DEVELOPMENTAL MORPHOLOGY IN RELATION TO CONSERVATION IN THE FAMILY PALMAE (ARECACEAE)

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CERTIFICATE

This is to certify that the thesis entitled **Developmental Morphology in relation to Conservation in the family Palmae (Arecaceae)** is a record *bona fide* research carried by Mr. P. K. Padmakumar under our guidance and supervision. No part of this work has been presented elsewhere for any degree, diploma, fellowship, or other similar titles.

December, 2003.

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DECLARATION

I here by declare that the thesis entitled **Developmental Morphology in relation to Conservation in the family Palmae (Arecaceae)** submitted by me in partial fulfilment for the degree of Doctor of Philosophy in Botany of the University of Calicut incorporates the results of the work done by me. This thesis has not been submitted by me to any other university for the award of any other degree, diploma or any other titles, and it represents the original work done by me.

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P.K. Padmakumar

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Chapter 1.

INTRODUCTION

INTRODUCTION

The state of Kerala by its location and topography has unique environmental characteristics. The steep variations in the topography and climate have proved to be the effective biogeographic barriers creating landlocked islands of biodiversity resulting in high level of endemism.

The Western Ghats constitute one of the 24 mega biodiversity centers of the world and it is one of the richest centers of endemism in the country (Mittermier *et al*, 1998). The Western Ghats harbour diverse tropical forest types such as wet evergreen, semi evergreen, moist and dry deciduous forests, high altitude sholas and open grasslands.

Like the other bio-geographic zones, the Western Ghats have been subjected to heavy anthropogenic pressure resulting in loss of forest cover with subsequent degradation of forest habitats. Developmental pressures like hydroelectric power projects, construction of dams, pressure of tourism, intensive logging, and unsustainable harvesting of medicinal and other plant genetic resources have had their impact on the biodiversity of the Western Ghats.

Conservation of biological diversity in different bio-geographic zones of the country has been one of the major goals today. However one of the zones that received special focus is the Western Ghats. This "hot spot" harbour some of the last and pristine patches of tropical forests of the country providing refuge to some of the most threatened and endemic species of flora and fauna.

As development pressure on the world natural resources increases, conservation and resource management discussions are focusing on sustainable use practices (W W F, 1992-1998). Clear definitions of sustainability or specific guidelines for sustainable development and sustainable resource use are, however, often lacking (F. A. O, 1999; Brown and Pearce, 1994; Brown and Brubaker, 2001). Inter generational equity is generally incorporated into definition of a sustainable society, but from a resource manager's perspective, this concept is some what intractable. Agroecosystem studies on sustainability are sometimes linked to production system characteristics such as productivity, resources population, stability, etc.

It thus becomes imperative to make an assessment of the status of forests of their health. Such assessment is possible only if pristine stands of forests are available with periodically collected data bases on their floristic composition, their change with time, periodic growth, microhabitats within these ecosystems, nutrient dynamics and many other ecological parameters for ready comparison and reference.

The Palm family Arecaceae (Palmae), comprising about 200 genera and 2700 species, is distributed throughout the tropics and subtropics. Palms with their graceful architecture often dominate the landscape, providing many of the essentials for human life. Arecaceae is the world's third most useful plant family, after grasses and legumes. Throughout the Asian tropics forest and their component palm species are being decimated at an alarming rate. This represents not only a threat to the environment but also a loss of valuable economic palm species upon which the poorest segment of the population is so dependent.

Therefore palm conservation has a very practical application, and conservation recommendations must strike a balance between conservation and utilization. The increasing demands on the world's natural resources pose a serious threat to palm biodiversity. The two main threats are over exploitation and habitat destruction. Species whose habitat range is limited to a small area are the most at risk. Apart from this, certain palms possess several distinctive botanical characteristics like single stemmed nature, dioecious condition, low germination percentage, etc. which are deleterious in the conservation point of view. Decrease in population necessitates the development of a strategy in conservation and sustainable utilization of palms for which detailed demographic studies of palms are necessary. Palm conservation is a relatively new area of investigation.

Moore (1977) provided the first treatment of the subject and directed the attention to the world's most threatened palm species.

Development morphology and population dynamics is basic to the understanding of natural systems and their components. The different traits of organisms are determined by process of natural selection, and accordingly, it is necessary to ask questions about selective forces and the adoptive significance of those traits to understand the evolutionary pattern. Plant population demography yield information on the ways plant members are regulated, the possible selective pathways for different environmental conditions.

Demographic studies have been shown to be useful in understanding the regulation of population numbers as well as designing management techniques. Demographic techniques are also used to ascertain the aspects of the life history that may be under intense selective pressures (Bannister, 1970; Sarukhan, 1978). Palms are attractive subjects for studies of demographic processes (Bannister, 1970: Bullock, 1980: Pinero *et al.*, 1984). Palms have a relatively fixed pattern of morphological development that provides convenient features for population analysis. Palms have been shown to have a very co-operative life form in demographic analysis because growth often can be directly recorded as the increase in height and number of leaves produced, especially in the tropics where palms are frequently abundant and generally the trees, lack growth rings (Pinero *et al.*, 1984; Oyama, 1984).

The study of the root system, represented by the totality of roots of each plant regardless of their morphogenic origin, is essential for the complete understanding of the ecological requirements of each plant to develop the strategy of conservation. In turn it forms the necessary basis of silvicultural practices.

Roots account for between 40 and 80 percentage of net primary production in a wide range of ecosystems from grasslands to forests (Fogel, 1985). Typically plant growth in non-agricultural condition is limited, more by soil derived resources than by carbon dioxide or solar radiation (Fitter, 1986). It seems axiomatic, therefore, that an understanding of the functioning of plants within natural communities must demand an equal understanding of the behavior of root and root systems.

The roots are much less variable morphologically and it is likely that root system rather than individual roots are the focus of natural selection. The studies on the functions of root systems in an ecological perspective must there fore be concentrated more on the morphology of root system than on that of individual root.

Individual root in soil varies greatly in size, longevity and activity, and their interaction with other organisms will depend on these variables, many of which are determined by the relationship of the root to the whole root system. The function and activity of root system is closely linked to their normal environment, soil-root morphology, and distribution has been identified as a balance between systematic biological mechanisms and their disruption by environmental factors, particularly change of soil density and soil surface contours. Study of root morphology is therefore important in understanding the interaction and dynamics with in the soil system.

Developmental morphological studies are important in naturally occurring species especially when they are wild and endemics to a certain extent and are facing threat in their natural habitats due to human interactions. The demographic studies correlated with developmental - morphological studies will help in formulating certain strategies in conservational activities of the species.

The present work envisages studying the growth and development of three species of palms in their natural habitat. The species selected are *Arenga wightii* Griff., *Phoenix loureiri* var. *humilis* (Becc.) S. Barrow and *Pinanga dicksonii* (Roxb.) Bl. All the three taxa are listed as vulnerable in their conservation status (Basu, 1991; Renuka, 1996, 1998, 2001).

The main objectives of the study are

1. To understand the population dynamics of the species selected

2. To find out the age-structure of the population
3. To discover whether any general pattern of population regulation exits for the selected species, and if so, to know factors are responsible for such patterns
4. To investigate the root system development
5. To develop conservation strategies for the selected species.

REVIEW OF LITERATURE

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Chapter 2.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Results of several demographic studies in Palms in natural habitats and cultivated fields under natural as well as restricted conditions have been published during the last two decades. Some of the studies gave a general understanding of population and community dynamics, while others concentrated on rare and endemic species and formulation of conservation strategy. Palm resource management studies are another major area of study where transition matrix models were formulated and used for resource management in palms.

STUDIES ON DEVELOPMENTAL MORPHOLOGY AND DEMOGRAPHY

The commencement of the studies on development in palms could be traced back to 1941 when Ball (1941) studied the development of the shoot apex and primary thickening meristem in *Phoenix canariensis* Chamb. He compared the developmental pattern of *Phoenix* with *Washingtonia filifera* (Linden) H. A. Wendl. and *Trachycarpus excelsus* Wendl. Later Siftan (1944) published the classic work on developmental morphology of vascular plants wherein many details have been given on the palm.

Tomlinson (1960) studied the pattern of emergence of leaves in seedlings of palms of different species and explained the morphological significance of these patterns in further growth and development of leaves. Tomlinson (1971) has also studied the details of shoot apex and its dichotomous branching in the Nypa palm. From those studies it was revealed that a specific pattern of development and growth exists in palms.

Kiew (1972) studied the natural history of a Malayan undergrowth palm *Iguanura geonomaeformis* Mart. Basu and Mukherji (1972) studied the details of germination of seeds of certain palms. The studies brought to light the details of germination percentage, mode of germination, viability of seeds, barriers of seed germination, and special methods that can be adopted to increase the germination rate, mortality of seedlings, etc.

Davis *et al.* (1975) studied the morphology and anatomy of juvenile *Elaeis guineensis*. Hnatiuk (1977) studied the population structure of *Livistona eastonii*.

Waterhouse and Quinn (1978) studied the growth pattern in the stem of *Archontophoenix cunninghamiana*.

Sarukhan (1978) has studied the demography of tropical trees and explained the tropical plant communities which show conspicuous seasonal patterns in vegetative and reproductive phenologies at both community and species level, despite the apparent absence of very dramatic photoperiodic and climatic fluctuations that regulate temperate zone plant phenologies.

Tomlinson (1979) has given a very detailed account of systematics and ecological studies on member of the family Palmae.

Bullock (1980) has studied the demography of an undergrowth palm in littoral Cameroon.

Savage and Ashton (1983) studied the population structure of five endemic palms in the Vallee de Mai, on Praslin Island and recorded the reproductive activity. According to them mortality in the populations of the commoner species *Lodoicea* and *Phoenicophorium* occurred in two unrelated stages that is juvenile and senile. Age calculation was done using leaf growth rates.

Pinero *et al.* (1984) studied the demography of *Astrocaryum mexicanum* in six plots in a tropical rainforest in Mexico. According to them there are differences between the plots in transition probabilities, survival and fecundity estimates of different age classes. Yearly estimates of transition probabilities from one age to the next are very less. The survival pattern with high mortalities during the first stage of life cycles is high and there is no mortality after its first reproduction. Individual fecundity shows an initial increase followed by constant values after the palm became aged.

Schatz *et al.* (1984) studied the stilt root and growth of arboreal palms *Socratea durissima* (Oerst.) Wendl., *Iriartea gigantea* Wendl. and *Welfia georgii* Wendl. Patterns in the growth of those palms supported the hypothesis that stilt roots enabled arboreal palms to produce an axis early in their development. The observations revealed that the height of stilt root is positively related to axis diameter in *Socratea* and *Iriartea* roots. However at maturity all three palms exhibited similar relationship between height and diameter.

Steven and Putz (1985) studied the mortality rates of *Bactris barronis, B. coloniata, B. major, Chamaedorea wendlandiana, Elaeis oleifera, Geonoma cuneata, G. interrupta, Synechanthus warscewiczianus* (understory palms), *Astrocaryum standleyanum, Cryosophila warscewiczii, Oenocarpus mapora, Scheelea zonensis* and *Socratea durissima* which are canopy and sub-canopy palms. According to them the mortality rate of palms is between 1-3% which was similar to the mortality rate of dicot trees of that area. But some palms appeared to suffer much higher mortality rate which reflected the extreme susceptibility of palms to death as a result of their growth having single terminal meristems.

Steven *et al.* (1987) studied the vegetative and reproductive phenologies of a palm assemblage in Panama and accordingly the palm species displayed substantial variation in reproductive phenology despite a shared uniform growth architecture. It might be seasonal, initiated by the commencement of rainy season and might have multiple flowering episodes, but all predictable. Fruiting again showed more synchronous nature. Palm vegetative phenology was also seasonal and appeared more responsive than the reproductive phenology to annual climatic variation. In many species rates of leaf expansion slowed during the dry season and in a species the total leaf production was relatively constant from year to year. Leaf production was correlated with individual height in certain species, but not generally related to the degree of canopy opening.

Vocks (1988) noted the changing sexual expression of a Brazilian rain forest palm *Attalea funifera* Mart. which produced male, female inflorescence and rarely inflorescences with male and female flower and according to the observation the possibility that sexual expression is related to size, competition, and the differential cost of male and female function. The field data suggested that *Attalea* changed sexual function during its life cycle, from male under various conditions to increasingly female as it became taller and less crowded. The cost of reproducing through female as opposed to male function is found to be 13.2 to 1 and the allocation of resources of reproduction is shown to increase with size. It was found that varying accesses to sunlight in the rain forest environment set thresholds to gender expression.

Demographic studies of *Astrocaryum sciophilum,* an understory palm of French Guiana was studied by Sist (1989), where the dynamics and seed dispersal of three populations of tropical forest were explained.

Mortality, number of leaves, stem height increment, number of inflorescences and probability of reproduction were observed in *Chamaedorea tapejilote* in high evergreen forests of Mexico by Oyama (1990). According to him the seedlings and non reproductive plants of both sex had high mortality rates. The mean stem height increment of mature male and female plants ranged from 6-12 cm per year. Male plants showed influence of spatial variation in growth rate but not the females. Males produced significantly more leaves per year than females. Both sexes had different rates of production of leaves during each year. The number of inflorescences produced per plant was positively correlated with height in both male and female plants but males produced significantly more inflorescences than females. The expression of sexes did not have any correlation with spatial variation of individuals in a plot. The irregular reproductive behaviour due to various factors is more expressed in females than in males.

Growth and survival of seedlings of *Welfia georgii* was noted by Vandermeer (1990). Majority of the populations showed a decrease in size over time due to their position in the understory. Overall survival was 61%. The mean of the rate of growth of leaflet width was approximately 0.09 cm per year and was related to the size of the seedlings in a complicated non-linear manner, in which very small individuals grew relatively rapidly, intermediate individuals degrew and larger seedlings also grew rapidly.

The effect of canopy shading on the growth of *Calamus manan* seedlings were studied by Sutiyono and Sukardi (1991) and according to them growth was much faster under the lightest shades.

The leaf production, reproductive pattern, germination and seedling survival of *Chamaedorea bartlingiana*, an understory palm in the natural forest of Venezuelan Andean, was studied by Ataroff and Schwarzkopf (1992).

Population dynamics, that is, survival, growth rate and fecundity of a population of Nikau palm *Rhopalostylis sapida* was studied by Enright and Waston (1992) in the natural habitat of New Zealand. Transition matrix analysis was compared for groups with classified height and groups with classified frond-scars. Estimates of 1.004 (height) and 1.007 (scars) were obtained for the finite rate of increase, suggesting that the population was a numerically stable component of the temperate forest in which it was found. Difference between the initiated and stable stage distribution, especially for the height-classified analysis indicated that the present population size structure was not constant with the measured rates of growth and survival. Measures of sensitivity, elasticity and selective pressure revealed that the high survival rate of palms in the mature and immediately pre-reproductive stages had the strongest influence on population growth rate. Faster growth through the seedling and juvenile stage would also markedly increase population growth rate. Fecundity was relatively insensitive to changes in growth rate.

The effective population size was used for the estimation of relative importance of genetic drift in tropical palm *Astrocaryum mexicanum* in the natural habitat in Mexico (Sarukhan and Pinero, 1993). The genetic neighbourhood area was fixed and effective population size and different overlapping generation method were used to estimate an effective density with demographic data. The effective density ranged from 0.040 to 0.351

individuals per m^2. The product of effective density and neighbourhood area yielded a direct estimate of the neighbourhood effective population size.

The abundance and site performance of rattans *Calamus exilis* and *Calamus zollingeri* were noted in two Indonesian National Parks by Siebert (1993). Populations of *C. exilis* were negatively related to high light intensities, conversely, population of *C. zollingeri* were positively related to high light intensities. According to him the abundance of *C. exilis* and *C. zollingeri* cane were in conjunction with their clustering growth habits. Vegetative propagation capabilities and varied light performance provide opportunities to develop sustainable cane harvesting system in combination with a variety of land use practices.

Basu and Basu (1993) noted the sex expression in Caryotoid palms *Arenga pinnata, Arenga undulatifolia, Caryota urens, Caryota mitis* and *Wallichia densifolia.* Accordingly the basipetal emergence of inflorescence after a definite period of vegetative growth was very characteristic in Caryotoid palms. In all monocarpic (hapaxanthic) palms there is a distinctive vegetative phase followed by a reproductive phase that ends in the death of the palm. In pleonanthic palms the flowering shoot only wither.

Pinard (1993) studied the impact of stem harvesting on population of *Iriartea deltoidea*. Population projection matrices were used to explore the population stability. Projections were based on survival probability estimates derived from size class distributions, growth rates, calculated from leaf production rates and leaf scar records and fecundity estimates obtained from seedling densities. Matrix analysis suggested all 5 populations studied were stable. Elasticity analysis indicated that population stability was most sensitive to changes in survival probabilities in palms of 10-15 m tall.

Vandermeer (1993) studied the successional pattern of understory palm in an old cocoa plantation on the Caribbean costs of Costa Rica. The study determined the proximity of forest and the methods of seed dispersal to test the hypothesis that mammal-dispersed palm species are concentrated closer to the forest than the bird dispersed species and the observation supported the hypothesis. Other observations were that, bird dispersed species were distributed throughout the plantation and that mammal dispersed species showed clumped distribution close to the forest and along a path.

Jong *et al.* (1994) studied the effects of plant spacing on the growth and development of sago palm on undrained deep peat with a spacing of 4.5, 7.5, 10.5 and 13.5 meters apart. At 4.5 m spacing the palm had the lowest frond emergence rate, a small trunk circumference at the base and 1 m height, the longest fronds, thinnest rachis, the smallest crown size, and the shortest creeping trunk. The canopy closed over after 3-4 years. At 7.5 m and 10.5 m spacing the canopy closed over 5-6 and 8 years respectively. With the increases in space, there was an increase in the prostrate stem length, trunk height of leader, and in number of suckers.

Soemarna and Anwar (1994) have studied the distribution and ecology of rattans in the Pasir Tugu Natural forest which has potential for rattan production. The growth of 12 rattan species was measured using strap and line plot method. Phyto-sociological data were tabulated for all the rattan species and also for the 54 supporting tree species which had an average of 140 stems/ha and an average basal area of 12 m^2/ha.

Ataroff and Schwargkopf (1994) observed the vegetative growth in *Chamaedorea bartlingiana*, a dioecious, solitary, understorey palm of Andean cloud forest. The main changes in vegetative morphology from germination to adult stages were described by them.

Setiyo (1994) has developed a model for the vegetative and total growth in oil palm. This dynamic model explains the relation between the growth and yield to climatic factors and plant characteristics.

Setiadi and Harisetijono (1994) studied the growth of rattan, *Daemonorops pericanthus* Miq. seedlings cultivated under *Cassia* trees. The effect on soil cultivation on the survival, height, growth, and number of leaves per plant over 3 years were tested. The results showed that the survival and growth were best in the plots cultivated once an year, the poorest in those not cultivated at all, although difference between plots were not significant for survival.

Breure (1994) has studied the development of leaves in *Elaeis guineensis* and the leaf opening rate was determined. The rachis length was determined on primordia dissected from palms planted in 4 densities. A sudden increment of light accelerated leaf production at both the rapid expansion stage and the proceeding slow expansion stage. The greatest acceleration of leaf production began 24 months after thinning probably because of the effect of the extra light on the rate of leaf initiation.

Jose *et al.* (1995) studied the competition of *Areca catechu* in mixed cropping system. The inter and intra component competitions were studied and found that intracomponent competition with intercomponent competition became significant only during 11th to 14th year of planting and in other periods neither inter nor intra component competition were significant.

Troy (1995) studied the spatial distribution and abundance of *Desmoncus polyacanthos* to quantify the relationship between forest canopy characteristics and the abundance and distribution.

Chia (1995) in his studies on the stem characteristics and growth of planted and wild *Calamus subinermis,* tried to understand the growth rates at 2 sites in Sabah. Canes planted at Kolapis had a mean annual increment of about 2.4 m at the age of 12 years. The mean stem diameter and mean internode length were 29 mm and 26.3 cm respectively. Wild canes on Berhala island had a mean diameter of 22 mm and mean internodal length of 26.5 cm. Length of stem covered with dried leaf sheaths was positively related to total stem length.

Rich *et al.* (1995) studied the leaf development and crown geometry of two Iriarteoid plams. Changes in the morphology of pinnately compound leaves and crown geometry during height growth of *Socratea exorrhiza* and *Iriartea deltoidea* of tropical wet forest of

Costa Rica revealed that light availability increased with height. The number of leaves per plant was relatively constant. Total leaf area, however, was much larger in taller individuals. Increases in linear dimension of leaves were responsible for less than half of this greater surface area. More important was the transition from a basically dorsi-ventral display of leaflets in small individual to a more radial display in taller plants. Production of leaflets in more than one plane resulted leaves whose surface area was more than twice the horizontally projected area and whose lateral light interception was gradually enhanced.

Olmsted and Alvarez-Buylla (1995) developed demography and matrix model of two palm species of Mexico *viz; Thrinax radiatae* and *Cocothrinax readii.* Patterns of survivorship, growth and reproduction were obtained from four populations. The abundance and population structure varied depending on habitat, flowering and fruiting. Leaf production varied in both the species, apparently as a function of rainfall and site. Seedling survival was high in comparison with other tree species. Growth rates of seedlings were directly related in the rate of adult survival and growth. From the data, a sustainable harvesting model was developed.

The dynamics of a remnant population of *Neodypsis decaryi* was characterized using a linear, stage structure demographic model by Ratsirarson *et al.* in 1996. This palm is a threatened key-stone species restricted to a narrow ecological zone in Madagascar. The population showed high mortality rate in early stage of life cycle followed by a period of lower adult mortality. Demographic results indicated that the population was either stable or increasing inside the reserve. Sensitivity and elasticity analysis indicated that adult state classes were the most sensitive to the changes in population growth rates. Restricted leaf collection and seed collection were recommended for conservation.

An assessment of the impact of leaf harvesting of the Asian palm *Livistona rotundifolia* was done by OBrien and Kinnaird (1996). Harvest intensity on subsequent growth and ecological sustainability were studied and recommendations for sustainable harvesting were formulated.

Germination and seedling growth of *Calamus tenuis* were studied by Siddiqi *et al.* (1997). According to them germination was 70% for the whole fruit, 10% for seeds with pulp and 86.66% for cleared seeds. Survival of seedlings in the field was 96.6%, and with one and half years, the sustained seedlings showed an average height of 109.78 cm with an average of 3.34 culms per plant.

Bernal (1998) studied the demography of the vegetable ivory palm *Phytelephas seemannii* was studied on the Pacific cost of Colombia and a female-based matrix model was used to determine the proportion of seed that can be sustainably harvested from the population. The density of the adult palm stands ranged from 240 to 420 per hectare. The sex ratio was 1:1, and juveniles and adults of both sexes produced an average of 1.8 and 6.1-7.4 leaves per year respectively. Adult females had fewer leaves than males. Leaves of females lasted for about 2.7 years in the crown, and those of males about 3.2 years. These figures reflected differences in growth habits. The population growth rate $\lambda = 1.059$ and was most sensitive to changes in survival of juveniles and adult, and relatively insensitive to changes in fecundity and growth. River channel migration was the most important cause of adult mortality. *Phytelephas seemannii* is apparently an efficient colonizer of the understorey in the late phase of riverine forest succession.

The spatial distribution of a mixed natural rattan population, environmental effect on rattan growth and shadow adjustments in Sabah, Malaysia were discussed by Rao (1998), and a model to estimate rattan growth from yield data was developed.

The effect of natural fruit size of *Euterpe edulis* on seedling germination vigour and seedling growth was evaluated by Fleig and Rigo (1998). Medium-sized fruits have higher germination percentage and speed followed by small and larger-sized fruits. Evaluation of total dry weight, shoot height, collar diameter, etc. of plants showed that significantly taller plants with a greater dry weight were obtained from larger fruits.

Stages of leaf development especially growth, was described by Carvalho *et al.* (1999) based on the studies infant and juvenile stages of *Euterpe edulis* of a natural forest which represent.

Individuals of widespread *Serenoa repens* and endemic *Sabal etonia* were monitored for growth performance and reproduction in natural habitat. Logistic regression models were developed for each palm species to estimate the probability of flowering in each vegetative association. These models accurately predicted flowering and non-flowering individuals. However, probability of flowering model that were generalized across vegetative associations of each species were less accurate than the association-specific model, which indicated the specific nature of flowering responses. Abrahamson (1999) came to the conclusion that the long-lived palms were highly vulnerable to anthropogenic disturbances because of their very limited ability to recolonize former habitats.

Relationship between microhabitat variables like altitude, inclination, topographic position, drainage, canopy height, etc. and the distribution and abundance of palms at natural habitat of Amazonian Ecuador were examined and studied by Svenning (1999). Cluster analysis showed that palm species distribution were strongly structured by topography. The main difference in species composition was between plots in the bottom land and plots on the upper slopes and hilltops. Logistic and logit analysis showed that 20 of the 31 palms and palm like taxa analyzed had distribution that were significantly related to the microhabitat variables measured mainly not to topography but also to drainage and canopy height. Spatial autocorrelation in the overall community structure was not explained by the microhabitat variables. Analysis of distributions or abundance of single species showed neighbourhood effects for seven taxa. Antagonistic pattern of microhabitat performance were recognizable among some species pairs of small palms, medium sized palm and palm like plants, but not among canopy palms. The conclusion was that microhabitat specialization was an important factor in maintaining the diversity of these palm community while, mass effects might also be important.

The local-scale spatial distribution of an abundant arborient palm *Iriartea deltoides* in natural habitat in Amazonian Ecuador was studied by Swenning and Balslev (1999). The seedling recruitment rate of *Iriartea* as influenced by environmental heterogeneity at the scale of 10 x 10 m and the influence of microhabitat heterogeneity on the survival probability of immature individuals after the early seedling phase, were assessed. The seedlings and small juveniles were correlated with the presence of streams and the presence of abundant number of adults was also seen correlated with the presence of stream. They concluded that microhabitat conditions act as a filter not only on germination and initial seedling establishment, but also in the survival of seedling and juvenile stages, and environmental heterogeneity strongly influenced local distribution and the effect is established both through differential germination or seedling establishment and differential mortality until the larger juvenile stage.

A comprehensive analysis was conducted by Barot *et al.* (1999) on the spatial pattern of *Borassus aethiopum* population and its environment to interlink between demographic process, plant spatial patterns and environmental heterogeneity. Map data was analysed for individual palms of all stages in the natural forest of West Africa. Juveniles and seedlings were aggregated, while adults had a random pattern or were more loosely aggregated. All stages except female adults were spatially associated with nutrient rich patches but association distances increased with stage in the life cycle, and seedlings were associated with female adults; whereas the association of juvenile at longer distances were not clear cut. The initial pattern of seedlings (close to maternal trees) resulted from low dispersal distance, while later stages (older seedling and juveniles) were mostly restricted to nutrient-rich patches through nutrient shortage away from these patches (environment induced mortality) and form dense clumps of immature palms. Competition on nutrient rich patches then favoured the few juveniles that manage to survive farther from these patches (density dependent mortality). The last surviving juvenile of a clump suddenly experienced almost no competition with conspecifics, due to the long distance between clumps of juveniles and root forging ability of the individuals of a clump.

Data on growth, survival and reproduction were recorded by Mendoza *et al.* (1999) for *Astrocaryum mexicanum, Chamaedorea alternarus* and *Reinhardtia graciis* var. *gracilis* of tropical rain forest of Mexico. Transition probability was estimated for each size class of each species. The demographic data were incorporated into Lefkovitch matrices to estimate population finite growth rates (λ) and results showed values of λ of 1.0142 for *Astrocaryum,* 1.3623 for *Chamaedorea* and 1.0184 for *Reinhardtia*. Elasticity analysis showed that fecundity had a relatively low value and thus makes a small contribution to the population growth rate.

The extent to which demographic variables like relative growth, rate of leaf area and height together with mortality and recruitment were important determinant of the competitive ability of endemic palms *Phoenicophorium borsigianum* and aggressively invasive dicotyledonous alien *Cinnamomum verum* were studied by Maarel –E-van-der (1999).

A demographic study of *Agenga westerhoutii* and *A. obtusifolia* was carried out for a total period of 17 months at Bakit Lagogng Forsest Reserve of Malaysia by Zakaria *et.al.* (1999). Three life stages had been defined for both species: seedling, juveniles and stemmed. In every population observed *A. westerhoutii* had seedlings as the most abundant stage but, *A. obtusifolia* had seedlings and juveniles as the dominant stage. The rate of increment was higher in *A. westerhoutii*. For both species the highest mortality occured during the seedling phase.

The growth rhythm and longevity of leaves of palms were studied by Freiberg and Freiberg (2000) in the natural forests of Costa Rica. They noted the production of leaves in defined interval throughout the year, which showed a slower rate of leaf production in the dry season. The maximum leaf-age of the palm *Cryosophila warscewiczii, Iriartea deltoidea* and *Calyptrogyne trichostachys* were estimated to be more than five years.

Correlations between geographical range-size, and plant structural and ecological characteristics of 45 palm taxa of natural forest of Peru were studied by Ruokolainen and

Vormisto (2000). They observed that the most wide spread palms tended to be tall and have relatively wide tolerance to difference in soil fertility and habitat quality. Caespitose growth form and fruit size were not related to the variation in range size. Tallness may be associated with better seed dispensers which contributed to wider ranges. The positive link between range size and edaphic and habitat generality demonstrated the importance of relatively deterministic environmental factors in controlling the distributions of plants.

Naturally occurring variation in micro-site features to determine correlation of post-dispersal seed survival and the performance of established seedlings of Amazonian palm *Astrocaryum murumuru* was studied by Cintra and Terborgh (2000) in the natural habitat of Peru. According to them, at small spatial scales variation in leaf litter, under-storey vegetation and incident light had significant effect on the palms. Seedlings growth and survival of the species were affected by variation in the biotic and abiotic component of microsites.

The inter cropping of *Calamus zollingeri* among Coffee and Cocoa crops was studied in by Siebert (2000). No significant differences were observed between the different sites with respect to seedling survival, growth or leaf production based on multiple PAR measurements.

The demography of natural population of *Euterpe edulis* was analysed by Reis *et al.* (2000). According to them natural populations showed a pyramid-shaped demographic structure with a large base of juvenile plants and a small number of reproductive individuals. These data suggested a strong dependence of a large population on a proportionally small number of genetically effective individuals. These individuals are responsible for the maintenance of genetic diversity, genetic structure and demographic structure for the entire population.

STUDIES ON ROOT DEVELOPMENT

Not many studies were conducted on the root system of palms.

Admotive and remotive type of germination was noticed in palm seed germination by Saakov (1954). Discussing the seed germination of *Caryota* in detail and noting other palm seed germinations, Mahabale and Nandini Shirke (1967) proposed that the germination was remotive in most palms.

Kozlova (1973) studied the growth characterization of date palm, Washington palm *Chamaerops, Trachycarpus* and *Palmetto* were studied after 1 year of germination. He noticed that the first three roots grew 72-79 cm in the soil and consisted of the primary embryonic root and 1-2 secondary roots while the last two grew 10-15 cm only and consisted of 3-6 ramified roots.

The number of adventitious roots of reedy palms and palms with big trunk were compared by Mahabale (1982) and observed that in the former it was less compared to that of the later but in genus *Calamus,* the roots were very few but very strong and stout. According to him, probably the stains and the counter stains produced by the leaves at the top were balanced by the roots formed in all directions around a palm pole.

Bavappa and Murthy (1961) noticed that in *Areca* the seed germinated with in 30 days after sowing and the root at this stage were about 6 mm long. Two other roots were produced from the region of the first root. Subsequent roots emerged from the point opposite to the site of emergence of the first root. Ninety days after sowing, new rootlets of various sizes were formed. Davis (1961) noticed that several lateral branches which again branched to form a cluster were formed from the main roots.

The relation between origin, size, shape, function and structure of roots of arecanut was studied by Davis (1961) and he classified roots into adventitious roots emanating from the bole of the root producing region, the rootlets that branch from the main roots or their branches, the pneumatophores or breathing roots, and the aerial roots which arise from the aerial part of the stem. Dransfield *et al.* (1979) while dealing with the palm taxonomy and ecology, described the root system of palms.

Calamus viminalis seedlings were found to produce a well developed seminal root within 10 days of germination (Banik and Ahmed, 1986). After one month, the lateral roots were found to appear from this system. At the age of 5 months, roots developed from the base of the stem also. Between 6 to 11 months seminal root growth were either stopped or the root was degenerated. The root system was of horizontal spreading type. Alvarado and Sterling (1993) evaluated the distribution pattern of root system of oil palm, *Elaeis guineensis* Jacq.

The architecture of root system of rattans were studied by Nasi (1994) and found that great consistency existed in it and it was rather simple and also had a highly opportunistic behavior with systematic regeneration of damaged roots. Importance of the proximal bottle neck created by the root system development was stressed. A peculiar growth strategy was noticed to have developed in rattans due to the allometric relationship established between different parts of the plant. Thus a supporting evidence was developed by Nasi for the hypothesis formulated during the study of the vegetative structure.

Thirty six Coryphoid palms and three other palms were selected by Seubert (1997) for the root-studies and for distinguishing each other. The relationship of genera and tribes as well as evolutionary trends with in the sub-family was established using root anatomy as a complementary tool.

ACINES *post processor* was used by Jourdan and Rey (1997) in oil palm (*Elaeis guineensis* Jacq.) for modeling and simulation of the architecture and development. In oil palm eight different morphological types of roots according to their developmental pattern and stage of differentiation following a transitional juvenile phase were noticed by Jourdan and Rey (1997). Root architectural unit of the oil palm, a morphological and functional unit of the root system with the relative position was developed from the studies. The oil palm ontogeny was explained with the root polymorphism and morphogenic gradient.

The root system of *Serenoa repens* had only primary growth and ranged in thickness from 8 mm (first order roots from the stem) to 0.8 -2.9 mm (ultimate root of third to fifth order) (Fisher *et al.* 1999). The thickest root occurred at soil depth > 20 cm and fine root <1.2 mm occurred at all depth (1-60 cm). Some second and third order roots were negatively geotropic and grew up to the mineral soil surface.

Jayasree *et al.* (2003) studied the development of root system in *Calamus thwaitesii* and *C. rotang* for 3 years from seed germination. They found that at the end of the period both species had almost the same number of main roots. While *C. thwaitesii* has more laterals, *C. rotang* has more sub laterals. The significant difference between the two species was noted with respect to the length and diameter of the laterals. When there was an increased elongation rate in main roots, there was a decrease in rate of growth of the laterals, and *vice versa.* Vertical growth was predominant during the early stage. The age factor influenced the root distribution pattern.

MATERIALS AND METHODS

P. K. Padmakumar "Developmental morphology in relation to conservation in the family palmae (arecaceae)" Thesis. Department of Botany , University of Calicut, 2003

Chapter 3.

MATERIALS AND METHODS

MATERIALS AND METHODS

SHOOT MORPHOLOGICAL STUDIES (s. l.)

Materials

Demographic studies were conducted on the three palms selected *Arenga wightii* Griff., *Phoenix loureiri* var. *humilis* (Becc.) S. Barrow and *Pinanga dicksonii* (Roxb.) Bl. were selected for the study. Since seed germination was very poor in case of *Pinanga,* root development studies could be carried out only for the two palms, viz.,*Arenga* and *Phoenix.* All the three palms are highly habitat sensitive. *Arenga wightii* commonly grows near along the sides of the streams of tropical evergreen forests of Western Ghats. *Phoenix loureiri* var. *humilis* is seen in the high altitude grasslands of Western Ghats. *Pinanga dicksonii* is an understorey palm in the evergreen forests.

All the three species are economically important and are listed as vulnerable in their conservation status (Renuka, 2001). Toddy and stem starch are extracted from *Arenga wightii* which are of high medicinal value and is commonly used by tribal people. The leaves of *Phoenix* are used for broom making. The over exploitation of leaves poses problems in sustainability. Toddy is also extracted from *Phoenix.* The nuts of *Pinanga* are used as an alternate of betel nut by the poor people.

Arenga wightii Griff., Calcutta J. Nat. Hist. 5: 475. 1845. Alam panei (Tamil), Kattuthengu (Malayalam). (Fig. 1).

Plants dioecious. Stem short, 1-9 m tall, soboliferous, forms dense clumps. Leaves pinnate, 5-8 m long; leaflets alternate, single-folded, induplicate, linear, densiform, white underneath leaflets auricled, obliquely overlies the petiole; leaf sheath covered with a great variety of hairs, extends beyond the petiole to form ligules, eventually disintegrating into a mass of black fibers; petiole well developed, ridged. Inflorescence interfoliar, bursting through the leaf sheaths in an acropetal sequence; spadix decurved, penducle 50-60 cm long ; flowers with scaly bracts; male flowers: sepals 3, imbricate; petals 3, imbricate; stamens numerous with short filaments, anther linear; female flowers: solitary on the branch of the spadix in a shallow cup; sepals small petals triangular; ovary 3-celled; style short, recurved. Fruit spirally arranged, crowded on the lower half of the branches of the spadix; seeds three in each fruit separating easily except at the base.

Moore (1973) included *Arenga* in Caryotoid palm group. Uhl and Dransfield (1986) treated it under the subfamily Arecoideae and under the tribe Caryoteae

Phoenix loureiri* var. *humilis (Becc.) S. Barrow, Kew Bull. 53(3): 563. 1998.

Phoenix loureirii Kunth, Enum. Pl. 3: 257. 1841.

Phoenix humilis Becc., Malesia 3:379, 380, t.. 44, 2, f. 22-24. 1890. Easa pullu (Tamil), Chitteenthal (Malayalam) (Fig. 2).

Stem clustering, 1.5 m tall, 60 cm diameter, clothed with spirally arranged leaf scar, at the crown region fibrous net of the petiole encircles the stem. Leaves pinnate, marcescent, 140 cm long; petiole adaxially flattened, 45 cm long; acanthophyll 3-14 cm long, arranged in different planes; leaflets up to forty seven on each side, arranged in groups of two each, leaflet 48 x 1.5 cm. Inflorescence inter-foliar, branching in one order; male inflorescence: rachilla in group of spiral, up to 60; bract triangular, subtending a solitary flower; male flower: outer perianth small, equal in size, rigid; innner perianth acute; stamens 6; female inflorescence: rachilla up to 30, rachilla in group spiral along the peduncle, adnate; bract small, triangular, subtending a solitary flower; female flower: outer perinath 3, orbicular; ovary dome-shaped, style short, carpels 3 of the one develops into fruit. Fruits restricted to the distal half of rachilla, each fruit obovoid, with apical remnance of stigma, 1.5-2 cm long; epicarp smooth, mesocarp fleshy, endocarp membraneous. Seed obovoid, hard; raphae present.

Moore (1973) included the genus under the Phoenicoid palm group and Uhl and Dransfield (1986) included the genus under the subfamily Coryphoideae and tribe Phoeniceae

Pinanga dicksonii (Roxb.) Bl., Rumphia 2: 85. 1838.

Areca dicksonii Roxb., Fl. Ind. 3: 616.1832. Kattukamuku (Mal.) (Fig. 3).

Plants monoecious, pleonanthic unarmed. Stem solitary, slender, smooth, green when young, 2-6 m tall, 7-10 cm diameter, leaf scars conspicuous. Leaves pinnate, 130 cm long; petiole adaxially channeled, axially rounded, glabrous; leaflets numerous, sessile, elongate, 50 cm long, breadth 7 cm broad, apical leaflet lobed, plicate, veins parallel, regularly arranged. Inflorescence intrafoliar, pendulous, branching of one order; penducle short, dorsiventrally flattened; spadix compound, rachilla unbranched, 4-8, distichous 15 cm long, stout, clothed with imbricating flowers; male flowers: sepals 3, petals 3, all equal; stamens 20-30, filament short, anther linear; female flower: sepals 3, petals 3, similar, staminodes six, style short, stigma three-lobed. Fruit a berry, oblong, fibrous, 1.2 x 1 cm.

In the earlier attempts of classification of palms by Martius (1849-53), Hooker (1883), Drude (1887) Satake (1962) and Potztal (1964) *Pinanga dicksonii* was placed close to *Areca*. Later Moore (1973) included the genus under the Arecoid palms. Uhl and Drasnfield (1986) included the species under the subtribe Arecinae of the tribe Areceae under the subfamily Arecoideae.

Study area

The study plots were selected in the natural forests areas in the Western Ghats (Fig. 4). The three species selected are seen only in specific areas and are not widely distributed throughout the forest.

Arenga wightii Griff. is usually seen in the evergreen forest at 300-1000 m elevation. In the Western Ghat region of Kerala it is commonly seen on the way to Peerumedu, Wayanad, Dhoni, Nelliampathy, Neriamangalam, Muthikulam, Attappady, Kottiyur and Sholayar. This is usually seen in valleys where moisture and humus are abundant.

Phoenix loureiri var. *humilis* Becc. is seen in grasslands at higher elevation of around 1000-2000 m. In Kerala it is seen at Silent Valley, Thekkady, Muthikulam, Eravikulam slopes, Chinnar, Nelliampathy, Peerumedu, Parambikulam, Ponmudi and Vallakkadavu grasslands.

Pinanga dicksonii (Roxb.) Bl. is distributed in the evergreen forests at 350-1000 m elevation in Wayanad, Nilambur, Pooyamkutty, Shenduruny, Silent Valley, Attappady and Muthikulam forests.

The main criteria for the selection of study plots were accessibility and the number of plants available in an area. Plots were selected where at least three 10x10 m plots could be selected. Two localities were selected for each species (Table 1). Three 10x10 m plots were taken in each locality. As a whole 6 plots were there for each species.

Table 1. Details of the study area

Taxa	Name of locality	Altitude (m)	No. of plots	Forest Division	Global position
Arenga wightii	Ambayathodu	479±15	3	Kottiyur	11^0 51.190^1 North 75^0 54.916' East
	Pullupara	643±20	3	Peerumedu	9^0 33.459' North 76^0 57.402' East
Phoenix loureiri var. *humilis*	Vallakkadavu (Periyar Tiger Reserve)	880±10	3	Vallakkadavu	9^0 31.630' North 77^0 15.00' East
	Kuttikanam	959±3	3	Peerumedu	9^0 33.89' North 76^0 58.420' East
Pinanga dicksonii	Rosemala (Shenduruny wildlife sanctuary)	518±30	3	Thenmala	8^0 55.721' North 77^0 10.537' East
	Nadukani	850±5	3	Nilambur	11^0 26.232' North 76^0 23.439' East

Fig. 1. *Arenga wightii*
Fig. 2. *Phoenix loureiri* var. *humilis*
Fig. 3. *Pinanga dicksonii*

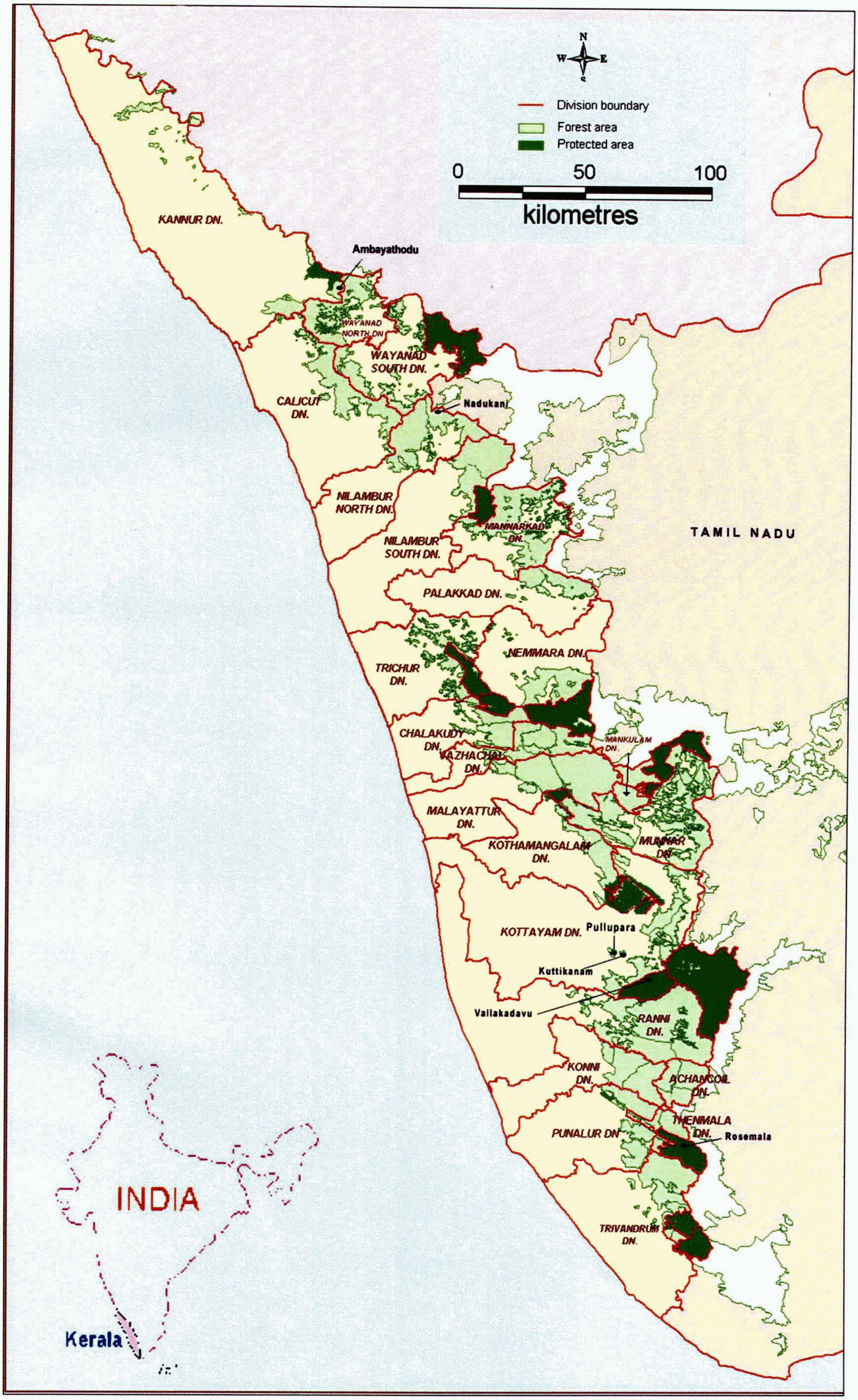


Fig. 4. Study area

***Arenga wightii* Griff.**

The experimental plots for the study of *Arenga wightii* were located at Ambayathodu in the Kottiyoor East forest range in the Northern part of Kerala and at Pullupara, in the Peerumedu forest range in Central Kerala.

Ambayathodu

The area is hilly and covered with tropical evergreen forest. The plots are along the sides of Adakkathodu stream.

Climate

The area is fairly cool and gets the benefits of both the South West and North East monsoons (Table 2). South West monsoon lasts from June to August and as such two seasons such as dry and wet could be distinguished in the area. Periods from November to April with low or no rainfall is considered as dry, and the remaining months of the year as wet.

Table 2. The average rainfall from the year 1999 to 2002

Month	Year			
	1999	2000	2001	2002
Jan.	-	0.91	-	-
Feb.	0.41	0.15	10.42	8.00
Mar.	-	-	-	-
Apr.	7.24	4.52	15.14	7.70
May	27.95	12.93	20.95	15.21
June	66.78	112.1	92.24	71.17
July	156.59	70.86	112.67	104.09
Aug.	60.68	142.59	108.84	105.31
Sept.	12.06	22.17	18.69	19.56
Oct.	26.42	18.16	16.87	14.76
Nov.	2.48	14.98	7.06	-
Dec.	-	-	-	-

values in cm

Habitat and vegetation

Due to climatic, edaphic and altitudinal conditions the forest seen here is of the tropical evergreen type with three distinct strata of vegetation and trees growing to about 45 m in height.

The plot 1 had 13 major plants of tree species other than *Arenga* (Fig. 5). Among those, one was above 20 m in height and 12 below 20 m height. Nine of them showed a canopy more than 1 m across. The tree species seen were *Aglaia, Syzygium, Litsea, Myristica, Garcinia, Elaeocarpus* and *Dipterocarpus.*

The plot 2 had 16 major plants of tree species (Fig. 6). Of these six were having a height of more than 20 m and 10 below 20 m. Seven plants showed a canopy of more than 1 m across. The tree species were *Dipterocarpus, Dillenia, Averrhoa, Holoptelea, Elaeocarpus, Syzygium, Mesua, Myristica, Neolitsea, Aglaia, Xanthophyllum* and *Litsea.*

Plot 3 had 10 major plants of tree species of which six were having above 20 m height (Fig. 7). Seven trees showed a canopy of above 1 m. The important tree species were of the genera *Dipterocarpus, Dillenia, Xanthophyllum, Neolitsea, Litsea, Holoptelea, Elaeocarpus, Syzygium, Mesua* and *Myristica.*

Pullupara

The area is hilly and part of the evergreen forest. The plots are near a stream. The altitude of the area is 643 m and the lowest and highest plots show a height difference of 20 m.

The area is a disturbed forest. There is the presence of large tree and the canopy is almost completely covered but the second and third strata of canopy are lacking.

Climate

From the (Table 3) a dry period from December to March and a wet season of April to November could be distinguished.

Table 3. The average rainfall from the year 1999 to 2002

Year	1999	2000	2001	2002
Jan.	-	-	-	-
Feb.	3.88	6.42	-	0.43
Mar.	0.64	0.38	0.76	1.65
Apr.	10.08	1.85	14.24	2.2
May	35.23	10.03	8.17	27.78
June	42.42	47.18	50.08	26.39
July	54.54	20.71	69.45	25.97
Aug.	15.5	60.11	30.53	27.32
Sept.	11.74	12.07	25.05	2.3
Oct.	5.12	11.17	18.49	36.2
Nov.	7.78	5.97	7.71	5.47
Dec.	0.3	5.43	-	-

values in cm

Habitat and vegetation

The area is included under the evergreen forest but due to human interaction the nature of the forest has changed very much. Eventhough the characteristic feature shown by the evergreen forest is not felt here, very large trees are present with closed canopy.

In plot 4 there were five large trees other than *Arenga* (Fig. 8). Among those one tree was above 20 m in height. All the five plants showed a canopy of more than one metre. Four families were represented by tree species. The tree species in the plot were belonging to the genera *Aglaia, Syzygium, Litsea* and *Elaeocarpus.*

In plot 5 there were three tree species other than *Arenga* (Fig. 9). All the trees were 20 or more than 20 meter in height. All the trees showed a canopy of more than 1 meter across. The three tree genera were *Dillenia, Elaeocarpus* and *Holoptelea.*

In plot 6 also there were three tree species other than *Arenga* (Fig. 10). Two of these trees were above 20 m height. All the tree species had canopy of more than one meter across. The tree genera were *Aglaia, Xanthophyllum* and *Neolitsea.*

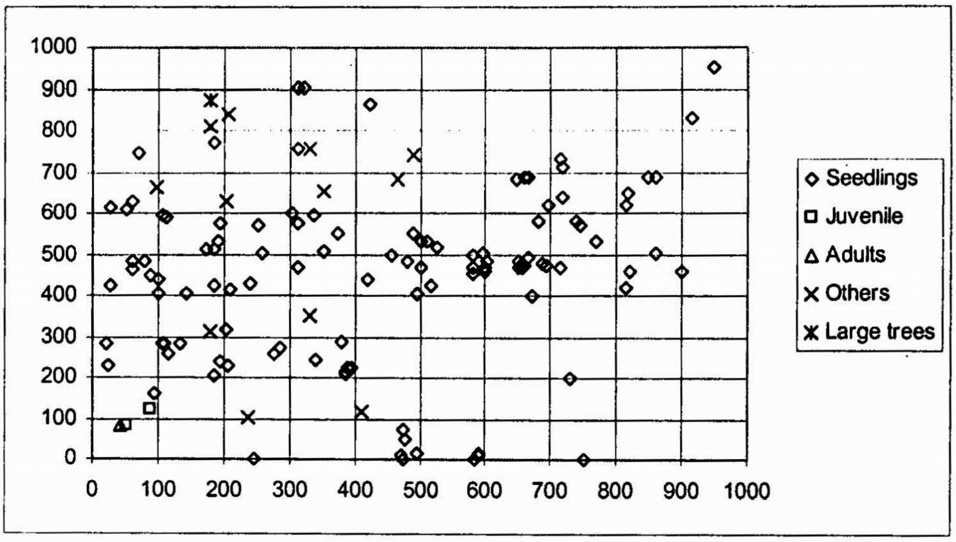


Fig. 5. Plot 1

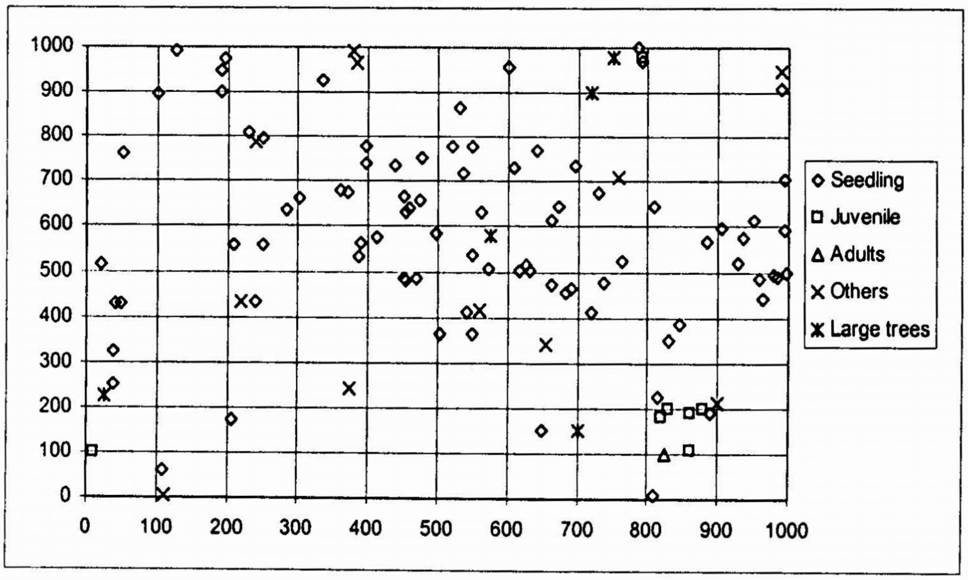


Fig. 6. Plot 2

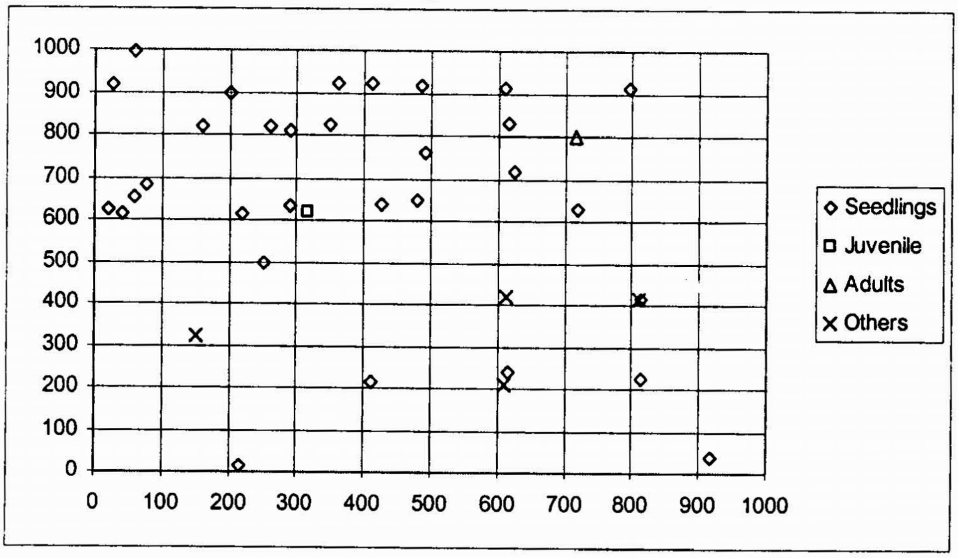


Fig. 7. Plot 3

Figs. 5, 6 & 7. Pattern of distribution of *Arenga wightii* Griff.

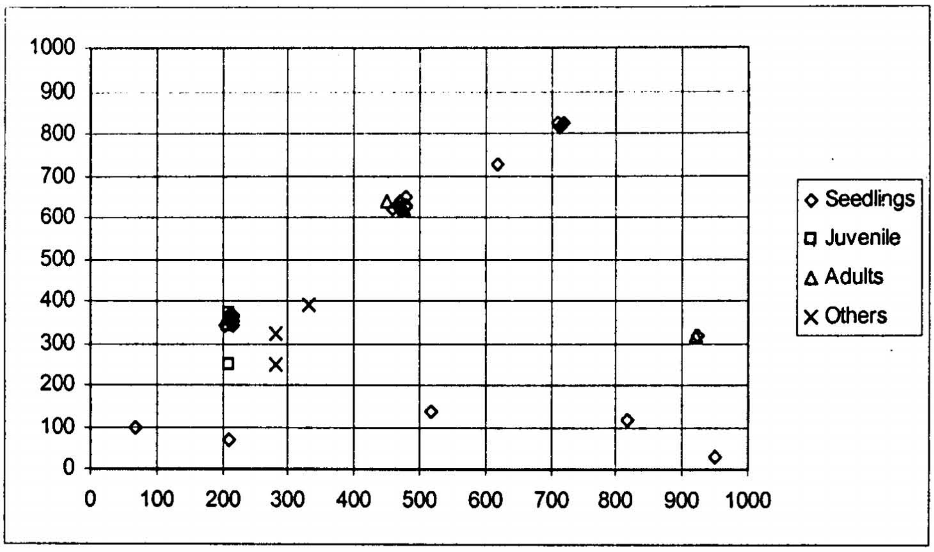


Fig. 8. Plot 4

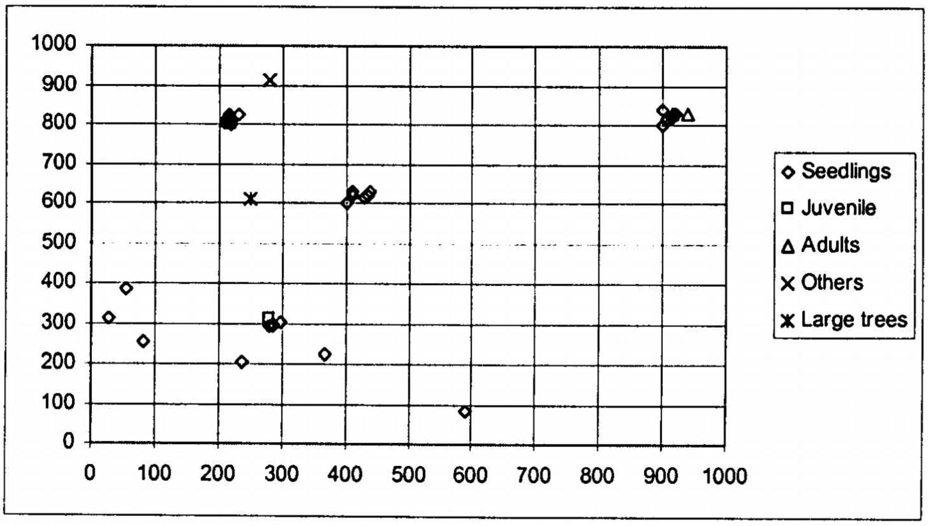


Fig. 9. Plot 5

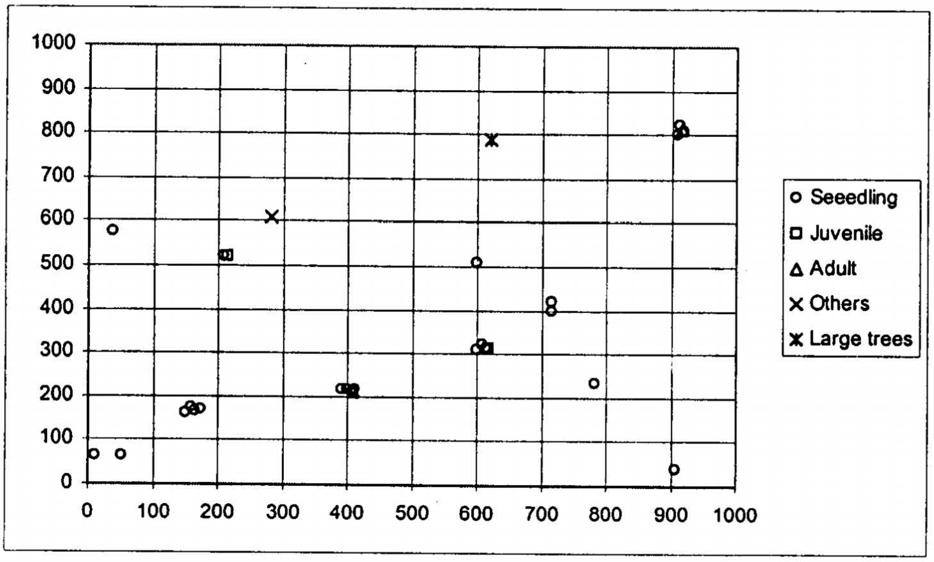


Fig. 10. Plot 6

Figs. 8, 9 & 10. Pattern of distribution of *Arenga wightii* Griff.

***Phoenix loureiri* var. *humilis* (Becc.) S. Barrow**

Vallakkadavu

Topographically the whole area is hilly in character.

Climate

Meteorological data collected (Table 4) showed a dry period from October to March and wet period from April to September .

Table 4. The average rainfall from the year 1999 to 2002

Year	1999	2000	2001	2002
Jan.	-	-	-	-
Feb.	4.1	8.21	2.3	0.81
Mar.	0.31	0.41	0.47	1.31
Apr.	15.4	6.3	12.9	4.1
May	42.6	27.2	19.6	29.2
June	45.9	49.4	42.7	32.3
July	49.2	33.2	58.5	41.2
Aug.	16.3	19.1	30.52	21.32
Sept.	11.3	9.2	21.6	12.3
Oct.	6.1	6.3	7.9	13.1
Nov.	8.3	4.1	3.2	2.8
Dec.	0.83	-	-	-

values in cm

Habitat and vegetation

Natural habitat was the characteristic grassland interspersed with mountain wet-temperate forest (Figs. 11, 12 &13). It was characterized by tall grasses of *Cymbopogon* and *Themeda* species. These grasses often reached 3 m in height.

Kuttikanam

Topographically the whole area is hilly in character.

Climate

The Meteorological data (Table 5) showed a dry period from December to April and wet period from May to November.

Table 5. The average rainfall from 1999 to 2002.

Year	1999	2000	2001	2002
Jan.	-	-	-	-
Feb.	3.88	6.42	-	0.43
Mar.	0.64	0.38	0.76	1.65
Apr.	10.08	1.85	14.24	2.2
May	35.23	10.03	8.17	27.78
June	42.42	47.18	50.08	26.39
July	54.54	20.71	69.45	25.97
Aug.	15.5	60.11	30.53	27.32
Sept.	11.74	12.07	25.05	2.3
Oct.	5.12	11.17	18.49	36.2
Nov.	7.78	5.97	7.71	5.47
Dec.	0.3	5.43	-	-

values in cm

Habitat and vegetation

Grassland is the natural habitat in all the three plots (Figs. 14, 15 &16). The grassland is interspersed with mountain wet temperate forests. Species of *Cymbopogon* and *Themeda* which grew to a height of about 3 m, were the common grass species.

***Pinanga dicksonii* (Roxb.) Bl.**

Rosemala

Climate

The rainfall data recorded from 1999–2001 (Table 6) showed a relatively dry period from December to March and a wet period from April to November.

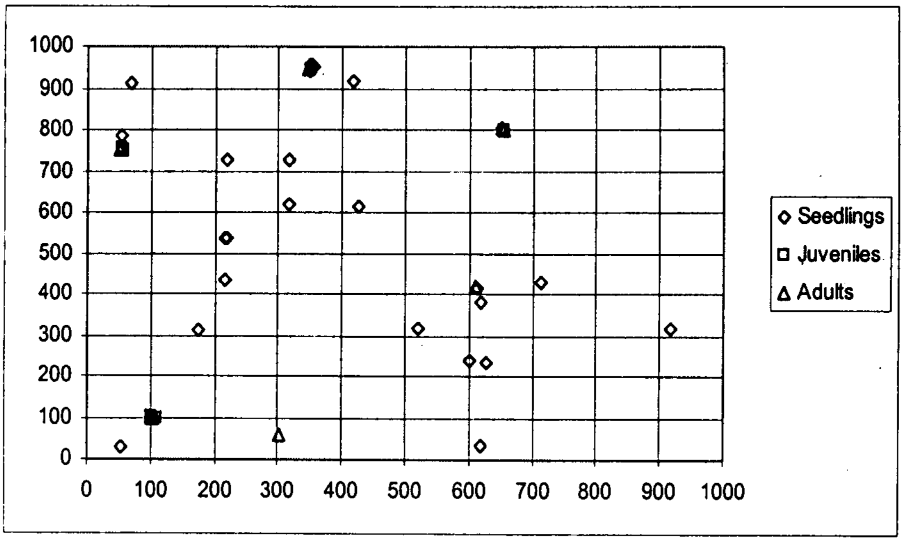


Fig. 11. Plot 1

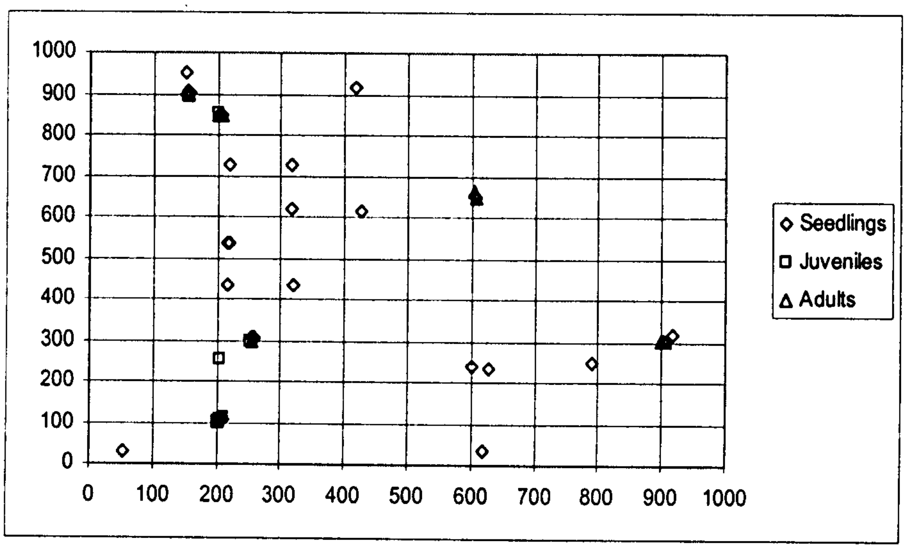


Fig. 12. Plot 2

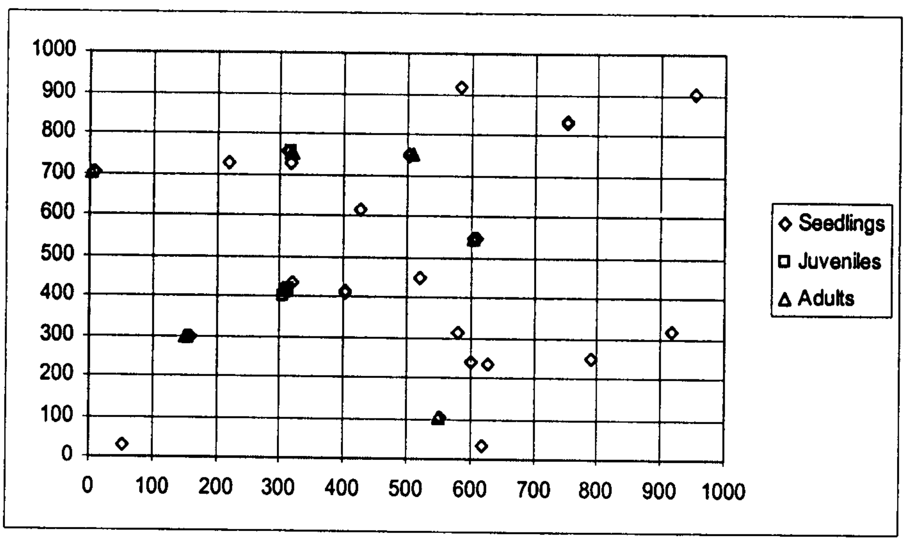


Fig. 13. Plot 3

Figs. 11, 12 & 13. Pattern of distribution of *Phoenix loureiri* var. *humilis*

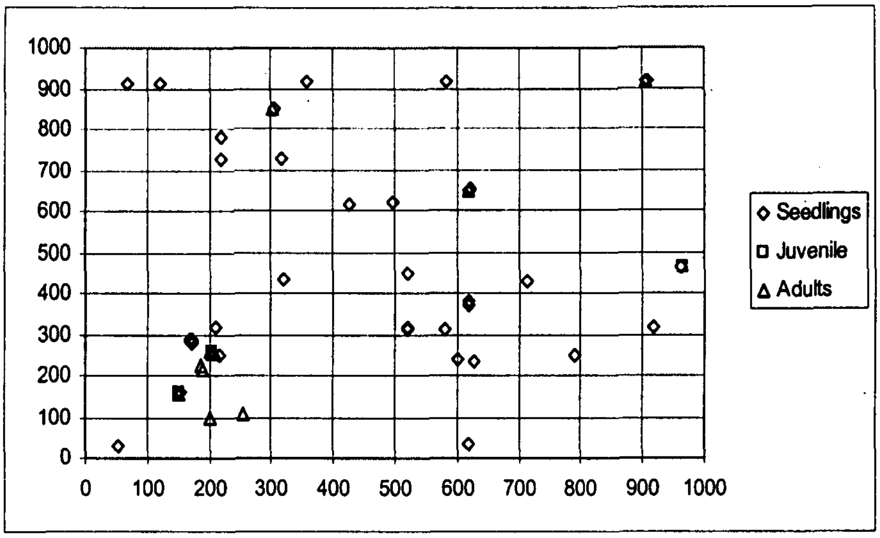


Fig. 14. Plot 4

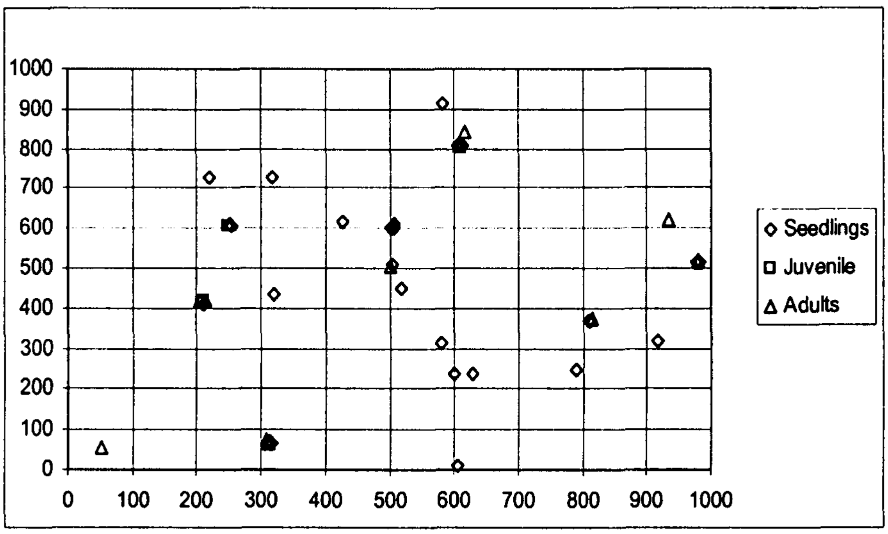


Fig. 15. Plot 5

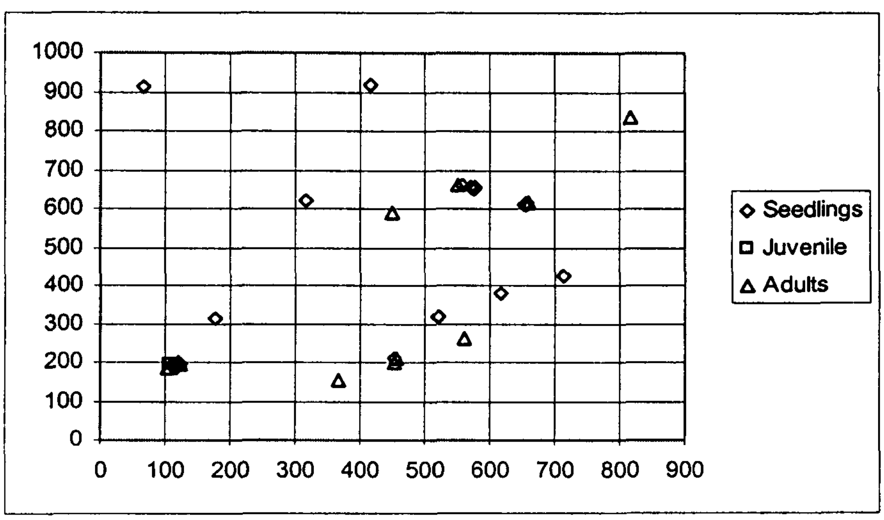


Fig. 16. Plot 6

Figs. 14, 15 & 16. Pattern of distribution of *Phoenix loureiri* var. *humilis*

Table 6. The average rainfall from the year 1999 to 2002

Year	1999	2000	2001	2002
Jan.	-	-	5.14	3.68
Feb.	6.2	25.98	1.58	1.88
Mar.	-	6.08	0.48	10.22
Apr.	19.4	6.32	35.86	15
May	47.86	20.64	23.82	26.82
Jun	47.92	46.88	38.66	23.22
Jul	40.58	15.76	39.42	41.48
Aug.	19.88	72.42	21.14	19.48
Sept.	8.96	27.24	25	7.36
Oct.	82.94	13.76	38.33	54.6
Nov.	5.46	19.42	45	28.62
Dec.	0.12	12.54	0.72	-

values in cm

Habitat and vegetation

The most luxuriant type of forest vegetation in this region is evergreen and is characterized by the presence of a relatively large number of species which grow to a height up to 45 m. The canopy is extremely dense and unbroken.

The plot 1 had 18 major plants other than *Pinanga*. Among this eight were *Calamus* species (Fig. 17). Six plants of tree species were 20 m or more in height and four were below 20 m. Sixteen plants had canopy diameter 1 or more than 1 meter and two plants had canopy below 1 m. The tree genera were of eight families and included species of *Dipterocarpus, Mesua, Caryota, Syzygium, Knema, Holarrhena, Lepisanthus* and *Holoptelea.* Rattans included *Calamus delessertianus, C. hookerianus* and *C. shendurunii.*

The plot 2 showed the presence of 13 plants other than *Pinanga* (Fig. 18). Among these five were dicotyledonous tree species and eight, *Calamus* species. Two plants of tree species were above 20 or more in height and three were below 20 m in height. All the 13 plants had a canopy width of 1 m. The important genera present were *Holoptelea*, *Knema* and *Lepisanthus*. *Calamus delessertianus*, *C. hookerianus* and *C. shendurunii* were the rattan species available. The major trees were represented by three families.

In Plot 3, apart from *Pinanga dicksonii*, there were 16 major plants (Fig. 19). Among these five were represented by tree species. *Gnetum*, a gymnospermous liana, very characteristic of tropical rain evergreen forest was also present in this plot. The total *Calamus* plants represented in the plot were10. All the five plants of tree species present in the plot were 20 m or above in height. All the 16 plants present in the plot showed a canopy width of 1 m or above. Five different families were represented by the tree species. The important tree genera were *Garcinia, Holarrhena, Lepisanthus* and *Litsea*. The rattan species included *Calamus delessertianus, C. hookerianus, C. thwaitesii* and *C. shendurunii.*

Nadukani

This area also showed the naturally growing patches of *Pinanga dicksonii*. The plots were located in the tropical evergreen forest at the western part of the Nilgiri Biosphere. The area is hilly and has characteristic vegetation of a tropical evergreen type.

Climate

The data (Table 7) collected showed that a seasonal stability is existed with a dry period from December to April and a wet period from May to November.

Table 7. The average rainfall from 1999 to 2002

Year	1999	2000	2001	2002
Jan.	0.6	5.48	-	-
Feb.	0.6	0.3	1.58	-
Mar.	1.96	0.12	-	5.84
Apr.	1.42	12.26	11.9	6.06
May	34.72	5.32	14.14	15.26
June	45.02	46.58	47.41	29.66
July	56.94	30.5	55.02	23.48
Aug.	28.98	45.86	21.12	32.32
Sept.	6.6	21.73	9	4.4
Oct.	31.02	13.58	26.06	37.92
Nov.	3.14	9.62	23.76	6.6
Dec.	-	11.84	1.8	1.88

values in cm

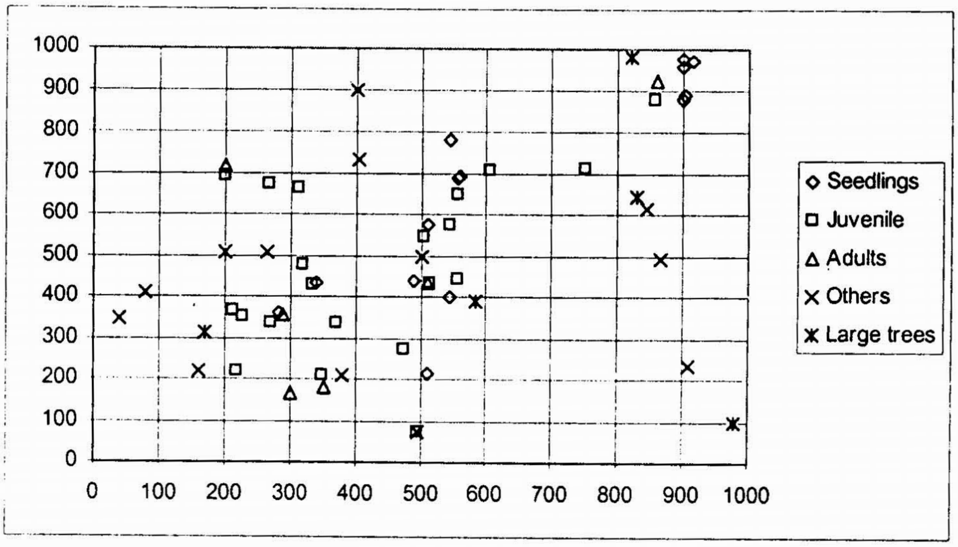


Fig. 17. Plot 1

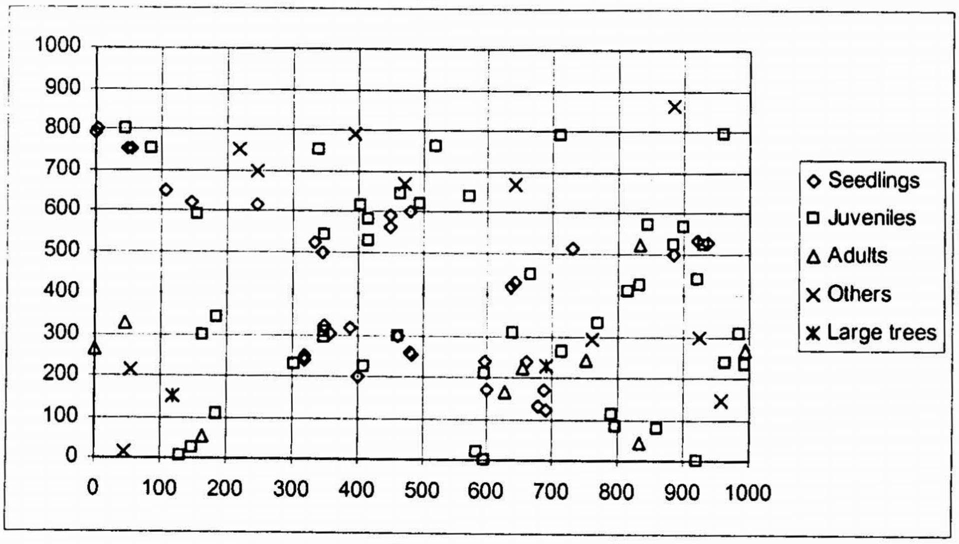


Fig. 18. Plot 2

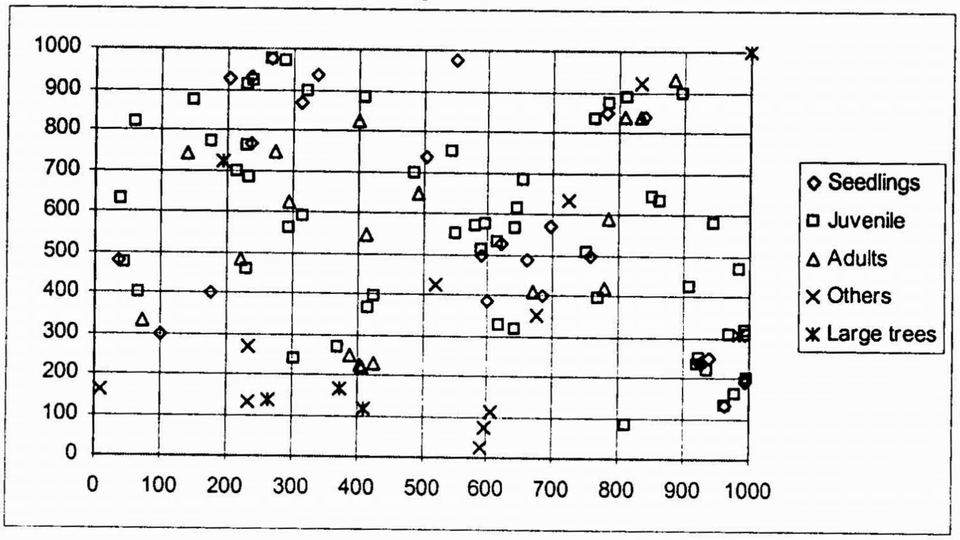


Fig. 19. Plot 3

Figs. 17, 18 & 19. Pattern of distribution of *Pinanga dicksonii*

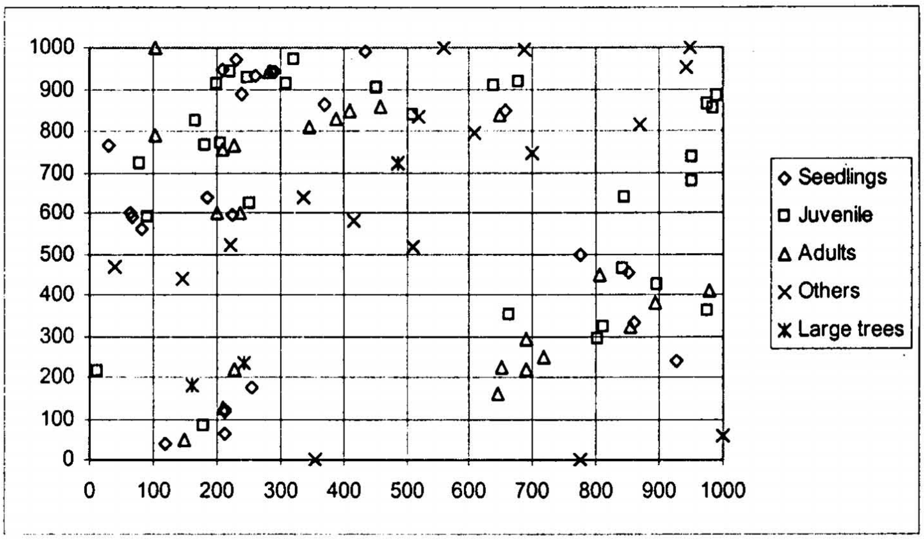


Fig. 20. Plot 4

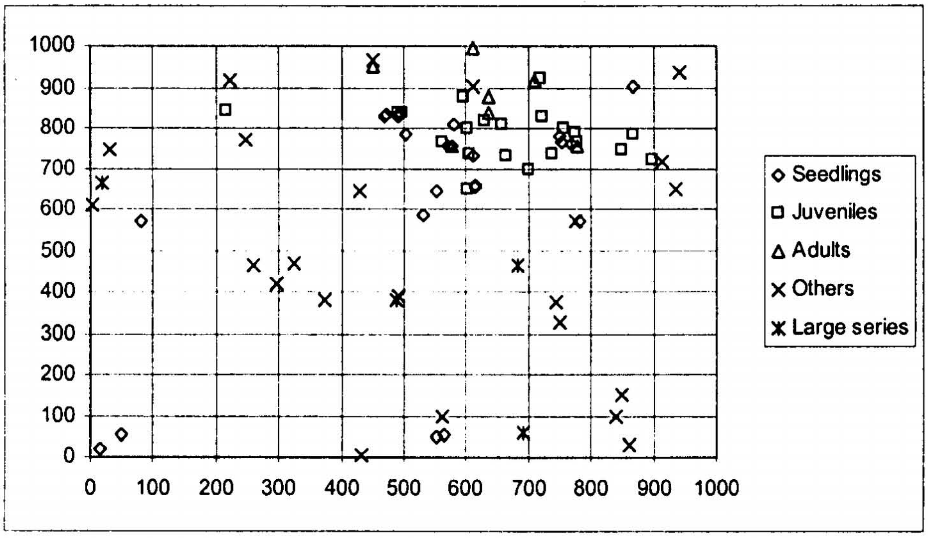


Fig. 21. Plot 5

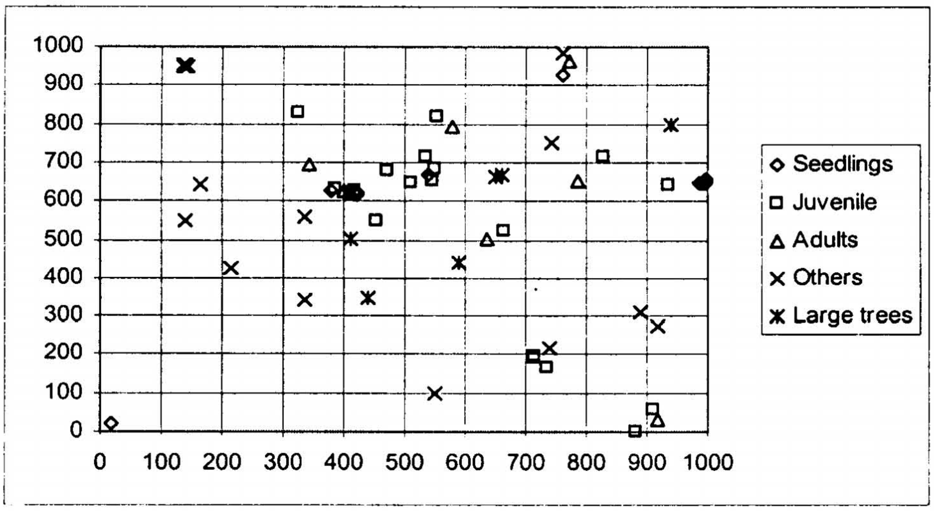


Fig. 22. Plot 6

Figs. 20, 21 & 22. Pattern of distribution of *Pinanga dicksonii*

Habitat and vegetation

The trees were about 45 m high and at least three strata of vegetation could be recognized. The trees of the top canopy had a spreading crown. The middle and lower stratum were also thick. Trees were often festooned with an array of orchids, ferns and mosses.

The plot 4 had 20 tree species other than *Pinanga* (Fig. 20). Six among those were 20 m or above in height. All the plants of tree species except one had the canopy of more than 1 m diameter. The tree species were represented by 10 families and the important genera were *Artocarpus, Calophyllum, Syzygium, Xanthophyllum, Knema, Garcinia, Litsea* and *Aglaia*.

In plot 5, apart from *Pinanga* there were 22 plants of major tree species (Fig. 21). This again had the presence of *Calamus* species and the gymnosperm *Gnetum*. Of the 22 plants of major tree species, three were 20 m or above in height while 19 were below 20 m. Among the 26 plants seen in the plot, 24 were having a canopy of more than 1 m across. The tree species represented 12 families and were *Artocarpus, Holoptelea, Neolitsea, Syzygium, Litsea, Mesua, Arenga, Xanthophyllum, Garcinia, Lasianthus* and *Knema*. The rattans were represented by *Calamus delessertianus.*

In plot 6, there were 17 plants of tree species and eight *Pandanus* plants and one plant of *Gnetum*. Five plants of tree species were 20 m or above in height (Fig. 22). Seventeen plants showed a canopy of 1 m across. The *Pandanus* plant was of up to a height of 1 m or below and with a canopy of 60 cm across. The tree species belonged eight families and were of the genera like *Litsea, Knema, Garcinia, Neolitsea, Artocarpus, Lasianthus, Arenga etc.* The rattans were represented by *Calamus delessertianus*.

Methodology

Observations for the present study were taken at an interval of 3 months for three years from 1999 to 2001. The plots for each species were taken at two different localities.

Each species had a total of 6 plots ie, 3 plots at one location. The plots were selected in such a way that each plot must represent a minimum number of 10 seedlings, 10 juvenile plants and 10 adult plants. Three plots of 10 m x 10 m were laid out at each location. The distance between the plots was more than 25 m. For the accurate measurements the plot was again divided in to 2 m x 2 m sub-plots.

All individual palm plants in the plot were marked with labelled tags. The relative position of each individual in the plot was recorded by measuring the positions from the assumed X and Y axes of the plot. All the individuals in the plot were classified according to their size, number of leaf or flowering conditions as seedlings, juvenile plant and adult plants.

In this study, three life stages have been defined for all three genera, seedling, juvenile and adult. In *Arenga* and *Phoenix* sucker is also representing a prominent stage. It was found that all the three groups have their own specific identifying features and also clearly distinguishable. There were abrupt and large gap between each of these stages – the plants studied fell naturally into any of these groups and at no time during the study was there a plant seemed to be between any of the stages. The categorization and criteria used for the three species are as follows:

In *Arenga* the characteristic features shown by the three different groups were as follows:

1. Seedlings - Newly formed plants from seeds with one or more simple entire leaf. No stem formation was noticed at this stage.

   Suckers were seen associated with juvenile or mature plant. Stem formation was not seen. Leaf was structurally similar to that of mature plant but very smaller in size and hence treated under the group of seedlings.

2. Juveniles – had a stem just emerged with a crown of leaf. The leaves were larger than that in suckers but smaller than adult, and are pinnately compound. The minimum height of the plant is 20 cm and the maximum height is 211 cm.

3. Adults – Individuals with well developed trunks having well defined leaf scars and with well developed leafy crown on top of trunk. The minimum height of the plant in this group was marked as 212 cm, the height of the smallest flowering plant within the plot selected.

In *Phoenix* the distinguishing characters were as follows.

1. Seedlings - from newly germinated seed. Seen individually without stem. The leaves were simple, entire and lanceolate or with minimum leaflets per leaf.

   Suckers were seen associated with a juvenile or adult plant forming a cluster. Stem was absent. The leaves were similar to that of the seedlings in size and appearance.

2. Juveniles – might be developed from a sucker or from a seedling. Development of the stem was considered to be the turning point from suckers to juveniles. Leaves were similar to that of a mature plant. The minimum height was1 cm and maximum was 14 cm.

3. Adults – Individuals having well developed trunk with clearly defined scars were considered as adults. The minimum height of the plant in this group was fixed as 15 cm, representing the smallest flowering plant within the plots.

In *Pinanga* three stages were identified as:

1. Seedlings – newly formed with one or more simple entire leaf to leaf having a maximum of four pairs of leaflet per leaf. The maximum height of the individuals in the group was 49 cm.

   Suckers were also seen with limited number. They were not seen in association with the main stem and formed new shoot occasionally.

2. Juveniles – well formed stem with the girth more or less equal to a mature plant, but less in height. Well developed leaf present. Height of the individuals this group varies from 50 to 307 cm.

3. Adults – Individuals with well developed stem and well developed leaves. The maximum height of plants of this category was marked as 308 cm, representing the smallest flowering plant within the plots marked.

Growth characters

Stem height

The height of all individuals was measured using a tape from the soil level upto the first leaf sheath.

Stem girth

Girth at breast height (GBH) of all adult plants was measured. For juvenile plants, the girth at 50 cm height was measured. In the case of *Pinanga*, for seedlings the girth of the stem part which is just above the soil level was measured if it shows the stem.

Phenological characters

Leaf formation

The total number of leaves in the plant was counted and recorded. In the successive observations the total number of leaves, new leaves produced and the young leaves just emerged were counted and entered in the data sheet. In *Arenga wightii,* where the leaf formation took much time, the size difference in newly formed leaf was marked. In order to identify the new leaves formed after each measurement, the youngest leaf was marked by removing 4 leaflets from the base of one side of young leaf in *Pinanga*. In *Arenga* and *Phoenix* the youngest leaf was tagged after each measurement.

Flowering and fruiting

The number of male and female inflorescences produced in the adult plants were counted and entered in the data sheet. The time interval for maturation of flower, the time interval for the fruit setting, ripening of fruits, etc. were also noted.

Survival characters of already established plants

The number of damaged adult, juvenile and seedling plants during the study period was recorded.

Establishment of new seedling from seed

The newly formed seedlings from the seeds during the time of observation were noted. Their growth pattern was noted as mentioned earlier. Mortality rate was monitored in the subsequent years.

Establishment of sucker

All the three species ·produced suckers as vegetative regenerative structures. Number of suckers produced by each plant was recorded. The number of suckers in each season and their survival rate also were noted.

Interacting characters

All the plots selected except for *Phoenix* contain other tree species and lianas like *Gnetum*, and *Calamus*. They were also marked with numbered labels. Their relative position in the plot was recorded by measuring their position from the X and Y axes assumed for the plot.

The height and girth at breast-height of each tree were measured. The canopy diameter was also measured.

Analysis of data

The data analysis was based on the method formulated by Zar (1974).

Recruitment and death rates

The transition from one stage to another e. g., from seedling to juvenile or from juvenile to adult is called recruitment. Recruitment may occur from seeds or as is the case in many plants, by the production of vegetative suckers. These suckers were initially physically attached to the parent, each capable of an independent existence if they were detached.

Rate of new recruitment was found out as follows:

Rate of new recruitment = $\frac{n}{N}100$, where '*n*' is the number of new recruitment, '*N*' is the total number of plants at the time of starting of the observation.

Rate of death could be calculated with the following formula

Rate of death = $\frac{n}{N}100$, where '*n*' is the number of deaths noted for that particular period, '*N*' is the total number of plant observed in that particular plot at the time of starting of the measurement.

Population dynamics

By counting the seedlings, juveniles and adults it would give the information regarding the different components of the populations at a particular period.

For studying the varying pattern of each group of plants in the plots in the consecutive observations of the whole period, regression was formulated. The varying factors used for the regression studies were the numbers of plants at each observation and the corresponding months. In order to find out the trends in total number of seedlings from time to time equations were developed with total number of seedlings as dependent variable and months as independent variable. Linear functional form was found to be best suited for the study and was used for the regression analysis.

Population flux

Summarization of the population dynamics for each species is the population flux. It was calculated for an annual basis for the whole period. From the Population flux the variation in the annual recruitment and death of the 3-year period were calculated. It gives the changing pattern of population in the consecutive years. The result would give information of change in population size, cumulative gains and cumulative losses yearly or for the total period and the different trends in the population yearly or for total period.

The rate of increase can be calculated by $\frac{b}{a}$, where '*b*' is the total number of plants in the final measurement and '*a*' is the number of plants in the initial measurement. The total new arrival and total mortality in the total period or year-wise also is included in the population flux. From the data, the total plants recorded during the period can be calculated by '*a* + *e*' where '*a*' is the initial number of plant and '*e*' the number of new arrival during the period.

The percentage of death of the whole period or for one year is included in the population flux which can be calculated with the following formula

Percentage of death = $\frac{f}{g}100$ Where '*f*' is the total mortality of the period and '*g*' is the number of total plants recorded.

The percentage of annual recruitment is also included in the population flux which can be calculated with the following formula.

Percentage of recruitment = $\frac{e}{g}100$

Where '*e*' is the total arrival between the period and '*g*', the number of total plants recorded.

The values will give the changes in population by time with the net population size, the cumulative totals and the cumulative losses. The cumulative losses were tabulated below the original population size annually or total time so that addition with the cumulative totals gives the next population size.

Age of the palms

Corner (1966) formulated a method by which the age of the palm can be calculated without resort to long term measurements. The leaf scars remain conspicuous in palm trunks. Though the number of leaves in the crown increase consistently until reproductive maturity is reached, leaf longevity is independent of tree age. Old leaves abscise almost as frequently in young palms, and at the same frequency in the mature palms. Therefore the age of a palm can be estimated by measuring the time interval between the abscission of the successive leaves, and then multiplying this time interval by the number of leaf scar on the trunk. To this must be added the longevity of the trunkless juvenile period.

Age of plant at juvenile or adult stage

$$= \text{Longevity of trunkless period} + \frac{\text{number of scars at last measurement}}{\text{Average no. of leaf fall per year}}$$

$$\text{Age of seedling} = \frac{\text{Total no. of leaf}}{\text{Average no. of leaf produced per year}}$$

Longevity of the trunkless period is taken as the ratio of the height at which juvenile period started to the average increase in height at juvenile stage.

Therefore,

Longevity of trunkless period of *Pinanga*

$$= \frac{50}{\text{Average increase height for juvenile of } \textit{Pinanga}}$$

Longevity of trunkless period of *Arenga*

$$= \frac{20}{\text{Average increase height for juvenile of } Arenga}$$

Longevity of trunkless period of *Phoenix*

$$= \frac{1}{\text{Average increase height for juvenile of } Phoenix}$$

Transition probabilities and yearly probabilities of surviving and remaining in the same stage

For all the three species for each of the three stages, yearly transition probabilities 'G_i' and yearly probabilities of surviving and remaining in the same stage 'P_i', were calculated using Caswell's (1989) method. Average yearly fecundities 'F_i' were calculated for the reproductive stages. All estimates of growth and survival rates were calculated assuming that the rates were equal for all individuals in each stage.

'G_i' was calculated as follows:

$$G_i = \frac{\sigma_i}{T_i}, \text{ i} = 1, 2, 3$$

Where 'σ_i' is the survival probability and 'T_i' is the average stage duration. For the seedling and juvenile stages 'σ_i' was calculated from the properties of individuals that survived through the study period. Among the adults deaths were rare. In these stages the defining size ranges were decided in to halves. Survival probabilities were calculated from the decrease in number of individuals from the first half to the second half of the stage.

The calculations of 'T_i' and the survival probabilities of the adult stage were based on the assumption that the size distribution with in the stage was stable stage duration 'T_i' was calculated as the average time required for the surviving individuals to pass through a given stage at the observed growth rate. Seedling growth rates were calculated from the increase in the number of leaves and for juveniles and adults by multiplying the number of new leaves produced per year with the number of leaf scars in the stem.

Yearly probabilities of surviving and remaining in the same stage, P_i was calculated as follows:

$$P_i = \sigma_i - G_i \quad i = 1, 2, 3$$

Estimate of sexual fecundities, F_{13} were calculated as the ratio between the number of new seedlings and the total number of adults and F_{23} is the ratio between the number of new juveniles and the total number of adults. This was done under the assumption that the import and export of seeds from the plot were equivalent. Since seedlings germinated after the first survey were recorded in the successive observations the growth and survival rates of seedlings and the sexual fecundities could be calculated for each year of observation.

The above mentioned parameters were used to construct transition matrices (Table 8).

Table 8. Transition Matrix model.

	Seedling	Juvenile	Adult
Seedling	P_1	R	F_{13}
Juvenile	G_1	P_2	F_{23}
Adult	0	G_2	P_3

Density of the taxa for three years

Density per hectare of palms of all the areas of the three taxa were calculated for each year. The method adopted is developed by Lefkovitch (1965) and modified by Usher (1972). The data is represented diagrammatically for each taxa at the regions.

ROOT MORPHOLOGICAL STUDIES

Materials

Only *Arenga wightii* and *Phoenix loureiri* var. *humilis* could be studied since the germination percentage of seeds of *Pinanga dicksonii* was very low and sufficient number of seedlings required for the experiments was not obtained.

Study area

The study was conducted in the campus of the Kerala Forest Research Institute (KFRI) Peechi, Kerala located at North latitude 10^0 31.784' and 0.076^0 20.871' East longitude. The altitude of the locality is 75 m above MSL. The field trials were carried out in the campus of the KFRI in Pattikkad range of Peechi Vazhani Wildlife Sanctuary Forest Division.

The study area was located in a moist deciduous forest. The plot had trees above 25 m height with discontinuously covered canopy.

Methodology

Observations for the present study were recorded at an intervals of 2 months for three years. The methodology adopted was developed by Ellis and Barnes (1973), Bohm (1979) and Ewing and Kasper (1993).

Mature fruits of *Arenga* and *Phoenix* were collected from the natural habitat. The fruits were cleaned by removing the pulpy part. Seeds were put to germination in moist sawdust, then the germinated seeds were transferred to potting bags having a mixture of soil and sand in a proportion of 3:1.The duration of time for germination and method of germination were observed. The seedlings were used for further field trials.

The experiment was laid out in a randomized complete block design with two species replicated five times. Thus 900 seedlings of each species were planted. The plot size was 90 m x 4.5 m with plants at an espacement of 1.5 m x 1.5 m. Thus in each plot there were three rows 60 germinated seedlings each with a total of 180 seedlings. Alternate plants from the central row were selected for recording observations, leaving all the plants in the other two rows to maintain uniform growing conditions throughout the observation period. Initial growth measurements of the root system of the germinated seedlings were made after 2 months. Later on, measurements were taken for both species at intervals of 2 months for 3 years. Thus 18 x 5 observations were recorded for each species.

For recording observations with respect to the morphology of root system, excavation of the entire root system was carried out, since this method could provide a clear picture of the entire root system of a plant as it exists naturally. Excavation was done by taking care not to damage even the smallest rootlet. Soil around each root was removed carefully and slowly after sprinkling adequate water. Before taking the plant out of soil, horizontal and vertical distances the roots had traversed were measured. After taking out, the roots were washed carefully with water to remove all the soil particles. The number, length and diameter of all the main roots and laterals were measured. Here, the first formed root and other roots emerging from the base of the plant are called main roots. The branches of the roots are called laterals and branches from them are referred as sub-laterals.

Growth characters

Number

The number of main roots, laterals and sub-laterals were counted. Number of root lets arising from these main roots and laterals were also counted. The data were subjected to analysis of variance in order to find variation in number of roots between the two species.

Length

By using a scale and a thread the length of the roots were measured. The metre thread after placing from the emerging point of the root to its tip is measured using a scale and the length was noted. The data with respect to the length of main roots, laterals and sub-laterals were also subjected to analysis of variance so as to find the variation in length between the two species and were followed by comparison of these mean values. Rate of increase in length of main roots, laterals and sub-laterals of the two species in each year from second year onwards) was calculated using the following formula $\frac{l_2 - l_1}{l_1}$

Where 'l_2' is the average length of the main / lateral / sub lateral / roots in a particular year, and 'l_1' the average length of main/lateral/sub lateral roots in the previous year. Regression functions were fitted for two species separately for mean total length of root to study the pattern of changes in the above character with the period.

Diameter

A vernier calipers was used to measure the diameter of main and lateral roots. An ocular micrometer was used to measure the diameter of sub-lateral. In order to find the variation in the diameter of roots of the two species the data were subjected to analysis of variance followed by comparison of their mean values. The rate of increase in diameter of main roots, laterals and sub-laterals of the two species in each year (from second year) was calculated using the formula

$$\frac{d_2 - d_1}{d_1}$$

Where 'd_1' is the average diameter of the main/lateral/sub-lateral roots in a particular year, and 'd_2', the average diameter of main/lateral/sub lateral roots in the previous year. Regression functions were fitted for species separately for mean diameter of root to study the pattern of changes in the above characters with the period.

Root spread

To get the maximum horizontal distance traversed by the root system, the distance between the two outer most roots were measured before taking the plant out of the soil. Vertical soil depth occupied by each of the main root was also measured using a meter scale. In order to find out the variations in horizontal spread and vertical depth of the root system of the species, the data were subjected to analysis of variance. This was followed by comparison of their mean value.

Soil volume exploited

Soil volume exploited by the root system of plants of the species of *Arenga* and *Phoenix* was calculated on an yearly basis using the formula

$$\pi\left(\frac{h}{2}\right)^2 v$$

Where 'h' is the mean horizontal spread of the root system in each year obtained from the data collected at two months interval and 'v', the mean vertical depth of the roots. The two species were compared based on the soil exploited by their root system.

Rooting density

Rooting density was calculated by using the formula

$$\frac{R\max}{S}$$

The rooting density of *Arenga* and *Phoenix* were calculated separately on yearly basis where R_{max} is the total length of the main roots, laterals and sub-laterals and '*S*' the soil volume exploited by the entire root system. The result obtained for two species were compared.

OBSERVATIONS

P. K. Padmakumar "Developmental morphology in relation to conservation in the family palmae (arecaceae)" Thesis. Department of Botany , University of Calicut, 2003

Chapter 4.

OBSERVATIONS

OBSERVATIONS

SHOOT MORPHOLOGICAL STUDIES (s. l.)

***Arenga wightii* Griff.**

1st Observation

The total number of plants in different plots varied from 21 in plot 6 to 108 in plot 1 (Table 9). The maximum number of juveniles was in plot 2 (7). In other plots the number was less. The maximum number of adults was in plot 4 (5) and in the rest, it ranged from one to four.

Table 9. Comparison of growth characters.

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PA 1	105	2	1	108	4	13	16	0	26	213	0	71.5	85
PA 2	83	7	1	91	3	14	18	0	33.2	231	0	52.7	58
PA 3	27	1	1	29	4	19	18	0	25	260	0	48	88
PP 4	23	2	5	30	4	10	13	0	35.5	285.4	0	46	56
PP 5	25	1	4	30	6	13	14	0	191	297.5	0	51	56.12
PP 6	17	2	2	21	4	16	16	0	77.5	299.5	0	53	56.5

PA- plots at Ambayathode, PP- plots at Pullupara, S - seedlings, J- juveniles, A- adults

The seedlings had least number of leaves. The average number varied from 3 to 6. In the juveniles the maximum number was noted in plot 3 (19) and the minimum in plot 4 (10). The average number of leaves in adults varied from 13 to 18. Among adults more number of leaves was noted in the plots at Ambayathode.

The average height of juveniles was maximum in plot 5 (191 cm) at Pullupara. The minimum height was in plot 3 at Ambayathode (25 cm). The maximum height among adults was in plot 6 (299.5 cm) at Pullupara and minimum was in plot 1 at Ambayathode. Among adults, plants at Pullupara had maximum height.

The average girth of juveniles ranged from 4.6 cm to 71.5 cm. The average girth of juveniles was maximum in plot 1 at Ambayathode and the minimum in plot 4 at Pullupara.

Among the adults, the maximum was in plot 1 (85 cm) and minimum in plot 4 (56 cm). The average girth of adults except in plot 1 was more or less equal (ranged from 56 cm to 58 cm).

After 3 months

In all the plots the total number of plants remained without change (Table 10). The maximum was in plot 1 (108). In all the plots the number of seedlings remained without change. The maximum number was present in plot 1 (105) and the minimum in plot 6 (17). In all the plots the number of juveniles remained without change. In plot 2, seven juveniles were present while in all other plots they were one or two. The number of adults also remained without change.

Table 10. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PA 1	105	2	1	108	3	13	15	0	26	213	0	71.5	85
PA 2	83	7	1	91	3	13	18	0	33.7	231	0	52.7	58
PA 3	27	1	1	29	4	18	18	0	25	260	0	48	58
PP 4	23	2	5	30	4	10	13	0	35.5	285	0	46	56
PP 5	25	1	4	30	6	13	14	0	191	298.2	0	51	56.2
PP 6	17	2	2	21	4	16	16	0	77.5	299.5	0	53	56.5

PA- plots at Ambayathode, PP- plots at Pullupara, S - seedlings, J- juveniles, A- adults

In all the plots except plot 1, the average number of leaves of seedlings remained without change. In plot 1, it decreased. Among juveniles in plot 2 and 3 the average number of leaves decreased. In all other plots it remained without change. For the adults the average number of leaves decreased in plot 1. In all other plots it remained without change.

The average height of juveniles increased in plot 2, and in all other plots it remained without change. The average height in juveniles was maximum in plot 5 (191 cm) and the minimum in plot 3 (25 cm). The average height of adults increased in plot 5. In all other plots it remained without change. The maximum was in plot 6 (299.5 cm).

In all the plots the average girth of juveniles and adults remained without change.

All seedlings produced new leaves. In all the plots, the average leaf formation was less than one. The average leaf fall in all plots except 6 was less than one and in 6, it was one.

The juveniles produced new leaves only in plot 1. Here the average leaf formation and average leaf fall were one.

The adult plants produced new leaves only in plot 6. The average formation and leaf fall were one in plot 6.

After 6 months

The total number of plants in all plots remained without change (Table 11). The maximum was noticed in plot 1(108) and the minimum in plot 6 (21). The average number of seedlings in the plots remained without change having maximum in plot 1(105) and minimum in plot 6 (17). The number of juveniles in all plots remained without change. The number of adults also remained without change in all plots.

Table 11. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PA 1	105	2	1	108	3	12	15	0	27	215	0	71.5	85
PA 2	83	7	1	91	3	13	17	0	34	234	0	82.7	58
PA 3	27	1	1	29	4	18	17	0	25	260	0	48	58
PP 4	23	2	5	30	4	10	13	0	35.5	285.4	0	46	56
PP 5	25	1	4	30	5	12	14	0	191	299.2	0	51	56.2
PP 6	17	2	2	21	4	15	16	0	77.5	301	0	53	56.5

PA- plots at Ambayathode, PP- plots at Pullupara, S - seedlings, J- juveniles, A- adults

In seedlings, the average number of leaves remained without change in all plots except 5. In plot 5 it decreased. For the juveniles, the average number of leaf decreased in plot 1, 5 and 6. In all other plots it remained without change. In adults the number decreased in plot 2 and 3. In all other plots it remained without change.

The average height of juveniles increased in plot 1 and 2. In all other plots it remained without change. The maximum height was noticed in plot 5. The average height of adults increased in plots 1, 2, 5 and 6 and in others it remained without change. Among adults, plots of Pullupara had maximum height. The average girths of the juveniles and adults remained without change in all the plots.

Seedlings produced new leaves in all plots. A single leaf is formed for all seedlings. The average leaf formation in all plots was less than one. The average leaf fall in all plots except plot 5 was less than one. In plot 6, it was one.

The juveniles produced more leaves in plots 2 at Ambayathode and 4 at Pullupara. The average leaf formation in these two plots was one. The average leaf fall was one in three plots, plot 1 located at Kottoyoor and plot 5 and 6 at Pullupara.

None of the adults produced new leaves. The average leaf fall was one in plots 2 and 4.

After 9 months

In all the plots the total number of plants increased. The rate of increase was maximum in plots 3 and 4 (Table 12). The minimum was noticed in plot 1. In all the plots the number of seedlings increased. The increase was proportional to the increase in total number of plants. The number of juveniles remained without change in all plots. The number of adults also remained without change in all plots.

Table 12. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PA 1	108	2	1	111	4	12	15	0	28	218	0	71.5	85
PA 2	85	7	1	93	3	13	17	0	34.2	234	0	52.7	58
PA 3	28	1	1	30	4	17	17	0	25	260	0	48	58
PP 4	24	2	5	31	4	10	11	0	35.5	287.8	0	46	56
PP 5	26	1	4	31	5	13	14	0	193	299.2	0	51	56.2
PP 6	18	2	2	22	4	15	15	0	77.5	301	0	53	56.5

PA- plots at Ambayathode, PP- plots at Pullupara, S - seedlings, J- juveniles, A- adults

Among seedlings, the average number of leaves remained same except in plot 1. In plot 1 it increased. The number ranged from three to five. In juveniles it increased in plot 5. In plot 3 it decreased. In all other plots the number remained without change. For the adults the average number of leaves decreased in plot 6. In all other plots the number remained without change.

The average height of juveniles increased in plots 1, 2 and 5. In all other plots it remained without change. Among juveniles the average height was maximum in plot 5 (193 cm). In adults it increased in plot 1 and 4. In all other plots the average height remained without change. Among adults average height was maximum in plots at Pullupara with a maximum of 301 cm (plot 6).

The average girth of juveniles and adults remained without change. The average girths for juvenilesand adults were maximum in plot 1(71.5 cm) and (85 cm) respectively.

Seedlings produced new leaves in all the plots, but the average leaf formation was less than one. But it was more than the previous observation. In all plots, the average leaf fall was also less than one. But it was more than the previous observation.

The juveniles produced new leaves in one plot (plot 2). In other plots, the new leaf formation was zero. The average leaf fall was one in plots 4 and 6. In all other plots it was less than one.

The adults produced new leaves in plots 4, 5 and six at Pullupara area. The average leaf formation was one for all. The average leaf fall was one in plot 6.

After 12 months

In 4 plots the average number of plants increased. The rate of increase was noticed in plot 2 at Ambayathode and plots 4, 5 and 6 at Pullupara (Table 13). The rate of new recruitment was less when compared with the previous observation. In plots 1 and 3, located at Ambayathode, the total number remained without change. Similarly the numbers of seedlings increased in plot 2 at Ambayathode and plots 4, 5 and 6 at Pullupara. In the other two plots no change occurred. The juveniles and adults of all pots remained without any change in number. The number of juveniles ranged from 1 to 7 and that of adults from 1 to 5.

Table 13. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PA 1	108	2	1	111	5	12	15	0	28	218	0	71.5	85
PA 2	86	7	1	94	3	13	17	0	34.8	234	0	52.7	58
PA 3	28	1	1	30	4	17	17	0	25	260	0	48	58
PP 4	25	2	5	32	4	10	13	0	35.5	287.6	0	46	56
PP 5	27	1	4	32	5	12	14	0	193	300.2	0	51	56.9
PP 6	19	2	2	23	4	14	15	0	78.5	301	0	53	56.5

PA- plots at Ambayathode, PP- plots at Pullupara, S - seedlings, J- juveniles, A- adults

In seedlings the average number of leaves was same in all plots except in plot 1 where it increased. The number of leaves varied between 3 and 5 in different plots. In juveniles, in the first four plots the number remained without change. It decreased in two plots (5 and 6). The maximum was in plot 3 (17) and the minimum in plot 4 (10). The average number of leaves in adults remained without change in all plots.

The average height of juveniles increased in two plots (plots 2 and 6) and in all other plots it remained without change. The maximum was in plot 5 (193 cm) and the minimum in plot 3 (25 cm). In adults the average height increased in last two plots. In all other plots it remained without any change. The adults with maximum height were noted at Pullupara.

The average girth of juveniles remained without any change in all plots. The maximum was in plot 1(71.5 cm). In adults also, the average girth remained without any change with a maximum of 85 cm in plot 1.

The seedlings produced new leaves in all plots. The leaf formation was less than the previous observation. In all the plots, the average leaf formation was less than one. The average leaf fall for the seedlings in plots 1 and 2 at Ambayathode were one and in other plots, it was less than one. The juveniles formed new leaves in 3 plots (1, 2 and 4). In all these plots, the average leaf formation was one. The average leaf fall was one in three plots (plot 1, 5 and 6).

The adults produced new leaves in plots 4, 5 and 6, located at Pullupara. In these the average leaf formation was one. The average leaf fall was one in plots 1, 4, 5 and 6. Of these the first plot was at Ambayathode and the other three at Pullupara.

After 15 months

The total number of plants in the last four plots increased in this observation (Table 14). Of these one plot was located at Ambayathode and the others at Pullupara. The rate of increase was less as in the previous observation. The seedlings increased their number in four plots. In the first two plots the number of seedlings remained without change. In other plots the number of juveniles and adults remained without change. The number of juveniles ranged from 1 to 7 and the adults from 1 to 5.

Table 14. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PA 1	108	2	1	111	6	12	16	0	29	218	0	71.5	85
PA 2	86	7	1	94	3	14	17	0	34.8	237	0	52.7	58
PA 3	29	1	1	31	4	17	17	0	27	262	0	48	58
PP 4	26	2	5	33	4	10	13	0	36.5	288.6	0	46	56
PP 5	29	1	4	34	5	13	14	0	193	300.7	0	51	56.2
PP 6	20	2	2	24	4	14	16	0	79.5	301	0	53	56.5

PA- plots at Ambayathode, PP- plots at Pullupara, S - seedlings, J- juveniles, A- adults

Among seedlings the average number of leaves remained same in all plots except in plot 1. In plot 1 the number increased. The maximum number was 6 and minimum was 3, both in plots at Ambayathode. The average number of leaves in juveniles increased in plot 2 and 5. In all other plots it remained without change. The maximum was in plot 3 (17) and minimum in plot 4 (10). The adults had a maximum of 17 leaves and a minimum of 13 leaves. The number of leaves increased in plot 1 and 6. In all other plots it remained the same.

In juveniles the average height increased in 4 plots (1, 3, 4 and 6). In the other two it remained without change. The maximum was in plot 5 (193 cm). In adults it increased in 4 plots (2, 3, 4 and 5). In the other two plots, it remained without change. The adults with maximum height was noted in plot 6 (301 cm) at Pullupara.

The average girth of juveniles and adults remained without change. For juveniles the maximum was 71.5 cm (plot 1) and for adults 85 cm (plot 1).

Seedlings produced new leaves in all plots. The rate of leaf formation was less than one in all plots. The average leaf fall also was less than one. There was no change in number of new leaves in seedlings. The maximum produced were in plot 1 (30).

The juveniles produced new leaves in 3 plots, plots 1 and 2 at Ambayathode and plot 4 at Pullupara. In all these plots the average leaf formation was one. The average leaf fall was one in four plots, plots 1 and 2 located at Ambayathode and plots 4 and 5 at Pullupara.

The adults produced new leaves in 5 plots; plots 1, 2 and 3 at Ambayathode and plots 5 and 6 at Pullupara. In the three plots at Ambayathode the average leaf formation was less than one. The average leaf fall was one in 4 plots; plots 2 and 3 at Ambayathode and 5 and 6 at Pullupara.

After 18 months

Table 15. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PA 1	108	2	1	111	7	13	16	0	30.5	221	0	71.5	85
PA 2	87	7	1	95	3	13	18	0	35.8	237	0	52.7	58
PA 3	28	1	1	30	5	17	18	0	27	262	0	48	58
PP 4	26	2	5	33	4	10	13	0	37.5	288.6	0	46	56
PP 5	29	1	4	34	5	12	14	0	193	300.7	0	51	56.2
PP 6	20	2	2	24	4	14	16	0	79.5	301	0	53	56.5

PA- plots at Ambayathode, PP- plots at Pullupara, S - seedlings, J- juveniles, A- adults

The total number of plants in all plots except in 2 plots remained without change in this observation (Table 15). The number decreased in plot 2 and 3. The decrease in number was due to the decrease in number of the seedling. The number of seedlings decreased in plots 2 and 3. In all other plots, the number remained without change. The maximum was noted in plot 1 and the minimum in plot 6.

Among seedlings, in two plots (plots 1 and 3) the average number of leaves increased. In all other plots, it remained without change. The number varied from 3 to 7. For juveniles, the average number decreased in two plots (plots 2 and 5). In plot 1, the average number increased. In all other plots, the number remained without change. The maximum was 17 (plot 3) and the minimum was 10 (plot 4). In adults, it increased in plot 2 and 3. In other plots, it remained without change. For juveniles the maximum was 17 and for adults, 18. The minimum were 10 and 13 respectively.

The average height of juveniles increased in 3 plots (plots 2, 3 and 4). In all other plots, the average height did not change. As earlier, the maximum height was in plot 5 (193 cm). For adults, the maximum height was observed at Pullupara (301 cm). The average height increased in plot 1 while it remained without change in other plots.

The average girth for juveniles and adults remained without change in all plots. The average girth for juveniles and adults were maximum in plot 1(71.5 cm and 85 cm respectively) at Ambayathode and the minimum in plot 4 at Pullupara (46 cm and 56 cm respectively).

The seedlings produced new leaves in all plots. In four plots more seedlings formed new leaves (plots 1, 2, 3 and 6). In plots 4 and 5 the number of seedlings that produced new leaves were decreased. In all the plots the average leaf formation was less than one.

The juveniles produced new leaves in two plots; plot 2 at Ambayathode and 5 at Pullupara. In both these plots the average leaf formation was one. The average leaf fall in plots 1, 2 and 6 was one. Of these the first two were at Ambayathode and the third at Pullupara.

The adults produced new leaves in 5 plots. In all the plots the rate of leaf formation was one. The average leaf fall was one in two plots (4 and 6) both located at Pullupara. In plot 5 it was less than one. The average leaf formation was comparatively high and leaf fall was less.

After 21 months

The total number of plants in all plots except plot 1 remained without change (Table 16). In plot 1 the number increased. The maximum number of plants was noted in plot 1. The number of seedlings increased in plot 1. In other plots, the number remained without change. The maximum was in plot 1 and the minimum in plot 6. The number of juveniles and adults remained without change. And their number varied from 1 to 7 and1 to 5 respectively.

Table 16. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PA 1	110	2	1	113	3	13	16	0	30.5	221	0	71.5	85
PA 2	87	7	1	95	2	13	18	0	36.8	237	0	52.7	58
PA 3	28	1	1	30	5	19	18	0	27	216	0	48	58
PP 4	26	2	5	33	4	11	13	0	37.5	290	0	46	56
PP 5	29	1	4	34	5	12	14	0	197	300.7	0	51	56.2
PP 6	20	2	2	24	4	15	16	0	79.5	303	0	53	56.5

PA- plots at Ambayathode, PP- plots at Pullupara, S - seedlings, J- juveniles, A- adults

The average number of leaves in seedlings decreased in plot 1 and 2 at Ambayathode. In other plots, the number remained without change. The maximum was 5 (plots 3 and 5) and the minimum 2 (plot 2). In juveniles, the number of average leaves increased in 3 plots (plots 3, 4 and 6). In other plots the number remained without change. The maximum in juveniles was in plot 3 (19) which were the highest. In adults, the maximum was in plots 3 and 4 (18 each). In other plots it remained without change.

The average height of juveniles increased in two plots (plots 2 and 5). In other plots it remained without change. The maximum was in plot 5 (197 cm) and the minimum in plot 3 (27 cm). The average height of the adult also increased in two plots (plots 4 and 6). In other plots, it remained without change. The adult plants with more height were recorded at Pullupara.

In all the plots, the average girth of juveniles and adults remained without change. The maximum of these were in plot 1 at Ambayathode and the minimum in plot 4 at Pullupara.

Seedlings produced new leaves in all plots. The leaf formation in seedlings was less. In plot 1, 25 new leaves formed and 20 in plot 2. In all other plots the average leaf formation was less than one.

The juveniles produced new leaves only in plots 4 and 6 located at Pullupara. In both these plots the average leaf formation was one. In plot 3 at Ambayathode the rate of leaf fall was one. And in plots 4 it was less than one.The adults produced new leaves in 4 plots of which plot 2 and 3 were at Ambayathode and plots 4 and 5 were at Pullupara. In al the plots the average leaf formation was one. In plot 5 it was same.

After 24 months

The total number of plants in all plots except 2 remained without change (Table 17). In plot 2 the total number of plants decreased. The number of seedlings also decreased. In all plots the number of juveniles and adults remained without change.

Table 17. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PA 1	110	2	1	113	3	13	16	0	31.5	221	0	71.5	85
PA 2	86	7	1	94	3	13	18	0	36.8	240	0	52.7	58
PA 3	28	1	1	30	5	18	18	0	27	262	0	48	58
PP 4	26	2	5	33	5	11	13	0	37.5	291.6	0	46	56
PP 5	29	1	4	34	5	13	14	0	197	301.7	0	51	56.2
PP 6	20	2	2	24	4	14	15	0	80.5	303	0	53	56.5

PA- plots at Ambayathode, PP- plots at Pullupara, S - seedlings, J- juveniles, A- adults

The average number of leaves increased among seedlings in plots 2 and 4. In other plots, it remained without change. In juveniles the average number decreased in plot 3 and 6. In plot 5, it increased. In other plots, it remained without change. With a decrease in number in plot 3, the maximum of average number among juveniles became equal to that of adults. The average number of leaves decreased in adults in plot 6. In other plots it remained without change.

The average height of juveniles increased in plot 1 and 6. In other plots, it remained without change. For adults, the average height increased in plots 2, 4 and 5. In other plots, it remained without change.

The average girth of juveniles and adults in all plots remained without change. The maximum and minimum of both were in plots 1 and 4 respectively.

Seedlings produced new leaves in all plots. The rate of leaf formation was less. Maximum was in plot 1 (25). In all plots the average leaf fall was less than one.

The juveniles produced new leaves in all plots except in one. In plot one more juvenile produced new leaves. The average leaf formation in plot 2 was less than one. In other plots it was one. Rate of leaf formation was more in plots at Pullupara. The leaf fall was noticed in 4 plots. In 3 plots at Ambayathode the rate of leaf fall was one.

The adults produced new leaves in the plots at Pullupara. At Ambayathode adults had no leaf formation. In all the plots the rate of leaf formation was one. The leaf fall was noticed in plots 4 and 6 at Pullupara. The rate of leaf fall was one in these plots.

After 27 months

In all plots, the total number of plants remained without change (Table 18). The maximum was in plot 1 (113). The number of seedlings had no change in any plot, with a maximum in plot 1 (110). The juveniles and adults also had no change in number.

The average number of leaves in seedlings also remained without change. In juveniles in plot 3, it increased and exceeded the adults. The minimum of juveniles was 11 (plot 4). In adults, the average number increased in plot 6. In other plots, it remained without change. The maximum in adults was 18 (plots 2 and 3).

Table 18. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PA 1	110	2	1	113	3	13	16	0	31.5	221	0	71.5	85
PA 2	86	7	1	94	3	13	18	0	38.1	240	0	52.7	58
PA 3	28	1	1	30	5	19	18	0	27	264	0	48	58
PP 4	26	2	5	33	5	11	13	0	39	292	0	46	56
PP 5	29	1	4	34	5	13	14	0	197	302.7	0	51	56.2
PP 6	20	2	2	24	4	14	16	0	81.5	303	0	53.	56.5

PA- plots at Ambayathode, PP- plots at Pullupara, S - seedlings, J- juveniles, A- adults

The average height of juveniles increased in plots 2, 4 and 6. In other plots it remained without change. For adults, it increased in plot 3, 4 and 5. In other plots it remained without change. The average girth of juveniles and adults remained without change in all plots.

Seedlings produced new leaves in all the plots. The average leaf formation was less than one. The total number of seedling with new leaves increased. Ordinally it was 27, 21, 5, 1, 6 and 4. The average leaf fall was also less than one.

The juveniles produced new leaves only in two plots; one at Ambayathode (29) and one at Pullupara (4). In plot 4 the average leaf formation rate was one. While in the other it was less than one.

The leaf formation in the adults was noticed only in plot 4 at Pullupara. The rate of leaf formation was less than one.

After 30 months

The total number of plants in the first five plots increased (Table 19). In plot 1, total number of plants was 115, which was the highest of all observations. In the last plot, it remained without change. The number of seedlings in the first five plots also increased. In the last plot it remained without change. In all plots, the number of juveniles and adults remained the same.

Table 19. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PA 1	112	2	1	115	3	13	16	0	31.5	221	0	71.5	85
PA 2	87	7	1	65	3	13	19	0	36.1	240	0	52.7	58
PA 3	30	1	1	32	5	17	19	0	27	264	0	48	58
PP 4	28	2	5	35	5	11	13	0	39	292	0	46	56
PP 5	31	1	4	36	5	11	13	0	197	302.2	0	57	56.2
PP 6	20	2	2	24	4	14	16	0	81.5	303	0	53	56.5

PA- plots at Ambayathode, PP- plots at Pullupara, S - seedlings, J- juveniles, A- adults

Among seedlings the average number of leaves had no change. In juveniles it decreased in plot 3 and 5. In other plots, no change occurred. In juveniles, the maximum was 17. In adults, it increased in plot 2 and 3. In plot 5 it decreased. The maximum was in plot 2 and 3 (19 each).

In all plots, the average height of juveniles and adults remained without change. The maximum in juveniles was 197 cm (plot 5) and in adults 303 cm (plot 6). The average girth of juveniles and adults also remained without change.

In all plots new leaves formed in seedlings. The number of seedlings formed new leaves was 29, 22, 9, 5, 5 and 2 respectively. In all plots the average leaf formation was less than one. The plots 1 and 2 comparatively produced more leaves.

The juveniles produced new leaves in three plots, plots 1 and 2 at Ambayathode and plot 4 at Pullupara. In the plots the average leaf formation was one. The leaf fall was noticed in 4 plots. Of the three plots at Ambayathode, one had an average leaf fall of two (plot 3), one had one (plot 1) and another had less than one (plot 2). In plot 4 at Pullupara, it was one.

Adults produced new leaves in all plots. The average leaf formation except in plot 4 was one. In plot 4 it was less than one. The average leaf fall in plot 1 and 5 were one and in plot 4 it was less than one. The adults showed high rate of leaf formation.

After 33 months

The total number of plants increased in 4 plots (plots 1, 2, 3 and 5) (Table 20). The maximum was in plot 1(113). The number of seedlings decreased in 4 plots. In plots 4 and 6, the total number and the number of seedlings remained unchanged. The number of juvenile decreased in plot 2. In other plots, no change in number was observed. Among adults, the number remained unchanged for all.

Table 20. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PA 1	110	2	1	113	3	13	17	0	24	223	0	71.5	85
PA 2	86	6	1	93	3	13	19	0	42.3	243	0	52.7	58
PA 3	29	1	1	31	5	17	19	0	17	264	0	48	58
PP 4	28	2	5	35	5	11	13	0	39	292.6	0	46	56
PP 5	27	1	4	34	5	11	13	0	197	302.7	0	51	56.2
PP 6	20	2	2	24	4	15	16	0	81.5	303	0	53	56

PA- plots at Ambayathode, PP- plots at Pullupara, S - seedlings, J- juveniles, A- adults

For seedlings, the average number of leaves remained without change in all the plots. It decreased in plot 6 among juveniles. In other plots it was same. The maximum was 17 (plot 3). For adults, the number increased in plot 1 and for other plots, there was no change. The maximum was 19 in plots 2 and 3.

The average height of juveniles increased in plots 1 and 2. It had no change in other plots. For adults, it increased in plots 1 and 2. Other plots had no changes. The adults with maximum height were noted at Pullupara. There was no change in the average girth of juveniles and adults. The maximum was in plot 1 and minimum in plot 4.

Seedlings produced new leaves in all the plots. The number of seedlings produced new leaves was 41, 27, 6, 3, 3 and 3 respectively. The number of leaves formed was more in plot 3, 4 and 5. In all plots the average leaf formation was less than one. The average leaf fall in plot 5 was one. In other plots it was less than one.

The juveniles produced new leaves in 2 plots. In plot 2 at Ambayathode the average leaf formation was one. The average leaf formation was one in the plot 6 at Pullupara also. The total number of plots that produced new leaves for juveniles decreased. The leaf fall decreased and was noticed in three plots. The average leaf fall was 2 in plot 2. In plots 1 and 6 it was one.

In all the plots except in one, adults produced new leaves. It decreased from the previous observation. In plots 2 and 3 at Ambayathode the average leaf formation was one. In the plots at Pullupara it was one in plots 6 and 4 and less than one in 5. The average leaf fall was one in all plots at Ambayathode. At Pullupara it was one in plot 6 and less than one in plot 4. No leaf fall was noticed in plot 5.

***Phoenix loureiri* var. *humilis* S. Barrow**

1st Observation

In the first observation seedlings dominated in all plots (Table 21). The percentage of seedlings in all plots was almost equal (60 – 70%). Adults were the next group (20 – 30%). The juveniles were least in number. When compared to the plots of Vallakadavu, plots at Kuttikanam had more plants per unit area.

The least number of leaves were in seedlings. In the case of leaf number, the adults and juveniles had slight difference. In seedlings, more number of leaves was in Vallakadavu region. The juveniles and adults had more leaves at Kuttikanam.

At Vallakadavu, all the seedlings had an average of 4 leaves and at Kuttikanam, it was 3. In the case of juveniles, it varied from 6-7 at Vallakadavu and 7-12 at Kuttikanam. The maximum average number of leaves in adult were in plot 5 and 6 (15 each) located at Kuttikanam. The lowest number was in plot 2 (8), located at Vallakadavu.

All the seedlings in all the plots were stemless. Among juveniles, the maximum average height was seen in plot 3 at Vallakadavu and plot 5 at Kuttikanam (8.5 cm each). The minimum height was in plot 6 (6.5 cm) at Kuttikanam. The adults had maximum height in plot 5 (71.2 cm) located at Kuttikanam. The minimum height was in plot 3 (26.5 cm) located at Vallakadavu. When compared, among adults, the tallest plants were present in the plots at Kuttikanam.

Table 21. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PV 1	24	6	11	41	4	7	10	0	7.5	41.3	0	44.5	46.3
PV 2	27	6	10	43	4	7	8	0	7	32.1	0	43.5	41.7
PV 3	27	4	10	41	4	6	9	0	8.5	26.5	0	46	37.5
PK 4	34	5	11	50	3	10	14	0	7.2	70.45	0	45.8	61.9
PK 5	33	4	14	51	3	7	15	0	8.5	71.2	0	44.2	66.4
PK 6	22	4	10	36	3	12	15	0	6.5	47	0	41.7	63.5

PV- plots at Vallakadavu, PK- plots at Kuttikanam, S - seedlings, J- juveniles, A- adults

The juveniles had slight variation in average girth in all the plots at two locations. For juveniles, the average girth was maximum in plot 3 (46 cm) and minimum in plot 6 (41.7 cm) located in Vallakadavu and Kuttikanam respectively. The adults showed variation in average girth between the two locations. The maximum was in plot 5 (66.4 cm) located at Kuttikanam and minimum in plot 3 (37.1 cm) at Vallakadavu.

In plots 2 and 3, the juveniles had more average girth than adults. In all other plots, adults had more average girth.

After 3 months

The total number of plants in all plots remained same except in plot 1 (Table 22). In plot 1, the number decreased by one. More number of plants in unit area was noted at Kuttikanam. Seedlings were the major groups in all the plots. The number of seedlings remained same in 5 plots. In plot1, the number decreased by one. The maximum number of seedlings was in plot 4 (34). The minimum number was in plot 6 (22). The number of juveniles in all the plots remained same. The adults also remained unchanged in number.

Table 22. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PV 1	23	6	11	40	4	7	9	0	7.5	41.3	0	44.5	46.3
PV 2	27	6	10	43	5	7	9	0	7	32.1	0	43.5	41.7
PV 3	27	4	10	41	5	6	9	0	8.5	26.5	0	46	37.1
PK 4	34	5	11	50	3	11	14	0	7.2	70.4	0	45.8	61.9
PK 5	33	4	14	51	3	11	14	0	8.5	71.2	0	44.2	66.4
PK 6	22	4	10	36	3	12	15	0	6.5	47	0	41.7	63.5

PV- plots at Vallakadavu, PK- plots at Kuttikanam, S - seedlings, J- juveniles, A- adults

The maximum number of leaves was in adults and minimum was in seedlings. Among seedlings, more leaves were noted at Vallakadavu. The number of leaves of seedlings increased in plot 2 and 3, while in all other plots it remained the same. The number was maximum in plot 2 and 3 (5 each) and minimum in plots 4, 5 and 6 (3 each).

In juveniles, the number of leaves increased in plot 4. In all other plots it remained the same. The maximum number of leaves was noted in plot 6 (12) and minimum in plot 3 (6). In adults more number of plants was noted at Kuttikanam. The number of leaves increased in plot 2 and 5. The number was maximum in plot 6 (15) and the minimum in plots 1, 2 and 3 (9 each). The average height of the juveniles and adults remained same in all plots. For juveniles, the average height was maximum in plots 3 and 5 (8.5 cm each) and the minimum in plot 2 (7 cm). Among adults, average height was maximum in plot 4 (70.45 cm) and minimum in plot 3 (26.5 cm).

In all the plots, the average girth of juveniles and adults remained the same. In plots 2 and 3, the juveniles had more girth than adults. In juveniles the average girth was maximum in plot 3 (46 cm) and the minimum was in plot 2 (43.5 cm). Among adults, the average girth was maximum in plot 5 (66.4 cm) and minimum in plot 3 (37.1 cm)

In seedlings new leaves formed in all the plots (Table 23). The maximum number of seedlings produced new leaves were noted in plot 2 (16) and 5 (24). In plots 2 and 3, the average leaf formation was 1. In all other plots, the average leaf formation was less than one. In plot 5, the average leaf fall was one, while in all other plots it was less than one. Juveniles and adults also produced new leaves. The average leaf formation for juveniles was one in all plots. The average leaf fall was also one. In adults, the leaf formation was maximum in plot 2. In plot 2, it was two and in all other plots, one. The average leaf fall was two in plot 1. In all other plots it was one.

Table 23. Comparison of leaf characters

Plots.	Seedlings				Juvenile				Adult			
	1	2	3	4	1	2	3	4	1	2	3	4
PV 1	6	6	0	0	3	3	1	1	6	6	1	2
PV 2	16	17	1	0	5	6	1	1	10	15	2	1
PV 3	12	13	0	0	4	4	1	1	8	12	1	1
PK 4	10	10	0	0	4	4	1	1	10	14	1	1
PK 5	14	14	1	1	2	2	1	1	13	19	1	1
PK 6	8	8	0	0	2	2	1	1	8	8	1	1

1. Total no. of plants produced new leaves, 2. Total no. of new leaves 3. Average leaf formation, 4. Average leaf fall

After 6 months

The number of total plants remained same. More plants in unit area were at Kuttikanam. Seedlings dominated in all plots (Table 24).

Number of seedlings was maximum in plot 4 (34) and minimum in 6 (22). The number of adults was maximum in plots 2, 3 and 6. Number of juveniles ranged between 4 and 6.

Table 24. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PV 1	23	5	11	39	4	9	11	0	7.8	41.3	0	45.5	46.3
PV 2	27	6	10	43	5	9	11	0	7	32.1	0	43.5	41.7
PV 3	27	4	10	41	5	7	11	0	8.5	26.5	0	46	37.1
PK 4	34	5	11	50	4	12	15	0	7.2	70.4	0	45.8	61.9
PK 5	33	4	14	51	4	7	18	0	8.5	71.2	0	44.2	66.4
PK 6	33	4	10	36	4	13	15	0	6.5	47.1	0	41.7	63.5

PV- plots at Vallakadavu, PK- plots at Kuttikanam, S - seedlings, J- juveniles, A- adults

The average number of leaves ranged between 4 and 5 in seedlings. The number increased in plots 4, 5 and 6. It remained same in plots 1, 2 and 3. In juveniles, the number increased in all plots except in plot 5 where it remained the same. The average number of leaves was maximum in plot 6 (13). These numbers exceeded in certain adult plants. The minimum was in plots 3 and 5 (7 each).

At Kuttikanam, the number of leaves was maximum for adults. Among adults, the number was maximum in plot 5 (18). At Vallakadavu, among all plots, the average number was minimum and same (11). In all the plots except 6, the number had increased. In plot 6 it remained same.

In juveniles the average height increased in plot 1 and in all other plots it remained same. The maximum height was in plot 3 and 5 (8.5 cm) and minimum in plot 6 (6.5 cm). Among adults height was maximum at Kuttikanam with a maximum in plot 5 (71.2 cm) and minimum in plot 3 (26.5 cm). In all plots the height remained same except in plot 6 where a slight increase was noticed.

The average girth of juveniles remained without change. It exceeds the girth of adults in plot 2 and 3. The maximum was in plot 3 (45 cm) and the minimum in plot 6 (41.7 cm). The average girth of adults remained unchanged in all plots with a maximum in plot 5 (66.4 cm) and a minimum in plot 2 (41.7 cm).

Among all the plots leaf production was high for all groups (Table 25). Seedlings formed new leaves in all the plots. The average leaf formation was one in all the plots. The average leaf fall was less than one in plots1, 4, 5 and 6. In plots 2 and 3 it was one. In all the plots the juveniles formed new leaves. The average leaf formation was 2 in plots 1, 4 and 5. In other plots it was one. The average leaf falls for the juveniles was 1 in all plots except 2 where it was less than one. The adults formed new leaves in a very high rate. It was 3 in all plots except plot

3 where it was 2. The average leaf fall was 3 in plot 6, 2 in plots 4 and 5, one in plots 1 and 2 and less than one in plot 3.

Table 25. Comparison of leaf characters

Plots	Seedlings				Juvenile				Adult			
	1	2	3	4	1	2	3	4	1	2	3	4
PV 1	12	21	1	0	5	8	2	1	11	33	3	1
PV 2	19	24	1	1	5	8	1	0	10	25	3	1
PV 3	21	28	1	1	4	4	1	1	10	19	2	0
PK 4	16	24	1	0	5	9	2	1	11	31	3	2
PK 5	27	30	1	0	3	6	2	1	14	47	3	2
PK 6	15	17	1	0	4	5	1	1	10	29	3	3

1. Total no. of plants produced new leaves, 2. Total no. of new leaves 3. Average leaf formation, 4. Average leaf fall

After 9 months

The total number of plants increased in all plots except in plot 6 where the number decreased (Table 26). The change in number was due to the change in number of the seedlings. In all plots except plot 6 the number of seedlings increased. The rate of recruitment of seedlings was maximum in plot 2 (18.9) and minimum in plot 5 (5.5). The number of seedlings was maximum in plot 4 (39) and minimum in plot 6 (21) in which there was a decrease in number. In all plots the average number of juveniles and adults remained the same.

Table 26. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PV 1	28	5	11	44	4	9	12	0	7.8	41.3	0	45.4	46.3
PV 2	37	6	10	53	4	7	10	0	7	32.1	0	43.5	41.7
PV 3	32	4	10	46	5	7	11	0	8.5	26.5	0	46	37.1
PK 4	39	5	11	55	4	12	16	0	7.2	70.4	0	45.8	61.9
PK 5	37	4	14	55	4	7	19	0	8.5	71.2	0	44.2	66.4
PK 6	21	4	10	35	4	13	18	0	6.5	47.3	0	41.7	63.5

PV- plots at Vallakadavu, PK- plots at Kuttikanam, S - seedlings, J- juveniles, A- adults

In all the plots the number of average leaf was maximum in adults and the minimum in seedlings. In all the plots except in plot 3 the seedlings had an average of 4 leaves. In all plots except plots 2 the average number remained same. In plot 2 it decreased. In juveniles also a similar condition was noticed. The maximum number for juveniles was noted in plot 6 (13) and the minimum in plots 2, 3 and 5 (7 each). In plots 1, 4, 5 and 6 the adults increased their average leaf number. In plot 3 it remained the same and in plot 2 it decreased. The maximum was in plot 5 (19) and the minimum was plot 2 (10).

Among juveniles the average height was maximum in plots 3 and 5 (8.5 cm each) and minimum in plot 6 (6.5cm). In all the plots it remained the same. For adults average height was maximum in plot 5 (71.2 cm) and minimum in plot 2 (32.1 cm). The average height for the adults was maximum at Kuttikanam. The average height remained same in all plots except 6 where it increased.

The average girth of juveniles remained same in all plots. The average girth of juveniles was more than that of adults in plot 2 and 3 the maximum was in plot 4 (45.8 cm) and the minimum in plot 6(41.7 cm). The adults had the same girth in all plots as in the previous observation. The average girth was maximum in plot 5 (66.4 cm) and minimum in plot 3 (37.1 cm).

The seedlings had new leaves in all plots (Table 27). The average leaf formation for the seedlings in all plots was one. The average leaf fall for 4 plots (1, 2, 5 and 6) was one. In plots 3 and 4 it was less than one. In all plots except 5 the leaf formation for juveniles was one. In plot 5 it was 2. The average leaf fall was one in all plots. The adult had a high rate of leaf formation. It was 3 in plots 4, 5 and 6. In the first three plots it was 2. The average leaf fall was also in a high rate. In plot 1, 2 and 5 it was 2. In plots 3, 4 and 6 it was one.

Table 27. Comparison of leaf characters

Plots	Seedlings				Juvenile				Adult			
	1	2	3	4	1	2	3	4	1	2	3	4
PV 1	23	25	1	1	4	6	1	1	10	25	2	2
PV 2	34	39	1	1	4	6	1	1	8	21	2	2
PV 3	21	22	1	0	4	4	1	1	9	18	2	1
PK 4	29	39	1	0	4	5	1	1	10	27	3	1
PK 5	30	37	1	1	4	8	2	1	14	42	3	2
PK 6	13	18	1	1	3	5	1	1	10	33	3	1

1. Total no. of plants produced new leaves, 2. Total no. of new leaves 3. Average leaf formation, 4. Average leaf fall

After 12 months

The total number of plants in all the plots remained the same (Table 28). The number of seedlings remained without change. The maximum number of seedlings was in plot 4 (39) and the minimum in plot 6 (21). The number of juveniles also remained unchanged. The number varied between 4 and 6 with 6 in plot 2 and 4 in plots 5 and 6. The number of juveniles also remained unchanged. Maximum was in plot 5 (14) and minimum in plots 2, 3 and 6 (10 each).

Table 28. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PV 1	28	5	11	44	4	9	10	0	7.8	41.6	0	45.4	46.3
PV 2	37	6	10	53	4	9	10	0	7	32.4	0	43.5	41.7
PV 3	32	4	10	46	4	6	10	0	8.5	26.5	0	46	37.5
PK 4	39	5	11	55	3	11	15	0	7.2	70.7	0	45.8	61.9
PK 5	37	4	14	55	4	8	18	0	8.5	71.5	0	44.2	66.4
PK 6	21	4	10	35	4	12	16	0	6.5	47.6	0	41.7	63.6

PV- plots at Vallakadavu, PK- plots at Kuttikanam, S - seedlings, J- juveniles, A- adults

Among seedlings in all the plots except 4 the average number of leaves was 4. In plot 4 it was 3. In plots 1, 2, 5 and 6 their number remained without change. In plots 3 and 4 it decreased. The average number of leaves in juveniles was maximum in plot 6 (12) and minimum in plot 5 (8). The average number of leaves increased in plots 2 and 5. It decreased in plots 3, 4 and 6. In plot 1 it remained unchanged. In adults the maximum number was in plot 5 (18) and minimum in plots 1, 2 and 3 (10 each). Except in plot 2, in all plots, the average number of leaf decreased in adults. In plot 2 it remained unchanged.

The average height of juveniles remained unchanged. The maximum height of 8.5cm was noted in plots 3 and 5. The minimum height was in plot 6 (6.5 cm). The maximum height of adults was noted in plots 5 (71.5 cm) and the minimum in plot 3 (26.5 cm). The average height of adults increased in all plots except 3 where it remained unchanged.

The average girth of juvenile was more than adults in plots 2 and 3. The average girth of juveniles was maximum in plot 3 (46 cm) and minimum in plot 6 (41.7 cm). In all the plots the average girth of juveniles remained unchanged. The adults also performed the same. The maximum was noted in plots 5 (66.4 cm) and minimum in plot 3 (37.1 cm).

Among seedlings, new leaves formed in all the plots but, the rate of leaf formation was very less (Table 29). In all the plots the rate was less than one. In 4 plots (2, 4, 5 and 6) the average leaf fall was one. In the other two plots it was less than one. In all the plots except plot 6, the juveniles had an average leaf formation of less than one. In plot 6 it was one. The average leaf fall was high in all plots for juveniles. In all plots except 5 it was one and in 5 it was two. The average leaf formation in adults was in a low rate. It was one in five plots and in plot 3 it was less than one. The average leaf fall was high with two in all plots except 1 where it was three.

Table 29. Comparison of leaf characters

Plots	Seedlings				Juvenile				Adult			
	1	2	3	4	1	2	3	4	1	2	3	4
PV 1	5	5	0	0	1	1	0	1	1	1	1	3
PV 2	8	8	0	1	2	2	0	1	3	5	3	2
PV 3	6	6	0	0	0	0	0	1	1	3	0	2
PK 4	3	3	0	1	1	1	0	1	5	6	1	2
PK 5	3	5	0	1	0	0	0	2	10	14	1	2
PK 6	3	3	0	1	2	2	1	1	6	6	1	2

1. Total no. of plants produced new leaves, 2. Total no. of new leaves 3. Average leaf formation, 4. Average leaf fall

After 15 months

The total number of plants in the plots remained unchanged (Table 30). The maximum number of plants was noted in plot 6 (35). The number of seedlings in the plots also remained unchanged with a maximum in plot 4 (39) and minimum in plot 6 (21). The number of juveniles also remained unchanged and the number varied from 4 to 6. Number of adults remained same with a maximum in plot 5 (14) and minimum in plots 2, 3 and 6 (10 each).

The average number of leaves in seedlings was 4 in all plots except 3 where it was 5. The number of leaves increased in plots 3 and 4. In all other plots it remained unchanged. The average number of leaves decreased in plots 1 and 2, it increased in plots 3 and 6 and remained unchanged in other two plots. In adults the number increased in plots 3, 4 and 6 while in all other plots it remained unchanged.

Table 30. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PV 1	28	5	11	44	4	8	10	0	7.8	41.6	0	45.4	46.3
PV 2	37	6	10	53	4	7	10	0	7.1	32.6	0	43.5	41.7
PV 3	32	4	10	46	5	7	11	0	8.5	26.5	0	46	37.1
PK 4	39	5	11	55	4	11	16	0	7.2	707	0	45.8	61.9
PK 5	37	4	14	55	4	8	18	0	8.5	71.5	0	44.2	66.4
PK 6	21	4	10	35	4	13	17	0	6.5	47.8	0	41.7	63.6

PV- plots at Vallakadavu, PK- plots at Kuttikanam, S - seedlings, J- juveniles, A- adults

The average height of juveniles ranged from 6.5 cm (plot 6) to 8.5 cm (plots 3 and 5). In all the plots except 2 the height remained the same. In plot 2 it increased. The height of adults increased in plots 2 and 6. In all other plots it remained with out change. The maximum height was noted in plot 5 (71.5 cm) and minimum in plot 3 (26.5 cm).

The average girth of juveniles remained with out change. The maximum was noted in plot 3 (46 cm) and minimum in plot 6 (41.7cm). The average girth of adults also remained unchanged. The maximum girth was observed at Kuttikanam with 66.4 cm (plot 5) and minimum of 37.1 cm (plot 3) located at Vallakadavu.

New leaves formed in all the plots for seedlings. But the rate of leaf formation was low (Table 31). It was one in plot 6. In all other plots it was less than one. The average leaf fall was also less than one in all plots except 3. In plot 3 it was one. In all the plots new leaves were formed among juveniles. The rate of leaf formation was one in all plots except 5 where it was 2. The average leaf fall was one in 4 plots (1, 2, 5 and 6). In plots 3 and 4 it was less than one. The rate of leaf formation in adults was 2 in plots 2, 4, 5 and 6 and in the other two plots it was one. The average leaf fall was less than one in plots 1 and 3, one in plots 2, 3 and 6 and 2 in plot 5. The average leaf falls for the adults and juveniles were less when compared with previous observation.

Table 31. Comparison of leaf characters

Plots	Seedlings				Juvenile				Adult			
	1	2	3	4	1	2	3	4	1	2	3	4
PV 1	5	11	0	0	2	3	1	1	7	14	1	0
PV 2	13	16	0	0	3	5	1	1	9	20	2	1
PV 3	13	13	0	1	3	3	1	0	9	13	1	0
PK 4	9	12	0	0	3	3	1	0	11	19	2	1
PK 5	15	17	0	0	4	6	2	1	14	30	2	2
PK 6	10	11	1	0	4	4	1	1	10	17	2	1

1. Total no. of plants produced new leaves, 2. Total no. of new leaves 3. Average leaf formation, 4. Average leaf fall

After 18 months

The number of total plants in all the plots remained with out change (Table 32). The maximum was noted in plot 4 and 5 (55 each) at Kuttikanam. The minimum number was noted also at Kuttikanam in plot 6 (35). There was no change in the number of seedlings. The number of juveniles ranged from 4 to 6. The number of adults ranged from 10 to 14. The number of juveniles and adults remained without change.

Table 32. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PV 1	28	5	11	44	4	9	12	0	7.8	41.9	0	45.4	46.3
PV 2	37	6	10	53	4	8	11	0	7.1	32.8	0	43.5	41.7
PV 3	32	4	10	46	5	8	10	0	8.5	26.5	0	46	37.1
PK 4	39	5	11	55	4	12	17	0	7.2	70.9	0	45.8	61.9
PK 5	37	4	14	55	4	8	14	0	8.5	71.9	0	44.2	66.4
PK 6	21	4	10	35	5	14	18	0	6.5	47.8	0	41.7	63.6

PV- plots at Vallakadavu, PK- plots at Kuttikanam, S - seedlings, J- juveniles, A- adults

In 4 plots the average number of leaves was 4. In plots 3 and 6 it was 5. The average number remained without change in the first five plots. In plot 6 it increased. The average number of leaves for juveniles was maximum in plot 6 (14). The minimum was in plots 2, 3 and 5 (8 each). In 5 plots (1, 2, 3, 4 and 6) the number of leaves increased. In 5^{th} plot it remained with out change. In all the plots except 5 the number of leaves in adults increased. In plot 5 it decreased. The maximum number was in plot 6 (18) and the minimum in plot 2 (11).

The average height of juveniles remained with out change. The height was maximum in plots 3 and 5(8.5 cm). The minimum height (6.5 cm) was noted in plot 6. The average height of adults increased in 4 plots (1, 2, 4 and 5). It remained same in two plots (3 and 6) was maximum (71.9 cm) in plot 5 and minimum (26.5 cm), in plot 3.

The average girth of juveniles and adults remained with out change. In juvenile the girth was maximum in plot 3 (46 cm) and minimum in plot 6 (41.7 cm). For adults it was 66.4 cm (plot 5) and 37.1 cm (plot 3).

The average leaf formation and leaf fall increased among the seedlings (Table 33). The average leaf formation was 1 in all the plots. The average leaf fall was 1 in last 4 plots and less than one in first 2 plots. The average leaf formation in juveniles increased but the average leaf fall decreased. It was one in plots 2, 3 and 4 where as in plots 1, 5 and 6 it was two. The average leaf fall for juvenile was one in plots 1, 3, 4 and 5. In the other two plots it was less than one. The average leaf formation in adults increased. It was maximum (4) in plot 1. In the three plots at Kuttikanam it was three and in two plots at Vallakadavu, it was two. The average leaf fall remained with out much change. It was two in all plots except 2 where it was one.

Table 33. Comparison of leaf characters

Plots	Seedlings				Juvenile				Adult			
	1	2	3	4	1	2	3	4	1	2	3	4
PV 1	17	32	1	0	5	12	2	1	11	42	4	2
PV 2	17	24	1	0	5	7	1	0	10	21	2	1
PV 3	19	28	1	1	4	5	1	1	10	24	2	2
PK 4	24	35	1	1	4	6	1	0	11	29	3	2
PK 5	27	36	1	1	4	7	2	1	14	30	3	2
PK 6	18	21	1	1	4	7	2	1	10	33	3	2

1. Total no. of plants produced new leaves, 2. Total no. of new leaves 3. Average leaf formation, 4. Average leaf fall

After 21 months

The total number of plants in all the plots remained unchanged (Table 34). The maximum of 55 were noted in plots 4 and 5 and the minimum (35) in plot 6. In all the plots the number of seedlings remained with out change. The maximum number (39) was in plot 4 and minimum

(21) in plot 6. The number of juveniles also remained the same and it varied between four and six. The number of adults ranged from 10 to 14. The number remained unchanged in all plots.

Table 34. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PV 1	28	5	11	44	4	10	12	0	7.8	42.1	0	45.6	46.3
PV 2	37	6	10	53	4	9	10	0	7.1	33	0	43.5	41.7
PV 3	32	4	10	46	5	7	10	0	8.5	26.9	0	46	37.1
PK 4	39	5	11	55	4	12	17	0	7.2	71	0	45.8	61.9
PK 5	37	4	14	55	4	8	19	0	8.5	72	0	44.2	66.4
PK 6	21	4	10	35	5	14	19	0	6.5	47.9	0	41.7	63.6

PV- plots at Vallakadavu, PK- plots at Kuttikanam, S - seedlings, J- juveniles, A- adults

Among seedlings the average number of leaves was either four or five in all plots. It remained with out change. For juveniles the average number of leaves increased in first two plots. It decreased in plot 3. In the plots at Kuttikanam it remained unchanged. The average number of leaves was maximum in plot 6 (14) and minimum in plot 3 (7). For adults in the last two plots at Kuttikanam, it increased to a maximum of 19. It decreased in plot 2 at Vallakadavu, to a minimum of 10.

The average height of juveniles ranged from 6.5 cm (plot 6) to 8.5 cm plot (3 and 5). In all the plots the average height remained unchanged.

The average height of adults increased in all the plots. The maximum was in plot 5 (72 cm) and the minimum in plot 3 (26.9 cm).

In all the plots the average girth of the juveniles remained with out change with a maximum in plot 3 (46 cm) and a minimum in plot 6 (41.7 cm). Adults remained unchanged in their girth from the previous observation with a maximum of 66.4 cm (plot 5) and a minimum 41.7 cm (plot 2). In plots 2 and 3 the average girth of adults was lesser than the juveniles.

Among seedlings, new leaves were produced in all the plots (Table 35). The average leaf formation decreased in plot 2 with less than one. In all other plots it remained the same. The average leaf fall for seedlings increased in plot 1 and 2 to one. It decreased in plot 4 to less than one. The average leaf formation in juveniles decreased in plot 6 to one. In all other plots it remained the same. The average leaf fall increased in plot 2 and 4 to one and decreased in plot 5 to two. The average leaf formation for adults decreased in two plots and average leaf fall increased in one plot. The average leaf formation for adults decreased in 3 plots (1, 3 and 4) to two. The average leaf fall increased in plot 2 to two and decreased in plot 3 to one.

Table 35. Comparison of leaf characters

Plots	Seedlings				Juvenile				Adult			
	1	2	3	4	1	2	3	4	1	2	3	4
PV 1	9	15	1	1	5	9	2	1	11	25	2	2
PV 2	15	16	0	1	5	7	1	1	8	15	2	2
PV 3	17	23	1	1	3	3	1	1	9	14	1	1
PK 4	14	23	1	0	4	5	1	1	11	23	2	2
PK 5	23	29	1	1	3	6	2	2	14	37	3	2
PK 6	12	15	1	1	4	5	1	1	10	28	3	2

1. Total no. of plants produced new leaves, 2. Total no. of new leaves 3. Average leaf formation, 4. Average leaf fall

After 24 months

The average number of plants in all plots except 6 increased (Table 36). The rate of increase was maximum in plot 2 (10.2) and minimum in plot 5 (5.2). The increase in number was due to the recruitment. The seedlings increased their number in 5 plots. In plot 6 it remained the same. In juveniles and adults their number remained unchanged.

Table 36. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PV 1	31	5	11	47	4	8	10	0	7.8	42.4	0	45.4	46.4
PV 2	43	6	10	59	4	8	10	0	7.1	33	0	43.5	43.7
PV 3	35	4	10	49	5	7	12	0	8.5	26.9	0	46	37.1
PK 4	41	5	11	57	4	11	15	0	7.2	71.1	0	45.8	61.9
PK 5	40	40	14	58	4	7	18	0	8.5	66.4	0	44.2	66.4
PK 6	21	4	10	35	4	13	17	0	6.5	48.1	0	41.7	63.6

PV- plots at Vallakadavu, PK- plots at Kuttikanam, S - seedlings, J- juveniles, A- adults

Among seedlings the average number of leaves remained the same in 5 plots. It decreased in plot 6. For the juveniles it decreased in 5 plots and in plot 3 it remained the same.

The maximum was in plot 6 (13) and minimum in 5 (7). The average number of adults decreased in 4 plots. In plot 2 and 3 it remained the same and the maximum was in plot 5 (18).

The average height of the juveniles remained unchanged. In three plots it had a maximum of 8.5 cm. The average height of adults increased in three plots. In plots 2, 3 and 5 it remained with out change. The maximum height 72 cm was in plot 5.

In all the plots the average girth of juveniles and adults remained with out change. In plot 2 and 3 the average girth of juveniles was more than the adults.

The average leaf formation and leaf fall decreased in most of the plots (Table 37). The average leaf formation for seedlings decreased in all plots. It was less than one in all plots. The average leaf fall decreased in the first three plots. It increased in plot 4 and remained same in plots 5 and 6. The juveniles produced the leaves only in plots 3, 5 and 6. The average leaf fall decreased in all plots except in 6 where it remained same. The leaf fall decreased in plot 5 and in all other plots it was same. In all the plots the adults formed new leaves. The average leaf fall decreased in all the plots. In three plots (1, 3 and 6) it was less than one. The average leaf fall of adults remained same in 5 plots. It increased in plot 6. The leaf fall rate of juveniles and adults were higher than leaf formation.

Table 37. Comparison of leaf characters

Plots	Seedlings				Juvenile				Adult			
	1	2	3	4	1	2	3	4	1	2	3	4
PV 1	6	6	0	0	0	0	0	1	3	3	0	2
PV 2	16	16	0	0	2	2	0	1	3	7	1	2
PV 3	9	9	0	0	0	0	0	1	3	3	0	1
PK 4	13	14	0	1	0	0	0	1	6	7	1	2
PK 5	13	14	0	1	1	1	0	1	11	14	1	2
PK 6	7	7	0	1	1	2	1	1	4	4	0	3

1. Total no. of plants produced new leaves, 2. Total no. of new leaves 3. Average leaf formation, 4. Average leaf fall

After 27 months

The total number of plants decreased in many of the plots (Table 38). The decrease in total number of plants was due to the decrease in number of seedlings. The maximum number of seedling was noted in plot 2 (41) and the minimum in plot 6 (20). The number of juveniles and adults remained with out change in all plots. The number of juveniles ranged from 4 to 6 and of adults ranged from 10 to 14.

Table 38. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PV 1	30	5	11	46	4	8	10	0	8	42.6	0	45.4	46.4
PV 2	41	6	10	57	4	8	10	0	7.1	33.3	0	43.5	41.7
PV 3	34	4	10	48	5	7	12	0	8.5	27	0	46	37.1
PK 4	40	5	11	56	4	11	16	0	7.2	71.5	0	45.8	61.9
PK 5	39	4	14	57	4	7	18	0	6.5	48.4	0	44.2	66.4
PK 6	20	4	10	34	5	14	18	0	6.5	48.4	0	41.7	63.6

PV- plots at Vallakadavu, PK- plots at Kuttikanam, S - seedlings, J- juveniles, A- adults

The average number of leaves was minimum among the seedlings. The number ranged between 4 and 5. In juveniles the average number of leaves ranged from 7 to 14. The maximum number (14) was noted in plot 6 at Kuttikanam. The minimum number (7) was noted in plot 3 at Vallakadavu and plot 5 at Kuttikanam. Among adults maximum was at plot 5 and 6 at Kuttikanam and minimum in plots 1 and 2 at Vallakadavu.

The average height of juvenile was maximum in plots 3 and 5 (8.5 cm) and minimum in plot 6 (6.5 cm). For adults it was 72.3 cm (plot 5) and 27 cm (plot 3)

In two plots the average girth of juveniles exceeded the adults. The maximum was noted in plot 3 (46 cm) and minimum in plot 6 (41.7). The maximum for adults was noted in plot 5 (66.4 cm) and minimum in plot 3 (37.1 cm).

Among seedlings new leaves formed in all the plots (Table 39). In all the plots the rate of leaf formation was one. The rate of leaf fall was below one in first four plots and one in last two plots. The leaf formation rate was law in juveniles. It was less than one in plots 1 and 4 and one in all other plots. The rate of leaf fall was one in all plots except plot 4 where it was less than one. The average leaf formation for adults was two in all plots except 1 where it was one and the average leaf fall in all plots was one.

Table 39. Comparison of leaf characters

Plots	Seedlings				Juvenile				Adult			
	1	2	3	4	1	2	3	4	1	2	3	4
PV 1	11	14	1	0	0	0	0	1	5	7	1	1
PV 2	26	27	1	0	3	3	1	1	8	15	2	1
PV 3	22	23	1	0	2	2	1	1	9	15	2	1
PK 4	18	20	1	0	1	1	0	0	11	22	2	1
PK 5	27	29	1	1	3	4	1	1	14	23	2	1
PK 6	12	15	1	1	4	4	1	1	10	18	2	1

1. Total no. of plants produced new leaves, 2. Total no. of new leaves 3. Average leaf formation, 4. Average leaf fall

After 30 months

The total number of plants decreased in 4 plots (1, 2, 3 and 5). The maximum number 56 was noted in plot 4 and the minimum 34 in plot 6, both located at Kuttikanam (Table 40). The number of seedlings in the plots 1, 2, 3 and 5 decreased. Maximum number was 40 in plot 4 and minimum number 20 in plot 6. The juveniles and seedlings remained without any change in number. The number of juveniles ranged from 4 to 6. The maximum number of adults were in plot 5 (14) and the minimum in plots 2, 3 and 6 (10 each).

Table 40. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PV 1	28	5	11	44	4	9	12	0	8	42.7	0	45.4	46.4
PV 2	37	6	10	53	5	9	11	0	7.1	33.5	0	43.5	41.7
PV 3	32	4	10	46	6	7	12	0	8.5	27.1	0	46	37.1
PK 4	40	5	11	56	5	14	17	0	7.2	71.7	0	45.8	61.9
PK 5	37	4	14	55	4	8	19	0	8.5	72.6	0	44.2	66.4
PK 6	20	4	10	34	5	7	19	0	6.5	48.5	0	41.7	63.6

PV- plots at Vallakadavu, PK- plots at Kuttikanam, S - seedlings, J- juveniles, A- adults

The average number of leaves increased in three plots among the seedlings (plots 2, 3 and 4). In the other plots the number remained without change. The maximum number was in plot 3 (6). In juveniles it increased in 4 plots. In plot 3 it remained with out change. In plot 6 it decreased. The maximum was in plot 4 (14). Among adults, it increased in all the plots except 3. In plot 3 it remained the same. The average number of leaves was maximum in plots 5 and 6 (19) at Kuttikanam.

The average height of juveniles remained with out change in all the plots. The maximum height 8.5 cm were noted in plots 3 and 5 and the minimum in plot 6 (6.5 cm). In all the plots the average height of the adults increased. The maximum height for the adult was in plot 5 (72.6 cm).

The average girth of the juveniles and adults remained with out change. In plot 2 and 3 the juveniles exceeded the adults. The maximum in adults was in plot 5 and in juveniles in plot 3. The minimum was in plot 3 for adults and plot 6 for juveniles.

Table 41. Comparison of leaf characters

Plots	Seedlings				Juvenile				Adult			
	1	2	3	4	1	2	3	4	1	2	3	4
PV 1	11	25	1	1	5	11	2	1	11	39	4	2
PV 2	18	24	1	0	5	8	1	0	9	22	2	2
PV 3	22	26	1	0	3	4	1	0	10	23	2	2
PK 4	16	25	1	0	5	7	1	0	11	28	3	2
PK 5	23	26	1	0	4	6	2	0	14	45	3	2
PK 6	14	19	1	0	4	6	2	1	10	28	3	2

1. Total no. of plants produced new leaves, 2. Total no. of new leaves 3. Average leaf formation, 4. Average leaf fall

Among seedlings new leaves formed in all the plots (Table 41). The average leaf formation was same as that of the previous observation with an average of one. The average leaf fall increased in first plot and decreased in last two plots. In all other plots it remained the same. In all the plots except one, the average leaf fall was less than one and in the first plot, one. The average leaf formation for the juveniles increased in four plots (1, 4, 5 and 6) and remained same in plots 2 and 3. The average leaf fall for the juveniles decreased in three plots (2, 3 and 5) in all other plots it remained the same. In all the plots adults formed new leaves. The average leaf formation for adults increased in 4 plots (1, 4, 5 and 6) and remained the same in plots 2 and 3. The average leaf fall of adults increased in all plots with an average of 2.

After 33 months

The total number of plants decreased in plots 1 and 4 and the rest remained same (Table 42). The maximum number was 55 and the minimum was 34. The number of seedlings decreased in two plots (1 and 4). In all other plots, it remained the same. The number of juveniles and adults remained without change in all plots. The number of juveniles ranged from 4 to 5 and the adults from 9 to 14.

Table 42. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PV 1	27	5	11	43	5	9	12	0	8.2	42.8	0	45.4	46.4
PV 2	37	5	9	51	5	9	11	0	7.6	34.8	0	43.8	44.5
PV 3	32	4	10	46	6	9	12	0	8.5	27.3	0	46	37.1
PK 4	38	4	11	53	5	14	17	0	7.7	71.8	0	46	61.9
PK 5	37	4	14	55	5	9	20	0	8.5	72.9	0	44.2	66.4
PK 6	20	4	10	34	6	15	22	0	6.5	48.5	0	41.7	63.7

PV- plots at Vallakadavu, PK- plots at Kuttikanam, S - seedlings, J- juveniles, A- adults

The average number of leaves in seedlings increased in the plots 1, 5 and 6. It remained same in all other plots. The number of leaves varied between 5 and 6. In juveniles it increased in plots 3, 5 and 6. In all other plots it remained the same. The maximum 15 was noted in plot 6. The number of leaves in adults increased in plots 5 and 6. In all other plots, it remained same. The maximum number was in plot 6 (22) and the minimum in plot 2 (11).

The average height of juveniles increased in 3 plots (1, 2 and 4). In the other three plots, it remained without change. The maximum height 8.5 cm was in two plots 3 and 5. The average height of adults increased in 5 plots. In plot 6 it remained without change. The maximum height 72.9 cm was at Kuttikanam and the minimum height 27.3 cm at Vallakadavu.

The average girth of juveniles and adults remained without change in this observation. In two plots, the girth of juveniles exceeded the adults.

In all plots, new leaves were formed in seedlings (Table 43). The average leaf formation was one in all the plots. It was same as in the previous observation. The average leaf fall in seedlings increased in the last 4 plots. In 5 plots it was one and in 1 it was less than one. In two plots the average leaf formation of juveniles decreased (1 and 6). In all other plots it remained the same. The average leaf fall increased in 4 plots. It remained same in plots 1 and 6.The average leaf formation among the adults decreased in 3 plots. In plots 2, 5 and 6 it remained the same. The average leaf fall in plots 1 and 2 increased. It decreased in plots 3 and 6. In plots 4 and 5 it remained the same.

Table 43. Comparison of leaf characters

Plots	Seedlings				Juvenile				Adult			
	1	2	3	4	1	2	3	4	1	2	3	4
PV 1	21	26	1	1	4	5	1	1	11	31	3	3
PV 2	19	21	1	0	4	4	1	2	8	20	2	3
PV 3	23	27	1	1	4	4	1	1	9	14	1	1
PK 4	32	37	1	1	4	5	1	1	11	25	2	2
PK 5	31	34	1	1	4	7	2	1	14	37	3	2
PK 6	20	24	1	1	4	5	1	1	10	26	3	1

1. Total no. of plants produced new leaves, 2. Total no. of new leaves 3. Average leaf formation, 4. Average leaf fall

Pinanga dicksonii **(Roxb.) Bl.**

1st Observation

In the first observation even though the number of plants in each plot showed variation, the juveniles represented the maximum (Table 44). In the plots located at the Rosemala region, the numbers of seedlings exceeded the numbers of adults while in plots located at Nadukani, the numbers of adults exceeded that of seedlings.

In all the six plots seedlings had lowest number of leaves and adults had the highest. Average number of leaves was more in Rosemala region when compared to Nadukani. Among the seedlings plot 6 had the minimum height of 8.5 cm and plot 2 had a maximum of 17 cm. The average height of seedlings and juveniles was more in the Rosemala region. The average height of juveniles was more in the plot 3 (182 cm) located in Rosemala region, where as the lowest height was in plot 5 (154.9 cm) located in Nadukani. At the same time, second highest of juvenile was in plot 4 (175.6 cm), located in Nadukani region. The juveniles in two regions had more or less same height. In the case of adults, the maximum height was in plot 4 (476 cm) located in Nadukani. Adults having more height were seen in Nadukani region. The lowest height in adults was noted in plot 1 (348.3 cm), located in Rosemala region. The variation in height among the plots was maximum in adult plants.

Table 44. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PR 1	9	21	6	31	2	5	5	12.2	172.6	348.3	1.7	6.2	7
PR 2	27	46	9	82	4	5	6	17	160	394.4	3.4	7.8	8.1
PR 3	18	56	18	92	3	4	5	9.6	182	373.1	2.3	6.9	7.9
PN 4	14	30	24	68	2	4	5	9	175.6	476	2.1	6.6	12
PN 5	8	22	11	41	2	3	5	11.4	154.9	393.7	2.8	6.4	9.5
PN 6	8	19	8	35	2	3	5	8.5	158.8	439.3	2.6	7.3	9.8

PR- plots at Rosemala, PN- plots at Nadukani, S - seedlings, J- juveniles, A- adults

The minimum and maximum girth for the seedlings as well as juveniles was seen in plots at Rosemala (plots 1 and 2). In Nadukani region, juveniles were with more or less equal girth. But in the case of the adults, the maximum girth was noted in the plot 4 (12 cm.) at Nadukani.

After 3 months

After 3 months, the number of juveniles was the major group among all the plots, followed by seedlings in 4 plots (Table 45). In two plots at Nadukani, the numbers of adults exceeded the seedlings. In plots 1, 3, 4 and 5 there was a decrease in number of the total plants from the first observation. The decrease in number was seen in all the three groups. In plot 5 at Rosemala there was an increase in number of seedlings. The maximum decrease in number was noted for juveniles. In plot 4, there was a decrease of eight juvenile plants. In the first three plots and in plot 6, the number of adults increased.

As in the case of the first observation, the maximum number of leaves was present in the adult plants and the minimum was in seedlings. The number of leaves in each group also showed a decrease in number in all the three groups.

Seedlings showed an increase in average height from the previous observation. Here the maximum height of seedling is seen in plot 5 (19 cm) while the minimum height is seen in plot

4 (10.4 cm). Even though the maximum height of seedling is seen in plot 5 other two plots show comparatively less height than Rosemala area. In all the plots, the juvenile plants showed increase in height. The maximum height of seedling was observed in plot 3 (18 cm) and the minimum height in plot 6 (161.2 cm). Both the region showed the average height of juveniles without much variation. There was a decrease in average height in all the plots where there was an increase in number. In plot 5 when there was decrease in plant number, the average height was increased.

Table 45. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants(cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PR 1	8	19	7	34	2	4	5	13.7	175.7	347.1	1.8	6.2	7.1
PR 2	27	44	11	82	4	5	6	18.7	161.5	381.7	3.5	7.8	8
PR 3	18	52	21	91	2	4	4	12.8	184.6	372.5	2.3	7	7.9
PN 4	12	22	24	58	2	3	4	10.4	181.3	462.8	2.1	6.1	11.7
PN 5	11	19	8	38	2	3	4	19	166	407.7	4	6.5	9.5
PN 6	8	17	9	35	1	3	4	10.8	161.2	429.8	2.6	7.3	9.5

PR- plots at Rosemala, PN- plots at Nadukani, S - seedlings, J- juveniles, A- adults

In plots 3, 4 and 6 the girth of the seedling remained without change from the previous observation. While in 1, 2 and 5 there was an increase in girth from the previous observation of which, plot 5 showed maximum. In juveniles, the girth increased slightly in plots 3 and 5 while all others remained unchanged. In three plots adults showed decrease in girth (plots 2, 4, 6) while in plots 3 and 5 remained unchanged. In the first plot there was an increase.

Seedlings did not produce any new leaf in three plots (1, 5 and 6) during the 3 months (Table 46). The average leaf formation was less than one in plots 3 and 4. An average of one leaf was produced in the seedlings in plot 2. The average leaf fall for seedlings of all plots was one. In all the plots, the juvenile plants produced new leaves but average leaf formation is less than one in plots 3, 4, 5 and 6. That is, the percentage of plants produced new leaves was very low. But the average leaf fall was more than one in two plots and one in all other plots.

In all the plots certain adult plants produced new leaves but it was less than an average of one in 3 plots, and leaf fall also was less than one in 3 plots. The average leaf fall never exceeded more than one in any of the plots

Table 46. Comparison of leaf characters

Plots	Seedlings				Juvenile				Adult			
	1	2	3	4	1	2	3	4	1	2	3	4
PR 1	0	0	0	1	11	12	1	2	5	5	1	0
PR 2	21	17	1	1	24	33	1	1	8	10	1	0
PR 3	1	1	0	1	5	7	0	1	3	3	0	0
PN 4	5	5	0	1	3	3	0	2	2	3	0	1
PN 5	0	0	0	1	4	6	0	1	0	0	0	1
PN 6	0	0	0	1	4	7	0	1	2	5	1	1

1. Total no. of plants produced new leaves, 2. Total no. of new leaves 3. Average leaf formation, 4. Average leaf fall

After 6 months

After 6 months five plots showed a decrease in number of total plants (Table 47). In plot 2 located at Rosemala, the number remained without change.

Table 47. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PR 1	4	18	7	29	3	5	6	14.5	173.5	352	2.2	6.3	7.1
PR 2	27	44	11	82	5	7	7	19.6	165.8	387.7	3.5	7.8	8
PR 3	16	51	22	89	4	5	6	12.8	185	371.9	2.3	7	7.9
PN 4	12	22	23	57	3	5	6	11.1	152.8	470.1	2.1	6.1	11.8
PN 5	4	19	7	30	3	4	5	20	167.8	409.2	4	6.7	9.5
PN 6	8	16	9	33	2	5	5	11.1	168	432.3	2.6	7.5	9.5

PT- plots at Rosemala, PN- plots at Nadukani, S - seedlings, J- juveniles, A- adults

The number of juveniles was more in all plots except plot 4. When compared to the previous observation the number decreased in plots 1 and 6. Even though in plot 3 there was a decrease, there was a simultaneous increase in the number of adult plants. In all other plots the number remained unchanged. There was a high mortality rate for seedlings. The adults also decreased in plot 4 and 5 where as in plots 1, 2 and 6, the number remained without change.

In this observation, the maximum number of leaves was observed in adult plants and the minimum number was noted in seedlings. In all the three groups, there was an increase in number of the leaves from the previous observation.

Seedlings increased in length in 5 plots. In plot 3 the height remained the same. The maximum height was noted in plot 5 at Nadukani while other two plots at this region showed the lowest height among different plots. The seedlings in the Rosemala region were with more height when compared to Nadukani. In 4 plots, the juvenile plants increased in height. In plot 1 and 6 average height of juveniles decreased. It was due to the transition of some seedlings to juvenile stage. Among adults, all the plots except plot 3 there was an increase in the average height of the plants.

The juvenile plants in all the plots were more or less of equal length with respect to the two regions. But the adult plants at Nadukani region showed more average length than at Rosemala.

The average girth of the seedling was less than the other two groups. Among juveniles, the maximum girth was in plot 5 (4 cm) and the minimum in plot 4 (2 cm). The increase in girth from the previous observation was noted only in plot 1. In all other plots, the girth of the seedlings remained same. The maximum girth was noted in plot 5 (4 cm) and the minimum in plot 4 (2 cm). In plots 1, 5 and 6, the average girth of juveniles increased. In all other plots it remained same. The maximum girth of juveniles was noted in plot 4. The increase in girth was noted only in plot 4 for the adult plants where in all other plots it remained same. The average girth of adults at Nadukani was higher when compared to Rosemala.

The seedlings produced new leaves in all the plots (Table 48). The average leaf formation was one or above one (2 in 3 plots). The average leaf fall for seedlings was less than one in three plots. In all the plots, the juvenile plants produced new leaves. The average leaf formation for juveniles was two in all plots. But the average leaf fall was less than one in 5 plots. In plot 1 it was one. In all the plots, the average leaf formation for adults was two. But the leaf fall was less than one in three plots. Compared with the previous observation, the rate of leaf formation was high and leaf fall was less.

Table 48. Comparison of leaf characters

Plots	Seedlings				Juvenile				Adult			
	1	2	3	4	1	2	3	4	1	2	3	4
PR 1	4	4	1	1	18	30	2	1	7	12	2	0
PR 2	27	54	2	0	43	88	2	0	10	21	2	1
PR 3	16	27	2	0	48	100	2	0	19	37	2	0
PN 4	8	14	1	1	21	43	2	0	22	50	2	0
PN 5	4	5	1	0	19	32	2	0	7	11	22	1
PN 6	8	15	2	1	13	25	2	0	7	15	2	1

1. Total no. of plants produced new leaves, 2. Total no. of new leaves 3. Average leaf formation, 4. Average leaf fall

After 9 months

In this observation the total number of plants in all plots except 3 remained same. In plot 3 there was a slight decrease in number (Table 49).

The juveniles were the major group in 5 plots. Their number remained same in all plots except 3 where there was a decrease in number by two. As in the previous observation, the number of adult plants was more than the seedlings except in plot 2. in which the number of seedling exceed the number of adults.

The number of leaves of juveniles and adults were equal in plots 3, 5 and 6 and in other plots, the adults had more. From the previous observation, there was slight increase in the number of leaves for all the groups.

In 4 plots (1, 3, 4 and 5) the height of the seedlings had increased and it decreased in two plots. The lowest height was in plot 6 (8.2 cm) and the highest in plot 5 (22. 2 cm). Both were located at Nadukani. The juvenile plants were more or less equal in size. They showed an increase in height in first five plots where as in plot 6 it decreased. The lowest height was in plot 6 (165.7 cm) and the highest in 4 (188.7 cm). The adults showed a variation in height in both regions. The adult plants at Nadukani were higher than at Rosemala.

Table 49. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PR 1	4	18	7	29	3	5	6	16	180.4	357.2	2.2	6.5	7.1
PR 2	25	46	11	82	5	6	7	18.8	165.9	391.8	3.1	7.8	8
PR 3	16	49	22	87	4	6	6	14.8	186.4	369.5	2.3	6.9	7.9
PN 4	12	22	23	57	3	5	6	11.4	188.7	475	2.1	6.2	11.8
PN 5	4	19	7	30	4	5	5	22.2	172.8	412.8	4	6.7	9.4
PN 6	8	16	9	33	2	5	5	8.2	165.7	437	2	7.5	9.5

PR- plots at Rosemala, PN- plots at Nadukani, S - seedlings, J- juveniles, A- adults

In 4 plots the girth of seedlings was equal to the previous observation. In plots 2 and 6 the average girth decreased. The plots which showed lowest girth (2cm) and highest girth (4cm) were in Nadukani. The average girth of juvenile plants was the same in three plots. It increased in two plots and decreased in one. The average girth of adults was comparatively high at Nadukani. In one plot it decreased and in another it increased. In 4 plots, the average girth remained unchanged.

In all the plots, new leaves were produced in certain seedlings (Table 50). The average leaves formed by the seedlings were one. The average leaf fall was also at a high rate. It was two in plot 2 and less than one in plot 5 while in all other plots it was one. The juveniles also produced new leaves in all plots. The average leaf formation in all the plots was one. The average leaf fall in all the plots except 5 was one and in 5, it was less than one. The average rate of leaf formation in adults was one and in plot 3, it was two. The average leaf fall for the adults was one in all plots except in plot 2 where it was two.

Table 50. Comparison of leaf characters

Plots	Seedlings				Juvenile				Adult			
	1	2	3	4	1	2	3	4	1	2	3	4
PR 1	3	4	1	1	17	18	1	1	7	8	1	1
PR 2	20	24	1	2	34	45	1	1	10	12	1	2
PR 3	15	18	1	1	39	48	1	1	18	26	2	1
PN 4	7	8	1	1	19	20	1	1	20	23	1	1
PN 5	4	5	1	0	16	19	1	0	6	6	1	1
PN 6	7	7	1	1	13	18	1	1	6	11	1	1

1. Total no. of plants produced new leaves, 2. Total no. of new leaves 3. Average leaf formation, 4. Average leaf fall

After 12 months

The total number of plants in all the plots increased in number (Table 51). The maximum increase in number was noted in plot 4 (4) while the maximum percentage of increase was noted in plot 5(12.1). The maximum number of plants in all the plots was juveniles except in plot 4. This was followed by adults in plots 3 and 4. In plot 2 the second major group was seedlings. In plot 1, 5 and 6 the seedlings and adults were equal in number. In all the plots there were new seedling recruitments. The total increase in number was due to the new recruitment.

Table 51. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PR 1	7	18	7	32	2	5	5	16.5	164.5	387.5	1.4	6.8	7.2
PR 2	25	47	12	84	4	6	6	16.5	164.5	387.5	2.5	7.9	8
PR 3	20	47	22	89	3	5	6	12.7	194.3	373.1	1.8	6.9	7.9
PN 4	17	21	23	61	2	4	6	9.1	194.8	483.5	1.6	6.3	11.8
PN 5	8	17	8	33	2	4	5	11.8	162.6	411.7	2	6.3	9.8
PN 6	10	15	10	35	2	5	5	7	167.3	425.7	1.4	7.6	9.6

PR- plots at Rosemala, PN- plots at Nadukani, S - seedlings, J- juveniles, A- adults

The maximum numbers of leaves were noted in the adults. The minimum numbers of leaves was in seedlings. When compared to the numbers of leaves of each group of each plot to the previous observation, a slight decrease in number was noted.

In this observation the average height of the seedlings were the least among the different groups. In all the plots except 1 the average height of the seedlings decreased. In plot 1 the average height of the seedlings increased. As in other observations the shortest was in plot 6 (7 cm). The highest were observed in plot 1 and 2 (16.5 cm) at Rosemala. In the plots 1, 2 and 5, the average height of the juveniles increased. In plot 3, 4 and 6, it decreased from the previous observation. The tallest plants among the adults were noted at Nadukani in plot 4 (483.5 cm) and the shortest in plot 3 (373.1 cm).

The lowest average girth was noted in the seedlings. In all the plots the average girth decreased from the previous observation. The lowest average girth in the seedlings was in plot 6 (1.4 cm) and the highest in plot 2 (2.5 cm). The lowest among the juvenile was in plot 4 and plot 5 (6.3 cm) and highest in plot 2 (7.9 cm). The average girth increased in 4 plots, it was same in plot 3 and decreased in plot 5.

The average girth of adults increased in 3 plots and remained same in 3 plots and the highest average girth was noted in the adults at Nadukani.

The seedling produced new leaves in all the plots (Table 52). But the rate of leaf production was very low. In 4 plots, the average leaf production for the seedlings was less than one.

Table 52. Comparison of leaf characters

Plots	Seedlings				Juvenile				Adult			
	1	2	3	4	1	2	3	4	1	2	3	4
PR 1	2	2	0	0	15	17	1	1	6	7	1	1
PR 2	9	11	0	1	24	26	1	1	7	7	1	1
PR 3	6	7	0	1	15	16	0	1	7	7	0	1
PN 4	6	8	1	0	9	10	0	1	9	11	0	1
PN 5	2	2	0	0	7	7	0	1	2	2	0	0
PN 6	7	8	1	1	5	6	0	1	3	3	0	1

1. Total no. of plants produced new leaves, 2. Total no. of new leaves 3. Average leaf formation, 4. Average leaf fall

In plots 4 and 6, the average leaf production was one. In all the plots, the juveniles also produced new leaves. But the average leaf formation was less than one in 4 plots. In plots 1 and 2 the average leaf production for juvenile was one. The average leaf production was one for the adults only in the plots 1 and 2 while in others, it was less than one. When compared with leaf production, leaf fall was low in seedlings, high in juveniles and adults. With in plots, seedlings showed an average of one leaf fall in 2 plots. Juveniles showed an average of one in all plots and adults, an average of one in 5 plots.

After 15 months

Except in plot 2 all the plots showed a decrease in total number of plants than in the previous observation (Table 53). The maximum decrease in number was noted in plot 5. Except in plot 2, all the plots showed a decrease in number. The number of adults exceeded the number of seedlings in the plots 3, 4, 5 and 6. In plot 2 the number of seedlings exceeded the adults. In plot 1 the number of adults and number of seedlings were equal in number. This had varied from the previous observation and from the first observation. The variation was due to the new recruitment of seedlings in plot 4 and 5 and due to mortality in plot 3. Mortality was there in case of adults also in plots 1, 3 and 6.

Table 53. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PR 1	6	19	6	31	2	4	5	12.1	186.9	367.6	1	6.8	7.1
PR 2	25	47	12	84	4	6	6	17.6	168.1	391.7	2.7	8.1	8
PR 3	19	47	21	87	2	5	5	11.8	196.3	381	1.7	6.8	11.1
PN 4	19	21	23	63	2	4	6	8.6	198.2	488.1	1.5	6.3	11.8
PN 5	10	17	8	35	2	4	5	10.5	167	415.8	1.6	6.3	9.8
PN 6	10	15	9	34	1	4	5	7.4	174.4	426.2	1.4	7.6	9.6

PR- plots at Rosemala, PN- plots at Nadukani, S - seedlings, J- juveniles, A- adults

Maximum number of leaves was noted in adults and the number remained more or less equal. The seedlings showed the minimum number of leaves. In the juveniles the number of leaves remained without much change from the previous observation but from the first observation it showed a slight increase in number.

In plots 2 and 6 the average height of the seedlings increased. The shortest seedling was observed in plot 6 (7.4 cm) and the highest in plot 2 (17.6 cm). In all the plots average height of the juvenile plants increased. The average height of the juveniles was almost equal in all plots. The average height of adults increased in all plots except in plot 1. The maximum average height of adults was noted in plot 4 at Nilumbur. The minimum height for the adults was observed in plot 1. In 4 plots (1, 3, 4 and 5) the average girth was decreased. In plot 2 it was increased and in plot 6 it remained the same.

The lowest of average height for seedling was noted in plot 1 (1 cm) and the highest in plot 2 (2.7 cm). The average girth of the juveniles remained the same in 4 plots. In one plot it increased and in another it decreased. At Nadukani, the girth remained the same in all the plots. The average girth remained same in the case of adults in 3 plots. In two plots it increased and in one plot it decreased. The maximum average girth noted in adults was 11.8 cm and minimum, 7.1 cm.

Table 54. Comparison of leaf characters

Plots	Seedlings				Juvenile				Adult			
	1	2	3	4	1	2	3	4	1	2	3	4
PR 1	2	2	0	1	12	17	1	1	4	5	1	1
PR 2	15	20	1	0	29	0	1	1	9	11	1	1
PR 3	6	8	0	1	10	13	0	1	4	4	0	1
PN 4	6	7	0	0	13	15	1	1	14	17	1	1
PN 5	2	2	0	0	11	13	1	1	4	4	1	0
PN 6	2	4	0	1					3	4	0	1

1. Total no. of plants produced new leaves, 2. Total no. of new leaves 3. Average leaf formation, 4. Average leaf fall

Seedlings produced new leaves in all plots (Table 54). But the average leaf formation was less than one in 5 plots. Only in plot 2, an average of one leaf was produced. In juveniles except in plot 3 the average leaf production was 1. In adults, the average leaf production was less than one in plot 3 and 6 while in all other plots it was one. The leaf fall was maximum in all the group for all plots. It was one in the case of seedlings in plot 1, 3 and 6. It was one in all the plots for juveniles except in plot 5 and it was 1 for the adults.

After 18 months

In this observation in plots 1, 4, 5 and 6 the total number of plants remained the same (Table 55). While in plots 2 and 3 there were a slight decrease in number. The number of plants in all the plots was represented more by the juveniles except in plot 4 where the adults exceeded in number. The number of adults exceeded the seedlings only in plots 3 and 4. In plots 2, 5 and 6 the seedlings were the major group. In plot 1 the number of adults and seedlings remained same. Another feature observed in this observation was the transition of seedlings (3) in plot 2 which remained the same for the last 4 observations.

Table 55. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PR 1	6	19	6	31	2	5	6	13	189	370.5	1.1	6.8	7.5
PR 2	22	49	12	83	4	7	6	16	169.2	324.6	2.6	8.1	8.1
PR 3	18	47	21	86	3	6	6	10.5	195.3	384	1.7	6.7	11.1
PN 4	19	21	23	63	3	5	6	9.1	202.8	492.8	1.5	6.4	11.8
PN 5	10	17	8	35	3	5	5	10.7	168.7	419.8	1.6	6.3	9.8
PN 6	10	15	9	34	2	5	6	8.4	177.4	428.6	1.4	7.7	9.7

PR- plots at Rosemala, PN- plots at Nadukani, S - seedlings, J- juveniles, A- adults

The average number of leaves for adults increased in plots 3, 4, 5 and 6 and that of juvenile plants also increased in all the plots.

In the plots 1, 4, 5 and 6 the average height of the seedlings increased where as in plots 2 and 3 it decreased. The seedlings with lowest height were in plot 4 (9.1 cm) and highest in plot 2 (16 cm). The seedlings with more height were observed at Rosemala. In plots 1, 4, 5 and 6 the juvenile plants increased in size. In plot 2 and 3 they decreased in size. In all the plots the average height of the adults increased. The adult plants in Rosemala region were higher and the maximum height was noted in plot 4 (492.8 cm) and the minimum in plot 1 (370.5 cm)

The seedlings increased their average girth in plot 1, in Rosemala region. There was a decrease in average girth in plot 2. In all other plots the average girths of the seeding remained same. The maximum girth was noted in plot 1(1.1 cm). The average girth of juveniles increased in 3 plots (2, 4 and 6) and same in 2 plots (2 and 5) and decreased in one (3). In the first two plots the average girth of the adult increased and in the last 4 plots the average girth of adults remained same. The lowest girth of adult was 7.5 cm and highest was 11.8 cm.

In this observation all the plots had new leaves for seedlings (Table 56). The average leaf formation was high. In plot 2, it was two and in all other plots, it was one. The average leaf fall rate was low for seedlings. It was less than one in plots 1, 4, 5 and 6. It was one in plot 3 and two in plot 2. The juveniles also formed new leaves in all plots. The rate of leaf formation was high. It was two in plots 2, 3, 4 and 6 and one in plots 1 and 5. The average leaf fall was in the rate of 1 in all plots. The adults also had the leaf production in all plots. It was 2 in plot 3 and 1 in all other plots. The leaf fall rate was one in plots 1, 2 and 4 and in other plots it was less than one.

Table 56. Comparison of leaf characters

Plots	Seedlings				Juvenile				Adult			
	1	2	3	4	1	2	3	4	1	2	3	4
PR 1	6	6	1	0	19	25	1	1	6	8	1	1
PR 2	16	25	1	2	44	73	2	1	9	15	1	1
PR 3	16	27	2	1	43	79	2	1	18	32	2	0
PN 4	15	16	1	0	21	33	2	1	17	22	1	1
PN 5	10	10	1	0	15	18	1	1	7	7	1	0
PN 6	8	13	1	0	12	24	2	1	7	13	1	0

1. Total no. of plants produced new leaves, 2. Total no. of new leaves 3. Average leaf formation, 4. Average leaf fall

After 21 months

In plot 2 there was a slight decrease in number (Table 57). The total number of plants in all other plots remained same. In plot 2, decrease in number was due to mortality of seedling and juveniles. Another feature noticed that the number of adult plants in the plot 2 remained unchanged and the number of seedlings and juveniles showed a decline. The major group in all the plots except 4 was the juveniles where in plot 4 adults were the major. Seedlings were the second major group in plots 2, 5 and 6 and in plot 3 and 4 adults exceed the seedlings. In plot 1 both were same in number.

The maximum number of leaves was noted in the adult plants in all the plots. The average number remained the same. But from the first observation it had an increased nature. The seedlings showed a decreased number of average numbers of leaves than the previous observation in plots 4 and 5 while in plot 6 it showed a decreasing trend for plots 1, 2, 5 and increasing trend for plot 1 and kept same for plot 3, 4 and 6. In 4 plots the seedlings increased in height. In plot 3 the height of the seedlings decreased and in plot 6 the height of the seedlings remained the same.

Table 57. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PR 1	6	19	6	31	2	6	6	13.3	195.5	377.1	1.1	7.3	7.5
PR 2	20	48	12	80	4	6	6	18	171.3	398.3	2.7	8.2	8.2
PR 3	17	48	21	86	3	6	6	8.7	197.7	389.3	1.5	6.6	11.1
PN 4	19	21	23	63	2	5	6	9.3	204.8	498.3	1.6	6.4	12.2
PN 5	10	17	8	35	2	4	5	11.5	171.8	423.8	1.7	6.5	10
PN 6	10	15	9	34	3	5	6	8.4	181.9	431.6	1.4	7.7	9.7

PR- plots at Rosemala, PN- plots at Nadukani, S - seedlings, J- juveniles, A- adults

The maximum height of the seedling was observed in plot 2 (18 cm) and the minimum in plot 6(8.4 cm). The average height of juveniles was maximum in plot 4 (204.8 cm) and minimum in plot 2 (171.3 cm). The average height of adult plants increased in all the plots. The maximum height was in plot 4 (498.3 cm) and the minimum in plot 1 (377.1 cm).

The average girth of the seedling was less than that of the other two groups. Among seedlings it was maximum in plot 2 (2.7 cm) and minimum in plot 1(1.1 cm). In plots1, 2 and 6 the average girth remained unchanged. In plots 4 and 5 it increased and in plot 3 it decreased. The girth of juveniles increased in plots 1, 2, 3 and 5 and it remained without change in plots 4 and 6. The adults increased in height in plots 2, 4 and 5 while in all other plots it remained same. The maximum girth in adults was in plot 4 (12.2 cm) the minimum average girth for adults was1 in plot 2 (8.2 cm)

All the plots except 6 produced new leaves in seedlings (Table 58). But the average leaf formation was very low. It was less than one in plots 1, 3, 5 and 6 and in plots 2 and 4, it was one.

All the plots produced new leaves in juvenile plants. The average leaf formation for juveniles was one. The adults also produced leaves in the rate of one per plant. In all plots except 5, it was less than one. The average leaf fall rate was one in all plots.

Table 58. Comparison of leaf characters

Plots	Seedlings				Juvenile				Adult			
	1	2	3	4	1	2	3	4	1	2	3	4
PR 1	2	2	0	0	19	24	1	1	6	7	1	2
PR 2	10	15	1	1	31	38	1	1	9	12	1	1
PR 3	6	7	0	1	36	41	1	1	19	26	1	1
PN 4	7	9	1	1	10	10	1	1	11	11	1	1
PN 5	1	1	0	0	8	9	1	1	3	3	0	1
PN 6	0	0	0	0	15	17	1	1	8	11	1	1

1. Total no. of plants produced new leaves, 2. Total no. of new leaves 3. Average leaf formation, 4. Average leaf fall

After 24 months

Increase in the number of total plants was observed in plot 3 (Table 59). In plot 2 and 4, the number of total plants decreased. In all other plots the numbers remained the same. In plot 2 there was a significant change in number (8 plants). It was due to the high mortality in the plot. Except plot 4 in all the plots juveniles was the major group. In plots 1, 5 and 6 seedlings were the second major group. In plot 3, adults were the second major group and in plot 2, adults and seedlings were same in number. In plots 1 and 3, there were new recruitments while heavy mortality was noted in plot 2.

The adults showed maximum average number of leaves and it was minimum in seedlings. The number of leaves in the adults in plot 2 had decreased while in all other plots it remained the same. There was an increase compared to the first observation. The number of seedlings also showed decrease in plots 1, 3 and 4.

Seedlings showed much variation in size. The highest average height among seedlings was 24 cm. (plot 2). The lowest average was in plot 1 (7.6 cm), located at Rosemala region. In 4 plots the average height of the seedlings increased. In plot 1 and 3 it decreased. In all the plots, except plot 1 the average height of juvenile increased. The maximum average height of juvenile was 211.7 cm. The average height of all adult plants except in plot 2 increased. Among the adults, the tall plants are located at Nadukani. The tallest average height of the adults was 499 cm and shortest was 379 cm.

Table 59. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PR 1	8	18	5	31	2	5	6	7.6	185.2	379	1	6	8
PR 2	13	48	13	74	4	6	7	24	177.3	396.4	2.8	8.1	8.3
PR 3	19	48	21	88	2	5	6	8.3	203.5	393.4	1.3	6.6	11.1
PN 4	19	18	24	61	2	5	6	11.3	211.7	499	1.6	5.9	12.1
PN 5	10	16	9	35	2	4	5	12.3	177.2	424.6	1.9	6.5	10
PN 6	10	15	9	34	1	5	6	11.2	186.6	434.3	1.4	7.8	9.8

PR- plots at Rosemala, PN- plots at Nadukani, S - seedlings, J- juveniles, A- adults

In three plots, the average girth of seedlings increased (plots 2, 3 and 5). In plots 4 and 6, it remained unchanged in 2 plots (6 and 4). In plot 1 the average girth of seedling decreased. The minimum girth noted in plot 1 (1 cm) and maximum girth in plot 2 (2.85 cm). In juveniles, the average girth was decreased in 3 plots. It remained the same in 2 plots (plot 3 & 5). In one plot it increased (plot 6). The maximum girth was in plot 2 (8.1 cm) and minimum in plot 4 (5.9 cm). The average girth of adult plants increased in plots 1, 2 and 6. It remained the same in plots 3 and 5. In plot 4, it decreased. The maximum girth for adult was in plot 4 (12.1 cm) and minimum in plot 1 (8 cm).

Table 60. Comparison of leaf characters

Plots	Seedlings				Juvenile				Adult			
	1	2	3	4	1	2	3	4	1	2	3	4
PR 1	1	1	0	1	17	18	1	2	8	8	1	1
PR 2	8	9	1	2	40	45	1	1	4	4	1	1
PR 3	3	3	0	1	15	16	0	1	7	7	0	1
PN 4	4	4	0	1	6	6	0	1	7	7	0	1
PN 5	0	0	0	1	2	3	0	2	0	0	0	0
PN 6	3	3	0	2	3	6	1	1	4	6	1	1

1. Total no. of plants produced new leaves, 2. Total no. of new leaves 3. Average leaf formation, 4. Average leaf fall

The seedlings produced new leaves in all the plots (Table 60). But the average new leaf formation was very low. Only in plot 2 it was one. In all other plots it was less than one. The average leaf fall for the seedlings in this observation was high. It was two in plots 2 and 6. In all the plots, the juvenile plants formed new leaves. But the rate of new leaf formation was very low. Only in plots 1, 2 and 6 it was one. In all other plots it was less than one. In the juveniles also the rate of leaf fall was one or above one. Adults also showed the same pattern. In three plots, they had the average leaf formation of one. In all other plots, it was less than one. The average leaf fall was one in all plots.

After 27 months

In this observation, two of the plots showed increase in number of total plants (Table 61). In two of the plots, the total number of plants decreased while in two other plots the number remained unchanged. The increase in number noted in plots 5 and 6 was due to the new recruitment of seedlings. The decrease in number noted in the plots 2 and 4 were due to the mortality. The major group was juveniles in 5 plots. In plot 4, the adults were the major group. Another change noted was the decrease in number of seedling in plot 2. Thus the adults became the second major group in this plot. So in plots 1, 2, 3 and 4, adults were the second major group and in plot 5 and 6, the seedlings.

Table 61. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PR 1	5	18	8	31	2	5	6	7.6	191	383.6	0.8	6.9	8.1
PR 2	10	49	13	72	4	7	7	24.8	181.1	399.6	3.1	8.2	8.6
PR 3	19	47	22	88	3	5	6	9	206.7	393.5	1.3	6.6	11
PN 4	16	18	24	58	3	6	7	14.6	217	500.5	2.1	6.1	12.6
PN 5	13	17	9	39	2	3	4	6.3	176.6	438.3	0.7	6.9	10.2
PN 6	12	14	10	36	2	4	5	9.3	155.2	425.7	1.1	8.2	10

PR- plots at Rosemala, PN- plots at Nadukani, S - seedlings, J- juveniles, A- adults

The average number of leaves was more in adults which remained the same in 3 plots. In plot 3, it increased while in plots 4 and 5 it decreased. The least average number of leaves was in seedlings, which showed an increase in plots 4 and 5 and a decrease in plot 6. In all other plots the number remained the same. Average leaf number in juveniles also increased in plots 2 and 4 while in plot 5 and 6 they decreasedThe height of seedlings increased in 3 plots (2, 3 and 4). In plot 1 it remained the same. In plots 5 and 6 the average height of the seedlings decreased. The average height varied in different plots. The maximum height was recorded in plot 2 (24.8 cm) and the minimum in plot 1 (7.6 cm). The juveniles increased in height in all plots except in plot 5 where it decreased. In case of adults the average height decreased in plot 6. In other plots it increased. When the height of the juveniles was considered there was no difference between two locations. But in the case of the adults, plants with more height were noted at Nadukani.

In three plots (1, 5, 6) the average girth decreased from previous observation. In plots 2 and 3 it increased. In plot 3 it remained the same. The minimum girth of the seedlings was in plot 1 (0.8 cm) and the maximum in plot 2 (3.1 cm), located at Rosemala region. The juvenile plants increased their girth in 4 plots (1, 2, 5 and 6). It remained same in plots 3 and 4. The highest girth was noted in plot 2 and 6 (8.2 cm each) and the lowest in plot 4 (6.1 cm). The average girth of adult increased in 5 plots. It decreased in one plot. The average girth for adult was maximum in plot 4 (12.6 cm) and minimum in plot 1 (8.1 cm).

In all the plots, the seedlings produced new leaves (Table 62). The average leaf formation was one except in plot 5 where it was less than one. The average leaf fall was comparatively less. In plot 2, it was 2. The average leaf formation for juveniles was one in three plots (1, 2 and 3), two in plot 4 and less than one in plots 5 and 6. The average leaf fall is one in 4 plots while less than one in 2 plots. In adults, the average leaf formation was one in plots1 and 2 and two in plot 4 and less than one in plots 3, 5 and 6. The average leaf fall for adults was one in 5 plots while in plot 4, it was less than one. The season favoured both leaf formation and leaf fall.

Table 62. Comparison of leaf characters

Plots	Seedlings				Juvenile				Adult			
	1	2	3	4	1	2	3	4	1	2	3	4
PR 1	4	4	1	0	17	18	1	1	8	8	1	1
PR 2	7	9	1	2	40	65	1	1	11	17	1	1
PR 3	11	15	1	1	15	23	1	1	6	7	0	1
PN 4	13	17	1	1	18	31	2	0	22	38	2	0
PN 5	2	2	0	0	4	7	0	0	1	2	0	1
PN 6	5	15	1	0	4	5	0	1	1	3	0	1

1. Total no. of plants produced new leaves, 2. Total no. of new leaves 3. Average leaf formation, 4. Average leaf fall

After 30 months

The total number of plants in all plots except 6 showed an increase in number (Table 63). Where ever this increase in number was noted there were new seeding recruitments. The percentage of recruitment was high in plots 1, 2, 4 and 5. Even though there was an increase in number the total number had not exceeded the numbers in the first observation. Except in plot 4, juveniles dominated in all plots. The adults dominated in plot 4. In plot 1 it was the second largest group and in plot 2, 5 and 6 they were less in number than the seedlings.

Table 63. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PR 1	6	16	9	33	2	6	6	5.4	195.4	389.3	5.7	7.1	7.7
PR 2	14	49	13	76	3	7	6	18	185.7	406.8	2.2	8.3	8.9
PR 3	22	46	22	90	3	6	7	8.3	213.2	396.8	1.1	6.7	11
PN 4	20	16	25	61	3	5	6	11.8	211	502.1	1.6	6.2	12.4
PN 5	15	16	9	40	2	4	5	5.5	179.4	441.7	0.6	7.1	10.4
PN 6	12	14	9	35	2	5	6	9.3	188.5	428.1	1.2	8.3	10.6

PR- plots at Rosemala, PN- plots at Nadukani, S - seedlings, J- juveniles, A- adults

The maximum average number of leaves was seen in adults and the minimum in seedlings. The average number of leaves of juvenile was equal to adults in plots 1. The average number of leaves is more than in the previous observation and the first observation in majority of plots.

The average height of the seedlings decreased in the first five plots. In plot 6 the average height of the seedling remained without change. The average height was maximum in plot 2 (18 cm) and minimum in plot 1 (5. 4 cm). Among juveniles average height increased in all except in plot 4. In plot 4, it decreased. It was maximum in plot 3 (213.2 cm) and minimum in plot 2 (185.7 cm). In all the plots the adults increased their height. When compared to Rosemala the adult plants at Nadukani showed maximum average height. The average height was minimum in plot 1 (389.3 cm) and maximum in plot 4 (502.1 cm)

The girth of the seedings also decreased in 4 plots. Only in plot 3 and 6 it increased. The maximum girth was in plot 2 (2.2) and the minimum in plot 1(0.5 cm). In all the plots the average girth of juveniles increased. The maximum girth was in plots 2 and 6 (8.3 cm) and minimum in plot 4 (6.2 cm). The average girth of adults decreased in 2 plots (plots1 and 4) and increased in 2 plots (plots 2 and 5) and remained the same in two plots (plots 4 and 6).

Table 64. Comparison of leaf characters

Plots	Seedlings				Juvenile				Adult			
	1	2	3	4	1	2	3	4	1	2	3	4
PR 1	1	1	0	0	16	19	1	1	7	9	1	0
PR 2	7	10	1	0	40	58	1	1	12	19	2	2
PR 3	10	15	1	0	41	66	2	1	20	28	1	1
PN 4	8	12	1	0	13	19	1	2	19	26	1	1
PN 5	3	6	0	1	15	32	2	1	8	15	2	0
PN 6	0	0	0	0	13	24	2	1	10	13	1	0

1. Total no. of plants produced new leaves, 2. Total no. of new leaves 3. Average leaf formation, 4. Average leaf fall

In all the plots except in plot 6 the seedlings produced new leaves (Table 64). The average leaf formation was one in plots 2, 3 and 4. In other plots it was less than one. The average leaf fall for seedlings was one in plot 5 while in other plots it was less than one. Among juveniles, new leaves were formed in all plots. The average leaf formation was two in plots 3, 5 and 6 and one in plots 1, 2 and 4. The average leaf fall was two in plot 4 and one in 5 plots. In all the plots adults produced new leaves. The rate of leaf formation for adults was two in 2 plots and one in 4 plots. The average leaf fall was less than one in 3 plots, while it was one in two plots (3 and 4) and two in plot 2.

After 33 months

The total number of plants decreased from the previous observation (Table 65). The decrease in number was among seedlings. The difference in the number among the juveniles and adults were due to the transition of plants to the higher groups. Juveniles were the major group in all plots except in 4. In plot 4 it was adults. In plots 1, 2 and 3 adults were the second major group and in plots 5 and 6, seedlings were the second.

Table 65. Comparison of growth characters

Plots	Number of plants				Average number of leaves			Average height of the plants (cm)			Average girth of the plants (cm)		
	S	J	A	Total	S	J	A	S	J	A	S	J	A
PR 1	6	16	9	31	1	5	5	2.8	194.3	391.7	0.3	7.1	7.7
PR 2	12	50	13	75	3	6	7	14.1	187.6	408.2	1.7	8.3	9
PR 3	20	40	24	84	3	6	6	8.5	211.8	393	1.1	6.8	10.5
PN 4	18	14	27	59	3	5	6	14.1	199.8	489.7	1.8	6.4	12.1
PN 5	14	14	10	38	2	5	6	6.8	176.7	449.7	0. 7	4.6	10.4
PN 6	12	14	9	35	2	5	6	10.9	194.6	444.4	1.2	8.3	10.7

PR- plots at Rosemala, PN- plots at Nadukani, S - seedlings, J- juveniles, A- adults

Average number of leaves was maximum in adults in all the plots while in plots 1 and 3 they were equal to the juveniles. Average number of leaves was less among seedlings.

The average height of seedlings was the lowest among different groups. In first two plots the average height of seedlings decreased. In the last four plots it increased. The maximum height among seedlings was in plots 2 and 4 (14.1 cm). The shortest was in plot 1 (2.8 cm). The average height of juveniles decreased in 4 plots and increased in two plots. Among juveniles the average height was maximum in plot 4 (199.8 cm). Among adults, taller plants were seen more in Nadukani. In 4 plots the average height of adults decreased. The maximum was 489.7 cm.

The average girth decreased in 3 plots and increased in one (plot 3). The average girth of juveniles was same in 3 plots (1, 2 and 6). It increased in 2 plots and decreased in one. In adults, it increased in 3 plots (2, 4 and 6), decreased in one plot (plot 3) and remained same in 3 plots. For adults the maximum was 10.5 cm.

In all the plots all the seedlings formed new leaves (Table 66). Average leaf formation was less than one in first two plots and one in last 4 plots. The average leaf fall in seedlings was one in all plots. In all the plots the juveniles also produced new leaves, at the rate of one per plant. The leaf fall rate was one in all plots except in 3. In plot 3 it was two. In adults new leaves were formed in all plots. The rate was less than one in 1st plot, one in 4 plots and two in the last plot. Among seedlings and adults, rate of leaf fall was more than leaf formation. In adults both had equal status.

Table 66. Comparison of leaf characters

Plots	Seedlings				Juvenile				Adult			
	1	2	3	4	1	2	3	4	1	2	3	4
PR 1	2	2	0	1	12	16	1	1	3	3	0	1
PR 2	4	4	0	1	35	40	1	1	5	7	1	0
PR 3	15	16	1	1	31	37	1	2	22	26	1	1
PN 4	10	10	1	1	7	8	1	1	17	17	1	0
PN 5	15	16	1	1	11	14	1	1	7	10	1	1
PN 6	12	12	1	2	13	17	1	1	9	14	2	2

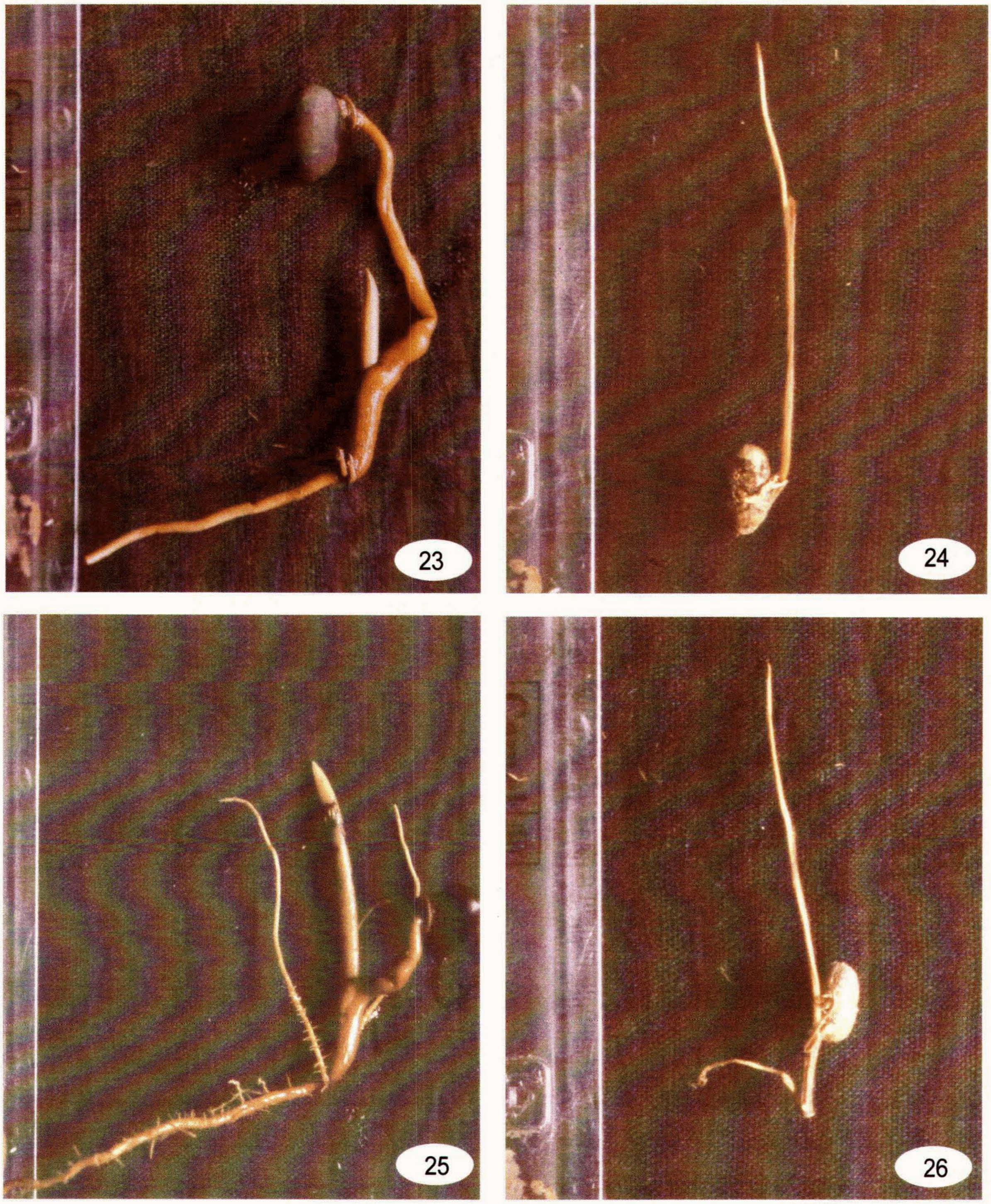
1. Total no. of plants produced new leaves, 2. Total no. of new leaves 3. Average leaf formation, 4. Average leaf fall

ROOT MORPHOLOGICAL STUDIES

The type of seed germination and the nature of origin of roots were similar in both the viz. *Arenga wightii* and *Phoenix loureiri* var. *humilis*. The embryonic root with plumule was pushed out of the seed by a haustorium, known as cotyledon stalk. In a seedling at an early phase the plumule was completely enclosed within the cotyledonary sheath, later it pierced the sheath and grew upwards (Figs. 23 & 24). The radicle will be in the opposite side. The cotyledonary stalk in *Arenga* was large and fleshy while that in *Phoenix* it was very small.

After 2 months

Arenga wightii developed a single root at this stage with a length of 15.32 cm (Fig. 25), and a diameter of 0.2 cm. The average number of laterals formed by it was 21, and had an average length of 1.67 cm. Average number of leaf present in the seedling was 1.



Figs. 23-26 Radicles at emergence and after 2 months

Fig. 23. *Arenga wightii* at emergence

Fig. 24. *Phoenix loureirii* var. *humilis* at emergence

Fig. 25. *Arenga wightii* after 2 months

Fig. 26. *Phoenix loureirii* var. *humilis* after 2 months

Phoenix loureiri var. *humilis* had an average of 1 root at this stage (Fig. 26). The average length of the main root at this stage was 9.80 cm and had an average thickness of 0.16 cm. The average depth of the soil occupied by the root was 6.73 cm and the average horizontal spread was 9.6 cm. The average number of lateral roots formed by the main roots was two. They had an average length of 0.60 cm. The average number of leaves in the seedlings was two.

The number of main roots at this stage was more in *Phoenix* but the number of laterals was more in *Arenga.* The soil depth occupied was more in *Arenga*. The main root length at this stage was more in *Arenga* but the thickness was more in *Phoenix*. The number of laterals also was more in *Arenga*.

After 4 months

The average number of main roots in *Arenga* at this stage was three. The average length of these main roots was 8.02 cm. These roots had an average diameter of 0.14 cm. The average depth of soil occupied by the roots was 7.97 cm. Their horizontal spread was 10.66 cm. The average numbers of laterals formed were 12.53. Their average length was 0.79 cm. Average green leaf at this stage was one.

The average number of main roots in *Phoenix* was 3 at this stage. Those roots had an average length of 10.60 cm and an average diameter of 0.19 cm. The average depth of soil occupied by the roots was 10.23 cm. Their horizontal spread was 9.60 cm. The average number of laterals formed by these main roots was four. They had an average length of 1.97 cm. The average number of green leaf in the seedlings was two.

The average number of roots in both *Arenga* and *Phoenix* were same but the laterals were more in *Arenga*. The main roots were longer in *Phoenix.* Root diameter also followed this pattern.

The depth and root spread were more or less same in both species.

After 6 months

Arenga had an average number of 4 roots and an average length of 10.60 cm (Fig. 27). The average depth of the soil occupied by the main roots was 9.84 cm while the peripheral roots had the horizontal spread of 9.20 cm. Fourteen laterals were produced and the average length was 2.11 cm. The average number of green leaves was two.

The average number of main roots in *Phoenix* was two. They had an average length of 14.40 cm (Fig. 28). The minimum length of the main root, which formed the laterals, was 7 cm. The average depth traversed by these main roots was 10.13 cm and the peripheral roots had a horizontal distance of 12.60 cm. They had an average of four lateral roots. The lateral roots had an average length of 1.24. An average of three green leaves was present.

In this stage also, the number of main roots exceeded in *Phoenix* but the number of laterals was more in *Arenga*. The depth and horizontal spread of roots was more in *Phoenix*.

After 8 months

The average number of roots in *Arenga* was 3. The average length of those roots was 11.80 cm and had an average diameter of 0.13 cm. The average depth of the soil occupied by the main roots was 7.29 cm. The peripheral roots had an average horizontal spread of 7.36 cm. The main roots form an average number of 19 laterals. The average length of the laterals was 0.53 cm. The seedling had two leaves as an average.

Phoenix had an average number of four roots and their average length was 14.20 cm and average diameter was 0.20 cm. The average depth of soil occupied by the roots was 9.15 cm and the average horizontal spread was 12.80 cm. These roots form an average of 3 laterals. The average length of the laterals was 1.28 cm. The average green leaf in the seedling was three.

The average number of roots was more in *Phoenix*. But the average number of laterals was more in *Arenga*. The average length and diameter of main root were more in *Phoenix*. The average vertical and horizontal lengths of roots were also more in *Phoenix*.

After 10 months

Arenga had an average number of three roots. The average length of these roots was 8.26 cm and the average diameter was 0.16 cm. The main roots form laterals at a minimum length of 4.50 cm. The average depth of soil occupied by these roots was 6.40 cm. The peripheral roots of *Phoenix* grew to an average horizontal distance of 9.96 cm. The average numbers of laterals was five. They had an average length of 1.46 cm. The average number of green leaf was one.

Phoenix had an average number of four roots. The average length of these roots was 10.93 cm and their average diameter was 0.23 cm. They formed laterals at a minimum length of 5 cm. The average depth traversed by roots was 9.60 cm and their horizontal spread was 9.80 cm. The average number of lateral roots formed was three. Their average length was 1.23 cm. The average number of green leaves was two.

Phoenix had more main roots but the laterals were more in *Arenga*. The depth and the horizontal spread of these two plants were more or less same. The length and diameter of the main roots were more in *Phoenix* while the laterals had more length in *Arenga*.

After 12 months

The average of roots in *Arenga* was three. They had an average length of 7.40 cm and average diameter of 0.16 cm (Fig. 29). They form lateral roots at a minimum length of 0.60 cm. The depth of soil occupied by the main roots was 5.10 cm and their horizontal spread was 7.20 cm. The average number of lateral roots formed was 11. These laterals had an average length of 0.58 cm. The average number of green leaves was two.

Phoenix had an average of three roots. The average length of these roots was 14.40 cm (Fig. 30) and their average diameter was 0.26 cm. The depth traversed by these roots was 12.10 cm and the peripheral roots had a horizontal spread of 15.20 cm. The minimum length of main root in order to form lateral was 3 cm. The average number of lateral was three. They had an average length of 1.85 cm. The average number of green leaves was two.

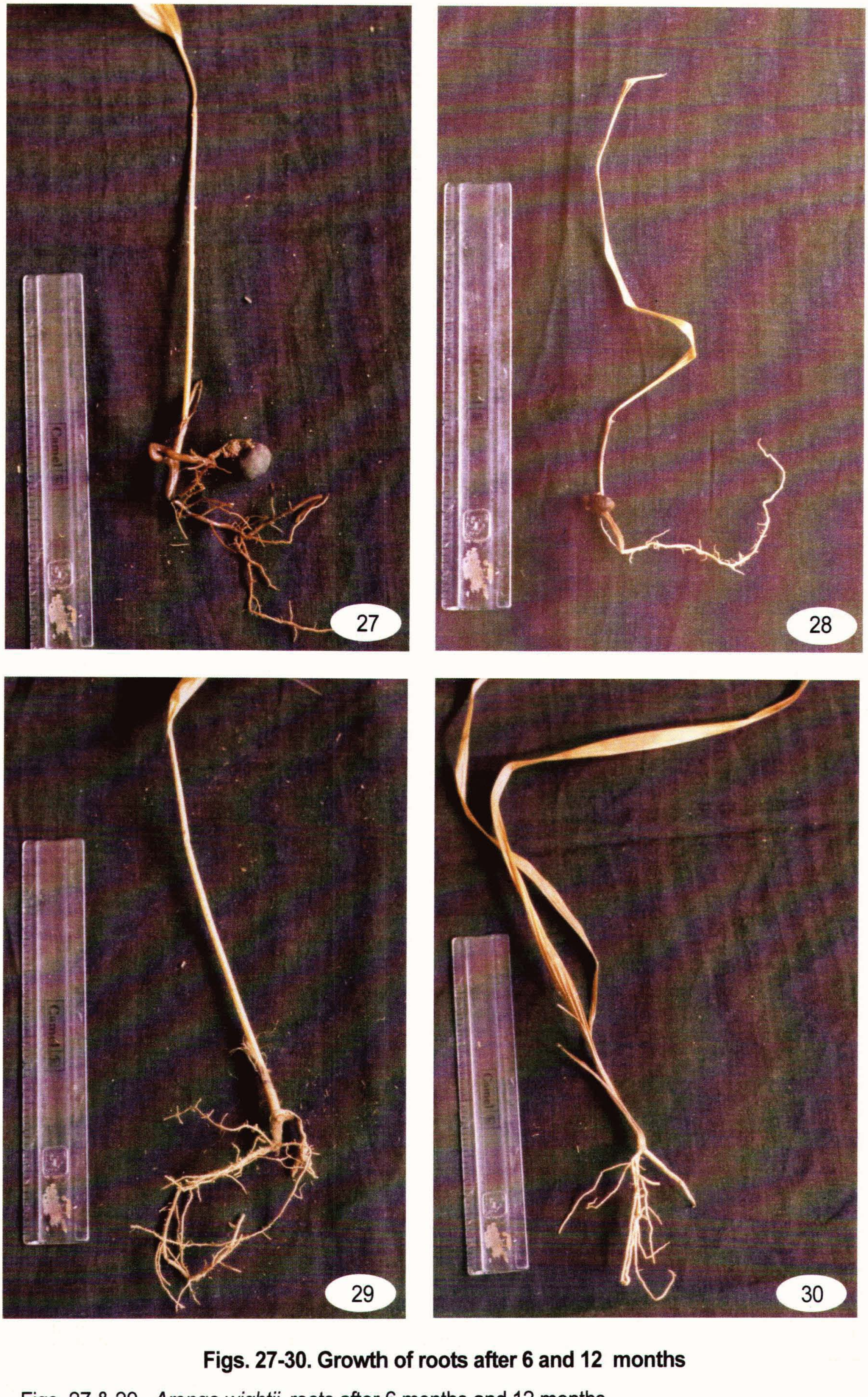
The average number of main roots was more in *Phoenix* but the average number of lateral roots was more in *Arenga*. The average length and diameter of main root was more in *Phoenix*. The depth and horizontal distance traversed by the roots were also more in *Phoenix*.

After 14 months

In *Arenga* the average number of roots was three. These roots had an average length of 11.04 cm and an average diameter of 0.12 cm. The depth traversed by these roots was 7.24 cm and their horizontal spread was 14.08 cm. The minimum length for lateral root formation was found to be 2.50 cm. The average numbers of laterals was five. Their average length was 0.93 cm. The average number of green leaf was two.

The average number of roots in *Phoenix* was four. They had an average length of 12 cm and an average diameter of 0.22 cm. They formed lateral roots at a minimum length of 7 cm. The average depth of soil occupied was 11.10 cm and their horizontal spread was 18.20 cm. The average number of laterals was five. They had an average of 0.93 cm length. The average number of green leaf was 2.60.

The average number of roots was more in *Phoenix* but the average number of lateral roots was more in *Arenga*. Roots in *Arenga* formed laterals at a minimum length than *Phoenix*. The average length and girth of main root was more in *Phoenix*. The average length of the laterals was also more in *Phoenix*. The average depth and horizontal spread of the root system was also less in *Arenga*.



Figs. 27-30. Growth of roots after 6 and 12 months

Figs. 27 & 29. *Arenga wightii* roots after 6 months and 12 months

Figs. 28 & 30. *Phoenix loureirii* var. *humilis* roots after 6 months and 12 months

After 16 months

Arenga had an average number of three roots. The average depth traversed by these roots was 5.59 cm and their horizontal spread was 5.14 cm. The average length of the main roots was 7.58 cm and their diameter was 0.13 cm. The average number of lateral was five. They had an average length of 0.96 cm and diameter of 0.02 cm. The average number of green leaves in seedling was two.

The average number of roots in *Phoenix* was four. They had an average length of 14.20 cm and diameter of 0.16 cm. The minimum length shown by the main root to produce lateral root was 7.20 cm. The average depth occupied by the roots in the soil was 7.93 cm and their horizontal spread was 9.60 cm. They laterals had an average length of 1.52 cm. The average number of leaves present in the seedlings was three.

The average number of root was more in *Phoenix* but the average number of lateral roots was more in *Arenga*. The average length and diameter of main root were more in *Phoenix*. They had lateral roots with more length and showed more horizontal spread.

After 18 months

Arenga had an average number of five roots. The average length of these roots was 9.62 cm (Fig. 31) and the average diameter was 0.18 cm. The average depth traversed by the roots was 5.56 cm and their horizontal spread was 6.70 cm. The average number of lateral roots was four. They had an average length of 0.99 cm. The average number of green leaf present was two.

Phoenix had an average number of four roots (Fig. 32) having an average length of 23cm and an average diameter of 0.34 cm. The depth traversed by these roots was 10.98 cm and their horizontal spread was 18 cm. The laterals originated from a point of 2.30 cm below the origin of the main roots. The average number of laterals was five with an average length of 0.76 cm. The average number of green leaf present was three.

The average number of root was more in *Phoenix*. They had more lateral roots also. But the laterals were formed in *Arenga* at a lower point. *Phoenix* had more root depth and spread. The length and diameter of the root were also more in *Phoenix*.

After 20 months

Arenga had an average of four roots. The average length of these roots was 10.72 cm and the average diameter was 0.13 cm. The minimum length of the root that produced laterals was 4 cm. The average depth of the soil occupied by the root was 9.46 cm. The peripheral roots had a horizontal spread of 11.24 cm. The average number of laterals was 11. Their average length was 0.71 cm. The average number of green leaves was two.

The average number of roots in *Phoenix* was four. The average depth of the soil occupied by the root was 8.46 cm and their horizontal spread was 11.60 cm. The average length of the root was 10.80 cm. The average number of laterals was three. They had an average length of 1.02 cm.

The average number of roots was more in *Phoenix*. But the number of root lets was more in *Arenga*. *Arenga* form laterals on main roots with a minimum length. *Arenga* root had more length while the diameter was more for *Phoenix* roots.

After 22 months

The average number of roots in *Arenga* was four. Their average length was 10.12 cm and average diameter was 0.2 cm. The main roots formed laterals at a length of 1 cm. The average number of laterals was seven. They had an average length of 1.02 cm. The depth traversed by the roots was 6.01 cm and their horizontal spread was 11.24 cm. The average number of green leaves present was three.

The average number of roots in *Phoenix* was five. They had an average length of 15.45 cm and an average diameter of 0.24 cm. These roots had a depth of 15.20 cm and their horizontal spread was 14.40 cm. The average number of laterals was four. They had the average length of 1.17 cm. The average number of green leaves present was four.

The average number of root was high in *Phoenix* but the average number of laterals was more in *Arenga*. The average root length was more in *Phoenix*. The average diameter was also same. *Arenga* formed laterals at a length of 1 cm. The depth and horizontal spread were also high in *Phoenix*.

After 24 months

Arenga had an average number of four roots. Their average length was 10.30 cm. They had an average diameter of 0.13 cm. Laterals produced at a length of 1.70 cm. The average depth traversed by the roots was 5.44 cm and had a horizontal spread of 15.80 cm. The average number of laterals was 19 and had an average length of 0.49 cm. The average number of leaves was two.

Phoenix had an average number of four roots with an average length of 16 cm and an average diameter of 0.29 cm. The minimum length required for the root to form laterals was 8 cm. The depth of the soil occupied by the root was 14.28 cm and their horizontal spread was 10.60 cm. The average number of laterals was three with an average length of 1.16 cm. The average number of green leaves present was three.

The average number of main root was more in *Phoenix* but the average number of laterals was more in *Arenga*. The average length and diameter were high in *Phoenix*. But

Arenga formed laterals at a lower level. The depth and horizontal spread of the root were also high in *Phoenix*.

After 26 months

The average number of roots in *Arenga* was three. They had an average length of 6.68 cm (Fig. 33) and average diameter of 0.14 cm. The average depth traversed by the roots was 5.44 cm and had a horizontal spread of 7.48 cm. The minimum length required for these roots to form the laterals was 1.20 cm. Their average number was three and average length was 1.34 cm. The average number of green leaves present was three.

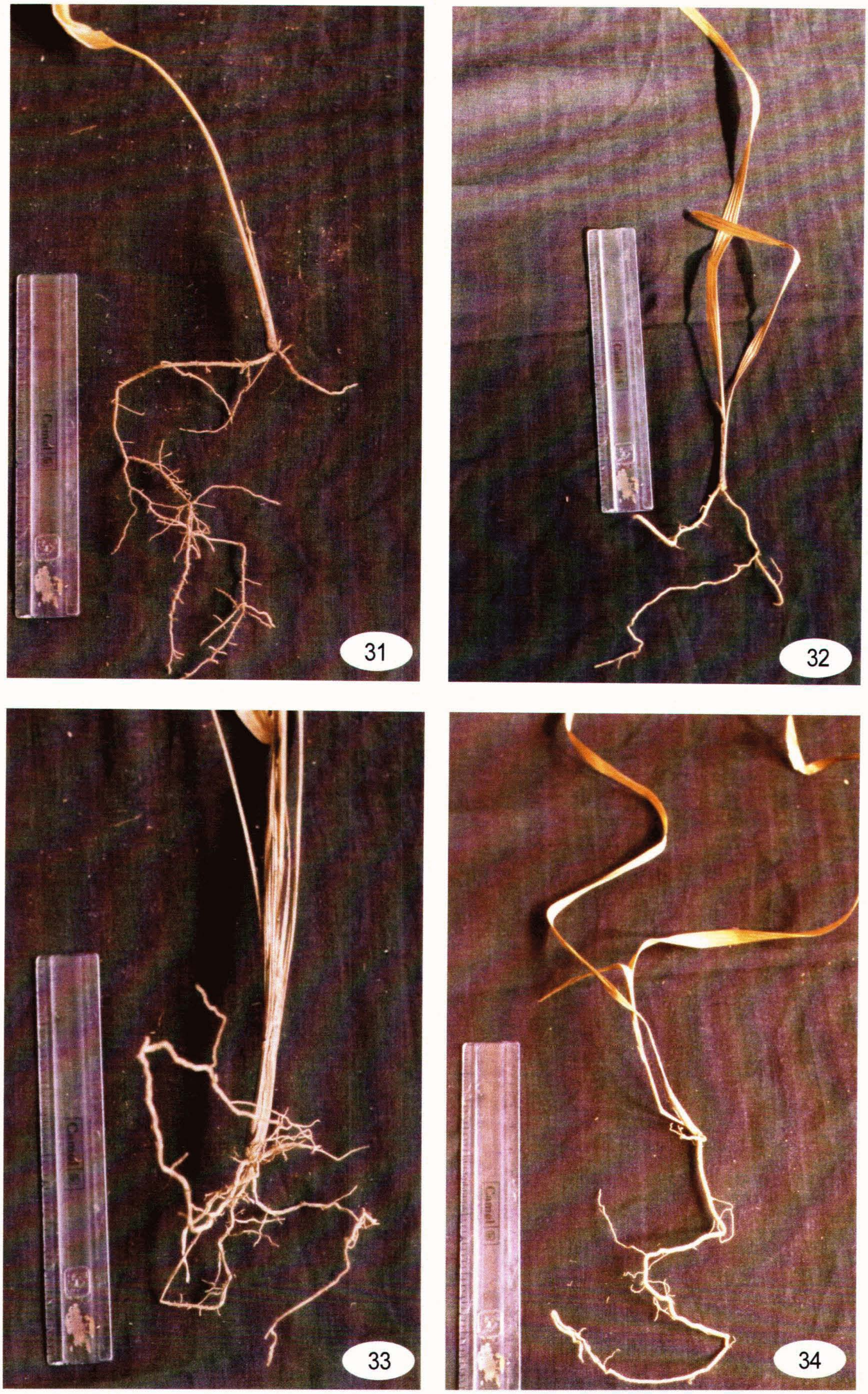
Phoenix had an average number of six roots. The depth traversed by these roots was 9.77 cm (Fig. 34) and their horizontal spread was 15 cm. The average length of the roots was 16 cm and. The average number of laterals was four with an average length of 1.25 cm. The average number of green leaves was three.

Phoenix had high number of main roots and lateral roots. The length and diameter of roots and laterals were high in *Phoenix*. The depth and horizontal spread of roots were also high in *Phoenix*.

After 28 months

Arenga had an average number of six roots with an average length of 10.10 cm and average diameter of 0.13 cm. The average depth of the soil occupied by the main roots was 6.29 cm and the horizontal spread was 12.50 cm. The average number of lateral roots was five. Their average length was 0.72 cm. The average number of green leaves was three.

Phoenix had an average number of five roots with an average length of 14.20 cm and average diameter of 0.25 cm. The average depth of the soil occupied by the main roots was 8.38 cm and a horizontal spread of 12.20 cm. The average number of laterals was two. They had 1.08 cm of average length. The average number of green leaves was two.



Figs. 31-34. Growth of roots after 18 and 26 months

Figs. 31 & 33. *Arenga wightii* roots after 18 and 26 months

Figs. 32 & 34. *Phoenix loureirii* var. *humilis* roots after 18 and 26 months

Phoenix showed more main roots but the laterals were more in *Arenga*. Their depth and horizontal spread were more in *Phoenix* while the roots of *Arenga* form more laterals with minimum length. The average length and diameter were also high in *Phoenix*.

After 30 months

The average number of roots in *Arenga* was five. They had an average length of 12.82 cm and an average diameter of 0.13 cm. The depth of the soil occupied the root was 7.39 cm with a horizontal spread of 9.32 cm. The average number of lateral roots was five with an average length of 0.95 cm. The average number of leaves present was four.

The average number of roots in *Phoenix* was five. They formed the lateral roots often length of 2 cm. The vertical distance traversed by the root system in the soil was 15.48 cm and their horizontal spread was 17.60 cm. The average length of the main root was 17.40 cm and average diameter was 0.28 cm. They form an average of five lateral roots. Their average length was 1.35. The average number of green leaf was three.

Phoenix had more number of roots. But the number of laterals was more in *Arenga*. The depth and horizontal spread were more in *Phoenix*. The average root length and root diameter were also more in *Phoenix*.

After 32 months

The average number of roots in *Arenga* was five. Their average length was 13.90 cm and average diameter was 0.14 cm. The depth of the soil occupied by the root was 6.64 cm with a horizontal spread of 11.80 cm. They formed lateral roots at a minimum length of 2.10 cm. The average number of lateral roots was four with an average length of 0.95. The average number of green leaves was four.

Phoenix had an average number of seven main roots. The depth of the soil occupied the root was 13.44 cm with a horizontal spread of 20.20 cm. They had an average length of 18.60

cm and average diameter of 0.39 cm. The average number of laterals was three with an average length of 1.51 cm. They had an average number of three green leaves.

More main roots were seen in *Phoenix* but the number of laterals was more in *Arenga*. The roots of *Phoenix* had more length and diameter. The average horizontal and vertical length was also more in *Phoenix*. But the roots of *Arenga* formed laterals at a short distance from the point of origin of the main roots.

After 34 months

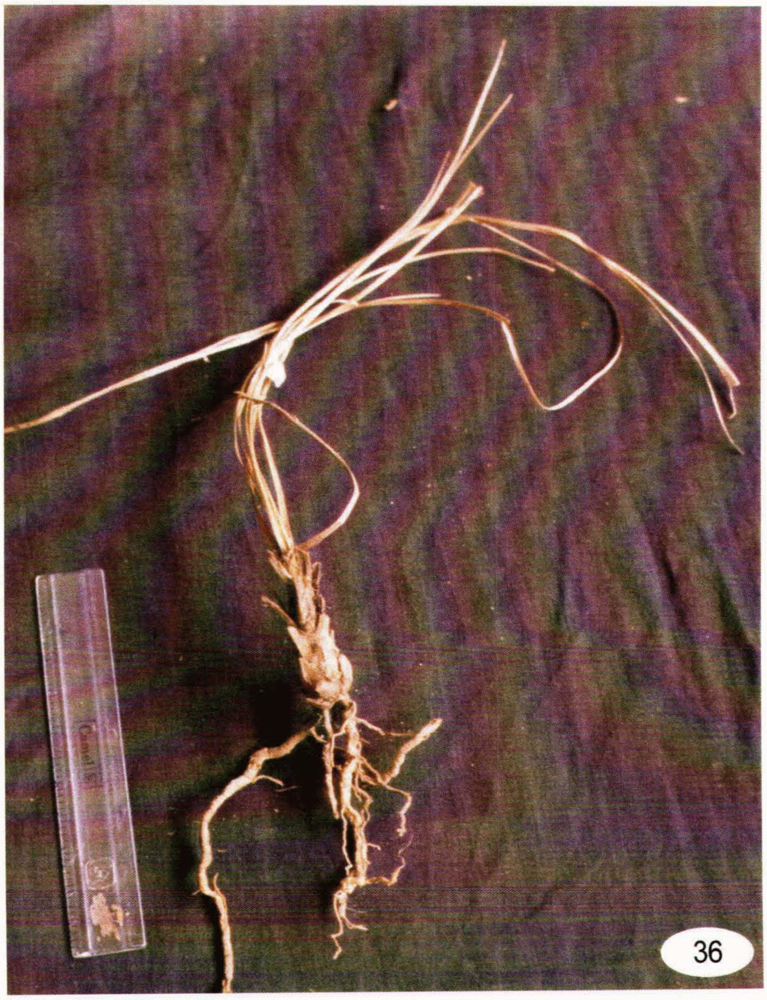
The average number of roots in *Arenga* was eight. The average length of these roots was 12.18 cm (Fig. 35) and average diameter was 0.15 cm. The depth of the soil occupied the roots was 7.75 cm with a horizontal spread of 17.12 cm. The average number of laterals was 7 with an average length of 0.70 cm. The average number of green leaves present was four.

Phoenix had an average number of five roots (Fig. 36). The depth of the soil occupied the root was 13.28 cm with a horizontal spread of 15.20 cm. These roots had an average length of 15 cm and an average diameter of 0.29 cm. The average number of laterals was three. Their average length was 1.35 cm. The average number of green leaves was three.

Arenga had more roots and rootlets. The average length and diameter of the roots were more in *Phoenix*. The average depth was more in *Phoenix* but the average horizontal spread was more in *Arenga*.

After 36 months

Arenga had an average number of six roots. These roots had an average length of 14 cm and average diameter of 0.13 cm. The depth of the soil occupied by the roots was 8.22 cm with a horizontal spread of 17.20 cm. The average number of laterals was four with an average length of 0.60 cm. They had an average of five leaves.



Growth of roots after 34 months

Fig. 35. *Arenga wightii*

Fig. 36. *Phoenix loureirii* var. *humilis*

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Phoenix had an average of five roots. The depth of the soil occupied the roots was 14.68 cm with a horizontal spread of 18 cm. The average length of the roots was 18.60 cm and average diameter was 0.47 cm. The average number of laterals was four and had an average length of 1.30 cm.

Arenga had more main roots when compared to *Phoenix*. But the average number of laterals was more in *Phoenix*. The horizontal and vertical length of the roots was more in *Phoenix*. The minimum length for lateral root formation was less in *Arenga*. The length and diameter of roots were more in *Phoenix*.

RESULTS

P. K. Padmakumar "Developmental morphology in relation to conservation in the family palmae (arecaceae)" Thesis. Department of Botany , University of Calicut, 2003

Chapter 5.

RESULTS

10

RESULTS

SHOOT MORPHOLOGICAL STUDIES (s. l.)

Arenga wightii Griff.

Population dynamics at three-months intervals

The population dynamics of *Arenga wightii* in plots 1-6 were shown in the Table 67 at 3-months interval. The results revealed that in all the 6 plots seedlings were the major component in the population. The second component changed from plot to plot.

In plot 1 and 2, juveniles were the second largest and adults, the third. In the third and sixth plots, adults and juveniles were equal in number. In plots 4 and 5 adults were the second followed by juveniles. The characteristic features were maintained throughout the study period. In all the plots seedlings showed an increase in number during the study period. The juveniles maintained the same number except in plot 2 where it decreased. The total number of plants in all the plots also showed an increase.

In all the plots the number of adults remained same throughout the period. In plots 1, 3, 4, 5 and 6 in the study period (33 months) the seedlings increased in number and juveniles remained without change. In plot 2 the seedlings increased in number while the juveniles decreased.

Table 67. Population dynamics at 3-months intervals

Location	Plots	Months	No. of Seedlings	No. of Juveniles	No. of Adults	Total No. of Plants
Ambayathode	1	0	105	2	1	108
		3	105	2	1	108
		6	105	2	1	108
		9	108	2	1	111
		12	108	2	1	111
		15	108	2	1	111
		18	108	2	1	111
		21	110	2	1	113
		24	110	2	1	113

Location	Plots	Months	No. of Seedlings	No. of Juveniles	No. of Adults	Total No. of Plants
Ambayathode		27	110	2	1	113
		30	112	2	1	115
		33	110	2	1	113
	2	0	83	7	1	91
		3	83	7	1	91
		6	83	7	1	91
		9	85	7	1	93
		12	86	7	1	94
		15	86	7	1	94
		18	87	7	1	95
		21	87	7	1	95
		24	86	7	1	94
		27	86	7	1	94
		30	87	7	1	95
		33	86	6	1	93
	3	0	27	1	1	29
		3	27	1	1	29
		6	27	1	1	29
		9	28	1	1	30
		12	28	1	1	30
		15	29	1	1	31
		18	28	1	1	30
		21	28	1	1	30
		24	28	1	1	30
		27	28	1	1	30
		30	30	1	1	32
		33	29	1	1	31
Pullupara	4	0	23	2	5	30
		3	23	2	5	30
		6	23	2	5	30
		9	24	2	5	31
		12	25	2	5	32
		15	26	2	5	33
		18	26	2	5	33
		21	26	2	5	33
		24	26	2	5	33
		27	26	2	5	33
		30	28	2	5	35
		33	28	2	5	35

Location	Plots	Months	No. of Seedlings	No. of Juveniles	No. of Adults	Total No. of Plants
Pullupara	5	0	25	1	4	30
		3	25	1	4	30
		6	25	1	4	30
		9	26	1	4	31
		12	27	1	4	32
		15	29	1	4	34
		18	29	1	4	34
		21	29	1	4	34
		24	29	1	4	34
		27	29	1	4	34
		30	31	1	4	36
		33	27	1	4	32
	6	0	17	2	2	21
		3	17	2	2	21
		6	17	2	2	21
		9	18	2	2	22
		12	19	2	2	23
		15	20	2	2	24
		18	20	2	2	24
		21	20	2	2	24
		24	20	2	2	24
		27	20	2	2	24
		30	20	2	2	24
		33	20	2	2	24

Rate of recruitment and death

The rate of recruitment and death was shown in Table 68. In plot 1, new recruitments were observed after 9, 21 and 30 months of observation. In plot 2, new recruitments were observed after 9, 12, 18 and 30 months. In plot 3, new recruitments were seen after the months of 9, 15 and 30 while in plots 4, 5 and 6 the new recruitments were noted after 9, 12, 15 and 30 months.

The deaths were noted in the observation after 15 (plot 6), 18 (plot 3), 24 (plot 2), 30 (plots 2, 4 and 6), 33 (plots 1, 2, 3 and 5) months.

Table 68. Rate of recruitment and death

Plot	Month	No. of new recruits	Recruitment rate per 3 months	No. of deaths	Death rate per 3 months (%)
1	3	0	0.0	0	0.0
	6	0	0.0	0	0.0
	9	3	2.7	0	0.0
	12	0	0.0	0	0.0
	15	0	0.0	0	0.0
	18	0	0.0	0	0.0
	21	2	1.8	0	0.0
	24	0	0.0	0	0.0
	27	0	0.0	0	0.0
	30	2	1.7	0	0.0
	33	0	0.0	2	1.8
2	3	0	0.0	0	0.0
	6	0	0.0	0	0.0
	9	2	2.2	0	0.0
	12	1	1.1	0	0.0
	15	0	0.0	0	0.0
	18	1	1.1	0	0.0
	21	0	0.0	0	0.0
	24	0	0.0	1	1.1
	27	0	0.0	0	0.0
	30	2	2.1	1	1.1
	33	0	0.0	2	2.2
3	3	0	0.0	0	0.0
	6	0	0.0	0	0.0
	9	1	3.3	0	0.0
	12	0	0.0	0	0.0
	15	1	3.2	0	0.0
	18	0	0.0	1	3.3
	21	0	0.0	0	0.0
	24	0	0.0	0	0.0
	27	0	0.0	0	0.0
	30	2	6.3	0	0.0
	33	0	0.0	1	3.2
4	3	0	0.0	0	0.0
	6	0	0.0	0	0.0
	9	1	3.2	0	0.0
	12	1	3.1	0	0.0
	15	1	3.0	0	0.0
	18	0	0.0	0	0.0

Plot	Month	No. of new recruits	Recruitment rate per 3 months	No. of deaths	Death rate per 3 months (%)
	21	0	0.0	0	0.0
	24	0	0.0	0	0.0
	27	0	0.0	0	0.0
	30	3	8.6	1	2.9
	33	0	0.0	0	0.0
5	3	0	0.0	0	0.0
	6	0	0.0	0	0.0
	9	1	3.2	0	0.0
	12	1	3.1	0	0.0
	15	2	5.9	0	0.0
	18	0	0.0	0	0.0
	21	0	0.0	0	0.0
	24	0	0.0	0	0.0
	27	0	0.0	0	0.0
	30	2	5.6	0	0.0
	33	0	0.0	4	12.5
6	3	0	0.0	0	0.0
	6	0	0.0	0	0.0
	9	1	4.5	0	0.0
	12	1	4.3	0	0.0
	15	2	8.3	1	4.2
	18	0	0.0	0	0.0
	21	0	0.0	0	0.0
	24	0	0.0	0	0.0
	27	0	0.0	0	0.0
	30	2	8.3	2	8.3
	33	0	0.0	0	0.0

Seasonal variation in recruitment and death

The graphical representation of the new recruitment in different plots at different observations indicated that eventhough recruitment was not restricted to specific periods, the maximum recruitment was seen at certain months (Fig.37) of the year.

The death in different plots was not restricted to particular period. The period of death varied in different plots. In the same plot itself the period was varying (Fig. 38).

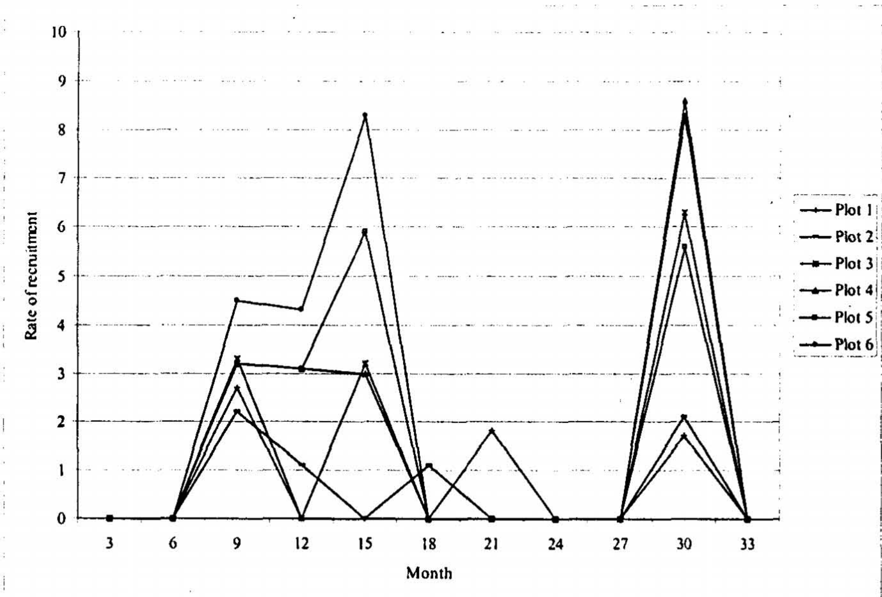

Fig. 37. Seasonal variation in recruitment

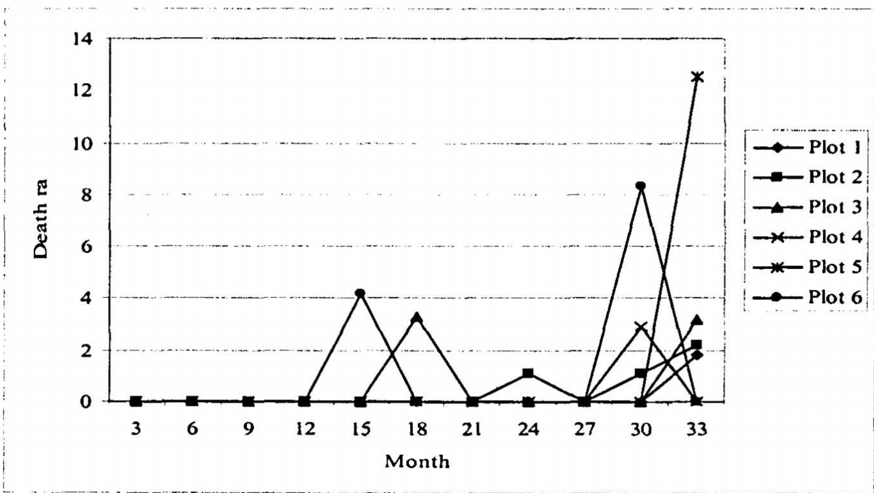

Fig. 38. Seasonal variation in death

Regression

In order to find out the trends in total number of seedlings from time to time, equations were developed with the total number of seedlings as dependent variable and months as independent variable. Result of analysis showed a linear trend in all the plots (Table 69), where 'y' is the total number of plants and 'X' is the time (month) of observation

Table 69. Regression analysis

Plot	Functional form	adj. R2
1	Y = 108+0.197 X	0.857
2	Y = 91.641+0.103 X	0.508
3	Y=29.026+0.0641 X	0.593
4	Y=29.756+0.156 X	0.906
5	Y=30.179+0.146 X	0.608
6	Y=21.192+0.110 X	0.772

The regression equation of plot1 indicated that the rate of change in number of seedling from year to year was 0.197. 85 percent of variation in numbers of seedlings was explained by the regression equation. The variation was due to the independence variable factor increase in months. This data indicated that there was no increase in the number of seedling happened in this plot on a yearly basis. It will take six years for an increase. In plot 2 it was 0.103 which was a very low value. 50 percent of variation in numbers of seedlings was explained by the regression equation. The variation was due to the independence variable factor increase in months.

In plot 3 it was 0.0641 which indicated that no new recruitment will took place in the plot. 59 percent of variation in numbers of seedlings was explained by the regression equation. The variation was due to the independence variable factor increase in months. In plot 4 the value was 0.156 and in plot 5 it was 0.146. In plot 4, 90 percent of variation in numbers of seedlings was explained by the regression equation and in plot 5, 60 percent of variation in numbers of seedlings was explained. The variation was due to the independent variable factor increase in months. In plot 6 rate of change of seedlings was 0.110 and 77 percent of variation in numbers of seedlings was explained. The variation was due to the independent variable factor increase in months.

From the above data it was clear that no new seedling arise in the plots in a stable sage. For this it will take a very long time.

Population flux for the first year

In plot 1, the number of plants in the plot at the time of first measurement was 108 (Table 70). After one year there were 111 plants in the plot. The net change in number for the year was 3. The rate of increase was 1.03. The number of arrivals during the year was 3 and the mortality rate was zero. The total number of plants recorded after 3 years was 111. The percentage of death for the period was zero. The percentage of annual recruitment for first year was 2.70.

In plot 2, there were 91 plants in the first observation and after one year, 94 plants. Net change in number was 3. Rate of increase was 1.03. The total number of plants during the period was 94. The percentage of death was zero. The percentage of annual recruitment in the plot was 3.19.

Table 70. Population flux for the first year

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
a. No. of plants in initial measurement	108	91	29	30	30	21
b. No. of plants in final measurement	111	94	30	32	32	23
c. Net change (*b-a*)	3	3	1	2	2	2
d. Rate of increase (*b/a*)	1.03	1.03	1.03	1.07	1.07	1.10
e. Total new arrivals	3	3	0	2	2	2
f. Total mortality	0	0	0	0	0	0
g. Total plants recorded	111	94	30	32	32	23
h. percentage of annual death	0.00	0.00	0.00	0.00	0.00	0.00
i. Percentage of annual recruitment	2.70	3.19	0.00	6.25	6.25	8.70

In plot 3, the total number of plants in the initial measurement was 29. After one year it increased to 30. Net change in number was one. The rate of increase was 1.03. There were no new arrivals in the plot during the year and the mortality was zero. The total number of plant during the year was 30. The percentage of annual death was zero and the percentage of annual recruitment was also zero.

In plot 4, 30 plants were present in the 1st observation and it increased to 32 after one year. The net change was two. The rate of increase was 1.07. There were two new arrivals in the plot during the year and the number of deaths was zero. The total number of plants during period was 32. The percentage of annual deaths was zero and the annual recruitment percentage was 6.25. The annual percentage of recruitment was high in this plot.

In plot 5, 30 plants were present in the first observation. After one year 32 plants were present. The net change in number was two. The rate of increase was 1.07. The number of new arrival for the first year was two and the number of death was zero. The total number of plants during period was 32. The annual death percentage was zero and the annual percentage of new recruitment was 6.25. This plot also showed a high percentage of the annual recruitment.

In plot 6, there were 21 plants at the time of first observation. After one year the total number of plants increased to 23. The net change in number was two. The rate of increase was 1.10. There were two new arrivals and no death during the time. The total plants recorded were 23. The annual percentage of death was zero and the percentage of recruitment was eight. This was the maximum among the 6 plots during the study period.

Population flux for the second year

In plot 1, there were 111 plants in the first observation (Table 71). There were 113 plants in the plot at the end of 2nd year. The net change in number was two. The rate of increase was 1.02. The number of new arrivals was two. There was no death at this time. The total number of plant during the period was 113. The percentage of annual death was zero and the percentage of annual recruitment was 1.77.

Table 71. Population flux for the second year

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
a. No. of plants in initial measurement	111	94	30	32	32	23
b. No. of plants in final measurement	113	94	30	33	34	24
c. Net change (*b-a*)	2	0	0	1	2	1
d. Rate of increase (*b/a*)	1.02	1.00	1.00	1.03	1.06	1.04
e. Total new arrivals	2	1	1	1	2	2
f. Total mortality	0	1	1	0	0	1
g. Total plants recorded	113	95	31	33	34	25
h. percentage of annual death	0.00	1.05	3.23	0.00	0.00	4.00
i. Percentage of annual recruitment	1.77	1.05	3.23	3.03	5.88	8.00

In plot 2, 94 plants were there in the plot at the time of first observation in the second year. In the last observation also after one year, there were 94 plants. The net change in number was zero. The rate of increase was one. There was one new arrival and one death during the period. The total plants recorded were 95. The percentage of annual death and annual recruitments were 1.05 each. Here the death and recruitment during the period was same.

In plot 3, in the initial observation there were 30 plants in the plot. In the final observation the no. of plants was same. So the net change in number of plants was zero. The rate of increase in number was one. There was a new arrival and the number of death noted during this period was also one. The total number of plants was 31. The percentage of annual death was 3.23. The percentage of new recruitment was also 3.23. Here the death percentage and recruitment percentage were same.

In plot 4, the observation in the plot starts with 32 plants. After one year the number was 33. The net change in number was one. The rate of increase was 1.03. There was a single new arrival in the plot. The number of death was zero. The total plants were 33. The percentage of annual death was zero. The percentage of annual recruitment was 3.03.

In plot 5, the plot had 32 plants at the time of first observation in the second year. The number of plants in the plot at the time of final observation was 34. The net change in number was two. The rate of increase was 1.06. The number of new arrival was two. No death was reported during period. The total number of plants recorded was 34. The percentage of annual death was zero and the percentage of annual recruitment was 5.88. Here a high rate of recruitment was observed.

In plot 6, there were 23 plants in the plot 6 at the time of initial measurement of second year. The total number of plants in the plot at the final observation was 24. The net change in number was one. The rate of increase in number was 1.04. There were two new arrivals in the plot. The number of deaths reported was one. The total number of plants was 25. The percentage of annual was 4.00 and the percentage of annual recruitment was 8.00. Here also the rate of recruitment was high.

Population flux for the third year

In plot 1, there were 113 plants in this plot at first observation in last year (Table 72). No change in number in this year. The rate of increase in the number in this plot was one. There were two new arrivals during the period and the number of death was also two. The total number of plants recorded was115. The percentage of annual recruitment was 1.74.

Table 72. Population flux for the third year

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
a. No. of plants in initial measurement	113	94	30	33	34	24
b. No. of plants in final measurement	113	93	31	35	32	24
c. Net change (*b-a*)	0	-1	1	2	-2	0
d. Rate of increase (*b/a*)	1.00	0.99	1.03	1.06	0.94	1.00
e. Total new arrivals	2	2	2	3	2	2
f. Total mortality	2	3	1	1	4	2
g. Total plants recorded	115	96	32	36	36	26
h. percentage of annual death	1.74	3.13	3.13	2.78	11.11	7.69
i. Percentage of annual recruitment	1.74	2.08	6.25	8.33	5.56	7.69

In plot 2, the number of plants in this plot was 93. Net change in number was –1. Rate of increase in number of plants was -0.99. The number of arrivals during period was two. But the death noted was three. The total number of plants recorded was 96. The percentage of annual death was 3.13 and the percentage of annual recruitment was 2.08. Here the percentage of annual death exceeded the annual recruitment.

In plot 3, there were 30 plants at the initial measurement in the last year. The number of plants at the time of final observation was 31. The net change in number was one. The rate of increase was 1.03. There were two new arrivals in the plot. The number of death noted was one. The total number of plants was 32. The percentage of annual death was 3.13 and the percentage of annual recruitment was 6.25. In this plot the percentage of annual recruitment exceeded the annual death.

In plot 4, at the time of first observation 33 plants were present. In the last observation there were 35 plants. So the net change in number was two. The rate of increase of plants was 1.06. There were three new arrivals and one death during the period. The total number of plants recorded was 36. The percentage of annual death was 2.78 and percentage of annual recruitment was 8.33 Here also the rate of new recruitment exceeded the rate of death.

In plot 5, at the time of initial observation there were 34 plants and in the final observation 32 plants were present. The net change in number was –2. The rate of increase was -0.94. There were two new arrivals and 4 deaths during the period. Total number of plants recorded was 36. The annual percentage of death was 11.11 and the annual percentage of recruitment was 5.56. Here the annual percentage of death exceeded the percentage of recruitment.

In plot 6, there were 24 plants in the plot at the time of initial measurement. The number of plants at the time of final observation was 24. Net change in number was zero. Rate of increase in number was one. There were two new arrivals and 2 deaths during the period. The total number of plants recorded was 26. The percentage of annual death was 7.69 and the percentage of annual recruitment was 7.69. Here the percentage of recruitment and death were equal.

Population flux for three years

In plot 1, the total number of plants in the initial measurement was 108 (Table 73). After three years it was 113. The net change was five. The rate of increase was 1.05. There were seven new arrivals. The number of death noted during the period was two. The total number of plants recorded was 115. Mortality rate was 1.74. Here the rate of increase was more than one and the percentage of recruitment exceeded the mortality.

Table 73. Population flux for three years

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
a. No. of plants in initial measurement	108	91	29	30	30	21
b. No. of plants in final measurement	113	93	31	35	32	24
c. Net change (*b-a*)	5	2	2	5	2	3
d. Rate of increase (*b/a*)	1.05	1.02	1.07	1.17	1.07	1.14
e. Total new arrivals	7	6	4	6	6	6
f. Total mortality	2	4	2	1	4	3
g. Total plants recorded	115	97	33	36	36	27
h. percentage of death	1.74	4.12	6.06	2.78	11.11	11.11
i. Percentage of recruitment	6.09	6.19	12.12	16.67	16.67	22.22

In plot 2, the total number of plants in the initial observation was 91. There were 93 plants in the plot after three years. The net change in number was two. The rate of increase in number was 1.02. The number of new plants was six and number of deaths was four. The total number of plants was 97. The percentage of death was 4.12 and the percentage of recruitment was 6.19. Here also the rate of increase of plants was more than one. The percentage of recruitment exceeded the percentage of death.

In plot 3, the total number of plants in the first measurement was 29. There were 31 after three years. The net change in number was two. The rate of increase was 1.07. The number of new arrivals was four and the deaths noted were two. The total number of plants was 33. The percentage of death was 6.06 and percentage of new recruitment was 12.12. Here also the rate of increase of plants was more than one. The percentage of recruitment exceeded the percentage of death.

In plot 4, there were 30 plants in the initial measurement. It was changed to 35 in the last year. Here change in number was five. The rate of increase was 1.17. The number of new arrivals was 6 and number of total death was one. The total number of plants recorded was 36. The percentage of death was 2.78 and the percentage of new recruitment was 16.67. Here also the rate of increase of plants was more than one. Here the difference in percentage of recruitment and percentage of death was high.

In plot 5, there were 30 plants at the time of first observation. The number of plants was 32 in the final measurement. The net change in number was two. The rate of increase was 1.07. There were six new arrivals and the death noted was 4. The total number of plants was 36. The percentage of death was 11.11 and the percentage of recruitment was 16.67. In this plot also, the rate of increase of plants was more than one. The percentage of recruitment exceeded the percentage of death.

In plot 6, there were 21 plants in the first year. It had changed to 24 in the final observation. The net change in number was three. The rate of increase was 1.14. The total number of plants was 27. The number of new recruits was six and the number of death was three. The percentage of death was 11.11 and the percentage of recruitment was 22.22. Here also the rate of increase of plants was higher than one. The percentage of recruitment exceeded the percentage of death.

Death and recruitment in different plots

The percentage of recruitment in all the plots exceeded the percentage of death (Fig. 39).

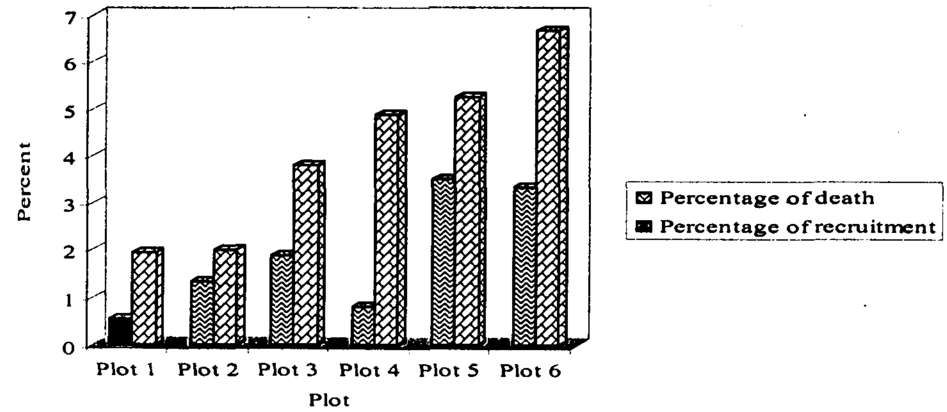

Fig. 39. Death and recruitment in different plots

The maximum percentage difference was noticed in plot 4 and the minimum in plots 2 and 5. But this cannot be considered as the only indicator for assuming that the population of *Arenga* was a stable one.

Percentage of seedlings in the population

The percentage of seedlings was similar in all plots (Fig. 40).

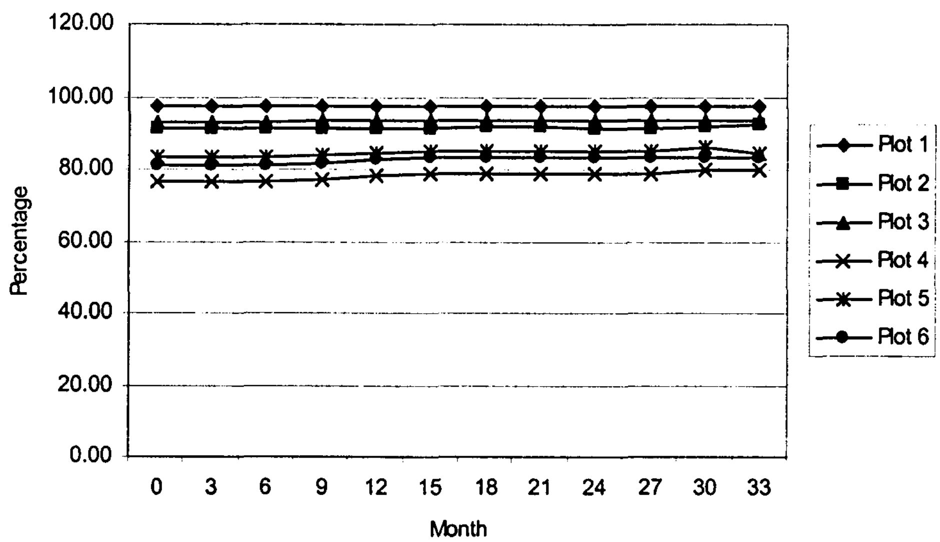

Fig. 40. Percentage contribution of seedlings in different plots

Slight variation in graph was due to the change in number of plants due to new recruitments and death during the different observations. Percentage contribution was maximum in plot 1 (97.39%) after 30 months of observation and minimum in plot 4 (76.67%) after the first observation.

Percentage of juveniles in the population

The graph showed a downward curve in plot 3 which was very significant (Fig. 41). This was due to the death of juveniles. The other slight variation noticed in other plots was not due to variation in the number of juveniles but due to the variation in percentage of seedlings in the plot. Percentage contribution was maximum in plot 6 (9.52%) after first month, 3 and 6 months of observation and minimum in plot 1 (1.74%) in observations after first month, 3 and 6 months.

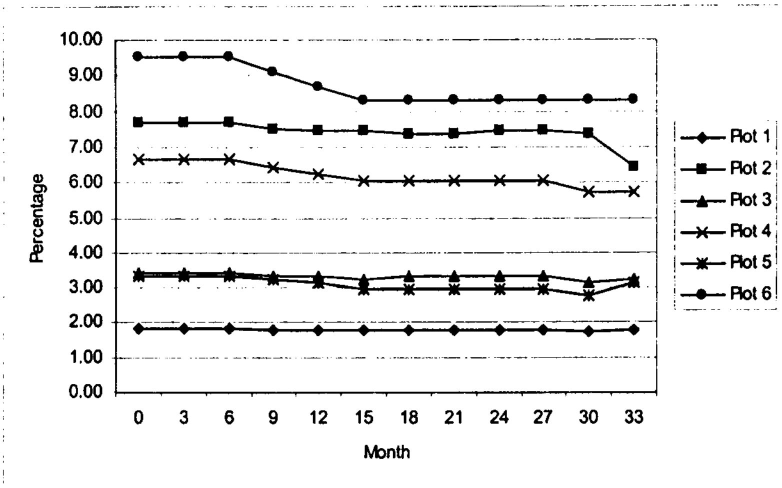

Fig. 41. Percentage contribution of juveniles in different plots

Percentage of adults in the population

The percentage contribution of adult plants in all the plots showed a similar pattern (Fig. 42). The number of adults in the plots did not change during the study period. Slight curve in the graph was due to the change in number of seedlings due to death and new recruitment at various observations which caused the percentage change in the adults. Percentage contribution was maximum in plot 4 (16.67%) after first, third and sixth months and minimum in plot 1 (0.08%) after 30 months.

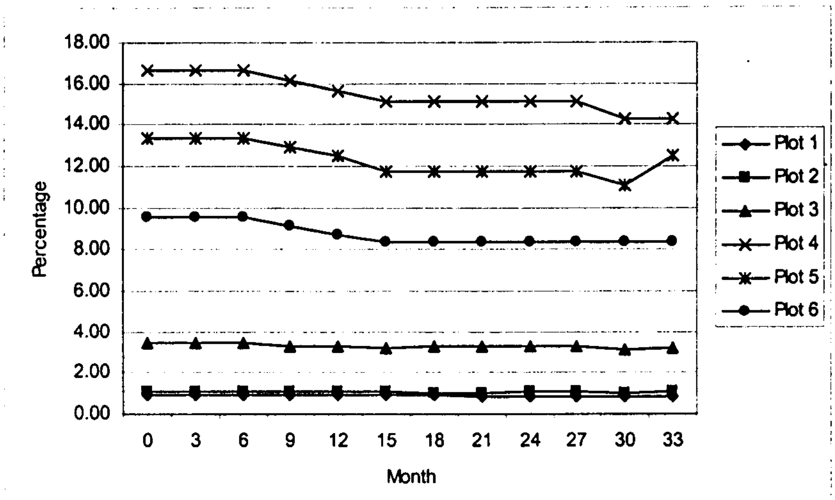

Fig. 42. Percentage contribution of adults in different plots

Comparison of three groups among the population

The seedling population was the major group in all the observations in all plots. Their percentage was very high when compared with that of the other two groups (Fig. 43). The percentage of seedlings showed slight variation in consecutive observations. It was due to the new recruitment and death happened in the plots. The number of adults remained constant in all the observations. So the variation in percentage was not expected but the recruitment and death occurred to the seedlings made slight change in the total number of plants in the plot and it caused slight percentage variation in adult plants. The juvenile plants were also very less in percentage which contributed less to the total population. The percentage variation was due to the death and again the change in number of seedlings caused variation in the percentage of the juveniles.

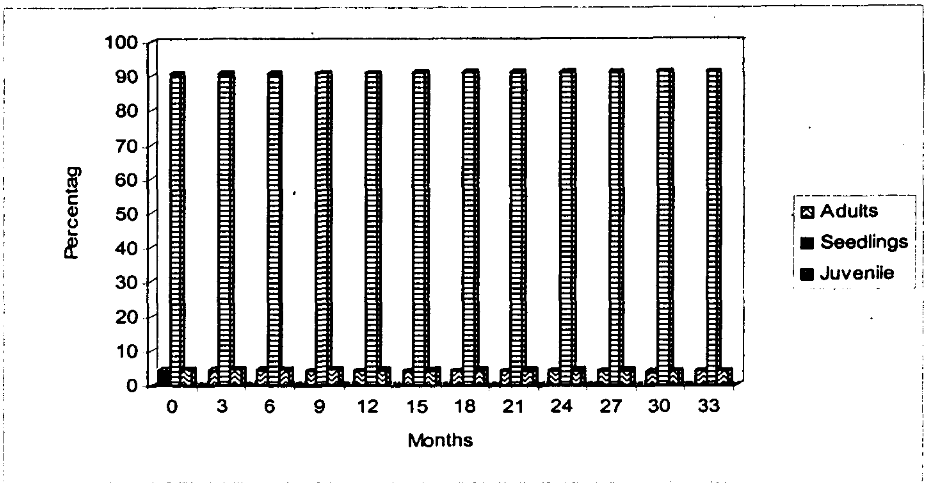

Fig. 43. The percentage of different categories in the whole population

Age group distribution

The yearly increase in height in different groups of *Arenga* showed variations (Table 74). In the seedlings all the plants were without stem. The longevity of trunkless period was 10 years. The juveniles showed variation in increase. Maximum increase was in plot 1 (2.91 cm). In plot 2 it was 2.10 cm and in plot 3, 0.78 cm. In plot 4 it was 1.27 cm, in plot 5, 2.18 cm and in plot 6, 1.48 cm. The average increase in height among juveniles was 1.93 cm.

Table 74. Average increase in height in each stage (cm)

Plot No.	Height increase of stem (cm)		
	Seedlings	Juveniles	Adults
1	0	2.91	3.64
2	0	2.10	4.36
3	0	0.78	1.45
4	0	1.27	2.62
5	0	2.18	1.55
6	0	1.48	1.27
Grand Total	0	1.93	2.23

This variation was seen in adults also. The increase in height was maximum in plot 2 (4.36 cm). The minimum increase in height was noted in plot 6 (1.27 cm). The average increase in height among the adults was 2.23 cm.

The distribution of different age groups of *Arenga* in different plots were calculated which also showed certain variations (Table 75). In the plot 1 age of 105 seedlings were calculated, of which 99 of them were below 10 years. Six were in the age group of 10-20 years. Two of the juveniles in the plot were between 10-20 years and the adults in the plot had an age above 40 years.

In plot 2, the age of 82 seedlings was calculated. 74 of them were below 10 years. Eight were in the age group of 10-20 years. There were six juveniles in the plot in the age group of 30-40 years. The adult plants in the plot were 30-40 years old.

The age of 27 seedlings in the plot 3 was calculated. 20 of them were below 10 years. Seven were between 10-20 years. One of the juveniles in the plot was between 10-20 years and the adult plant in the plot was in the age group of 30-40 years.

In plot 4, the age of 23 seedlings was calculated. 16 of the seedlings were below 10 years. Seven were in the age between 10-20 years. Two of the juveniles were in the age group between 10-20 years. Among the five adult plants, one was between 20-30 years. Another one was 30-40 years and the remaining three adults were in the age group of above 40 years.

In plot 5, the age of 25 seedlings was calculated. 13 of them were below 10 years. Twelve were in the age group of 10 -20 years. The juvenile was in the age group of 30-40 years. The ages of four adult plants were calculated of which one was in the age group of 20-30 years, one was in the age group of 30-40 years and the remaining two are above 40 years of age.

The age of 17 seedlings was calculated in plot 6. 10 of the seedlings were in the age group of below 10 years and seven were of 10-20 years. The age of two juveniles were calculated. One juvenile was in the age group between 10-20 years and another between 30-

40 years. There were two adult plants in the plot of which one was between 30-40 years and another, above 40 years.

Table 75. Distribution of number of plants in different age groups

Plot No.	Stages	Age groups (years)				
		<10	10-20	20-30	30-40	>40
1	Seedlings	99	6			
	Juveniles		2			
	Adults					1
2	Seedlings	74	8			
	Juveniles		5		1	
	Adults				1	
3	Seedlings	20	7			
	Juveniles		1			
	Adults				1	
4	Seedlings	16	7			
	Juveniles		2			
	Adults			1	1	3
5	Seedlings	13	12			
	Juveniles					1
	Adults			1	1	2
6	Seedlings	10	7			
	Juveniles		1		1	
	Adults				1	1

***Phoenix loureiri* var. *humilis* S. Barrow**

Population dynamics at three-months intervals

The population dynamics analysis showed that in all the 6 plots of *Phoenix*, seedlings were the major group (Table 76). The second major group was adults and the third, juveniles. This pattern was observed in all plots.

The maximum variation in number was shown by seedling in all the plots. It was due to the new recruitment and deaths in all the plots. In plot 1, the number of seedlings showed an increase from the 9^{th} month and came to a maximum at 24^{th} month. Then it gradually decreased.

In plot 2 the number remained same up to the 9^{th} month and then increased and attained the maximum value at the 24^{th} month. Then the number decreased.

In plot 3 also the number of seedlings was constant up to the 6 months. Then an increase in 9th month and remained constant up to the 21st month. At 24th month it was maximum and then showed a decline in the successive observations.

In the first three observations the number of seedlings in the plot 4 remained the same. During 9th month it showed an increase and reached a maximum at 24th month. Their number decreased in the successive observations.

In plot 5, the number of seedlings remained same up to 6 months. In the 9th month the number increased and remained constant up to 21st month. In the 24th month again the number increased and from then onwards it decreased.

In plot 6 the number was same up to 6 months and then it decreased and remained constant up to 24 months. After that the number decreased again.

Table 76. Population dynamics at 3 months interval

Location	Plots	Months	No. of Seedlings	No. of Juveniles	No. of Adults	Total No. of Plants
Vallakadavu	1	0	24	6	11	41
		3	23	6	11	40
		6	23	5	11	39
		9	28	5	11	44
		12	28	5	11	44
		15	28	5	11	44
		18	28	5	11	44
		21	28	5	11	44
		24	31	5	11	47
		27	30	5	11	46
		30	28	5	11	44
		33	27	5	11	43
	2	0	27	6	10	43
		3	27	6	10	43
		6	27	6	10	43
		9	37	6	10	53
		12	37	6	10	53
		15	37	6	10	53
		18	37	6	10	53

Location	Plots	Months	No. of Seedlings	No. of Juveniles	No. of Adults	Total No. of Plants
Vallakadavu		21	37	6	10	53
		24	43	6	10	59
		27	41	6	10	57
		30	37	6	10	53
		33	37	5	9	51
	3	0	27	4	10	41
		3	27	4	10	41
		6	27	4	10	41
		9	32	4	10	46
		12	32	4	10	46
		15	32	4	10	46
		18	32	4	10	46
		21	32	4	10	46
		24	35	4	10	49
		27	34	4	10	48
		30	32	4	10	46
		33	32	4	10	46
Kuttikanam	4	0	34	5	11	50
		3	34	5	11	50
		6	34	5	11	50
		9	39	5	11	55
		12	39	5	11	55
		15	39	5	11	55
		18	39	5	11	55
		21	39	5	11	55
		24	41	5	11	57
		27	40	5	11	56
		30	38	5	11	54
		33	38	4	11	53
	5	0	33	4	14	51
		3	33	4	14	51
		6	33	4	14	51
		9	37	4	14	55
		12	37	4	14	55
		15	37	4	14	55
		18	37	4	14	55
		21	37	4	14	55
		24	40	4	14	58
		27	39	4	14	57
		30	37	4	14	55

Location	Plots	Months	No. of Seedlings	No. of Juveniles	No. of Adults	Total No. of Plants
Kuttikanam		33	37	4	14	55
	6	0	22	4	10	36
		3	22	4	10	36
		6	22	4	10	36
		9	21	4	10	35
		12	21	4	10	35
		15	21	4	10	35
		18	21	4	10	35
		21	21	4	10	35
		24	21	4	10	35
		27	20	4	10	34
		30	20	4	10	34
		33	20	4	10	34

When the adult plants were considered, in all the plots the number of plants remained the same. In all the observations, there was no death or new recruitment to this group during the three year period of observation.

Among juveniles the number remained same in all the three years of observations in plots 3, 4, 5 and 6. A decrease in number was observed in plot 1 in the 3rd observation. In plot 2 a decrease in number was noticed in the last observation. The decrease in number was due to the death. There was no conversion of seedlings to juveniles during the study period.

Rate of recruitment and death

The recruitment and death in different plots of *Phoenix* showed a similar pattern without much variation (Table 77). In plot 1, the new recruitments were observed in two times. The maximum number was in the 9th month and next was in the 24th month.

In plot 2 relatively higher numbers of plants appeared in the measurement after 9th month. A lesser number of plants appeared in the plot in the ninth observation after 24 months.

In plot 3 also the maximum number of plants appeared in the 9th month. New seedlings appeared after 24 months also.

In plot 4 the maximum number of new plants appeared in the plot at the 9th month. During 24th month also there is the appearance of new seedlings.

In plot 5 also the first appearance of the new seedling is in the observation after 9 months. In the observation at 24 month also there is the appearance of new seedlings. In plot 5 no new seedlings were observed at any interval.

In all the plots except 5 and 6 the fourth observation shows more number of seedlings were present during the 9th month. In plot 5 in the 9th and 24th months the seedlings appeared in equal number.

Table 77. The rate of recruitment and death

Plot	Months	No. of new recruits	Recruitment rate per 3 months	No. of deaths	Death rate per 3 months (%)
1	3	0	0.0	1	2.5
	6	0	0.0	1	2.6
	9	5	11.4	0	0.0
	12	0	0.0	0	0.0
	15	0	0.0	0	0.0
	18	0	0.0	0	0.0
	21	0	0.0	0	0.0
	24	3	6.4	0	0.0
	27	0	0.0	1	2.2
	30	0	0.0	2	4.5
	33	0	0.0	1	2.3
2	3	0	0.0	0	0.0
	6	0	0.0	0	0.0
	9	10	18.9	0	0.0
	12	0	0.0	0	0.0
	15	0	0.0	0	0.0
	18	0	0.0	0	0.0
	21	0	0.0	0	0.0
	24	6	10.2	0	0.0
	27	0	0.0	2	3.5
	30	0	0.0	4	7.5
	33	0	0.0	2	3.9
3	3	0	0.0	0	0.0
	6	0	0.0	0	0.0
	9	5	10.9	0	0.0

Plot	Months	No. of new recruits	Recruitment rate per 3 months	No. of deaths	Death rate per 3 months (%)
3	12	0	0.0	0	0.0
	15	0	0.0	0	0.0
	18	0	0.0	0	0.0
	21	0	0.0	0	0.0
	24	3	6.1	0	0.0
	27	0	0.0	1	2.1
	30	0	0.0	2	4.3
	33	0	0.0	0	0.0
4	3	0	0.0	0	0.0
	6	0	0.0	0	0.0
	9	5	9.1	0	0.0
	12	0	0.0	0	0.0
	15	0	0.0	0	0.0
	18	0	0.0	0	0.0
	21	0	0.0	0	0.0
	24	3	5.3	1	1.8
	27	0	0.0	1	1.8
	30	0	0.0	2	3.7
	33	0	0.0	1	1.9
5	3	0	0.0	0	0.0
	6	0	0.0	0	0.0
	9	3	5.5	0	0.0
	12	0	0.0	0	0.0
	15	0	0.0	0	0.0
	18	0	0.0	0	0.0
	21	0	0.0	0	0.0
	24	3	5.2	0	0.0
	27	0	0.0	1	1.8
	30	0	0.0	1	1.8
	33	0	0.0	0	0.0
6	3	0	0.0	0	0.0
	6	0	0.0	0	0.0
	9	0	0.0	1	2.9
	12	0	0.0	0	0.0
	15	0	0.0	0	0.0
	18	0	0.0	0	0.0
	21	0	0.0	0	0.0
	24	0	0.0	0	0.0
	27	0	0.0	1	2.9
	30	0	0.0	0	0.0
	33	0	0.0	0	0.0

No similarity was observed between the pattern of new recruitment and death of plants. The occurrence of death was restricted to certain period which was applicable in all plots. In plot 1 death occurred in third and sixth months in equal rates. The occurrence of death was noticed at 27th, 30th and 33rd months also.

In plot 2, death occurred between 27th and 33rd months only. In plot 3, death was noted between 27th and 30th months. In plot 4, death started from 24th months onwards. In plot 5, the occurrence of death during 27th and 30th month and in plot 6, death occurred during the 9th and 27th months.

Seasonal variation in recruitment and death

The graph showed that (Fig. 44) the new recruitments were at a specific period in all plots. Maximum new recruitments were observed during the 9th month. Plot 2 showed maximum new recruitment. The new recruitments also occurred at 24 month. Here also the maximum number of new recruitments was observed in plot 2.

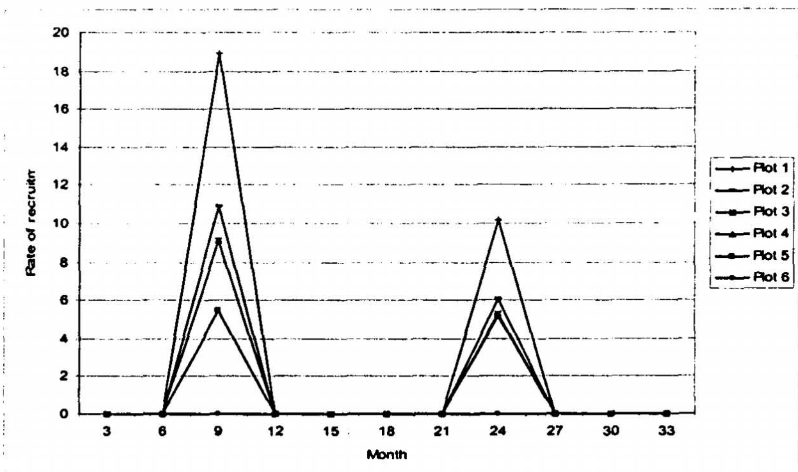

Fig. 44. Seasonal variation in recruitment

There was no particular period or pattern for the occurrence of the death (Fig. 45). The rate of death at different period varied considerably. As in new recruitments, the rate of death also was maximum in plot 2.

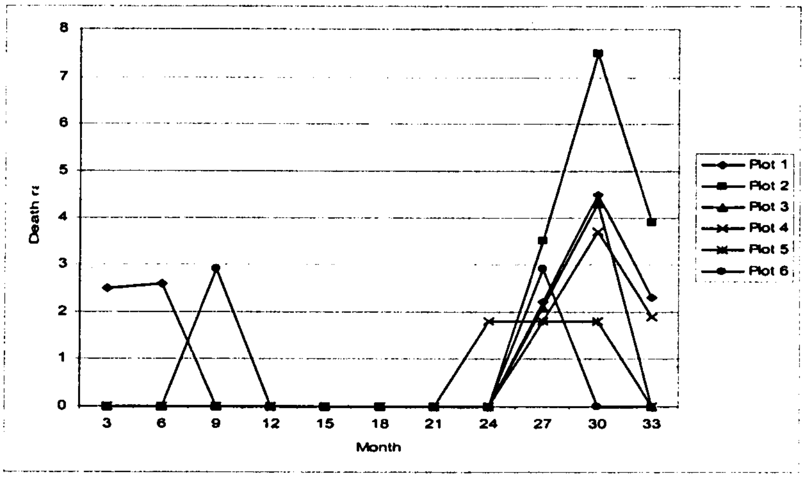

Fig. 45. Seasonal variation in death

Regression

In order to find the trend in total number of seedling from time to time, equations were developed with total number of seedlings as dependent variable and month as independent variable. Result of analysis showed a linear trend in all the plots (Table 78), where 'y' is the total number of plants and 'X' is the time (month) of observation.

The regression equation of plot1 indicated that the rate of change in number of seedling from year to year was high in *Phoenix* i.e., 0.22 and 50 percent of variation in numbers of seedlings was explained by the regression equation. The variation was due to the independence variable factor increase in months. In plot 2 the rate of change was 0.51 and 56 percent of variation in numbers of seedlings is explained by the regression equation. The variation was due to the independence variable factor increase in months. In Plot 3 the rate of change in number of seedling was 0.27 and 64 percent of variation in numbers of seedlings was explained by the regression equation. In plot 4 it was 0.21 and in plot 5 it was 0.22. In plot

4, 42 percent of variation in numbers of seedlings was explained by the regression equation and 61 percent in plot 5. In plot 6 the value was very low as 0.06 and 83 percent of variation in numbers of seedlings was explained by the regression equation. The variation was due to the independence variable factor increase in months.

Table 78. Regression analysis

Plot no	Functional form	Adj. R^2
1	Y=37.3807+0.22920 X	0.5035
2	Y=38.0379+0.51571 X	0.5643
3	Y=38.2190+0.27239 X	0.6426
4	Y=48.4211+0.21080 X	0.4273
5	Y=48.6067+0.22755 X	0.6119
6	Y=36.0385+0.0629 X	0.8346

The high values of the rate of change in number of seedling in the first three plots were at Vallkadavu where natural habitat was not disturbed very much while in the last three plots at Kuttikanam the rate is low.

Population flux for the first year

In plot 1, there were 41 plants in this plot at first observation in last year (Table 79). The rate of increase in the number in this plot was 1.07. There were five new arrivals during the period and the number of death was two. The total number of plants recorded was 46. The percentage of annual recruitment was 10.87.

In plot 2, the number of plants in this plot was 42. Net change in number was 11. Rate of increase in number of plants was 1.26. The number of arrivals during period was 10. But the death noted was zero. The total number of plants recorded was 53. The percentage of annual death was zero and the percentage of annual recruitment was 18.87.

Table 79. Population flux for the first year

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
a. No. of plants in initial measurement	41	42	41	50	51	36
b. No. of plants in final measurement	44	53	46	55	55	35
c. Net change (*b-a*)	3	11	5	5	4	-1
d. Rate of increase (*b/a*)	1.07	1.26	1.12	1.10	1.08	0.97
e. Total new arrivals	5	10	5	5	3	0
f. Total mortality	2	0	0	0	0	1
g. Total plants recorded	46	53	46	55	55	36
h. Percentage of annual death	4.35	0.00	0.00	0.00	0.00	2.78
i. Percentage of annual recruitment	10.87	18.87	10.87	9.09	5.45	0.00

In plot 3, there were 41 plants at the initial measurement in the last year. The number of plants at the time of final observation was 46. The net change in number was five. The rate of increase was 1.12. There were five new arrivals in the plot. The number of death noted was zero. The total number of plants was 46. The percentage of annual death was zero and the percentage of annual recruitment was 10.87. In this plot the percentage of annual recruitment exceeded the annual death.

In plot 4, at the time of first observation 50 plants were present. In the last observation there were 55 plants. So the net change in number was five. The rate of increase of plants was 1.10. There were five new arrivals and one death during the period. The total number of plants recorded was 55. The percentage of annual death was zero and percentage of annual recruitment was 9.09 Here also the rate of new recruitment exceeded the rate of death.

In plot 5, at the time of initial observation there were 51 plants and in the final observation 55 plants were present. The net change in number was 4. The rate of increase was 1.08. There were three new arrivals and no deaths during the period. Total number of plants recorded was 55. The annual percentage of death was zero and the annual percentage of recruitment was 5.45.

In plot 6, there were 36 plants in the plot at the time of initial measurement. The number of plants at the time of final observation was 35. Net change in number was negative one. Rate of increase in number was -0.97. There were no new arrivals and one deaths during the period. The total number of plants recorded was 36. The percentage of annual death was 2.78 and the percentage of annual recruitment was zero.

Population flux for the second year

In plot 1, the number of plants in the plot at the time of first measurement was 44(Table 80). After one year there were 47 plants in the plot. The net change in number for the year was 3. The rate of increase was 1.07. The number of arrivals during the year was 3 and the mortality rate was 0. The total number of plant recorded after 3 years was 47. The percentage of death for the period was 0%. The percentage of annual recruitment for first year was 6.38.

In plot 2, there were 53 plants in the first observation and after one year, 59 plants. Net change in number was six. Rate of increase was 1.11. The total number of plants during the period was 59. The percentage of death was zero. The percentage of annual recruitment in the plot was 10.17.

In plot 3, the total number of plants in the initial measurement was 46. After one year it increased to 49. Net change in number was three. The rate of increase was 1.07. There were three new arrivals in the plot during the year and the mortality was 0. The total number of plant during the year was 49. The percentage of annual death was 0 and the percentage of annual recruitment was also 6.12.

In plot 4, 55 plants were present in the 1st observation and it increased to 57 after one year. The net change was 2. The rate of increase was 1.04. There were 2 new arrivals in the plot during the year and the number of deaths was one. The total number of plants during period was 58. The percentage of annual deaths was 1.72 and the annual recruitment percentage was 5.17. The annual percentage of recruitment was high in this plot.

Table 80. Population flux for the second year

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
a. No. of plants in initial measurement	44	53	46	55	55	35
b. No. of plants in final measurement	47	59	49	57	58	35
c. Net change (*b-a*)	3	6	3	2	3	0
d. Rate of increase (*b/a*)	1.07	1.11	1.07	1.04	1.05	1.00
e. Total new arrivals	3	6	3	3	3	0
f. Total mortality	0	.0	0	1	0	0
g. Total plants recorded	47	59	49	58	58	35
h. Percentage of annual death	0.00	0.00	0.00	1.72	0.00	0.00
i. Percentage of annual recruitment	6.38	10.17	6.12	5.17	5.17	0.00

In plot 5, 55 plants were present in the first observation. After one year 58 plants were present. The net change in number was three. The rate of increase was 1.05. The number of new arrival for the first year was three and the number of death was zero. The total number of plants during period was 58. The annual death percentage was 0 and the annual percentage of new recruitment was 5.17. This plot also showed a high percentage of the annual recruitment.

In plot 6, there were 35 plants at the time of first observation. After one year the total number of plants increased to 35. The net change in number was zero. The rate of increase was one. There were zero new arrivals and no death during the time. The total plants recorded were 35. The annual percentage of death was zero and the percentage of recruitment was zero.

Population flux for the third year

In plot 1, the number of plants in the plot at the time of first measurement was 47 (Table 81). After one year there were 43 plants in the plot. The net change in number for the year was -4. The rate of increase was -0.91. The number of arrivals during the year was zero and the mortality rate was four. The total number of plant recorded after 3 years was 47. The percentage of death for the period was 8.51. The percentage of annual recruitment for the year was zero.

Table 81. Population flux for the third year

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
a. No. of plants in initial measurement	47	59	49	57	58	35
b. No. of plants in final measurement	43	51	46	54	55	34
c. Net change (*b-a*)	-4	-8	-3	-3	-3	-1
d. Rate of increase (*b/a*)	0.91	0.86	0.94	0.95	0.95	0.97
e. Total new arrivals	0	0	0	0	0	0
f. Total mortality	4	8	3	4	2	1
g. Total plants recorded	47	59	49	57	58	35
h. Percentage of annual death	8.51	13.56	6.12	7.02	3.45	2.86
i. Percentage of annual recruitment	0.00	0.00	0.00	0.00	0.00	0.00

In plot 2, there were 59 plants in the first observation and after one year, 51 plants. Net change in number was -8. Rate of increase was -0.86. The total number of plants during the period was 59. The percentage of death was 6.12. The percentage of annual recruitment in the plot was zero.

In plot 3, the total number of plants in the initial measurement was 49. After one year it increased to 46. Net change in number was -3. The rate of increase was -0.94. There were no new arrivals in the plot during the year and the mortality was three. The total number of plant during the year was 49. The percentage of annual death was 6.12 and the percentage of annual recruitment was zero

In plot 4, 57 plants were present in the 1st observation and it increased to 54after one year. The net change was -3. The rate of increase was -0.95. There were no new arrivals in the plot during the year and the number of deaths was four. The total number of plants during period was 57. The percentage of annual deaths was 7.02 and the annual recruitment percentage was zero.

In plot 5, 58 plants were present in the first observation. After one year 55 plants were present. The net change in number was -3. The rate of increase was -0.95. The number of new arrival for the first year was zero and the number of death was two. The total number of plants during period was 58. The annual death percentage was 3.45 and the annual percentage of new recruitment was zero.

In plot 6, there were 35 plants at the time of first observation. After one year the total number of plants increased to 34. The net change in number was -1. The rate of increase was -0.97. There were zero new arrivals and one death during the time. The total plants recorded were 35. The annual percentage of death was 2.86 and the percentage of recruitment was zero.

Population flux for three years

In plot 1, the total number of plants in the initial measurement was 41 (Table 82). After three years it was 43. The net change was two. The rate of increase was 1.05. There were seven new arrivals. The number of death noted during the period was two. The total number of plants recorded was 49. Mortality rate was 12.24.

In plot 2, the total number of plants in the initial observation was 42. There were 51 plants in the plot after three years. The net change in number was nine. The rate of increase in number was 1. 21. The number of new plants was 16 and number of deaths was eight. The total number of plants was 59. The percentage of death was 13.56 and the percentage of recruitment was 27.12.

In plot 3, the total number of plants in the first measurement was 41. There were 46 after three years. The net change in number was five. The rate of increase was 1.12. The number of new arrivals was eight and the deaths noted were three. The total number of plants was 49. The percentage of death was 6.12 and percentage of new recruitment was 16.33. Here also the rate of increase was more than one. The percentage of recruitment exceeded the percentage of death.

Table 82. Population flux for three years

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
a. No. of plants in initial measurement	41	42	41	50	51	36
b. No. of plants in final measurement	43	51	46	54	55	34
c. Net change (*b-a*)	2	9	5	4	4	-2
d. Rate of increase (*b/a*)	1.05	1.21	1.12	1.08	1.08	0.94
e. Total new arrivals	8	16	8	8	6	0
f. Total mortality	6	8	3	5	2	2
g. Total plants recorded	49	59	49	58	57	36
h. Percentage of death	12.24	13.56	6.12	8.47	3.51	5.56
i. Percentage of recruitment	16.33	27.12	16.33	13.56	10.53	0.00

In plot 4, there were 50 plants in the initial measurement. It was changed to 54 in the last year. Here change in number was four. The rate of increase was 1.08. The number of new arrivals was eight and number of total death was five. The total number of plants recorded was 58. The percentage of death was 8.47 and the percentage of new recruitment was 13.56. Here also the rate of increase was more than one. Here the difference in percentage of recruitment and percentage of death was high.

In plot 5, t here was 51 plants at the time of first observation. The number of plants was 55 in the final measurement. The net change in number was four. The rate of increase was 1.08. There were six new arrivals and the death noted was two. The total number of plants was 57. The percentage of death was 3.51 and the percentage of recruitment was 10.53. In this plot also, the rate of increase was more than one. The percentage of recruitment exceeded the percentage of death.

In plot 6, there were 36 plants in the fist year. It had changed to 34 in the final observation. The net change in number was -2. The rate of increase was 0.94. The total number of plants was 36. The number of new recruits was zero and the number of death was two. The percentage of death was 5.56 and the percentage of recruitment was zero.

Death and recruitment in different plots

The graph (Fig. 46) shows that in the first five plots the percentage of recruitment exceeded the percentage of death. In plot 5 the percentage of death was high.

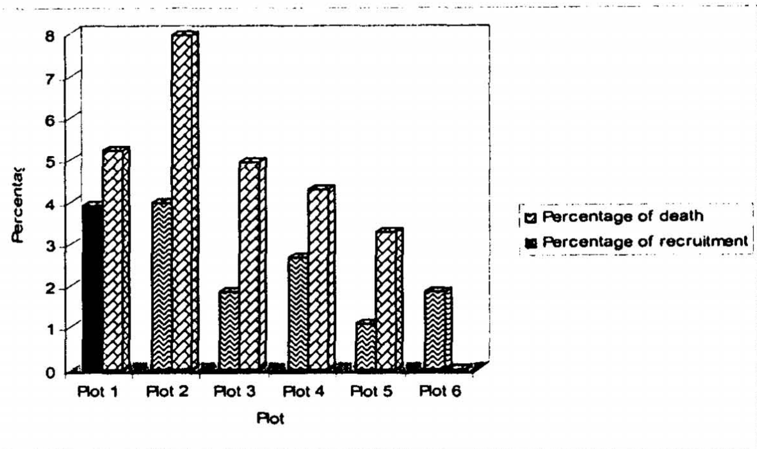

Fig. 46. Death and recruitment in different plots.

Percentage of seedlings in the populations

The percentage of seedling in the populations in all plots showed similarity (Fig. 48).

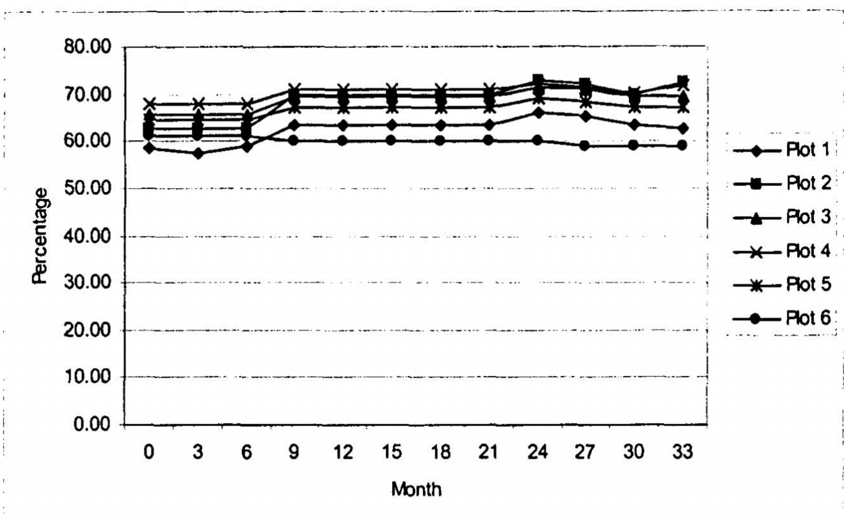

Fig. 47. Percentage contribution of seedlings in different plots

Percentage contribution was maximum in plot 2 (72.88%) after 24 months and minimum in plot 1 (57.5%) after 3 months. The variation in percentage in different plots was due to the new arrivals in the plots or due to the death of the existing plants. The new recruitments and deaths were noted only in seedling category. The upward curve showed the time of new recruitment and the downward curve show the time of death in the plot. The graph showed that death and new recruitment in the plot occurred at the same time.

Percentage of juveniles in the populations

The ups and downs in the graph were due to the changes in number of seedlings (Fig. 49). The juveniles follow the same pattern in number. Percentage contribution was maximum in plot 1 (15%) at 3 months and minimum in plot 5 (1.74%) at 24 months. The recruitment to this group during the period was nil. Death was noted only in few occasions.

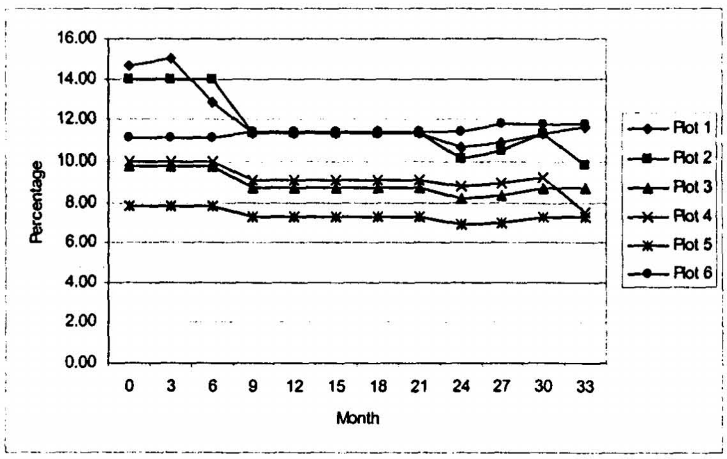

Fig. 48. Percentage contribution of juveniles in different plots

Percentage of adults in the population

The deviation in the graph was almost similar for all plots except for 6 (Fig. 50). Percentage contribution was maximum in plot 6 (29.41%) during 27, 30 and 33 months and minimum in plot 2 (16.9%) after 24 months. The deviation in percentage was not due to the new recruitment or death but due to the change in number of the seedlings in the plots. When the number of seedlings increased or the percentage of seedling increased due to new recruitment, the graph showed a downward curve. When there was certain death of seedling in the plot, the graph showed an upward curve.

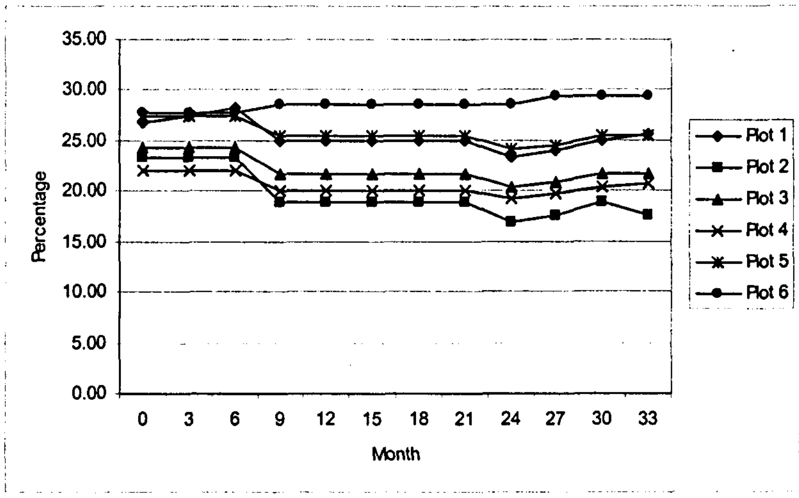

Fig. 49. Percentage contribution of adults in different plots

Comparison of three groups among the population

From the population structure it is clear that in all the plots seedlings were the major group. It was maintained in all the observations (Fig. 47). The adults were the second.

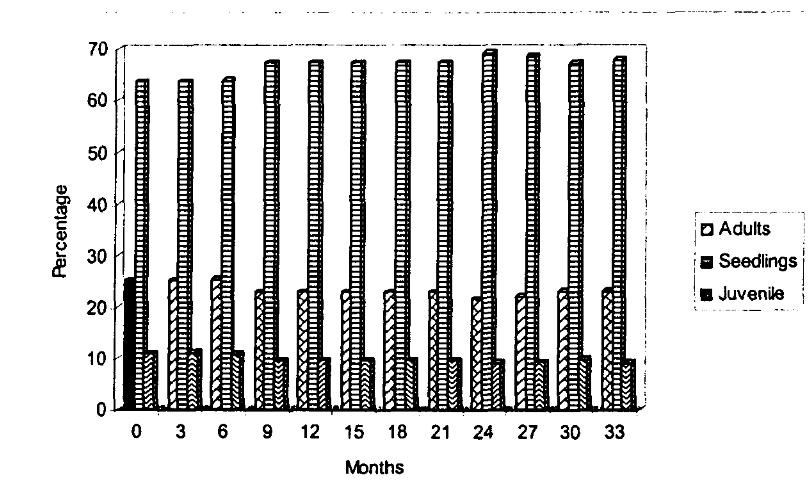

Fig. 50. Percentage of different categories in the whole population

The number of seedlings showed variations. The percentage was maximum in observations after 9, 12 and 15 months. There was a decrease in number at 15th month and again increased at 24th and 27th months. This change was due to the death and new recruitment in the plot.

The percentage of adults and juveniles also showed slight variation. But it was due to the change in number of seedlings. New recruitments and death to this category happened in few occasions only.

Age group distribution

The increase in average height of different groups of plant in different plots showed variation (Table 83). In the seedlings there were no height differences because all the seedlings in all the plots were with out stem. In the juvenile group, only two plots showed increase in average height. In plot 1 it was 0.12 cm and in plot 2 it was 0.06. In all other plots there was no significant increase in average height. So the average increase in height in juveniles of *Phoenix* was considered as 0.10 cm.

The minimum height of the juveniles was 1 cm. The longevity of the trunk less period for all the plots was 10 years. The distribution of plants in different age group in different plots was also calculated.

In plot 1 there were 31 seedlings. All the seedlings were below 25 years (Table 84). The age of six juveniles were calculated. Three of them were below 25 years and another three were between 25-50 years. The age of 11 adult plants were also calculated. Eight of them were in the age group of 25-50 years. Two of them were 50-75 years and one in the age group of 75-100 years.

Table 83. Average increase in height in each stage

Plot No.	Height increase of stem (cm)		
	Seedlings	Juveniles	Adults
1	0	0.12	0.53
2	0	0.08	0.51
3	0	0.00	0.29
4	0	0.00	0.50
5	0	0.00	0.55
6	0	0.00	0.55
Grand Total	0	0.04	0.49

Table 84. Distribution of number of plants in different age group of *Phoenix*

Plot No.	Stage	Age groups (years)				
		<25	25-50	50-75	75-100	>100
1	Seedlings	31				
	Juveniles	3	3			
	Adults		8	2	1	
2	Seedlings	43				
	Juveniles	4	2			
	Adults	2	7	1		
3	Seedlings	35				
	Juveniles		4			
	Adults	1	6	2	1	
4	Seedlings	42				
	Juveniles	1	4			
	Adults	1	2	2	1	5
5	Seedlings	39				
	Juveniles	2	2			
	Adults		5	2	1	6
6	Seedlings	21				
	Juveniles	4				
	Adults		5	2	1	2

In plot 2 the age of 43 seedlings were calculated. All of them were below 25 years. Ages of six juveniles were calculated. Four of them were below 25 years while two were in the age group of 25-50. Ages of 10 adults were calculated. Two of them were below 25 years. Seven of them 25-50 years and one was in the age group of 50-75.

In plot 3 the age of 35 seedlings were calculated. All the seedlings were below 25 years. Age of four juveniles was calculated. All the four juveniles were between 25-50 years. Ages of 10 adult plants were calculated. One of them was below 25 years and six were 25-50 years. Two adult plants were 50-75 years and one was in the age group of 75-100.

Age of 42 seedlings was calculated in plot 4. All the seedlings in the pot were below 25 years. Age of five juveniles was calculated. One of the juvenile was below 25 years while four juveniles were between 25 and 50. Age of 11 adult plants was calculated. One of the adult was below 25 years. Two adult plants were 25-50 years and two were in the age group of 50-75. One was in the age group of 75-100 years and five plants were above 100 years.

Age of 39 seedlings was calculated in plot 5. All the 39 seedlings were below 25 years. Age of four juveniles was calculated. Two of them were below 25 years and another two were in the age group of 25-50. Age of 14 adult plants was also calculated. Five adult plants were in the age group of 25-50. Two were in the group of 50-75 years. One was in the group of 75-100 years and six were above 100 years.

In plot 6 the age of 21 seedlings were calculated. All the seedlings were below 21years. Age of four juveniles was calculated and all were below 25 years. Among 10 adults, five were in the age group of 25-50 years. Two were in the group of 50-75 years and one was between 75 to100 and two others were above 100 years.

***Pinanga dicksonii* (Roxb.) Bl.**

Population dynamics at three months intervals

The population dynamics of *Pinanga dicksonii* in plots 1 to 6 are shown in the Table 85 at 3 month intervals. The result indicated that in all the 6 plots the juveniles was the major component in the population followed by seedlings and adults with varying percentages.

In plot 1 the second major component varies from stage to stage. During 6, 9, 24, 27, 30 and 33 months the adult were the second major group. While after 0 and 3 month observations seedlings was the second major group.

In plot 2 except the during 24, 27 and 33 months seedlings were the second major group. During 24th month, both seedlings and adults were equal in number while during 27 and 33 months adults were the second major group.

In the third plot, except the during 0 and 30 months, adults were the second major group while in 0 and 30 months observations, the adults and seedlings were equal in numbers. In plot 4, in all observations the second major group was adults.

In plot 5 except during 3, 6, 9 and 12 months, the seedling were the second major group. While in 3, 6 and 9 months observations, adults were the second major group and in 12 months they were equal in number.

In the 6th plot except during 0, 3, 6, 9 and 12 month observations, seedlings were the second major group. While during 3, 6 and 9 months adults were the second and during first and 12th months they were equal in number.

Table 85. Population dynamics at 3-months intervals

Location	Plots	Months	No. of Seedlings	No. of Juveniles	No. of Adults	Total No. of Plants
Rosemala	1	0	9	21	6	36
		3	8	19	7	34
		6	4	18	7	29
		9	4	18	7	29
		12	7	18	7	32
		15	6	19	6	31
		18	6	19	6	31
		21	6	19	6	31
		24	5	18	8	31
		27	5	18	8	31
		30	7	17	9	33
		33	6	16	9	31
	2	0	27	46	9	82
		3	27	44	11	82
		6	27	44	11	82
		9	25	46	11	82
		12	25	47	12	84
		15	25	47	12	84

Location	Plots	Months	No. of Seedlings	No. of Juveniles	No. of Adults	Total No. of Plants
Rosemala		18	22	49	12	83
		21	20	48	12	80
		24	13	48	13	74
		27	10	49	13	72
		30	14	49	13	76
		33	12	50	13	75
	3	0	18	56	18	92
		3	18	52	21	91
		6	16	51	22	89
		9	16	49	22	87
		12	20	47	22	89
		15	19	47	21	87
		18	18	47	21	86
		21	17	48	21	86
		24	19	48	21	88
		27	19	47	22	88
		30	22	46	22	90
		33	20	40	24	84
Nadukani	4	0	14	30	24	68
		3	12	22	24	58
		6	12	22	23	57
		9	13	21	23	57
		12	17	21	23	61
		15	19	21	23	63
		18	19	21	23	63
		21	19	21	23	63
		24	19	18	24	61
		27	16	18	24	58
	5	30	20	16	25	61
		33	18	14	27	59
		0	11	22	8	41
		3	4	19	8	31
		6	4	19	7	30
		9	4	19	7	30
		12	8	17	8	33
		15	10	17	8	35
		18	10	17	8	35
		21	10	17	8	35
		24	10	16	9	35
		27	13	17	9	39
		30	15	16	9	40

Location	. Plots	Months	No. of Seedlings	No. of Juveniles	No. of Adults	Total No. of Plants
		33	15	14	9	38
	6	0	8	19	8	35
		3	8	17	9	34
		6	8	16	9	33
		9	7	17	9	33
		12	10	15	10	35
		15	10	15	9	34
		18	10	15	9	34
		21	10	15	9	34
		24	10	15	9	34
		27	12	14	10	36
		30	12	14	10	36
		33	12	14	9	35

In plot 1 and 4 in the study period (33 months) the seedlings and juvenile showed a decrease in number while the number of adults increased. In plot 2 the seedlings showed a decrease in number while the juveniles and adults increased. In plot 3, 5 and 6 seedlings and adults showed an increase in number while the juveniles decreased.

Apart from the above changes the total number of plants showed a decrease in first 5 plots while in the sixth plot, the number was maintained as such.

Rate of recruitment and death

The new recruitments were observed in plot 1 after 12 and 30 months while death was noted at 3, 6, 15 and 33 months (Table 86). In plot 2 new recruits were observed at 12 and 30 months while death was noted during 18, 21, 24, 27, 30 and 33 months. The new recruitments were observed at 12, 24 and 30 months in plot 3 while death was noted at 3, 6, 9, 12, 15, 18, 30 and 33 months. In plot 4 new recruitments were observed during 12, 15 and 30 months while death was noted at 3, 6, 9, 24, 27, 30 and 33 months. In the fifth plot new recruitments were observed at 12, 15, 27 and 30 months and death was observed during 3, 6, 12, 30 and

33 months. In the 6th plot new recruitments were observed at 12 and 27 months and death was noted at 3, 6, 12, 15 and 33 months.

Table 86. The rate of recruitment and death

Plot	Month	No. of new recruits	Recruitment rate per 3 months	No. of deaths	Death rate per 3 months (%)
1	3	0	0.0	2	6
	6	0	0.0	5	17
	9	0	0.0	0	0
	12	3	9.4	0	0
	15	0	0.0	1	3
	18	0	0.0	0	0
	21	0	0.0	0	0
	24	0	0.0	0	0
	27	0	0.0	0	0
	30	2	6.1	0	0
	33	0	0.0	2	6
2	3	0	0.0	0	0.0
	6	0	0.0	0	0.0
	9	0	0.0	0	0.0
	12	2	2.4	0	0.0
	15	0	0.0	0	0.0
	18	0	0.0	1	1.2
	21	0	0.0	3	3.8
	24	0	0.0	6	8.1
	27	0	0.0	2	2.8
	30	5	6.6	1	1.3
	33	0	0.0	1	1.3
3	3	0	0.0	1	1.1
	6	0	0.0	2	2.2
	9	0	0.0	2	2.3
	12	4	4.5	2	2.2
	15	0	0.0	2	2.3
	18	0	0.0	1	1.2
	21	0	0.0	0	0.0
	24	2	2.3	0	0.0
	27	0	0.0	0	0.0
	30	3	3.3	1	1.1
	33	0	0.0	6	7.1
4	3	0	0.0	10	17.2
	6	0	0.0	1	1.8

Plot	Month	No. of new recruits	Recruitment rate per 3 months	No. of deaths	Death rate per 3 months (%)
	9	0	0.0	1	1.8
	12	4	6.6	0	0.0
	15	2	3.2	0	0.0
	18	0	0.0	0	0.0
	21	0	0.0	0	0.0
	24	0	0.0	2	3.3
	27	0	0.0	1	1.7
	30	4	6.6	3	4.9
	33	0	0.0	2	3.4
5	3	0	0.0	10	32.3
	6	0	0.0	1	3.3
	9	0	0.0	0	0.0
	12	4	12.1	1	3.0
	15	2	5.7	0	0.0
	18	0	0.0	0	0.0
	21	0	0.0	0	0.0
	24	0	0.0	0	0.0
	27	4	10.3	0	0.0
	30	3	7.5	2	5.0
	33	0	0.0	2	5.3
6	3	0	0.0	1	2.9
	6	0	0.0	1	3.0
	9	0	0.0	0	0.0
	12	3	8.6	1	2.9
	15	0	0.0	1	2.9
	18	0	0.0	0	0.0
	21	0	0.0	0	0.0
	24	0	0.0	0	0.0
	27	2	5.6	0	0.0
	30	0	0.0	0	0.0
	33	0	0.0	1	2.9

Seasonal variation in recruitment and death

The graph (Fig. 51) showed the variation in rate of new recruitment. Here it is clear that the new recruitment in all the plots were maximum in the same period. The rate of recruitment was maximum in plot 5 while the rate showed variation in other plots.

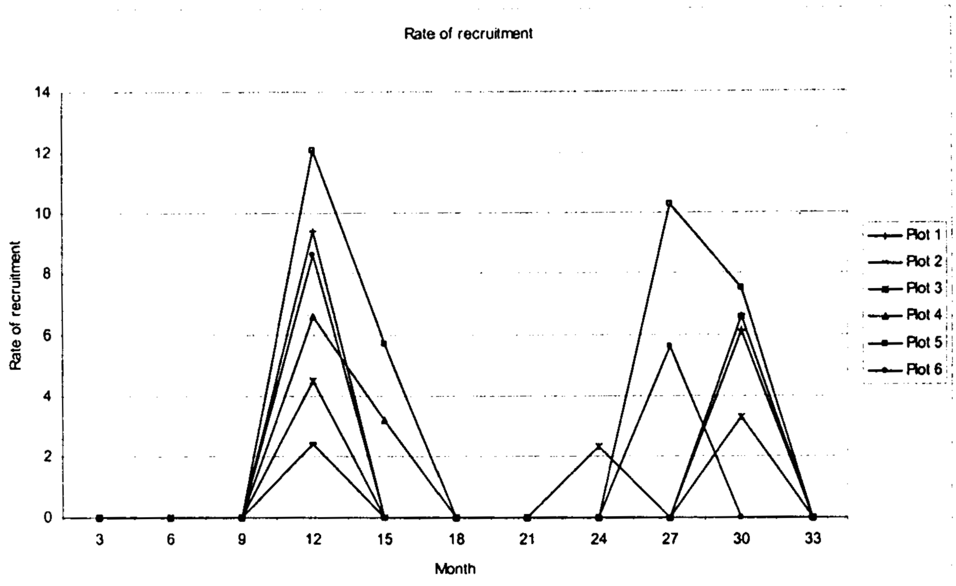

Fig. 51. Seasonal variation in recruitment

Comparison of rate of death during the period

The graph (Fig. 52) indicates that the death occurred to different groups of plants in the plot were not in a particular pattern or period.

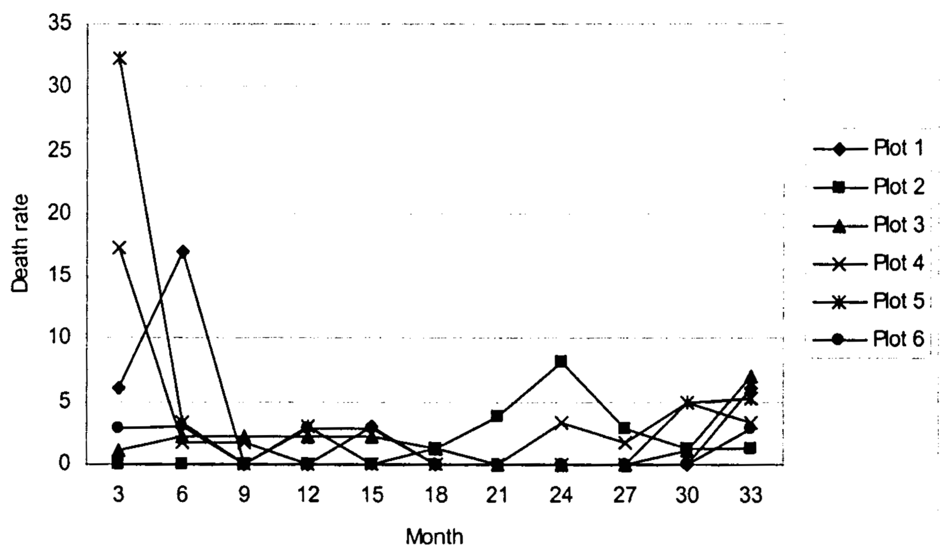

Fig. 52. Seasonal variation in death

Regression

For studying the pattern of total number of plants (y) during the study period, different functional forms were tried. In all the plots except in plot 2 no pattern was observed. In the case of plot 2 a linear form was observed (Table 87).

Table 87. Regression analysis

Plot	Functional form	Adjusted R^2
Plot 2	Y=84.551 - 0.296 X	0.574

Where 'y' is the total number of plants and 'X' is the time (month) of observation. The linear regression pattern is agreeable in plot 2 only. Here the rate of change in number of seedling from year to year is 0.296. Here 57 percent of variation in numbers of seedlings is explained by the regression equation. The variation is due to the independence variable factor increase in months.

This shows that the yearly rate of change is not possible in *Pinanga.* It will take 4 years for the establishment of a single seedling.

Population flux for the first year

In plot1, there were 36 plants at the time of first observation (Table 88). After one year the plot had 32 plants. The net change in number was –4. The rate of increase was -0.89. The number of new arrivals was three. The number of deaths reported was seven. The total number of plants recorded during the period was 39. The percentage of annual death was17.95 and the percentage of annual recruitment were 7.69. Here the rate of increase in number was less than one. The percentage of death exceeded percentage of new recruitment.

In plot 2, in the initial and final measurement of plot for the period, the number of plants present was 82 and 84 respectively. Net change in number was two. The rate of increase was 1.02. The total number of new arrivals was two and the total death was zero. The total number of plants recorded was 84. The percentage of annual death was 0 and the percentage of annual recruitment was 2.38. Here the rate of increase was more than one, mortality was nil but new recruitments were recorded.

Table 88. Population flux of *Pinanga* for the first year

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
a. No. of plants in initial measurement	36	82	92	68	41	35
b. No. of plants in final measurement	32	84	89	61	33	35
c. Net change (b-a)	-4	2	-3	-7	-8	0
d. Rate of increase (b/a)	0.89	1.02	0.97	0.90	0.80	1
e. Total new arrivals	3	2	4	4	4	3
f. Total mortality	7	0	7	12	12	3
g. Total plants recorded	39	84	96	72	45	38
h. percentage of annual death	17.95	0	7.29	16.44	26.67	7.89
i. Percentage of annual recruitment	7.69	2.38	4.17	5.48	8.89	7.89

In plot 3, there were 92 plants in the first measurement and 89 in the final measurement. The net change was –3. The rate of increases was -0.97. The number of deaths and new recruitment in the plot were respectively seven and four. The percentage of annual death was 7.29 and percentage of annual recruitment was 4.17. The total number of plants recorded was 96. Here the rate of increase was less than one. The percentage of recruitment was less than the percentage of annual death.

In plot 4, in the initial measurement the number of plants was 68 and in the final measurement it was 61. The net change was –7. The rate of increase in number was -0.90. There were 4 new arrivals and 12 deaths reported during the period. The total number of plants was 72. The percentage of annual death was 16.44 and percentage of annual recruitment was 5.48. Here the rate of increase was less than one. The percentage of annual death exceeded the percentage of annual recruitment.

In plot 5, the number of plants in the initial and final measurements was 41 and 33 respectively. The net change in number was –8. The rate of increase was -0.80. The number of new arrivals was four and the number of death was 12. The total number of plants recorded during the period was 45. The percentage of death was 26.67 and the percentage of new recruitment was 8.89.

In plot 6, there were 35 plants in the initial measurement. No change in number was noticed in the final measurement. The rate of increase was one. The number of new arrivals was three. The total number of plants recorded during the period was 38. The percentage of annual death was 7.89 and percentage of annual recruitment also had the same value.

Population flux for the second year

In plot 1, in the initial and final measurements in the second year the number of plants was 32 and 31 respectively (Table 89). The net change was –1. The rate of increase was -0.97. There were no new recruitment and death reported was one. A total of 32 plants were reported. The percentage of annual death was 3.13 and percentage of annual recruitment was zero.

Table 89. Population flux of *Pinanga* for second year

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
a. No. of plants in initial measurement	32	84	89	61	33	35
b. No. of plants in final measurement	31	74	88	61	35	34
c. Net change (*b-a*)	-1	-10	-1	0	2	-1
d. Rate of increase (*b/a*)	0.97	0.88	0.99	1	1.06	0.97
e. Total new arrivals	0	0	2	2	2	0
f. Total mortality	1	10	3	2	0	1
g. Total plants recorded	32	84	91	63	35	35
h. percentage of annual death	3.13	11.90	3.30	3.17	0	2.86
i. Percentage of annual recruitment	0	0	2.20	3.17	5.71	0

In plot 2, there were 84 plants in the initial measurement and 74 plants in the final measurement. The net change in number was –10. The rate of increase was -0.88. There were no new recruitment and number of deaths was 10. The number of plants recorded was 84. The percentage of annual death and annual recruitment were 11.90 and zero respectively.

In plot 3, there were 89 plants in the initial measurement and 88 plants in the final. The net change was –1 and the rate of increase was -0.99. The new arrivals were two and the death reported was three. There were 91 plants totally recorded during the period. The percentage of annual death was 3.30 and the percentage of recruitment was 2.20.

In plot 4, 61 plants were present in the initial measurement and 61 in the final measurement. The net change was zero. The rate of increase was one. The number of new recruitment was two and death reported was two. The total plants recorded were 63. The annual percentage of death was 3.17 and the annual percentage of recruitment was 3.17.

In plot 5, the no. of plants in the initial measurement was 33 and in the final measurement were 35. The net change was two and the rate of increase was 1.06. The number of new recruitment was two and the death reported was zero. Total plants recorded were 35. The annual percentage of recruitment was 5.71 and the annual percentage of death was zero.

In plot 6, the total plants in the initial measurement were 35 and in the final measurement were 34. The net change was –1 and the percentage of increase was -0.97. The number of new arrivals was zero and the number of death was one. The total number of plants recorded was 35. The annual percentage of recruitment and death were zero and 2.86 respectively.

Population flux of third year

In plot 1, 31 plants were present in the initial measurement and 31 plants in the final measurement. The net change was zero (Table 90). The rate of increase was one. The total number of plants recorded was 33 where as the number of new arrivals was two and death was 2. The annual percentage of death was 6.06 and annual percentage of new recruitment was 6.06.

In plot 2, 74 plants were present in the initial measurement and 75 plants in the final measurement. The net change was one and the rate of increase was 1.01. The total plant recorded was 79. The number of death was four and number of new recruitment was five. The percentage of annual death was 5.06 and the percentage of annual recruitment was 6.33.

Table 90. Population flux of *Pinanga* for third year.

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
a. No. of plants in initial measurement	31	74	88	61	35	34
b. No. of plants in final measurement	31	75	84	59	38	35
c. Net change (*b-a*)	0	1	-4	-2	3	1
d. Rate of increase (*b/a*)	1	1.01	0.95	0.97	1.09	1.03
e. Total new arrivals	2	5	3	4	7	2
f. Total mortality	2	4	7	6	4	1
g. Total plants recorded	33	79	91	65	42	36
h. percentage of annual death	6.06	5	7.69	9.23	9.52	2.78
i. Percentage of annual recruitment	6.06	6.33	3.30	6.15	15.67	5.56

In plot 3, the rate of increase in the third year was -0.95. The total plant recorded was 91. The annual percentage of death was 7.69. The percentage of annual recruitment was 3.30.

In plot 4, the rate of increase was -0.97. The total plant recorded was 65. The annual percentage of death and new recruitment were 9.23 and 6.15 respectively.

In plot 5, the rate of increase was 1.09. The total plant recorded was 42. The percentage of death and new recruitment were 9.52 and 16.67 respectively.

In plot 6, the rate of increases was 1.03. The total plant recorded was 36. The annual percentage of death and new recruitment were 2.78 and 5.56 respectively.

Population flux for three years

In plot 1, the number of plants in the initial measurement was 36 (Table 82). After 3 years the total number was 31 (Table 91). The net change in number was –5. The rate of increases was -0.86. The number of arrivals during the period was five and the total mortality was 10.

The total number of plants recorded was 41. The percentage of death was 24.39. The percentage of recruitment was 12.20. The value indicates that the percentage of recruitment was half that of percentage of death.

Table 91. Population flux of *Pinanga* for 3 years.

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
a. No. of plants in initial measurement	36	82	92	68	41	35
b. No. of plants in final measurement	31	75	84	59	38	35
c. Net change (*b-a*)	-5	-7	-8	-9	-3	0
d. Rate of increase (*b/a*)	0.86	0.91	0.91	0.85	0.93	1.00
e. Total new arrivals	5	7	9	10	13	5
f. Total mortality	10	14	17	20	16	5
g.Total plants recorded	41	89	101	78	54	40
h. Percentage of death	24.39	15.73	16.83	25.32	29.63	12.50
i. Percentage of recruitment	12.20	7.87	8.91	12.66	24.07	12.50

In plot 2, the number of plants in first observation was 82. The number of plants after the last observation was 75. Net change was -7. The rate of increase was -0.91. The number of arrivals during the period was seven and the mortality was 14. The total plants recorded were 89. The percentage of death was 15.73 and the new recruitment percentage was 7.87. In this plot also the value of new recruitment percentage was half of the death percentage.

In plot 3, there were 92 plants in the first observation. The number was reduced to 84 at the last observation. Net change in number was -8. The rate of increase was -0.91. There were 9 new arrivals during the period and 17 deaths. The total number of plants was 101. The percentage of death was16.83 and the percentage of new recruitment were 8.91. Here also the value of new recruitment percentage was half of the death percentage.

In plot 4, the no. of plants at the first observation was 68 and in the last observation, there were 59 plants. Net change in number was -9. The rate of increase was -0.85. The number of new arrivals was 10. The number of deaths during the period was 20. The total number of plants recorded was 78. The percentage of death was 25.32 and the percentage of new recruitment was 12.66. Here also the values were in the same ratio as in the first 3 plots.

In plot 5, the number of plants at the first observation was 41. The total number of plants after three year was 38. The net change was -3. The rate of increase was -0.93. The number of new arrivals was 13. The numbers of deaths was 16. The total number of plants recorded was 54. The percentage of annual death was 29.63 while the percentage of recruitment was 24.07.

In plot 6, the total number of plants in the first observation was 35. The number was same in the last observation. Here the net change in number was zero. The rate of increase was one. The number of new arrivals was 5. Number of deaths was also the same. The total number of plants recorded was 40. The percentage of death was 12.50 and the percentage of new recruitment was 12.50. Apart from all other plots the percentage of death and percentage of new recruitment were same.

The results revealed that all the plots except in plot 6, net change in number was a negative value. The maximum among them was in plot 4 and the minimum in plot 5. In the plot 6 the net change was zero.

Rate of increase in number was maximum in plot 6 and minimum in plot 5. In all other plots other than 6, the value was less than one where in 6 it was one.

The new arrivals were maximum in plot 5 and the minimum in plots 1 and 6. The mortality was maximum in plot 4 and minimum in plot 6. The percentage of death was maximum in plot 5 and minimum in plot 6. The per5centage of recruitment was maximum in plot 5 and minimum in plot 2.

Rate of death and recruitment in different plots of *Pinanga*

From the graph (Fig. 53) it was clear that the percentage of death was more than the percentage of recruitment. In the plots 1, 2, 3, 4 and 5 the same pattern was followed, while in plot 6 the percentage of death and percentage of recruitment were same. The difference in the percentage of death and percentage of recruitment were maximum in plot 4. The difference in percentage of death and percentage of new recruitment was minimum in plot 6. In plots1, 2 and 3 the difference in percentage of the two factors was almost same.

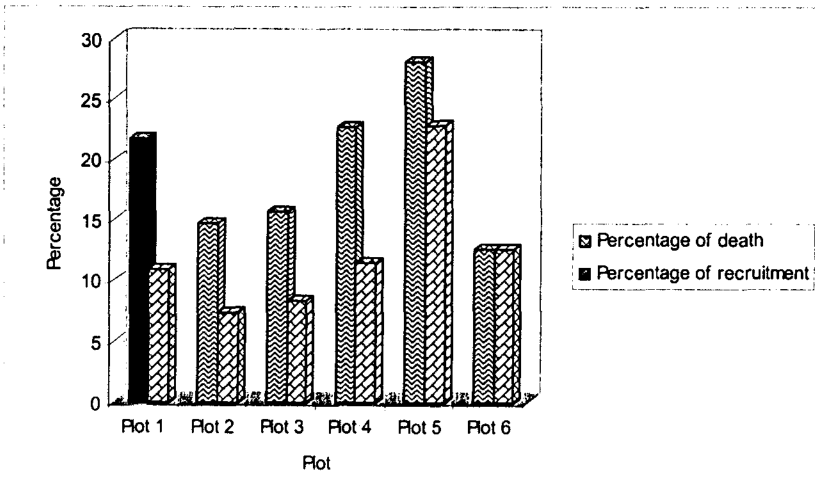

Fig. 53. Death and recruitment in different plots of *Pinanga*

Percentage of seedlings in the population

Percentage contribution was maximum in plot 5 (39.47%) at 33 month and minimum was also in the same plot (1.74%) at 3rd month (Fig. 54).

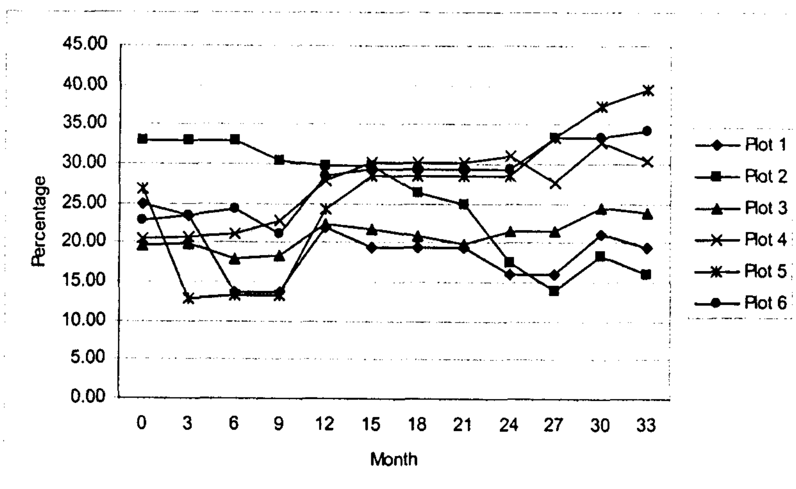

Fig. 54. Percentage contribution of seedlings of *Pinanga* in different plots

The graph clearly indicates that the number of new recruitment and death in all the plots were very high. Compared with other two groups, the juveniles and adults, the seedlings were the most variable population. All the plots showed a more ore less similar pattern of new recruitment and deaths. The maximum variable dynamics in the population was shown by the seedlings.

Percentage of juveniles in the population

The graph indicates a decrease in percentage among total population (Fig. 55). The population of juveniles was not a stable one. There was chance of death even in the juvenile stage. Here except one plot all other plots showed a decrease in percentage. Percentage contribution was maximum in plot 2 (68.05%) at 27th month and minimum in plot 4 (23.72%) at 33 month. Death was not the only reason for this decrease. There was conversion of the juvenile plant to adult plants during the three year of observation. Here it is clear that the total loses to the juvenile group by death and conversion was not compensated by the conversion of seedlings to juveniles.

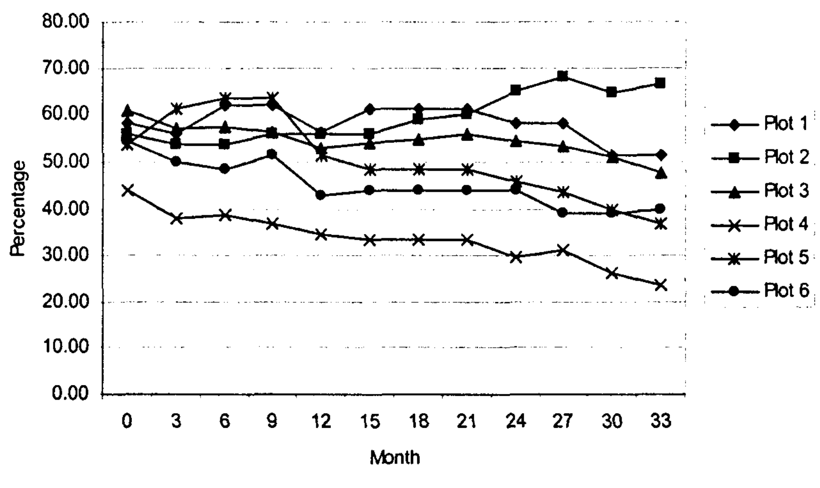

Fig. 55. Percentage contribution of juveniles of *Pinanga* in different plots

Percentage of adults in the population

The graph shows that the population of adult plants was not stable, but their percentage showed an increasing trend (Fig. 56). Percentage contribution was maximum in plot 4 (45.76%) after 33 months of observation and minimum in plot 2 (10.9%) during the first month. This indicates that the number of new recruitments to this group from the juvenile group was more than the number of death occurred. From the graph this was the most stable group among the population. In all the plots after three years the percentage and number of plants were increasing.

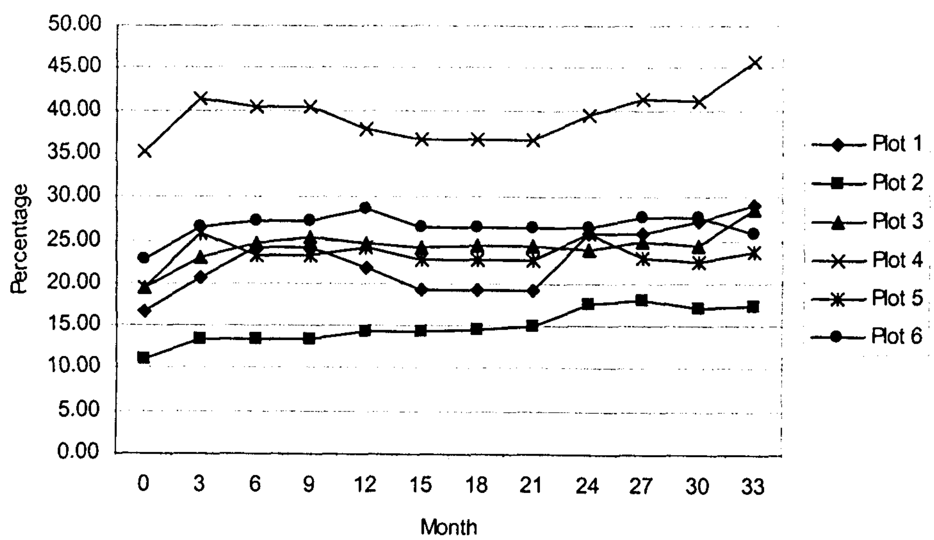

Fig. 56. Percentage contribution of adults

Comparison of three groups among the population

In all the plots juveniles was the major group (Fig. 57). The seedlings were second major group in 6 observations. This pattern was not in successive observations that is, new recruitment and death were observed in those plots. Adults were the second major group in the remaining 6 observations. The new recruitment and death were observed to those groups also.

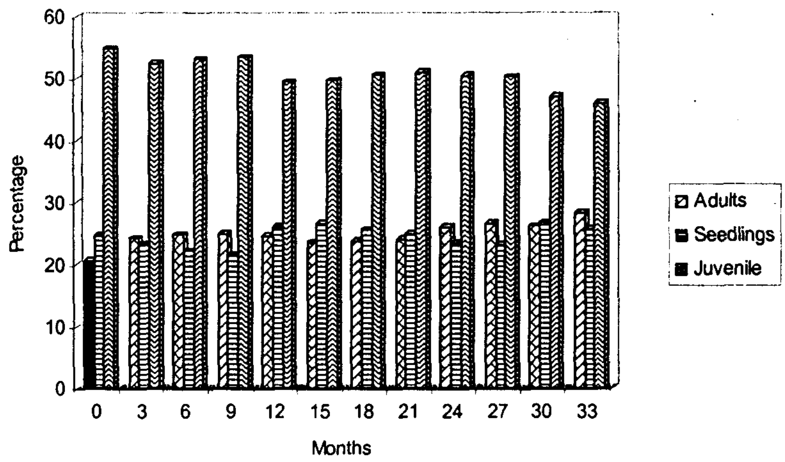

Fig. 57. Percentage of different categories in the whole population

The juveniles, the major group in the population, showed a decrease in number after three year of observation. Even though there was new recruitment, the number was decreasing. In the adults also the population was not stable even though there was new recruitment at times, the percentage of this group did not show an increasing pattern. The seedling also showed this unstable pattern.

Age of the plants

The average increase in height per year in the different groups of *Pinanga* showed variations (Table 92). It was an average of 4.19 cm in seedlings. This was the lowest value among the different groups. In juveniles it had an average of 21.88 cm, which was the highest value among the three different groups. The adults had an average yearly increase in height of 20.02 cm which was less than the juveniles. This value coincides with the internodal length of the different groups. In the case of seedlings the internodal length was very less. The juvenile plants had the maximum internodal length. The adults after a certain height had internodal length less than that of the middle portion of the stem.

Table 92. Average increase in height in each stage (cm)

Plot No.	Height increase of stem (cm)		
	Seedlings	Juveniles	Adults
1	2.36	27.93	27.64
2	7.51	22.63	14.02
3	4.19	25.00	14.06
4	2.54	15.78	22.32
5	2.25	19.18	34.37
6	4.16	16.93	13.23
Grand Total	4.19	21.88	20.02

With in the different plots also, variations were seen in the different groups. In seedlings the average height per year was maximum in plot 2 (7.51 cm). The minimum increase in height was in plot 5 (2.25 cm). All the other plots had an average increase in height of less than the mean value.

In the case of the juveniles the increase in average height per year was maximum in plot 1 (27.93 cm). The minimum increase in height per year was in plot 4. Here the difference in height was 15.78 cm. Two plots 2 and 3 had more than the mean value of height difference while in plots 5 and 6 increase in average height was less than the mean value.

In the adult groups of plants the maximum height difference of 34.37 cm per year was noted in plot 5. The minimum height difference per year in adult was in the plot 6 (13.25 cm). In plots 2 and 3 average height difference was less than the mean value and in plots 1 and 4 the average height difference was more than the mean value.

While calculating the longevity of the trunk less period, the maximum period was observed in the juvenile plants of plot 4 where it was 3.17 and the minimum period was in plot no 1. Here it was only 1.79 year. In other plots the longevity of trunkless period was varied between these two figures.

Age distribution pattern in the different plots showed variations. But a common pattern was shown in all the plots.

In plot 1 the age was calculated for 31 plants (Table 93). All the eight seedlings among these were below 10 years age. Of the 18 juvenile plants, 14 were below 10 years, three were between 10 to15 and one was above 15 year old. There were five adult plants of which three were below 10 years, one was in the age group of 10-15 and another one was in the age group of 15-20.

In plot 2 the age of 84 plants was calculated. There were 30 seedlings in this plot. All the seedlings were below 10 year old. The juvenile plants in this plot were represented by 45 plants. 34 of these juvenile plants were below 10 years old. 10 were in the age group between 10-15 years while one juvenile plant was in the age group of 15-20. There were nine adult plants in the plot. Three of them were below 10 years age. Six of the adult plants were in the age group of 10-15 years.

Table 93. Distribution of plants in different age group of *Pinanga*

Plot No.	Stage	Age groups (years)					
		<10	10-15	15-20	20-25	25-30	>30
1	Seedlings	8					
	Juveniles	14	3	1			
	Adults	3	1	1			
2	Seedlings	30					
	Juveniles	34	10	1			
	Adults	3	6				
3	Seedlings	24					
	Juveniles	18	12		9	1	1
	Adults		4	6	5	1	1
4	Seedlings	22					
	Juveniles		8	1			
	Adults	5	6	6	3		
5	Seedlings	17					
	Juveniles	9	5	1		1	
	Adults		3	3		1	
6	Seedlings	13					
	Juveniles	9	4	2			
	Adults	1	2	2	2		

Plot 3 was calculated for 86 plants. Of these 24 were seedlings. All the seedlings in the plot were below 10 years of age. In this plot there were 45 juvenile plants. The juvenile plants showed very much variation in the age group. 18 of the juvenile plants were below 10 years age. 12 were in the age group between 10-15 years. Nine of the juvenile plants were in the age group between 20-25 years and there were two juvenile plants which had an age above 25 years. There were 17 adult plants in the plot. Four of the adult plants were in the age group between 10-15 years. Six were in the age group between 15-20 years. Five of them were between 20-25 years and two adult plants were above 25 years old.

In plot 4, age was calculated for 63 plants. There were 22 seedlings in the plot. All the seedlings were below 10 years of age. 21 juveniles were present of which eight were in the age group of 10-15 years. Two juvenile plants were in the age group of 15-20 years and one was between 20-25 years. There were 20 adult plants in the plot. Five of them were below 10 years of age. Six adult plants were in the age group of 10-15 years and another six were in the age group of 15-20 years. Three adult plants were with the age between 20-25 years.

In plot 5, age was calculated for 39 plants. All the 17 seedlings in this plot were with below 10 years of age. There were 15 juveniles in the plot. Nine of the juveniles were with the age group of below 10 years. Five were between 10-15 years. There was one juvenile plant in the plot which had more than 25 years of age. Seven adult plants were there in the plot. Three adult plants in the plot were in the age group of 10-15 years. Three were with in the age group of 15-20 years and there was one adult plant with more than 25 years.

The age of 35 plants of plot 6 were calculated. All the 13 seedlings in the plot were below 10 years of age. There were 15 juveniles in the plot. Nine of the juveniles were with below 10 years of age. Four were in the age group of 10-15 years. The two remaining juveniles were in the age group of 15-20 years. There were seven adult plants in the plot. One of the adults was below 10 years. Two of the adults were in the age group of 10-15 years. Two other adults were in the age group of 15-20 and another two were in the age group between 20-25 years.

Stage durations for the 3 taxa

The calculated stage duration for the three species is listed in Table 94.

Table 94. Stage duration of the three taxa (in years)

Taxa	Stage duration (years)		
	Seedling	Juvenile	Adult
Arenga	10.4	24.1	74.4
Phoenix	11.11	19.5	277.6
Pinanga	2.3	13.1	23.6

The three taxa were entirely different in stage duration for each stage. The minimum stage duration for each stage was shown by *Pinanga*. Regarding the seedling stage of both *Arenga* and *Phoenix* showed a more or less equal duration (10.4 and 11.11 year respectively). But in the juvenile stage the maximum duration was shown by *Arenga* (24.1 year) while it was very less in *Phoenix* (19.5 years). The maximum duration was for the adult stage of *Phoenix* (277.6 years) while it was less in *Arenga* (74.4 years).

Matrix models

The matrix model for transition in *Arenga* is given in tables 95-97.

Table 95. Transition matrix of *Arenga* for the first year

	Seedling	Juvenile	Adult
Seedling	P_1 =0.99	R =0	F_{13} =0.93
Juvenile	G_1 =0.09	P_2 =0.95	F_{23} =
Adult	0	G_2 =0.05	P_3 =0.99

Table 96. Transition matrix of *Arenga* for the second year

	Seedling	Juvenile	Adult
Seedling	P_1 =0.99	R =0	F_{13} =0.43
Juvenile	G_1 =0.09	P_2 =0.95	F_{23} =
Adult	0	G_2 =0.05	P_3 =0.99

Table 97. Transition matrix of *Arenga* for the third year

	Seedling	Juvenile	Adult
Seedling	P_1 =0.99	R =0	F_{13} =0.07
Juvenile	G_1 =0.09	P_2 =0.85	F_{23} =
Adult	0	G_2 =0.05	P_3 =0.99

P_1 is the probabilities of surviving and remaining in the seedling stage. P_2 and P_3 are the same for the juveniles and adults. G_1 is yearly transition probabilities for the seedling to the next stage. G_2 is the same for the juveniles. F_{13} is the ratio between the number of new seedlings and the total number of adults. F_{23} is the ratio between the new recruitment of juveniles to the total number of adults. Since the calculation is based on the assumption that no new recruitment occurred in the juvenile stage F_{23} remains zero.

The P_1 values, the probabilities of surviving and remaining in same stage, for all the three stages were very high. The P_1 values of seedlings for all the threes years were 0.99. But on field observation the number of leaves in the seedlings was gradually decreasing. The F_{13} value of the first year was 0.93, in the second year it was 0.43 and in the third year 0.07 which shows that seedling formation was not uniform for every year as in *Pinanga* and *Phoenix*. The probability of survival was high and the P_1 values were high. This value declined after a short period. The survival rate of juveniles for the three years 0.95, 0.95 and 0.85, indicated that once the juvenile stage was attained the plant will survive. The survival rate of adults was also high (0.9, 0.96, and 0.96). Once the adult stage is attained the plant will survive

G_1 values were less in *Arenga.* Once the plant has attained a stage it will remained in the same stage for a long period. The G_1 values for seedling were 0.09 in all the three observation while it was 0.5 (G_2) in the juvenile stage.

The fecundity (F_{13}) showed very much variation in the three consecutive years. It was 0.93 in the first year, 0.43 in the second year and 0.07 in the third year. This indicates the nature of fruiting in *Arenga*.

The transition matrix model for *Phoenix* for the three years is given below (Tables 98-100).

Table 98. Transition matrix of *Phoenix* for the first year

	Seedling	Juvenile	Adult
Seedling	P_1 =0.9	R =0	F_{13} =0.43
Juvenile	G_1 =0.10	P_2 =0.96	F_{23} =
Adult	0	G_2 =0.01	P_3 =0.99

Table 99. Transition matrix of *Phoenix* for the second year

	Seedling	Juvenile	Adult
Seedling	P_1 =0.9	R =0	F_{13} =0.27
Juvenile	G_1 =0.10	P_2 =0.99	F_{23} =
Adult	0	G_2 =0.01	P_3 =0.99

Table 100. Transition matrix of *Phoenix* for the third year

	Seedling	Juvenile	Adult
Seedling	P_1 =0.82	R =0	F_{13} =0
Juvenile	G_1 =0.09	P_2 =0.92	F_{23} =
Adult	0	G_2 =0.01	P_3 =0.99

The probabilities of surviving and remaining in the same stage, P_1 values, indicates that it was very high in all the stages. Among this, values of the seedlings were 0.9, 0.9 and 0.82 in the consecutive three years. This gives the idea that once the seedlings were established in the plot, the survival rate was high and these values were more or less equal in all the three years which indicate that the seedlings were formed in the same rate in all the three years. That is fruit formation was uniform for the three years. The 'P_2' values of juveniles also were very high with 0.96, 0.99 and 0.92 respectively for the consecutive three years. The adults also had a very high value (0.99, 0.99 and 0.99). This high value was an indication that once the stage was attained death occurrence was very less and the transition from one stage to another will take more time. The 'G_1' values were very low in *Phoenix*. The transition probability form seedling to juvenile stage was 0.10 and that of juvenile to adult was 0.01. The stage duration of *Phoenix* was very high. So the transition was very slow. The lowest *G*1 values agree with the observation of stage duration.

The F_{13} value was 0.43 for the first year and 0.27 in the second year. In the third year it was zero. This was due to the lack of new seedling formation in the last year. The germination rate was very less.

The transition matrix for the three years for *Pinanga* is given in the tables 101-103.

Table 101. Transition matrix of *Pinanga* for the first year

	Seedling	Juvenile	Adult
Seedling	P_1 =0.47	R =0	F_{13} =0
Juvenile	G_1 =0.43	P_2 =0.79	F_{23} =
Adult	0	G_2 =0.06	P_3 =0.96

Table 102. Transition matrix of *Pinanga* for the second year

	Seedling	Juvenile	Adult
Seedling	P_1 =0.49	R =0	F_{13} =0
Juvenile	G_1 =0.38	P_2 =0.91	F_{23} =
Adult	0	G_2 =0.08	P_3 =0.96

Table 103. Transition matrix of *Pinanga* for the third year

	Seedling	Juvenile	Adult
Seedling	P_1 =0.47	R =0	F_{13} =0.08
Juvenile	G_1 =0.43	P_2 =0.84	F_{23} =
Adult	0	G_2 =0.07	P_3 =0.96

Due to high mortality in all the three years, the 'P_1' values were relatively small. The 'P_2' values were comparatively less than the 'P_3' values. But there was only slight difference when compared with 'P_1' values. When the yearly transitional values 'G_1' was considered 'G_1' values are high when compared with the 'G_2' values in all the years.

The 'P_1' values for the three years in *Arenga* were 0.47, 0.49 and 0.47 respectively. This indicates that the mortality was high in the seedlings of *Pinanga*. The 'P_2' values were 0.79, 0.91 and 0.84 respectively. This indicates that once the juvenile stage was attained the mortality decreased. In adults, the probability of surviving and remaining in the same stage was 0.96, 0.96 and 0.96 respectively for the three consecutive years of observation.

The 'G_1' values for the three years for the transition of seedlings to juvenile were 0.43, 0.38 and 0.43 for the three consecutive years. This was a comparatively high value when compared with the transition of juvenile to adult. The juvenile to adult transition values were 0.06, 0.08 and 0.07 respectively.

The ratio between the number of new seedlings and the total number of adults, sexual fecundity F_{13} was 0, 0 and 0.08 respectively in the three consecutive years. These values were nil or very less which indicated the low germination rate of seeds of *Pinanga*.

Density of the taxa/hectare in three years

In *Arenga* the seedlings shows a density per hectare of 2467 in the first year at Ambayathode and 789 at Pullupara (Table 104). The density of seedlings per hectare in the second year is 2489 at Ambayathode and 833 at Pullupara. In the final year it increased to 2500 and 833 respectively. When *Phoenix* is considered in the 1st year it increased 956 at Vallakadavu and 1311 at Kuttikanam. In the second year it increased to 1300 and 1267 respectively. But in the 3rd year it decreased to 1100 and 689 respectively. In *Pinanga*, in the 1st year density of seedlings per hectare at Rosemala is 600 and that of Nadukani is 200. In the second year it increased to 556 and 367 respectively, and in the 3rd year it is increased to 656 at Rosemala and reduced to 333 at Nadukani. Among the three taxa *Arenga* shows the maximum density per hectare of seedlings, which is the major group among the population. The least density per hectare is observed in *Pinanga*, which is less than the other two life stages.

When the juveniles are considered *Arenga* at Ambayathode shows 111 plants per hectare while at Pullupara it is 56. In the second year the density per hectare remains the same. But in the 3rd year in the Ambayathode population it is reduced to 100, while at Pullupara it remains same. In *Phoenix* in first year at Vallakadavu the density per hectare in juveniles is 167 while at Kuttikanam it is 156. In the second year it increased to 189 at Vallakadavu but in Pullupara it reduced to 133. In the 3rd year at Vallakadavu it shows decrease while in the Kuttikanam the numbe remains same.

Table 104. Density per hectare of the selected species

year	Species	Category	Density/hectare	
			Area 1	Area 2
1	*Arenga*	Seedlings	2467	759
		Juveniles	111	56
		Adults	33	122
	Phoenix	Seedlings	956	1311
		Juveniles	167	156
		Adults	33	33
	Pinanga	Seedlings	200	600
		Juveniles	578	589
		Adults	267	822
2	*Arenga*	Seedlings	2459	833
		Juveniles	111	56
		Adults	33	122
	Phoenix	Seedlings	1300	1267
		Juveniles	189	133
		Adults	29	42
	Pinanga	Seedlings	556	367
		Juveniles	10611	522
		Adults	422	259
3	*Arenga*	Seedlings	2500	833
		Juveniles	100	56
		Adults	33	122
	Phoenix	Seedlings	1100	689
		Juveniles	133	133
		Adults	30	30
	Pinanga	Seedlings	656	333
		Juveniles	1500	560
		Adults	744	333

The density per hectare of juveniles at Rosemala is 578 and that of Nadukani is 589. In the second year it increased to 1611 at Rosemala and reduced to 522 at Nadukani. While in the 3rd year at Rosemala it reduced to 1500 and increased to 560 at Nadukani. Among the 3 taxa, at juvenile sage, *Pinanga* shows the maximum density per hectare and it is least in *Arenga*.

In the adult stage, the maximum density per hectare was noticed in *Pinanga*, which shows an increasing trend yearly. The least density per hectare of adults was noted in *Arenga*.

Ratios between the number of mature trees and seedlings shows that it was highest in the plots of *Arenga* at Ambayathode. The ratio remains without much change in the successive years. In *Phoenix* it remained different in area 1 and same in area 2 with slight change yearly. In *Pinanga* the ratio is 1:1 which is the lowest among the three taxa in the two areas and remained without change which indicates that the regeneration is very less here (Table 105).

Table 105. Ratios between the number of mature trees and seedlings

Year	Species	Area 1	Area 2
1	*Arenga*	1:74	1:6
	Phoenix	1:29	1:40
	Pinanga	1:1	1:1
2	*Arenga*	1:75	1:7
	Phoenix	1:45	1:30
	Pinanga	1:1	1:1
3	*Arenga*	1:75	1:7
	Phoenix	1:37	1:30
	Pinanga	1:1	1:1

The result showed (Tables 104 & 105 and Figs. 58, 59 & 60) that *Phoenix* showed a stable population in the undisturbed Vallakadavu region. In *Arenga* the population structure of Ambayathode is more stable than the disturbed Pullupara area. The most unstable population is of *Pinanga*.

Arenga in the 1st year the stable index is of Arenga at Ambayathode and of *Phoenix* at Vallakadavu and Kuttikanam (Fig. 58) evidenced by pyramid shaped index with a large number of seedlings and limited number of adults. The index of Arenga at Pullupara is not stable because of the less number of juveniles. Index is of *Pinanga* is also unstable.

In the second and third year of observation also the stability of the index remain same as that of the 1st year (Figs. 59 & 60).

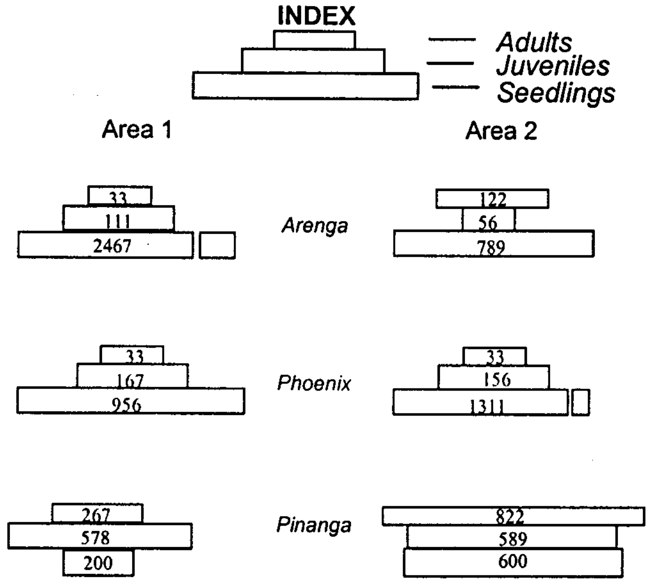

Fig. 58. Number of individuals per hectare in the first year, of different categories of plants of three taxa in two areas

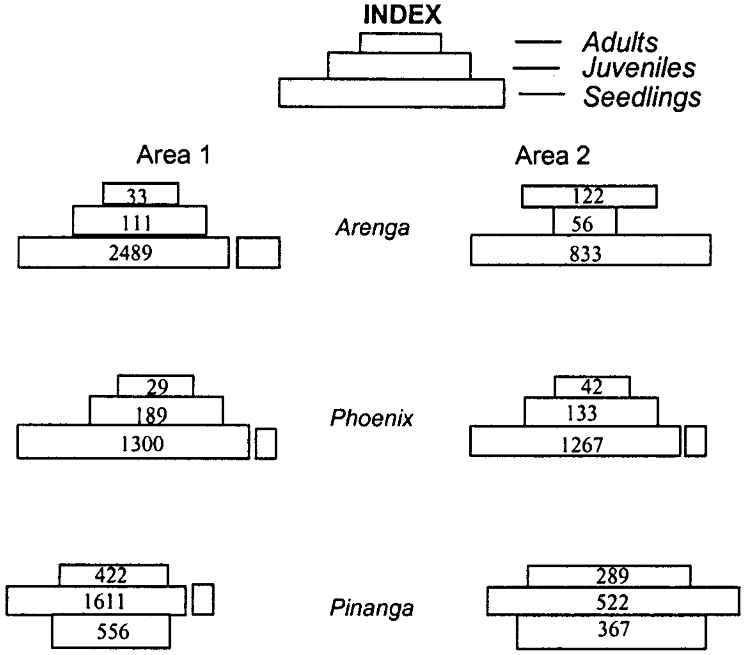

Fig. 59. Number of individuals per hectare in the second year, of different categories of plants of three taxa in two areas

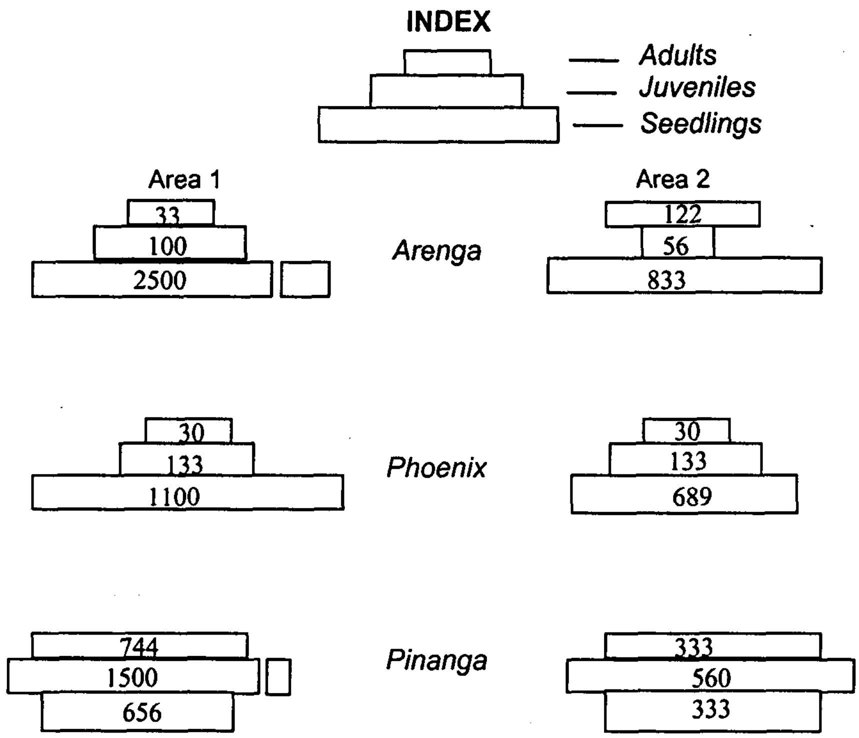

Fig. 60. Number of individuals per hectare in the third year, of different categories of plants of three taxa in two areas

ROOT MORPHOLOGICAL STUDIES

Root growth of the two species *Arenga wightii* and *Phoenix loureiri* var. *humilis* were compared separately for each period with respect to each of the growth parameters such as number of roots, their length, diameter and spatial orientation.

Number of main roots and laterals

Seedlings of *Arenga* and *Phoenix* had a single main root in the initial stage while at the end of the first year the seedling of *Arenga* had three main roots. In *Phoenix* the number of main roots was up to two. After two years the number of main roots in *Arenga* and *Phoenix* was four. After three years *Arenga* seedlings had an average of six roots while the *Phoenix* seedlings had five.

The number of main roots increased with age in both the species (Table 106). Analysis of variance on data with respect to the number of main roots showed that at initial stage and after one year it was highly significant. But in the observations after two years and three years, the variance was not significant.

Table 106. Comparison of mean number of main roots

Period	Mean number of main roots		
	Arenga	*Phoenix*	Result
Initial	1	1	XX
Year 1	3	2	XX
Year 2	4	4	Ns
Year 3	6	5	Ns

XX- highly significant, X- significant, Ns- not significant

When the number of laterals was considered *Arenga* had 20 -21 laterals in the initial stage while *Phoenix* had 4 -5 laterals. After one year, *Arenga* showed an increase up to 28 -29. In *Phoenix* also the number of laterals increased to 16 -17. After two years the number of laterals increased in *Arenga* to 68-69. But it decreased in *Phoenix* to 12-13. After 3 years the number of laterals in *Arenga* decreased to 22-23. While in *Phoenix* the number of laterals increased to 18-19.

The increase in number of laterals was not steady as in main roots (Table 107). Analysis of variance on data with respect to the number of lateral roots showed that in the initial stage the variance was not significant. After one year also the variance was not significant and after 2 years the variance was highly significant. But after 3 years it was not significant.

Table 107. Comparison of mean number of laterals

Period	Mean number of laterals roots		
	Arenga	*Phoenix*	Result
Initial	21	5	Ns
Year 1	28	16	Ns
Year 2	69	13	XX
Year 3	22	19	Ns

XX- highly significant, X- significant, Ns- not significant

Length of main roots and laterals

A comparison of mean values of main root length between the two species at different periods showed variation. In the initial stage the main root length of *Arenga* was 15.32 cm and that of *Phoenix* was 6.82 cm. After one year in *Arenga* the root length decreased due to the transplantation to the field. Here the main root length was 7.40 cm. *Phoenix* showed an increase in average length of main root to 14.40 cm. After 2 years both *Arenga* and *Phoenix* showed an increase in main root length. In *Arenga* the main root length was 10.30 cm and in *Phoenix*, 16 cm. After 3 years both the species showed an increase in main root length. In *Arenga* it was 14 cm and in *Phoenix*, 18.60 cm.

Analysis of variance on data with respect to the length of main roots showed that in the initial stage high significant difference between the species (Table 108). After one year there was significant difference between the species for the length of main roots. After 2 years the difference between the two species was not significant. After 3 years the difference between the species was highly significant.

Table 108. Comparison of mean lengths of main roots

Periods	Length of main roots (cm)		
	Arenga	*Phoenix*	Result
Initial	15.32	6.82	Ns
Year 1	7.40	14.40	Ns
Year 2	10.30	16.00	X
Year 3	14	18.60	Ns

XX- highly significant, X- significant, Ns- not significant

When the lateral root length was considered, variations were seen in *Arenga* and *Phoenix*. In the initial stage the average length of lateral root was 2.08 cm and in *Phoenix* 0.64 cm. After one year it decreased to 0.88 cm in *Arenga*. In *Phoenix* it increased to 1.94 cm. After 2 years both the species showed a decrease in the length of laterals. In *Arenga* it was 0.72 cm and in *Phoenix* it was 1.11 cm. After 3 years In *Arenga*, the laterals had a length of 0.52 cm and in *Phoenix*, 1.34 cm.

Analysis of variance of data with respect to the length of the laterals showed a high significant difference between the species in initial stage (Table 109). In the first and second years there was no significant difference between the two species. While during the third year there was very significant difference between the two species.

Table 109. Comparison of mean lengths of lateral roots

Periods	Length of laterals (cm)		
	Arenga	*Phoenix*	Result
Initial	2.08	0.64	Xx
Year 1	0.88	1.94	Ns
Year 2	0.72	1.11	Ns
Year 3	0.52	1.34	Xx

XX- highly significant, X- significant, Ns- not significant

Diameter of main roots and laterals

A comparison of mean values of main root diameter between the two species at different periods showed that during the early stages the diameter attained by the main roots of both species was almost similar (Table 110). But later, the diameter of the main root decreased in *Arenga*. In *Phoenix* the diameter of the main root gradually increased with the period.

Table 110. Comparison of mean diameter of main roots

Periods	diameter of main roots (cm)		
	Arenga	*Phoenix*	Result
Initial	0.20	0.16	Ns
Year 1	0.17	0.25	x
Year 2	0.14	0.29	XX
Year 3	0.12	0.48	X

XX- highly significant, X- significant, Ns- not significant

Analysis of variance data with respect to the diameter of main root showed no significant difference between the two species in the initial stage. While after one year it showed significant variation. After two years it was highly significant and after three years also it significantly varied.

The comparison of the diameter of the lateral roots of two species showed that in the initial stage both the species had same diameter. In *Phoenix* it did not increase in the successive years (Table 111). In *Arenga* there was an increase in diameter of the laterals in the successive two years but in the third year it decreased.

Table 111. Comparison of mean diameter of laterals

Periods	diameter of laterals (cm)		
	Arenga	*Phoenix*	Result
Initial	0.02	0.02	Ns
Year 1	0.10	0.02	Xx
Year 2	0.10	0.02	Xx
Year 3	0.02	0.02	Ns

XX- highly significant, X- significant, Ns- not significant

Analysis of variance of data with respect to the length of the laterals was not significant in initial stage but turned highly significant for the next two years. After three years it again became non significant

Vertical growth

Vertical growth was very prominent in *Phoenix* in the initial stages, while in *Arenga*, it was not much prominent (Table 112). In the initial stage the vertical root length in *Arenga* was 14.24 cm and in *Phoenix* it was 9.80 cm. After one year, the vertical length of *Arenga* root decreased to 5.09 cm while in *Phoenix*, it increased to 11.88 cm. In the successive years showed increase in a similar manner.

Table 112. Comparison of vertical growth of main roots

Period	Vertical root growth (cm)		
	Arenga	*Phoenix*	Result
Initial	14.24	9.80	Xx
Year 1	5.09	11.88	X
Year 2	9.83	15.94	Ns
Year 3	7.86	14.98	Xx

XX- highly significant, X- significant, Ns- not significant

Variance analysis showed that in the initial stage the difference of vertical growth was highly significant. After two years the difference became not significant and in the 3rd year it again became highly significant.

Horizontal growth

The horizontal growth in both the species in the early stages were almost similar. In *Arenga* horizontal growth increased (Table 113). In *Phoenix* it increased after one year. But after 2 years, horizontal growth decreased from the previous year. In the last measurement it again increased.

Table 113. Comparison of horizontal growth of main roots

Periods	Horizontal root growth (cm)		
	Arenga	*Phoenix*	Result
Initial	6.20	9.60	X
Year 1	7.20	15.20	X
Year 2	15.80	10.60	Ns
Year 3	17.20	18.00	Ns

XX- highly significant, X- significant, Ns- not significant

Analysis of variance showed that in the initial stage the difference in horizontal growth was significant. After one year also, the difference was significant. But in the 2nd and 3rd years, the variance became non significant.

Regression

Regression lines were fitted to find the trend of root length and root diameter during the period for the two species (Table 114). The regression equation for root length was fitted separately for *Arenga* and *Phoenix*. Regression equation fitted for root length of *Arenga* showed that 30% of the variation in the root length could be explained by the age of the plant. Similarly in the case of the *Phoenix* 31% of variation in root length could be explained by the age of the plant.

Table 114. Regression lines for root length and diameter

Dependent Variable(Y)	Species	Regression Equation	Adjusted R^2
Root Length	*Arenga*	Log Y=1.9070+0.1790 log X	0.3057
	Phoenix	Y=8.4178+0.1492 log X	0.3129
Root Diameter	*Arenga*	Log Y= -2.0660+0..2490 log X	0.4769
	Phoenix	Y= 0.1563+0.0054 log X	0.5111

X= month

The regression equation for root diameter was fitted separately for the two species. In *Arenga* 48 percent of the variation in root diameter could be explained by age of the plant.

Similarly in *Phoenix* 51 percent of the variation in root diameter could be explained by age of the plant.

Soil volume exploited

The soil volume exploited by the root system of *Arenga* showed an increase with the age of the plant. In *Phoenix* in the second year there was a decrease and then it increased in the third year. In the nursery the plant seldom has enough soil at its disposal to allow optimal development of its root system. The information on exploited soil volume in the two species in each year can be made use of in overcoming this drawback. Moreover effective soil volume can be calculated.

It was noted that (Table 115) the soil volume exploited by *Arenga* (301.41 cm^3) was much lesser than that of *Phoenix* (1412.52 cm^3). In the second year in *Arenga* showed an enormous increase (2020.30 cm^3) and in *Phoenix* also it was increased (2614.05 cm^3). In the third year both the species showed an increasing trend. In *Arenga*, it increase to 3254.24 cm^3 while in *Phoenix* it increased to 4735.02 cm^3.

Table 115. Comparison of soil volume exploited

Period (Year)	Soil volume (cm^3)	
	Arenga	*Phoenix*
First	301.41	1412.52
Second	2020.30	2614.05
Third	3254.24	4735.02

Rooting Density

Rooting density is often found to affect the balance of nutrient uptake from different parts of the soil profile which in turn may influence the growth of the seedling. In this study, the rooting density was calculated year wise, for three years. In *Arenga*, rooting density decreased with increase in soil volume exploited. But in *Phoenix* in the second year it showed an increase.

Rooting density in *Arenga* in the first year was 0.0198 cm/cm^3 (Table 116). While in *Phoenix* it was 0.0053 cm/cm^3. In the second year, in *Arenga* it decreased to 0.005 cm/cm^3 while in *Phoenix* it increased to 0.012. In the last year both species showed a decrease. In *Arenga* it was 0.0026 and in *Phoenix* it was 0.0034 cm/cm^3.

Table 116. Comparison of rooting density (cm/cm^3)

Period (year)	*Arenga*		*Phoenix*	
	Soil Volume	Rooting Density	Soil Volume	Rooting Density
First	301.41	0.0198	2614.05	0.0053
Second	2020.30	0.0052	1412.52	0.0121
Third	3254.24	0.0026	4735.02	0.0034

DISCUSSION

P. K. Padmakumar "Developmental morphology in relation to conservation in the family palmae (arecaceae)" Thesis. Department of Botany , University of Calicut, 2003

Chapter 6.

DISCUSSION

DISCUSSION

SHOOT MORPHOLOGY

In Western Ghats, the palm population is decreasing. Many palms are much restricted in distribution and the destruction of evergreen forests is affecting the growth of their population. Some species are also threatened because of their increasing utilisation (Davis, 1985; Davis and Johnson, 1987; Padmanabhan and Sudersan, 1988). Renuka (1996) reported that *Pinanga* is the most endangered palm in Western Ghats followed by *Bentinckia* and *Arenga*.

A study on the developmental and population biology will show clearly why and where the decline in population is occurring and it will help to the formulation of appropriate conservation measures.

An initial survey in the different forest regions in the Western Ghats of Kerala showed that three palms, *Arenga wightii*, *Phoenix loureiri* var. *humilis* and *Pinanga dicksonii* were found only at specific areas and the distribution was determined by various geographic, climatic, vegetational factors.

Arenga is found in evergreen forests between altitudes 800 to 1000 m above mean sea level. It is generally found along the steep banks of streams with varying population size throughout Kerala. So seedling establishment of this species in such areas is very difficult eventhough they produce large number of seeds with good germination percentage. The high average rain fall and high soil erosion due to strong flow of water create difficulty in seedling establishment.

Normally this plant takes a long time for maturation. This is a hapaxanthic species and the terminal inflorescence bud is activated first followed by axillary buds in acropetal succession. Once flowering is finished, the life of the plant will be completed. The palm has suckering habit. The colonization due to suckering was more prominent in the disturbed forest regions.

The leaves of *Arenga* are a delicious food for the elephants and a considerable expanse of populations are destroyed by the elephants.

Phoenix loureiri var. *humilis* is found in the grasslands of Western Ghats at elevations of about 1000 m and above. When found in shady places, the plants showed variations in morphological characters such as less clustering nature, more elongated leaf, more elongated acanthophyll, leaflets with less stiffness, etc. Once established, it forms a group of large number of plants by clustering. The species is dioecious and clusters of both male and female plants are seen in the same region in a ratio 1:1. Morphologically both the sexes are with the same characters. The plants can be distinguished only at the time of flowering. But generally the male plants are dwarfer than the female plants and large number of plants was seen in a female cluster. Flowering starts first in the male plants during a season. The distributional difference in the species is thought to be related to climatic or elevation factors.

Phoenix is a pleonanthic palm which produces inflorescence throughout the life period. Large number of fruits is formed in every inflorescence. In a season, up to 10 inflorescences are formed in a mature plant.

The leaf harvesting for broom making and thatching is very common and deleterious to the species. In the disturbed grasslands grazing and fire are the other threats to the species. All these factors seriously affect the existence of the populations.

Pinanga dicksonii is found in the deep evergreen forests from an altitude of 900 m upwards. The microclimate is very specific for this species. A slight change in the habitat will affect the population. At present this species is restricted to very deep evergreen forests. This species is found as undergrowth. It was found that only very few adult plants produced fruits in a season. The number of seeds in an inflorescence was also very few. Suckering was shown by the plant but it does not lead to the cluster formation. Number of suckers formed was very less when compared with the other two palms.

Population dynamics

Population dynamics of the three species showed differences in patterns. In *Arenga* and *Phoenix* seedlings were the dominant stage throughout the study period. In *Pinanga*, juveniles were the dominant stage in all the plots except one. The life form and reproductive behaviour of palms strongly influence the population structure.

Arenga was caespitose and showed the sexual and vegetative reproductive methods at the same time. But the adult plants were larger in size and clustered. *Phoenix* was also caespitose. It also showed the sexual and vegetative reproductive methods simultaneously. The cluster formed as a result of mode vegetative propagation showed more than one adult plant in the same cluster. In *Pinanga* the plants were solitary but sucker formation was noticed with out clustering. Flowering and fruiting was rare in this species.

The percentage of seedlings in different study plots of *Arenga* was significantly high. The maximum percentage of seedling was noted in plot 1 (97.39%). The minimum percentage was in plot 4 (76.67 %). In *Arenga*, the number of seedlings varied in different plots but was comparatively higher when compared to the other two palms. In a specific natural environment, the seedling concentration should be high for the survival of a few numbers of the species (Burgess, 1975). At the same time it was observed that the average number of leaves in seedlings was decreasing year after year during the study period. This indicates that some of the seedlings will be perished in the long run. A similar observation was reported by Clancy and Sullivan (1990) in *Rapidophylum hysterix* where they concluded that seedlings were not contributing to the population to a perceptible extent. The number of seedlings was more in the undisturbed areas (plots at Ambayathode) while it was less in the disturbed areas (plots at Pullupara). It is assumed that lack of grazing and other disturbances from the animals contributed to the highest seedling density in the undisturbed areas.

It was observed that the mortality rate was higher when the seedlings were clustered in a particular area. This agreed with the observation of Wilson and Janzon (1972).

Seedlings were the dominant stage in the population. A similar observation was recorded for *Chaemadorea tepejilote* (Oyama, 1990).

The view of Burgess (1975) that the high concentration of seedling is necessary to ensure the survival of a few was found correct in *Arenga.* In all the plots seedlings were formed the major group. The undisturbed area in Vallakadavu and the disturbed area in Kuttikanam did not show any variation in this aspect. This was because the majority of the plants which were included under seedlings were the small suckers with the characters of seedlings.

In *Phoenix* it was observed that the number of seed production and the number of seedlings established were not related. Here the condition coincided with the observation of Clancy and Sullivan (1990) that the seedlings are not contributing to the population to a perceptible extent. For this, two reasons could be found out. One of the reasons was the failure of germination and the longer period required for germination. In *Arenga obtusifolia* Koebernik (1971) made a similar observation. Secondly, in a constant population like *Phoenix* the rate of recruitment was balanced by almost equal rate of deaths as evidenced from the present study.

As suggested by Burgess (1975) the possibility for the absence of the abundance of the seedlings in the plots of *Phoenix* might be due to the fact that fruits being edible would have facilitated seed dispersal by birds to other far off areas. In *Pinanga,* the observation was similar to that by Orellano and Ayora (1993) in *Thrinax radiata.* They observed that the population of *Thrinax radiata*, a Mexican solitary palm, consisted of juvenile and adult plants and no seedlings were found. Similarly the study of *Pinanga* showed juveniles or adults as the dominant stage in the populations. It was assumed that microenvironmental effect was the major obstacle for the seedling to survive. The low seed production rate also contributed to this.

Population flux and rate of recruitment and death

In a constant population, a high rate of recruitment should be balanced by an equal number of deaths. The study showed that this did not occur in *Arenga* and *Phoenix* during the 36 months of study and the total number of plants at the end was greater than the number of plants at the beginning. The recruitment rate observed in *Phoenix* also showed that it was not a constant behaviour which occurred all the time. It is believed that the rate of death especially at the seedling stage also increased to give a more constant final population. These two genera were obviously long lived plants and a 36 month study period gave certain indications of their whole in the long life span life population dynamics. While in *Pinanga* the deadline in population was clearly noted.

No new recruitment was observed in juvenile stage in any of the observations in *Arenga* and *Phoenix*. In both, the transition of seedling to juvenile stage seemed to be particularly difficult. This result indicated that a huge number of seedlings were eliminated before transition. The transition of seedlings to juvenile stage was comparatively more difficult than the transition of juvenile to the adult stage. The ratio of juveniles remained constant in both these genera. Thus the population had a very high mortality in the seedling and higher survival rate in the juvenile and adult plants in *Arenga* and *Phoenix*.

In *Pinanga*, mortality was noted in all the stages. The death rate was high both in seedling stage and juvenile stages. It was observed that one of the reasons for the decrease in number of seedlings and juveniles were due to their transition to the next stage. But the major reason for the decrease in total number in all the plots was the mortality that occurred in all the stages. So the survival ship of *Pinanga* was not as strong as in *Arenga* and *Phoenix*.

The survivorship pattern found in *Arenga* and *Phoenix* shows similarity to those reported in *Astrocaryum mexicanum* by Pinero *et al.* (1984) and the studies of Hartshorn (1975), Van Velen (1975), Sarukhan (1978) and Enright and Ogden (1979) in other tree species. This pattern was represented by a very high mortality in the early stages and a high survivorship during the reproductive period. A different pattern has been found in the vegetative and sexually reproducing palm *Podococcus barteri* by Bullock (1980) where a high mortality was observed for seed and seedling. But stolons and adults had very low mortality. This was similar to the situation for perennial herbs with vegetative reproduction (Sarukhan and Gadgil, 1974).

The mortality of *Pinanga* was especially high in all groups of individuals. Damage due to tree fall was very common in this species and the plant was not resistant as the other two palms. The habitat and the other peculiarities of the genus also led to more death.

The demographic data obtained for *Arenga* and *Phoenix* suggested a strong dependence of large population on a proportionally small number of genetically effective individuals. These individuals are responsible for the maintenance of genetic diversity, genetic structure and demographic structure for the entire population. Such a dependency has important consequence for the species management especially when natural regeneration is the only source of new seedlings. The typical reproductive strategy of the species included the maintenance of a large seedling collection. This was similar to the observations of *Euterpe edulis* by Negreiros (1982) where the natural population show a pyramid shaped demographic structure (Reis *et al.*, 1999), with large base of non-reproductive plants and a smaller number of reproductive individuals.

Phoenix showed high rate of seed production but number of seedlings formed is very less. Oyama (1990) reported the same phenomena. Accordingly reproductive out put probably vary among individuals in response to many factors including environmental conditions and ontogenic history. Seedlings that are seen near the palm may not necessarily be the offspring, since it is dependent on the dispersal mechanism also.

In *Arenga*, the highest mortality of seedlings was either by the fall of large canopy trees or their large branches or trees or by uprooting due to heavy flow of rain water. Similar observations have been recorded for other species by Sarukhan (1978). The chance of survival after an individual reached mature stage was high and nearly constant.

Accidental or random factors leading to mortality are fall of large canopy trees or their large branches which break or bend the trunks of the palms.

Population flux in *Arenga*

The climatic factors have much influence on the number of seedling formation in *Arenga.* New recruitment occurs at specific months of the year. The maximum recruitment rate among all the plots was 8.6 and the minimum was 1.1. The new seedlings appeared only in very few observations because these observations were after the end of a huge recruitment (related with the availability of seeds). Much of the new recruitment was noted after 9, 12 and 30 months. This may be perhaps due to the favourable season in the forest region. Eventhough the recruitment rate was high in the last three plots it may not be related with the population dynamics. It was due to the availability of seed and more open area due to disturbance in the forest region.

Climatic variations had influence in the rate of death of seedlings. The maximum death rate per 3 months was noted as 12.5 and minimum as 1.1. Most of these deaths were noted in the observations after 15 and 33 months. The rate of death was high in the plots at Pullupara where the rate of recruitment also was high. It was at a low rate in the plots at Ambayathode where the rate of recruitment was also low. The rate difference might be influenced by the difference in the rainy season noted in the South and North of Kerala. The absence in new recruitments in many observations was due to the unfavourable season observed in the region. The percentage of seedlings in the plots at Ambayathode was high. In *Arenga*, the life span of seedling was very long and within this period the mortality rate was high for one or two years old seedlings. Once it withstands this period, there is a chance for survival. But the decrease in number of leaves noted in the seedlings in all the plots indicated that eventhough the seedlings survived for a short period, the rate of mortality will be high in the initial stages. The death may occur to the seedlings later and only few will be transferred to the juvenile stage.

In *Arenga* once the juvenile stage was attained, very little death was observed. The only one death noted was in the 33rd month of observation. Among adults also no death was noted.

Some possible causes of high mortality among seedlings were competition in dense stands, fungal attack, gushing of rain water, soil erosion, animal predation, trampling by field workers, and damage by fallen trees. Competition between new seedlings was assumed to be mostly for water, light and space. Mortality among juveniles and adults was rare. Root and crown competition were probably the most important factors among the juvenile and adults. Adults possessing a hard and tall trunk were very unlikely to become victims of fallen trees. No mortality was observed for the plants with stem for 33 months and the rate of survival was 100%. The survival of juvenile was less than 100%. Among seedlings eventhough the mortality rate was less, the number of death was high with respect to size of the whole population.

Population flux in *Phoenix*

As in the case of *Arenga*, in *Phoenix* also the time of the year have much influence on the number of seedlings. New recruitment occurred only in certain times. The maximum recruitment noted was 18.9 and the minimum was 5.2. These new recruitments were noted in the observations after 9 and 24 months. The arrival of the new seedlings was related with the rainy season. In some plots new recruitment was not noted. In the other two plots located in the same area at Kuttikanam, the rate of recruitment was less. This was due to the disturbances such as grazing, soil erosion, less humus content in the soil etc. which prevented the germination of seedlings.

Climate also has influence in the death of the seedlings. The maximum death rate noted was 7.5 and the minimum was 1.8. The death observed was in the months of 3, 6, 27, 30 and 33. As in recruitment, the death was also high in plots at Vallakadavu. This was due to the seasonal variations. The habitat of *Phoenix* is the grasslands. During the rainy season the whole area will be covered with new sprouts. The time of germination of the seedling is the same as that of grass which will completely cover the area. Once the grasses fully cover the area, germination of other seeds might not be possible. During rainy season, grasses also will be sprouting and this newly formed thick cover will smother palm seeds. In a disturbed area like Kuttikanam, the grass covering was incomplete which favoured germination. This may be the reason for less germination in certain plots. It indicated the necessity of the microclimate maintenance for the population of *Phoenix* to have a stable stage. This is a major threat in the Western Ghats regions where the habitat of this species faces the intervention of the human beings either for harvesting the leaves or for agricultural purposes. The influence of forest fire which regularly occurred in the grasslands has certain influence in the stability of populations of *Phoenix* which is to be studied further.

The death occurred to the juveniles was at a higher rate than that in *Arenga*. But the survivorship of the adults was 100% in the 33 months of observations.

In determining the population structure of *Phoenix,* microclimatic conditions have more influence than in *Arenga*. In addition to the above reasons the comparatively high mortality in seedlings also caused by fungal attack, erosion by rain, soil erosion, and animal predation. The mechanical damage may be the main reason for the mortality of juveniles.

Population flux in *Pinanga*

In *Pinanga* also the climate had much influence on the recruitment of new seedlings in the plots. The maximum recruitment rate noted was 12.1 and the minimum was 2.3. The major new recruitments were during the months of 12th and 30th month. This was related with the arrival of favourable seasons in the forest region.

In the death of the seedlings also the climate had certain influences. The maximum death rate noted was 32.3 and the minimum was 1.1. But the death occurred were not restricted to any months as in *Arenga* and *Pinanga*. It occurred in almost all the observations among all the plots. From this it is clear that the unfavourable season alone is not the cause of death. Other factors have also influenced the mortality of the seedlings. The habit itself accelerated the mortality rate. As in other two species, fungal attack, erosion by rain, soil erosion and damage by fallen trees influenced the rate of mortality. Apart from all these reasons the slight change in the microclimatic conditions easily affected the mortality of seedlings in a more severe manner than in the case of other two palms.

Another feature noticed in *Pinanga* was the new recruitments in the plots. Unlike the other two genera, there was the transition of seedlings to the juveniles in all the plots during the 33 months of observation. At the same time the mortality of the juveniles were also high. The rate of mortality in juveniles was due to crushing by fallen branches of trees. As this is an understorey palm seen in the tropical evergreen forests, the chance of such type of damage was very high.

The transition of juveniles to adults was also noted in all plots during these 33 months. Mortality was also noted. This was also due to the crushing by fallen branches or trees. The habit of the adult with a slender stem favoured the damage to the plant.

The high mortality rate among seedlings, juveniles and adults has different reasons. But in all the cases the habitat of the plant has certain influence. Being an understorey palm, *Pinanga* is very slender. The stem is with an average girth of 15 cm while the height of the plant was up to 4-5 m and not hard and is easily breakable. The plants were seen very close to each other in a population. So a natural calamity will damage many plants at a time. Up to 27 adult plants were observed in one plot as compared with the 5 for *Arenga* and 14 for *Phoenix*. One of the reasons of high mortality in *Pinanga* was the habit and the habitat itself. These two factors influenced the population structure more in *Pinanga* than in the other two genera.

Arenga and *Phoenix* had seedlings as the dominant group in the population while in *Pinanga* juveniles or adults were the dominant groups. In *Arenga* adults was represented with a maximum number of 4-5 plants in a plot. In *Phoenix* the maximum was 14, and average number was10. In *Pinanga* the minimum was 6 and the maximum was 27. The major reason for such a population structure in these three genera may be the root and crown competitions and the clustering nature of palm.

In the three taxa the mortality was shown maximum by the seedlings. Among the juveniles, rate of survival was less than 100%. The survivorship was maximum in *Arenga* and *Phoenix,* and in *Pinanga* it was less. Among adults, 100% survivorship was shown by *Arenga* and *Phoenix*. But in *Pinanga* the survivorship was less than 100%. The transition form one stage to another was not noticed in *Arenga* and *Phoenix* while in *Pinanga* the transition from seedling to juvenile stage and juvenile stage to adult stage were noticed.

In this study, another phenomenon noted was the relation between the rainfall and the recruitment and death in all the three taxa. The major amount of rain was available during the months of June, July and August. During the months October, November and December rainfall was available in a lesser quantity. The vegetative growth, seedling germination and establishment were highly influenced by this factor. In the Kerala part of the Western Ghats this factor has high influence in determining the structure of vegetation.

In *Arenga* in the first two observations i.e., during February to May, no new recruitment was observed. From third observation (June) onwards new recruitments were observed in the plots and it stopped during the dry period. The next recruitment period started with the next rainy season. A similar trend was noticed in the other two taxa also.

The embryo in the fallen mature fruit remained in a dormant stage until water was available. Unlike the seeds of many other angiosperms the palms have a hard seed coat. So a sudden appearance of seedlings as in the case of other plants couldnot be noticed in palms. The delay in the observation of seedling in the plots immediately after the onset of the rains may due to this reason.

Another feature noticed was that in *Phoenix* the germination of seeds and the appearance of seedling were restricted to a few months only. In *Arenga* and *Pinanga* the new recruitments occurred for a period of more than three months, it was absent only for a short period during the peak of summer. This might be because of the effect of the habitat. Both *Arenga* and *Pinanga* were seen in the evergreen forests and the moisture in the soil was retained for a longer period under such a habitat, which provided a suitable condition for the germination of seeds. Hence even after the actual rainy season, seed germination and seedling establishment continued. In the case of *Phoenix* the habitat was more exposed to sunlight due to the absence of large trees in the grasslands. So within a short time after the rain fall the area become dry and sufficient amount of water would not be available to the seed and hence germination took place only during the rainy seasons.

The analysis of the occurrence of death in different plots showed that death might occur at any time of the year. Among the three taxa studied, *Pinanga* showed a continuous occurrence of death throughout the year. In *Arenga* and *Phoenix* eventhough it was not noticed in all months, the trend showed that it might happen at any month of the year. In *Arenga* and *Phoenix* the factors, which lead to the death, were limited compared to that in *Pinanga*.

Age group distribution in the three species

In all the three palms the leaf production at all the stages was easily countable. It was noted that the leaf production rate was the least in *Arenga* (less than one per year) while it was maximum in *Phoenix* (more than six per year). In *Pinanga* the rate was in between the above two (3 or 4 per year). The above rates were for adults and among the other two groups also the same pattern was followed.

In all the three species the leaf scars were clear, prominent and easily countable. In *Arenga* and *Pinanga* the numbers of leaf scars in the stem of adult plants were limited (in *Arenga* it varies from 42 to 84, in *Pinanga* it varied from 10-75). For *Phoenix* the numbers of scars in a large plant was more and the counting was much difficult; it varied from 72-2070. In juveniles of *Arenga* it varies from 6-41 while in *Pinanga* the maximum was 9. In the juveniles of *Phoenix* the leaf scar ranged from 30-71. Among the three species the maximum internodal length was noted in the adults of *Pinanga*. The internodal length in *Arenga* was less than *Pinanga* and in *Phoenix* it was minimum or very less.

The maximum height increase for adults was noted in *Pinanga* (21.88 cm). For juveniles it was 1.92 cm. It was minimum in *Phoenix* (0.04 cm). In *Arenga* among adults maximum was 2.23 cm. In certain observation the decrease in height was noted due to the death of certain tall plants especially in the case of *Pinanga*.

Secondary growth was absent in palms due to the absence of vascular cambium, the increase in girth noted in the adult plants was negligible. Nevertheless, Sarukhan (1978) has shown that the growth rate of palms was remarkably constant and short term measurements would reflect the overall growth rates with remarkable accuracy.

The pattern of growth at different plots was same for a species. *Arenga* at Ambayathode and Pullupara showed the same pattern. Similarly *Phoenix* at Vallakadavu and Kuttikanam and *Pinanga* at Rosemala and Nadukani also showed the same pattern specific to the species. The variation in height showed by these plants was due to the difference in habitat.

But when the growth of different genera was compared there was great difference in all the above growth characters. They were characteristic of each genus, which might be genetically controlled. The age-group distribution of the same species at different locations showed similarity. The age-group distribution of a particular species will give indications regarding the growth and stability of the population.

Age group distribution in *Arenga*

The data on age group distribution clearly indicated that eventhough a population contained large number of seedlings at a particular time it would not determine the final population structure. The large number of seedlings which were seen at a particular time would perish within a short period. In *Arenga* it was noted that in all the plots the number of leaves in majority of seedlings decreased in the successive observations. The rate of decrease in the number of leaves coincided with the high rate of mortality observed during the seedlings.

In the case of the juveniles 11 of them were in the age group of 10-20 years while two of them were in the age group of 30 to 40 years. When adults were considered, five of them were in the age group of 30-40 and seven of them were in the age group of above 40 years.

From the above data it was clear that the number of seedlings which transformed in to mature plants were very limited. At the same time each group had its own age period. The maximum seedlings were below 10 years of age. The transition from one life-form to the next was very limited. Majority of this group would perish in their age group itself. For the juveniles the age level was in between 10 and 20 years. The maximum juveniles in the plot were in this age group. The transition from this group to the higher level was very rare. Once transformed in to this age group they have to show maximum vigour to transform to the next stage. The adults were maximum in the age group of above 40 years.

The transition from one stage to the next was influenced and regulated by many factors. The physical environment was exerting a selective force on the transition mechanism. The light availability, soil condition, the canopy of the particular area and the disturbance happened to the particular area influence this process. The influence of the factors in the population of *Arenga* at the two localities was similar.

The competition for light was very crucial in the seedling stage. The seedlings have to compete much with the juvenile and adult plants. Majority of the seedlings cannot withstand this competition and this was a major reason for the high rate of mortality observed among the seedlings. The high percentage of seedlings in the population has certain relation with nature of seed, type of germination etc. In *Arenga* the seedling depended on the endosperm and for survival in the initial stage after germination and its stabilisation. But once the seedling has established it has to prepare its own food material. Then the competition for light comes. Majority of seedlings cannot withstand this competition for light.

Within the age of 10 years, many of the seedlings perish and only a limited number of plants get transited to the next stage.

In the plots at Ambayathode this was very evident. In plot 1, the number of seedlings in the age-group of below 10 years was 99 while that of age-group of 10-20 years was five. In plot 2 it was 74 and seven and in plot 3 it was 20 and six respectively. The maximum canopy was observed in plots 1 and 2 while in the plot 3 the canopy had brakes and light was available for the under growing seedlings. So the transition rate was high in plot 3.

The area of plots at Pullupara was highly disturbed and the canopy also was not continuous. Hence light was available for the under-growing plants more than that in the plots at Ambayathode. In plot 4 there were 16 plants in the age-group of below 10 years while in the next group it was six. In plot 5 it was 13 and 10 respectively. In plot 6 it was 10 and seven. So from the age-group studies it was clear that light has maximum influence on mortality, transition, and age-group distribution of seedlings of *Arenga*.

The juvenile and adults were apparently free of competition compared to seedlings. Therefore the mortality rate also was low. So once the juvenile or adult stage was reached it would survive eventhough the transition was slow.

The soil condition of the habitat influenced the pattern of age group distribution. In evergreen forests, the water holding capacity of the soil was very high. Seed germination was promoted by such soil. The increased number of seedlings at Ambayathode might be due to this. At Pullupara the soil condition was not as in the evergreen forest because of human interaction. In this soil humus content and water holding capacity was low. The competition after survival would be high in such areas and only the fittest would survive. Once established, their survival rate would be higher than the seedlings which germinated under very favourable conditions. At Ambayathode, the soil condition favoured the production of new seedlings but due to high rain fall the chance of disturbance to the seedlings was high. The leaves fallen from the canopy would cover the seedlings leading to their death. The variation in the age-group pattern of the seedlings in the two regions was influenced by the above said factors.

The canopy influenced the germination in two ways. In one way it favoured germination by producing favourable temperature and keeping the soil wet. At the same time by preventing enough light for the normal growth of seedlings it inhibited the seedling growth. The leaf fall and fallen branches also badly affected the seedling population. The influence of the canopy on the juveniles and adults was very less compared to that on the seedlings.

Age group distribution in *Phoenix*

Unlike in *Arenga*, a continuity of the group was observed in *Phoenix*. This continuity exists in all plots.

In plot 1, thirty one seedlings and three juveniles were below 25 years of age. Three juveniles and eight adults were in the age group of 25 to 30. Two adults were in the age group of 50 to 75 and one, 75 to 100. In plot 2, 43 seedlings, four juveniles and seven adults were below the age-group of 25. Here two juveniles and seven adults were in the age-group of 75-100. In plot 3, 35 seedlings were below 25 years. Four juveniles and six adults were in the age-group of 25-50. In plot 4, 42 seedlings were in the age-group of below 25. In this group, there were one juvenile and one adult. Four juveniles and two adults were in the age-group of 25-50. Here 2 adults were more than 100 years of age-group. In plot 5, 39 seedlings and two juveniles were below 25 years of age. The adults show continuity from 25-50 age-group to above 100 years of age (6 plants). In plots 6 also, the same pattern was noted. 21 seedlings were below 25 years of age. Adults start from 25-50 age-groups (5 plants) to above 100 years of age (2 plants).

Eventhough continuity existed in the age-group distribution of different growth forms, two significant characteristics observed were the limit in the number of seedlings and the high mortality observed. *Phoenix* is a pleonanthic life form. During each flowering season large number of seeds was formed. But the age-group distribution of the population did not coincide with this fact, so definitely certain factors were influencing this phenomenon. The phenomenon which determines this character may be phenological, interspecific interactions, interactions of predators and the effect of physical environment.

It was observed that the species was andromorphic where the male flowers mature first. In a particular area the production of male flowers started in the early flowering season. So there were a certain barriers for pollination. The production of the seeds was related with the availability of pollinating agents. The natural habitat of *Phoenix,* the grasslands, was subjected to many types of disturbances. Any disturbance like human interaction, grazing or forest fire would affect the pollination, which inturn the seed production. All those interactions were very common in the grass lands of Western Ghats. Totally there were many barriers in the production of seed in *Phoenix* which influenced the production of seedlings.

Once the fruits were formed there were other disturbing factors. The fruits of *Phoenix* were edible which many animals and birds commonly eat. These predators might distribute the seeds beyond the boundary of grass lands, the natural habitat of *Phoenix. Phoenix* normally germinated in the grass lands, so the distribution of seeds beyond the boundary by the predators resulted in low quantity of seed available in the natural habitat.

From the observation during three years and in the field trials it was found that seed viability was only for a short period. The seed which was formed in a season will germinate in the next rainy season. The seed will not be viable for the next year. Hence for germination a very favourable condition must be available for the seeds immediately. From the germination of seeds at Ponmudi region of Western Ghats it was noticed that the presence of a rocky soil with a limited depth favoured the rate of germination.

When compared with *Arenga* the seeds of *Phoenix* were small. The amount of nutritive tissue or the endosperm was less in quantity than that in *Arenga* and the germinating seed had to soon become independent. Any unfavourable situation soon after the germination would affect the immediate survival of seedling.

The germination of the two taxa, *Arenga* and *Phoenix* were studied in detail. It was noted that the germinated seeds of *Phoenix* formed a single root from the radicle in the initial stage. No secondary roots or rootlets were observed in *Phoenix* during this period. While in *Arenga,* the number of secondary roots and rootlets in the initial stages of seed germination were very high compared to that in *Phoenix*. The limitation in the development of root system in the stage might be the influencing factor in the establishment of the seedlings of *Phoenix*.

The eophylls of *Arenga* and *Phoenix* show morphological differences. In *Arenga* the eophylls were flat with large photosynthetic surface. In *Phoenix* the eophyll was lanceolate or needle like with less photosynthetic area which was also an unfavourable phenomenon which prevented the establishment of seedling in *Phoenix*.

The germination of the seedlings was during the monsoon season. The germination of the grasses was also during the same season. The grass would occupy the whole area within a short time. There would be a competition for nutrition between seedlings of *Phoenix* and grasses. The fertile top soil strata would be completely occupied by spreading root system of the grasses. The structure and morphology of the grass root system makes this easy and it was very harmful to the germination and establishment of seedlings of *Phoenix*. *Phoenix* seedlings had to compete with grass for light also. It was noted that the newly formed seedlings of *Phoenix* is completely covered and smothered under the fast growing grasses. Sometimes the *Phoenix* seedlings were to escape this and reach the light. Thus *Phoenix* seedlings face a very harmful competition from the natural habitat which was a barrier for the establishment of seedling.

Once the seedlings were established this factor would not have any influence the population structure and it was evident from the age group distribution.

Another factor which restricted the seedlings growth was the forest fire. The forest fire was very common and regular in the grass lands of Western Ghats. However during the study period, there was no incidence of fire. The newly established seedlings of *Phoenix* are with one or two lanceolate leaves. If there is forest fire the newly formed seedling and the seedling of the age of two or three years will be completely burned. The effect of forest fire on the juvenile and adults is not very serious as on seedlings. The leaves of these groups will be burned but the terminal bud would remain with out damage. In the next monsoon season these plants will develop new leaves at high rate than the normal one. So the mortality due to fire is not influencing the continuity in the age group of juveniles and adults. The discontinuity in the age-group of seedlings and the continuity in the age - group of juveniles and adults might be due to this factor also.

The grazing by the wild animals is very common in the grasslands. The newly established seedlings are similar in appearance to the emerging grass seedlings. The high mortality rate of the seedlings is due to increased animal grazing. In the case of juveniles and adults grazing will not do much harm.

All these factors with its characteristic features were influencing in the study plots at Vallakadavu. In the last 3 plots at Kuttikanam the human intervention was very high. Here apart from the other factors the physical environment was also influencing the population structure. Here the texture of soil was entirely different from the other places. The humus content in the soil was very low. At the same time the establishment of grasses in the field was not vigorous when compared to other areas. Grazing by the domestic animals instead of the wild animals was noted here. At the same time the anthropogenic disturbances like cutting of leaf, collection of fruits etc. were prevalent in this area. All the above factors influence adversely in different degrees the population structure of *Phoenix* which leads to the age-group distribution restrictions and continuity of different groups which was observed in the analysis.

Age group distribution in *Pinanga*

The pattern of age group distribution in *Pinanga* showed more similarity with that of *Phoenix* than *Arenga*. From the observation it is clear that there is a trend to keep the continuity between different age-groups and different group of plants as was noted in *Phoenix* also. Population of the first stage, seedlings, were found maximum in below 10 years of age and it did not extend to the next age-group. The juveniles also showed higher count in the below 10 years age group. The presences of juveniles were noticed in the next two age groups also. At the same time the number of juvenile plants gradually decreased in the age groups 10-15 and 15-20 years. In case of adults, its distribution extended to all the age groups. But in the first age group there was only a minimum number of adult plants and in the other stages number was more or less similar. This observation is very significant in understanding the trend in the demographic structure.

Unlike the other two genera *Arenga* and *Phoenix,* number of juvenile and adults is more in *Pinanga* and it is very significant that they keep the continuity. This may be due to the transition from one stage to the next and due to the limited age duration of *Pinanga.*

The conversion from one stage of growth to the next stage is very fast in *Pinanga*. This can be related with the habit and habitat of the species. In the other two species the height increment was very less with an annual average of 0.17 cm in *Arenga* and 0.11 cm in *Phoenix*. *Pinanga* showed an annual average height increment of 15.57 cm which ranged from 12.04 cm to 19.16 cm in plot 6 and 1. In *Arenga* the leaf-size is large which decreases the competition for light. In *Phoenix* since it is growing in the open area i.e., grasslands, a competition for light does not occur. But *Pinanga* is an understorey palm. The number of leaves in the plant is comparatively less (generally 5 to 7) when compared to the other two taxa. The leaf size is also less compared to that of *Arenga*. So a competition for light becomes necessary. To achieve maximum light in order to keep the photosynthetic apparatus efficient, the plant may try to increase in height and produce new leaves. This may be the reason for the high rate of increase in height noted in *Pinanga*. The high mortality rate in the seedlings also is prominent.

The tendency to grow fast is noted in all the stages of *Pinanga*. In the seedlings the average height increase annually is 4.19 cm. In juveniles it is 21.88 cm. In *Arenga* and *Phoenix* there is no stem formation during the seedling stage. In juveniles the annual height increment is 1.92 cm and 0.04 cm respectively which will not lead to a conversion to the adult stage. In *Pinanga*, in the case of adults the average annual height increment is 20.02 cm. In *Arenga* and *Phoenix* it is 2.23 cm and 0.49 cm respectively which shows that these two palms are very slow growing.

The average annual increment in height is high in juveniles of *Pinanga*. The average inter nodal length also is maximum in the juvenile stage. Juvenile needs more light for photosynthesis than the seedlings and since it is an under storey palm, it grows fast to extend its leaves to the sunlight. This will result in long internodes.

The consequence of this differential growth can be related to the life expectancy of plants. Individuals that do not grow enough to achieve a certain height to avoid the shade of other plants, did not reproduce and the rate of mortality will high in this group (Pinero *et al.*, 1984). All other things being equal, and light acting as a limiting factor for tropical plants (Okali, 1972; Waterhouse and Quinn, 1978; Bullock and Bawa, 1981; Fetcher *et al.*, 1983; Langenheim *et al.*, 1984 and Chazdon, 1986), the individuals that grow more during their first life cycle stages (seedlings and juveniles) can reach a height that confers on them the highest probability of survival. Plants that stay under shade conditions for long period of time eventually die if the conditions do not change (Ashton, 1981). This is true in case of *Pinanga* also.

Comparison of age group distribution of the three species

The age group distribution pattern in *Pinanga* showed the highest mortality in the juvenile and adult stages than *Arenga* and *Phoenix*. It is clear that the light factor is highly influencing the growth and survivability of this species.

Morphologically the species *Pinanga* is weaker than *Arenga* and *Phoenix*. The stem of the plant is not so hard as *Arenga* or *Phoenix*. It has got more height than the other two taxa. At the same time the girth of the plant is very less when compared with other two taxa. The root system is not well developed as in the case of *Arenga* or *Phoenix*. Because of the anatomical peculiarities the wood of the *Pinanga* is not hard as the other two taxa.

In *Pinanga* the limitation in the number of seedling is due to the limitation in the number of seeds produced. Clark and Clark (1987) found that the production of seeds would be more in plants where enough light was available or plants would be reproductively active if light availability was more. In *Austrocaryum mexicanum*, a very well studied under storey palm, light availability produced by the formation of gaps in canopy enhanced growth rates in younger stages and reproductive out put in mature plants (Sarukhan *et al.*, 1985).

In *Pinanga* it was noted that only few plants among the adults produced inflorescences in a season. In a plot only 3 or 4 plants produced inflorescences during the study period. Definitely light was acting as a limiting factor, which influenced the production of flower.

The number of seeds formed in an inflorescence was very limited when compared with *Arenga* and *Phoenix*. The pattern of inflorescence was similar in all the three taxa where it emerged on a common stalk with rachilla. The number of rachilla in *Arenga* may go up to 70-80 where in *Phoenix* it may be 30-40. But in *Pinanga* the main stalk had 4 to 5 rachilla. In *Arenga* more than 70 fruits were formed while in *Phoenix* it is only up to 25. In *Pinanga* less than 10 seeds only were formed in a single rachilla. Totally in an inflorescence 30-40 seeds were formed. This clearly indicates that the reproductive out put in this species is very less.

In *Arenga* and *Phoenix* a regular reproductive pattern was noticed during the observation. But in *Astrocaryum mexicanum* (Pinero and Sarukhan, 1982) and in *Chamaedorea tapejilote* (Oyama, 1990) an irregular pattern of reproductive behaviour was reported. In *Pinanga* also, such an irregular pattern was noticed. Corroborating the earlier finding that when the environment was heterogeneous, both in space and time, non-synchronous reproduction would be favoured. But the reproductive output from such a non-synchronous reproductive pattern would be less.

From the data of age distribution of different species studied it can be concluded that the correlation between the micro site conditions and individual reproductive behaviour and output is significant. At the same time the highly dynamic nature of the habitat of these three taxa are trying to overcome the barriers. Among these *Arenga* and *Phoenix* show more survival percentage because of the phenological peculiarities and *Pinanga* is unable to keep a stable population because of their adverse effect.

Stage duration of the three species

The stage duration of the three species was entirely different and seedlings had the least duration among all the species. In *Pinanga* the juveniles have very less duration (13.1 years) than the adults (23.6 years). In *Arenga* juveniles had more duration (84.1 years) than the adults (74.4 years). In *Phoenix* the juveniles had a short period only (19.5 years) when compared with the adults (277.6 years).

Kiew (1972) had studied the natural history of a Malayan undergrowth palm *Iguanura geonomaeformis*. According to him such species would reach the critical diameter for vertical growth more quickly. The reason for the short duration of the juvenile stage in *Pinanga* is because of the above reason. Here during the transition stage of the seedling to the juvenile the stem is having a small diameter. At this period the plant will not grow vertically. At the same time as explained earlier the plant is subjected to a very high rate of competition for light and nutrition. For the survival of the plant fast growth is necessary and force is developed in the juvenile stage in order to attain the maximum girth and length with in a short period. This may lead to the short duration of the juvenile stage. At the same time the resource of the plant is not shared for any other development in this stage.

In *Arenga* the duration of the juvenile stage was long. The maximum girth of the stem was attained during the juvenile stage itself. Hence, vertical growth was slow during this stage. At the same time there was production of suckers in the juvenile stage. For the production of the suckers the parent plant has to share the resources. The leaves of juveniles are smaller compared to that of the adults and the amount of food will be very less. The little resource produced is shared for the production of the suckers which results in the slow growth of the juveniles in *Arenga*.

In *Phoenix* the juvenile stage duration was very shorter than the adult stage. It was related with the reproductive capacity of the species. Once the seedling has established and juvenile stage has reached, further development to the adult stage is very fast. It is attained within a period of 19.5 years. This short duration is not because of the morphology of the stem. The stem in juvenile stage is with equal girth as that of the adult plant. At the same time sucker formation is noticed in *Phoenix*. So the resource sharing also takes place here. But usually the suckers are fully formed at the adult stage. The number of suckers formed is comparatively less than that of with *Arenga*. So the short duration in the juvenile stage of *Phoenix* may be related with the high rate of annual leaf formation and the favourable physical environment than in the other two genera.

Phoenix produces 8-10 new leaves in each year, which increases the photosynthetic capacity of the plant. The productive capacity of the plant is higher than the other two species in the juvenile stage. This is because the habitat of the plant is the grassland and the light factor that affects the growth of the juvenile stages of the other two species has no adverse effect on *Phoenix*. At the same time the plant is not subjected to a competition of food and water since it is seen in the grassland. Large trees were absent in the plots and the grasses has a fibrous root system which will not reach a great depth in the soil. The competent grass will absorb the raw materials only from the upper strata of the soil. The strong root system of *Phoenix* pierces the soil too deeply where the root system of grasses is completely absent. In each year a large amount of biomass is added to the soil from the population of grass which increases the fertility of the soil. At the same time the grasses will act as a cover for the soil which provides a very favourable atmosphere for the growth of the juvenile *Phoenix* plant. So unlike the other two species *Phoenix* has a short duration juvenile-stage.

In *Pinanga* the stage duration for juvenile is 13.1 years. The morphological characters of the species and the physical environment determine the short duration.

In *Arenga* stage duration for adults was less than that of the juveniles. This is because of the hapaxanthic reproductive character of the plant. The stage duration of the plant was calculated related to the hight of the adult plant (number of leaf scars on adult plant). Adult plants of *Arenga* are not growing indefinitely as in *Phoenix* or *Pinanga.*

In *Phoenix* the adults grows for a long period. Morphological characters of the plant favour this. The very hard remnant of the leaf scar that completely cover the stem surface is a highly protective sheath for the stem. The drooping dry leaves and fibrous covering at the crown perfectly protects the single growing terminal bud without any damage.

The fibrous root system is also very adaptable for the survival of the plant. The high rate of annual leaf production will keep the photosynthetic formation very efficient. At the same time the physical atmosphere of the habitat is very favourable for the plant. All these conditions lead to high stage duration for the adults of *Phoenix*.

The stage duration of the adult of *Pinanga* is 23.6 years. It agrees with the observations of Ashton (1981) where he found that the plants that stay under shade condition for long periods of time eventually died if the conditions do not change. This cumulative effect of the influence of the physical environment can be noted in oldest adult plants.

Matrix models in the three species

P_1 is the probabilities of surviving and remaining in the seedling stage. P_2 and P_3 were the same for the juveniles and adults. G_1 was yearly transition probabilities for the seedling to the next stage. G_2 was the same for the juveniles. F_{13} was the ratio between the number of new seedlings and the total number of adults. F_{23} was the ratio between the new recruitment of juveniles to the total number of adults. Since the calculation was based on the assumption that no new recruitment occurred in the juvenile stage F_{23} remains zero.

The P_1 values are very high in *Arenga* which indicates that the probabilities of surviving and remaining in the same stage for seedling are high. This is because that the observations started just after a mass seedling formation followed by the fall of mature seeds from a mature inflorescence which occurs occasionally in *Arenga.* In the seedlings the average leaf number showed a decrease which indicate that the seedlings will die with in short time. In *Phoenix* a lesser values is observed in P_1 which indicates that seedling population is not stable while in *Pinanga* the P_1 values are very low where in actual observation it was seen that the mortality is very high.

The P_2 values of *Arenga* and *Phoenix* are high while in *Pinanga* it is low. This again coincides with the observations that the mortality of juveniles is high in *Pinanga.* The P_3 values also showed the same pattern which coincides with field observation.

The G_1 values of *Arenga* and *Pinanga* are very low while in *Pinanga* it is very high. This again coincides with the field observation where in *Arenga* and *Phoenix* the transition from seedling to juvenile was very less or nil while in *Pinanga* it was observed at a high rate.

The G_2 values of *Arenga* and *Phoenix* are very less while in *Pinanga* it is high. Here also the conversion of juvenile to adult was very rare in *Arenga* and *Phoenix* while certain conversions were noted in *Pinanga.*

The F_{13} values in *Arenga* decreased gradually in the consecutive years. This may be due to the fact that the observation started after a huge recruitment. In *Phoenix* also the same trend was noted. In *Pinanga* the F_{13} values were very less or nil in all the observations which indicated that the seeds were not available in the plots at the time of observation.

The demographic behaviour of the three species showed more similarities in the probability of surviving and remaining in the same stage in the case of juveniles and adults. Among these *Phoenix* and *Arenga* are similar, while in the case of seedlings they show variation. *Pinanga* varies very much form the other two in the case of seedlings. But in all the genera the population is slightly decreasing. The difference is noted in the juvenile growth probability because of the difference in the stage durations.

In all the species the mortality is highest among the seedlings. Among these the maximum mortality of seedling is noted in *Pinanga.* Among juveniles and adults the mortality is very less for *Arenga* and *Phoenix* while *Pinanga* it is higher.

This transition values are also high in *Pinanga* while in the other two groups it is very less. It is again related with the stage duration.

The sexual fecundity is lowest in *Pinanga* which coincides with the observation of the reproductive potential of the species. In *Phoenix* yearly difference is there which may be due to the diminishing nature of the population. In *Arenga* also the sexual fecundity varies in the three years of observations which may be related with the availability of seed or the diminishing nature of population.

Density of the population

The density per hectare, ratios between the number of mature trees and seedlings and the index pyramid represented graphically show that the maximum unstable population is that of *Pinanga.* Variation in population study indicates that conservational measures were very necessary for the species. The study areas for the species were far apart and this variation in global position had not shown any difference in the instability of its population.

In *Arenga* the undisturbed habitat shows a stable population, while in the disturbed area the population structure is gradually diminishing. Hence habitat protection is essential for the survival of this species.

In *Phoenix,* in both the disturbed and undisturbed regions seedling population is gradually decreasing. In the disturbed area the rate of decrease is high. This indicates that the disturbance in the natural habitat is deleterious to this taxon.

It is clear that *Pinanga* needs different methods of conservation in order to protect the species from extinction. The raising of seedlings to a sustainable number only will stabilize the population. But the number of seeds that is produced naturally in this species is very less when compared with the other two. And at the same time the low germination rate and high mortality of seedlings are characteristic features of this species. The mortality rate noticed in juvenile and adult stages is uncommon among the other two taxa. In *Arenga* in the undisturbed region the number of seedlings was high but further observations in the growth of the seedlings indicate that this higher number of seedlings poorly helps to a stable population. In the disturbed area even though the number of adults which can contribute to the stability of the population by providing enough seeds is present it is not contributing to a stable population, so certain urgent measures has to be taken to conserve this taxa also.

In *Phoenix* at present, even though the population index is that of a stable one, the changes in the yearly basis shows that the population is gradually deteriorating and the rate of deterioration is high in the disturbed region. On the same time when compared with *Arenga* the number of seedlings is very less in this species. But the observations show that enough seeds are produced in this taxon. A strategy has to be developed in this species in order to enhance the number of seedlings and the humanly interaction is to be reduced to maintain a stable population.

ROOT MORPHOLOGY

In the developmental morphological studies and demographic studies of the three palms *Arenga wightii*, *Phoenix loureiri* var. *humilis* and *Pinanga dicksonii* it was observed that the mortality was maximum among seedlings. The seedling establishment is influenced by many factors; among this root system of the plants has a major role.

A thorough knowledge of the structure and development of root system is essential for full understanding of the ecological requirements of each plant species which in turn is a necessary basis for silvicultural practices. Each species is distinguishable by their characteristic root morphology (Weaver, 1926). The growth of plants during the early phase of a plantation management, when seedling responds vigorously to silvicultural manipulation, is regarded as critical. During this period the roots confined initially as a mat in a narrow planting wedge ramify throughout the soil.

A basic knowledge of the root morphology, volume of soil exploited and the influence of edaphic factors on the root system are necessary for standardisation of nursery practices.

Woody monocots in general posses profusely branched fibrous root system. Experimental data available on the morphology and growth pattern of roots were however mostly confined to dicots.

In many other palms, the germination is adjacent ligular like that in rattans (Bavappa and Murthy, 1961; Tan, 1983).

The growth of primary root is soon arrested and is replaced by adventitious roots produced from obconical base. These roots produce laterals and sub-laterals as they grow. Same type of development was reported in oil palm, *Elaeis guineensis* (Tinker, 1976), and in rattan spp. (Jayasree *et al*, 2003)

But pneumatophores are not observed in both *Phoenix* and *Arenga* during the study in the experimental plot as well as in natural habitat.

Davis (1961) described the roots of arecanut in relation to their origin, size, shape, function and structure and reported the presence of pneumatophores or breathing roots. Lakshmana (1993) also reported the presence of negatively geotropic roots or pneumatophores in the mature plants of *Calamus nagbettai, C. metzianus,* and *C. rotang.* Dransfield (1974) studied the root system of *C. caesius* and observed four distinguishable roots in swampy soil; horizontal spreading roots, vertical geotropic roots, vertical apogeotropic roots and fine lateral roots. But Jayasree *et al*, 2003 reported that in *Calamus thwaitesii* and *C. rotang* no pneumatophores were seen

The number, length and diameter of main roots as well as laterals increased with age. A comparative study with the above parameters showed slight differences in the initial stage.

The number of roots in the initial stages in both the taxa was similar and a gradual increase was noticed in both the species. Analysis of variance indicated that it is highly significant in the initial stages while in the 2nd and 3rd year it was not so significant.

The number of roots formed in the initial stage in the seedling is influenced by many factors. In both the species the nutritive tissue in the initial stage was similar. In *Arenga* the seeds are larger in size and the amount of nutrition it can provide for the seedling will be high in the initial stage while in *Phoenix* the seeds are very small and the nutrition it can contribute to the seedling is very less. It may have certain influence in the root formation in the initial stage. A similar observation was noted by Aguiar and Nakane (1983) in seeds of *Eucalyptus citriodora.*

The number of lateral roots formed in each species may be influenced by the age of the plant. In *Arenga* the number of laterals formed in the consecutive years is 28, 68 and 22. While in *Phoenix* it is 16, 12 and 18 only. In the case of lateral roots also the analysis of variance was not significant in the initial stages. While in the second year it was highly significant and in the last year it was not significant.

The analysis of variance indicates that even though all these variations are shown by these two species, the growth pattern shows similarities. The differences noted may be due to the difference in the habitat. Riopel (1966) suggested that the longitudinal dispersion of lateral roots might result from the depletion of critical metabolites in the roots.

In the 3rd year there was a significant increase in the mean length of main and lateral roots in case of *Phoenix*. Diameter also increased significantly in the 3rd year for this genus. The differences in the spatial orientation of the roots in the two species were not significant.

According to Tschirch (1905) the quantitative and qualitative variations in the several roots give rise to the concept of heterorhizic root system in which variations of structure are paralleled by corresponding difference in root function. The roots were distinguished as roots specialized for anchoring the plant and extending the root system, and smaller roots which were adapted for absorption. The absorbing roots might be short roots and anchoring roots were fast growing. They might vary in number. With all these we can see that the variation in number of roots, root length and root diameter results from differences in the size of the plant, anatomical peculiarities, inheritable stability and competition with the living and nonliving components of the environment.

The regression equation for root length fitted for both *Arenga* and *Phoenix* showed that in *Arenga* 30 percent of variation in root length could be explained by age of the plant and in *Phoenix* it was 31 percent. While 47 percent variation in diameter could in Arenga and 51 percent in *Phoenix* could be explained by the age factor.

Volume of soil available for rooting is an important factor governing the growth of seedlings. In fact the soil is only partly utilized and a large proportion of the soil is not being exploited by the roots.

In *Arenga* soil volume exploited in the second year is about seven times the volume exploited in the first year. There is eleven times increase in the exploited soil volume in the third year. In *Phoenix* in the second year there was a decrease in the soil volume exploited.

In the third year the volume exploited is about two times the volume exploited in the first year. A comparison shows that *Phoenix* is exploiting more soil volume than *Arenga*.

Efficiency in nutrient uptake was influenced by the rooting density. Rooting density could be expressed relative to soil volume. Newman (1969) reviewed data for a wide range of species and found that in the family Poaceae. Atkinson and Wilson (1979) describe the consequences of a law rooting density value. If root density is high, flow rates will always tend to be low and gradients at the root surface will be rare. Where root density is low, as in fruit trees, the contrary will be true.

Root density varies with depth. So reduced soil water potentials will not be the same at all depths and this will therefore, affect the balance of nutrient uptake from different parts of the soil profile.

In *Arenga* the rooting density was higher in the first year which gradually decreased in the second and third year. While in *Phoenix* the value increased in the second year which decreased in the third year. Since both the species has more or less equal rooting density both the species are equal in their efficiency in nutrient and water up take.

CONSERVATION MEASURES

From the study of the current status of the three palms it is noted that the most vulnerable is *Pinanga dicksonii* because of the high mortality in all the three stages; seedling, juvenile and adult and production of low quantity of seeds and hence the low number of seedling formation. In *Arenga* and *Phoenix* eventhough the danger is not as much as in *Pinanga* they are facing population destruction. Conservation and sustainable utilization of palms assume importance in the current context when forest wealth of the state as a whole has been on decline. In the absence of concrete efforts towards their replenishment, all the three palms are likely to face the threat of extinction.

The destructive characteristics in *Pinanga* are more deleterious. It is with solitary stem, forming underground stolons in limited number only. The stem is more vulnerable to any kind of damage. The flowering and seed formation are very less. Germination percentage is also very less. The conservation strategy has to be developed considering all these aspects. At the same time the over exploitation and habitat destruction is very harmful to this species.

Conservation in the form of live collections is the first strategy to be adopted. Since the number of seeds formed is very less, *ex situ* conservation is also recommended.

In *Pinanga* mortality is noted in all stages. The reason for this is the damage to the plants due to tree fall. A judicial cutting of the canopy to a sustainable level in the regions where this species is found will decrease the mortality.

The climatic factors have more influence in *Pinanga* than in *Arenga* and *Phoenix*. The light availability will influence the palm in its photosynthetic and reproductive efficiency. Canopy manipulation will help in this aspect also.

The number of inflorescences and seeds formed in *Pinanga* is very less. So apart from the *in situ* and *ex situ* conservation methods, tissues culture method can be adopted for seedling production in this genus. The sucker production is also limited in the species. Suitable techniques to enhance the production and growth of the suckers should also be adopted.

In *Arenga* and *Phoenix* mortality is very high in the seedling stage. Here also, the over exploitation and habitat destruction makes the condition more serious.

In *Arenga* the human activities and grazing contributed to the high mortality rate of seedlings. The control of the above two factors will promote the stability of populations. Here, the dependency of the population on a small number of genetically effective individuals is high. So the maintenance of a large seedling collection will help in conservation. The life-span of seedlings is very long and the mortality is high in the initial stages. New recruitment is seasonal. So protecting the very young seedlings will help for a stable population.

Competition in dense stands which is very common in *Arenga* adversely affects the population structure. Hence a judicial thinning carried out in the dense stands would lead to a stable population.

In *Phoenix* the germination barriers like the seed-coat and longer period for germination, lead to low rate of germination and seedling production. The thick mantle of grass-roots will inhibit the further development of germinated seeds. Hence artificial methods which could enhance the germination rate are to be adopted for this taxon.

Here the genetically effective individuals, which determine the population structure is limited in number. So here a large population of seedlings is required to promote new generation. Hence enrichment-planting in the natural habitat is recommended for this species. New techniques for seed germination and sucker growth also should be developed.

The environmental condition has much influence in *Phoenix* in determining the population structure. Hence protection of habitat is a must. Here also *in situ* and *ex situ* conservation can be adopted.

In all the three species the high rate of mortality was noted in seedlings. So when the strategy for conservation is developed a high importance may be given for the conservation of seedlings.

With threats of different nature looming large over the forests of Western Ghats leading to the present scale of deforestation, *in situ* conservation of remnant species areas is most desirable. This is possible if forest areas with minimum human interference are set aside.

Soil protection methods like gully-plugging will help to minimise soil erosion, which will help in the establishment of seedlings in all the three species.

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SUMMARY

P. K. Padmakumar "Developmental morphology in relation to conservation in the family palmae (arecaceae)" Thesis. Department of Botany , University of Calicut, 2003

Chapter 7.

SUMMARY

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Palms are ubiquitous elements of hydric to xeric tropical to warm temperate environments. Biologically they are indicators as well as functional elements of the ecosystems of these regions and in their broad range of adaptation they interface with a large proportion of world population. Palms provide humans with an enormous array of useful products and thus touch upon many aspects of the human conditions, ranging from food procurements to production of industrial commodities.

Demographic studies in palms in natural and cultivated fields under natural as well as restricted conditions have been published during the last two decades. Some of these studies give a general understanding of population and community dynamics, while others concentrated on rare and endemic species and formulation of conservation strategies. Palm resource management is the other major area of studies where transition matrix models were formulated and used for resource management.

The developmental studies were conducted in three selected palms viz., *Arenga wightii, Phoenix lourieri* var. *humilis* and *Pinanga dicksonii* and the root development studies were done in the first two palms.

All the three palms are highly habitat sensitive and are seen distributed in the very special and restricted habitats in Western Ghats. Economically these palms are important for the aborigines.

The study plots were selected in the natural forest areas of Western Ghats. The three are not widely distributed in the forest. The main criteria for the selection of study plots were accessibility and the number of plants available in the area.

Three plots of 10 x 10 m size were selected in each locality. Plots were selected in such a way that each plot must represent of a minimum number of 10 seedlings, 10 juveniles and 10 adults. Two localities were selected for each species. As a whole six plots were there for each species.

For *Arenga,* the plots were selected at Ambayathode and Pullupara. The plots of *Phoenix* were at Vallakadavu and Kuttikanam. For *Pinanga,* the plots were selected at Rosemala and Nadukani. Observations were made regular intervals of three months for three years.

All individual plants were marked with labelled tags. All the individuals in the plot were classified according to their size, number of leaf or favouring conditions on seedlings, juveniles and adults. Undergrowth characters the height of the stem and the girth of the stem in each observation was measured. Under phenological characters the leaf formation, flowering and fruiting; survival characters of already established plants and the establishment of new seedlings from seed and sucker were studied. The interacting characters were also studied.

The rate of recruitment and rate of death were calculated using the formulas $\frac{n}{N}100$ where '*n*' is the number of new recruitments or number of deaths. The population dynamics of the species were studied at three months interval. The population flux for each species was calculated at an yearly basis. Using the formula $\frac{f}{g}100$ where '*f*' is the total mortality of the period and '*g*' the number of plants recorded.

The leaf scars remain conspicuous on the palm trunk. Though the number of leaves in the crown increases consistently until reproductive maturity is reached, leaf longevity is independent for three age, old leaves abscise almost frequently in growing palms. There fore, the age of the palm was estimated by measuring the time interval between the abscission of the successive leaves as follows,

Age of the juvenile of adult stage

$$= \text{Longevity of trunkless period} + \frac{\text{number of scars at last measurement}}{\text{Average no. of leaves fall per year}}$$

$$\text{Age of seedling} = \frac{\text{Total no. of leaves}}{\text{Average no. of leaves produced per year}}$$

The transitional probabilities and yearly probabilities of surviving and remaining in the same stage was calculated by the formula

$$G_i = \frac{\sigma_i}{T_i}, \text{ i} = 1, 2, 3$$

and

$$p_i = \sigma_i - G_i \text{ i} = 1, 2, 3$$

All the parameters studied in all the three species were compared. The root morphological studies were conducted in the campus of the Kerala Forest Research Institute, Peechi. Observations for the present study period were made at regular intervals of two months for three years.

Mature fruits of *Arenga* and *Phoenix* were collected and germinated. The seedlings were used for various trials. The experiments were laid out in a randomized complete block design for recording observations with respect to the morphology of root system; excavations of the entire root system were carried out.

Growth characteristics were calculated based on the data recorded on the number; length and diameter of the root. Rate of increase in length of the main roots and lateral roots of the two species in each year was calculated using the formula

Where l_2 is the average $\frac{l_2 - l_1}{l_1}$ length of root in a particular year and l_1 the average length of the root in the previous years.

The diameter of the roots was measured using Vernier callipers. Rate of increase in diameter of main roots and laterals were calculated using the formula $\frac{d_2 - d_1}{d_1}$

where 'd_2' is the average diameter of the root in a particular year and d_1 the average diameter of the root in the previous year.

Soil exploited by the root system of the two species of palms was calculated on an yearly basis making use of the formula

$$\pi\left(\frac{h}{2}\right)^2 v$$

where '*h*' is the mean horizontal spread and '*v*', the vertical depth of the roots.

Rooting density at each observation period of the species was calculated separately for each year by applying the formula

$$\frac{R\max}{S}$$

where R_{max} is the total root length and '*S*', the soil volume exploited. The result of all the parameters of the two palms was compared.

The population dynamics studies revealed that the seedling is the major component in the population of *Arenga* and *Phoenix.* In *Pinanga* the major component was either adult or juvenile plants. The maximum numbers of seedlings were seen for *Arenga* when compared to other taxa. Throughout the study period, the same pattern was maintained by the three taxa.

The new recruitments which lead to the changes in number in the populations were noted only among the seedling populations in *Arenga* and *Phoenix.* In juveniles and adults no new recruitment was noted in these species. The transition to the next stage of the life form in these two species was very low. At the same time there were possibilities of death to these life forms. In *Pinanga* the new recruitment to the seedling population was very low when compared with others. Transition rate of one life form to the other was comparatively high in *Pinanga.* The demographic data suggested a strong dependence of large population on a proportionally small number of genetically effective individuals. The low rate of transition in *Arenga* and *Phoenix* was due to the physical environment which acted as a selective force on transition. The light availability, soil conditions and the canopy structure of that area were the major factors affecting the rate of transition. The high rate of transition in *Pinanga* was related with the habit and habitat of the species. The lesser number of leaves, the smaller size of the leaves, etc. were the influencing factors.

The survivorship pattern found in *Arenga* and *Phoenix* showed very high mortality in the early stages and a high survivorship during the reproductive stage. In *Pinanga* the mortality rate was high in all stages. In *Phoenix,* the duration of seedling stage was longer and that of *Pinanga*. The duration of juvenile stage was longer for *Arenga* and shorter for *Pinanga*. The duration of adults was more in *Phoenix* and shorter in *Pinanga*.

The probabilities of surviving and remaining in the same stage were high in *Arenga* and *Phoenix* while it was very less in *Pinanga* and hence the transitional probability was high in *Pinanga*.

In *Arenga,* in a specific natural environment, the seedlings concentration should be high for the survival of a few members of the species. At the same time the mortality rate was higher when the seedlings were aggregated in a particular area.

In *Phoenix* the number of seed production and the number of seedlings established were not related. Failure of germination and seed predation were the reasons.

The micro-environmental effect was the major obstacle for the survival of the seedlings in *Pinanga*.

Other possible causes of high mortality among seedlings were competition in dense stands, fungal attack, erosion by rain, soil erosion, animal predation, trampling by field workers, damage by fallen trees etc.

In all the three taxa the new recruitment was seasonal, while death might occur at any time of the year.

The population dynamics of the three taxa studied showed that the most vulnerable among the three taxa was *Pinanga*. At the same time *Arenga* and *Phoenix* were also not showing a stable population structure. Mortality was high among seedlings, juveniles and adults in *Pinanga*. The mortality rate in the juveniles and adults of *Arenga* and *Phoenix* was low. In *Arenga* and *Phoenix* the largest group among the population was seedlings but in

Pinanga, it varied to juvenile or adult stage. The new recruitment and death showed same seasonal patterns in all the three taxa.

Regarding the growth in height, *Pinanga* showed the highest rate while *Phoenix* showed lowest rate. The average number of leaves produced showed the highest value in *Phoenix* and the lowest value in *Arenga.*

The age calculation showed that among the three genera *Phoenix* was long lived and *Pinanga* was with shortest life-duration.

The type of seed germination and the nature of origin of roots were similar for the two taxa studied viz., *Arenga wightii* and *Phoenix lourieri* var. *humilis*

Morphological studies of the root system of the two taxa revealed that the number of roots was increasing with age both in *Arenga* and *Phoenix,* while it was more in *Arenga.* The number of lateral roots also was high in *Arenga*. The length of the main root and lateral roots also was increasing with age and it was more in *Phoenix*. More vertical depth was noted in *Phoenix,* while the horizontal depth was high in *Arenga* at certain stages.

When compared the soil volume exploited in the first year by the two taxa the lowest value was noted in *Arenga* which gradually increased with time factor. In *Phoenix* it showed a fluctuation.

The strategies that can be adopted for conservation must mainly concentrate on seedling populations.

In *Arenga* the human activities and grazing contributed to the high mortality rate of seedlings. The control of the above two factors will promote the stability of populations. Here the dependency of the population on a small number of genetically effective individuals was high. So the maintenance of a large seedling collection will help in conservation.

In *Arenga* the life-span of seedlings is very long and the mortality is high in the initial stages. New recruitment is seasonal. So protecting the very young seedlings will help for a stable population.

Competition in dense stands which is very common in *Arenga* adversely affected the population structure. Hence a judicial thinning carried out in the dense stands would lead to a stable population.

In *Phoenix* the germination barriers like the seed-coat and longer period for germination, lead to low rate of germination and seedling production. The thick mantle of grass-roots will inhibit the further development of germinated seeds. Hence artificial methods which could enhance the germination rate are to be adopted for this taxon.

In *Phoenix* the genetically effective individuals, which determine the population structure was limited in number. So here a large population of seedlings is required to promote new generation. Hence enrichment-planting in the natural habitat is recommended for this species. New techniques for seed germination and sucker growth also should be developed.

The environmental condition has much influence in *Phoenix* in determining the population structure. Hence protection of habitat is a must. Here also *in situ* and *ex situ* conservation can be adopted.

In *Pinanga* mortality was noted in all stages. The reason for this was the damage to the plants due to tree fall. A judicial cutting of the canopy to a sustainable level in the regions where this species was found will decrease the mortality.

The climatic factors have more influence in *Pinanga* than in *Arenga* and *Phoenix*. The light availability will influence the palm in its photosynthetic and reproductive efficiency. Canopy manipulation will help in this aspect also.

The number of inflorescences and seeds formed in *Pinanga* was very less. So apart from the *in situ* and *ex situ* conservation methods, tissues culture method can be adopted for this genus. The sucker production was also limited in the species. Suitable propagation techniques to enhance for effective propagation of the palm, the production and growth of the suckers should also be adopted.

Soil protection methods like gully-plugging will help to minimise soil erosion, which will help in the establishment of seedlings in all the three species.

Chapter 7.

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