds is not influenced by the concentration of the acid. The germination percentage observed (8.29 per cent) in the experiment under T_3 (acid pretreatment) was significantly better than in T_0 (control) which recorded only 7.21 per cent. This indicates that the actual germination must have occurred as a result of better imbibition of water by the teak fruit which were soaked in H_2SO_4 (conc. 20 per cent) for 12 hours rather than any particular effect of the acid alone. Ching (1973) had observed that some of the inactive essential systems of dormant mature seeds are reactivated on imbibition of water thereby triggering the start of the germination process. Higher concentration of the acid for shorter durations may hasten the weathering process rather than the imbibition process and there is every likelihood of killing the dormant embryo is the process. Ngulube (1986) in Africa obtained a germination percentage of only 3 8 per cent after immersing the teak fruits in 98 per cent concentrated sulphuric acid for two hours. Since the toughness of the seed coat or endocarp varies between seed lots the optimum strength of the acid as well as the period of immersion could be determined only by specific experiments (Bonner et al., 1974).

It may be concluded that soaking the teak fruits for 12 hours in concentrated H_2SO_4 did not help much in influencing the germination percentage of the teak seeds. The growth and dry matter production of seedlings in this treatment was lesser than that of control (T_0), inspite of recording a higher speed of germination and germination value.

Of the four pretreatments used in this study the treatment with Gibberellic acid (T_4) was found to be the best with respect to germination characters, biometric and biomass observations of teak seedlings. The GA_3 treatment has shown consistently good results in the case of teak seeds from the time of germination to the final biomass observations and was significantly superior to all the other four pretreatments. The seeds in this treatment started to germinate from the 5th day after sowing and reached the peak value of germination by the 10th day compared to the T_3 treatment where the seeds started to germinate from the 19th day only to reach the peak value by the 24th day

Presoaking in GA_3 solution has been used successfully to break the seed dormancy of many species by several workers (Bachelard, 1967 Shatat, 1985 Zaitoun, 1986; Holloway, 1987; Maithani and Bahuguna, 1987). The effect of GA_3 in breaking dormancy at 100 ppm and 50 ppm had been tried out successfully on teak fruit by Somabutra (1964). In the present study also GA_3 obviously played a role in breaking the dormancy of the teak seeds to a certain extend. The 12 hour period of soaking of the teak fruits in GA_3 100 ppm solution was sufficient to enable the penetration of GA_3 through the felty mesocarp and stony endocarp to reach the teak seeds A six fold increase in germination percentage over control (T_0) was recorded by this treatment in this experiment

Increases in endogenous gibbrellic acid in the seed are usually associated with the termination of dormancy in seed undergoing dormancy releasing treatments even though the stage of the germination process at which this increase occurs is still not clear (Leadem 1987) Very little work regarding the exact mechanism on the mode of action of gibberellins in breaking dormancy and initiating germination of seeds of tree species have been done In the case of cereals, the mode of action of GA_3 in controlling germination has been described by Paley (1960). According to the hypothesis proposed by Khan (1975) on herbaceous seeds gibberellins have a primary role in the absence of inhibitors like Abscisic acid (ABA) and when such inhibitors are present cytokinins are required to overcome the negative effects of endogenous regulators. Data on published research relating to his work in the case of seeds of woody plants is very scarce.

The dry matter production of the three month old seedlings was significantly increased over control (T_0) by GA_3 pretreatment. Thanchai (1965) had reported that the growth of one year old teak seedlings were significantly different from control when GA_3 100 ppm has used for treating the teak seeds. Further, spraying of GA_3 solution at low concentrations on one month old seedlings (Seth and Mathuada 1959) as well as the application of 1 per cent GA_3 in the form of lanolin paste on one week old teak seedlings have been found to have a promotive effect on growth and dry matter production of shoot and root by Mishra and Mishra (1984) The higher values on biometric and biomass characters recorded in GA_3 pretreatment (T_4) may be due to the initial higher speed of germination and germination value (GV) giving the teak seedlings a head start over the seedlings from other pretreatments in this trial. But whether the exogenous application by presoaking the teak fruits had any promotive effect on the further growth of the teak seedlings will be revealed only by further biochemical studies. However from the performance of the various pretreatments it appears that presoaking the teak fruits in GA_3 at 100 ppm for 12 hours is helpful to get good germination and enhanced seedling growth within a shorter time 2.5 to 3 kg of teak fruits can be treated with 10 litres of 100 ppm GA_3 solution made up from 1 g of GA_3 (cost of 1 g GA_3 is - Rs.94/-). From one kilogram of fruits containing on an average 1500-2000 teak fruits about 2000 extractable seeds having a potential germination of 70 per cent with 45-50 per cent actual germination using GA_3 100 ppm as pretreatment, at least 1000 healthy seedlings can be expected Hence under controlled conditions in the laboratory 2500-3000 healthy seedlings can be obtained from 2.5 - 3 kg of teak fruits sown as such in vermiculite or sand medium This is enough for planting in one hectare at 2 x 2 m espacement Whereas in the normal method of alternate wetting and drying about 25-30 kg of teak fruits is needed, at the rate of 10 kg per standard seed bed (Plate 5) to get sufficient planting material for stump planting in one hectare at the recommended spacing. Considering these factors, this pretreatment using GA_3 seems to be advantageous. Moreover when the availability of good quality seeds is limited this method is helpful in obtaining the maximum number of seedlings

5.4 Effect of germination media

Selection of an ideal germination medium is important, the choice of which is influenced by other factors like the type and behaviour of the seed in question, the working conditions as well as the experience of the operator (Justice, 1972). In this study two germination media viz. sand and vermiculite have been used considering their relative cheapness easy availability and more or less satisfying the desired qualities of an ideal germination media. Gupta et al (1975) had earlier recommended sand, as an ideal germination medium for large seeds of some common Indian tree species. Sand has also been recommended as a medium for teak fruit germination by ISTA (1976)

The main difference between these two media noticed in this experiment was in the mean number of lateral roots and the mean tap root length of the seedlings produced. The teak seedlings germinated in vermiculite (M_2) medium showed a significantly higher value for the mean tap root length (38 54 cm) compared to that in sand (M_1) medium (25.87 cm). But the mean number of lateral roots was significantly higher in sand (25 87 cm) than in vermiculite which recorded only 16.60 cm (Plate 6). The increase in tap root length may be attributed to the case in penetration and passage afforded to the main root by vermiculite medium. Due to resistance in penetration through sand the growth and elongation of the main tap root must have been affected.

The teak fruits grown in vermiculite were with higher values for the biomass observations than those in sand, eventhough there was no significant difference between the two media with respect to mean height of seedling, mean coll r diameter and mean diameter of taproot. Tanukit (1966) had observed that smaller sized stumps were obtained when sand was used as a germination medium for teak fruits even though the plant per cent and

Plate 5 A view of teak nursery showing growth of 3 month old seedlings after broadcasting teak fruits at the rate of 8-10 kg/standard bed

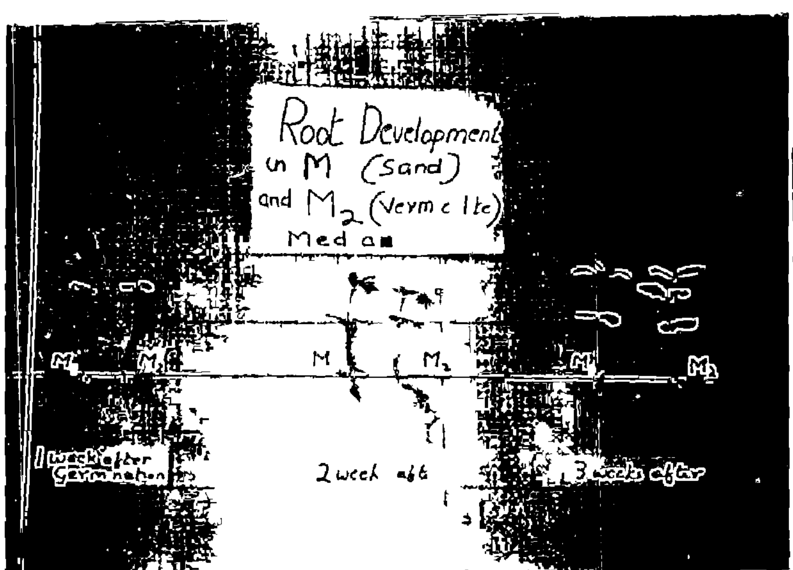


Plate 6. Development of root system of the teak seedlings in sand and vermiculite media.

and seedling height was better in sand than in soil Sukhcharoen (1968) did not observe any significant difference in germination and plant percentage between various germination media including sand.

The higher germination in vermiculate compared to sand may be due to the increased water absorbtion retention qualities of exfoliated vermiculite thereby increasing the amount of available water to seeds Ching (1973) has found that imbibition of water by seed is necessary for reactivation of essential systems like soluble enzymes in seeds to initiate the process of germination. This process must have occurred more quickly in the teak seeds in vermiculite medium resulting in higher speed of germination, germination value (GV) and culminating in the higher biomass production of the seedlings when the biomass observations were taken at the end of three months

5 5 Selection of the best treatment combination for the production of healthy teak seedlings in the nursery

From the results obtained it is evident that the combination of G_3 grade (>15 mm diameter fruits),

T_4 pretreatment (GA_3 100 ppm) and M_2 medium (vermiculite) has given the best results for almost all the parameters studied. Hence it is suggested that for the production of healthy teak seedlings in the nursery, the $G_3T_4M_2$ treatment combination may be practised.

Summary

SUMMARY

A nursery trial was conducted at the Main Campus of the Kerala Agricultural University, Vellanikkara during the summer of 1988, using teak fruits collected from seven selected middle aged teak plantations in Trichur Forest Division to find out a suitable method for the production of healthy seedlings of teak (Tectona grandis Linn.f) The trial was laid out in Factorial Randomised Block Design with three replications

The observations on fruit characters of graded teak fruits by cutting test were recorded before the start of the germination trial The germination characters such as speed of germination, germination value (GV) germination percentage, plant percentage and viability percentage were recorded during the course of the 30 day observation period before potting the seedlings in polybags filled previously with potting mixture After the expiry of three months, biometric observations like mean height mean collar diameter, mean taproot length, mean

diameter of taproot, number of lateral roots and mean length of the longest lateral root.of the three month old seedlings were recorded The lateral roots taproot, stem and leaves were separated and dried to constant weight and the dry weight noted The entire seedling biomass was then worked out. The study led to the following conclusions.

1. In the fruit lots collected from the middle aged teak plantations the proportion of small medium and large sized fruits in the sample was in the ratio 3 4.2 by weight

2. The average emptiness of the ungraded teak fruits used in this experiment was 0.79 as against 0.82, 0.74 and 0.67 respectively for small, medium and large fruits.

3 The proportion of large seeds in the total number of extractable seeds per 100 fruit numbers was found to increase as the fruit size increased from G_1 to G_3 However, the proportion of small seeds in the total number remained more or less unchanged.

4. The mean estimated viability percentage of teak fruits used in this experiment, determined by cutting test was 51 33 per cent This was also found to increase with increase in fruit diameter from G_1 grade to G_3 grade.

5. The viability percentage of treated and untreated teak fruits (seeds), determined at the end of the germination test varied from 5 67 per cent to 56.00 per cent with a mean of 35 07 per cent.

6. The maximum viability percentage of teak seeds at the end of the germination test was recorded in untreated seeds This observation points to the need for proper pretreatment of teak seeds for breaking dormancy thereby ensuring quick and uniform germination in the nursery

7. The mean germination percentage of different grades of teak fruits subjected to different pretreatments and sown in different media was 22.87 per cent which was about 12 per cent less than the actual mean viability percentage (35.07 per cent) determined by germination cutting and tetrazolium tests

8. The teak seedlings from fruits with a diameter above 15 mm recorded the highest biometric and biomass values at the end of three months

9. The presowing treatment with Gibberellic acid proved superior with respect to germination characters and subsequent seedling growth and dry matter production. In this method the teak fruits (seeds) were soaked in GA_3 at 100 ppm for 12 hours before sowing The locally practised method consisting of alternate wetting and drying for three consecutive days was the second best

10. The acid pretreatment (T_3) by presoaking the teak fruits in 20 per cent concentrated H_2SO_4 for 12 hours was with the lowest viability percentage in tetrazolium test indicating the unsuitability of this method

11 The germination percentage of teak fruits was significantly better in vermiculite (M_2) medium compared to sand (M_1) medium The subsequent root development of the seedlings was also better in that medium when observations were taken at the end of three months

From the study it can be concluded that presoaking larger fruits (above 15 mm diameter) in GA_3 at 100 ppm for 12 hours, when sown in vermiculite medium, ensures better germination of teak seeds and subsequent growth. Such seedlings after potting in polybags can be used for casuality replacement during June-July in areas where stump planting is practised during the premonsoon showers in April-May Also such seedlings are best suited to areas where planting of polypotted seedlings are in vogue.

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Appendices

Appendix-I Abstract of analysis of variance - Fruit characters of teak

Source	df	Mean squares				
		Mean number of fruits per kilogram	Mean weight of 100 fruits	Number of seeds extracted from 100 fruits		
				Large seeds	Small seeds	Total
Block	2	7.000	0.055	0.335	1.333	1.556
Treatments (G)	3	489053.671**	584.521**	1870.445**	38.972**	1853.441**
Error	6	26.000	0.355	1.444	1.888	5.320

* Significant at 5 per cent level
** Significant at 1 per cent level

Appendix-I (Contd)

Source	Df	Mean, squares					
		Number of 1, 2, 3, 4 and empty fruits in 100 numbers					Average emptiness per fruit
		One seeded teak fruits	Two seeded teak fruits	Three seeded teak fruits	Four seeded teak fruits	Empty fruits	
Block	2	3.250	0.583	0.083	0.085	3.250	0.00003
Treatment	3	76.250**	69.194**	38.750**	0 555	446 889**	0.01130
Error	6	3.805	2.644	0.416	0.639	3.138	0.00002

* Significant at 5 per cent level
** Significant at 1 per cent level

Appendix-II Abstract of analysis of variance Germination characteristics

Source	Df	Mean squares: Speed of germination	Germination value (G.V.)	Germination percentage	Plant percentage	Viability percentage
Block	2	0.15	0.009	0.074	0.324	7 594
Fruit grade (G)	3	2.014**	4.305**	257 608**	193 897**	913 557**
Pretreatment (T)	4	87.413**	90.598**	5083 709**	3635 154**	5816.359**
Media (M)	1	0.053	0.089*	4 41**	15.406**	4.391
Interaction (GxT)	12	0 726	2.216**	37.886**	29.376**	40 503*
Interaction (TxM)	4	0.032*	0 059*	0 407	10 763**	3 227
Interaction (MxG)	3	0.003	0.024	2 586*	1 497*	18.505
Interaction (MxGxT)	12	0 009	0.013	0.809	1 907*	7.113
Error	78	0.005	0.016	0 502	0.308	8 036

* Significant at 5 per cent level
** Significant at 1 per cent level

Appendix III Abstract of analysis of variance - Biometric observations of teak seedlings

Source	Df	Mean squares		
		Mean height of seedling	Mean collar diameter	Mean lehgth of taproot
Block	2	1.172	0.005	0 902
Fruit grade (G)	3	58 203**	11 268**	19 370
Pretreatment (T)	4	800 980**	58 946**	91 857
Media (M)	1	1 500	0.009	4812 055
Interaction (G x T)	12	4 490**	0 199*	1 682
Interaction (T x M)	4	5 832**	0 054	23 029
Interaction (M x G)	3	0 651	0 086	0 310
Interaction (M x G x T)	12	0 618	0 039	0 585
Error	78	0 417	0.049	0 852

* Significant at 5 per cent level
** Significant at 1 per cent level

Appendix III (Contd)

Source	Df	Mean squares		
		Width at maximum diameter of taproot	Number of lateral roots	Length of longest lateral root
Block	2	0 109	3 410	7 359
Fruit grade (G)	3	11.420**	12 000**	4 234
Pretreatment (T)	4	77.618**	145.326**	164.969**
Media (M)	1	0.001	13230.000**	0.422
Interaction (G x T)	12	0.519*	1 875	2.010
Interaction (T x M)	4	0.074	11.375*	59 436**
Interaction (M x G)	3	0.057	2.180	3 799
Interaction (M x G x T)	12	0.058	0 969	5 366
Error	78	0 066	1 477	4.568

* Significant at 5 per cent level
** Significant at 1 per cent level

Appendix IV Abstract of analysis of variance - Biomass observations of teak seedlings

Source	Df	Mean squares		
		Mean dry weight of stem	Mean dry weight of leaves	Total shoot biomass
Block	2	0.003	0 001	0 005
Fruit grade (G)	3	2 794	4 082**	15 582**
Pretreatment (T)	4	17 263**	100 583**	196.517**
Media	1	0.011	0.146**	0 239**
Interaction (G x T)	12	0.060**	0 355**	0 485**
Interaction (M x G)	3	0.003	0.044**	0 057*
Interaction (M x G x T)	12	0.001	0.020**	0.020*
Error	78	0.004	0 002	0 006

* Significant at 5 per cent level
** Significant at 1 per cent level

Appendix IV (Contd.)

Source	Df	Mean squares			
		Mean dry weight of taproot	Mean dry weight of lateral roots	Total root biomass	Total biomass of seedling
Block	2	0 000	0 000	0 001	0 008
Fruit grade (G)	3	1 451**	0 699**	4.129**	32.729**
Pretreatment (T)	4	14 619**	7.272**	41.218**	414 751**
Media (M)	1	0 033**	0 021**	0 098**	0 656**
Interaction (G x T)	12	0.062**	0 164**	0 343**	1 129**
Interaction (T x M)	4	0.004*	0.010*	0.005	0 047*
Interaction (M x G)	3	0 011*	0.005	0 020*	0 086**
Interaction (M x G x T)	12	0.006*	0.004	0.016*	0 036*
Error	78	0.001	0.002	0 004	0 007

* Significant at 5 per cent level
** Significant at 1 per cent level

INVESTIGATIONS ON THE PRODUCTION OF HEALTHY SEEDLINGS OF TEAK (*Tectona grandis* Linn f) IN THE NURSERY

By

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ABSTRACT OF THE THESIS

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ABSTRACT

Teak seeds have dormancy which may vary from a few weeks to a year or even years Selection of a suitable pretreatment to overcome this dormancy has been an age old problem Several complex and inter-related factors like the physiological condition of the fruit the special fruit characteristics and the after ripening phenomena complicate the problem

A study was conducted using fruits from seven middle aged teak plantations in Trichur Forest Division A germination trial was carried out in Factorial Randomized Block Design The fruits were size graded and four presowing treatments were tested in vermiculite and sand media and the germination characters recorded during a 30 day observation period A cutting test was also performed before hand to estimate the average emptiness viability percentage and other fruit characters of the size graded teak fruits Thereafter the seedlings were transplanted from the germination trays to polybags filled previously with potting mixture and kept in the open After completion of three months the seedlings were taken out from the polybags and the biometric observations recorded The tap root lateral roots leaves and stem were separately dried to constant weight and the dry weight recorded The dry matter production of the entire seedling was also computed From this data the effect of fruit grading pretreatments and germination media was analysed statistically

It was found that larger sized fruits (above 15 mm diameter) were superior to the other grades with respect to germination characters, seedling growth and dry matter production. The pretreatment of the fruits using GA_3 at 100 ppm was significant with respect to germination characters biometric and biomass observations of the teak seedlings Vermiculite was a better germination medium for teak seed germination then sand and the seedlings grown in that medium recorded better tap root growth and dry matter production

The potted seedlings thus produced can be used for planting in areas where seedling planting is resorted to for raising new plantations and for replacement of casualities during June-July in areas where stump planting is adopted as the method of artificial regeneration during premonsoon showers in the month of April-May