A COMPREHENSIVE STUDY ON THE PHENOLOGY, MORPHOLOGY AND SEED GERMINATION OF SELECTED ANGIOSPERMS OF CALICUT UNIVERSITY FLORA

Thesis Submitted to
the University of Calicut for the Degree of
Doctor of Philosophy in Botany

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PHYSIOLOGY AND BIOCHEMISTRY DIVISION
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CERTIFICATE

This is to certify that the thesis entitled **"A Comprehensive Study on the Phenology, Morphology and Seed Germination of Selected Angiosperms of Calicut University Flora"** submitted by Smt. **KOCHUTHRESIAMMA ANDREWS**, in part-fulfilment of the requirements for the degree of **Doctor of Philosophy in Botany**, University of Calicut, is a bonafide record of research work undertaken by her in this Department under my supervision during the period 2002-2008 and that no part there of has been presented or submitted before for any other degree or diploma.

C.U. Campus

Prof. (Dr.) Nabeesa Salim

Dedicated to

Holy Family

DECLARATION

I hereby declare that the thesis entitled "**A Comprehensive Study on the Phenology, Morphology and Seed Germination of Selected Angiosperms of Calicut University Flora"** submitted by me in part-fulfilment of the requirements for the degree of **Doctor of Philosophy** in **Botany**, **University of Calicut,** has not been submitted before for any other degree or diploma.

Place: C.U. Campus **Kochuthresiamma Andrews**
Date :

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Thesis Outline

The author started the project with the premise that climatic factors in general and rainfall in particular have close association with flowering and fruiting phenology of plants. More importantly, the distribution or occurrence of flowering plants may be expected to have significant links with meteorological data of that area.

Plan of study:

The area selected for the study is Calicut University Campus. Identification of Angiosperm species of Campus flora, their phylogenetic classification, flowering and fruiting phenology, fruit and seed morphology, seed dispersal, germination, storage, classification and seedling characterisation and their correlations with rain fall form the body of the dissertation.

Presentation of material:

The dissertation commences with an ***Introduction*** and is followed by ***Review of literature*** where references have been made to the important publications on the topic. In the ***Materials and Methods*** section the author has followed standard/routine procedure of systematics, developmental biology, germination behaviour and seedling morphology. The data obtained are represented in tables and/or as figures and a detailed account on results obtained is given under ***Results*** section. In the ***Discussion*** section an integrated picture of flowering and fruiting phenology, fruit/seed dispersal, classification, germination behaviour, *etc.* in relation to rainfall has been attempted. The main part of the discussion constitutes the interpretation and correlations of experimental data in comparison with current literature. Tentative conclusions have been drawn about the likely influence of rainfall on flowering, fruiting, seed germination behaviour, seedling morphology and their diversity, which are comparable to a tropical flora. In the ***Summary and Conclusions***, a brief methodology, approach, salient observations and conclusions drawn during discussion are included. The dissertation ends with an alphabetically arranged ***Bibliography***.

Angiosperms exhibit wide variations in the pattern of vegetative and reproductive phenology both on large and small geographic scales. Phenological studies are aimed at the correlation between plant growth and development on one hand and seasonal climate in particular, on the other. In order to explain phenological diversity climate, seasonality and species composition are to be taken into consideration (Kochmer and Handel, 1986; Heideman, 1989, Wright and Calderon, 1995). Phenological studies have been carried out primarily on the flora of tropical seasonal forests (Reich, 1995; Murali, 1997; Justiniano and Fredericksen, 2000; Morellato *et al*., 2000), neotropical forests (Morellato *et al.*, 1989; van Schaik *et al*., 1993 and Hamann, 2004) and evergreen mountain rainforest (Bendix *et al*., 2006). Although phenological studies in which the pattern of flowering and fruiting in seasonal forests have been correlated with variation in rainfall and temperature, the relationship between climate and reproductive phenology of plants remain ambiguous.

Phenological studies so far conducted in India are found to be pertaining to tropical rainforest tree species (Singh and Singh, 1998;

Kushwaha and Singh, 2005; Singh and Kushwaha, 2006). In addition to flowering and fruiting phenology, effect of meteorological data, particularly that of rainfall, on seed size, production, dispersal and germination have been investigated only in tree species (Murali, 1997; Poulin *et al*., 1999; Bendix *et al., 2006).*

Seasonal occurrence and duration of flowering and fruiting of plants depend on rainfall and many other environmental factors such as temperature, relative humidity, specific wet and dry seasonality of the area and the impact of these environmental factors vary from plant to plant (Morellato *et al., 2000;* Bendix *et al.,* 2006; Singh and Kushwaha, 2006).

Flowering plants differ considerably with respect to flowering and fruiting phenology and number, size, shape and dispersal mechanism of their seeds. Even though such information is of considerable interest, there is shortage of data concerning the seed germination biology in relation to phenological events.

Only very few comprehensive studies exist regarding the seed number, shape, size/weight, dispersal mechanism of angiosperms of a particular flora or region (Baker, 1972; van der Pijl, 1972; Grime *et al.,* 1981). Almost all phenological studies on seed biology pertaining to different climatic conditions have been conducted on flora in general and trees in particular of different types of forests (Garwood, 1983; Foster, 1986; Murali, 1997).

Although seed dispersal and germination behaviour have been investigated in specific plant forms such as trees (Ng, 1973; Marshall, 1986), only very few data are available on seed biology of plants growing in a restricted area or local flora (Grime *et al.*, 1981).

According to Baskin and Baskin (2001), much information is available in the literature on seed germination phenology of individual species and these data show that each species has a characteristic germination season (or seasons) and the most important objective of seed germination ecology is to explain how the timing of germination is controlled in nature. Fruiting phenology also appears to be rightly correlated with seed development, seed dispersal and germination (Baskin and Baskin, 2001).

Seed biological/ physiological aspects that are controlled by flowering and fruiting phenology under varying climatic conditions are desiccation sensitivity, storability/ longevity and dormancy distribution of seeds. Desiccation sensitivity is considered as an advanced character (Dickie and Pritchard, 2002; Pritchard *et al*., 2004; Daws *et al., 2005).* According to Oliver *et al.* (2000), Dickie and Pritchard (2002), flora of tropical rain forest constitute species with desiccation sensitive seeds in abundance.

To date, precise phenological information with respect to flowering and fruiting in general and seed biology in particular of a local flora with varying monthly rainfall is scarce. Hence, this study aims to provide new insight into the phenology of flowering, fruiting and seed biology and their correlations to monthly rainfall variations of Calicut University Campus flora.

The University of Calicut came into being on 23rd July 1968. The main campus, where the headquarters of the university is located, is at Thenhipalam, 23 km south of Kozhikode city at the western boundary of Malappuram district of Kerala in south India, and is 10 km away from Kozhikode airport. It covers over an area of 500 acres on both sides of the Mangalore-Edappally N.H. 17 spread in three Panchayats, Thenhipalam, Pallikkal and Chelambra. The campus falls within latitude N-11^{0}8’19.13” N and S-11^{0}7’58.10” N and longitude E- 75^{0} 53’32.63” E and W- 75^{0} 53’11.20” E at an altitude of 40-60 meters above sea level.

The Campus area constitute mainly level plots amidst undulating terrain of rocky hills interspersed with dry and moist valleys and patches of green paddy fields. Laterite is widespread and forms capping over hard rocks. Small areas with clayey soils are also present in the campus. Due to the variation in the topography and soil type, considerable diversity can be expected in the flora of the campus. Geographically, the flora of Calicut University Campus is much similar to the tropical flora and also quite a large number of plants, particularly avenue trees and ornamental plants have been introduced to the campus.

Although the Calicut University campus is comparatively a very small area, studies on botanical survey and identification of the flora have already been undertaken (Sivarajan, 1974; Manilal and Sivarajan, 1976). Those authors identified and cited the plant names and flowering time of each species. Nevertheless, the present author proposes a systematic study for the phylogenetic classification of angiosperms as one of the objectives of the investigation. Even though identification of all flowering plants may not be possible during the study of 2 years, a phylogenetic classification of the flora of Calicut University Campus is envisaged.

As mentioned above, systematic studies have been conducted on different types of flora (van Schaik *et al.*, 1993; Justiniano and Fredericksen, 2000; Bendix *et al.*, 2006) and phenological studies on plant growth and development pertaining to climate, particularly rainfall (Morellato *et al.*, 2000; Singh and Kushwaha, 2005). Despite the availability of meteorological data such as temperature, humidity etc. in the present study, rainfall only is proposed to be taken as an environmental factor for the phenological studies because significant fluctuations do occur in the rate of rainfall that control or affect other climatic conditions of plant growth particularly seed biological aspects.

As phenologically significant processes in plant growth and differentiation include flowering, fruiting, seed dispersal, germination etc. and these developmental phases are dependent on and controlled by climatic conditions, the foremost objective of the investigation is the elucidation of the effect and importance of rainfall on phenological aspects of flowering, fruiting and seed biology.

For the systematic investigations of phenology of flowering and fruiting (Justiniano and Fredericksen, 2000; Morellato *et al.,* 2000; Bendix *et al.,* 2006; Singh and Kushwaha, 2006) repetitions of phenological cycles and synchronising of events during successive years are to be studied. However, in the present study the duration of investigation is only 2*years and hence phenological cycles which get triggered by climatic condition like rainfall are not directly comparable with existing publications on phenological studies of flowering and fruiting. Nevertheless, the results are correlated to the reproductive phenology of tropical flora (Richards, 1952; 1996; Huston, 1994; Reich, 1995) since the phytogeography of Calicut University Campus is tropical.

In addition to flowering and fruiting phenology, morphology of fruits and seeds, dispersal mechanism *etc.,* also are included as the objectives of the present study. Seed biological aspects such as distribution of dormancy, effect of drying, storage and germination behaviour are proposed to be studied. Correlation of seed character with phenology will enable a tentative classification of seeds based on germination on one hand and storage on the

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** The author did her Ph.D.work under FIP.

other.

Another important aspect of the investigation is seedling emergence and the classification of functional morphological types of seedlings. Similarly, morphological variations, rather modifications of the cotyledons also are proposed to include in the investigation. In short, the author proposes an integrated interdisciplinary approach with different experimental strategies and perspectives for the study of Calicut University Campus flora.

The phenology of flowering and fruiting of tropical plants is known to be controlled by a number of environmental factors such as temperature, light, rainfall, relative humidity etc. Comprehensive studies by many authors on reproductive phenology of plants in relation to environment revealed climate functions as the triggering and synchronising master control factor of phenological cycles in tropical rain forests (Frankie *et al.*, 1974; Opler *et al.*, 1976; Newstrom *et al.*, 1994). Fruiting phenology appears to be correlated with seed dispersal mechanisms and phenology of tropical forest trees exhibit some adaptive significance due to seed dispersal when soil moisture conditions are favourable for seedling establishment (van Schaik *et al.*, 1993).

Borchert (1983) opined that in many tree species the switching from vegetative to floral phase requires a signal in which drought or shortage of soil moisture is involved. According to the author, in contrast to habitats subjected to a regular cycle of dry and wet seasons, the synchronisation of phenological events may not be expected, in a perhumid habitat like evergreen forests, which lack xeric periods, because high degree of species diversity exists in that particular habitat.

Phenological characteristics of 453 individuals representing 39 tree species investigated in two dry forests of Bolivia revealed that flowering and fruiting were bimodal, with a major peak occurring at the end of the dry season (August - October) and a minor peak during January in the rainy season (Justiniano and Fredericksen, 2000). Fruiting at the end of the dry season might have evolved to reduce seedling mortality by dispersing seeds when soil moisture conditions are favourable for seed germination and rapid seedling growth. It has been observed that sub-canopy species are less seasonal in their fruiting and flowering, perhaps because of reduced variability in solar radiation, soil moisture, and relative humidity in the forest under-story (Justiniano and Fredericksen, 2000).

Parallel to the phenological recordings, meteorological parameters also are to be monitored in detail since these factors are closely related to flowering and fruiting of plants. Various hypotheses have been put forth addressing individual elements of the climate as a proximate factor that trigger seasonality in the equatorial tropics (**Caldwell, 1968**). According to Caldwell *et al*. (1998), rainfall is an indicator of clouds, which appears to play a role in meteorological cues. Similarly factors like, shortage of assimilates during rainy season (Wright *et al*., 1999), prolonged drought and solar radiation (Numata *et al.*, 2003) and solar irradiance peak (Hamann, 2004) are also known to induce and control flowering and fruiting. Phenological aspects such as the periodicity of flowering and fruiting have been addressed in respect of rhythmic cycles and influence of climatic conditions (Mikich and Silva, 2001).

A comparative study on the phenology of Atlantic rain forest trees by Morellato *et al.* (2000) revealed that flowering pattern did not differ significantly among trees of four forest sites analyzed, suggesting the occurrence of a general flowering pattern. Fruiting phenologies were seasonal in all the four forests and hence it seems that climatic factors did not limit the fruit production. Those authors concluded that seasonal variation in day length has got influence on ever-wet forest tree phenology.

An analysis of the proximate control of the flowering in tropical deciduous forest species indicated that the timing of vegetative phenology strongly determined the flowering periods and thus flowering depended indirectly on environmental periodicity (Rivera *et al.*, 2002).

Bendix *et al.* (2006) related the flowering and fruiting activity of 12 tree species in an evergreen tropical rain forest in South Ecuador over a period of 3-4 years, with the meteorological parameters of the area. Those authors observed two groups of trees – one of which flowered during the less humid months (September to October) and the other group started flowering during rainy season (April to July) and suggested that rainfall and minimum temperature appear to be the only parameters with a periodicity free of long term variations and the phenological events of most of the plant species show a similar periodicity.

Singh and Kushwaha (2006) analyzed the diversity of flowering and fruiting phenology of trees in a tropical deciduous forest in India and suggested that in these forests, common tree species show wide range of leafless periods due to different timings of leaf fall within the annual cycle and in tropical deciduous forest trees flowering periodicity has evolved as an adaptation to the annual leafless duration. According to those authors the wide diversity of seasonal flowering and fruiting with linkages to leaf-flush time and leafless period reflect the fact that variable reproductive and survival strategies are involved in tree species under a monsoonal bioclimate. Those authors further suggested that flowering periodicity has evolved as an adaptation to an annual leafless period and the time required for the fruit to develop. The direct relationship between leafless period (inverse of growing period) and time lag between onset of vegetative and reproductive phases reflect the partitioning of resource use for supporting these phases. Predominance of summer flowering coupled with summer leaf flushing seems to be a unique adaptation in trees to survive under a strongly seasonal tropical climate (Singh and Kushwaha, 2006).

Seed dispersal, germination and dormancy are critical events regulating the spatial and temporal distribution of plants. Dispersal and dormancy traits are considered as adaptive mechanisms and the significance of this behaviour is related to restrict germination during most favourable season of the year (Garwood, 1982). According to this author, maturation, dispersal and germination of tree seeds in the seasonally dry tropical forest ecosystem are synchronized to seasons.

Whitmore (1983) and Garwood (1989) opined that many fast growing shade-intolerant tropical pioneer species produce small, dry and orthodox seeds which may remain viable for several years in the soil, beneath the forest canopy. Those authors further suggested that many slow growing, shade tolerant, primary forest species have relatively large, moist, recalcitrant seeds that never become components of the persistent soil seed bank, but germinate in the moist shaded under-story of the forest. According to Garwood (1983) in the seasonal tropical forests, seeds of many species dispersed in the late rainy season are dormant through the reminder of the rainy season as well as the following dry season and germinate in the next rainy season.

A study undertaken by Murali (1997) on the patterns of seed size, germination and seed viability of 99 tree species in the Western Ghats of Karnataka revealed that there is a strong link between flowering time, fruiting time, seed viability and time of germination. Seed size is influenced by dispersal pattern, habit and habitat of the plant species, which depend on the seasonal variations of moisture availability. According to Murali (1997), the species, which flower during the rainy season, have lighter seeds and seeds produced during drier months and in larger quantity are either wind dispersed or explosive dispersed and meant for the lower survival probabilities. They are with longer viability and may show dormancy. Species, which flower during the dry season, produce heavier seeds whereas species, which fruits during the rainy season, have heavier, moist seeds with shorter viability. These larger seeds take more time for germination, and are with shorter maturity and are animal dispersed during wet period.

Seed size is known to control germination pattern and vigour potential. Dharmalingam and Basu (1989) studied the influence of achene size on germination and vigour potential in sunflower seeds and found that 100-achene weight, seed weight and pericarp weight showed a linear association with achene size. Even though the germination potential of achenes did not differ considerably, the field emergence was significantly more in the case of large and medium size achenes than the smaller ones. Seed vigour evaluations confirmed the superiority of the large and medium size achenes over the small and ungraded ones.

Based on a comparative study of tropical seeds which included under three ecologically well defined groups, Garwood and Lighton (1990) stated that tropical forest species differ in seed moisture content and seed mass and these seeds experience different environmental moisture regimes after dispersal. Plant species differ greatly in seed and seedling traits and these traits are often associated with regeneration in particular habitats (Kitajima and Fenner, 2000)

Earlier studies in tropical forest communities have shown the existence of significant associations of seed mass with cotyledon functions (Garwood, 1996; Kitajima, 1996a; b; Ibarra – Manriquez *et al*., 2001). According to Garwood (1996), Leishman *et al.* (2000) and Westoby *et al*. (2002) seed size and seedlings are associated in such a way that size of the large seed-reserve supports seedling survival in shaded habitat. Zanne *et al*. (2005) opined that storage cotyledons are less strongly associated with forest than with gap habitats suggesting alternate methods for provision of energy than storage cotyledons for survival in shade. According to Moles *et al*. (2004), large seeds are most strongly associated with tall trees in closed canopy forest where light availability is low.

Idu and Omonhinmin (2001) described the seed morphology of 136 species of 68 genera of Asteraceae and systematic keys based on seed morphology for the identification of genera have been provided. The orientation, colour, thickness and measurements, which make up the morphometrics differ considerably from taxa to taxa. The differences in the shape and size of seeds apparently varied considerably between and within different taxa.

An elaborated study on the evolutionary and ecological correlations of early seedling morphology of tree species revealed that seed size and cotyledon morphology are the key juvenile traits that have evolved in response to changes in plant species and habitat strategies (Zanne *et al.*, 2005). According to those authors species with large seeds, big seedlings, thick storage cotyledons, slow germination, large adult stature and dispersal by large animals are associated with forest and gap habitats while species with small seeds, seedlings with thin photosynthetic cotyledons, fast germination, small adult stature and dispersal by small animals are associated with open habitats.

Investigations on the changes in seed dormancy and germination of 23 common species (annual and perennial grasses, legumes and other dicotyledons) from herbaceous communities in northern Australia during storage of 8 months revealed that initial levels of seed dormancy get changed widely during storage and rates of changes in dormancy and response to the different storage conditions showed that species with several types of dormancy characteristics are able to co-exist (McIvor and Howden, 2000). According to those authors, generally, dormancy declined with time in such a way that the rate of greatest decline occurred in the seed exposed on the soil surface and least for those stored in the laboratory. There was an approximately linear increase in germination rate over time for all storage treatments and germination rate of seeds stored on the soil surface, was increased more rapidly than those of seeds stored in laboratory and oven. Those authors suggested that almost all species germinated faster after exposure on the soil surface than after storage for the same time in the laboratory.

Liu *et al*. (2005) studied the storage behaviour of dormancy and various methods for breaking the dormancy of *Garcinia cowa* seeds in connection with ecological function and germplasm conservation and opined that thick seed coat of *G. cowa* seeds act as a mechanical barrier to both water permeability and radicle protrusion. The failure of germination would be attributed mainly to dormancy and no water-soluble inhibitors exist in the seeds. The most effective method of breaking seed dormancy reported was the total removal of seed coat.

On the basis of seed morphology and germination behaviour, a category, known as recalcitrant seeds are characterized by larger size, high moisture content and short life span (Chin *et al*., 1984). It is generally believed that recalcitrant seeds never go into dormancy but instead continue their development and progress towards germination (Berjak *et al*., 1990). Well-documented aspects of recalcitrant seeds are desiccation-sensitivity

(Berjak and Pammenter, 2001; Kermode and Finch-Savage, 2002) and mode of storability (Finch-Savage, 1992; Tompsett and Pritchard, 1993). According to Pammenter *et al*. (1998) and Pammenter and Berjak (1999; 2000a; b) desiccation sensitivity is probably an ancient character with tolerance having evolved independently a number of times and recalcitrance places constraints on the regeneration niches open to the species producing such seeds.

Although recalcitrant seeds shed with very high moisture content, they vary in the initial water content, extent of dehydration they tolerate, their response to drying rate, shortage of life span and response to low temperature (Pammenter and Berjak, 1999). Recalcitrance is presumed to be highly significant ecologically. High moisture content of the recalcitrant seeds is similar to vegetative tissue, which is sensitive to desiccation. According to Oliver and Bewley (1997) this character is ancestral and tolerance is evolved independently a number of times, including more than once in the angiosperms. von Techman and van Wyk (1994), Pammenter and Berjak (2000a; b) also agree with the view of Oliver and Bewley (1997).

As mentioned earlier, a characteristic feature of recalcitrant seeds is their short life span and it will place constraints on the range of environmental conditions in which regeneration through seeds can occur. Recalcitrant seeds are common in mesic tropical forests and these conditions would be favourable for germination and seedling establishment and hence there has been no pressure driving the evolution of desiccation tolerance and seeds of these species, are not often found in soil seed bank since their life span is short and these seeds never show dormancy (Pammenter and Berjak (1999; 2000 a; b).

Garwood and Lighton (1990) suggested that seed respiration rates provide new insight into the physiology of recalcitrant seeds since viability apparently depends on the availability of oxygen as reported earlier by King and Roberts (1980) and Tompsett (1983).

Dussert *et al*. (2000) studied the relationship between seed desiccation sensitivity, seed water content at maturity and climatic characteristics of native environments of nine *Coffea* species and very highly significant correlation was found between the duration of seed development and the duration of rainy season in their native environments. Flowering in all *Coffea* species occurred only a few days after the main rain fall marking the end of the dry season and mature seeds were shed at the end of the rainy season. According to those authors, no significant correlation existed between the level of desiccation sensitivity as quantified by the water content or the water activity at which half of the initial viability was lost, and the duration of seed development or the seed water content at maturity. However, level of seed desiccation tolerance was significantly correlated with the number of dry months following seed shedding. So a higher level of desiccation tolerance corresponds to an adaptation to drought

Desiccation tolerance is an important functional trait and is an integral part of plant regeneration ecology (Tweddle *et al.*, 2003). Those authors opined that about 92% of spermatophyte species tolerate desiccation permitting the moisture content to reduce to low levels. In addition, the level of drying that recalcitrant seeds can tolerate vary due to range of other factors including seasonal differences in the extent of pre-shedding drying (Finch-Savage and Blake, 1994) and environmental features such as post harvest drying conditions (Berjak and Pammenter, 1994).

It has been recognized that moist tropical forest trees show high frequencies of desiccation sensitivity (Vazquez-Yanes *et al.*, 1999; Farnsworth, 2000) while species from arid and highly seasonal habitats are overwhelmingly desiccation tolerant (Dickie *et al.*, 1992, Hong *et al.*, 1998). Similarly, desiccation sensitivity at the seed stage is more frequent among species having non-dormant seeds compared to dormant seeds (Farnsworth, 2000; Pammenter and Berjak, 2000 a; b; Dickie and Pritchard, 2002).

By analysing the data set of 886 trees and shrubs from 15 vegetation zones Tweddle *et al.* (2003) agreed with many of the above views and suggested that seeds of species from moist habitats are desiccation sensitive than from highly seasonal or arid habitats. Those authors further opined that non-pioneer evergreen forest trees produce desiccation-sensitive seeds and desiccation sensitivity at the seed stage is more frequent in species having non-dormant seeds compared to dormant seeds.

In a study of ecological implications of 225 tree and shrub taxa consisting of 36 recalcitrant and 189 orthodox seeds from semi-deciduous tropical forest in central Panama, Daws *et al.* (2005) reported that desiccation sensitive seeds are larger than desiccation tolerant seeds and desiccation sensitive seeds germinate more rapidly resulting in reduced duration of seed exposure to predation and low investment in the physical defense and desiccation sensitive seeds are more efficient in using resource based on seed mass. On the other hand, seeds produced by desiccation – tolerant pioneer species rely on the occurrence of open (high-light) microsites for successful germination and seedling establishment. The less rapid germination and greater speed of seedling development period of the seeds of pioneer species may be advantageous in an environment of unpredictable rainfall. According to those authors, in habitats of benign, uniform climate that are continuously conducive to germination and seedling establishment, there may be no selection driving the evolution or maintenance of desiccation tolerance, particularly for large seeds that will dry slowly.

An important method to study germination biology of seeds is comparison of germination among groups of species classified with respect to various criteria including life pattern, family, geographical distribution ecology, seed shape, weight, storage behaviour and colour (Grime *et al*., 1981). In a comparative study of seed germination biology of a local flora, those authors suggested that marked differences existed in the capacity of freshly collected seeds for immediate germination and dry seeds exhibited increased germination rate. Rate of germination showed a progressive decline with increasing seed weight and there was a positive correlation between the rate of germination and relative growth of seedlings. Another important observation was recurrent association between features of seed morphology and germination, which were related to ecological characteristics and therefore exist in several species.

Several factors in the environment- water, oxygen, light, temperature and many biotic factors determine whether or not germination occur and the rate at which it does so (Mayer and Poljakoff-Mayber, 1989; Bewley and Black, 1994). Dalianis, (1980) determined optimum temperatures for rapid germination, emergence and seedling elongation of Berseem and Persian clover in conjunction with studies of the effect of seed size and planting depth. The study revealed that seed size exerts no influence on germination, except that large seeds were inferior to other seed sizes in both species. However, there was a definitive superiority of large seeds over medium and medium over small in terms of seedling elongation rate and length. In addition, large seeds were superior to medium and to small at every planting depth in terms of seedling emergence rate and at deep plantings in terms of emergence percentage. At shallow depths seed size had no effect in Berseem clover, but medium sized seeds were superior in Persian clover.

By studying germination biology of 105 species of Australian plants, Jurado and Westoby (1992) elucidated that germinability, propensity to germinate at different temperatures and germination speed are related to plant growth form, perenniality, seed size and seed dispersal mode and those authors opined that in arid environments with unpredictable climate, plants select to germinate at times which give the best chance for seedling establishment. Almost all species produced at least some seeds, which were dormant, consistent with the idea that risk spreading was important in arid zones. However, dispersal mode and plant perenniality were not found to be associated with germinability. Seeds of most species germinated rapidly relative to high rainfall environments, as might be expected in an environment where wet soils were usually temporary. Faster germination tended to be associated with low germinability, suggesting a spectrum of strategies from species that risk a small number of their seeds in many rainfall events, to those that germinate only in large rainfall events but then risk large number of seeds.

Studies on the effect of storage and temperature on the germination response of two morphologically different categories of *Cassia tora* seeds showed that they were physiologically different (Bhattacharya and Saha, 1997). Almost 100% viability was retained in both categories of seeds up to 1 year of storage. Thereafter the viability of one category of seeds was lost more rapidly than that of the other category. An important observation was that the temperature sensitivity of one category of seeds restricted the germination to regimes or seasons of favourable temperature only. This probably compensated for the lack of hard seededness and the shorter viability period and helped the seedlings to emerge in a season when chances of survival were better. The production of a large number of seeds of two categories multiplied the chances of establishment and also assured wide distribution in time and space.

A comprehensive study on ecology of seed germination by Baskin *et al*. (2004) revealed that in the seeds of annual weeds- *Capsella bursa-pastoris* and *Descurainia sophia* originating from high northern latitudes, low temperature inhibited dormancy-breaking in winter and so those authors hypothesized that the seeds that mature at high latitudes in late summer and/or early autumn would not germinate until they had been exposed to high summer temperatures. Consequently, germination would be delayed until the second autumn. According to those authors most seeds of these two annual weeds that mature in late summer do not geminate in the first autumn, but they may do so the following spring or in some subsequent autumn or spring.

Thapliyal and Phartyal (2005) suggested that germination of seeds is programmed over a period of time and germination patterns of seeds reflect adaptive response to the seasonal changes in their habitat. An investigation on dispersal and germination syndromes of tree seeds in a monsoonal forest in northern India by those authors revealed that in most tropical forests, 3 month monsoon period is the prime determinant of all biological processes including seed germination, seedling establishment and plant growth.

Based on the results of their investigation, Thapliyal and Phartyal (2005) suggested six patterns of seed germination 1) average germination percentage of fresh seeds lower than that of stored seeds, indicating an after-ripening requirement. 2) initial high germination percentage followed by low values, indicating a steep to moderate decline in viability following harvest; 3) no germination after 1 or 2 months of seed storage, due to complete loss of viability, indicating short seed longevity. 4) fresh seed germination in some species equaled the average germination value of stored seeds, indicating constant germination for one whole seedling cycle; 5) Germination of both fresh and stored seeds remained constantly low throughout the season, indicating a requirement for some kind of pre-treatment or having poor quality of seeds; 6) initial high germination followed by decline and again increase, showing a seasonal rhythm of germination.

Seedling development and establishment also are dependent on ecology of habitat as well as metabolic potential of seeds. According to Molofsky and Augspurger, (1992), larger seeds produce seedlings, which emerge from a greater soil depth and are less affected by the smothering effects of leaf litter. Larger seeds produce seedlings with deeper roots so improving access to soil moisture during drought (Metcalfe and Grubb, 1995). The metabolic effect is reported to have lower potential of relative growth rate in seedling and indicate the inherently lower metabolic rate and so the resources would be consumed more slowly, allowing longer survivorship of seedlings in the face of a variety of hazards (Cornelissen *et al*., 1996; Wright and Westoby, 1999; Bloor and Grubb, 2003). Another possibility opined by Kitajima (1996a; b) was related to seed mass and the functional morphology of cotyledons and their character showed general correlation between seed size and seedling performance that occurs *via* the correlation between seed mass and functional morphology of the cotyledons.

Significant variations occur in the shape and function of cotyledons. Shape vary from laminar and primarily photosynthetic in function, to being globoid and predominantly concerned with storage and in the extreme case where they are completely enclosed in the seed coat, entirely storage in function (Kitajima, 1992; Garwood, 1996). Small seed-masses are often associated with photosynthetic type cotyledons, while storage-type cotyledons occur most frequently among larger-seeded species (Wright *et al*., 2000). The seedlings of larger-seeded species perform better because they have more mobilizable reserves available to them during times of carbon deficit as in deep shade or for interim support while replacing photosynthetic tissue lost through herbivory or mechanical damage. A greater proportion of seed reserves in larger seeded species remains uncommitted during seedling deployment and is thus held in reserve to provide seedlings that germinate in hazardous environments (Westoby *et al*., 1996). However, Saverimuttu and Westoby (1996) suggested that the reserve effect of cotyledons explains the greater seedling longevity in larger seeded species. In larger seeded species, a relatively greater proportion of original seed mass is found to be retained in the cotyledons to act as reserves for the newly expanded seedling (Kidson and Westoby, 2000). Green and Juniper (2004 a; b) refuted the concept of reserve effect and stated that no evidence exists to demonstrate the correlation between better seedling performance and larger seeded species.

The terms cryptocotylar and phanerocotylar are used to describe the permanence of cotyledons within the seed coat or endocarp. Duke (1969) recorded phanerocotylar germination as a general characteristic for the family Annonaceae, and also pointed out that cryptocotyly probably takes place in species with large seeds. Many authors use the word cryptocotylar when the cotyledons remain enclosed by the seed coat or endocarp, and phanerocotylar when the cotyledons emerge from these structures (Duke, 1965; 1969). The expressions epigeal and hypogeal germination are used to describe the conditions where the cotyledons are carried above or stay below ground surface, respectively, depending on the hypocotyl development (Rizzini, 1965; Kozlowski, 1972). Some authors consider the terms cryptocotylar and hypogeal to be synonyms (Duke, 1969).

In cryptocotyly, the seed may or may not be carried to above ground during germination; the situations in which the testa ruptures, the cotyledons develop chlorophyll, and the cotyledons remain at or below soil level or ensheathed in part by the testa. Cryptocotyly is part of syndrome of characters associated with certain modes of seedling development. Duke (1969) remarked that their first leaves are cataphylls. According to Ng (1978), the seeds of cryptocotylar species are larger and took longer time to germinate. Lack of endosperm and tree habit and large seeds are associated with cryptocotyly.

Phanerocotylar seedlings have either cotyledons or paracotyledons, the latter outnumber the former and alternate or opposite eophylls may be present. Garwood (1996) suggested classification of seedlings into five categories based on cotyledon's position and functions. Large amount of reserves favour growth under low-light conditions while small reserves and photosynthetic cotyledons favour fast growth in light-rich environments (Ng, 1978; Kitajima, 1996a; b; Garwood, 1996).

Ibarra - Manriquez *et al.* (2001) studied the seedling morphology of 173 trees and 37 lianas from a community perspective to identify major patterns of seedling functional types in a Mexican rainforest. Most common seedling type was PEF (Phanerocotylar Epigeal Foliaceous) followed by CHR (Cryptocotylar Hypogeal Reserve), PER (Phanerocotylar Epigeal Reserve), PHR (Phanerocotylar Hypogeal Reserve) CER (Cryptocotylar Epigeal Reserve). Animal dispersal syndrome of heaviest fleshy seeds was correlated with CHR type and PEF seedling associated with the lightest seeds of pioneer species. The results showed an evolutionary convergence of seedling types at the community level worldwide and the existence of a phylogenetic inertia in the evolution of initial seedling morphology. Those authors suggested that survival of the fittest seedlings depended on the seedling morphology or seedling types which consisted of size, function, position of cotyledons and the amount of maternal seed reserves. Based on phylogenetic signal tests, closely related species typically had similar cotyledon types, but did not have similar seed sizes, supporting that cotyledon morphology is phylogenetically more conservative than seed size (Garwood, 1996).

Species with photosynthetic cotyledons use light energy as an energy source earlier than those with reserve cotyledons (Kitajima, 2002). Reserve cotyledons, on the other hand provide resources to support seedling energy demands during times of stress and may be an adaptation to growing in low light (Ibarra- Manriquez *et al*., 2001).

Franceschini (2004) reported an unusual case of epigeal cryptocotylar germination found in *Rollinia salicifolia* Schltdl. (Annonaceae) and described and discussed the seedling morphology in relation to the terminology used for germination studies. The morphological characters shown by *R. salicifolia* seeds and seedlings - a non-chlorophyllous embryo, abundant endosperm, thick woody seed coat, thickened hypocotyl and non-photosynthetic haustorial cotyledons - are closely related to its epigeal cryptocotylar germination.

Maia *et al*. (2005) analysed the relation between seed size, seedling morphology and germination for 11 non-pioneer tree species typical of Amazonian Varzea floodplain forests and presented a classification of seedling morphology and establishment strategies. The seedlings were classified according to seed weight and size (length x width) and the position and function of their cotyledons. The most frequent seedling type was PEF (Phanerocotylar Epigeal Foliaceous) followed by CHR (Cryptocotylar Hypogeal Reserve), PHR (Phanerocotylar Hypogeal Reserve) and PER (Phanerocotylar Epigeal Reserve), which also had the smallest seeds and the highest germination percentages.

Based on morphological and functional features, the seedlings of dicotyledonous plants were divided into 17 distinct types by Ye (1983). The most primitive type of dicotyledonous seedling is the ‘Polyalthe Type’. Its seedling morphology is similar to that found in the seedlings of *Cycas* and *Ginkgo*, and perhaps similar to those of seed ferns. According to Ye (1983), the "Magnolia" type is evolutionarily more advanced. From the Magnolia type several different evolutionary lines resulted in different seedling types. A number of evolutionary ‘dead ends’ arose from the ‘Polyalthe type’. These are restricted to families of Magnoliidae.

Paria and Kamilya (1999) suggested that seedling morphological characteristics of different taxa could be utilised in the context of Plant taxonomy. According to those authors, a good procedure for identifying plants depends upon keys in which some discriminating features are taken into account and in their investigations in Euphorbiaceae, seedling characters have been used in the construction of keys for identification. The preliminary analysis of the distribution of seedling characters in the Euphorbiaceae suggested that they may prove quite important in phylogenetic studies of the family.

Seedlings of one species are usually uniform, although they may differ in measurements of parts and speed of development. The organs and characters of seedlings are limited in number, but their diversity is much and as such, specific combinations of morphological characteristics may be used for identification of species. In view of paucity of such data in Indian Flora, an attempt has been made to investigate the seedling morphology of Euphorbiaceae (Paria and Kamilya, 1999), Bignoniaceae (Paria *et al.,* 1995), Asteraceae (Ahammed and Paria, 1996), Polygonaceae (Kamilya and Paria, 1993) and Leguminosae (Paria *et al.*, 2006) which offered ample scope for the construction of artificial keys for identification.

Seed germination and seedling development have been studied in *Myrtus communis* to elucidate the presence of morphological and anatomical adaptations that enhance successful seedling establishment under biotic and abiotic stresses (Aronne and De Micco, 2004). Those authors suggested that on water scarcity, a dense ring of hairs was developed in the lower region of the hypocotyl, which helps in water absorption and also in anchorage. Early development of suberized layer of exodermis in the radicle and phenolics in the hypocotyl cortical parenchyma also were noticed. These characteristics are formed to a strategy of water absorption, anchorage and also act as defense against animal predation through phenolics. According to those authors, these features together with the absence of dormancy, fast germination and high germinability can be considered advantageous in order to maximize reproductive success, seedling establishment and survival in Mediterranean environments.

Jain (1982) opined that adaptations, of seed/seedling to environmental changes or phenomena require that the behaviour of plants should be synchronized with change of the prevailing season. Examples include annual grassland communities possessing seeds with after-ripening requirement for germination which is linked with probability of summer rainfall and dormancy-cycling in buried seeds of annuals of humid temperate climates (Baskin *et al*., 1993; Baskin and Baskin, 1998; Baskin and Baskin, 2001).

An investigation undertaken by Hodgson and Mackey (1986) revealed that the major families in the Sheffield region of Central England are specialized to varying degrees with respect to three ecologically important attributes: growth rate, seed size and germination behaviour. These attributes help many species in evolutionarily advanced families to exploit highly productive and disturbed habitats and to exploit the less productive habitats by a large number of species of primitive families consisting of a greater proportion of rare species. Lesser number of heavier seeds with large reserves produced usually on apical or basal placenta will increase the probability of seedling establishment under unfavourable environmental conditions as in the shaded environment of woodland. Biennials tend to have heavier seeds than annuals. Seed weight is to some extent a function of plant height. Families with endospermous seeds usually produce large seeds in moist environment and the embryo is small, and a period of embryonic growth, with the seed in an imbibed state, may follow seed set and precede germination. Even though, two-celled form of proembryo development is characteristic of larger seeded families, it usually prevails in drier habitat and together. In dry habitats, if seed coat is impervious, a non-endospermic seed with a relatively large embryo is favoured. These conclusions reached above can be used to provide an idealized classification of seeds within a local flora. If the interrelationship between seed size and other attributes have a general relevance, the distribution of the familial character status may be used to predict lines of ecological specialization within the Dicotyledons.

Species with small seeds, small seedlings, thin photosynthetic cotyledons, fast germination, small adult stature and dispersal by small animals were associated with open habitats. Many of these relationships are well documented (Ng, 1978; Garwood, 1996; Kitajima and Fenner, 2000; Ibarra–Manriquez *et al*., 2001). According to Kitajima and Fenner (2000), Leishman *et al*. (2000) and Westoby *et al*. (2002) seed dispersal mechanism and cotyledon types and function are directly related each other and are dependent on ecological conditions. For example, photosynthetic cotyledons are advantageous in high light environment where small seed size can be compensated for the faster autotrophic growth. Ibarra–Manriquez *et al*. (2001) opined that reserve cotyledons provide resources to seedling during time of stress and it is an adaptation to grow in low light.

A correlation between evolutionary and ecological aspects of early seedling morphology in East African Trees and shrubs species drawn by

Zanne *et al*. (2005) revealed that seed size and cotyledon morphology are two key juvenile traits that have evolved in response to changes in plant species life history strategies and habitat associations. According to those authors, species with large seeds, large seedlings, thick storage cotyledons, slow germination, large-stature adults and dispersal by large animals were common in forest and gap habitats. An opposite suite of traits was common in open habitats.

3.1 STUDY AREA

Field study was conducted for a period of two years from January 2005 to December 2006. Regular trips to the entire area of Calicut University campus enabled the author to observe phenology of flowering and fruiting of almost all plants in general and angiosperms in particular.

The study includes observations of inflorescence/flower colour, fruit development and collection of mature fruits whenever they were available, during the two-year period 2005-2006, encompassing a wide range of seed sizes and cotyledon types. Species with fruiting frequencies greater than two years or at lower densities were more likely to have been missed. Many herbs and grassland species were unable to be sampled. Ripe fruits/seeds at the point of natural dispersal were collected from several plants as far as possible, according to the availability.

The establishment and maintenance of a large and representative seed collection of native species is essential for the continuity of comparative work. Seeds were collected in as large a quantity as possible taking care to sample at random without bias towards larger or taller infructescences.

3.1.1 Meteorological Data and Geography

Calicut University campus is located 10 km away from the meteorological station at Kozhikode Airport at Karippur, where rainfall, maximum and minimum temperatures, relative humidity etc. are recorded daily.

Map of the Calicut University Campus was downloaded from the Google Earth of Internet. Geography of the area was referred from Kerala Gazetteer of Malappuram District – published by Adoor K.K. Ramachandran Nair, printed at Government Press, Ernakulam (Anonymous, 1986). Meteorological data of Kozhikode airport was obtained from the India Meteorological centre, Thiruvananthapuram.

3.1.2 Phenology

To all appearances, healthy individuals on different micro sites were selected for study. Flowering comprises floral bud initiation, anthesis and floral persistence (Rathcke and Lacey 1985). However, when observing very tall trees only the blossoming phase could be clearly distinguished. Since the transition from flowering to fruiting is gradual, fructification was recorded only when fruits became visible. Fruiting period of a species was considered as the duration from the first fruit formation to the last amongst its individuals.

Phenology of flowering and fruiting of the plants was studied mainly based on observations, which were recorded almost daily from January 2005 to December 2006. The presence of flowers and fruits was noted with the aid of binoculars, in certain cases. If any plant of a species had flowers or fruits, the species as a whole was considered to be flowering or fruiting during that month. This method was followed because some species do not have synchronous flowering or fruiting patterns. Character classification, descriptive terminology and colour terms were obtained from Radford *et al*. (1974); Stearn (1992).

3.1.3 Identification and Field note

While collecting specimens, the information such as plant nomenclature, family, local name, ecological note, date of collection, habit etc. and detailed information like phenology and morphology of flowers, fruits as well seeds were recorded in the field book. Each plant species was designated by a code letter ‘K’ followed by a serial number (1-92) as per the order of collection, represented as Kn.

The highly organized library and the Taxonomy division of the Botany Department were very helpful for the identification. Identification of the plant species were confirmed by consulting the various floras such as Gamble and Fischer (1915-1936), Manilal and Sivarajan (1982), Matthew (1983), Sasidharan and Sivarajan (1996), Sivarajan and Mathew (1996), Mohanan and Sivadasan (2002), and Sasidharan (2004), besides referring different research articles and periodicals published time to time. Reference for author citations and abbreviations obtained from Brummitt and Powell, 1992. All the same, it had been further reconfirmed by consulting the concerned herbarium sheets at Calicut University Herbarium (CALI). The nomenclature were updated mainly by consulting Sasidharan (2004). Data on life form, habitat and dispersal agents are from personal observations and from the published literature.

3.1.4 Seed Dispersal

The seed dispersal modes were inferred from fruit morphology, observational data on dispersal agents, taken from the literature (van der Pijl, 1972; Weberling, 1989) and the author's direct observations in the field. The dispersal syndrome of each species was deduced from the diaspores (fruits or seeds) and field observations.

For each species the timing of dispersal was classified based on whether dispersal occurred in low (3.56 -121.47), average (124.27-243.57) or high (251.9-756) mm rainfall period.

Fruits dispersed by birds and mammals (zoochory) included fleshy fruits, arillate or mimetic seeds. Fruits or seeds with laminar expansion like wings or trichomes were considered as wind dispersed (anemochory). Explosive species possessed generally capsular fruits that eject their seeds at varied distance from the mother plant (autochory). Fruits without any apparent characteristic described above, were classified as dispersed by gravity (barochory). Association between seedling type and dispersal mode was assessed contrasting animal vs. non-animal.

3.2 COLLECTION/HARVESTING

Freshly collected fruits / seeds were used in all the experiments. These were mostly collected from many parent plants depending on the availability. It is likely, however, that some collections came from a single parent. For some species, ripe seeds were available for several weeks or months, in others availability of seeds was only for a few days.

3.2.1 Shelling of fruits and cleaning of seeds

Fruits after collection were brought to the laboratory and shelled and seeds were cleaned manually. Fleshy fruits were cleaned by removing the pulp on the same day of collection so as to guard against fungal infection and decay or fermentation. They were cleaned in running tap water by rubbing on sieves to remove the pulp. Seeds with sarcotesta were cleaned with paper, cloth or sawdust to remove the sarcotesta and washed thoroughly in running water. Tiny dry fruits were tied loosely in muslin cloth and threshed within it to extract the seeds and the chaff removed by blowing slightly. Wings, Kapok, Pappuses and flesh were also removed from seeds. To improve seed purity, removal of seeds of other plants, empty seeds and other contaminants was done by handpicking/winnowing. Air current was used to separate lightweight materials according to their terminal velocities. The cleaned seeds were spread evenly at room temperature for a short while and they were used for germination tests.

3.2.2 Measurement of seed size and weight

Individual seed weight was determined from a group of 5-50 seeds in the case of small seeds or from the individual weight of each seed for normal seeds as the case may be. Data of seed weight was represented as ‘thousand seed weight’ (TSW). Likewise, the measurements and morphology of the seeds and the total weight of seeds per fruit were also taken to find out the shelling percentage. The seed size was measured using a grid/graph paper under dissection microscope.

Shelled and cleaned seeds were grouped into three lots and used for storage and germination studies. One lot of seeds was kept for germination immediately after shelling as fresh seeds (KnD), second lot of seeds were air dried (KnDA) under laboratory condition (30 ± 3°C) and the third lot of seeds was subjected to sun dry (KnDS). Seeds of all the three treatments were used for moisture content determination and germination studies. After air drying/sun drying, the seeds were packed in sealed polythene bags (150 gauges) by labeling the code of the stored sample (SKnDA/SKnDS) and date of packing, and stored at room temperature in the laboratory.

3.2.3 Shelling Percentage

Weights of 10-20 individual fruits were taken and the average value was calculated. Total weight of seeds of individual fruits (10-20) also were taken. All weights were taken using Schimadzu electronic balance. Shelling percentage was calculated using the formula,

$$\frac{\text{Weight of total seeds /fruit}}{\text{Weight of fruit}} \times 100$$

3.3 GERMINATION STUDIES

3.3.1 Moisture Content

Seed moisture content (MC) was determined by drying pre weighed (FW) seed lot of about 5-50 seeds per species depending on the seed size at 100^{o}C for 1 hour and then at 60^{o}C in a hot-air oven until a constant weight (DW) was obtained. Moisture content was calculated according to ISTA rules (1985) using the formula,

$$MC = \frac{(FW - DW)}{FW} \times 100$$

3.3.2 Petri dish Germination

One lot each of fresh, air-dried and sun-dried seeds were used for germination in Petri dish.

Counted batch of seeds were placed on 2 layers of whatman No.1 filter paper dampened with distilled water in a well labeled 11 cm (diameter) Petri dish. They were incubated at room temperature in dark in the shelves of a cupboard except for approximately 20 minutes of light per day when germination count was made and filter paper was dampened or changed. To prevent molding, filter paper was changed after every week or alternate weeks.

Very big seeds, which were difficult to germinate in Petri dishes, were placed on moist cotton in transparent plastic boxes or rolled in moist germination paper towels.

A seed was recorded as germinated, once the radicle has emerged. Germinated seeds were counted and removed daily. Very small seeds were observed under a dissection microscope. Any seeds, which did not germinate during the study period, were dissected or crushed and classified as dormant if the embryo and endosperm were firm and intact, or as dead, if the tissues become soft and began to decay.

3.3.3 Field Germination

One lot each of fresh, air-dried and sun dried seeds was used for germination under field conditions. Germination pots of various sizes (30-50 cm) were filled with cleaned sand. The number of seeds sown per pot was determined primarily by seed size and ranged from one per pot in the case of large seeded species to 100 for the smallest seeded species. Germination media were kept moist by regular watering and germination was recorded daily. Monitoring of germination ceased when no further seeds had germinated for at least 2 weeks. If the seeds of a species not decayed, monitoring period was extended. Germination was checked daily and all germinated seedlings were removed and planted separately to observe seedling morphology. Germination data were noted and further growth/ development was observed daily after de Vogel (1980). For each taxon, the mean time to germinate (MTG) was calculated using the following equation according to Daws *et al*. (2005).

$MTG = \Sigma (n \times d)/N$; where,

n = number of seeds germinated between scoring intervals;

d = the incubation period in days at that time point; and

N = total number of seeds germinated in the treatment.

Preliminary studies on seed germination behaviour showed that all seeds of many species are not germinable and some seeds remained ungerminated. Hence seeds of all species are classified as ‘readily germinable’ and that ‘required scarification’ (hard). Similar classification was followed in the case of air-dried, air-dried stored, sun- dried and sun-dried stored seed lots also.

3.3.4 Scarification

Seed lots that required scarification (hard) were subjected to mechanical method of breaking dormancy by rubbing with sandpaper.

3.4 SEED STORAGE BEHAVIOUR

As mentioned earlier, seeds of various treatments such as air-dried and sun-dried were stored in polythene bags and kept at room temperature. Germination studies in field were conducted on stored seeds after 6-8 months storage. Germination data were taken as described earlier.

3.5 SEEDLING MORPHOLOGY

Seedlings were harvested, morphological characters were noted and photographs were taken using Nikon D 100 camera. Some of the harvested specimens were preserved in FAA and/or pressed immediately. Herbarium specimens of seedlings are kept with the author. Morphology of cotyledons of some seedlings was drawn using the camera lucida of a WILD M5 stereomicroscope.

3.5.1 Cotyledons

Cotyledon type was classified and described by a three-letter code according to Garwood (1996). The first letter of the code refers to cotyledon exposure: C (Cryptocotylar = inside seed coat), P (Phanerocotylar = free of seed coat). The second letter refers to cotyledon position: E (Epigeal = above ground), H (Hypogeal = at or below ground). The third letter refers to functional morphology: F (Foliaceous = thin and photosynthetic), R (Reserve = Storage).

3.6 PHOTOGRAPHS

Photographs of seeds, seedlings etc. were obtained with a digital camera (Nikon D100).

3.7 FORMAT AND PRESENTATION

Families of the concerned species are assigned following the classification of APG II (2003) and the orders to which the plants of the present study belong to are highlighted in the correlation phenogram (Fig.3). The correct name of each species is followed by the author/s name (nomenclature citations) and the names are arranged in alphabetical sequence in a tabular form (Table 2). The description of the species is in the following sequence - habit, phenology, inflorescence, flower, fruit and seed (Tables 4 and 5). Hierarchical taxonomic matrix system is provided for character description of plants and their interrelationship (Fig. 3.1 a-j). It is prepared with more emphasis on morphological characters to facilitate easy identification. Illustrations and photographs are provided for rare and interesting cases (Figs. 5, 10, 11 and 12). Seed size, shape, colour and surface architecture were compared using photographs (Fig. 7) prepared by exposing seeds mounted on graph paper (Bedell, 1998). As far as possible, the habits, flowers, fruits, seeds and various stages of seedlings were photographed so as not to miss any useful and important character details.

The format proposed by Radford *et al*. (1974) and Stearn (1992) was followed for general presentation of the data.

3.8 STATISTICAL ANALYSIS OF DATA

Names of the plants investigated are arranged in alphabetical order of botanical names with author citations. The data include family, habit, flowering and fruiting time, morphology of flower, fruit and seed and the accession number or code to each sample of the specimens.

The data presented in Microsoft excel worksheet were used for statistical analysis. Different statistical analyses were made, to understand the patterns of different parameters/correlation of each other, in the campus flora. The data were subjected to statistical analyses with the software SPSS.

3.9 BIBLIOGRAPHY

For reference citation in the bibliography section, accepted abbreviations of Journals were taken from Biosis (Anonymous, 1991).

4.1 STUDY AREA

4.1.1 TOPOGRAPHY

4.

Calicut University Campus area with enough level plots amidst the undulating terrain of profusely rocky hills interspersed with dry and moist valleys with its contour roads and beautiful patches of green paddy fields provides a very captivating natural picturesque setting (Fig.1). Laterite is widespread and forms extensive capping over the hard rocks. Small areas with clayey soils are also present in the valleys. As with every present day landscape of the Western Ghats, here also much of the tropical wet evergreen forest supports a large proportion of the plant diversity, which survives as such fragments in a human dominated matrix of cultivated plants and developed areas.

4.1.2 Meteorological Data

From the meteorological data obtained from Kozhikode Airport for the period of 2002-2006 average monthly rainfall of 5 years (2002-2006) was taken for correlating phenology of flowering as well as fruiting of plants in the study area. (Table 1, Fig. 2).

Average annual rainfall of 2002-2006 was 167 cm and the annual rainfall received during the South West monsoon months, i.e., June to September was about 81%. Rainfall in June and July, form about 44% of the total rainfall of the year. A fairly good amount of rainfall occurred as thundershowers during pre-monsoonal rain in April and May and post-monsoon months of October and November with a very little rainfall during Northeast monsoon season from December to February. For the present study instead of correlating monthly rainfall to phenological aspects of flowering and fruiting, rainfall readings were categorized into three classes namely low (3.56 to 121.5), average (124.3 to 243.6) and high (251.9 to 756 mm).

Since the investigation was carried out during 2 years (2005 & 2006), significant fluctuations have occurred in the rainfall (Fig. 2). Nevertheless, average rainfall of five years (Table 1) was taken into consideration for phenological studies of flowering and fruiting because the processes of flowering and fruiting take place as a result of continuous developmental changes particularly in perennial plants.

4.2 SYSTEMATICS OF PLANTS

Seeds of ninety-two taxa of the campus flora (angiosperms) were collected for the study (Table 2, 3). The classification suggested by APG II (2003) was followed as given in a correlation phenogram (Fig. 3). As per this phylogenetic classification (APG II, 2003), majority of the plants included in the present study, came under clades Eurosids I, Eurosids II and Euasterids I (Table 3, Fig.3). Magnoliids, Monocots, Eudicots, Core Eudicots, Rosids, Asterids and Euasterids II also were represented by a few species.

Botanical names of the plants included in the present study with author citation and their families, orders and clades are given in Table 2. Maximum plants (31%) of the campus flora come under Fabaceae followed by Verbenaceae (5%), Rubiaceae (4.3%), Myrtaceae (4.3%) and Apocynaceae (4.3%). Out of the total 35 families, remaining ones are represented by a few numbers coming in the range 1-3% of the total taxa (Table 3, Figs. 3.1a-j).

4.3 HABIT AND PHENOLOGY OF FLOWERING/FRUITING

Table 4 shows the habit, phenology of flowering /fruiting and mode of seed dispersal of each taxon. The flora consisted of 18 herbs, 37shrubs and 37 tree species. Phenology of flowering revealed that in almost all species, the flowering periods spread over was a period of 2 to 8 months while some species produced flowers throughout the year. Phenology of fruiting also followed more or less similar pattern as that of flowering phenology (Fig. 4).

Seed dispersal was found to occur by both non-living and living agents in herbaceous plants whereas in shrubs more plants showed dispersal by living organisms in comparison with the non-living agents (Table 4). Almost similar trend was shown by trees also. Generally seed dispersal by living agents was more compared to that by nonliving agents.

4.4 MORPHOLOGY OF REPRODUCTIVE STRUCTURES

General morphology of inflorescence type, flower colour, fruit morphology such as colour, texture and shape, seed morphology pertaining to colour, shape and surface architecture are given in Table 5. Almost all types of inflorescences occurred in the plants included in the present study (Table 5). Figure (5) showed the variations in fruit morphology and variations in seed size, shape and colour are given in Fig. (7).

4.4.1 Fruit morphology

Ninety-two taxa studied showed eighty-four species with simple fruits, seven with aggregate and one with multiple fruit (Fig.5). Twenty-eight fruits were dehiscent; twenty indehiscent while thirty-two were fleshy fruits. Most common type of fruit observed was a legume, which was dehiscent, or an indehiscent pod. Drupe, berry, capsule, utricle, follicle, achene, lomentum, samara, carcerule and schizocarp were the different types of fruits observed in the study. About eighty fruits were dark coloured while twelve were light coloured. Utricle was seen in *Achyranthes aspera*, multiple syncarpium in *Morinda pubescens*, aggregate fruits in *Calotropis gigantea, Catharanthus pusillus, Helicteres isora, Polyalthia korintii, P. longifolia, Tabernaemontana heyneana* and *Uvaria narum*. Feathery achene or cypsela, characteristic of Asteraceae was noticed in *Tridax procumbens* and *Chromolaena odorata*, which were adapted for wind dispersal. Winged samara helping in wind dispersal was observed in *Hiptage benghalensis* and *Peltophorum pterocarpum*. Carcerule fruit, characteristic of Lamiaceae was seen in *Hyptis suaveolens, H. capitata* and *Leucas indica*

4.4.2 Shelling Percentage

Wide variations were observed in the values of shelling percentage distribution among the seeds of ninety two species and variation spread over was around 0.24% to 91.2% (Fig.6). Maximum shelling percentage was shown by *Zizyphus oenoplia* and *Tectona grandis* in which fruit weights were highly reduced compared to the seed weight whereas in *Averrhoa carambola* the lowest shelling percentage was due to negligible seed weight and highly succulent fruit wall. There was no significant variation between the shelling percentage values of orthodox and recalcitrant seeds. However, most of the recalcitrant and intermediate seeds were characterised by low shelling percentage values.

Generally, seeds developed during low and average rainfall showed comparatively more shelling percentage values whereas, low shelling percentage values were shown by seeds produced during high and average rainfall.

4.4.3 Seed Morphology

Morphological variations of the seeds are represented in table 5 and figure 7, where seeds are arranged based on seed size/weight. Variations in the spermoderm (seed surface) pattern were observed in the different taxa studied. They were mainly smooth, reticulate, tuberculate, foveolate or rugulate (Table 5). In *Pongamia pinnata*, the ornamentation was rugulate, but the rugae were broad and flat. The ornamentation was striate in *Hydnocarpus pentandra* while it was smooth in *Adenanthera pavonina*.

Amaranthaceae was represented by a single plant with very small seeds. Three plants came under Annonaceae with distinct seed morphological variations. Seeds of Apocynaceae were represented by four plants. Shape and size of these seeds were almost uniform, but one plant showed small oblong seeds. Araceae was represented by only one plant, seeds of which were of moderate size. Asteraceae was represented by two plants, with very small seeds appendaged with pappus hairs, which is a typical family character. One plant coming under Balsaminaceae was having very small rounded seeds with tuberculate surface architecture.

4.4.4 Thousand seed weight

Thousand seed weight (Fig.7) ranges from 0.2g represented by *Chromolaena odorata* of Asteraceae to 29,541g represented by *Entada rheedei* of Fabaceae. There were twenty one plants showing thousand seed weight below 10g represented by Amaranthaceae, Apocynaceae, Asteraceae, Brassicaceae, Balsaminaceae, Convolvulaceae, Fabaceae, Lamiaceae, Malvaceae, Phyllanthaceae, Solanaceae and Verbenaceae.

Weight-wise arrangement of thousand seed weight (TSW) distribution revealed wide variation between the members of the same family (Fig.7). For example, in Fabaceae, seed weight (TSW) varied from 1.5 gram to 29,541 g. Annonaceae seed weight varied from 76 grams to 1773 grams. In Salicaceae the seed weight variations was from 14 g to 1452 g, in Malvaceae it ranged from 1.4 to 992.54 g and in Myrtaceae seed size varies from 11.9 g to 999 g.

There are some other families, which are having negligible variations between the seed weight. Examples are, Asteraceae and Rhamnaceae with 0.2 to 0.4 g and 54 to 65 g variations respectively.

4.5 MOISTURE CONTENT AND SEED CLASSIFICATION

On the basis of moisture content, seeds were classified into orthodox, intermediate and recalcitrant (Tables 6 a, b, c). Eighty-one plants produced orthodox seeds, which contained moisture content in the range of 4.1 to 47.06%. Intermediate seeds were shown by three species containing the moisture content varying from 48.9 to 65.41%. Seeds having 39.47 to 51.9% moisture content were grouped under recalcitrant category by considering the most important quality of recalcitrant seeds, i.e. desiccation sensitivity and such seeds were produced by 8 species.

Classification and characterization of seeds produced by the 92 taxa of the present study were done on the basis of meteorological data i.e. rainfall of the campus. Correlations were drawn between rainfall status and various parameters such as seed storage type flowering- and fruiting phenology, seed dispersal mechanism, seed moisture content and seed weight (Table 6 a, b, c).

Under low rainfall period distribution of seed types showed maximum orthodox seeds followed by recalcitrant and intermediate seeds one each (Table 6a). Flowering of plants which produced fruits under low rainfall was distributed in such a way that minimum number of plants flowered under high rainfall whereas almost equal number of plants produced flowers under either average or low rainfall. Mode of seed dispersal in the plants that produce fruits in the low rainfall period included almost all mechanisms (Table 6a), mostly by non-living agents (autochory, anemochory etc.).

As mentioned above, almost all seeds produced by plants that fruit during low rainfall produced orthodox seeds and the moisture content of these seeds was around 18% in spite of the occurrence of one recalcitrant and one intermediate seeds with very high moisture content. Average seed weight of the seeds represented in terms of thousand seed weight is 157 g with very wide differences between each other (Table 6a).

The category of plants which fruit during average rainfall also produced orthodox seeds in most cases and one plant each bore recalcitrant and intermediate seed out of 34 taxa (Table 6b). Flowering phenology of the plants coming under this group was mostly fallen under average rainfall where as some plants flowered during low as well as high rainfall. Dispersal mechanism of seeds, produced by these plants that fruit during average rainfall was by living agents such as ornithochory, zoochory etc. with a few incidence of autochory or anemochory. Average value of moisture content of the seeds produced by these plants was around 25% in spite of the occurrence of one recalcitrant and one intermediate seeds with very high moisture content. Seed weight expressed as thousand seed weight (TSW) was very high and showed wide variations i.e., 0.4 to 4966 g.

Comparatively lesser number of plants comes under the group that fruit during the period of high rainfall (Table 6c). Out of 22 numbers, 6 plants were having recalcitrant seeds, one intermediate and the rest orthodox seeds. Flowering of this group of plants was occurred during low, average and high rainfall. Seed dispersal was found to be by means of living agents (Zoochory, Ornithochory etc.) in most of the cases. Maximum amount of moisture content was present in this group of plants due to the occurrence of more recalcitrant seeds. Thousand seed weight was the highest compared to other two categories of plants.

4.6 GERMINATION STUDIES

General observations of seed germination behaviour such as moisture content, germination percentage under Petri dish and field conditions, days required for germination, dormancy distribution, effect of scarification, drying and storage are given in Table 7. On the basis of above observations seeds were classified into ‘readily germinable’, which required no scarification, and ‘scarified’ seeds which possessed dormancy. Seeds showing very low germination rate were grouped under the category, which required scarification treatment. Thirty-two plants produced readily germinable seeds in which many of them showed cent percent germination in Petri dish (Table 7a). Mean time germination (MTG) of these readily germinable seeds varied widely. In the field comparatively more seeds were readily germinable. Most of the germinable seeds in Petri dishes showed comparatively more germination percentage in the field where mean time germination was very high. In addition to the germinable seeds in Petri dishes, a number of plants produced readily germinable seeds in the field.

Seeds, which did not germinate in Petri dishes and in the field, were scarified and thereafter subjected to germination in Petri dishes and in the field (Table 7b). ‘Scarified’ seeds of thirteen plants showed very high germination percentage (75 - 100%) in Petri dishes but a large number of seeds samples remained ungerminated. But under field conditions, the germination percentage was comparatively higher than that of the Petri dishes. A large number of scarified seeds did not germinate in the field. Mean time germination was shorter in ‘scarified’ seeds than the readily germinable seeds. Similarly MTG was more in the case of field studies compared to the Petri dishes. Even after scarification, considerable number of seeds remained ungerminated in the Petri dishes, some of which were found to be decayed and or became imbibed and soft while others remained as hard.

Seeds of 46 plants after air-drying exhibited very high germination rate without any treatment (Table 7c). In Petri dishes, most of the seed lots showed cent percent germination. The mean time germination varied from plant to plant. Air-dried seeds also showed very high germination percentage in the field. The number of plants, which produced readily germinable seeds, when air-dried, was more in the field than in the Petri dish. Mean time germination was more in the case of seeds germinated in the field than that germinated in Petri dishes.

Air-dried seeds, which were not readily germinable, after scarification, showed cent percent germination in many cases in Petri dishes and in the field (Table 7d). But a number of seed lots remained ungerminated even after scarification both in Petri dishes and in the field. Mean time germination varied widely irrespective of the germination in Petri dish /field.

Seeds of many plants when subjected to sun-drying were readily germinable in both Petri dish and in the field (Table 7e). Mean time germination varied from 1.2-140 days in Petri dish condition while in the field MTG was widely distributed in most cases as the spread over was 3-277 days.

In the case of sun-dried seeds of many plants which were not readily germinable showed cent percent germination after scarification in Petri, dishes (Table 7f). But in the field the number of plants, which produced seeds that required sun drying was comparatively lesser and the germination percentage also was less than the Petri dish-germinated seeds. Mean time germination was more in the field than in the Petri dishes. Sun dried seeds, which were not readily germinable, on scarification showed only negligible germination rate both in Petri dishes and in the field. The MTG was widely varied between the species.

Twelve seed samples were germinable in the field after air-drying and storage (Table 7g). Wide variations were observed in the distribution of mean time germination in air-dried stored seeds. Air-dried stored seeds, which were not germinable in the field, when scarified, showed germination in 14 species (Table 7h). But some seed samples showed very low germination percentage and most of them were not germinable. The mean time germination was comparatively shorter than the readily germinable sample of the air-dried stored seeds.

Sun-dried stored seeds showed ready germination only in sixteen plants in the field and their MTG varied from 2-399 days (Table 7i). Sun-dried stored seeds, which were not readily germinable, on scarification, exhibited only very feeble germination rate in the field and the MTG also was comparatively shorter (Table 7j). A number of seeds remained ungerminated even after scarification.

4.7 SEEDLING MORPHOLOGY

Ten types of seedlings were observed in the flora of Calicut University Campus and are classified as follows (Table 8, Fig. 8).

1. Cryptocotylar Epigeal Haustorial (CEH),
2. Cryptocotylar Hypogeal Haustorial (CHH),
3. Cryptocotylar Hypogeal Reserve (CHR)
4. Cryptocotylar Semi hypogeal Haustorial (CSH)
5. Hypocotylar Hypogeal Reserve (HHR)
6. Hypocotylar Semi hypogeal Reserve (HSR)
7. Phanerocotylar Epigeal Foliaceous (PEF)
8. Phanerocotylar Epigeal Reserve (PER)
9. Phanerocotylar Hypogeal Reserve (PHR)
10. Phanerocotylar Semi hypogeal Reserve (PSR)

Comparatively, Phanerocotylar type of seedling was abundant in the 92 taxa of the present study and total ten combinations were observed (Table 8,

Fig. 8). Cryptocotylar cotyledons occur only in seven species. Out of the 92 taxa, seedlings of one plant each produced Cryptocotylar Epigeal Haustorial (CEH), Cryptocotylar Hypogeal Haustorial (CHH), Cryptocotylar Semi hypogeal Haustorial (CSH) and Hypocotylar Hypogeal Reserve (HHR) and Hypocotylar Semi hypogeal Haustorial (HSR) type of seedlings. Cryptocotylar Hypogeal Reserve (CHR) type of seedling occurs in four species. Phanerocotylar Epigeal Foliaceous (PEF) seedlings are present in 62 plants while Phanerocotylar Epigeal Reserve (PER) seedling is produced by 11 plants. Phanerocotylar Hypogeal Reserve (PHR) and Phanerocotylar Semi hypogeal Reserve (PSR) types are occurred in 3 and 6 species respectively.

4.8 COTYLEDONS

Majority of the cotyledons came out of the seeds during germination and were mainly epigeous, foliaceous, photosynthetic, petiolate and entire. Deviations from this normal type also were observed.

Following are the various modifications of cotyledons found in the seeds of the taxa included in the present study. Descriptions are mainly based on the morphological modifications.

4.8.1 Figure and Shape

Generally, the cotyledons were of two types: thin or thick. Majority of them were thin with plane faces. The outlines of thin cotyledons were of different types. They were narrow and linear as in *Cyclea peltata*, *Datura metel* and *Achyranthes aspera* (Fig. 9a) or spatulate as in *Tridax procumbens* (Fig.11a). Lanceolate cotyledons were seen in *Cochlospermum religiosum* and *Solanum melongena* (Fig. 11b). Elliptic or subrhombic cotyledons were observed in *Psidium guajava* and *Leea indica* (Fig. 11c). Rhombic cotyledons noticed in *Memecylon umbellatum* (Fig. 10a). *Hyptis capitata* was with triangular cotyledons (Fig. 11d) while obovate cotyledons were seen in *Macaranga peltata*, *Gliricidia sepium, Cassia javanica, Senna alata* and *Evolvulus nummularius* (Fig. 11e). Ovate or cordate cotyledons were present in *Ixora coccinea, Tinospora cordifolia, Bixa orellana and Mimosa pudica* (Fig. 11f) while ovate-oblong cotyledons in *Samanea saman* (Fig. 11g) and oblong cotyledons were noticed in *Peltophorum pterocarpum (Fig11i*). Orbicular cotyledons were seen in *Tabernaemontana heyneana, Adenanthera pavonina, Urena lobata* and *Impatiens balsamina* (Fig. 11h).

The shape of the apex of the cotyledons also varied. They were of **1)** obtuse end as in *Macaranga peltata* and *Peltophorum pterocarpum* (Fig. 11i), **2)** acute end as in *Chassalia curviflora, Ixora coccinea and Morinda pubescens* (Fig. 11j) or **3)** emarginate as in *Hyptis suaveolens, Impatiens* *balsamina* and *Helicteres isora* (Fig. 12a).

Similarly, the shape of the base of the cotyledons also varied. For example, auricled cotyledons were observed in *Peltophorum pterocarpum, Mimosa pudica* and *Caesalpinia pulcherrima* (Fig. 11i). The prominent feature of the auricled cotyledons was the presence of small ear-like lobes (auricles) at their base destined to fill the vacant space inside the seeds.

In addition to the above mentioned variations of the thin cotyledons, there were thick ones showing **1)** plano-convex form as in *Quassia indica, Pongamia pinnata* and *Vigna trilobata* (Fig. 12b), **2)** concave-convex cotyledons in *Sterculia guttata* and *Centrosema pubescens* (Fig. 12c), **3)** thick, strap shaped and truncate in *Cardiospermum halicacabum and Allophylus serratus* (Fig.10b) or **4)** Lobed cotyledons as seen in *Vateria indica* in which cotyledons were thick, fleshy, plaited and lobed (Fig. 10c).

4.8.2 Surface of the cotyledons

Majority of the cotyledons were glabrous or smooth as in *Delonix regia, Senna siamea* and *Tamarindus indica* (Fig. 12d). Hairy cotyledons were observed in a few as in *Leucas indica* (Fig. 12e).

4.8.3 Exposure of the cotyledons

During germination, the cotyledons came out of the seed or remained with in it. **1**) Cryptocotylar: - Cotyledons were not exposed from the seed during germination as in *Clerodendrum viscosum, Polyalthia longifolia, Uvaria narum* and *Cajanus scarabaeoides* (Fig. 9b). **2)** Phanerocotylar: - Cotyledons came out from the seed during germination as in majority of the speciesas in *Bixa orellana* and *Solanum violaceum* (Fig. 9c). **3)** Hypocotylar: - Cotyledons ill developed or absent and major part of the seed was hypocotyl, in which the reserve was stored for the developing seedling. e.g.:- *Careya arborea* and *Garcinia xanthochymus* (Figs. 12f, 9d).

4.8.4 Position of the cotyledons

1) Epigeal: - Majority of the cotyledons came well above the soil level during germination due to the growth of the hypocotyl. eg:- *Rauvolfia tetraphylla, Calotropis gigantea, Cyclea peltata* and *Acacia auriculiformis* (Fig. 9e). **2)** Hypogeal:- In certain cases the cotyledons remained below the soil level due to suppressed growth of the hypocotyl and overgrowth of the epicotyl. eg:- *Syzygium cumini* and *Entada rheedei* (Figs. 10j, 12g). **3)** Semi hypogeal: - In some rare cases, even though epicotyl growth was prominent, hypocotyl also grown to some extent resulting in the raising of cotyledons at or above soil level. E.g.: - *Quassia indica, Sterculia guttata and Centrosema pubescens* (Fig. 10d).

4.8.5 Lifespan of the cotyledons

The cotyledons fell off easily after germination or they remained and grew along with the seedlings and were persistent and so there occurred different types of cotyledons based on duration.

1) Deciduous: The cotyledons finally fallen off as in *Cyclea peltata, Bixa orellana, Vateria indica* and *Sterculia guttata*. **2)** Caducous**:** The cotyledons fall off very early as in the case of *Cardiospermum halicacabum, Allophylus serratus, Centrosema pubescens, Vigna trilobata* and *Solena amplexicaulis*. In cryptocotylar species also the cotyledons were deciduous or caducous. In *Polyalthia longifolia* the cotyledons along with the seed were seen attached for a long period and were so deciduous. Cryptocotylar and epigeal cotyledons got detached during germination itself and were so, caducous. eg:- *Uvaria narum*. **3)** Macrescent: In certain cases cotyledons remain as withered or faded and will not fall off until the part which bears it is perfected as in *Hyptis capitata*.

4.8.6 Colour of the Cotyledons

1) Green - Usually the aerial cotyledons were thin, foliaceous and green in colour. e.g.:- *Rauvolfia tetraphylla, Senna alata, Catharanthus pusillus* and *Bixa orellana* (Fig. 10e). Thick green cotyledons were noticed in *Tamarindus indica, Adenanthera pavonina* and *Samanea saman* (Figs. 10h, i). **2)** Greenish white- Greenish white cotyledons were observed in *Vigna* *trilobata* and *Sterculia guttata* (Fig. 10f). **3)** Cream coloured cotyledons in *Entada rheedei* and *Vateria indica* (Fig. 10c). **4)** White cotyledons in *Polyalthia longifolia* (Fig. 10g) and **5)** Reddish brown cotyledons in *Centrosema pubescens* (Fig. 10d).

4.8.7 Functions of the cotyledons

Cotyledons are nutritive in function providing food to the developing seedling. The food may be stored in the cotyledons, absorbed from the endosperm or prepared by the cotyledons itself, according to which the cotyledons were of different types.

1) Photosynthetic: - About 68% of the seeds were with thin, green coloured, foliaceous and photosynthetic cotyledons. e.g.:- *Rauvolfia tetraphylla* (Fig. 10e). **2)** Reserve: - About 29% of the seeds were having thick, cream coloured, fleshy and storage cotyledons e.g.:- *Vateria indica* (Fig. 10c). **3)** Haustorial: - About 3% of the seeds showed thin, white, membranous and haustorial cotyledons which absorb food from the endosperm and were cryptocotylar. eg:- *Polyalthia longifolia* (Fig. 12h). **4)** Reserve cotyledons becoming Photosynthetic: - In certain epigeal cases, after germination, thick and reserve type cotyledons became green and foliaceous and the thickness of the cotyledons also varied. e.g.:- *Adenanthera pavonina* and *Samanea saman, (*Fig.10h, i).

4.8.8 Venation of the Cotyledons

The cotyledons showed venation, like the foliage leaves for the conduction of food materials. They were palmately nerved or pinnately nerved. **1)** Palmately nerved**:** e.g. - *Macaranga peltata, Bixa orellana, Peltophorum pterocarpum* (Fig.11i.). **2)** Pinninerved: e.g. - *Clitoria ternatea, Rauvolfia tetraphylla*, *Polyalthia korintii* and *Leea indica* (Fig. 11c). **3)** Vein indistinct or obscure: *Cyclea peltata, Adenanthera pavonina, Samanea saman* and *Mimosa pudica* (Fig. 11f).

4.8.9 Arrangement of the cotyledons

Like the foliage leaves the cotyledons also showed different arrangements and were opposite or alternate. **1)** Opposite: Usually the cotyledons were arranged in an opposite manner. e.g.:- *Delonix regia, Ixora coccinea*, *Impatiens balsamina* (Fig. 12a). **2)** Alternate: In certain rare cases, cotyledons were seen arranged singly in an alternate manner e.g. - *Sterculia guttata* (Fig.12i).

4.8.10 Direction of the cotyledons

The cotyledons were directed in different directions. **1)** Diverging laterally**:** Most of the cotyledons were seen diverging laterally as in *Cyclea peltata, Cassia javanica, Rauvolfia tetraphylla* and *Bixa orellana* (Fig. 9c). **2**) Facing each other vertically: In certain cases cotyledons were held vertically so that they were facing each other. Such cotyledons were sessile or short stalked and thick as in *Tamarindus indica, Adenanthera pavonina* and *Samanea saman* (Figs. 10h, i). In certain cases, such cotyledons are long petioled as in *Zizyphus mauritiana* or *Evolvulus nummularius (*Fig. 9f).

4.8.11 Stalk or Petiole of the cotyledons

Cotyledons were usually with a short stalk. But in certain cases sessile cotyledons were also observed. **1)** Sessile: Cotyledons were without stalk as in *Syzygium samarangense*, *Vigna trilobata* and *Adenanthera pavonina,* (Fig.10h). **2)** Short stalked: Usually the cotyledons were short stalked as in *Cassia fistula, Phyllanthus reticulatus, Bixa orellana, Impatiens balsamina,* and *Senna siamea* (Fig.12a). **3)** Long petioled**:** Long petioled cotyledons were observed in few cases as in *Hyptis capitata, Tectona grandis, Urena lobata, Hyptis suaveolens* and *Hydnocarpus pentandra* (Figs. 9g, h). **4)** Radical: some of the long-petioled cotyledons were arising vertically from near the ground level, but placed well above due to the length of the stalk and they were connate at the base to provide additional strength to carry the cotyledons well above to stand upright e.g.: - *Zizyphus mauritiana* (Fig. 9f).

4.8.12 Insertion of the cotyledons

1) Basal: The petiole was usually attached at the base of the cotyledon lamina as in most cases e.g.: - *Chromolaena odorata*, *Hyptis capitata* and *Tectona grandis* (Fig. 9g). **2)** Peltate: The insertion of the cotyledons was between the margins slightly beneath the centre. E.g.: -*Tamarindus indica* and *Samanea Saman* (Fig. 11g). **3)** Subpeltate: The insertion of the cotyledons was between margins just above the base, e.g. - *Bixa orellana* (Fig. 12j).

In addition to the normal cotyledons of varying size and shape, there were a number of modifications observed among the taxa studied. Overgrowing cotyledons, which showed considerable growth after quitting the seed during germination, was a character of *Hydnocarpus pentandra* (Fig. 9h). Similarly unequal cotyledons due to variations in sizes were present in *Memecylon umbellatum* and *Bixa orellana* (Fig. 10a). In asymmetric cotyledons, two halves of one and the same cotyledon appeared as unequal e.g., *Bixa orellana (*Fig. 9c). Seeds of *Cyclea peltata* were very broad, but the cotyledons were narrow (Fig. 9a).

In certain cases, the cotyledons of all the seeds within the endocarp of the drupe fruit appeared as soldered together to form a single mass as observed in *Syzygium cumini* (Fig. 10j). During germination, a single 'seed' produced several seedlings and each seedling possessed two unequal/irregular cotyledons. Cotyledons were absent in *Garcinia xanthochymus* (Fig. 9d) seeds and in *Careya arborea*, the cotyledons were highly reduced and scale-like (Fig. 12f). In both these seeds, the reserve materials were stored in swollen hypocotyls, which appeared as cotyledons.

During the phenological studies of flowering, fruiting, seed biology and seedling morphology of the flora of Calicut University Campus, 92 taxa have been identified (Table 2, Fig. 3) and classified according to APG II systematics (APG II, 2003). In the revised and updated classification for the families of flowering plants provided by APG II, plants are classified phylogenetically. It became clear that none of the previous classifications accurately reflected phylogenetic relationships of flowering plants and the communications about plant evolution referring to the old classification schemes became increasingly difficult. To alleviate this problem a group of flowering plant systematists, calling themselves the Angiosperm Phylogeny Group (APG) proposed a new classification for the families of flowering plants (APG, 1998) and was updated in APG II (2003).

Since the APG II system is a phylogenetic classification, it is found clear that the plants included in the present study come under the families of primitive and advanced clades. Only a few plants (1-3) are coming under the primitive orders such as Magnoliales, Alismatales, Liliales, Ranunculales, Caryophyllales and Santalales. Majority of the plants are fallen in the advanced families of the clades Rosids, Eurosids I, Eurosids II and Euasterids I. These four clades are represented by more number of families, whereas other clades are represented by one or two families each (Table 3).

Earlier, a systematic study of the flowering plants of Calicut University Campus recorded 372 dicotyledonous and 75 monocotyledonous species during a period of five years (Sivarajan, 1974; Manilal and Sivarajan, 1976). Those authors emphasised only the enumeration of plants following Bentham and Hooker’s system of classification and listed the plant names based on the flowering time of each species. In the present study, the data obtained with respect to flowering and fruiting phenology which are related rather dependent on rainfall are analysed and correlated to seed, germination behaviour and seedling morphology of 92 species of the flora of Calicut University Campus.

Although in the area of present study, the seasonality exists, dry warm climate gradually ranges to wet season and hence the seasonality is considered based on rainfall and the present author adopted a classification as low-, average- and high- rainfall period (Tables 6a, b, c). Many studies on fruiting phenology of tropical plants report seasonality, ranging from the extreme in forests with distinct wet and dry cycles (Frankie *et al*., 1974; Hilty, 1980; Howe and Smallwood, 1982). According to Morellato *et al.* (2000), seasonal duration of flowering and fruiting is known to determine phenological behaviour of tropical plants. Fruiting phenology is known to be related to seasonality of a region (Bendix *et al.*, 2006), who opined that plants that flower in spring or summer, fruit later in the same year.

Observations of flowering phenology revealed that number of species (28) flower (Tables 9, 10) during comparatively dry season (December to May). This character has been reported in the pattern of flowering in the plants of Indian tropical forests (Singh and Kushwaha, 2006). The wide diversity of flowering and fruiting phenology of the species included in the present study is presumed to be due to 1) variation in the habit and vegetation in general, of the composite flora which include perennial trees that are sensitive to photoperiodic/thermoperiodic floral induction, 2) shrubs showing different duration of vegetative growth and 3) annuals with very short lifespan and so are characterised by comparatively early flowering and completion of life cycle and senescence within a short period. Nevertheless, rainfall plays a critical rather spatial and temporal role in the control of flowering in all the species one-way or the other.

According to van Schaik (1986), van Schaik *et al.* (1993) and Bollen and Donatl (2005), there is high variability in synchronicity of flowering and fruiting periodicity in many tropical plants. In accordance with the above view, synchronicity of flowering and fruiting occurs in a few species of the present study as shown by *Leea indica* and *Morinda pubescens* (Table 4).

Although synchronization of flowering with particular season of the annual cycle by many species appears to be under the control of prevailing climatic conditions of that season (Singh and Kushwaha, 2006), only some perennials of the taxa included in the present study exhibited synchronisation of flowering with season as observed in deciduous species such as *Cassia fistula* and *Delonix regia* (Table 4). This characteristic feature is reported to be very common in tropical plants in general and deciduous plants in particular (Justiniano and Fredericksen, 2000; Kushwaha and Singh, 2005).

Flowering/fruiting phenology variations of plants have been attributed to the positions in the canopy or sub-canopy of forest plants because of the variability in solar radiation (Justiniano and Fredericksen, 2000). However, the effect of canopy on flowering phenology cannot be attributed to the variation in flowering phenology of the plants in the present study because the Campus flora is not that thickly populated like forest flora and hence the effect of canopy on flowering/fruiting can be ruled out.

Tropical plants are sensitive to changes in day length (Richards, 1952; 1996) and according to Wright and van Schaik (1994), changes in day length may explain the regular seasonal behaviour of some plants in climates with no clear seasonal variation in temperature or rainfall. Most of the perennial trees of the Campus flora are characterized by annual flowering, but the seasonal climate of the study area is not with a distinct prolonged dry or moist period. Hence, the flowering of plants in the area is under the control of light to a certain extent and this observation is in consonance with the view of Wright and van Schaik (1994). However, changes in day length are responsible for regular seasonal behaviour since perennial plants exhibit seasonal (annual) flowering irrespective of the rainfall or temperature. Morellato *et al.* (2000) stated that despite low climate seasonality and in the absence of a dry season, phenological patterns of flowering and fruiting of Atlantic rain forest trees were significantly seasonal. An important feature of Atlantic rain forest was the ever green appearance with only few deciduous species and the peak seasonal leaf fall (Morellato *et al.,* 2000). In the present study also, despite the rare occurrence of deciduous species (*Cochlospermum religiosum, Cassia javanica, Gliricidia sepium* etc.), the greenish appearance is due to predominance of evergreen trees and shrubs (Table 4).

Normally, phenological events of flowering and fruiting are investigated over a period of several successive years and in most studies, emphasis is given to the relationship between meteorological data and phenology of plant developmental phases (Howe and Smallwood, 1982; van Schaik *et al*., 1993; Wright *et al.,* 1999; Bendix *et al*., 2006). However, in the present study, although an attempt is made to correlate flowering and fruiting phenology to one of the essential components of the meteorological data, the rainfall, continuous observation over a period of many successive years is lacking since the investigation was carried out only for two years.

Several species of the Campus flora exhibit flowering/fruiting during a few months in spite of the significant variations in the rainfall (Table 1) and it seems that those plants require no specific time-bound signal for floral induction and this speculation is in accordance with the view of Frankie *et al*. (1974) and Hamann (2004). At the same time, in several perennial species, a fairly well defined flowering periodicity, which coincides with a specific season, is obviously observed. This behaviour is corroborated with the view of Schongart *et al.* (2002), who suggested that tropical tree species show a short flowering period during a particular season of the year and the periodicity is repeated annually.

A number of species showed irregular fruiting compared to their flowering, indicating failure of fruit set since fruit abortion in many species occurred due to heavy rains and absence of pollination or other environmental factors may further be responsible (Wright *et al*., 1999). In the present study plants such as *Calotropis gigantea* that flower during September to April produce fruits mainly during January to March (Table 4). This species is characterized by anemochory and the dry period of January to March presumably encourages wind dispersal of the seeds (Table 4). The seed morphology showing tuft of plumose hairs is an additional adaptation for the anemochory.

According to Morellato *et al.* (2000) in spite of low climatic seasonality and absence of dry season in Atlantic rain forest, flowering of trees is significantly seasonal and concentrated during wet season. In the Campus of Calicut University, the flowering phenology of most of the trees (37 species) occurs during comparatively dry season and others are having prolonged flowering period (Table 4). Flowering and fruiting process are influenced by day length/photoperiodism (Salisbury and Ross, 1992; Wright and van Schaik, 1994 and Richards, 1952; 1996). Morellato *et al.* (2000) opined that fruiting phenology is aseasonal suggesting that climatic factors do not limit the fruit production and the fruit/seed production is dependent on rainfall as well as dispersal mode. In the present study the fruiting phenology varies as per the rainfall and hence the plants are classified accordingly for a comparative correlation (Table 6 a, b, c).

Seed dispersal is taken as one of the parameters for the present study of the flora consisting of 92 species and wind dispersal (anemochory) is a common character of plants that fruit during low rainfall period (Table 6a). Similarly majority of tree species show flowering as well as fruiting during low rainfall (Table 4) and hence the probability of seed dispersal by anemochory is more. Wind dispersal is a general character of canopy trees or vine or small trees (Howe and Smallwood, 1982). Those authors suggested that wind-dispersed plants are relatively common in dry habitats and animal-dispersal gain importance in wet habitat of tropical forest. According to

Frankie *et al*. (1974) wind dispersed fruits tend to be produced in dry seasons in deciduous forests of Northern Costa Rica. Conversely animal-dispersed (zoochorous) fruits tend to be produced during the wet months of the year.

When a comparison is made between the three periods of rainfall, (Tables 6a-c), zoochory is maximum in the average rainfall period whereas dispersal by nonliving agents was maximum in low rainfall period. According to Bendix *et al.* (2006) the fruit productivity is closely related to dispersal which is dependent upon or controlled by rainfall. Thompson (1981) suggested that a herb that fruit in spring normally adopt ant dispersal while that in late summer and autumn take advantage of migrant birds for dispersal. Plants of the same family in the same habitat may follow this type of difference in dispersal mechanisms based on seasonal changes.

Seed dispersal is positively correlated to fruiting phenology in such a way that anemochory is very common in dry season (Justiniano and Fredericksen, 2000; Ibarra-Manriquez *et al.*, 2001). In the present study, maximum species showed dispersal of seeds by non-living means during low rainfall and it gradually decreased through average- to high rainfall periods (Table 10). On the other hand, maximum dispersal was observed by living agents in plants having fruiting phenology during average rainfall period.

Seed size and weight vary widely among the species of the present study (Fig. 7). Variations in seed size (Martin and Barkley, 1961) and seed weight (Hodgson and Mackey, 1986) occur within each family and the seeds of some species may be more than 100 times heavy compared to those of other species from the same family. However, average seed weight of a family as a phenological trait cannot be taken as a criterion for evaluating the ecological or family-wise characterisation because, wide variations in size (Fig. 7) and weight were observed within the families of the Calicut University Campus flora. For example, seed size/weight of plants in Fabaceae varies from 1.5 to 29,541 g/1000 seeds (Fig. 7). In this group, wide variation exists in the habit of plants also. This may be the reason for significant difference in seed size of members in a family which is in accordance with the view of Corner (1976), according to whom seed size is restricted by plant size as shown in herbaceous habit in which case growing season is limited and rapid development from the flower to ripe seed, in fact occurs within weeks.

Most important parameters adopted for the study of seed morphology/ classification, by the present author include seed dispersal (Table 4), seed shape and size/weight (Fig. 7). Variation in seed size is not much significant in families like Asteraceae which is having 0.2 to 0.4 g/ 1000 seed weight (Fig. 7) and found to be correlated to anemochory. Wide variations in seed size, shape, surface architecture and weight occur in Fabaceae (Fig. 7), the thousand seed weight (TSW) of which varies from 1.5 to 29,541 grams as shown by *Alysicarpus vaginalis* and *Entada rheedei* respectively.

According to Augspurger and Hogan (1983), Foster (1986) and Ganeshaiah and Shaanker (1991), seed size is an important feature in determining the dispersal distances and survival of seedling. Seed size variations have been reported among families (Martin and Barkley, 1961; Foster, 1986), life form (Salisbury, 1974), habitat (Baker, 1972) and phenology of flowering (Foster, 1986; Mazer, 1989). In accordance with the views of Foster (1986), seed size variation is related to flowering phenology. In the present study ‘thousand seed weight’ values of different species are 0.2 to 25,833, 1.5 to 29,541 and 0.7 to 4,965 grams during low-, average- and high rainfall periods respectively (Table 6a, b, c). Seed size variation is observed between life forms in such a way that thousand seed weight values range from o.4 to 74.7, 0.2 to 29,541 and 1.4 to 25,833 grams in herbs, shrubs and trees respectively.

Wide variation in the fruit size may be due to fruiting time or season, which indirectly get influenced by different dispersal mechanisms (Murali and Sukumar, 1974). According to Murali (1997), species which fruit during rainy season produce heavier seeds and are with shorter viability than species which fruit during the dry season. In the present study, more or less similar observation is made in the trees of *Garcinia xanthochymus* and *Polyalthia longifolia* which fruit during rainy season and the seeds are comparatively heavier than most of the other seeds (Fig. 7).

Seed size/mass is also reported to be associated with desiccation sensitivity/tolerance (Hong and Ellis, 1997; 1998; Dickie and Pritchard, 2002; Pritchard *et al.*, 2004). Daws *et al.* (2005) opined that desiccation-sensitive seeds are significantly larger and typically shed during wet season and both these traits reduce the rate of drying and hence the risk of desiccation-induced mortality of desiccation- sensitive seeds. Those authors suggested that seeds of large–seeded species dry slowly and germinate rapidly reducing the duration of seed exposure to predation and hence only low investment is required for physical defence, and based on all these characteristics, desiccation-sensitive (recalcitrant) seeds are more advanced. It has been suggested that desiccation tolerance is the ancestral character of seeds and has subsequently been lost in species with desiccation-sensitive seeds (Farnsworth, 2000; Oliver *et al.,* 2000; Dickie and Pritchard, 2002).

Although recalcitrant taxa span a broad range of habits like herbs, vines, palms, canopy trees etc., most of them occupy wet forests, riverine, flooded or coastal environment and 79 % of the species are native to the tropics (Farnsworth, 2000). In the present study, out of 92 species only 8 bear recalcitrant seed types and most of them are trees (Table 7; Figs. 3.1.a - h).

The habitat of the study area is found to be viable for considerable occurrence of recalcitrant species in spite of the variations in rainfall and/or seasonality.

The taxa which produce recalcitrant seeds in the present study are *Polyalthia longifolia* (Magnoliids), *Dracaena* sps. (Monocots), *Syzygium cumini*, *S. samarangense* and *S. caryophyllatum* (all come under Rosids), *Garcinia xanthochymus* (Eurosids I), *Vateria indica* (Eurosids II) and *Careya arborea* (Asterids) and the percentage is only 8.7 of the total plants. Tweddle *et al*. (2003) reported that desiccation sensitive seeds are most common in tropical rainforests where they contribute more than 47 percentages of species.

Desiccation sensitive seeds are short lived and the sensitivity depends on many factors and most studied aspects are distribution of moisture content at the time of maturity or harvesting and desiccation sensitivity (Hong and Ellis, 1996; Pammenter and Berjak, 1999). Dussert *et al.* (2000) investigated the desiccation sensitivity of coffee seeds and stated that seed moisture content is not directly correlated with level of seed desiccation sensitivity, but highly significant correlation exists between the duration of seed development and that of the wet season. In the present study more number of seeds with high moisture content (41 to 44 %) and hence classified under recalcitrant, belong to the plants having the fruiting period of high rainfall, and these seeds are highly desiccation sensitive (Table 6c). This observation is in conformity with the views of Dussert *et al.* (2000) who reported a highly significant correlation between duration of seed development of nine species of *Coffea* and the duration of rainy season in their native environment. Conversely, in *Coffea racemosa*, seed development occurred during a period of about 2 months when rainy season was very short and seeds were found to be highly tolerant to desiccation (Eira *et al.,* 1999).

Apart from the recalcitrant seeds, 'intermediate' type of seeds (Ellis *et al*., 1990) also is observed in the study area. Seeds of *Amorphophallus hohenackeri, Averrhoa carambola* and *Sterculia guttata* showed 50-58% moisture content and are grouped under intermediate category due to more storability compared to recalcitrant seeds (Tables 6a, b, c). Even though the fruiting phenology of these species happened to be spread during low-, average- and high- rainfall, the moisture content was maximum in these seeds. Ellis *et al.* (1990) proposed the term 'intermediate' seeds which are slightly desiccation tolerant and the moisture content may be higher than recalcitrant seeds and the desiccation tolerance is not as high as that of orthodox seeds.

According to Tweddle *et al.* (2003), seeds of species from comparatively moist habitats are more likely to display desiccation sensitivity than those from highly seasonal and arid habitats. In tropical and subtropical areas, the proportion of species with desiccation sensitive seeds declines as the habitat become drier. Effect of different habitat on the longevity of *Syzygium cumini* seeds has been reported by Anilkumar (1998), who suggested that the seeds collected from the trees of tropical rainforest were viable only up to 7 days, whereas in the present study the *S. cumini* seeds collected from the Calicut University Campus showed longevity up to 14 days (Table 7), plausibly due to the comparatively drier habitat of the area of present study, than the tropical rainforest.

According to Daws *et al*. (2005), desiccation-sensitive seeds germinate rapidly and the mean time germination (MTG) values are short compared to desiccation tolerant seeds. The MTG of recalcitrant as well as intermediate seeds shows only negligible variation between the species except *Garcinia xanthochymus*, which is having dormancy (Table 7a). Immediate germination is one of the important characteristic of recalcitrant seeds and hence MTG values are very low, indicating the readily germinable nature of recalcitrant seeds (Pammenter and Berjak, 1999).

Seed storage studies revealed that average germination percentage of fresh seeds of some species was lower than that of stored seeds indicating the requirement of an after-ripening. In the present study, *Hyptis capitata* and *Mukia maderaspatana* seeds are found to require an after-ripening period (Table 7). Seeds of *Rauvolfia tetraphylla* and *Peltophorum pterocarpum* are characterised by reduced germination percentage due to storage and this observation is in agreement with the view of Thapliyal and Phartyal (2005). Another important observation made by those authors was complete loss of viability of seeds due to storage during 1 or 2 months indicating short seed longevity as observed in *Syzygium cumini* included in the present study. According to those authors, germination percentage of fresh seeds equalled the germination value of stored seeds in certain cases. They opined that in some trees, the germination percentage of both fresh and stored seeds remained consistently low throughout the season indicating a requirement for some treatment. Similar seed behaviour is seen in *Cassia javanica and Mimosa diplotricha* seeds of the present study (Table 7). According to Thapliyal and Phartyal (2005), storage of seeds also results in an initial high germination followed by decline and again increase showing a seasonal rhythm of germination and in *Solanum melongena,* of the present study, more or less similar type of germination behaviour is observed (Table 7).

Results of many comprehensive studies (Baker, 1972; van der Pijl, 1972; Grime *et al.,* 1981) showed that flowering plants differ considerably with respect to the number, size, shape and dispersal mechanism of their seeds and fruits. Even though germination behaviour is considered as a parameter for the comparison between different species of Calicut University Campus flora, the variations within the seed population of the same taxa are not studied independently because seed polymorphism may result in the production of 2 or more distinct types of seeds, which differ in their dormancy/germination requirements. The germination characteristics of the flowering plants included in the present investigation show significant variations among the different species. Marked differences occur in the germination capacity of freshly collected seeds. Out of 92 species examined, 32 species exhibited above 40 % germination and are designated as readily germinable seeds in Petri dish (Table 7a), whereas in the field more number (55) of species produced readily germinable seeds.

According to Grime *et al.* (1981), with increasing seed weight, there is a progressive decline in the representation of readily germinable seeds. However, in the present study such a correlation cannot be made because wide variation occurs in the seed weight of readily germinable seeds as well as the seeds, which required scarification (Table 7a, b).

Significant variation is observed in the behaviour of readily germinable seeds between Petri dish and field germination. More number of species showed readily germinable seeds inclusive of recalcitrant and intermediate types under field conditions compared to Petri dish germination (Table 7a). This observation indicates the intervention of some soil factors that stimulates germination. Contradictory to this observation, Grime *et al.* (1981) opined that it would be unwise to assume that the capacity of fresh seeds to germinate in the laboratory is a reliable indication that under field conditions germination occurs soon after harvesting and their view is supported by the fact that many of the species which displayed high initial germinability are known to accumulate as buried seed banks in the field and may germinate later.

Air-drying and sun drying showed some effect on germination of seeds. The germination percentage of *Cassia javanica* seeds in Petri dishes decreased due to air-drying and sun drying, whereas in field MTG was decreased due to sun drying. In *Cajanus scarabaeoides* air-drying has increased the germination percentage in field and Petri dish, while sun drying has resulted in decreased germination percentage in both field and Petri dish conditions. In the case of *Cassia tora* seeds, germination decreased from 90% to 10 % in Petri dish due to sun drying (Table 7). Even though the germination percentage of *Hyptis suaveolens* seeds remained the same in the field, MTG values increased from 16.11 of fresh seeds (Table 7a) to 21.55 (Table 7c) and to 30.22 (Table 7e) due to air-drying and sun-drying respectively.

Of the 92 species tested, seeds of 59 plants failed to attain a final germination percentage of above 40 percentages and in many other species germination was incomplete (Table 7). Seeds, which were not readily germinable, when scarified mechanically, most of them germinated. Many of the plants with dormant seeds showed their fruiting phenology during low rain fall, and so the climate is comparatively dry. According to Fenner (1985), high level of seed dormancy is a characteristic feature of plants of dry regions. The dormancy which get overcome by mechanical scarification is found to be seed coat imposed type. Even though the present study was not designed to provide a thorough analysis of the causes and types of seed dormancy in each species, many seeds are characterized by some inherent mechanisms to restrain germination. In tropical regions, physical and physiological types of dormancy are the most commonly observed types (Baskin and Baskin, 2001).

There occurred a wide range of dormancy in fresh, dried and stored seeds of many species. Even after mechanical scarification of hard seeds, some seeds remained hard (Table 7b). Similarly dried as well as stored seeds also exhibited lack of germination (Table 7d, f, h, j) and these observations reveal that in addition to seed coat imposed (physical) dormancy which get broken by mechanical scarification, other types of dormancy such as morphophysiological dormancy due to underdeveloped embryo or chemical dormancy due to germination inhibitors (Bewley, 1997; Baskin and Baskin, 2001) also are shown by the seed samples. So, several types of dormancy characteristics co-exist in these species. According to Baskin and Baskin (2001), annual species are characterised by morphophysiological dormancy, and physical dormancy (seed coat imposed) is common in members of Fabaceae. Notwithstanding, in the present study, some plants of Fabaceae are having highly germinable seeds which exhibit cent percent germination within 24 hours as shown in *Gliricidia sepium.* This observation is in consistent with the view of Flores and Rivera (1985) who opined that seeds of tropical deciduous tree species are non-dormant and in *G. sepium*, seeds germinate during 24-48 hours.

Air-drying as well as sun drying resulted in increased germination percentage in the seeds of some species like *Macaranga peltata, Bauhinia purpurea* etc. Seeds with physical dormancy usually germinate as a result of drying during hot season (Jurado and Westoby, 1992; Aziz and Khan, 1993; 1994). However, occurrence of secondary (induced) dormancy cannot be ruled out in these species because seeds which come under readily germinable category showed dormancy after drying as observed in *Cochlospermum religiosum, Samanea saman, Senna siamea* and *Vigna trilobata* (Table 7d, f) and/or due to storage in *Peltophorum pterocarpum, Hiptage benghalensis* and *Uvaria narum* (Table 7j). Induced dormancy may be due to hormonal imbalance or environmental change and/or heredity (Bewley and Black, 1982; Bewley, 1997; Baskin and Baskin, 2001). Nevertheless, it can also be concluded that the dormancy and germination characteristics of a species may depend on storage conditions in accordance with the view of McIvor and Howden (2000). Similar conclusions have already been drawn in seed population of temperate species (Grime *et al.,* 1981; Baskin and Baskin, 1988) and tropical species (Elberse and Breman, 1989).

Storage effect on seeds is another important aspect of the present study. Both air-dried and sun dried seeds were stored under laboratory conditions and seeds were retrieved after 6 to 12 months for germination studies. Under both Petri dish and field conditions a large number of seeds (*Syzygium cumini* and *Gliricidia sepium*) exhibited cent percent germination. Dry storage has been recommended for beneficial effects upon percentage and rate of germination particularly in annuals, the seeds of which are shed during summer (Grime *et al.,* 1981). In perennials marked improvement in germinability occurs during dry storage, especially in small seeded species (Grime *et al*., 1981).

An important observation of storage studies was breaking of dormancy, i.e. germination percentage was increased in stored seeds of *Bixa orellana*, *Mukia maderaspatana, Alysicarpus vaginalis* and *Hyptis capitata* compared to their respective control (fresh seeds). Decrease in germination percentage was also observed during storage as in *Rauvolfia tetraphylla, Peltophorum pterocarpum, Cochlospermum religiosum, Macaranga peltata* and *Adenanthera pavonina*. Viability loss was another effect of seed storage as shown by *Hiptage benghalensis, Cansjera rheedei, Quassia indica* and *Uvaria narum*. All these storage effects of seeds are well documented (Mayer Poljakoff-Mayber, 1989; Bewley and Black, 1994; Copeland and Mc Donald, 1995; Bewley, 1997; Bedell, 1998; Baskin and Baskin, 2001). Storage in the laboratory conditions have been reported to improve germination in *Chromolaena odorata* (Ambika and Jayachandra, 1989). Those authors reported that prolonged storage resulted in complete loss of viability in *C. odorata* seeds.

As mentioned earlier, recalcitrant seeds are readily germinable since dormancy is absent in them and germination is considered as a continuum of development (Farrant *et al.*, 1988; Pammenter and Berjak, 1999). But *Garcinia cowa* seeds, categorised as recalcitrant (Liu *et al.,* 2002), are characterized by seed coat imposed (physical) dormancy (Liu *et al.,* 2005). Seeds of *Garcinia xanthochymus* of the Calicut University Campus flora are found to be not readily germinable in Petri dish, and 43 days are required to obtain cent percent germination in the field. After scarification, cent percent germination was obtained within 15 days in Petri dishes (Table 7) and this is the only species that possesses dormant recalcitrant seeds, out of 92 taxa of the present study. All other recalcitrant (*Syzygium cumini*, *S. samarangense*, *Careya arborea*, *Polyalthia longifolia*, *Vateria indica* and *Dracaena* sp.) and intermediate (*Amorphophallus hohenackeri*, *Averrhoa carambola* and

Sterculia guttata) seeds are readily germinable (Table 7). Seed coat imposed dormancy has already been reported in *Garcinia cambogia* (Mathew and George, 1995) and in *Garcinia gummi-gutta* (Anilkumar *et al.*, 2002).

Risk spreading of germination is generally common in environments with unpredictable or fluctuating climates. Almost all species are characterized by having at least some seeds, which may be dormant for a short or long period and this behaviour or phenomenon is the risk spreading of germination. According to Jurado and Westoby (1992) out of 105 species of Australian forest, 103 species showed readily germinable seeds which had at least 20% of their seeds ungerminated after 10 days and the authors opined that this observation is in agreement with expectations for unpredictable environments in which species would be selected for avoiding complete loss of their seed bank in case of a given environment (like rainfall) that promotes germination but turns out to be insufficient for seedling establishment. According to Bewley (1977), Bewley and Black (1982; 1983; 1994) and Baskin and Baskin (2001), seed dormancy is a device for optimizing the distribution of germination temporally and spatially in an ecological context for spread and survival of the species. This phenomenon has been attributed to seed polymorphism or apparent germination polymorphism (Baskin and Baskin, 2001). According to those authors this is presumably because of a protection measure against damages in the environment to which the seeds are exposed during dispersal and/or soil seed banking. So it can be imagined that plant may avoid putting all its eggs in one basket lest the damage leading to extinction.

Even though the seeds of *Cyclea peltata* and *Crotalaria pallida* are readily germinable requiring 10-11 days only, germination spread-over shows wide range reaching 293 and 208 days respectively. This behaviour of *Cyclea peltata* and *Crotalaria pallida* is a typical example of risk spreading of germination as suggested by Haig and Westoby (1988) and Jurado and Westoby (1992), since the spread over of germination during 7-10 months enable the seeds to germinate under favourable environmental conditions of rainfall for seedling establishment.

Long-lived perennials produce seeds through several growth seasons and thus spread the risk through several generations, whereas annuals have to relay solely on their seed banks (Haig and Westoby, 1988; Jurado and Westoby, 1992). As per this hypothesis, seeds from annual species should have lower germinability than perennial species. Garwood and Lighton (1990) stated that many fast growing tropical pioneer species produced small, dry orthodox seeds, which may remain viable for several years in the soil. In seasonal tropical forest, seeds of many species dispersed in the rainy season are dormant through the remainder of the rainy season and the following dry season and germinate in the next rainy season (Garwood, 1983).

Seed germination is followed by seedling emergence and a variety of morphological structures and physiological adaptations are related to evolutionary and ecological significance. Variations in size, function and position of cotyledons and amount of seed reserves occur from seed to seed. In a study on seeds and seedlings of Malayan rain forest trees, Ng (1978) distinguished four types of germination - epigeal, hypogeal, semi hypogeal and durian. Later, de Vogel (1980) described 16 different types of seedlings and compared to the four described by Ng (1978). Ten functional types of cotyledons, phanerocotylar epigeal foliaceous (PEF), phanerocotylar epigeal reserve (PER), phanerocotylar semi hypogeal reserve (PSR), cryptocotylar hypogeal reserve (CHR), Phanerocotylar hypogeal reserve (PHR), hypocotylar semi hypogeal reserve (HSR), hypocotylar hypogeal reserve (HHR), cryptocotylar semi hypogeal haustorial (CSH), cryptocotylar hypogeal haustorial (CHH) and cryptocotylar epigeal haustorial CEH) are observed in the 92 taxa of the present study. Different taxa tend to exhibit similar seedling types suggesting the existence of a high degree of evolutionary convergence among distantly related taxa (Ng, 1978; Garwood, 1983; 1996). The frequency of seedling types vary among species depending upon difference in seed size and dispersal syndrome in such a way that CHR seedlings are predominantly produced by animal-dispersed seeds while dispersal by non living agents occur in PEF seedlings (Ibarra-Manriquez *et* *al.,* 2001).

Baraloto and Forget (2007) opined that large sized seeds of French Guiana woody plants were characterised by hypogeal type of cotyledons and seedling survival was mainly dependant on cotyledon types than seed size and hence for evaluating seedling establishment and performance using seed size, seedling morphology must also be considered. However, in the present study, when seed weight/ seed size (Fig. 7) is compared to seedling type based on cotyledons, it is evident that seeds with larger size and weight are characterised by hypogeal or semi hypogeal cotyledons whereas in seeds with light weight/ small size, cotyledons are epigeal (Table 8). Nevertheless, epigeal cotyledons are shown by a number of seeds with considerable seed weight and size.

A classification of seedlings of tree species growing in Amazon Varzea flood plain forest, proposed by Maia *et al.* (2005), revealed that four main types of seedlings exist after classifying according to seed weight and size as well as position and function of cotyledons. The most frequent seedling type was PEF followed by CHR, PHR and PER. Phanerocotylar epigeal foliaceous seedlings were having smallest seeds and highest germination percentage. According to those authors, dominance of PEF seedlings is attributed to the nutrient rich environment of Varzea and also predominant occurrence of reserve types taken together (64%) is due to the necessity of fast growth in an environment with extreme flood condition.

The frequency of seedling types is associated with species taxonomic affinity, and the frequency may be low or high depending on ecological, biogeographical or phylogenetic reasons (Ibarra-Manriquez *et al.,* 2001). The seedling type spectrum consisting of the ten different types, of the Calicut University Campus flora, is unique because investigation undertaken so far revealed only lesser number of seedling types. Seedling morphology of 210 species of woody plants from Mexico Los Tuxtlas (Neotropical) rain forest revealed only 5 types; CER, CHR, PEF, PER and PHR (Ibarra-Manriquez *et al.*, 2001). Similarly, Garwood (1996) revised the classification of seedling types and established the five seedling types, which encompassed most seedling morphological species variation depending on the function and position of the cotyledons.

A comparative approach to analyse the significance of seedling types, life forms and seedling establishment within and between the families reveals that in herbs (18 numbers), most frequent type of seedling is PEF i.e. in twelve species (Table 8). Out of 37 shrubs, 29 species produced seedlings with PEF types. In addition to PEF, herbs showed CHR, PER and PSR cotyledons. But shrubs produced 6 different seedling types inclusive of PEF. Eight types of morphological forms of cotyledons were shown by trees in which CEH and CHH types were absent.

When a comparison is made between seed weight and seedling types, species of cryptocotylar group are having average seed size, i.e. between 11 - 1773 g / 1000 seeds, whereas wide variation was shown by PEF seedlings. Among the phanerocotylar seedlings, reserve types are having maximum TSW even though variations are there between species. The exorbitant seed weight of reserve type phanerocotylar seedlings indicates the essentiality of seed reserves, which are mobilized during seedling growth. On the other hand, in spite of the variation in the seed weight, many species with very low seed weight are present in the PEF group, because these seedlings become autotrophs soon after emergence.

Studies on seed size and seedling morphology and their correlations revealed that large seeds are more likely to be dispersed by zoochory to distant shaded habitat where they have to depend on their reserve cotyledons for energy and nutrients (Hewitt, 1988; Kitajima and Fenner, 2000; Leishman *et al.,* 2000; Westoby *et al.,* 2002). Similarly seed size determines the amount of reserves available to a seedling and functional morphology of cotyledons determines how these resources are used during initial seedling growth (Garwood, 1996; Kitajima, 1996a; b; 2002; Green and Juniper, 2004 a; b).

The present author observed that seeds of *Entada rheedei, Vateria* *indica* and *Pongamia pinnata* are large by size/weight (Fig. 7) and their cotyledons are of reserve types. The functional morphology of cotyledons of *V. indica* and *P. pinnata* is of PSR type, whereas that of *E. rheedei* is PHR type. According to Zanne *et al.* (2005), species with large seeds, large seedlings, thick storage cotyledons, slow germination, large adult stature and dispersal by large animals are associated with forest and gap habitat. Species with small seeds, small seedlings, thin photosynthetic cotyledons, fast germination, small adult stature and dispersal by small animals are associated with open habitat. Correlation can also be drawn between seedling morphology, seed size and phylogeny. Zanne *et al.* (2005), concluded that cotyledon morphology is phylogenetically more conservative than seed size and all these traits are not only co-occurring but interdependent also.

Phanerocotylar hypogeal reserve (PHR) seedling type is shown by *Syzygium cumini* and *S. samarangense*, the seeds of which are highly moist and heavy and *Entada rheedei,* which is a liana species also produce PHR seedling. According to Ibarra- Manriquez *et al.* (2001), PHR seedlings are emerged from large seeds and are common in liana species.

Correlations can also be drawn between seedling types and seed dispersal mechanisms (Ibarra- Manriquez *et al*., 2001). Analysis of data on seedling type indicates that in all cryptocotylar reserve as well as haustorial types, dispersal of seed is by living means (Table 8) probably due to seed/fruit weight, fleshy texture and hence edible as shown by *Uvaria narum, Clerodendrum viscosum* and *Syzygium caryophyllatum*. Similarly, in the phanerocotylar reserve types also, more number of species are characterised by animal dispersal as observed in *Sterculia guttata, Vateria indica* and *Syzygium samarangense* (Table 8). But in PEF types, both living and nonliving dispersal mechanisms are seen probably due to the diversity in seed weight as well as dehiscent/nondehiscent behaviour of fruits.

Even though the significance of seedling types has been established in terms of morphological structures, their physiological roles and ecological adaptations also are correlated to seedling types (Hladik and Miquel, 1990; Kitajima, 1992; Paz *et al*., 1999). In the present investigation an ecological approach is not relevant because the study area is not having a much heterogenous nature since the University Campus area is only 500 acres.

Significant variations also occur in the distribution of different types of seedlings in the present study. Phanerocotylar epigeal foliaceous (PEF) seedlings occur in abundance (68%) and pattern of distribution is in the order PEF>PER>PSR>PHR and cryptocotylar seedlings are very sparse (Table 8). According to Ibarra- Manriquez *et al.* (2001), PEF and CHR seedlings occur in high frequencies in neotropical regions. PEF seedlings are characterised by faster growth (Popma and Bongers, 1988) and are having high photosynthetic efficiency (Strauss- Debenedetti and Bazzaz, 1991). In the forest flora, PEF seedlings are associated with gap dependent species (Martinez-Ramos and Samper, 1998). Kitajima (1992) also opined that foliaceous photosynthetic cotyledons enable the plants to use maximum light resources. The abundant occurrence of PEF cotyledons in Calicut University Campus flora can be positively correlated to the features of tropical flora as reported by earlier authors as described above.

According to Ibarra- Manriquez *et al.* (2001), PEF seedlings show wide range of variations which are related to seed size variations both within and among species and the CHR seedling types having large seed size, develop in the shade and are abundant in arboreal species. In the present study, CHR seedlings are present in *Clerodendrum viscosum, Amorphophallus hohenackeri, Syzygium caryophyllatum* and *Cajanus scarabaeoides* which are seemed to be growing mostly in shades (Table 8). Large seeds are constrained to disperse and hence germinate in the shade near the neighbourhood of maternal plant is most probable (Howe and Smallwood, 1982) and animal dispersal is most common and face mortality risks. All the CHR seedlings of this study are characterized by large seed size and zoochory/ autochory (Table 6a, b, c).

Ibarra- Manriquez *et al.* (2001), attempted to draw phylogenetic pattern in the distribution of seedlings and stated that some families of Magnoliids showed the same seedling type. Nevertheless, according to those authors, seedling morphology as described by position and function of cotyledons is a trait that is constrained at taxonomic levels. Garwood (1996) also agreed with this view and suggested that from an evolutionary perspective, seedling type seems to be a very conservative trait. However, Ibarra- Manriquez *et al.* (2001), stated that plants of the primitive clad Magnoliids showed PEF, CHR and CER seedlings and hence could be the earlier seedling types appearing in the evolution of woody angiosperm of tropical rain forests and PER and PHR seedlings arose later with the Rosids. But the Magnoliids of the present study, namely, *Polyalthia korintii, P. longifolia* and *Uvaria narum* show seedling types PEF, CSH and CEH respectively.

Morphological forms of seedling types have consistently been used as a parameter for identification/classification of families like Bignoniaceae (Paria *et al.,* 1995), Asteraceae (Ahammed and Paria, 1996), Polygonaceae (Kamilya and Paria, 1993) and Leguminosae (Paria *et al.,* 2006). Nevertheless, in the present study, the species studied under Asteraceae, Lamiaceae, Menispermaceae, Phyllanthaceae, Rhamnaceae, Rubiaceae and Solanaceae showed only PEF type of cotyledons. But in families like Fabaceae, the cotyledon types are PEF, PER, PSR, PHR and CHR and in Annonaceae CEH, PEF and CSH types are observed. However, cotyledon types of these families mentioned above cannot be considered as typical family characters because some families are represented only by a few number of plants in the present study.

Green and Juniper (2004a; b) examined the reserve effect of cotyledons and a seed-seedling allometry in tropical forest trees. Westoby *et al.* (1996) and Leishmann *et al.* (2000) suggested that seedlings of large seeded species are more advantageous due to their large size. The reserve effect proposes that large-seeded species retain greater proportion of their initial seed resources and hence their seedlings are better proficient to cope with resource deficits. However, the reserve effect may favour large-seeded species, but their performance is similar to smaller-seeded species in terms of their biomass allocation (Green and Juniper, 2004a; b).

Seedlings from larger-seeded species have been shown to perform better than those from smaller-seeded species (Westoby *et al.,* 1996). Those authors distinguished three mechanisms, seedling size effect, metabolic effect and reserve effect through which the seed mass is translated into better seedling performance. The reserve effect of Westoby *et al.*, (1996) is similar to cotyledon functional morphology hypothesis proposed by Garwood (1996) and Kitajima (1996 a; b). Kidson and Westoby (2000) put forth the larger-seed-later-commitment hypothesis which describes larger total resources in the cotyledons of larger seeds. Those authors proposed an allometric pattern of quantity distribution of resources. Larger-seeded species tend to mobilize their metabolic resources over a longer period into the autotrophically functioning structure. However, Kidson and Westoby (2000) suggested that larger-seeded-later-commitment mechanism explains a superior performance by larger seeded species only in face of the hazards of seedling establishment

and these species allocate relatively less reserves to cotyledon area reflecting the initial functional size of the seedling and relatively more to dry mass per unit area of cotyledon reflecting stored metabolites (reserves).

Existence of six types of cotyledons based on cotyledon traits have conclusively been established in plants (Ng, 1978; 1991; Garwood, 1996; Ibarra-Manriquez *et al.* 2001) using the three pairs of traits; phanerocotylar (P) or cryptocotylar (C), Epigeal (E) or hypogeal (H) and foliaceous (F) or reserve (R). In an extensive study on the seedling morphology of Euphorbiaceae, Pujol *et al.* (2005) stated that four trait combinations were observed –PEF, PER, PHF and CER in which PEF was most frequent. In addition to the combinations of the three pairs of traits, Pujol *et al.* (2005) suggested a few more combinations. According to those authors, in the trait of form, foliaceous (F) or reserve (R), the reserve type can be of two types, because in some seeds especially endospermous, thin white cotyledons absorb the nutrients from the surrounding endosperm and their cotyledons are haustorial in function abbreviated as R(h). Following the classification of

Pujol *et al.* (2005), the present author grouped the cotyledons of three species (Table 8) under the haustorial form, 'H' (*Uvaria narum, Dracaena* sp. and *Polyalthia longifolia)*. Similarly in the trait of position, besides epigeal (E) or hypogeal (H), another position designated as semi-hypogeal 'S' is taken into consideration in the present study. According to Saha *et al.* (1998),

Polyalthia longifolia seedlings are phanerocotylar. But the present study reveals that the seedling is cryptocotylar since the cotyledons are white, papery thin and never come out of the seed during germination and hence haustorial in function in accordance with the view of Pujol *et al.* (2005). Contradictory to the view of Saha *et al.* (1998), morphological observations of the seedlings of *Polyalthia longifolia* (Figs. 9b, 10g) confirmed that due to the above mentioned characters of cotyledons shown by this plant the seedling is designated as cryptocotylar semi-hypogeal Haustorial (CSH) (unpublished data). Seedlings of *Garcinia xanthochymus* (HSR), *Quassia indica* (PSR), *Pongamia pinnata* (PSR), *Solena amplexicaulis* (PSR) and *Centrosema virginianum* (PSR) come under semi hypogeal type. The seedlings of *Garcinia xanthochymus* come under Hypocotylar semihypogeal reserve (HSR) type and the seed reserves are not stored in the cotyledons but in the swollen hypocotyl which is having vasculature connecting the two poles of the seed. Joshi *et al.* (2006) showed that in *G. gummi-gutta*, any seed fragment that contains vasculature, produce a root and shoot irrespective of its size and position with precise polarity.

Epigeal cryptocotylar germination is reported to be very scarce. Three species out of 90 forest species of Venezuela (Ricardi 1999a; b) and five species out of twenty humid forest species of Mexico (Ibarra-Manriquez *et al.,* 2001) are described as epigeal cryptocotylar germination. In the present investigation, out of 92 species only one species (*Uvaria narum*) showed epigeal cryptocotylar germination and the cotyledons are haustorial in function (Table 8). Franceschini (2004) reported an unusual case of epigeal cryptocotylar germination in a member of Annonaceae, *Rollinia salicifolia*, the seeds of which are characterized by non-chlorophyllous embryo, abundant endosperm, thick woody seed coat, thickened hypocotyl and non-photosynthetic haustorial cotyledons. According to the author, epigeal cryptocotylar germination in *R. salicifolia* is the first record of this type of germination in Argentina. A similar incidence of epigeal cryptocotylar germination in *Uvaria narum*, the only case, out of 92 species included in the present study is found to be a coincidence and more over, both the plants, *R. salicifolia* and *U. narum* belong to the same family Annonaceae and are characterised by CEH (cryptocotylar epigeal haustorial) seedlings.

Distinguishable variation in the morphology of cotyledon is an important observation of the present study. In addition to seedling classification based on functional form/morphology, variations of cotyledon also have been investigated in almost all species of the present study. Cotyledonary characters such as shape, surface, exposure, position, life span, colour, venation etc. revealed significant variations between them. Systematic and elaborate studies on seedlings in general and cotyledons in particular by Chattopadhyay and Paria (1995), Paria *et al.* (1995), Paria and Kamilya

of(1999) and Paria *et al.* (2006) revealed that variations in the morphology of cotyledons are of importance in systematic studies in such a way that this character can even be utilized for the identification of taxa. In the present study also the cotyledonary characters of individual species of the same family exhibit variations. In the family Fabaceae, *Acacia auriculiformis* showed thin and foliaceous cotyledons (Fig. 9e) while in *Adenanthera pavonina,* cotyledons are thick and reserve type, which become green and photosynthetic after germination (Fig. 10h). In *Centrosema pubescens,* a member of the same family, the cotyledons are thick and reserve as in *A. pavonina,* but reddish brown in colour (Fig. 10 d).

Though pretty old, a descriptive voluminous account on seedlings (published in two volumes) by Lubbock (1892) and rather a recent book by Hzn (1972) give family-wise description of various types of cotyledons in a number of plants coming under almost all families and those authors stated that significant variations do occur in the cotyledons of different plants under the same family. In the present study also similar findings and conclusions are arrived at as observed in the members of Fabaceae.

The author attempts correlation between all the parameters adopted and results obtained in order to draw some conclusions of the investigation. Rainfall as a triggering factor for phenology of flowering and fruiting affect soil-water storage and RH on one hand, solar irradiance and temperature on the other, and their cumulative effect controls flowering/fruiting (Bendix *et al.,* 2006). Flowering phenology usually depends on both photoperiod and thermoperiod (Salisbury and Ross, 1992; Rivera *et al.,* 2002; Taiz and Zeiger, 2002) and the rainfall significantly contributes to changes in the periodicity of light and temperature (Borchert *et al.,* 2004; 2005).

The two important parameters of the investigation – monthly fruiting phenology and rainfall are inversely related to each other (Tables 9, 10) in such a way that during higher rain falls lesser number of plants exhibited fruiting. Moisture content of seeds and average seed weight values were directly proportional to rainfall. Dispersal by both living and non-living means was comparatively lower in months of high rainfall. Number of plants, which produce orthodox seeds was lesser during rainy season, whereas plants with recalcitrant and intermediate seeds, were more during /prior to heavy rains (Tables 9, 10).

Interrelationships between flowering/fruiting phenology and rainfall indicate the occurrence of these two important reproductive phases or processes of plants throughout the year despite the considerable fluctuations in the number of plants. Notwithstanding, irrespective of their habit, maximum number of species flower during months of average rainfall irrespective of their habit and it can be concluded that flowering and /fruiting frequently synchronise in most of the species of the Campus apparently in response to the tropical climate that prevail in the area. However, phenological periodicity cannot be established over the observations made on the species included in the study because the period of investigation is only 2 years. So, periodic studies for several years are required to examine the influence of meteorological data on phenological events. Notwithstanding, correlations between most of the data have been drawn, and presented in the hierarchical taxonomic matrix system, for character descriptions and correlations (Fig. 3.1a-j). Phylogenetic classification of the 92 taxa, important morphological characters and classification of seeds are correlated each other. Salient features of this data analysis reveals that Eurosids consists maximum number of plants and only Eurosids I and II produce orthodox, intermediate and recalcitrant seeds (Fig. 3.1 f, g).

In this study the author addresses a phylogenetic classification of 92 species, out of 447 species reported earlier (Sivarajan, 1974; Sivarajan and Manilal, 1976) of Calicut University Campus and examination of flowering/fruiting phenology under varying monthly rainfall which is an important cue of reproductive phenology. Since the flora comprises large number of angiosperm members with different types of habit, studies on germination of seeds, which are produced during varying rainfall demonstrate the seedling emergence almost throughout the year and gradual/fast seedling establishment leading to the sustainable greenery of the Campus, more or less similar or comparable to the evergreen tropical forest.

The parameters adopted by the present author for the investigation and resultant observations on systematics, flowering /fruiting phenology, seed dispersal, storage, dormancy, germination, seedling classification and modifications of cotyledons etc. of 92 angiosperm species of Calicut University Campus indicate many characteristic features of the tropical forest flora. The observations made in this investigation by the author appear to have significant relevance to consider the flora more or less similar or comparable to a tropical vegetation because all observations are characteristic features, rather it forms a scenario consisting of plant diversity with distinctive features which can be causatively linked with a typical tropical forest flora in accordance with the reports and views of Richards (1952, 1996) and Huston (1994).

Calicut University campus covers an area of about 500 acres and the flora consists of naturally growing plants of different habits and also species planted by people. Systematics and phenological aspects of reproductive development of the flora have not yet been carried out. Objectives of the study include a phylogenetic classification and phenology of flowering and fruiting of the angiosperm flora of Calicut University Campus. Phenology of flowering/and fruiting are correlated with meteorological data particularly rainfall of the campus area. Along with the phenological observations of flowering /fruiting, morphological studies also are conducted on fruits and seeds collected from 92 species. Seed germination behaviour, classification, distribution of dormancy and their relationship with rainfall also are investigated. A classification of seedling types based on seedling emergence, morphology and establishment and modifications of cotyledons also become the part of the study.

Systematics was done as per APG II phylogenetic classification. Standard methods of fruit/seed collection and post harvest technology were followed for seed drying, storage and germination. Germination percentage, mean time germination *etc.* were calculated using routine methods/formulae. Morphology of seedlings and cotyledons was represented by photographs and camera lucida drawings.

Based on monthly rainfall, three periods - low, average and high rain fall were categorised and flowering/fruiting phenology was correlated to these three rainfall periods.

Systematics studies revealed that majority of plants out of the 92 taxa come under advanced clades/families, whereas a few plants/families were fallen under primitive clades also. More numbers of plants showed flowering/fruiting under average rainfall. The flora consisted of trees, shrubs and herbs, which are annuals and/or perennials showing annual flowering. Fruits and seeds of different morphology and various seed-dispersal mechanisms also were observed.

Germination studies led to a classification of seeds into ‘readily germinable’ and dormant types. Drying and storage showed increased rate of germination in many species but seeds of a number of species lost their viability due to drying/storage. Based on storability or desiccation sensitivity, orthodox, intermediate and recalcitrant seeds were found to be existed. Variations of seedling morphology enabled to classify them into different functional types. Modification of cotyledon morphology was another important character of the Campus flora. These observations and their correlations or comparison with the phenology of flowering/fruiting and rainfall are discussed with current literature and the following conclusions are made.

1. Phylogenetic classification, as per APG II scheme, of 92 species reveals that more numbers of plants/families come under advanced clades, whereas primitive families are represented by a few members.

2. Flowering phenology showed more number of plants flowered during average rainfall which has been reported as a character of Indian as well as other tropical forests. Annual flowering of many herbs as well as shrubs with short life-span and perennials with annual flowering are dependant on rainfall and these features are typical characters of tropical flora.

3. Seed dispersal mechanism is found to be directly related to rainfall in such a way anemochory is more common in plants which fruit during low rainfall and zoochory is maximum in average and heavy rainfall.

4. Seed size/weight is an important feature in determining dispersal

distance and the variation in seed size is very high in the flora and so also the dispersal mechanism.

5. Recalcitrant and intermediate seeds are characterised by large size, very high MC, low MTG and short storability and their fruiting phenology is directly related to high rainfall.

6. Difference in germination rate and MTG leading to the classification of seeds into ‘readily germinable’ and ‘hard types’ is an important ecological character for germination and/or survival of seedlings, which depend on rainfall.

7. Distribution of dormancy - mainly morphological - observed in many of the species is an important ecological character or adaptation for survival and this observation also is a feature of tropical flora.

8. Difference in the germination rate and MTG between Petri dish- and field- germination is indicative of the requirement of some soil/ other ecological factors that might control the germination behaviour.

9. Air-drying and sun drying of seeds imposed dormancy in some species and loss of viability in others revealing some sort of sustenance of the taxa depending upon the climatic conditions.

10. Variation of seedling morphology is another manifestation of the

diversity in the Campus flora and some seedling types are unique to this flora. Phanerocotylar epigeal foliaceous (PEF) type of seedlings, occur abundantly.

11. Diversity in the morphology and modifications of cotyledons is remarkable and this character also is another aspect of the diversity of the flora.

12. Sets of morphological characters that exist in the various taxa of the flora differ so widely that generalities are often difficult to discern.

13. This diversity may be due partly to the broad range of characters/parameters that have been taken into consideration for the investigation.

14. In cognizant of the reality that the data from a relatively small area and small fraction of the plant species, the author has tried to avoid generalizing the statements too broadly, on the basis of the observations.

15. Nevertheless, correlations between flowering/fruiting phenology and rainfall which controls/affects all other climatic factors are found to be related to the variations in habit, fruit/seed morphology and their dispersal mechanism. Seed germination behaviour, desiccation sensitivity, dormancy, seedling emergence/ establishment and

variations and/ or diversity of seedling types and cotyledons also are found to be the characteristic features of the flora of tropical region to which category the Calicut University Campus belongs.

Ahammed, J. and Paria, N. 1996. Systematic value of seedling morphology in some Indian Asteraceae. *Acta Bot. Indica* **24**: 49-55.

Ambika S.R. and Jayachandra 1989. Influence of storage on seed germination in *Chromolaena odorata. Seed Res*. **17**: 143-152.

Anilkumar, C. 1998. *Physiological and Biochemical Aspects of seed storage and viability in Syzygium* Species. Ph.D. Thesis, Calicut University, Calicut.

Anilkumar, C., Babu, K.P. and Krishnan, P.N. 2002. Dormancy mechanism and effects of treatments on the germination of *Garcinia gummi-gutta* (Clusiaceae) seeds. *J. Trop. For. Sci*. **14:** 322-328.

Anonymous. 1986. *Kerala District Gazetteers – Malappuram*. Published by Adoor K.K. Ramachandran Nair, Government Press, Ernakulam.

Anonymous. 1991. *BIOSIS - Serial Sources for the BIOSIS Previews Database, Volume 1990*. Biosis, Philadelphia.

APG 1998. An ordinal classification for the families of flowering Plants. *Ann. Mo. Bot. Gard*. **85:** 531-553.

APG II 2003. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG II. *Bot. J. Linn. Soc.* **141**: 399-436.

Aronne, G. and DeMicco, V. 2004. Hypocotyl features of *Myrtus Communis* (Myrtaceae): a many-sided strategy for possible enhancement of seedling establishment in the Mediterranean environment. *Bot. J. Linn. Soc.* **145**: 195-202.

Augspurger, C.K. and Hogan, K.P. 1983. Wind dispersal of fruits with variable seed number in a tropical tree (*Lachocarpus pentaphyllus*: Leguminosae). *Am. J. Bot*. **70**: 1031-1037.

Aziz, S. and Khan, M.A. 1993. Survivorship patterns of some desert plants. *Pak. J. Bot.* **25**: 67-72.

Aziz, S. and Khan, M.A. 1994. Life history strategies of *Tephrosia strigosa* Willd. - a desert summer annual. *Bangladesh J. Bot.* **23**: 139-146.

Baker, H.G. 1972. Seed size in relation to environmental conditions in California. *Ecology*, **53**: 997-1010.

Baraloto, C. and Forget, P.-M. 2007. Seed size, seedling morphology and response to deep shade and damage in neotropical rainforest trees. *Am.*

J. Bot. **94**: 901-911.

Baskin, C.C. and Baskin, J.M. 1988. Germination ecophysiology of herbaceous plant species in a temperate region. *Am. J. Bot.* **75**: 286-305.

Baskin, C.C. and Baskin, J.M. 2001. *Seeds*: *Ecology, Biogeography and Evolution of Dormancy and Germination*. Academic Press. San Diego.

Baskin, C.C., Chesson, P.L. and Baskin, J.M. 1993. Annual seed dormancy cycles in two desert winter annuals. *J. Ecol.* **81:** 551-556.

Baskin, C.C., Milberg, P., Andersson, L. and Baskin, J.M. 2004. Germination ecology of seeds of the annual weeds *Capsella bursa-pastoris* and *Descurainia sophia* originating from high northern latitudes. *Weed Res.* **44**: 60-68.

Bedell, P.E. 1998. *Seed Science and Technology: Indian Forestry Species*. Allied Publishers Limited, New Delhi.

Bendix, J., Homeier, J., Ortiz, E.C., Emck, P., Breckle, S.-W., Richter, M. and Beck, E. 2006. Seasonality of weather and tree phenology in a tropical evergreen mountain rain forest. *Int. J. Biometeorol.* **50**: 370-384.

Berjak, P., Farrant, J.M. and Pammenter, N.W. 1990. Recalcitrant (homoiohydrous) seeds; the enigma of their desiccation sensitivity. *Seed Sci. Technol.* **18**: 297-310.

Berjak, P. and Pammenter, N.W. 1994. Recalcitrance is not an all-or-nothing situation. *Seed Sci. Res.* **4**: 263-264.

Berjak, P. and Pammenter, N.W. 2001. Seed recalcitrance- current perspectives. *South Afr. J. Bot.* **67**: 79-89.

Bewley, J.D. and Black, M. 1982. *Physiology and Biochemistry of Seeds in Relation to Germination*. Vol.2. *Viability, Dormancy and Environmental Control.* Springer-Verlag, Germany.

Bewley, J.D. and Black, M. 1983. *Physiology and Biochemistry of Seeds in Relation to Germination*. Vol.1. *Development, Germination and Growth*. Springer-Verlag, Germany.

Bewley, J.D. and Black, M. 1994. *Seeds*: *Physiology of Development and Germination.* 2nd edn. Plenum Press, New York.

Bewley, J.D. 1997. Seed germination and dormancy. *Plant Cell* **9**: 1055-1066.

Bhattacharya, A. and Saha, P.K.1997. Germination behaviour of two morphologically different types of seed of *Cassia tora* at different temperatures. *Weed Res.* **37**: 87-92.

Bloor, J.M.G. and Grubb, P.J. 2003. Growth and mortality in high and low light: trends among 15 shade-tolerant tropical rain forest tree species. *J. Ecol.* **9**: 77-85.

Bollen, A. and Donatl, G. 2005. Phenology of the littoral forest of Sainte Luce, Southeastern Madagascar. *Biotropica*. **37**: 32-43.

Borchert, R. 1983. Phenology and control of flowering in tropical trees. *Biotropica* **15**: 81-89.

Borchert, R., Meyer, S.A., Felger, R.S. and Porter-Bolland, L. 2004. Environmental control of flowering periodicity in Costa Rican and Mexican tropical dry forests. *Global Ecol. Biogeogr.* **13**: 409-425.

Borchert, R., Renner, S.S., Calle, Z., Navarrete, D., Tye, A., Gautier, L., Spichiger, R. and von Hildebrand, P. 2005. Photoperiodic induction of synchronous flowering near the Equator. *Nature* **433**: 627-629.

Brummitt, R.K. and Powell, C.E. (Eds.) 1992. *Authors of Plant Names*. Royal Botanic Gardens, Kew.

Caldwell, M.M. 1968. Solar ultraviolet radiation as an ecological factor for alpine plants. *Ecol. Monogr*. **38**: 243-268.

Caldwell, M.M., Bjorn, L.O., Bornman, J.F., Flint, S.D., Kulandaivelu, G., Teramura, A.H. and Tevini, M. 1998. Effects of increased solar ultraviolet radiation on terestrial ecosystems. *J. Photochem. Photobiol. B: Biol.* **46:** 40-52.

Chattopadhyay, S.P. and Paria, N. 1995. Correlation coefficient of some character pairs in certain tree seedlings with respect to their growth habit. *J. Indian Bot. Soc*. **74**: 249-252.

Chin, H.F., Hor, Y.L. and Lassim, M.M.B. 1984. Identification of recalcitrant seeds. *Seed Sci. Technol*. **12**: 429-436.

Copeland, L.O. and McDonald, M.B. 1995. *Principles of Seed Science and Technology*. 3rd edn. Chapman and Hall, New York.

Cornelissen, J.H.C., Diez, C.P. and Hunt, R. 1996. Seedling growth, allocation and leaf attributes in a wide range of woody plant species and types. *J. Ecol.* **84**: 755–765.

Corner, E.J.H. 1976. *The Seeds of Dicotyledons* (2Vols.). Cambridge University Press, Cambridge, U.K.

Dalianis, C.D.1980. Effect of temperature and seed size on speed of germination, seedling elongation and emergence of berseem and Persian clovers *(Trifolium alexandrinum* and *T. resupinatum*). *Seed Sci.Techno*l. **8**: 323-331.

Daws, M.I., Garwood, N.C. and Pritchard, H.W. 2005. Traits of recalcitrant seeds in a semi-deciduous tropical forest in Panama: some ecological implications. *Funct. Ecol.* **19:** 874-885.

de Vogel, E.F. 1980. *Seedlings of Dicotyledons*. Centre for Agricultural Publishing and Documentation, Wageningen, Netherlands.

Dharmalingam, C. and Basu, B.N. 1989. Influence of achene size on germination and vigour potential in Sunflower. *Seed Res*. **17**: 128-134.

Dickie, J.B., Balick, M.J. and Linington, I.M. 1992. Experimental investigations into the feasibility of *ex situ* preservation of palm seeds: an alternative strategy for biological conservation of this economically important plant family. *Biodiv*. *Conserv.* **1**: 112-119.

Dickie, J.B. and Pritchard, H.W. 2002. Systematic and evolutionary aspects of desiccation tolerance in seeds. In: M. Black and H.W. Pritchard (Eds.) *Desiccation and Survival in Plants*: *Drying Without Dying*. CAB International, Wallingford, U.K. 239-259.

Duke, J.A. 1965. Keys for the identification of seedlings of some prominent woody species in eight forest types in Puerto Rico. *Ann. Mo. Bot. Gard*. **52:** 314-350.

Duke, J.A. 1969. On tropical tree seedlings I. Seeds, seedlings, systems and systematics. *Ann. Mo. Bot. Gard*. **56**: 125-161.

Dussert, S., Chabrillange, N., Engelmann, F., Anthony, F., Louarn, J. and Hamon, S. 2000. Relationship between seed desiccation sensitivity, seed water content at maturity and climatic characteristics of native environments of nine *Coffea L.* species. *Seed Sci. Res.* **10**: 293-300.

Eira, M.T.S., Walters, C., Caldas, L.S., Fazuoli, L.C., Sampaio, J.B. and Dias, M.C. 1999. Tolerance of *Coffea* spp. seeds to desiccation and low temperature. *Rev. Bras. Fisiol. Vegetal* **11**: 97-105.

Elberse, W.T.H. and Breman, H. 1989. Germination and establishment of Sahelian rangeland species I. Seed properties. *Oecologia* **80**: 477-484.

Ellis, R.H., Hong, T.D. and Roberts, E.H. 1990. An intermediate category of seed storage behaviour? 1. Coffee. *J. Exp. Bot.* **41**: 1167-1174.

Farnsworth, E. 2000. The ecology and physiology of viviparous and recalcitrant seeds. *Annu. Rev. Ecol. Syst.* **31**: 107-138.

Farrant, J.M., Pammenter, N.W. and Berjak, P. 1988. Recalcitrance- a current assessment. *Seed Sci. Technol.* **16**: 155-166.

Fenner, M. 1985. *Seed Ecology*. Chapman and Hall, New York 151.

Finch-Savage, W.E. 1992. Seed development in the recalcitrant species *Quercus rober* L.: germinability and desiccation tolerance. *Seed Sci. Res.* **2**: 17-22.

Finch-Savage, W.E. and Blake, P.S. 1994. Indeterminate development in desiccation-sensitive seeds of *Quercus rober* L. *Seed Sci. Res.* **4**: 127-133.

[*]Flores, E.M. and Rivera, D.I. 1985. Germinacion y desarrollo de la plantula

---

[*] *original not seen

de *Gliricidia sepium* (Jacq.) Steud (Papilionaceae). *Rev. Biol. Trop.* **33:** 157-161.

Foster, S.A. 1986. On the adaptive value of large seeds for tropical moist forest trees: a review and synthesis. *Bot. Rev.* **52**: 260-299.

Franceschini, M.C. 2004. An unusual case of epigeal cryptocotylar germination in *Rollinia salicifolia* (Annonaceae). *Bot. J. Linn. Soc.* 2004. **146:** 53-56.

Frankie, G.W., Baker, H.G and Opler, P.A. 1974. Comparative phenological studies of trees in tropical wet and dry forests in the lowlands of Costa Rica. *J. Ecol*. **62**: 881-919.

Gamble, J.S. and Fischer, C.E.C. 1915-1936. *The Flora of the Presidency of Madras.* Adlard and Son Ltd., London.

Ganeshaiah, K.N. and Shaanker, U.R. 1991. Seed size optimization in a wind dispersed tree *Butea monosperma:* a trade-off between seedling establishment and pod dispersal efficiency. *Oikos* **60**:3-6.

Garwood, N.C. 1982. Seasonal rhythm of seed germination. In: E.G. Leigh, Jr., A.S. Rand and D. Windsor (Eds.) *The Ecology of a Tropical Forest: Seasonal Rhythms and Long-term Changes.* Smithsonian Press. Washington DC: 173-185.

Garwood, N.C. 1983. Seed germination in a seasonal tropical forest in

Panama: a community study. *Ecol. Monogr*. **53**: 159-181.

Garwood, N.C. 1989. Tropical soil seed banks: a review. In: M.A. Leck, V.T. Parker and R.L. Simpson (Eds.) *Ecology of Seed Banks.* Academic Press, New York. 149-209.

Garwood, N.C. and Lighton, J.R.B. 1990. Physiological ecology of seed respiration in some tropical species. *New Phytol.* **115**: 549-558.

Garwood, N.C. 1996. Functional morphology of tropical tree seedlings. In: M.D. Swaine (Ed.) *The Ecology of Tropical Forest Tree Seedlings: Man and the Biosphere Series,* vol. 17. UNESCO. Parthenon, Paris, France. 59-129.

Green, P.T. and Juniper, P.A. 2004a. Seed-seedling allometry in tropical rain forest trees: seed mass- related patterns of resource allocation and the 'reserve effect'. *J. Ecol.* **92**: 397-408.

Green, P.T. and Juniper, P.A. 2004b. **Seed mass, seedling herbivory and the reserve effect in tropical rainforest seedlings.** *Funct. Ecol.* **18: 539-547.**

Grime, J.P., Mason, G., Curtis, A.V, Rodman, J., Band, S.R., Mowforth, M.A.G., Neal, A.M and Shaw. S. 1981. A comparative study of germination characteristics in a local flora. *J. Ecol.* **69**: 1017-1059.

Haig, D. and Westoby, M. 1988. Inclusive fitness, seed resources and maternal care. In: J. Lovett Doust and L. Lovett Doust (Eds.) *Plant Reproductive Ecology: Patterns and Strategies*. Oxford University Press, New York. 60-79.

Hamann, A. 2004. Flowering and fruting phenology of a Philippine submontane rain forest: climatic factors as proximate and ultimate causes. *J. Ecol.* **92**:24-31.

Heideman, P.D. 1989. Temporal and spatial variation in the phenology of flowering and fruiting in a tropical rainforest. *J. Ecol.* **77**: 1059-1079.

Hewitt, N. 1998. Seed size and shade-tolerance: a comparative analysis of North American temperate trees. *Oecologia* **114**: 432-440.

Hilty, S.L. 1980. Flowering and fruiting periodicity in a premontane rainforest in Pacific Columbia. *Biotropica* **12:** 292-306.

Hladik, A. and Miquel, S. 1990. Seedling types and plant establishment in an African rain forest. In: K.S. Bawa and M. Hadley (Eds.) *Reproductive Ecology of Tropical Forest Plants*: *Man and the Biosphere Series*, vol. 7. UNESCO, Paris, France. 261-282.

Hodgson, J.G. and Mackey, J.M.L. 1986. The ecological specialization of Dicotyledonous families within a local flora: some factors constraining optimization of seed size and their possible evolutionary significance. *New phytol*. **104**: 497-515.

Hong, T.D. and Ellis, R.H. 1996. *A Protocol to Determine Seed Storage Behaviour (IPGRI Technical Bulletin No. 1)*. International Plant Genetic Resources Institute, Rome, Italy.

Hong, T.D. and Ellis, R.H. 1997. *Ex situ* biodiversity conservation by seed storage: multiple–criteria keys to estimate seed storage behaviour. *Seed Sci. Technol*. **25**: 157-161.

Hong, T.D. and Ellis, R.H. 1998. Contrasting seed storage behaviour among different species of Meliaceae. *Seed Sci. Technol*. **26**: 77-95.

Hong, T.D., Linington, S. and Ellis, R.H. 1998. *Compendium of Information on Seed Storage Behaviour. Vols. 1 and 2*. Royal Botanic Gardens, Kew.

Howe, H.F. and Smallwood, J. 1982. Ecology of seed dispersal. *Annu. Rev. Ecol. Syst*. **13**: 201-228.

Huston, M. 1994. *Biological Diversity: The Co-existence of Species on Changing Landscapes*. Cambridge University Press, New York.

Hzn, D.B. 1972. *Seedlings of Some Tropical Trees and Shrubs Mainly of South East Asia*. Centre for Agricultural Publishing and Documentation, Wageningen.

Ibarra-Manriquez, G., Martinez-Ramos, M. and Oyama, K. 2001. Seedling functional types in a lowland rain forest in Mexico. *Am. J. Bot.* **88**:

1801-1812.

Idu, M. and Omonhinmin, A.C. 2001. Seed morphology of some taxa of Asteraceae. In: J.K. Maheshwari and A.P. Jain (Eds.) *Recent Researches in Plant Anatomy and Morphology*. Scientific Publishers, Jodhpur, India.1-30.

ISTA 1985. International rules for seed testing. *Seed Sci. Technol.* **13**: 338-341.

Jain, S.K. 1982. Variation and adaptive role of seed dormancy in some annual grassland species. *Bot. Gaz.* **143**: 101-106.

Joshi, G., Kumar, A.N.A., Gowda, B. and Srinivasa, Y.B. 2006. Production of supernumerary plants from seed fragments in *Garcinia gummi-gutta* : evolutionary implications of mammalian frugivory. *Curr. Sci.* **91**: 372-376.

Jurado, E. and Westoby, M. 1992. Germination biology of selected central Australian plants. *Aust. J. Ecol.* **17**: 341-348.

Justiniano, M.J. and Fredericksen, T.S. 2000. Phenology of tree species in Bolivian dry forests. *Biotropica.* **32**: 276-281.

Kamilya, P. and Paria, N. 1993. Seedling morphology of some members of the Polygonaceae and its taxonomic implications. *Rheedea* **3:** 29-34.

Kermode, A.R. and Finch-Savage, B.E. 2002. Desiccation sensitivity in orthodox and recalcitrant seeds in relation to development. In: M. Black and H. W. Pritchard (Eds.) *Desiccation and Survival in Plants: Drying Without Dying.* CAB International, Oxford. 149-184.

Kidson, R. and Westoby, M. 2000. Seedmass and seedling dimensions in relation to seedling establishment. *Oecologia* **125**: 11-17.

King, M.W. and Roberts, E.H. 1980. Maintenance of recalcitrant seeds in storage. In: H.F. Chin and E.H. Roberts, (Eds.) *Recalcitrant Crop Seeds*. Tropical Press, Kuala Lumpur, Malaysia. 53-89.

Kitajima, K. 1992. Relationships between photosynthesis and thickness of cotyledons for tropical tree species. *Funct. Ecol.* **6**: 582-589.

Kitajima, K. 1996a. Cotyledon functional morphology, patterns of seed reserve utilization and regeneration niches of tropical tree seedlings. In: M.D. Swaine (Ed.) *The Ecology of Tropical Forest Tree Seedlings.* Parthenon, Paris, France, 193-210.

Kitajima, K. 1996b. Ecophysiology of tropical tree seedlings. In: S.S. Mulkey, R.L. Chazdon and A.P. Smith (Eds.) *Tropical Forest Plant Ecophysiology.* Chapman and Hall, New York. 559-596.

Kitajima, K. and Fenner, M. 2000. Ecology of seedling regeneration. In: M. Fenner (Ed.) *Seeds: The Ecology of Regeneration in Plant*

Communities. CAB International, Wallingford, UK. 331-359.

Kitajima, K. 2002. Do shade-tolerant tropical tree seedlings depend longer on seed reserves? Functional growth analysis of three Bignoniacea species. *Funct. Ecol.* **16**: 433-444.

Kochmer, J.P. and Handel, S.N. 1986. Constraints and competition in the evolution of flowering phenology. *Ecol. Monogr*. **56**: 303-325.

Kozlowski, T.T. 1972. *Seed Biology*: *Vol.1, Importance, Development and Germination*. Academic Press, New York.

Kushwaha, C.P, and Singh, K.P. 2005. Diversity of leaf phenology in a tropical deciduous forest in India. *J. Trop. Ecol.* **21**: 47-56.

Leishman, M.R., Wright, I.J., Moles, A.T. and Westoby, M. 2000. The evolutionary ecology of seed size. In: M. Fenner (Ed.) *Seeds: The Ecology of Regeneration in Plant Communities*. 2nd edn. CAB International, Wallingford, UK. 31-57.

Liu, Y., Chen, J., Bai, Z.L., Deng, X.B. and Zhang, L. 2002. Seed dispersal, seed predation and seedling spatial pattern of *Garcinia cowa* (Guttiferae). *Acta Phytoecol. Sin.* **26:** 427-434.

Liu, Y., Qiu, Y., Zhang, L. and Chen, J. 2005. Dormancy breaking and storage behaviour of *Garcinia cowa* Roxb. (Guttiferae) seeds: implications for ecological function and germplasm conservation. *J.*

Integr. Plant Biol. **47**: 38-49.

Lubbock, J. 1892. *A Contribution to Our Knowledge of Seedlings. Vol.1.* Regan Paul, Trench, Trübner and Co. Ltd., London.

Maia, L.A., Maia, S. and Parolin, P. 2005. Seedling morphology of non-pioneer trees in Central Amazonian varzea floodplain forests. *Ecotropica.* **11**:1-8.

Manilal, K.S. and Sivarajan, V.V. 1976. *Flowering plants of the Calicut University Campus*. Calicut University Press, Calicut.

Manilal, K.S. and Sivarajan, V.V. 1982. *Flora of Calicut*. Bishen Singh Mahendra Pal Singh, Dehra Dun, India.

Marshall, D.L. 1986. Effect of seed size on seedling success in three species of *Sesbania* (Fabaceae). *Am. J. Bot*. **73:** 457-464.

Martin, A.C. and Barkley, W.D. 1961. *Seed Identification Manual*. Cambridge University Press, Cambridge, UK.

Martinez-Ramos, M. and Samper, C. 1998. Tree life history patterns and forest dynamics: a conceptual model for the study of plant demography in patchy environments. *J. Sustain. For.* **6**: 85-125.

Mathew, K.L. and George, T.S. 1995. Dormancy and storage of seeds in *Garcinia cambogia* Desr. (Kodampuli). *J. Trop. Agri***. 33**: 77-99.

Matthew, K.M. 1983. *The flora of Tamil Nadu – Carnatic* Vol.2. Part I and II. St. Joseph's College, Thiruchirapalli.

Mayer, A.M. and Poljakoff-Mayber, A. 1989. *The Germination of Seeds*. 4th edn. Pergamon Press, England.

Mazer, S.J. 1989. Ecological, taxonomic and life history correlates of seed size among Indiana dune angiosperms. *Ecol. Monogr.* **59**: 153-175.

McIvor. J.G., and Howden, S.M. 2000. Dormancy and germination characteristics of herbaceous species in the seasonally dry tropics of northern Australia. *Aust. Ecol.* **25**: 213-222.

Metcalfe, D.J. and Grubb, P.J. 1995. Seed mass and light requirements for regeneration in south east Asian rain forest. *Can. J. Bot.* **73**: 817-826.

[*]Mikich, S.B., Silva, S.M. 2001. Composição Florística e Fenologia das Espécies Zoocóricas de Remanescentes de Floresta Estacional Semidecidual no Centro-Oeste do Paraná, BRASIL. *Acta Bot. Bras*. **15**: 89-113.

Mohanan, N. and Sivadasan, M. 2002. *Flora of Agasthyamala*. Bishen Singh, Mahendra Pal Singh, Dehra Dun.

Moles, A.T., Falster, D.S., Leishman, M.R. and Westoby, M. 2004. Small seeded species produce more seeds per spuare metre of canopy per

---

[**] original not seen

year, but not per individual per lifetime. *J. Ecol.* **92**: 373-383.

Molofsky, J. and Augspurger, C.K. 1992. The effect of leaf litter on early seedling establishment in a tropical forest. *Ecology* **73**: 68-77.

Morellato, L.P.C., Rodrigues, R.R., Filho, H.F.L. and Joly, C.A., 1989. Estudo comparative da fenologia de especies arboreas de floresta de altitude e floresta mesofila semidecidua na Serra do Japi, Jundiai, Sao Paulo. *Rev. Bras. Bot.* **12:** 85-98.

Morellato, L.P.C., Talora, D.C., Takahasi, A., Bencke, C.C., Romera, E.C. and Zipparro, V.B. 2000. Phenology of Atlantic rain forest trees: a comparative study. *Biotropica* **32**: 811-823.

Murali, K.S. and R. Sukumar. 1994. Reproductive phenology of a tropical dry deciduous forest, Southern India. *J. Ecol.* **82**: 759-767.

Murali, K.S. 1997. Patterns of seed size, germination and seed viability of tropical tree species in southern India. *Biotropica* **29**: 271-279.

Newstrom, L.E., Frankie, G.W. and Baker, H.G. 1994. A new classification for plant phenology based on flowering patterns in lowland rain forest trees at La Selva, Costa Rica. *Biotropica* **26**: 141-159.

Ng, F.S.P. 1973. Germination of fresh seeds of Malaysian trees. *Malays. For.*

36: 54-65.

Ng, F.S.P. 1978. Strategies of establishment in Malayan forest trees. In: P.B. Tomlinson and M.H. Zimmermann (Eds.), *Tropical Trees as Living Systems*. Cambridge University Press, Cambridge, U.K. 129-162.

Ng, F.S.P. 1991. *Manual of Forest Fruits, Seeds and Seedlings*. *Malayan Forest Record. No.* ***34****. Vol. I and II*. Forest Research Institute, Kuala Lumpur, Malaysia.

Numata, S., Yasuda, M., Okuda, T., Kachi, N. and Noor, N.S.M. 2003. Temporal and spatial patterns of mass flowerings on the Malay peninsula. *Am. J. Bot*. **90**: 1025-1031.

Oliver, M.J. and Bewley, J.D. 1997. Desiccation-tolerance of plant tissues: a mechanistic overview. *Hort*. *Rev*. **18**: 171-213.

Oliver, M.J., Tuba, Z. and Mishler, B.D. 2000. The evolution of vegetative desiccation tolerance in land plants. *Plant Ecol*. **151**:85-100.

Opler, P.A., Frankie, G.W. and Baker, H.G. 1976. Rainfall as a factor in the release, timing and synchronisation of anthesis by tropical trees and shrubs. *J. Biogeogr*. **3**: 231-236.

Pammenter, N.W., Greggains, V., Kioko, J.I., Wesley-Smith, J., Berjak, P. and Finch-Savage, W.E. 1998. Effects of differential drying rates on viability retention of seeds of *Ekebergia capensis*. *Seed Sci*. *Res*. **8**:

463-471.

Pammenter, N.W. and Berjak, P. 1999. A review of recalcitrant seed physiology in relation to desiccation tolerance mechanisms. *Seed Sci*. *Res*. **9**: 13-37.

Pammenter, N.W and Berjak, P. 2000a. Some thoughts on the evolution and ecology of recalcitrant seeds. *Plant Species Biol*. **15**: 153-156.

Pammenter, N.W and Berjak, P. 2000b. Evolutionary and ecological aspects of recalcitrant seed biology. *Seed Sci. Res*. **10**: 301-306.

Paria, N., Kamilya, P. and Bhattacharyya, B. 1995. Seedling morphology in taxonomic study of some members of the Boraginaceae. *J. Nat. Bot. Soc*. **49:** 75-81.

Paria, N.D. and Kamilya, P. 1999. Seedling morphology of some Indian Euphorbiaceae with reference to taxonomy and conservation of biodiversity. In: R.K. Tandon and P. Singh (Eds.) *Biodiversity, Taxonomy and Ecology.* Scientific Publishers, India. 97-129.

Paria, N.D., Sanyal, S. and Das (Ghosh), M. 2006. Correlation coefficient of some character pairs in five tree seedlings of Leguminosae. *J. Bot. Soc. Bengal.* **60:** 134-139.

Paz, H., Mazer, S.J. and Martinez-Ramos, M. 1999. Seed mass, seedling emergence and environmental factors in seven rain forest *Psychotria*

(Rubiaceae). *Ecology* **80**:1594-1606.

Popma, J. and Bongers, F.1988. The effect of canopy gaps on growth and morphology of seedlings of rain forest species. *Oecologia* **75**: 625-632.

Poulin, B.S., Wright, S.J., Lefebvre, G. and Calderon, O. 1999. Interspecific synchrony and asynchrony in the fruiting phenologies of congeneric bird-dispersed plants in Panama. *J. Trop. Ecol.* **15:** 213-227.

Pritchard, H.W., Daws, M.I., Fletcher, B.J., Gamene, C.S., Msanga, H.P. and Omondi, W. 2004. Ecological correlates of seed desiccation tolerance in tropical African dry land trees. *Am. J. Bot.* **91**: 863-870.

Pujol, B., Mühlen, G., Garwood, N., Horoszowski, Y., Douzery, E.J.P. and McKey, D.2005**.** Evolution Under domestication: contrasting functional morphology of seedlings in domesticated cassava and its closest wild relatives. *New Phytol.* **166**: 305-318.

Radford, A.E., Dickison, W.C., Massey, J.R. and Bell, C.R. 1974. *Vascular Plant Systematics*. Harper and Row, New York.

Rathcke, B. and Lacey, E.P. 1985. Phenological patterns of terrestrial plants. *Annu. Rev. Ecol. Syst.* **16**: 179-214.

Reich, P.B. 1995. Phenology of tropical forests: patterns, causes and consequences. *Can. J. Bot.* **73**: 164-174.

*Ricardi, M. 1999a. Morfologia de plantulas de arboles de un Bosque montano bajo. *Plantula* **2**: 1-72.

*Ricardi, M. 1999b. Morfologia de plantulas de arboles de bosques tropofilos de los estados de Apure y Amazonas, Venezuela. *Plantula* **2**: 103-118.

Richards, P.W.1952. *The Tropical Rain Forest: An Eco-logical Study*. Cambridge University Press, Cambridge.

Richards, P.W. 1996. *The Tropical Rain Forest: An Ecological Study.* 2nd edn. Cambridge University Press, Cambridge, England.

Rivera, G., Elliott, S, Caldas, L.S., Nicolossi, G., Coradin, V.T.R. and Borchert, R. 2002. Increasing day-length induces spring flushing of tropical dry forest trees in the absence of rain. *Trees* **16:** 445-456.

Rizzini, T.C. 1965. Experimental studies on seedling development of Cerbado woody plants. *Ann. Mo. Bot. Gard.* **52**: 410-426.

Saha (Das) B., Sarkar, S. and Paria, N. 1998. Seedling morphology of some important timber yielding plants and its taxonomic implications. *Himalay. Ecol.Dev.* **6**: 12-15.

Salisbury, E.J. 1974. Seed size and mass in relation to environment. *Proc. R. Soc. Lond. B. (Biol.Sci.)* **186**: 83-88.

**original not seen

Salisbury, F.B. and Ross, C.W. 1992. *Plant Physiology,* 4th Edn. Wadsworth, Inc., California.

Sasidharan, N. and Sivarajan, V.V. 1996. *Flowering Plants of Thrissur Forests (Western Ghats, Kerala, India).* Scientific Publishers, Jodhpur, India.

Sasidharan, N. 2004. *Biodiversity Documentation for Kerala, Part 6*: *Flowering Plants*, *KFRI Handbook No.17*. Kerala Forest Research Institute, Peechi, Kerala.

Saverimuttu, T. and Westoby, M. 1996. Seedling survival under deep shade in relation to seed size. *J. Ecol.* **84**: 681-689.

Schőngart, J., Piedade, M.T.F., Ludwigshausen, F., Horna, V. and Worbes, M. (2002). Phenology and stem growth periodicity of tree species in Amazonian floodplain forests. *J. Trop. Ecol.* **18:** 581-597.

Singh, K.P. and Singh, J.S. 1988. Certain structural and functional aspects of dry tropical forest and savanna. *Int. J. Ecol. Environ. Sci.* **14**: 31-45.

Singh, K.P. and Kushwaha, C.P. 2005. Emerging paradigms of tree phenology in dry tropics. *Curr. Sci.* **89:** 964-975.

Singh, K.P. and Kushwaha, C.P. 2006. Diversity of flowering and fruiting phenology of trees in a tropical deciduous forest in India. *Ann. Bot.* **97**: 265-276.

Sivarajan, V.V. 1974. *Flora of Calicut. Ph.D. Thesis*, Calicut University, Calicut.

Sivarajan, V.V. and Mathew, P. 1996. *Flora of Nilambur*. Bishen Singh Mahendra Pal Singh, Dehra Dun.

Stearn, W.T. 1992. *Botanical Latin*, 4th edn. David and Charles, London.

Strauss-Debenedetti, S. and Bazzaz, F.A. 1991. Plasticity and acclimation to light in tropical Moraceae of different successional positions. *Oecologia* **87**: 377-387.

Taiz, L. and Zeiger, E., 2002. *Plant Physiology, 3rd edn*. Sinauer Associates, Inc., U.S.A.

Thapliyal, R.C. and Phartyal, S.S. 2005. Dispersal and germination syndromes of tree seeds in a monsoonal forest in northern India. *Seed sci. Res.* **15**: 29-42.

Thompson, J.N. 1981. Elaisomes and fleshy fruits: phenology and selection pressures for ant-dispersal seeds. *Am. Nat.* **117**: 104-8.

Tompsett, P.B.1983**.** The influence of gaseous environment on the storage life of *Araucaria hunsteinii* seed. *Ann. Bot.* ***52*****:** 229-237.

Tompsett, P.B. and Pritchard, H.W. 1993. Water status changes during development in relation to the germination and desiccation tolerance of

Aesculus hippocastanum L. seeds. *Ann. Bot.* **71**: 107-116.

Tweddle, J.C., Dickie, J.B., Baskin, C.C. and Baskin, J.M. 2003. Ecological aspects of seed desiccation sensitivity. *J. Ecol.* **91**: 294-304.

van der Pijl, L. 1972. *Principles of Dispersal in Higher Plants*. Springer–Verlag, New York.

van Schaik, C.P. 1986. Phenological changes in a Sumatran rainforest. *J. Trop. Ecol*. **2**: 327-347.

van Schaik, C.P., Terborgh, J.W. and Wright, S.J. 1993. The phenology of tropical forests: adaptive significance and consequences for primary consumers. *Annu. Rev. Ecol. Syst*. **24**: 353-377.

Vazquez- Yanes, C., Orozco-Segovia, A. and Sanchez-Coronado, M.E. 1999. Recalcitrance among the seeds of the woody plants growing at the northern lmit of the tropical rain forest in the American Continent. In: M. Marzalina, K.C. Khoo, N. Jayanthi, F.Y. Tsan and K.B. Pillay, (Eds.) *IUFRO Seed Symposium 1998: Recalcitrant Seeds*. *Proceedings of the Conference*. Forest Research Institute of Malaysia, Kuala Lumpur. 329-334.

von Techman, I. and van Wyk, A.E. 1994. Structural aspects and trends in the evolution of recalcitrant seeds in dicotyledons. *Seed Sci*. *Res*. **4**: 225-239.

Weberling, F. 1989. *Morphology of Flowers and Inflorescences* (R.J. Pankhurst, trans.) Cambridge University Press, Cambridge, U.K.

Westoby, M., Falster, D.S., Moles, A.T., Vesk, P.A. and Wright, I.J. 2002. Plant ecological strategies: some leading dimensions of variation between species. *Annu. Rev. Ecol. Syst.* **33**: 125-159.

Westoby, M., Leishman, M. and Lord, J. 1996. Comparative ecology of seed size and dispersal. *Philos. Trans. R. Soc. Lond. B. Biol. Sci.* **351**: 1309-1318.

Whitmore, T.C. 1983. Secondary succession from seed in tropical rain forests. *For. Abstr.* **44**: 767-779.

Wright, I.J. and Westoby, M. 1999. Differences in seedling growth behaviour among species: trait correlations across species, and trait shifts along nutrient compared with rainfall gradients. *J. Ecol.* **87**: 85-97.

Wright, I.J., Clifford, H.T., Kidson, R., Reed, M.L., Rice, B.L. and Westoby, M. 2000. A survey of seed and seedling characteristics in 1744 Australian dicotyledon species: cross-species trait correlations and correlated trait-shifts within evolutionary lineages. *Biol. J. Linn. Soc.* **69:** 521-547.

Wright, S.J. and Calderon, O. 1995. Phylogenetic patterns among tropical flowering phenologies. *J. Ecol.* **83**: 937-948.

Wright, S.J. and van Schaik, C.P. 1994. Light and phenology of tropical trees. *Am. Nat*. **143**: 193-199.

Wright, S.J., Carrasco, C., Calderon, O. and Paton, S. 1999. The El Nino southern oscillation, variable fruit production and famine in a tropical forest. *Ecology* **80**:1632-1647.

Ye, N. 1983. Studies on the seedling types of dicotyledonous plants (Magnoliophyta, Magnoliopsida). *Phytologia* **54***:* 161-189.

Zanne, A.E., Chapman, C.A. and Kitajima, K. 2005. Evolutionary and ecological correlates of early seedling morphology in East African trees and shrubs. *Am. J. Bot.* **92**: 972-978.

Table 1 Meteorological Data of Calicut University Campus *

MONTHLY MEAN MAXIMUM TEMPERATURE (°C)												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002	32.6	33.8	34.6	34.7	32.5	29.8	29.6	28.9	31.3	30.8	32.1	32.9
2003	33.6	34.1	35.7	34.2	33.0	30.3	29.3	29.5	31.1	30.7	32.6	32.8
2004	32.8	33.8	34.3	33.7	30.1	29.2	28.7	28.7	30.4	30.8	32.2	32.9
2005	32.5	33.6	34.1	33.3	33.5	30.0	28.3	29.5	29.1	30.3	30.9	31.5
2006	33.1	33.6	33.4	33.7	32.0	30.0	29.2	29.5	29.2	30.7	31.4	32.5
MONTHLY MEAN MINIMUM TEMPERATURE (°C)												
2002	22.2	23.1	24.8	25.1	24.6	23.4	23.3	22.5	23.0	22.5	23.3	21.5
2003	22.2	23.7	24.9	25.1	25.5	23.5	22.7	23.1	23.0	23.2	23.0	21.7
2004	21.9	22.7	24.9	25.1	23.9	23.1	22.8	22.6	23.3	23.1	23.1	21.6
2005	22.6	23.1	25.0	24.9	25.8	23.5	22.9	23.1	23.1	23.1	23.1	22.5
2006	22.5	22.4	24.1	25.9	24.5	23.6	22.9	23.1	23.0	23.3	23.4	21.7
MONTHLY RAINFALL (in mm)												
2002	0.0	0.0	13.2	62.1	393.7	477.5	322.6	432.2	74.1	418.5	103.9	0.0
2003	0.0	8.2	3.5	129.9	197.5	862.0	586.2	227.0	113.6	219.1	54.6	0.0
2004	0.0	0.0	0.0	112.1	649.1	915.8	416.1	422.0	72.4	407.5	128.7	0.0
2005	26.2	1.2	0.0	115.1	85.8	697.4	661.6	245.6	390.5	200.8	117.7	39.0
2006	0.0	0.0	139.8	17.3	589.5	827.3	712.7	450.1	727.3	450.9	174.0	0.0

* Data based on the recording of Kozhikode Airport obtained from India Meteorological Centre, Thiruvananthapuram.

Table 2 Classification of Plants included in the Study arranged Alphabetically according to Angiosperm Phylogeny Group II (2003)

Sl. No.	Code	Botanical Names	Clade	Order	Family
1	K78	*Acacia auriculiformis* A. Cunn. ex Benth.	Eurosids I	Fabales	▯Fabaceae
2	K11	*Acacia mangium* Willd.	Eurosids I	Fabales	▯Fabaceae
3	K85	*Achyranthes aspera* L.	Core Eudicots	Caryophyllales	Amaranthaceae
4	K15	*Adenanthera pavonina* L.	Eurosids I	Fabales	▯Fabaceae
5	K14	*Albizia chinensis* (Osbeck) Merr.	Eurosids I	Fabales	▯Fabaceae
6	K74	*Allophylus serratus* (Roxb.) Kurz	Eurosids II	Sapindales	Sapindaceae
7	K76	*Alysicarpus vaginalis* (L.) DC.	Eurosids I	Fabales	◆Fabaceae
8	K31	*Amorphophallus hohenackeri* (Schott) Engl. & Gehrm.	Monocots	Alismatales	Araceae
9	K66	*Averrhoa carambola* L.	Eurosids I	Oxalidales	▯Oxalidaceae
10	K20	*Bauhinia purpurea* L.	Eurosids I	Fabales	▯Fabaceae
11	K4	*Bixa orellana* L.	Eurosids II	Malvales	Bixaceae
12	K56	*Breynia vitis-idaea* (Burm. f.) Fischer	Eurosids I	Malpighiales	▯Phyllanthaceae
13	K7	*Caesalpinia coriaria* (Jacq.) Willd.	Eurosids I	Fabales	▯Fabaceae
14	K28	*Caesalpinia pulcherrima* (L.) Swartz	Eurosids I	Fabales	▯Fabaceae
15	K92	*Cajanus scarabaeoides* (L.) Thouars	Eurosids I	Fabales	◆Fabaceae
16	K25	*Calotropis gigantea* (L.) R. Br.	Euasterids I	Gentianales	❑Apocynaceae
17	K18	*Cansjera rheedei* Gmel.	Core Eudicots	Santalales	Opiliaceae
18	K55	*Canthium rheedei* DC.	Euasterids I	Gentianales	Rubiaceae
19	K44	*Cardiospermum halicacabum* L.	Eurosids II	Sapindales	Sapindaceae

Continued . . .

Sl. No.	Code	Botanical Names	Clade	Order	Family
20	K46	*Careya arborea* Roxb.	Asterids	Ericales	Lecythidaceae
21	K34	*Cassia fistula* L.	Eurosids I	Fabales	▯Fabaceae
22	K1	*Cassia javanica* L.	Eurosids I	Fabales	▯Fabaceae
23	K60	*Catharanthus pusillus* (Murr.) G. Don	Euasterids I	Gentianales	Apocynaceae
24	K90	*Centrosema pubescens* Benth.	Eurosids I	Fabales	◆Fabaceae
25	K30	*Chassalia curviflora* (Wall. ex Kurz) Thw.	Euasterids I	Gentianales	Rubiaceae
26	K87	*Chromolaena odorata* (L.) King & Robins.	Euasterids II	Asterales	Asteraceae
27	K40	*Cleome viscosa* L.	Eurosids II	Brassicales	*Brassicaceae
28	K3	*Clerodendrum viscosum* Vent.	Euasterids I	Lamiales	Verbenaceae
29	K29	*Clitoria ternatea* L.	Eurosids I	Fabales	◆Fabaceae
30	K8	*Cochlospermum religiosum* (L.) Alston	Eurosids II	Malvales	Cochlospermaceae
31	K35	*Crotalaria pallida* Dryand.	Eurosids I	Fabales	◆Fabaceae
32	K32	*Cyclea peltata* (Lam.) Hook. f. & Thoms.	Eudicots	Ranunculales	Menispermaceae
33	K89	*Datura metel* L.	Euasterids I	Solanales	Solanaceae
34	K17	*Delonix regia* (Boj. ex Hook.) Rafin.	Eurosids I	Fabales	▯Fabaceae
35	K59	*Dracaena sp.*	Monocots	Liliales	Liliaceae
36	K53	*Duranta erecta* L.	Euasterids I	Lamiales	Verbenaceae
37	K37	*Entada rheedei* Spreng.	Eurosids I	Fabales	▯Fabaceae
38	K91	*Evolvulus nummularius* (L.) L.	Euasterids I	Solanales	Convolvulaceae
39	K52	*Flacourtia montana* Graham	Eurosids I	Malpighiales	♣Salicaceae
40	K63	*Garcinia xanthochymus* Hook. f. ex Anders.	Eurosids I	Malpighiales	Clusiaceae
41	K16	*Gliricidia sepium* (Jacq.) Kunth ex Walp.	Eurosids I	Fabales	◆Fabaceae

Continued . . .

Sl. No.	**Code**	**Botanical Names**	**Clade**	**Order**	**Family**
42	K24	*Helicteres isora* L.	Eurosids II	Malvales	•Malvaceae
43	K10	*Hiptage benghalensis* (L.) Kurz	Eurosids I	Malpighiales	Malpighiaceae
44	K54	*Hugonia mystax* L.	Eurosids I	Malpighiales	Linaceae
45	K50	*Hydnocarpus pentandra* (Buch.-Ham.) Oken	Eurosids I	Malpighiales	♣Salicaceae
46	K82	*Hyptis capitata* Jacq.	Euasterids I	Lamiales	▯Lamiaceae
47	K69	*Hyptis suaveolens* (L.) Poit.	Euasterids I	Lamiales	▯Lamiaceae
48	K73	*Impatiens balsamina* L.	Asterids	Ericales	Balsaminaceae
49	K45	*Indigofera tinctoria* L.	Eurosids I	Fabales	◆Fabaceae
50	K9	*Ixora coccinea* L.	Euasterids I	Gentianales	Rubiaceae
51	K67	*Leea indica* (Burm.f.) Merr.	Rosids	No order	Vitaceae
52	K75	*Leucas indica* (L.) R. Br. ex Vatke	Euasterids I	Lamiales	▯Lamiaceae
53	K12	*Macaranga peltata* (Roxb.) Muell. -Arg.	Eurosids I	Malpighiales	Euphorbiaceae
54	K58	*Memecylon umbellatum* Burm. f.	Rosids	Myrtales	Melastomataceae
55	K79	*Mimosa diplotricha* C. Wight & Sanvalle	Eurosids I	Fabales	▯Fabaceae
56	K68	*Mimosa pudica* L.	Eurosids I	Fabales	▯Fabaceae
57	K49	*Morinda pubescens* J. E. Smith	Euasterids I	Gentianales	Rubiaceae
58	K65	*Mukia maderaspatana* (L.) Roem.	Eurosids I	Cucurbitales	Cucurbitaceae
59	K5	*Peltophorum pterocarpum* (DC.) Backer ex Heyne	Eurosids I	Fabales	▯Fabaceae
60	K48	*Phyllanthus emblica* L.	Eurosids I	Malpighiales	▯Phyllanthaceae
61	K39	*Phyllanthus reticulatus* Poir.	Eurosids I	Malpighiales	▯Phyllanthaceae
62	K33	*Polyalthia korintii* (Dunal) Benth. & Hook. f. ex Hook. f. & Thoms.	Magnoliids	Magnoliales	Annonaceae
63	K47	*Polyalthia longifolia* (Sonn.) Thw.	Magnoliids	Magnoliales	Annonaceae

Continued . . .

Sl. No.	**Code**	**Botanical Names**	**Clade**	**Order**	**Family**
64	K27	*Pongamia pinnata* (L.) Pierre	Eurosids I	Fabales	◆Fabaceae
65	K57	*Premna serratifolia* L.	Euasterids I	Lamiales	Verbenaceae
66	K42	*Psidium guajava* L.	Rosids	Myrtales	Myrtaceae
67	K19	*Quassia indica* (Gaertn.) Nooteb.	Eurosids II	Sapindales	Simaroubaceae
68	K2	*Rauvolfia tetraphylla* L.	Euasterids I	Gentianales	Apocynaceae
69	K13	*Samanea saman* (Jacq.) Merr.	Eurosids I	Fabales	▯Fabaceae
70	K84	*Senna alata* (L.) Roxb.	Eurosids I	Fabales	▯Fabaceae
71	K77	*Senna occidentalis* (L.) Link	Eurosids I	Fabales	▯Fabaceae
72	K26	*Senna siamea* (Lam.) Irwin & Barneby	Eurosids I	Fabales	▯Fabaceae
73	K72	*Senna tora* (L.) Roxb.	Eurosids I	Fabales	▯Fabaceae
74	K61	*Solanum melongena* L.	Euasterids I	Solanales	Solanaceae
75	K70	*Solanum violaceum* Ortega	Euasterids I	Solanales	Solanaceae
76	K62	*Solena amplexicaulis* (Lam.) Gandhi	Eurosids I	Cucurbitales	Cucurbitaceae
77	K71	*Stachytarpheta jamaicensis* (L.) Vahl	Euasterids I	Lamiales	Verbenaceae
78	K83	*Sterculia guttata* Roxb. ex DC.	Eurosids II	Malvales	•Malvaceae
79	K41	*Syzygium caryophyllatum* (L.) Alston	Rosids	Myrtales	Myrtaceae
80	K6	*Syzygium cumini* (L.) Skeels	Rosids	Myrtales	Myrtaceae
81	K36	*Syzygium samarangense* (Bl.) Merr. & Perry.	Rosids	Myrtales	Myrtaceae
82	K23	*Tabernaemontana heyneana* Wall.	Euasterids I	Gentianales	Apocynaceae
83	K86	*Tamarindus indica* L.	Eurosids I	Fabales	▯Fabaceae
84	K81	*Tectona grandis* L. f.	Euasterids I	Lamiales	Verbenaceae

Continued . . .

Sl. No.	Code	Botanical Names	Clade	Order	Family
85	K22	*Tinospora cordifolia* (Willd.) Hook. f. & Thoms.	Eudicots	Ranunculales	Menispermaceae
86	K43	*Tridax procumbens* L.	Euasterids II	Asterales	Asteraceae
87	K80	*Urena lobata* L.	Eurosids II	Malvales	Malvaceae
88	K21	*Uvaria narum* (Dunal) Wall. ex Hook.f. & Thoms.	Magnoliids	Magnoliales	Annonaceae
89	K51	*Vateria indica* L.	Eurosids II	Malvales	Dipterocarpaceae
90	K64	*Vigna trilobata* (L.) Verdc.	Eurosids I	Fabales	◆Fabaceae
91	K88	*Zizyphus mauritiana* Lam.	Eurosids I	Rosales	Rhamnaceae
92	K38	*Zizyphus oenoplia* (L.) Mill.	Eurosids I	Rosales	Rhamnaceae

Mimosaceae = □Fabaceae ; Papilionaceae = ◆ Fabaceae; Averrhoaceae = □Oxalidaceae; Caesalpiniaceae = □Fabaceae; Euphorbiaceae with 2 ovules = □ Phyllanthaceae ; Asclepiadaceae =❑Apocynaceae; Capparaceae = *Brassicaceae; Flacourtiaceae = ♣Salicaceae; Sterculiaceae = •Malvaceae; Labiatae =□Lamiaceae; Leeaceae = Vitaceae

Continued . . .

Table 3 Systematic Position and Numbers of the Plants included in Each Group in the Present Study

No.	Clades	Orders	Families	Codes of plants
1	Magnoliids (3)	Magnoliales (3)	Annonaceae (3)	K [21, 33, 47]
2	Monocots (2)	Alismatales (1)	Araceae (1)	K31
		Liliales (1)	Liliaceae (1)	K59
3	Eudicots (2)	Ranunculales (2)	Menispermaceae (2)	K [22, 32]
4	Core Eudicots (2)	Caryophyllales(1)	Amaranthaceae(1)	K85
		Santalales (1)	Opiliaceae (1)	K18
5	Rosids (6)	No order (1)	Vitaceae (1)	K67
		Myrtales (5)	Myrtaceae (4)	K [6,36,41,42]
			Melastomataceae (1)	K58
6	Eurosids I (43)	Malpighiales (9)	Phyllanthaceae (3)	K [32,48,56]
			Salicaceae (2)	K [50,52]
			Clusiaceae (1)	K63
			Malpighiaceae (1)	K10
			Linaceae (1)	K54
			Euphorbiaceae (1)	K12
		Oxalidales (1)	Oxalidaceae (1)	K66
		Fabales (29)	Fabaceae (29)	K [**]
		Rosales (2)	Rhamnaceae (2)	K [38,88]
		Cucurbitales (2)	Cucurbitaceae (2)	K [62,65]
7	Eurosids II (10)	Brassicales (1)	Brassicaceae (1)	K40
		Malvales (6)	Bixaceae (1)	K4
			Cochlospermaceae (1)	K8
			Malvaceae (3)	K [24,80,83]
			Dipterocarpaceae (1)	K51
		Sapindales (3)	Sapindaceae (2)	K [44,74]
			Simaroubaceae (1)	K19
8	Asterids (2)	Ericales (2)	Lecythidaceae (1)	K46
			Balsaminaceae (1)	K73
9	EuasteridsI(20)	Gentianales (8)	Apocynaceae (4)	K [2,23,25,60]
			Rubiaceae (4)	K [9,30,49,55]
		Lamiales (8)	Verbenaceae (5)	K [3,53,57,71,81]
			Lamiaceae (3)	K [69,75,82]
		Solanales (4)	Solanaceae (3)	K [61,70,89]
			Convolvulaceae (1)	K91
10	Euasterids II (2)	Asterales (2)	Asteraceae (2)	K [43,87]
**K [1,5,7,11,13,14,15,16,17,20,26,27,28,29,34,35,37,45,64,68,72,76,77,78,79,84,86,90,92]				

Figures, in parentheses indicate numbers of plants included and in the square brackets represent code numbers.

Table 4 Habit and Phenology of Plants

Code No.	Habit	Flowering Period	Fruiting period	Seed Dispersal
K1	Tree	April-June	Jan.-May	Barochory
K2	Woody shrub	Throughout the year	Throughout	Ornithochory, Zoochory
K3	Woody pubescent shrub	Throughout	Feb.-Dec.	Ornithochory, Zoochory
K4	Small, everygreen tree	July-Dec.	Aug. - Jan.	Autochory
K5	Large tree	July-March	Jan.-Sept.	Anemochory
K6	Tree	Jan.-April	Feb.-July	Zoochory
K7	Medium tree	May-Jan.	July-April	Zoochory
K8	Small Deciduous tree	Dec.-Jan.	Feb.-May	Anemochory
K9	Woody shrub	Throughout	Throughout	Zoochory
K10	Woody climbing shrub	Nov.-Jan.	March-June	Anemochory
K11	Tree	July-may	March-June, Sept.-Dec.	Anemochory
K12	Tree perennial	Dec.-Mar	Feb.-May	Ornithochory
K13	Tree	July-Jan.	Jan.-May	Zoochory
K14	Small tree	May-Sept.	Sept.-Mar	Anemochory
K15	Large Deciduous tree	Dec.-Mar	Jan.-May	Autochory
K16	Large shrub	Dec.-April	Jan.-June	Autochory
K17	Tree	Feb.-June	Aug.-Mar	Barochory, Autochory
K18	Climbing shrub	Jan.-Feb.	Feb.-May	Ornithochory/Zoochory
K19	Small tree	Jan.-Feb.	Mar-May	Zoochory
K20	Tree	Nov.-Mar	Dec. - Apr.	Autochory
K21	Woody straggling shrub	July-Dec.	Nov.-Jan.	Zoochory
K22	Deciduous woody climber	Dec.-Feb.	Jan.-May	Ornithochory
K23	Woody shrub	Throughout	April-Sept.	Zoochory

Continued . . .

Code No.	Habit	Flowering Period	Fruiting period	Seed Dispersal
K24	Sub Deciduous small tree	Nov.-Dec.	Jan.-May	Autochory
K25	Pubescent shrub	Sept.-April	Jan.-May	Anemochory
K26	Medium Tree	April-Nov.	May-Dec.	Anemochory/Autochory
K27	Medium tree	Jan.-April	April-Dec.	Zoochory
K28	Small tree	Throughout	Throughout	Autochory
K29	Herbaceous climber	Throughout	Throughout	Autochory
K30	Shrub	June-Dec.	July-Jan.	Zoochory
K31	Tuberous erect herb	Mar-April	April-June	Ornithochory/Zoochory
K32	Woody twiner	Jan.-April	Feb.-May	Ornithochory/Zoochory
K33	Small tree	Nov.-Mar	Dec.-June	Zoochory/Ornithochory
K34	Tree	Feb.-Nov.	Sept.-April	Zoochory
K35	Undershrub	Throughout	Throughout	Autochory
K36	Small tree	Jan.-Feb.	May-June	Zoochory
K37	Woody liana	Aug.-Dec.	June-Feb.	Barochory/hydrochory
K38	Woody, prickly straggling shrub	Aug.-Dec.	Jan.-Feb.	Ornithochory/ Zoochory
K39	Woody straggling shrub	June-Feb.	Dec.-Sept.	Ornithochory/Barochory
K40	Erect, pubescent herb	Jan.-July	April-Aug.	Zoochory
K41	Small tree	Jan. -June	May-Dec.	Ornithochory/Zoochory
K42	Small tree	Mar-Dec.	Mar-Dec.	Ornithochory/Zoochory
K43	Herb	Throughout	Throughout	Anemochory
K44	Herb, tendril climber	Throughout	Throughout	Ornithochory/Barochory
K45	Undershrub	Sept.-Dec.	Nov.-May	Autochory
K46	Tree, Deciduous	Dec.-Feb.	Feb.-June	Zoochory
K47	Tall tree	Jan.-Mar	May-Sept.	Zoochory /Barochory

Continued . . .

Code No.	Habit	Flowering Period	Fruiting period	Seed Dispersal
K48	Large Deciduous tree	Sept.-May	Oct.-July	Zoochory/ Barochory
K49	Small tree	Throughout	Throughout	Zoochory /Barochory
K50	Evergreen tree	Feb.-April	Jan.-June	Zoochory /Barochory
K51	Large resinous tree	Jan.-Mar	April-July	Zoochory/ Barochory
K52	Evergreen tree	May-Nov.	July-Dec.	Zoochory
K53	Armed, scandent shrub	Feb.-Nov.	July-Feb.	Zoochory/Ornithochory
K54	Straggling shrub	April-Dec.	May-Dec.	Zoochory
K55	Straggling thorny shrub	Mar-Oct.	April-Oct.	Zoochory
K56	Large woody shrub	Mar-May	July-Jan.	Zoochory
K57	Woody shrub to small tree	May-Dec.	June-Feb.	Zoochory/Ornithochory
K58	Tree	May-June	June-Sept.	Zoochory/Ornithochory
K59	Shrub	June	August	Zoochory/Barochory
K60	Erect herb	May-Nov.	May-Nov.	Autochory/ Anemochory
K61	Thorny under shrub	Mar-Oct.	Aug.-April	Ornithochory/Zoochory
K62	Herbaceous tendril climber	Mar-Oct.	Aug.-Dec.	Ornithochory/Zoochory
K63	Medium evergreen tree	Feb.-July	Sept.-June	Zoochory
K64	Twining herbs	July-Dec.	Aug.-Dec.	Autochory
K65	Scabrous herbaceous tendril climber	July-Mar	Aug.-March	Ornithochory/Zoochory
K66	Small tree	Nov.-May	May-March	Zoochory
K67	Shrub	Throughout	Throughout	Ornithochory/Zoochory
K68	Prickly, diffuse undershrub	Throughout	Throughout	Zoochory
K69	Hairy, aromatic undershrub	Sept.-Jan.	Sept.-Jan.	Ornithochory/Zoochory
K70	Thorny undershrub	July-April	July-April	Ornithochory/Zoochory
K71	Tall herb or undershrubs	July-Feb.	Nov.-April	Zoochory

Continued . . .

Code No.	Habit	Flowering Period	Fruiting period	Seed Dispersal
K72	Undershrub	Sept.-Jan.	Sept.-Feb.	Autochory
K73	Erect herb	Aug.-Dec.	Sept.-Dec.	Autochory
K74	Woody undershrub	Sept.-Nov.	Oct.-Dec.	Ornithochory/Zoochory
K75	Erect herb	Throughout	Throughout	Zoochory
K76	Diffuse herb	Sept. -Dec.	Nov.-Dec.	Autochory
K77	Erect undershrubs	Aug.-Mar	Aug.-mar	Autochory
K78	Tree	July-Feb.	Oct.-May	Autochory
K79	Sensitive, prickly, straggling undershrub	Sept.-Feb.	Nov.-Mar	Autochory
K80	Tomentose undershrub	Sept.-Feb.	Oct.-Mar	Zoochory
K81	Large Deciduous tree	Mar-Oct.	Oct.-Mar	Anemochory
K82	Erect herb	Nov.-Jan.	Jan.-Mar	Anemochory
K83	Medium, Deciduous tree	Dec.-Feb.	Jan.-Mar	Zoochory/Ornithochory
K84	Large shrub	June-Dec.	Oct.-May	Autochory
K85	Erect pubescent herb	Aug.-May	Aug.-May	Zoochory
K86	Large tree	April-May	Oct.-April	Zoochory
K87	Viscid-pubescent straggling sub shrub	Dec.-Mar	Dec.-May	Anemochory
K88	Armed small tree	Oct.-April	Nov.-May	Zoochory
K89	Woody shrub	Oct.-June	Dec.-July	Autochory
K90	Pubescent, herbaceous twiner	Oct.-March	Oct.-May	Autochory
K91	Herb, prostrate creeper	Throughout	Throughout	Zoochory
K92	Pubescent, herbaceous twiner	Sept.-April	Nov.-April	Autochory

Continued . . .

Table 5 Reproductive Morphology

	Flower		**Fruit**			**Seed**	
Code number	**Inflorescence Type**	**Colour**	**Type**	**Surface architecture**	**Shape**	**Surface architecture**	**Shape**
K1	Raceme	Pink	Dry indehiscent pod	Black leathery	Long terete	Brown, smooth	Thick, flat round
K2	Umbellate cymes	Greenish white	Fleshy drupe	Deep purple, smooth	Globose	Ivory white, rugose	Trigonous
K3	Cymose panicle	White	Fleshy drupe	Deep purple, smooth	Globose	Black rugose	Oblong trigonous
K4	Racemose panicle	Pink	Loculicidal capsule	Red, bristly	Subglobose or ovoid	Reddish orange	Trigonous
K5	Racemose panicle	Yellow	Samara	Brown, leathery	Thin lenticular	Brown smooth	Flat oblong
K6	Cymose panicle	Greenish white	Fleshy drupe	Deep purple, smooth	Ovoid or ellipsoid	Purplish-white	Oblong or globose
K7	Racemose panicle	Greenish white	Indehiscent pod	Brown, leathery	Thick flat long, twisted	Yellowish green smooth	Ovoid to orbicular
K8	Raceme	Yellow	3-5-valved capsule	Brown, striate, leathery	Globose or pear-shaped	Dark-brown, hairy	Reniform or cochleate
K9	Corymbose cyme	Scarlet red	Drupe	Red, smooth	Globose	Cream, smooth	Compressed, peltate, concave ventrally
K10	Racemose panicle	White	Samara with 3 wings	Straw-coloured, rugose	Oblong, winged	Brown, rugose	Subglobose
K11	Cylindric, racemose spike	Yellowish white	Spiral legume	Straw coloured, lathery	Curved, cylindrical	Black, smooth	Compressed oval to elliptic
K12	Racemose panicle	Greenish white	Fleshy capsule	Green gland-dotted	Globose	Black, smooth	Spheroid
K13	Raceme	Pink	Fleshy indehiscent pod	Black, rugose	Compressed cylindrical	Brown	Compressed ovoid
K14	Raceme	Yellowish white	Indehiscent pod	Straw-cololured	Flat elliptical	Brown	Flat, oval
K15	Raceme	Pale yellow	Legume	Brown with yellow interior	Compressed ellipsoid	Scarlet red, hard, shining	Lenticular
K16	Dense raceme	Pink	Legume	Straw-coloured	Compressed oblong	Brown, smooth	Flat, round

Continued . . .

	Flower		**Fruit**			**Seed**	
Code number	**Inflorescence Type**	**Colour**	**Type**	**Surface architecture**	**Shape**	**Surface architecture**	**Shape**
K1	Raceme	Pink	Dry indehiscent pod	Black leathery	Long terete	Brown, smooth	Thick, flat round
K17	Corymb	Reddish orange with mottled odd petal	Dehiscent pod	Dark brown, woody	Long flat, thin	Black, smooth	Ellipsoid
K18	Spike	Greenish Yellow	Drupe	Orange red, smooth	Globose	Cream, smooth	Round
K19	Umbel	Greenish yellow	Dry drupe	Reddish brown, leathery	Lenticular with a narrow wing	Cream, scarious	Reniform
K20	Raceme	Pink	Legume	Brown, smooth	Oblong, thin. flat	Brown, smooth	Orbicular, plano-convex
K21	Solitary	Greenish yellow	Aggregate of berries	Red, smooth	Spherical, linear, Oblong fruitlet	Brown, smooth	Sub- compressed round
K22	Raceme	Greenish yellow	Fleshy drupe	Red, smooth	Globose	Chalk-white, rugose	Hemispherical, curved
K23	Corymbose cyme	White	Aggregate of 2 fleshy follicles	Orange red, coriaceous	Ellipsoid decurved	Dark brown, crustaceous	Oblong ellipsoid, Compressed or irregular
K24	Few flowered cluster	Red	Aggregate of 5 twisted follicles	Greenish brown, pubescent	Beaked spirally twisted	Black, tubercled	Small round
K25	Umbellate panicle	Lilac	Aggregate of 2 follicles	Brown, ventricose	Boat shaped inflated, tapering	Sooty brown, smooth	Ovate, planoconvex crowned by hairs
K26	Raceme	Yellow	Legume	Brown, torulose	Ellipsoid, thin, flat	Brown, smooth	Compressed oval
K27	Raceme	Lilac	Indehiscent pod	Brown, glabrous, leathery	Elliptic to obliquely oblong	Reddish brown, rugose	Thick, compressed reniform
K28	Corymb	Orange	Legume	Dark brown	Oblong flat straight	Greenish brown, smooth	Compressed oval
K29	Solitary	Blue	Legume	Light brown	Linear oblong compressed	Brown and black	Subglobose or compressed
K30	Cymose panicle	Pinkish white	Drupe	Deep purple	Globose	Light brown	Orbicular dorsally rounded & grooved ventrally
K31	Spadix	Greenish yellow	Berry	Red, smooth	Sub globose or	Ash coloured,	Hemispherical, ovoid

Continued . . .

	Flower		**Fruit**			**Seed**	
Code number	**Inflorescence Type**	**Colour**	**Type**	**Surface architecture**	**Shape**	**Surface architecture**	**Shape**
K1	Raceme	Pink	Dry indehiscent pod	Black leathery	Long terete	Brown, smooth	Thick, flat round
					ovoid	smooth	
K32	Panicle	Greenish yellow	Drupe	Whitish, smooth	Globose	Ash coloured or black	Curved
K33	Few flowered or solitary	Greenish with brown dots	Aggregate of berries	Red, smooth	Globose	Brown	Compressed round
K34	Pendulous raceme	Yellow	dry indehiscent pod	Black, leathery	Long, terete	Brown shiny	Compressed round
K35	Simple raceme	Yellow	Legume	Light brown, leathery	Oblong, inflated	Brown shiny	Compressed reniform
K36	Cyme	Greenish white	Berry	Pink, smooth	Depressed turbinate	Brownish white	Trigonous or irregular
K37	Cylindric spike	Yellow	Huge lomentum	Brown woody	Flat, oblong jointed	Dark brown, shiny	Flat orbicular
K38	Cymose panicle	Greenish white	Drupe	Black	Globose	Brown, smooth	Oval, plano- convex
K39	Solitary	Greenish white or reddish brown	Berry	Dark purple	Globoid	Black, crustaceous	Small, irregularly trigonous
K40	Solitary	Yellow	Capsule	Light brown	Linear, terete	Black, tubercled	Small, compressed reniform
K41	Cymose panicle	White	Fleshy Drupe	Dark purple, smooth	Globose	Light brown	Globose
K42	Solitary or few-flowered	White	Berry	Greenish yellow	globose or obovoid	Light brown, hard, smooth	Reniform
K43	Heterogamous capitulum	Yellowish white	Feathery achene	Black, with silky pappus	Turbinate or oblong	White	Oblong
K44	Raceme	White	Loculicidal, 3-valved capsule	Green, membranous	Depressed pyriform winged at angles	Black with white hilum; smooth	Globose
K45	Raceme	Reddish pink	Legume	Brown, torulose, leathery	Slender, cylindric sharply pointed	Brown, smooth	Cylindric truncate
K46	Spike	Yellowish white	Fibrous berry	Yellowish green woody	Large globose	Dark brown, smooth	Flat ellipsoid
K47	Fascicles	Greenish	Aggregate of berries	Dark purple	Globose cluster of ovoid fruitlets	Light brown, smooth	Oblong with lateral groove

Continued . . .

	Flower		**Fruit**			**Seed**	
Code number	**Inflorescence Type**	**Colour**	**Type**	**Surface architecture**	**Shape**	**Surface architecture**	**Shape**
K1	Raceme	Pink	Dry indehiscent pod	Black leathery	Long terete	Brown, smooth	Thick, flat round
K48	Fascicle	Greenish white	Fleshy capsule	Yellowish green, smooth	Depressed globose	Drak brown, smooth	Trigonous
K49	Solitary heads	White	Multiple, syncarpium of bony pyrenes	Greenish brown	Ovoid or subglobose	Black, crustaceous	Oblong or obovoid
K50	Male in fascicle; female solitary	White or yellowish	Large berry	Brown, hard, tomentose	Globose	Black, striate	Subovoid obtusely angular
K51	Panicle	White	3-valved capsule	Pale brown, coriaceous	Ovoid	Brown	Ovoid
K52	Cymose panicle	Greenish	Berry	Red. smooth	Globose	Pink, rugose	Flat, subquadrate
K53	Panicled raceme	Blue	Drupe	Smooth, orange	Globose	Yellowish white,	concave-convex, Subtriangular
K54	Few-flowered cluster	Yellow	Drupe	Red, smooth	Globose	Light brown, striate	Compressed globose
K55	Axillary fascicle	Greenish white	Drupe	Orange red, smooth	Subglobose	Dark brown, rugose	Oblong compressed
K56	Axilary fascicle	Greenish white	Drupe	Red turning dark, smooth	Depressed globose	Dark brown	Trigonous
K57	Panicled cyme	Greenish white	fleshy drupe	Dark purple, smooth	Globose	Cream, striated	Turbinate
K58	Panicle	Blue	Drupe	Dark brown, smooth	Sub globose	Pale brown, pitted	Sub globose
K59	Racemose panicle	Greenish white	Drupe	Orange brown, smooth	Globose	Pearl white	Subglobose
K60	Few-flowered raceme	White	Aggregate of 2 follicles	Brown	Slender cylindric	Black Muricate	Oblong
K61	Few-flowered raceme	Blue	Berry	Yellow, smooth, shiny	Globose	Cream crustaceous pitted	Discoid
K62	Racemose or	Pale yellow	Berry	Orange red,	Oblong-ovoid	Grey, crustaceous	Compressed globose

Continued . . .

	Flower		**Fruit**			**Seed**	
Code number	**Inflorescence Type**	**Colour**	**Type**	**Surface architecture**	**Shape**	**Surface architecture**	**Shape**
K1	Raceme	Pink	Dry indehiscent pod	Black leathery	Long terete	Brown, smooth	Thick, flat round
	solitary			smooth			
K63	Axillary fascicle	Greenish white	Berry	Dark yellow, smooth	Globose	Light brown, papery	Compressed Ovoid or oblong
K64	Few-flowered raceme	Yellow	Legume	Black, leathery	Subterete	Mottled brown or black	Subquadrate
K65	Fascicle or solitary	yellow	Berry	Red, smooth	Globose	Cream	Compressed ovoid
K66	Panicle	Purple	Berry	Greenish yellow, smooth	Ovoid, 5-lobed & 5-angled	Dark brown	Compressed ovoid
K67	Corymbose cyme	Greenish white	Berry	Black purple, smooth	Depressed globular	Dark brown	Wedge-shaped
K68	Globose head	Pink	Lomentum	Brown, membranous	Flat, oblong	Brown	Flat orbicular
K69	Cymose cluster	Blue	Carcerule	Black, ribbed	Ovoid or oblong	Black rugose	Compressed oblong
K70	Cymose cluster	Blue	Berry	Yellow, smooth	globose	Cream, pitted, crustaceous	Small flat Discoid
K71	Spike	Blue	Drupe	Black, striated	Cylindric	Cylindric	Black, striated
K72	Few-flowered raceme	Yellow	Legume	Black	Sub-tetragonous slender, curved	Brown, shiny striated	Rhombohedral
K73	Solitary or few-flowered cluster	Pink	Loculicidal capsule	Yellow green, tomentose	Ellipsoid inflated	Brownish black, tubercled	Globose
K74	Fascicle	Yellow	Drupe	Red, smooth	Globose	Black	Ovoid
K75	Verticillaster	White	Carcerule	Black, ribbed	Ovoid or oblong	Black	Trigonous ovoid
K76	Raceme	Reddish purple	Lomentum	Black	Tetragonous or subterete	Cream or greenish yellow	Sub-orbicular
K77	Corymbose panicle	Yellow	Legume	Brown	Flat, compressed torulose	Greyish brown	Compressed ovoid
K78	Cylindric spike	Yellow	Legume	Brown	Ligulate, flat	Light brown,	Compressed or ovate

Continued . . .

	Flower		**Fruit**			**Seed**	
Code number	**Inflorescence Type**	**Colour**	**Type**	**Surface architecture**	**Shape**	**Surface architecture**	**Shape**
K1	Raceme	Pink	Dry indehiscent pod	Black leathery	Long terete	Brown, smooth	Thick, flat round
					spirally coiled	smooth	
K79	Raceme of globose heads	Pink	Lomentum	Light brown	Compressed ellipsoid	Smooth	Orbicular
K80	Solitary	Pink	Schizocarp of 5 mericarps	Brown with glochidiate spines	Depressed globular	Brown, smooth	Obovoid
K81	Cymose panicle	Greenish white	Drupe	Brown, spongy	Sub-globose	Light brown, membranous	Ovoid
K82	Globose spike	White	Carcerule	Light brown, ribbed	Ovoid or oblong	Black, smooth	Ovoid
K83	Axillary panicle	Dull orange	Follicle	Red, woody	Obovoid,	Black, smooth	Ovoid
K84	Raceme	Yellow	Quadrangular legume	Black, leathery	Cylindrical, 4 winged	Black, smooth	Flat triangular
K85	Spike	Greenish yellow	Utricle	Brown, membranous	Conoidal	Brown, smooth	Small obovoid
K86	Raceme	Pink yellow striped	Indehiscent pod	Brown, brittle	Linear oblong, incurved	Dark brown, polished	Compressed obovate orbicular
K87	Homogamous Capitulum	White	Achene, feathery	Black with silky pappus	Turbinate or oblong, 4-angled	White, smooth	Oblong or obovoid
K88	Cymose panicle	Greenish	Drupe	Red, smooth	Globose	Brown	Ovoid, planoconvex
K89	Solitary	White	Capsule	Light brown, spinous	Ellipsoid or ovoid	Light brown, rugose	Compressed subreniform
K90	Raceme	Bluish white	Legume	Light brown, pubescent	Compressed, linear oblong	Greenish brown, smooth	Subquadrate
K91	Solitary	White	Capsule	Light brown	Ovoid, 4-lobed	Dark brown, fibrous	Trigonous
K92	Raceme	Yellow	Legume	Brown, villous	Oblong, compressed	Brown smooth	Flat, thick ovoid

Continued . . .

Table 6a-c List of Plants that Fruit during Various Rainfall Periods and their Flowering Time and Seed Characters

Table 6a Fruiting Period - Low Rainfall (3.56 - 121.47 mm)

Code	Storage Type	Flowering period (Based on rainfall)	Dispersal	MC%	TSW
K1	Orthodox	High	Barochory	9.32	126
K8	Orthodox	Low	Anemochory	23.53	45.6
K12	Orthodox	Low	Ornithochory	9.2	39
K13	Orthodox	Average	Zoochory	8.94	154
K14	Orthodox	High	Anemochory	9.59	33.55
K15	Orthodox	Low	Autochory	11.6	226.7
K17	Orthodox	High	Barochory, Autochory	4.13	495.74
K18	Orthodox	Low	Ornithochory/Zoochory	23.73	156
K20	Orthodox	Low	Autochory	18.88	266
K21	Orthodox	High	Zoochory	31.84	127
K22	Orthodox	Low	Ornithochory	17.86	126
K24	Orthodox	Low	Autochory	16.67	1.4
K25	Orthodox	Low	Anemochory	37.5	15.78
K32	Orthodox	Low	Ornithochory/Zoochory	22.86	20
K34	Orthodox	High	Barochory/Zoochory	13.66	148
K38	Orthodox	Average	Ornithochory/ Zoochory	9.57	54
K45	Orthodox	Average	Autochory	14.29	4.6
K46	Recalcitrant	Low	Zoochory	43.88	733
K65	Orthodox	Average	Ornithochory/Zoochory	45.05	13.3
K71	Orthodox	Average	Zoochory	11.93	1.13
K72	Orthodox	Average	Autochory	33.04	16.51
K76	Orthodox	Average	Autochory	11.8	1.5
K77	Orthodox	Average	Autochory	10.97	17
K78	Orthodox	Average	Autochory	10.78	19.2
K79	Orthodox	Average	Autochory	14.84	7.7
K80	Orthodox	Average	Zoochory	9.5	11.71
K81	Orthodox	High	Anemochory	12	826
K82	Orthodox	Low	Anemochory	5.38	0.3
K83	Intermediate	Low	Zoochory/Ornithochory	48.92	992.54
K84	Orthodox	High	Autochory	5.94	34.32
K86	Orthodox	Average	Zoochory	17.2	691.6
K87	Orthodox	Low	Anemochory	8.4	0.2
K88	Orthodox	Low	Zoochory	18.25	65
K90	Orthodox	Low	Autochory	12.91	29.69
K92	Orthodox	Low	Autochory	11.16	11.04
			Total	615.12	5511.11
			Average	17.57	157.46
			Count	35	35

Continued...

Table 6b Fruiting Period - Average Rainfall (124.27 - 243.57mm)

Code	Storage Type	Flowering period (Based on rainfall)	Dispersal	MC%	TSW
K2	Orthodox	Average	Ornithochory, Zoochory	26.92	35
K3	Orthodox	Average	Ornithochory, Zoochory	29.85	33.5
K4	Orthodox	High	Autochory	4.26	22.58
K7	Orthodox	High	Zoochory	14.75	414
K9	Orthodox	Average	Zoochory	34.55	60
K16	Orthodox	Low	Autochory	15.04	137.8
K19	Orthodox	Low	Zoochory	6.98	1121
K28	Orthodox	Average	Autochory	24.87	176.59
K29	Orthodox	Average	Autochory	15.91	42.34
K33	Orthodox	Low	Zoochory/Ornithochory	29.73	76
K35	Orthodox	Average	Autochory	22.22	4.54
K39	Orthodox	High	Ornithochory	17.57	1.31
K43	Orthodox	Average	Anemochory	15.38	0.4
K44	Orthodox	Average	Ornithochory	44.47	12.94
K48	Orthodox	Average	Zoochory	25	23.5
K49	Orthodox	Average	Zoochory	20.63	69.82
K50	Orthodox	Low	Zoochory	32.56	1452
K53	Orthodox	High	Zoochory/Ornithochory	25	16
K56	Orthodox	Average	Zoochory	47.06	8.33
K61	Orthodox	High	Ornithochory/Zoochory	12.7	3.32
K62	Orthodox	High	Ornithochory/Zoochory	12.91	74.67
K63	Recalcitrant	High	Zoochory	50.15	4965.88
K64	Orthodox	High	Autochory	27.29	13.2
K66	Intermediate	Low	Zoochory	51.85	55.11
K67	Orthodox	Average	Ornithochory/Zoochory	38.8	26.6
K68	Orthodox	Average	Zoochory	25.07	4.14
K69	Orthodox	Average	Ornithochory/Zoochory	15.05	9.3
K70	Orthodox	Average	Ornithochory/Zoochory	35.21	3.8
K73	Orthodox	Average	Autochory	32.12	5.27
K74	Orthodox	Average	Ornithochory/Zoochory	26.42	68.7
K75	Orthodox	Average	Zoochory	23.27	2.04
K85	Orthodox	Average	Zoochory	12.07	1.84
K89	Orthodox	Average	Autochory	11.74	13.81
K91	Orthodox	Average	Zoochory	7.86	1.5
			Total	835.26	8956.83
			Average	24.57	263.44
			Count	34	34

Continued...

Table 6c Fruiting Period - High Rainfall (251.92 - 756mm)

Code	Storage Type	Flowering period (Based on rainfall)	Dispersal	MC%	TSW
K5	Orthodox	Average	Anemochory	7.59	76.15
K6	Recalcitrant	Low	Zoochory	51.9	999
K10	Orthodox	Low	Anemochory	7.14	140
K11	Orthodox	Average	Anemochory	10	20
K23	Orthodox	Average	Zoochory	31.86	62.53
K26	Orthodox	High	Anemochory/Autochory	11.48	23.84
K27	Orthodox	Low	Zoochory	19.6	1381
K30	Orthodox	High	Zoochory	39.29	35.5
K31	Intermediate	Low	Ornithochory/Zoochory	65.41	70.53
K36	Recalcitrant	Low	Zoochory	44.59	321.3
K37	Orthodox	Average	Barochory	5.39	25941
K40	Orthodox	High	Zoochory	11.62	0.72
K41	Recalcitrant	Average	Ornithochory/Zoochory	40.91	147
K42	Orthodox	High	Ornithochory/Zoochory	26.09	11.9
K47	Recalcitrant	Low	Zoochory	42.83	1773
K51	Recalcitrant	Low	Zoochory	41.51	25833
K52	Orthodox	High	Zoochory	30	14
K54	Orthodox	High	Zoochory	28.23	183
K55	Orthodox	High	Zoochory	41.73	100.45
K57	Orthodox	High	Zoochory/Ornithochory	28.57	16.3
K59	Recalcitrant	High	Zoochory	39.47	185
K60	Orthodox	High	Autochory/ Anemochory	17.37	2.85
			Total	643.00	60938.07
			Average	29.21	2969.91
			Count	22	22

Continued...

Table 7 Storage and Germination Behaviour of the Seeds

Code	Storage		Sample	MC%	Germination							
					Petridish				Field			
	Type	Days*			US		S		US		S	
					%	Days	%	Days	%	Days	%	Days
K1	Orthodox	0	K1D	9.32	20	4	100	2	35	607		
			K1DA	7.41	10	6	100	2	20	741		
			K1DS	3.48	0		100	2	35	455		
			SK1DA	11.72	0		100	3	20	305	100	8
			SK1DS	8.2	0		90	3	30	129	80	12
K2	Orthodox	0	K2D	26.92	0		0		85	244	50	182
			K2DA	14	0				0		20	119
			K2DS	7.5	0		0		80	251	-	-
			SK2DA	10.28					10	11	20	23
			SK2DS	9.54					0		20	65
K3	Orthodox	0	K3D	29.85	10	31	0		20	467	-	-
			K3DA	6.38	5	97	0		80	47	-	-
			K3DS	4.77	0		-	-	20	19	20	19
			SK3DA	8.2	-	-	-	-	10	203	0	
K4	Orthodox	0	K4D	4.26	5	35	25	6	15	174	-	-
			K4DA	2.38	15	15	40	20	25	102	-	-
			K4DS	2.5	20	22	35	9	50	307	-	-
			SK4DA	9.73	-	-	-	-	60	209	40	202
			SK4DS	9.52	-	-	-	-	40	51	40	20
K5	Orthodox	0	K5D	7.59	80	124	100	1	90	429	-	-
			K5DA	8.67	30	18	100	2	80	491	-	-
			K5DS	2.63	0		100	2	20	577	-	-
			SK5DA	10.08	-	-	-	-	40	13	80	20
			SK5DS	6.87	-	-	-	-	0		40	3
K6	Recalcitrant	0	K6D	51.9	100	7	-	-	100	16	-	-
		2	K6DA2	47.66	100	14	-	-	100	19	-	-
		4	K6DA4	43.01	100	26	-	-	100	28	-	-
		5	K6DA5	38.58	90	22	-	-	100	47	-	-
		8	K6DA8	36.92	80	43	-	-	100	50	-	-
		14	K6DA14	30.05	60	24	-	-	20	22	-	-
		17	K6DA17	27.09	0		-	-	0	-	-	-
K7	Orthodox	0	K7D	14.75	95	17	-	-	70	15	-	-
			K7DA	12.5	70	15	-	-	30	9	-	-
			K7DS	3.57	90	73	-	-	50	45	-	-
			SK7DA	14.21	-	-	-	-	0		0	
			SK7DS	13.36	-	-	-	-	100	15	100	5
K8	Orthodox	0	K8D	23.53	100	17	-	-	50	19	-	-
			K8DA	11.76	0		90	26	80	61	-	-
			K8DS	10.34	0		80	8	10	352	-	-
			SK8DA	13	-	-	-	-	40	31	60	37
			SK8DS	11.42	-	-	-	-	40	22	100	18
K9	Orthodox	0	K9D	34.55	100	41	-	-	90	93	-	-
			K9DA	4.88	100	38	-	-	100	63	-	-
			K9DS	2.65	80	34	-	-	90	174	-	-

Continued...

Code	Storage		Sample	MC%	Germination							
					Petridish				Field			
	Type	Days*			US		S		US		S	
					%	Days	%	Days	%	Days	%	Days
K1	Orthodox	0	K1D	9.32	20	4	100	2	35	607		
			K1DA	7.41	10	6	100	2	20	741		
			K1DS	3.48	0		100	2	35	455		
			SK9DA	10.29	-	-	-	-	40	21	60	98
			SK9DS	9.8	-	-	-	-	80	109	80	100
K10	Orthodox	0	K10D	7.14	100	2	-	-	100	2	-	-
			K10DA	4.92	100	3	-	-	95	8	-	-
			K10DS	3.25	100	2	-	-	100	4	-	-
			SK10DA	9.52	-	-	-	-	0		0	
			SK10DS	10.18	-	-	-	-	0		0	
K11	Orthodox	0	K11D	10	20	10	80	6	10	5	-	-
			K11DA	5.26	30	50	100	6	30	197	-	-
			K11DS	1.27	0		100	5	0		-	-
			SK11DA	9.42	-	-	-	-	0		20	4
			SK11DS	5.86	-	-	-	-	0		0	
K12	Orthodox	0	K12D	9.2	0		0		100	67	-	-
			K12DA	8.54	0		0		95	31	-	-
			K12DS	5	40	72	70	40	95	20	-	-
			SK12DA	8.27		-	-	-	0		0	
			SK12DS	7.37		-	-	-	0		20	53
K13	Orthodox	0	K13D	8.94	85	40	-	-	80	248	-	-
			K13DA	10.71	85	21	90	1	100	186	-	-
			K13DS	5.16	35	87	90	4	70	537	-	-
			SK13DA	13.12	-	-	-	-	20	11	40	2
			SK13DS	11.9	-	-	-	-	80	9	100	20
K14	Orthodox	0	K14D	9.59	0				0		-	-
K15	Orthodox	0	K15D	11.6	25	115	75	7	95	362	-	-
			K15DA	13	20	76	70	7	80	242	-	-
			K15DS	9.1	0		65	7	90	456	-	-
			SK15DA	14.42	-	-	-	-	60	157	80	181
			SK15DS	11.21	-	-	-	-	60	185	40	10
K16	Orthodox	0	K16D	15.04	100	1	-	-	100	1	-	-
			K16DA	11.38	100	1	-	-	100	2	-	-
			K16DS	8.63	100	2	-	-	100	5	-	-
			SK16DA	12.6	-	-	-	-	0		0	
			SK16DS	10.66	-	-	-	-	60	4	20	4
K17	Orthodox	0	K17D	4.13	0		100	10	45	437	-	-
			K17DA	4.55	0		85	7	30	495	-	-
			K17DS	5.44	0		90	32	5	498	-	-
			SK17DA	4.38	-	-	-	-	0		0	
			SK17DS	4.86	-	-	-	-	0		100	132
K18	Orthodox	0	K18D	23.73	0		-	-	5	57	-	-
			K18DA	10.67	0		-	-	0		-	-
			K18DS	7.14	0		-	-	0		-	-
			SK18DA	10.96	-	-	-	-	0		0	
			SK18DS	10.76	-	-	-	-	0		0	
K19	Orthodox	0	K19D	6.98	20	38	-	-	30	42	-	-

Continued...

Code	Storage		Sample	MC%	Germination							
					Petridish				Field			
	Type	Days*			US		S		US		S	
					%	Days	%	Days	%	Days	%	Days
K1	Orthodox	0	K1D	9.32	20	4	100	2	35	607		
			K1DA	7.41	10	6	100	2	20	741		
			K1DS	3.48	0		100	2	35	455		
			K19DA	7.84	20	24	-	-	20	16	-	-
			K19DS	6.24	0		-	-	20	31	-	-
			SK19DA	9.58	-	-	-	-	0		0	
			SK19DS	8.79	-	-	-	-	0		0	
K20	Orthodox	0	K20D	18.88	0		-	-	35	6	-	-
			K20DA	12.66	15	2	-	-	35	5	-	-
			K20DS	8.61	60	3	-	-	60	5	-	-
			SK20DA	14.71	-	-	-	-	0		0	
			SK20DS	12.4	-	-	-	-	0		0	
K21	Orthodox	0	K21D	31.84	0		0		70	131	-	-
			K21DA	14.15	0		0		15	78	-	-
			K21DS	8.37	0		0		20	46	-	-
			SK21DA	12.8					0		0	
			SK21DS	11.14	-	-	-	-	0		0	
K22	Orthodox	0	K22D	17.86	75	16	-	-	90	7	-	-
			K22DA	9.38	40	21	-	-	90	11	-	-
			K22DS	4.72	90	15	-	-	90	10	-	-
			SK22DA	9.73	-	-	-	-	60	28	40	30
			SK22DS	8.38	-	-	-	-	0		0	
K23	Orthodox	0	K23D	31.86	50	444	-	-	55	422	-	-
			K23DA	8.7	30	436	-	-	40	334	-	-
			K23DS	4.94	10	348	-	-	0		-	-
			SK23DA	9.29	-	-	-	-	0		0	
			SK23DS	8.66	-	-	-	-	0		20	
K24	Orthodox	0	K24D	16.67	0		15	149	15	346	-	-
			K24DA	14.29	5	685	-	-	0		-	-
			K24DS	14.5	5	2	-	-	0		-	-
			SK24DA	12.69	-	-	-	-	10	35	10	3
			SK24DS	12.5	-	-	-	-	0		10	9
K25	Orthodox	0	K25D	37.5	70	1	0		75	10	-	-
			K25DA	11.11	100	635	-	-	90	180	-	-
			K25DS	5.88	75	2	60	527	100	101	-	-
			SK25DA	9.91	-	-	-	-	30	25	5	58
			SK25DS	9.62	-	-	-	-	0		0	
K26	Orthodox	0	K26D	11.48	55	39	100	2	55	404	-	-
			K26DA	10.42	70	100	-	-	45	186	-	-
			K26DS	8	20	85	100	3	15	473	-	-
			SK26DA	12.7	-	-	-	-	20	40	40	28
			SK26DS	9.33	-	-	-	-	20	5	40	7
K27	Orthodox	0	K27D	19.6	60	10	-	-	60	6	-	-
			K27DA	11.67	50	12	-	-	50	25	-	-
			K27DS	7.54	40	11	-	-	30	8	-	-
			SK27DA	12.93	-	-	-	-	0		0	
			SK27DS	11.73	-	-	-	-	0		0	

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Code	Storage		Sample	MC%	Germination							
					Petridish				Field			
	Type	Days*			US		S		US		S	
					%	Days	%	Days	%	Days	%	Days
K1	Orthodox	0	K1D	9.32	20	4	100	2	35	607		
			K1DA	7.41	10	6	100	2	20	741		
			K1DS	3.48	0		100	2	35	455		
K28	Orthodox	0	K28D	24.87	30	13	20	9	80	8	-	-
			K28DA	17.78	20	3	-	-	30	3	60	2
			K28DS	8.75	60	7	-	-	40	3	40	2
			SK28DA	14.9	-	-	-	-	-	-	0	
			SK28DS	14.34	-	-	-	-	-	-	20	10
K29	Orthodox	0	K29D	15.91	95	65	-	-	95	160	-	-
			K29DA	5	90	15	-	-	90	22	-	-
			K29DS	7.14	60	100	90	8	80	369	-	-
			SK29DA	12.24	-	-	-	-	80	7	100	7
			SK29DS	10.36	-	-	-	-	50	9	100	3
K30	Orthodox	0	K30D	39.29	10	40	0		90	354	-	-
			K30DA	18.18	0		40	291	80	348	-	-
			K30DS	08.33	30	52	25	50	60	342	-	-
			SK30DA	12.30	-	-	-	-	0		30	3
			SK30DS	10.80	-	-	-	-	0		-	-
K31	Intermediate	0	K31D	65.41	90	18	-	-	85	23	-	-
		2	K31DA2	58.21	90	26	-	-	100	27	-	-
		5	K31DA5	52.63	70	26	-	-	90	50	-	-
		124	K31DA124	24.46	20	7	-	-	-	-	-	-
			K31DS	56.00	10	13	-	-	50	25	-	-
			SK31DS	56.45	40	13	-	-	70	31	-	-
K32	Orthodox	0	K32D	22.86	0		0		95	293	-	-
			K32DA	07.14	0		0		55	213	-	-
			K32DS	06.25	0		0		90	414	-	-
			SK32DS	07.77	-	-	-	-	0		10	3
K33	Orthodox	0	K33D	29.73	0		0		80	278	-	-
			K33DA	13.79	0		0		60	230	-	-
			K33DS	09.38	0		0		80	305	-	-
			SK33DA	11.94	-	-	-	-	0		0	
			SK33DS	13.22	-	-	-	-	0		0	
K34	Orthodox	0	K34D	13.66	90	90	100	3	95	189	-	-
			K34DA	12.01	50	74	100	3	75	301	-	-
			K34DS	8.27	0		75	7	55	307	-	-
			SK34DA	15.35	-	-	-	-	20	56	20	4
			SK34DS	11.72	-	-	-	-	0		60	6
K35	Orthodox	0	K35D	22.22	80	122	100	2	50	208	-	-
			K35DA	8.89	75	111	100	1	80	286	-	-
			K35DS	4.65	0		95	3	5	339	-	-
			SK35DA	13.36	-	-	-	-	40	14	90	11
			SK35DS	7.03	-	-	-	-	60	39	60	4
K36	Recalcitrant	0	K36D	44.59	40	28	0		90	49	-	-
K37	Orthodox	0	K37D	5.39	0		100	8	0		100	35
			K37DA	5.00	0		100	15	0		100	42
			K37DS	4.58	0		100	30	0		90	32

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Code	Storage		Sample	MC%	Germination							
					Petridish				Field			
	Type	Days*			US		S		US		S	
					%	Days	%	Days	%	Days	%	Days
K1	Orthodox	0	K1D	9.32	20	4	100	2	35	607		
			K1DA	7.41	10	6	100	2	20	741		
			K1DS	3.48	0		100	2	35	455		
			SK37DA	6.89	--	-	-	-	0		100	27
			SK37DS	6.03	-	-	-	-	-	-	100	30
K38	Orthodox	0	K38D	9.57	0		0		5	4	-	-
			K38DA	10.64	0		0		5	7	-	-
			K38DS	4.26	0		0		0		-	-
			SK38DA	12.03	-	-	-	-	20	10	0	
			SK38DS	11.5	-	-	-	-	0		0	
K39	Orthodox	0	K39D	17.57	0		10	6	65	15	-	-
			K39DA	18.29	0		0		25	8	45	6
			K39DS	13.11	0		-	-	55	22	55	17
			SK39DA	8.66	-	-	-	-	40	35	85	35
			SK39DS	13.01	-	-	-	-	10	15	40	33
K40	Orthodox	0	K40D	11.62	0		15	273	25	347	-	-
			K40DA	6.42	0		10	124	55	365	-	-
			K40DS	11.15	0		0		15	392	-	-
			SK40DA	1.17	-	-	-	-	30	33	50	118
			SK40DS	8.09	-	-	-	-	0		0	
K41	Recalcitrant	0	K41D	40.91	100	9	-	-	70	76	-	-
			K41DA	13.64	0		-	-	0		-	-
			K41DS	11.28	0		-	-	0		-	-
			SK41DA	14.66	-	-	-	-	0		0	
			SK41DS	13.87	-	-	-	-	0		0	
K42	Orthodox	0	K42D	26.09	25	34	-	-	60	30	-	-
			K42DA	13.64	40	150	-	-	100	29	-	-
			K42DS	10	20	151	-	-	75	217	-	-
			SK42DA	12.27	-	-	-	-	0		0	
			SK42DS	10.01	-	-	-	-	0		0	
K43	Orthodox	0	K43D	15.38	30	276	-	-	40	147	-	-
			K43DA	22.96	5	616	-	-	30	35	-	-
			K43DS	10.74	10	230	-	-	60	148	-	-
			SK43DA	9.09	-	-	-	-	0		0	
			SK43DS	5.93	-	-	-	-	0		20	15
K44	Orthodox		K44D	44.47	0		0		50	242	40	69
			K44DA	20.08	0		-	-	0		20	160
			K44DS	7.18	0		0		0		10	327
			SK44DA	18.64	-	-	-	-	40	52	40	25
			SK44DS	8.22	-	-	-	-	0		40	148
K45	Orthodox	0	K45D	14.29	85	34	-	-	85	35	-	-
			K45DA	16	65	17	-	-	65	356	-	-
			K45DS	5.49	55	56	100	12	45	48	-	-
			SK45DA	16.13	-	-	-	-	0		10	9
			SK45DS	14.32	-	-	-	-	10	8	10	5
K46	Recalcitrant	0	K46D	43.88	100	1	-	-	-	1	-	-
		1	K46DA1	39.49	100	2	-	-	-	-	-	-

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Code	**Storage**		**Sample**	**MC%**	**Germination**							
					Petridish				**Field**			
	Type	**Days***			**US**		**S**		**US**		**S**	
					%	**Days**	**%**	**Days**	**%**	**Days**	**%**	**Days**
K1	Orthodox	0	K1D	9.32	20	4	100	2	35	607		
			K1DA	7.41	10	6	100	2	20	741		
			K1DS	3.48	0		100	2	35	455		
		2	K46DA2	31.16	80	6	-	-	-	-	-	-
		3	K46DA3	23.11	50	5	-	-	-	-	-	-
		4	K46DA4	20.16	0		-	-	-	-	-	-
K47	Recalcitrant	0	K47D	42.83	90	9	-	-	90	54	-	-
			K47DA	29.12	40	22	-	-	70	31	-	-
			K47DS	21.83	0	-	-	-	0	-	-	-
		3	K47DA3	40.72	90	14	-	-	-	-	-	-
		10	K47DA10	33.78	60	17	-	-	-	-	-	-
		18	K47DA18	28.74	0		-	-	-	-	-	-
K48	Orthodox	0	K48D	25	0		0		10	6	-	-
			K48DA	17.65	0		0		0		-	-
			K48DS	12.5	10	6	0		20	8	-	-
			SK48DA	12.23	-	-	-	-	0		20	5
			SK48DS	12.3	-	-	-	-	0		0	
K49	Orthodox	0	K49D	20.63	0		0		10	278	-	-
			K49DA	12.5	0		0		0		-	-
			K49DS	13.64	0		0		25	143	-	-
			SK49DA	10.55	-	-	-	-	0		0	
K50	Orthodox	0	K50D	32.56	0		0		30	175	-	-
			K50DA	11.65	30	21	0		30	48	-	-
			K50DS	8.78	0		0		75	263	-	-
			SK50DA	10.34	-	-	-	-	50	4	0	
			SK50DS	8.76	-	-	-	-	0		0	
K51	Recalcitrant	0	K51D	41.51	100	3	-	-	100	3	-	-
			K51DA10	26.76	60	12	-	-	-	-	-	-
K52	Orthodox	0	K52D	30	0		-	-	0		-	-
			K52DA	18	0		-	-	0		-	-
			K52DS	11.11	0		-	-	0		-	-
			SK52DA	14.33	-	-	-	-	0		0	
			SK52DS	13.37	-	-	-	-	0		0	
K53	Orthodox	0	K53D	25	0		5	51	0		-	-
			K53DA	17.39	5	48	0		5	45	-	-
			K53DS	14.29	0		-	-	0		-	-
			SK53DA	12.36	-	-	-	-	0		0	
			SK53DS	11.13	-	-	-	-	0		0	
K54	Orthodox	0	K54D	28.23	0		0		10	336	-	-
			K54DA	12.66	0		0		15	405	-	-
			K54DS	7.59	0		-	-	0		-	-
			SK54DA	12.29	-	-	-	-	0		0	
			SK54DS	10.55	-	-	-	-	0		0	
K55	Orthodox	0	K55D	41.73	0		0		10	6	-	-
			K55DA	14.89	0		-	-	0		-	-
			K55DS	11.11	0		-	-	0		-	-
			SK55DA	13.14	-	-	-	-	0		0	

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Code	Storage		Sample	MC%	Germination							
					Petridish				Field			
	Type	Days*			US		S		US		S	
					%	Days	%	Days	%	Days	%	Days
K1	Orthodox	0	K1D	9.32	20	4	100	2	35	607		
			K1DA	7.41	10	6	100	2	20	741		
			K1DS	3.48	0		100	2	35	455		
			SK55DS	12.18	-	-	-	-	20	14	20	9
K56	Orthodox	0	K56D	47.06	0		-	-	50	172	-	-
			K56DA	15.38	0		-	-	40	118	-	-
			K56DS	8.58	5	78	-	-	30	148	-	-
			SK56DA	11.78	-	-	-	-	20	6	10	5
			SK56DS	11.22	-	-	-	-	0		0	
K57	Orthodox	0	K57D	28.57	0		-	-	40	139	-	-
			K57DA	11.76	0		-	-	55	240	-	-
			K57DS	10.53	0		-	-	20	149	-	-
			SK57DA	11.14	-	-	-	-	40	53	20	28
			SK57DS	11.06	-	-	-	-	0		0	
K59	Recalcitrant	0	K59D	39.47	100	83	-	-	100	198	-	-
			K59DA	20.36	-	-	-	-	0		-	-
K60	Orthodox	0	K60D	17.37	80	246	-	-	25	254	-	-
			K60DA	6.83	90	129	60	333	60	294	30	283
			K60DS	11.76	80	143	-	-	0		-	-
			SK60DA	9.62	-	-	-	-	0		10	18
			SK60DS	9.84	-	-	-	-	20	34	0	
K61	Orthodox	0	K61D	12.7	0		-	-	70	286	30	321
			K61DA	15.34	0		0		0		0	
			K61DS	8.04	0		-	-	0		20	54
			SK61DA	11.79	-	-	-	-	40	39	40	40
			SK61DS	11.79	-	-	-	-	0		0	
K62	Orthodox	0	K62D	12.91	0		0		0		0	
			K62DA	10.33	-	-	-	-	20	333	40	54
			K62DS	7.84	0		0		0		0	
			SK62DA	9.53	-	-	-	-	0		0	
K63	Recalcitrant	0	K63D	50.15	0		100	15	100	43	-	-
		20	K63DA20	39.68	-	-	100	125	-	-	100	10
		75	K63DA75	14.5	-	-	60	179	-	-	40	21
		94	K63DA94	15.5	-	-	0		-	-	-	-
		14	K63DS14	35.52	-	-	100	157	-	-	100	19
K64	Orthodox	0	K64D	27.29	90	4	-	-	70	97	50	2
			K64DA	15.58	55	24	100	5	60	350	75	4
			K64DS	7.45	0		90	9	10	3	80	4
			SK64DA	15.13	-	-	-	-	0		60	33
			SK64DS	10.39	-	-	-	-	0		80	108
K65	Orthodox	0	K65D	45.05	0		-	-	10	268	-	-
			K65DA	11.85	0		-	-	0		0	
			K65DS	9.38	0		-	-	0		0	
			SK65DA	12.37	-	-	-	-	70	102	40	10
			SK65DS	10.29	-	-	-	-	60	18	100	51
K66	Intermediate	0	K66D	51.85	80	12	-	-	100	12	0	
			K66DA	10.71	100	32	-	-	20	33	0	

Continued...

Code	Storage		Sample	MC%	Germination							
					Petridish				Field			
	Type	Days*			US		S		US		S	
					%	Days	%	Days	%	Days	%	Days
K1	Orthodox	0	K1D	9.32	20	4	100	2	35	607		
			K1DA	7.41	10	6	100	2	20	741		
			K1DS	3.48	0		100	2	35	455		
			K66DS	6.07	60	14	-	-	100	25	0	
			SK66DA	9.97	-	-	-	-	0		0	
			SK66DS	9.32	-	-	-	-	0		0	
K67	Orthodox	0	K67D	38.8	0		0		40	490	5	261
			K67DA	17.01	0		0		0		0	
			K67DS	10.08	0		0		0		10	101
			SK67DA	14.42	-	-	-	-	0		-	-
			SK67DS	13.01	-	-	-	-	10	25	-	-
K68	Orthodox	0	K68D	25.07	40	19	100	2	80	10	70	46
			K68DA	13.82	50	25	100	2	60	13	100	141
			K68DS	7.48	10	138	100	3	10	234	0	
			SK68DA	20.04	-	-	-	-	-	-	90	12
			SK68DS	11.42	-	-	-	-	-	-	80	49
K69	Orthodox	0	K69D	15.05	100	100	-	-	90	21	100	14
			K69DA	15.21	100	16	-	-	90	110	40	117
			K69DS	7.09	80	29	-	-	90	203	100	50
			SK69DA	11.61	-	-	-	-	20	4	-	-
			SK69DS	11.57	-	-	-	-	70	20	-	-
K70	Orthodox	0	K70D	35.21	0		0		55	423	45	343
			K70DA	12.52	0		0		40	356	15	31
			K70DS	8.01	0		0		60	405	5	336
			SK70DA	9.09	-	-	-	-	0		-	-
			SK70DS	9.15	-	-	-	-	10	111	-	-
K71	Orthodox	0	K71D	11.93	0		5	7	100	314	85	42
			K71DA	10.29	0		0		50	204	90	16
			K71DS	5	5	5	0		80	96	95	100
			SK71DA	31.16	-	-	-	-	-	-	35	75
			SK71DS	11.98	-	-	-	-	-	-	30	65
K72	Orthodox	0	K72D	33.04	90	17	-	-	50	166	70	53
			K72DA	13.27	75	282	100	6	80	445	100	55
			K72DS	7.94	10	10	55	88	25	250	80	268
			SK72DA	14.25	-	-	-	-	-	-	45	5
K73	Orthodox	0	K73D	32.12	40	335	-	-	80	242	30	293
			K73DA	9.9	15	182	0		35	181	0	
			K73DS	9.86	40	242	-	-	40	227	15	416
			SK73DA	13.05	-	-	-	-	10	20	-	-
			SK73DS	11.59	-	-	-	-	10	46	-	-
K74	Orthodox	0	K74D	26.42	0		-	-	20	48	20	123
			K74DA	9.27	0		-	-	0		0	
			K74DS	6.06	0		-	-	25	50	0	
K75	Orthodox	0	K75D	23.27	0		-	-	80	419	50	432
			K75DA	7.86	0		10	24	50	160	90	359
			K75DS	4.93	5	255	-	-	40	320	95	261
			SK75DA	12.08	-	-	-	-	0		0	

Continued...

Code	Storage		Sample	MC%	Germination							
					Petridish				Field			
	Type	Days*			US		S		US		S	
					%	Days	%	Days	%	Days	%	Days
K1	Orthodox	0	K1D	9.32	20	4	100	2	35	607		
			K1DA	7.41	10	6	100	2	20	741		
			K1DS	3.48	0		100	2	35	455		
			SK75DS	10.39	-	-	-	-	0		0	
K76	Orthodox	0	K76D	11.8	50	199	100	89	15	44	85	138
			K76DA	8.77	30	137	100	82	15	170	100	37
			K76DS	6.98	20	29	100	6	5	43	90	161
			SK76DA	12	-	-	-	-	20	27	80	49
			SK76DS	8.99	-	-	-	-	40	6	0	
K77	Orthodox	0	K77D	10.97	15	255	85	14	40	301	85	105
			K77DA	10.74	25	50	90	15	15	94	95	18
			K77DS	7.44	0		60	112	0		90	366
			SK77DA	11.12	-	-	-	-	0		100	53
			SK77DS	9.45	-	-	-	-	0		40	22
K78	Orthodox	0	K78D	10.78	35	86	100	2	60	195	70	17
			K78DA	10.45	70	279	100	3	70	396	60	93
			K78DS	3.3	20	30	100	4	0		80	267
			SK78DA	10.98	-	-	-	-	40	31	40	26
			SK78DS	10.69	-	-	-	-	0		0	
K79	Orthodox	0	K79D	14.84	15	265	85	67	35	233	95	55
			K79DA	4.92	30	82	90	71	20	143	100	16
			K79DS	3.8	10	216	100	48	10	234	80	9
			SK79DA	10.16	-	-	-	-	20	80	40	9
			SK79DS	8.2	-	-	-	-	20	24	20	9
K80	Orthodox	0	K80D	9.5	45	253	75	6	25	100	75	4
			K80DA	9.53	40	147	100	28	50	113	30	11
			K80DS	6.34	35	103	95	87	20	26	90	122
			SK80DA	11.15	-	-	-	-	60	13	60	13
			SK80DS	8.79	-	-	-	-	80	12	40	6
K81	Orthodox	0	K81D	12	0		0		0		10	71
			K81DA	10.94	0		0		0		0	
			K81DS	7.59	0		0		0		0	
			SK81DA	12.16	-	-	-	-	0		0	
			SK81DS	10.72	-	-	-	-	0		0	
K82	Orthodox	0	K82D	5.38	5	85	0		20	130	90	47
			K82DA	6.2	0		0		85	192	80	113
			K82DS	6.67	35	131	35	14	30	173	80	121
			SK82DA	23.81	-	-	-	-	100	7	100	10
			SK82DS	13.85	-	-	-	-	60	13	100	7
K83	Intermediate	0	K83D	48.92	0		-	-	70	7	90	3
			K83DA	9.26	-	-	-	-	-	-	100	4
			K83DS	8	-	-	-	-	-	-	100	5
			SK83DA	12.48	-	-	-	-	0		0	
			SK83DS	11.85	-	-	-	-	0		0	
		24	K83DA24	10.2							100	4
			K83DS3	8.22							80	10
K84	Orthodox	0	K84D	5.94	0		50	91	10	127	85	15

Continued...

Code	Storage		Sample	MC%	Germination							
					Petridish				Field			
	Type	Days*			US		S		US		S	
					%	Days	%	Days	%	Days	%	Days
K1	Orthodox	0	K1D	9.32	20	4	100	2	35	607		
			K1DA	7.41	10	6	100	2	20	741		
			K1DS	3.48	0		100	2	35	455		
			K84DA	6.04	0		90	1	5	19	90	8
			K84DS	5.72	0		100	4	0		100	11
			SK84DA	7	-	-	-	-	0		80	88
			SK84DS	6.35	-	-	-	-	0		60	80
K85	Orthodox	0	K85D	12.07	90	12	-	-	70	47	30	3
			K85DA	12.57	90	9	-	-	100	11	-	-
			K85DS	8.85	100	11	-	-	65	35	-	-
			SK85DA	12.96	-	-	-	-	60	5	60	1
			SK85DS	12.77	-	-	-	-	100	5	80	7
K86	Orthodox	0	K86D	17.2	0		-	-	20	4	90	4
			K86DA	14.58	0		-	-	100	7	-	-
			K86DS	7.95	0		-	-	70	21	100	2
			SK86DA	14.77	-	-	-	-	70	9	100	9
			SK86DS	14.66	-	-	-	-	70	7	100	9
K87	Orthodox	0	K87D	8.4	20	63	-	-	50	24	0	
			K87DA	11.48	0		-	-	60	32	30	27
			K87DS	12.32	20	57	-	-	35	23	15	14
			SK87DA	14.86	-	-	-	-	40	10	80	19
			SK87DS	15.91	-	-	-	-	80	9	80	20
K88	Orthodox	0	K88D	18.25	50	10	-	-	70	9	70	9
			K88DA	8.98	20	9	-	-	20	6	60	4
			K88DS	5.19	60	22	-	-	60	10	60	39
			SK88DA	8	-	-	-	-	35	5	-	-
			SK88DS	8.42	-	-	-	-	0		-	-
K89	Orthodox		K89D	11.74	10	75	-	-	100	47	80	62
			K89DA	10.92	0		-	-	60	91	80	45
			K89DS	9.56	0		-	-	90	54	80	111
			SK89DA	10.2	-	-	-	-	80	45	60	34
			SK89DS	9.17	-	-	-	-	100	56	40	56
K90	Orthodox	0	K90D	12.91	0		100	4	20	133	60	1
			K90DA	9.56	0		65	7	20	10	60	6
			K90DS	9.51	0		100	2	30	245	70	28
			SK90DA	12.47	-	-	-	-	0		80	14
			SK90DS	12.69	-	-	-	-	20	14	80	10
K91	Orthodox	0	K91D	7.86	0		-	-	60	9	50	192
			K91DA	7.57	0		-	-	30	53	0	
			K91DS	6.92	0		-	-	10	11	0	
			SK91DA	8.56	-	-	-	-	0		0	
			SK91DS	6.6	-	-	-	-	0		0	
K92	Orthodox	0	K92D	11.16	40	18	80	39	50	25	80	10
			K92DA	9.71	50	144	100	3	70	90	80	44
			K92DS	7.11	30	155	85	20	40	294	90	118
			SK92DA	11.01	-	-	-	-	100	15	100	11
			SK92DS	10.88	-	-	-	-	20	13	40	4

Continued...

D-Fresh seeds; Kn - Code; DA - Air dried; DS - Sundried; SKn Stored; US - Unscarified; S - Scarified.

[*] Days specified in the case of recalcitrant or intermediate seeds only, where viability period is short and hence daily germinability was analysed.

Continued...

Table 7 a-j Classification of Seeds Based on Germination Behaviour

Table 7a List of Plants that Produce Fresh Readily Germinable Seeds and their Germination Behaviour

Plants	Petridish			Plants	Field		
Code	G%	MTG (Days)	MC%	Code	G%	MTG (Days)	MC%
K5D	80	62	7.59	K5D	90	142.5	7.59
K6D	100	7	51.9	K6D	100	12.7	51.9
K7D	95	6.36	14.75	K7D	70	6.93	14.75
K8D	100	10.5	23.53	K8D	50	11.6	23.53
K9D	100	27.7	34.55	K9D	90	33.11	34.55
K10D	100	2	7.14	K10D	100	2	7.14
K13D	85	19.12	8.94	K13D	80	34.75	8.94
K16D	100	1	15.04	K16D	100	1	15.04
K22D	75	10.13	17.86	K22D	90	2	17.86
K23D	50	354.2	31.86	K23D	55	341.18	31.86
K25D	70	1	37.5	K25D	75	4.53	37.5
K26D	55	10.73	11.48	K26D	55	55.73	11.48
K27D	60	7.33	19.6	K27D	60	4.67	19.6
K29D	95	10.32	15.91	K29D	95	22.47	15.91
K31D	100	12.89	65.41	K31D	85	15.94	65.41
K34D	90	37.11	13.66	K34D	95	61.89	13.66
K35D	80	44	22.22	K35D	50	86.2	22.22
K41D	100	4.75	40.91	K41D	70	16.21	40.91
K45D	85	6.18	14.29	K45D	85	9.88	14.29
K47D	90	6.8	42.83	K47D	90	40	42.83
K51D	100	2.4	41.51	K51D	100	2.3	41.51
K59D	100	80.5	39.47	K59D	100	136.5	39.47
K64D	90	1.33	27.29	K64D	70	30.29	27.29
K66D	80	9.5	51.85	K66D	100	11.2	51.85
K69D	100	56.9	15.05	K69D	90	16.11	15.05
K72D	90	8.33	33.04	K72D	50	59	33.04
K85D	90	4.89	12.07	K85D	70	8.14	12.07
K88D	50	10	18.25	K88D	70	14	18.25
K46D	100	1	43.88	K2D	85	161	26.92
K60D	80	157.93	17.37	K12D	100	26.7	9.2
K76D	50	70.7	11.8	K15D	95	105.47	11.6
K80D	45	140.44	9.5	K17D	45	349.2	4.13
				K21D	70	48.57	31.84
				K28D	80	3	24.87
				K30D	90	171.56	39.29
				K32D	95	101.67	22.86
				K33D	80	197.25	29.73
				K36D	90	19.22	44.59
				K39D	65	7	17.57
				K42D	60	20.55	26.09
				K44D	50	109.4	44.47
				K56D	50	87.5	47.06
				K61D	70	189.57	12.7
				K63D	100	43	50.15
				K68D	80	6.5	25.07
				K70D	55	67.4	35.21
				K71D	100	99.95	11.19
				K73D	80	158.56	32.12
				K75D	80	162.13	23.27
				K78D	60	51	10.78
				K83D	70	4.43	48.92
				K87D	50	14.3	8.4
				K89D	100	33.5	11.74
				K91D	60	6.5	7.86
				K92D	50	17	11.16

Continued …

Table 7b List of Plants that Produce Hard Seeds and their Germination Behaviour after Scarification

Plants	Petridish			Plants	Field		
Code	G%	MTG	MC%	Code	G%	MTG	MC%
K37D	100	8	5.39	K37D	100	35	5.39
K62D	0		12.91	K62D	0		12.91
K67D	0		38.8	K67D	5	261	38.8
K77D	85	8.12	10.97	K77D	85	9.41	10.97
K79D	85	17.06	14.84	K79D	95	4.89	14.84
K81D	0		12	K81D	10	71	12
K82D	0		5.38	K82D	90	26.72	5.38
K84D	50	36.4	5.94	K84D	85	1.88	5.94
K90D	100	2.25	12.91	K90D	60	1	12.91
K1D	100	2	9.32	K74D	20	123	26.42
K2D	0		26.92	K76D	85	4.94	11.8
K3D	0		29.85	K80D	75	2.06	9.5
K4D	25	3.2	4.26	K86D	90	2.78	17.2
K11D	80	3	10				
K12D	0		9.2				
K15D	75	5	11.6				
K17D	100	5.3	4.13				
K21D	0		31.84				
K24D	15	64.66	16.67				
K28D	20	5.5	24.87				
K30D	0		39.29				
K32D	0		22.86				
K33D	0		29.73				
K36D	0		44.59				
K38D	0		9.57				
K39D	10	4	17.57				
K40D	15	96	11.62				
K44D	0		44.47				
K48D	0		25				
K49D	0		20.63				
K50D	0		32.56				
K53D	5	51	25				
K54D	0		28.23				
K55D	0		41.73				
K63D	100	11.5	15.15				
K68D	100	1.5	25.07				
K70D	0		35.21				
K71D	5	7	11.932				
K78D	100	2	10.78				
K92D	80	20.75	11.16				

Continued …

Table 7c Effect of Air-drying on Germinability of Seeds

Seed Type	Petridish			Seed type	Field		
Code	**G%**	**MTG**	**MC%**	**Code**	**G%**	**MTG**	**MC%**
K6DA2	100	9.8	47.66	K6DA2	100	15.5	47.66
K6DA4	100	16.9	43.01	K6DA4	100	24.4	43.01
K6DA5	70	22.57	38.58	K6DA5	100	24.5	38.58
K6DA8	80	33	36.92	K6DA8	100	30.6	36.92
K9DA	100	19.7	4.88	K9DA	100	19.9	4.88
K10DA	100	2.1	4.92	K10DA	95	2.42	4.92
K13DA	85	8.76	10.71	K13DA	100	18.3	10.71
K16DA	100	1	11.38	K16DA	100	1.05	11.38
K25DA	100	32.95	11.11	K25DA	90	23.56	11.11
K26DA	70	32.86	10.42	K26DA	45	47.77	10.42
K27DA	50	7.4	11.67	K27DA	50	11.8	11.67
K29DA	90	10	5	K29DA	90	11.78	5
K31DA5	70	16	52.63	K31DA5	90	40	52.63
K31DA2	90	15	58.21	K31DA2	100	22.44	58.21
K34DA	50	30.7	12.01	K34DA	75	107.53	12.01
K35DA	75	56.87	8.89	K35DA	80	73.31	8.89
K45DA	65	3.77	16	K45DA	65	37.54	16
K60DA	90	120.11	6.83	K60DA	60	262.5	6.83
K64DA	55	9.55	15.58	K64DA	60	78.08	15.58
K68DA	50	13	13.82	K68DA	60	7.5	13.82
K69DA	100	9.5	15.21	K69DA	90	21.55	15.21
K72DA	75	75.53	13.27	K72DA	80	109.44	13.27
K78DA	70	127.43	10.45	K78DA	70	210.86	10.45
K85DA	90	4	12.57	K85DA	100	3.8	12.57
K92DA	50	60.6	9.71	K92DA	70	39.57	9.71
K6DA14	60	23	30.05	K3DA	80	31.81	6.38
K7DA	70	9.14	12.5	K5DA	80	145.44	8.67
K46DA3	50	4.4	23.11	K8DA	80	37.25	11.76
K46DA2	80	5.5	31.16	K12DA	95	16.53	8.54
K46DA1	100	2	39.49	K15DA	80	104.81	13
K47DA10	60	16.17	33.78	K22DA	90	3	9.38
K47DA3	90	12.66	40.72	K30DA	80	138.25	18.18
K51DA10	60	11.33	26.76	K32DA	55	131.45	7.14
K66DA	100	20.8	10.71	K33DA	60	80.83	13.79
				K40DA	55	172.94	6.42
				K42DA	100	19.65	13.64
				K47DA	70	31	29.12
				K57DA	55	124.27	11.76
				K71DA	50	58.3	10.29
				K75DA	50	146.8	7.86
				K80DA	50	46	9.53
				K82DA	85	72.47	6.2
				K86DA	100	7	14.58
				K87DA	60	15.83	11.48
				K89DA	60	19.67	10.92

Continued …

Table 7d Effect of Air-drying and Scarification on Germinability of Seeds

Seed type	Petridish			Seed type	Field		
Code	**G%**	**MTG**	**MC%**	**Code**	**G%**	**MTG**	**MC%**
K37DA	100	15	5	K37DA	100	42	5
K39DA	0		18.29	K39DA	45	5.67	18.29
K61DA	0		15.34	K61DA	0		15.34
K67DA	0		17.01	K67DA	0		17.01
K70DA	0		12.52	K70DA	15	16.67	12.52
K73DA	0		9.9	K73DA	0		9.9
K76DA	100	14.6	8.77	K76DA	100	15.4	8.77
K77DA	90	5.78	10.74	K77DA	95	5.84	10.74
K79DA	90	7.83	4.92	K79DA	100	3.5	4.92
K81DA	0		10.94	K81DA	0		10.94
K84DA	90	1	6.04	K84DA	90	2.39	6.04
K90DA	65	4.23	9.56	K90DA	60	3.17	9.56
K1DA	100	2	7.41	K2DA	20	63.5	14
K3DA	0		6.38	K28DA	60	1.17	17.78
K4DA	40	12	2.38	K44DA	20	94	20.08
K5DA	100	2	8.67	K62DA	40	35	10.33
K8DA	90	8.66	11.76	K65DA	0		11.85
K11DA	100	2.5	5.26	K66DA	0		10.71
K12DA	0		8.54	K74DA	0		9.27
K15DA	70	4.71	13	K88DA	60	4	8.98
K17DA	85	5.74	4.55	K91DA	0		7.57
K21DA	0		14.15				
K30DA	40	288.5	18.18				
K32DA	0		7.14				
K33DA	0		13.79				
K38DA	0		10.64				
K40DA	10	104.5	6.42				
K48DA	0		17.65				
K49DA	0		12.5				
K50DA	0		11.65				
K53DA	0		17.39				
K54DA	0		12.66				
K71DA	0		10.29				
K75DA	10	24	7.86				
K80DA	100	11	9.53				
K82DA	0		6.2				

Continued …

Table 7e Effect of Sun-drying on Germinability of Seeds

Seed Type	**Petridish**			**Seed Type**	**Field**		
Code	**G%**	**MTG**	**MC%**	**Code**	**G%**	**MTG**	**MC%**
K7DS	90	31.33	3.57	K7DS	50	37.6	3.57
K9DS	80	19.63	2.65	K9DS	90	66.56	2.65
K10DS	100	2	3.25	K10DS	100	3	3.25
K16DS	100	2	8.63	K16DS	100	2.8	8.63
K20DS	60	3	8.61	K20DS	60	3.5	8.61
K22DS	90	5	4.72	K22DS	90	5.22	4.72
K25DS	75	1.2	5.88	K25DS	100	15.65	5.88
K29DS	60	43.33	7.14	K29DS	80	135	7.14
K45DS	55	27.27	5.49	K45DS	45	20.89	5.49
K66DS	60	12	6.07	K66DS	100	15.9	6.07
K69DS	80	14.63	7.09	K69DS	90	30.22	7.09
K85DS	100	5.5	8.85	K85DS	65	7.92	8.85
K88DS	60	22	5.19	K88DS	60	28.8	5.19
K28DS	60	4.33	8.75	K2DS	80	236.63	7.5
K60DS	80	140.6	11.76	K4DS	50	115.4	2.5
				K12DS	95	12.16	5
				K13DS	70	178.5	5.16
				K15DS	90	226.17	9.1
				K30DS	60	130.33	8.33
				K31DS	50	28.29	56
				K32DS	90	101.44	6.25
				K33DS	100	276.5	9.38
				K34DS	55	220	8.27
				K39DS	55	9.73	13.11
				K42DS	75	52.6	10
				K43DS	60	19.92	10.74
				K50DS	75	102.33	8.78
				K70DS	60	266.33	8.01
				K71DS	80	38.56	5
				K86DS	70	15.5	7.95
				K89DS	90	29.78	9.56

Continued …

Table 7 f Effect of Sun-drying and Scarification on Germinability of Seeds

Seed Type	Petridish			Seed Type	Field		
Code	G%	MTG	MC%	Code	G%	MTG	MC%
K37DS	100	30	4.58	K37DS	90	32	4.58
K44DS	0		7.18	K44DS	10	327	7.18
K62DS	0		7.84	K62DS	0		7.84
K64DS	90	5.11	7.45	K64DS	80	1.44	7.45
K67DS	0		10.08	K67DS	10	101	10.08
K68DS	100	1.8	7.48	K68DS	0		7.48
K72DS	55	46.36	7.94	K72DS	80	75.94	7.94
K76DS	100	2.2	6.98	K76DS	90	64.06	6.98
K77DS	60	61.83	7.44	K77DS	90	19	7.44
K78DS	100	2.9	3.3	K78DS	80	39.88	3.3
K79DS	100	7.45	3.8	K79DS	80	2.13	3.8
K80DS	95	24.58	6.34	K80DS	90	31.11	6.34
K81DS	0		7.59	K81DS	0		7.59
K82DS	35	14	6.67	K82DS	80	33.38	6.67
K84DS	100	1.9	5.72	K84DS	100	2.35	5.72
K90DS	100	1.25	9.51	K90DS	70	10.86	9.51
K92DS	85	5.12	7.11	K92DS	90	58	7.11
K1DS	100	2	3.48	K3DS	20	19	4.77
K2DS	0		7.5	K28DS	40	2	8.75
K4DS	35	4.57	2.5	K61DS	20	38.5	8.04
K5DS	100	2	2.63	K65DS	0		9.38
K8DS	80	6.25	10.34	K73DS	15	203.33	9.86
K11DS	100	2.7	1.27	K74DS	0		6.06
K12DS	70	21.43	5.	K75DS	95	159.16	4.93
K13DS	90	1.88	5.16	K87DS	15	10.33	12.32
K15DS	65	5.85	9.1	K91DS	0		6.92
K17DS	90	15.33	5.44				
K21DS	0		8.37				
K26DS	100	4.8	8				
K30DS	25	50	8.33				
K32DS	0		6.25				
K33DS	0		9.38				
K34DS	75	4.6	8.27				
K35DS	95	1.63	4.65				
K38DS	0		4.26				
K40DS	0		11.15				
K48DS	0		12.5				
K49DS	0		13.64				
K50DS	0		8.78				
K70DS	0		8.01				
K71DS	0		5				

Continued …

Table 7g Effect of Air-drying and Storage on Germinability of Seeds

Seed Type	Field		
Code	**G%**	**MTG**	**MC%**
SK4DA	60	88.33	9.73
SK15DA	60	153.66	14.42
SK22DA	60	20.33	9.73
SK29DA	80	4.5	12.24
SK50DA	50	4	10.34
SK65DA	70	34.14	12.37
SK80DA	60	6.67	11.15
SK82DA	100	6	23.81
SK85DA	60	3	12.96
SK86DA	70	8	14.77
SK89DA	80	26.5	10.2
SK92DA	100	11.2	11.01

Table 7h Effect of Air-drying, Storage and Scarification on Germinability of Seeds

Seed Type	Field		
Code	**G%**	**MTG**	**MC%**
SK1DA	100	3.7	11.72
SK2DA	20	16	10.28
SK3DA	0		8.2
SK5DA	80	7.5	10.08
SK7DA	0		14.21
SK8DA	60	23.67	13
SK9DA	60	55.33	10.29
SK10DA	0		9.52
SK11DA	20	4	9.42
SK12DA	0		8.27
SK13DA	40	40	13.12
SK16DA	0		12.6
SK17DA	0		4.38
SK18DA	0		10.96
SK19DA	0		9.58
SK20DA	0		14.71
SK21DA	0		12.8
SK23DA	0		9.29
SK24DA	10	3	12.69
SK25DA	5	58	9.91
SK26DA	40	14.85	12.7
SK27DA	0		12.93
SK28DA	0		14.9
SK30DA	30	3	12.3
SK33DA	0		11.94
SK34DA	20	4	15.35
SK35DA	90	6.11	13.36
SK37DA	100	27	6.89
SK38DA	0		12.03
SK39DA	85	16.64	8.66
SK40DA	50	38	1.17
SK41DA	0		14.66
Seed Type	**Field**		
Code	**G%**	**MTG**	**MC%**
SK1DA	100	3.7	11.72
SK42DA	0		12.27
SK43DA	0		9.09
SK44DA	40	19	18.64
SK45DA	10	9	16.13
SK48DA	20	5	12.23
SK49DA	0		10.55
SK52DA	0		14.33
SK53DA	0		12.36
SK54DA	0		12.29
SK55DA	0		13.14
SK56DA	10	5	11.78
SK57DA	20	25.5	11.14
SK60DA	10	18	9.62
SK61DA	40	33	11.79
SK62DA	0		9.53
SK64DA	60	17.33	15.13
SK66DA	0		9.97
SK75DA	0		31.16
SK76DA	80	31.75	12
SK77DA	100	15	11.12
SK78DA	40	16.5	12.08
SK79DA	40	7	10.98
SK81DA	0		10.16
SK83DA	0		12.16
SK84DA	80	26.5	7
SK87DA	80	12.5	14.86
SK90DA	80	9.25	12.47
SK91DA	0		8.56

Continued …

Table 7i Effect of Sun-drying and Storage on Germinability of Seeds

Seed Type	Field		
Code	**G%**	**MTG**	**MC%**
SK7DS	100	9.8	13.36
SK9DS	80	60.25	9.8
SK13DS	80	7.13	11.9
SK15DS	60	121.67	11.21
SK16DS	60	3	10.66
SK29DS	50	9	10.36
SK31DS	70	31	56.45
SK35DS	60	35.33	7.03
SK65DS	60	16	10.29
SK69DS	70	9.57	11.57
SK80DS	80	6.5	8.79
SK82DS	60	9.33	13.85
SK85DS	100	2.2	12.77
SK86DS	70	6.5	14.66
SK87DS	80	8.25	15.91
SK89DS	100	399.4	9.17

Table 7j Effect of Sun-drying, Storage and Scarification on Germinability of Seeds

Seed Type	Field		
Code	**G%**	**MTG**	**MC%**
SK1DS	80	5.44	8.2
SK2DS	20	65	9.54
SK4DS	40	16	9.52
SK5DS	40	3	6.87
SK8DS	100	13.6	11.42
SK10DS	0		10.18
SK11DS	0		5.86
SK12DS	20	53	7.37
SK17DS	100	88.8	4.86
SK18DS	0		10.76
SK19DS	0		8.79
SK20DS	0		12.4
SK21DS	0		11.14
SK22DS	0		8.38
SK23DS	20	24	8.66
SK24DS	10	9	12.5
SK25DS	0		9.62
SK26DS	40	4.5	9.33
SK27DS	0		11.73
SK32DS	10	3	7.77
SK33DS	0		13.22
SK34DS	60	5	11.72
SK37DS	100	30	6.03
SK38DS	0		11.5
SK39DS	40	20.5	13.01
SK40DS	0		8.09
SK41DS	0		13.87
SK42DS	0		10.01
SK43DS	20	9.5	5.93
SK44DS	40	151	8.22
SK45DS	10	5	14.32
SK48DS	0		12.3
SK50DS	0		8.76
SK1DS	80	5.44	8.2
SK52DS	0		13.37
SK53DS	0		11.13
SK54DS	0		10.55
SK55DS	20	9	12.18
SK56DS	0		11.22
SK57DS	0		11.06
SK60DS	0		9.84
SK61DS	0		11.79
SK64DS	80	36	10.39
SK66DS	0		9.32
SK75DS	0		10.39
SK76DS	0		8.99
SK77DS	40	13.5	9.45
SK78DS	0		10.69
SK79DS	20	9	8.2
SK81DS	0		10.72
SK83DS	0		11.85
SK84DS	60	28	6.35
SK90DS	80	5.75	12.69
SK91DS	0		6.6
SK92DS	40	4	10.88

Continued …

Continued …

Continued …

Table 8 Relation Between Seedling Types, Habit & Dispersal

Code	Seedling Type	Habit	Dispersal
K21	CEH	shrub	L
K59	CHH	shrub	L
K3	CHR	shrub	L
K31	CHR	herb	L
K41	CHR	shrub	L
K92	CHR	herb	NL
K47	CSH	tree	L
K46	HHR	tree	L
K63	HSR	tree	L
K1	PEF	tree	NL
K12	PEF	tree	L
K14	PEF	tree	NL
K18	PEF	shrub	L
K2	PEF	shrub	L
K20	PEF	tree	NL
K22	PEF	shrub	L
K23	PEF	shrub	L
K24	PEF	tree	NL
K25	PEF	shrub	NL
K26	PEF	tree	NL
K28	PEF	tree	NL
K29	PEF	herb	NL
K30	PEF	shrub	L
K32	PEF	shrub	L
K33	PEF	tree	L
K34	PEF	tree	L
K35	PEF	shrub	NL
K38	PEF	shrub	L
K39	PEF	shrub	L
K4	PEF	tree	NL
K40	PEF	herb	L
K42	PEF	tree	L
K43	PEF	herb	L
K45	PEF	shrub	NL
K48	PEF	tree	L
K49	PEF	tree	L
K5	PEF	tree	NL
K50	PEF	tree	L
K53	PEF	shrub	L
K54	PEF	shrub	L
K55	PEF	shrub	L
K56	PEF	shrub	L
K57	PEF	tree	L
K58	PEF	shrub	L
K60	PEF	herb	NL
K61	PEF	shrub	L
K65	PEF	herb	L
K67	PEF	shrub	L
K68	PEF	shrub	L
K69	PEF	shrub	L
K7	PEF	tree	L
K70	PEF	shrub	L
K71	PEF	herb	L
K72	PEF	shrub	NL
K73	PEF	herb	NL
K75	PEF	herb	L
K76	PEF	herb	NL
K77	PEF	shrub	NL
K78	PEF	tree	NL
K79	PEF	shrub	NL
K8	PEF	tree	NL
K80	PEF	shrub	L
K81	PEF	tree	NL
K82	PEF	herb	NL
K84	PEF	shrub	NL
K85	PEF	herb	L
K87	PEF	shrub	NL
K88	PEF	tree	L
K89	PEF	shrub	NL
K9	PEF	shrub	L
K91	PEF	herb	L
K10	PER	shrub	NL
K11	PER	tree	NL
K13	PER	tree	L
K15	PER	tree	NL
K16	PER	shrub	NL
K17	PER	tree	NL
K44	PER	herb	L
K64	PER	herb	NL
K66	PER	tree	L
K74	PER	shrub	L
K86	PER	tree	L
K36	PHR	tree	L
K37	PHR	shrub	NL
K6	PHR	tree	L
K19	PSR	tree	L
K27	PSR	tree	L
K51	PSR	tree	L
K62	PSR	herb	L
K83	PSR	tree	L
K90	PSR	herb	NL

L=Living; NL=Non-living means

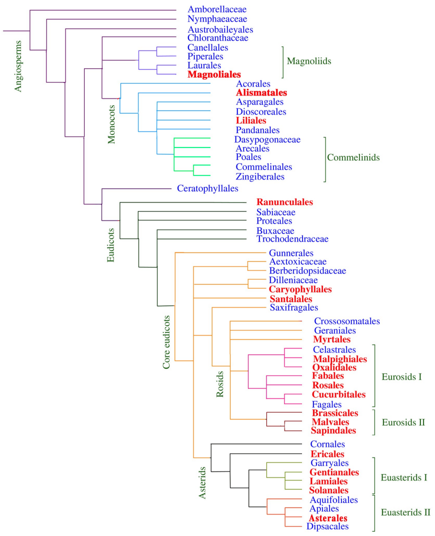
Table 9 Relation between Monthly Fruiting Phenology and Various Plant/Seed Characters

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	5.24	1.88	31.3	87.3	383.12	756.00	539.84	355.38	275.58	339.36	115.78	7.8
No.of Plants	61	62	62	58	58	42	39	44	49	53	59	63
Orthodox	58	57	57	53	49	33	34	40	45	50	56	60
Recalcitrant	1	3	3	4	7	7	4	3	3	2	2	2
Intermediate	2	2	2	1	2	2	1	1	1	1	1	1
Average MC.%	21.11	21.33	21.03	22.48	24.42	28.16	27.58	25.84	25.50	23.35	22.12	22.32
Average TSW(g)	626.65	645.68	246.74	694.71	711.58	1549.65	1478.47	718.59	747.56	687.21	619.32	585.62
Dispersal (non living)	25	25	25	21	20	12	10	13	17	19	22	25
Dispersal (living)	36	37	37	37	38	30	29	31	32	34	37	38
Flowering (Low rain)	11	21	23	23	25	12	5	3	3	3	5	8
Flowering (average rain)	35	29	28	25	23	21	22	23	27	30	34	35
Flowering (high rain)	15	12	11	10	10	9	12	18	19	20	20	20

Table 10 Relation between Fruiting Phenology based on Rainfall and Various Plant/Seed Characters

Category	**Low**	**Average**	**High**
Rain fall (mm)	3.56-121.47	124.27-243.57	251.92-756
No. of Plants	35	34	22
Orthodox	33	32	15
Recalcitrant	1	1	6
Intermediate	1	1	1
Average MC.%	17.57	24.57	29.21
Average TSW	157.46	263.44	2969.91
Dispersal (Non living)	18	10	6
Dispersal (Living)	17	24	16
Flowering (Low rain)	16	5	7
Flowering (Average rain)	12	21	5
Flowering (High rain)	7	8	10

Fig. 3 Correlation phenogram of Angiosperms as per Angiosperm Phylogeny Group II (2003)



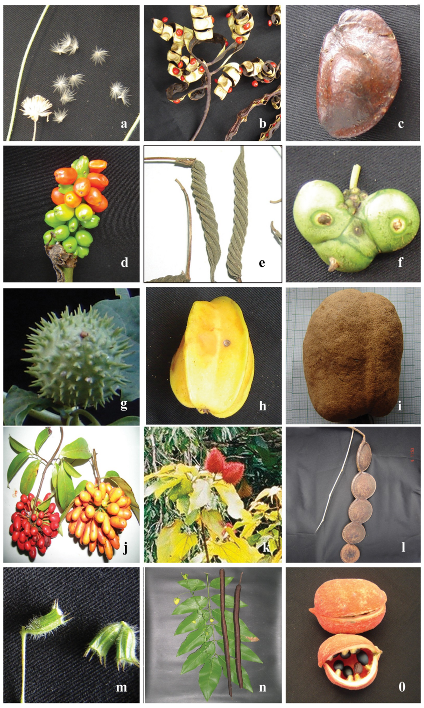
The orders to which the plants of the present study belong to are given in red colour

Fig. 1 Calicut University Campus Map

N - 11° 8'19.13"N
S - 11° 7'58.10"N

E - 75°53'32.63"E
W - 75°53'11.20"E

Fig. 5 Fruit morphology

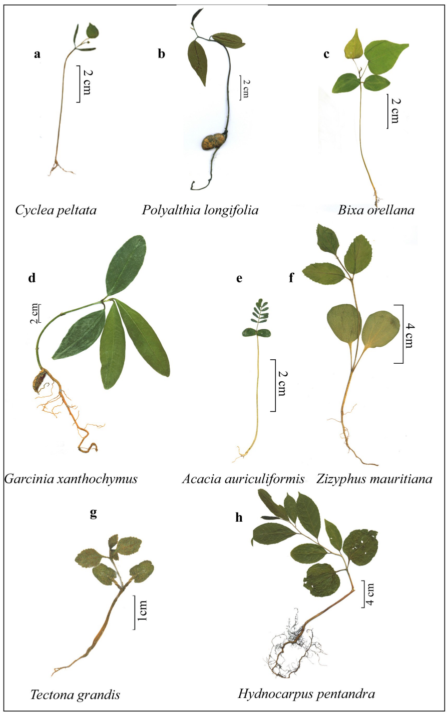


a. *Tridax procumbens*; b. *Adenanthera pavonina*; c. *Quassia indica*; d. *Amorphophallus hohenackeri*; e. *Helicteres isora*; f. *Morinda pubescens*; g. *Datura metel*; h. *Averrhoa carambola*; i. *Vateria indica*; j *Uvaria narum*; k. *Bixa orellana*; l. *Entada rheedei*; m. *Hyptis suaveolens*; n. *Cassia fistula*; o. *Sterculia guttata.*

Fig. 10 Seedling types - Photographs

a. *Memecylon umbellatum*; b. *Cardiospermum halicacabum*; c. *Vateria indica*; d. *Centrosema pubescens*; e. *Rauvolfia tetraphylla*; f. *Sterculia guttata*; g. *Polyalthia longifolia*; h. *Adenanthera pavonina*; i. *Samanea saman*; j. *Syzygium cumini*.

Fig. 9 Seedling types - scan of herbarium specimens

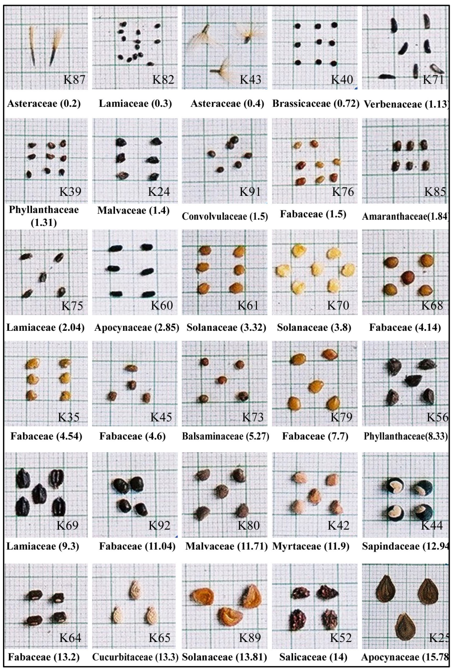


Cyclea peltata *Polyalthia longifolia* *Bixa orellana*

Garcinia xanthochymus *Acacia auriculiformis* *Zizyphus mauritiana*

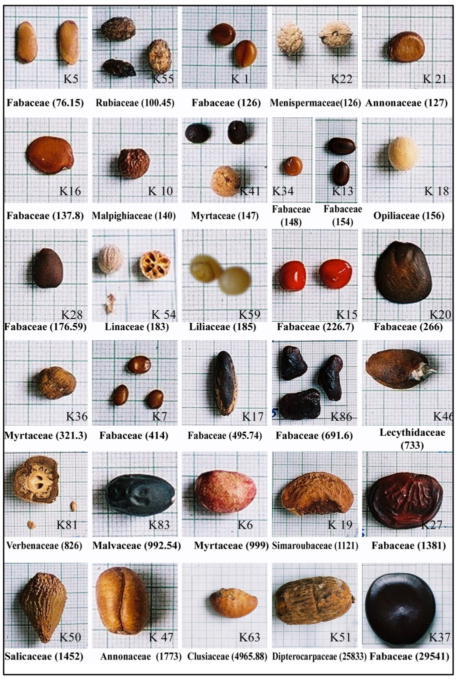
Tectona grandis *Hydnocarpus pentandra*

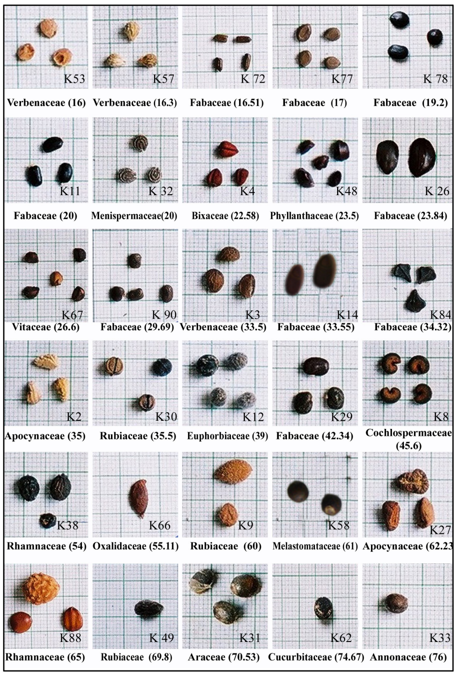
Fig. 7 Weight-wise* arrangement of seeds on graph paper showing diversity of measurements, shape and surface architecture



***Seed weight values (g) are of thousand seeds**

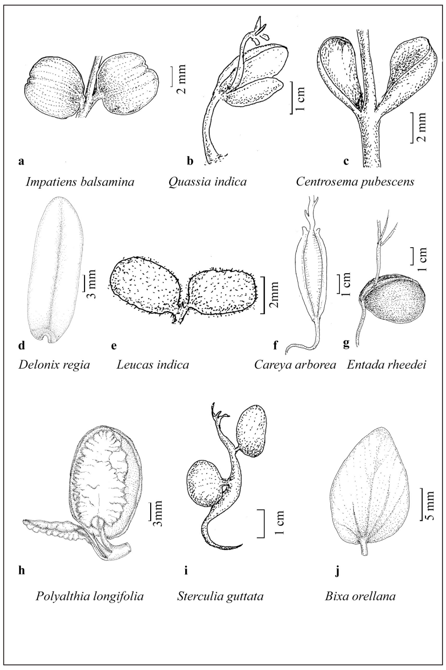
Continued ...


K5
Fabaceae (76.15)
K55
Rubiaceae (100.45)
K 1
Fabaceae (126)
K22
Menispermaceae(126)
K 21
Annonaceae (127)
K16
Fabaceae (137.8)
K 10
Malpighiaceae (140)
K41
Myrtaceae (147)
K34
Fabaceae (148)
K13
Fabaceae (154)
K 18
Opiliaceae (156)
K28
Fabaceae (176.59)
K 54
Linaceae (183)
K59
Liliaceae (185)
K15
Fabaceae (226.7)
K20
Fabaceae (266)
K36
Myrtaceae (321.3)
K7
Fabaceae (414)
K17
Fabaceae (495.74)
K86
Fabaceae (691.6)
K46
Lecythidaceae (733)
K81
Verbenaceae (826)
K83
Malvaceae (992.54)
K6
Myrtaceae (999)
K 19
Simaroubaceae (1121)
K27
Fabaceae (1381)
K50
Salicaceae (1452)
K 47
Annonaceae (1773)
K63
Clusiaceae (4965.88)
K51
Dipterocarpaceae (25833)
K37
Fabaceae (29541)


K53
Verbenaceae (16)
K57
Verbenaceae (16.3)
K 72
Fabaceae (16.51)
K77
Fabaceae (17)
K 78
Fabaceae (19.2)
K11
Fabaceae (20)
K 32
Menispermaceae(20)
K4
Bixaceae (22.58)
K48
Phyllanthaceae (23.5)
K 26
Fabaceae (23.84)
K67
Vitaceae (26.6)
K 90
Fabaceae (29.69)
K3
Verbenaceae (33.5)
K14
Fabaceae (33.55)
K84
Fabaceae (34.32)
K2
Apocynaceae (35)
K30
Rubiaceae (35.5)
K12
Euphorbiaceae (39)
K29
Fabaceae (42.34)
K8
Cochlospermaceae (45.6)
K38
Rhamnaceae (54)
K66
Oxalidaceae (55.11)
K9
Rubiaceae (60)
K58
Melastomataceae (61)
K27
Apocynaceae (62.23
K88
Rhamnaceae (65)
K 49
Rubiaceae (69.8)
K31
Araceae (70.53)
K62
Cucurbitaceae (74.67)
K33
Annonaceae (76)

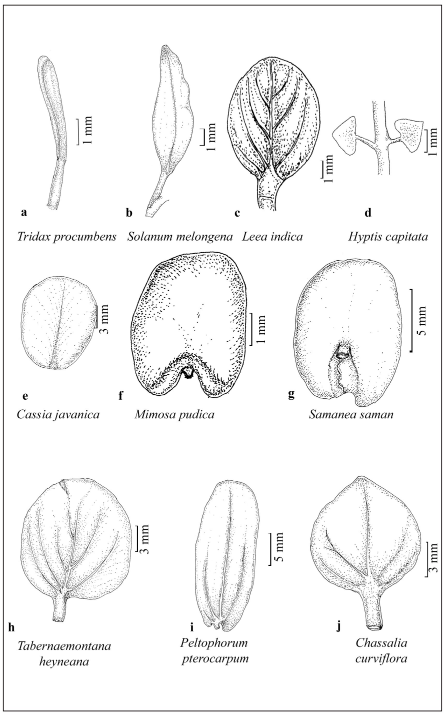
Continued .....

Fig. 12 Variations of cotyledons



a *Impatiens balsamina*
b *Quassia indica*
c *Centrosema pubescens*
d *Delonix regia*
e *Leucas indica*
f *Careya arborea*
g *Entada rheedei*
h *Polyalthia longifolia*
i *Sterculia guttata*
j *Bixa orellana*

Fig. 11 Variations of cotyledons - camera lucida diagrams



a *Tridax procumbens*
b *Solanum melongena*
c *Leea indica*
d *Hyptis capitata*
e *Cassia javanica*
f *Mimosa pudica*
g *Samanea saman*
h *Tabernaemontana heyneana*
i *Peltophorum pterocarpum*
j *Chassalia curviflora*