EVALUATION OF ORNAMENTAL BANANAS AND BROMELIADS FOR TROPICAL LANDSCAPES

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Evaluation of ornamental bananas and bromeliads for tropical landscapes"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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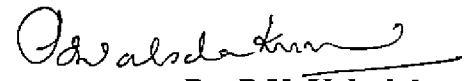
Certified that this thesis, entitled **"Evaluation of ornamental bananas and bromeliads for tropical landscapes"** is a record of research work done independently by **Mrs. Hazmin H.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.



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Dedicated to My
Loving Husband

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Introduction

1. INTRODUCTION

Blooms and foliage add to the beauty of any environment both interior and exterior. Ornamental bananas and Bromeliads with their varied characteristics are suitable for a wide range of landscapes and interiorscapes in the tropical areas. Some of the ornamental bananas are with colourful bracts and flowers, which are used in flower arrangements. Bromeliads possess a multitude of colour charms, brilliant patterns of leaf variegation and texture, elegant flower shapes and colours. They can survive in varied growth habits and are tolerant to low light levels. They can play an important role as indoor plants and hardier genera can be used as landscape plants also.

Ornamental bananas mainly belong to the sections Rhodoclamys and Callimusa of the genus *Musa* under the family Musaceae. They can be grown for their colourful inflorescence and ornamental foliage which add to the tropical look of the garden. The broad flat leaves of some of them will stand out in a landscape planting in clumps giving a sunny tropical look. They also thrive well in low wet spots or on the edges of ponds. Since they have a shallow root system, the dwarf varieties can be planted in containers. They can be put in large planters around the pool or out on the patio.

Ornamental bananas are distributed from West Africa to the Pacific but they are predominantly of South East Asian origin. Commonly grown ornamental bananas are *Musa velutina, M. ornata, M. coccinea, M. laterita, M. rubra, M. rosea, M. acuminata* var. *sumatrana and M. lasiocarpa.*

Bromeliads belong to Bromeliaceae, the family of pineapple. They *are* native to the American tropics. Most ornamental species are grown primarily for their colourful foliage and exotic shapes. The leaves are very attractive, range from grass like, two inches long, in *Tillandsias* to several feet long in *Billbergias*. The inflorescence is made up of brilliantly coloured bracts, which are large and leaf like forming dense spikes. This combination of highly coloured bracts and the contrasting

coloured fruits, which remain on the plant for several months, add to the aesthetic value of Bromeliads. *Aechmea, Billbergia, Cryptanthus, Neorgelia, Dyckia, Nidularium, Tillandsia, Vriesea* and *Pitcarnea* are the most popular genera of Bromeliads.

Most important centre for Bromeliad production are Netherlands, Belgium and USA (Florida, California and Hawaii). These are cultivated for the purpose of cut flowers, potted flowers, potted foliage and for crowns and as shrubs and climbers. Asian countries like Malaysia, Indonesia, Thailand and Philippines are providing massive number of tissue culture plantlets of Bromeliads and ornamental bananas along with many foliage plants. Commercial tissue culture firms in India export more than 40 million tissue culture plantlets to the US and other countries (Govil and Gupta, 1997). These plants have huge demand in the international market.

Kerala has congenial condition for producing Bromeliads and ornamental bananas. Bromeliad and ornamental banana production can provide a new growing sector in our horticulture industry specializing in landscape plant production. We can specialize in the production of wide array of species, hybrids and cultivars. Artificial pollination is possible for production of seeds in both the groups of plants. They can be easily propagated by suckers. Tissue culture method of large-scale production can also be employed. Another method of crop improvement is by mutation breeding using gamma rays.

In this context the present investigation on evaluation of ornamental bananas and Bromeliads was undertaken with a view to study their performance and to recommend them for tropical landscapes, interior plantscapes and to explore the possibility of induction of variability.

Review of Literature

2. REVIEW OF LITERATURE

Bromeliads and ornamental bananas can be valued for their beautiful foliage and attractive flowers. These plants are typically suited for growing under the humid tropical climate prevailing in Kerala. They need only less management and can be grown with minimum inputs. As attractive potted plants, these plants, especially Bromeliads are having wide demand. The present study was conducted to test their suitability under different shade levels and to evaluate their performance under indoor and outdoor conditions in our tropical environment. The effect of ethylene on the production of flowers in Bromeliads, possibilities of evolution of novel varieties by irradiation and hybridization were also studied. A brief review of the literature relevant to the study is presented in this chapter.

2.1 ORNAMENTAL BANANAS

Ornamental bananas come under the family Musaceae. They are grown preliminarily for their beautiful foliage or coloured inflorescence and the small inedible fruits full of seeds (Schmidt, 2007). The varied characteristics of ornamental bananas make them suitable for a wide range of landscapes from backyards to coastal resorts. Some *Musa sp.* and hybrids with colourful floral bracts and flowers are utilized in ornamental landscapes and tropical flower arrangements (Sharrock, 1996).

Ornamental bananas under the genus *Musa* include self-peeling 'Hot Pink' or 'Fuzzy Pink' (*M. velutina*), 'Ornata' (several varieties of *M. ornata*), Blood/Rojo/Zebrina or 'Variegated Red' (*M. acuminata sub sp. zebrina*) and 'Okinawa torch' (*M. coccinea*). They can be used as a living fence. The plants absorb noise well, grow quickly and can block the view. *Musa coccinea*, a brightly coloured, crimson-flowered ornamental has been recommended as a component in a living fence (Nelson *et al.*, 2007). *Musa balbisiana* is used as a wind break. 'Ae Ae' is the most ornamental of the bananas with green-and-white variegated foliage and white striped fruits (Schmidt, 2007). They can also be grown as pot plants under indoor condition. *Musa accuminata sub sp. sumatrana* called as 'Blood banana' is an attractive indoor banana

plant with its dark red blotches on the leaves and dark cinnamon red under side and a moderate height. It reaches to a height of 8' and can be grown in a container. It can make a dull corner of a landscape more attractive (Mc Laughlin, 2006). *Musa basjoo* called the 'Japanese banana' can tolerate temperature as low as -20°C, so can be grown in sundecks, patios and near swimming pools thus giving a tropical feel to the garden.

2.1.1 Taxonomic classification

The family Musaceae includes plants found in the genera *Ensete, Musa* and *Musella* (Constantine, 2006). Members of the Musaceae are distributed from West Africa to the Pacific, but are predominantly of Southeast Asian Origin. The genus *Musa* is divided into four sections, two of which contain species with a chromosome number 2n = 20 (Callimusa and Australimusa) while the species in the other two sections (Eumusa and Rhodochlamys) have a basic chromosome number 11 (2n = 22). The species in the sections Callimusa and Rhodoclamys are of ornamental interest only, as the characteristic of parthenocarpy is absent and they do not produce edible fruit (Devouard, 2004).

The centre of origin of Callimusa is centered around Indochina, Malaysia and Myanmar. They bear plain bracts which are firm, shiny and plain on the outer surface, rarely glaucous and strongly imbricate when closed. They bear upright flower stalks, variously coloured buds and flowers, and small seedy fruit. Under this section, *Musa coccinea, M. violascens, M. alinsanaya, M. beccarii, M. campestris, M. borneensis, M. exotica, M. flavida* etc., are having ornamental interest (Delin and Kress, 2000).

The section Rhadoclamys includes the majority of the ornamental species. They are distributed from India to Indo-china region. They are characterized by the erect inflorescence, at least at the base, with the fruits pointing towards the bunch apex. They have relatively few fruits and are best known for their brightly coloured bracts which make them popular as ornamental (Sharrock, 1997). They include *Musa ornata, M. velutina, M. laterita, M. sanguinea, M. manni, M. rosea, M. rubra* etc. (Hakkinen and Sharrock, 2007; Delin and Kress, 2000).

The ornamental species under Eumusa (2n = 22) are *M accuminata sumatrana sub sp. zebrina* called the Blood banana and *M. basjoo* called the Japanese banana. They are distributed from Southern India to Japan.

The genus *Musella* consists of two species; *Musella lasiocarpa* and *M. splendida*. Due to its swollen base and persistent flower bracts, Cheesman (1947) in his monumental series "Classification of the bananas" reclassified it as *Ensete lasciocarpum*. But Simmonds (1962) reverted its classification back to *Musa*. Wu (1976) adapted the name *Musella lasciocarpa*. It is indigenous to Yunnan province in South China, primarily at elevations from 1500 m to 2500 m while *Musella splendida* is distributed in the northern mountain ranges (Valmoyer and Danh, 2002).

The genus *Ensete* probably originated in Asia and spread at an early stage to Africa. They are monocarpic, unbranched herbs that sucker rarely and are used for food, fibre and as ornamentals (Delin and Kress, 2000). They bear wide spreading paddle shaped long leaves with usually crimson midribs. Two Ethiopean coloured leaf cultivars have found their way into ornamental horticulture are *E. ventricosum* "Maurelii" and "Montbeliardii" which have spectacular reddish tinged foliage (Constantine, 2002). According to Simmonds (1962) they consist of about six species. They are *E. gilletii, E. glaucum, E. homblei, E. perrieri, E. superbum, E. ventricosum* and *E. wilsonii*.

2.1.2 Environmental requirements

Bananas can be grown from sea level up to 2000 m altitude. They tolerate a wide range of soils, but well drained loams are optimal. Heavy, clayey soils are suboptimal, especially if they are low in organic matter and aeration. They tolerate a wide range of soil acidity; pH 5.5-7.5 being optimal (Nelson *et al.*, 2006). They need a uniformly warm to hot climate condition to flourish well. A temperature of 26-28°C is required for shoot growth and 29-30°C for fruit growth. Growth is slowed down at 16°C and stops at 10°C. If the temperature falls below 10°C, it results in chilling injury. Winds above 25 mph and 45 mph may cause tall and short cultivars to topple. Water stress leads to reduction in fruit number and chocking and collapse of the

pseudostem. Banana cultivars with *Musa balbisiana* genes tend to be more drought tolerant than cultivars of *Musa accuminata* (Crane *et al.*, 2005). Breeding trials suggest that the section Rhodoclamys is not only compatible with Eumusa members, but is a potential source of resistance to biotic and abiotic stress. So it could be very well exploited both in conventional and molecular breeding programmes to develop synthetic intersectional hybrids (Uma *et al.*, 2007). Bananas are not flood tolerant. They are moderately shade tolerant up to 50 per cent but results in delayed fruit growth and plant development. The minimum rainfall requirements for *Musa* depend on soil type, planting location, sun exposure and variety or species. Annual rainfall of 2000 mm or higher is required for commercial production and some dwarf *Musa* species used in ornamental landscapes are relatively drought-tolerant and can withstand a wider range of rainfall and distribution patterns (Nelson *et al.*, 2006).

2.1.3 Cultural requirements

For best growth banana plants should be planted in full sun though they tolerate a slight shade. A part of the landscape, which is away from other trees, buildings , structures and power lines is selected. They may be planted 3 m or more adjacent to out door walls as sunscreen. Dwarf species may be planted 6 m or more from other plants and 2.5 m away from other small statured plants. Tall species are planted 4 m away from other banana plants (Crane *et al.*, 2005).

Banana requires adequate soil moisture for optimum growth and development. It needs about 1.0-1.5 inches of water per week especially during prolonged drought periods. A weed free area of 1.0-2.0 m around the plant should be maintained with a well drained organic mulch. In a home landscape with lawn maintain a grass free area of 1.5-2.5 m away from the pseudostem and should be protected from mechanical damage from lawn mowing equipments. Excess watering leads to decline of the plant so the timers in sprinklers in a lawn should be adjusted (Crane *et al.*, 2005).

2.1.4 Flowering and seed production

Flowering in bananas occurs after a vegetative phase of leaf growth. The shoot apical meristem differentiates into an inflorescence that emerges from the top of the pseudostem. The basal flowers are female and distal flowers male. This transition in flower type along the inflorescence maximizes outcrossing in species. Colourful bracts that are the principal feature of ornamental flowering bananas subtend the flowers. By the time male flowers on an inflorescence are shedding pollen, the females are no longer receptive. Therefore, two inflorescences flowering out of synchronization are required to produce seed; the male flowers on the first inflorescence pollinate the females on the second. These inflorescences can be on the same clump as there is no self-incompatibility in the bananas. Relatively rarely in the family, the basal flowers are functionally hermaphrodite and can be self pollinated to produce viable seed. The best known example is *Musa velutina*. Hermaphrodite flowers are common in *Ensete*. Constantine (2004) reported that *M lasiocarpa* does not have hermaphrodite flowers while *Musella splendida* do have. The inedible, ornamental *Musa* varieties such as 'Fuzzy Pink' or 'Pink Velvet' banana (*M. velutina*), or fibre species such as the *abaca* 'Manila Hemp' (*M. textiles*), are two examples of *Musa* species that are commonly grown from seed (Crane *et al.*, 2005).

In nature, insects, birds and bats pollinate bananas. Pollen transfer in cultivated plants can be done with a small brush, or by removing stamens from male flowers and dabbing them on to the female flowers. Banana seed produced commercially are obtained from open pollinated plants that are grown wild. The advantage of this is that seedlings are variable and the opportunity exists to select desirable ornamental forms. Major disadvantage of the uncontrolled nature of seed production is uncertain seed quality.

2.1.5 Vegetative propagation

In *Musa* and *Musella* vegetative propagation is mainly by suckers. Suckers of *Musa* and *Musella* arise as lateral buds opposite to the corresponding leaf on the true stem and not from the axillary buds (Wu, 1976). In *Musa*, suckers initially grow

horizontally away from the parent plant on a rhizome before appearing above ground. The rhizomes are usually short while in ornamental species like *Musa laterita* and *M. itinerans*, the rhizomes are short producing a more open stand, though not obvious in pot grown plants. The sucker pseudostem should be about 30 cm tall before removal when it will have independent roots. After removal, the sucker should have all its unrolled leaves cut off to reduce water loss and potted into a small pot in gritty compost and watered in. Stood in a warm, shaded situation the sucker will establish in a few weeks. When grown for ornamental purpose removal of suckers is not necessary other than for aesthetic reasons (Constantine, 2006).

Musa are prone to throw bud sports and those affecting the colour or stature of the plant may have ornamental potential. Variegated sports are the most desirable but these can be unstable and difficult to propagate with fidelity.

In *Musella* the suckers are not rhizomatous (Valmoyer and Danh, 2002). They arise very close to or even underneath the broad base of the parent pseudostem, often emerging between old leaf bases and frequently in pairs. They may be difficult to remove for propagation. So it is usually easier to obtain them after a plant has flowered when it can be broken up (Constantine, 2006).

According to Macias (2001), the enhancement of suckering in *Musa* by apical mutilation involved outgrowth of pre-existing lateral buds released from apical dominance. Observations made on *E. ventricosum* suggest that the origin of the suckers largely, and perhaps exclusively, involved the *de novo* regeneration of shoots *via* callus from the central axial meristem.

In the genus *Ensete*, vegetative propagation is only practiced in *E. ventricosum*. In this induction of suckers is by meristem scooping (Collingbourne, 2000). A larger plant at flowering stage is best for this purpose. It is done by cutting the plant down to just above ground level and removing the growing point. The stump is then lightly covered in compost and new shoots will develop from the callused surface. In about a month the central part of the cut surface calluses and shoots

regenerate eventually emerging through the compost mulch. When they reach 10-15 cm in height, after about three months, they can be cut off at the base and rooted (Constantine, 2006).

2.2 BROMELIADS

2.2.1 History and Origin

The second voyage of Christopher Columbus to the New World in 1493, made the Europeans aware of the family Bromeliaceae. There he found the Carib tribes cultivating pineapple which is the most popular Bromeliad (Benzing, 1980; Pertuit, 1995). Reilly (2005) reported that Bromeliads are endemic to the Tropical America, except one species, i.e. *Pitcarnea felicinia,* which was left to the African continent due to the continental drift.

2.2.2 Habitat and distribution

Bromeliads occur in a wide range of altitude. Black and Dehjan (2003) reported that their natural habitat is distributed from the dry desserts of South Western United states to the equatorial tropical rain forests, i.e., they occur from hot dry deserts to the moist rainforests. They are referred as air plant, since they can take their nutrition from air. They range in size from 25 mm to 10.5 m. According to the nature of habitat, among Bromeliads, there are epiphytes which grow on other plants, saxicolous species growing on rocks and terrestrial species growing on the ground (Black and Dehjan, 2003).

2.2.3 Adaptation of the plant

Bromeliads are one among the most adaptable group of plants having tremendous ability to survive extreme conditions, offering infinite varieties, plant forms and colour combinations. They have special type of roots by which they can take their nutrition from air. According to Cathcart (1995), the scales with trichomes or peltate scales which cover the leaves help them to survive harsh conditions. These trichomes are moisture absorbing organs which form attractive bands, stripes, spots

and patterns. They have an advanced photosynthetic pathway referred as CAM metabolism, which helps the plants to survive under arid habitats (Pierce *et al.*, 2002). Anderson (2004) reported that they have rosette shaped leaves which act as water holding cups. The stoma cells in the leaves close during the day thus reducing the transpiration loss to a minimum, interfering with the gas exchange (Heer and Montgomery, 2006).

In general Bromeliads are inexpensive and easy to grow, require very little care. They can reward the grower with brilliant long lasting blooms and ornamental foliage. Bromeliads can thus make excellent interior plants and provide incredibly long lived out door colour as well.

2.2.4 Taxonomic classification

Bromeliads are monocots belonging to the class 'Liliopsida' coming under the order Poales. They belong to the family Bromeliaceae. The French botanist Jaume Saint Hilaire (1805) defined the Bromeliaceae and formed the family name from the genus *Bromelia.*

The super order Bromeliflorae are group of monocots comprising of two families. The Bromeliaceae comprises of 45 genera with about 200 species, and the Rapteaceae with 16 genera and 80-100 species (Smith, 1979).

Bromeliaceae consists of three sub families based on the growth habit. They are Pitcarnioideae, Tillandsioideae and Bromelioideae (Pertuit, 1995; Benzing, 1980).

Pitcarnioideae are the most primitive forms and they resemble the grass family from which they are evolved. They include mainly the terrestrial forms having heavy spines on their leaf edges and do not have the cups for holding water. They have extensive root system and can grow on soil or on rocky surface. They bear tiny fruits called capsules having winged seeds. Commonly cultivated ornamental species are *Dyckia, Hechtia, Pitcarnea* and *Puya* (Benzing, 1980).

Barfurs *et al.* (2002) reported that the subfamily Tillandsioideae consists of about 1300 species comprising of *Aclantarea, Catopsis, Glomeropitacarnea, Guzmania, Mezobromelia, Racinaea, Tillandsia, Vriesea* and *Werauhia*. Most are epiphytic and have rosette like cup for holding water. The leaves are spiny and fruits are having wet seeds which are dispersed by birds and animals which consume them. Plants are having entire or smooth leaf margins with unusual foliage markings and colours, some species producing fragrant flowers (Black and Dehjan, 2003).

Bromelioideae, the third subfamily, consists of 30 genera with wide range of plant forms grown for garden and interior purpose. These are the most evolved forms with special adaptation to the xeric environment. *Aechmea, Billbergia, Cryptanthus, Neorgelia* and *Nidularium* are the most popular species under the sub family. These are mostly epiphytic, with spiny leaf edges and having attractive markings and patterns on the foliage which are often cup shaped. The fruit is a dry capsule bearing winged seeds dispersed by wind (Black and Dehjan, 2003).

2.2.5 Development of hybrids

Hybridization has been considered as a key phenomenon in plant evolution because it results in a large amount of genetic recombination and may enable the founding of new evolutionary lineages (Stebbins, 1959). It is known that Bromeliad genera easily hybridize by hand manipulation (Mc Williams, 1974). Little is known about natural hybridization within Bromeliaceae. A few records of natural hybrids are available for genera such as *Tillandsia* (Gardner, 1984), *Vriesea* (Read, 1984) and *Pitcarnia* (Luther, 1984).

Natural pollination of Bromeliads is performed by humming birds and night moths. Self pollination is observed in some species like *Guzmania graminifolia* due to a jelly like substance covering the flower bud thus preventing the entry of tiny insects (Foster, 1996).

To evolve new varieties with attractive colour and inflorescence, breeders are using interspecific and intergeneric hand pollinations. Butcher (1999) reported that

the intergeneric hybrids seem fertile, but bigeneric hybrids are sterile. Bigenerics like Cryptbergias were developed by crossing *Cryptanthus beuckerii* and *Billbergia nutans*. These have good decorative value as foliage plants but the flowers are aborted and have little attraction.

Interspecific crosses between spineless and spined *Aechmea* were attempted in order to obtain spineless offspring. This resulted in 50 per cent spineless plants. Intergeneric hybrids between *Vriesea* and *Tillandsia* (Vrielandsia) and *Vriesea* and *Guzmania* (Vriesmania) were released. These new interspecific and intergeneric hybrids are unique for the Bromeliad market (Vervaeke *et al.*, 2003).

2.2.6 Seed production in Bromeliads

Only 1-5 per cent of Bromeliads are self sterile (Morris, 2007). To create fertile seeds, two plants from different origins should be selected as parents. Two plants from the same mother result in seeds that are not viable. Self pollination should be prevented by emasculating the flowers one day before pollination (Foster, 1996). In case the two parent plants which do not bloom at the same time, pollen grains can be collected and kept sealed in a ziploc bag and stored in the freezer. It remains viable for 18 months (Flower, 2001). Pollination can be done using a paint brush. Seed set and maturation is indicated by swelling of the ovary and change in colour and easy detachment of the berry. *Cryptanthus* takes nine months and *Tillandsia* a year for maturation (Flower, 2001).

Seeds are sown in pots or flats on a surface of moist sphagnum moss or finely screened potting soil containing 50-75 per cent organic matter. A glass cover should be maintained over the pot to maintain high humidity thus preventing from drying out. They are placed under fluorescent lights with the spectral characteristics of natural light for about 16 hr a day with a fan to reduce the heat from the light.

The seeds should be kept moist several times a day. Application of balanced, diluted water soluble fertilizer is recommended. Allowing them to dry between the mistings is also necessary (Paroz, 2005). Direct summer sun should be

avoided. The germination time varies according to the genus from a couple of weeks to several months. They are transplanted to small pots when they reach a height of about 3-4 cm. Plants from seeds need three to six years to flower, depending on the genus. *Neorgelia, Aechmea* and *Billbergia* mature in 2-3 years while slow growing *Tillandsia* will take 4-7 years (Paroz, 2005).

2.2.7 Albino Bromeliads

Variegated bromeliads sometimes produce pups which have no variegation. They are white coloured due to lack of chlorophyll. They cannot produce carbohydrate which is essential for the plant. Ultimately they die if detached from the plant. They may survive for years if not detached from the mother plant (Reilly, 2005).

2.2.8 Environmental requirements

2.2.8.1 Light

Bromeliads can tolerate a wide range of light intensities. According to the tolerance level, they are selected for indoor and outdoor cultivation. Generally Bromeliads with thick, hard, grey, or fuzzy foliage withstand the highest light intensities while those with soft, green thin leaves grow best under lower light intensities (Black and Dehjan, 2003). They usually require 12 to 16 hrs of relatively bright light daily. More compact growth and better leaf and inflorescence colour are obtained at 3000-4000 foot candle (Plever, 2006). Bromeliads need strong light to grow well and produce flowers (Frogge, 2005). The general recommendation is to grow bromeliads where the light level is approximately 1,500 foot candles or where orchids grow well (Black and Dehjan, 2003). Plants in the genera *Dyckia, Puya, Hechtias, Ananas*, and the hard leaved species in *Aechmea* and *Billbergia* grow best at high light levels. So they can be grown outdoor, while plants in the genera *Guzmania, Neorgelia, Nidularium, Cryptanthus* and *Vriesea* can be grown under low light level, so can be grown indoor (Black and Dehjan, 2003).

Bayer (2007) reported that if foliage become bleached or brown, light intensity should be reduced. A yellow or pale green plant indicates that the light level

is too high while a darker green than normal with a more open or elongated shape indicates low light intensities. Different species require different light requirement for better colour development. *Cryptanthus* 'Strawberries flambe' get broader leaves and more larger flowers under light in the sun. *Neorgelia* 'Gaspacho' and *Neorgelia* 'Little Rose,' are strikingly coloured and compact under fluorescent lights (Plever, 2006).

Under indoor condition, Bromeliads need moderate to full sun. Schoelhorn (2003) reported that most of the colourful types prefer shade, moisture and warm temperature to look their best and last long. They should be placed in east south or west window, where they will receive full sun for three to four hours a day (Anderson, 2007).

Guzmanias have proven to be the best suitable and easy to grow house plants, some of them being *G. lingulata* var. *minor* and *G. remgi* etc. Some *Neorgelias* have proven suitable are *Neorgelia* 'Alley Cat', *N.* 'Gaspacho', *N.* 'Little Rose', *N.* ampullacea and *N. carolinae* Forma 'Tricolour'. They range in colour from purple/yellow, red, orange, hot pink etc. These are *Neorgelias* that are light responsive and can be grown indoor near a south, east or west window or under fluorescent light.

Earthstars are a group of Bromeliads that grow well indoor. Earthstar such as the zebra plant *Cryptanthus zonatus*, red earthstars (*C. acaulis* 'Rubei') and the *Cryptanthus bivittatus* hybrid 'colour band' Cc x 'It' have red bronze, copper and white striped leaves. They can be successfully grown indoor along with succulents and cacti in a dish garden (Anderson, 2007).

Relf (1997) reported that Bromeliads also grow well under fluorescent lights. A broad spectrum of light can be achieved with more intense light and less heat. *Cryptanthus* grows well under artificial light. Artificial lights are placed about 30 cm above the top of the plant and kept for 16 daily (Trinklein, 2007).

2.2.8.2 Temperature

Temperature is an important factor influencing the growth of Bromeliads growing indoor and outdoor conditions. Temperature and light are linked through the

process of photosynthesis . Photosynthesis builds sugar and starch which are broken down by respiration to provide energy for the development of new tissues and maintenance (Pennisi, 2006).

Generally Bromeliads prefer temperature between 11 and 36°C. But they tolerate high temperature if there is good air circulation. *Guzmania* and soft leaved *Tillandsia* are least tolerant to high temperature and make excellent plants for cooler growing condition so they do best under indoor also. In a home environment they do best under 21.1 and 23.8°C during day and between 15.5 and 18.8°C at night. The soft leaved species need higher temperature while those with very hard stiff leaves are tolerant to cold (Black and Dehjan, 2003). Varieties like 'Scarlet star' (*Guzmania*) and 'Flaming sword' (*Vriesea*) thrive at 27°C so they are kept indoor in a climate of lower summer. Others like *Tillandsias* and Variegated pineapple (*Ananas*) will bloom if kept outdoor in a warm summer climate. Relf (1997) reported that during summer they can be taken outdoors and placed under a tree or shady place where they can benefit from rain and fresh air. He reported that their ideal temperature for growth to be between 10-26.6°C. While growing indoor, plants should not be moved outdoor suddenly since it causes sun burn. *Tillandsia* species require 5-10°C night temperature. In climates where it is not possible to give the xeric plants like *Tillandsia* an adequately low night temperature, forcing the plants to revert to day time is done. This is provided by increasing the humidity and decreasing the vapour pressure deficit.

Prince (2002) reported that genus *Pitcarnea* is very sun tolerant. Other full sun lovers are *Aechmea mexicana, A. bractrata, A. rubens, Hohinbergia cartellonosii, Ananas comosus, A. bractatus, Neorgelia cruenta* and *N. composita.*

2.2.8.3 Water and air requirement

Watering the bromeliads depends upon the type of potting mixture, humidity, light, temperature and air circulation provided in the growing environment and whether the plants are grown outdoor or indoor. Bromeliads are extremely tolerant to low moisture conditions and will survive prolonged periods of drought (Black and Dehjan, 2003). They prefer water with pH of 4.7.

Bromeliads have a rosette of broad leaves which create a cup or vase in the centre (Black and Dehjan, 2003). This structure holds water for use under extreme condition. The cup of the plant should never be left empty since it may cause salt damage due to residues of fertilizers. So flushing off the cup is recommended (Head, 2007). While growing outdoor the central cup should be kept filled with water, and the plants should be watered more than once a week. But while growing indoor cup need not be kept filled, but the soil should be kept moist (Russ, 2007). Epiphytic *Tillandsia* which are mounted should be irrigated by misting or immersing them in a container of water daily (Black and Dehjan, 2003).

Soft leaved plants require more water and humidity than stiff leaved ones. Most *Vriesea* and *Nidularium* come under this group. Most bromeliads grow indoors at a R.H. of 40-60 per cent. Londers *et al.* (2003) suggested that leaf turgour pressure builds up under high humidity and results in leaf damage. So under closed green house condition humidity during night periods should be increased.

Humidity can be increased by placing potted plants on a two to three inch bed of wet gravel. Water evaporating from the gravel increases the humidity. According to Black and Dehjan (2003), humidity can be increased by using humidifiers, grouping the plants together, setting the pots on rodes such as lava chips, in a plastic saucer with water kept below the pot level in the saucer. Another method of increasing humidity is misting the plants frequently during day time (Russ, 2007). *Nidularium, Vriesea* and *Pitcarnea* like humid atmosphere. Mounted bromeliads need good air circulation due to their epiphytic nature. Fresh air supply, CO_2 and moisture are the other requirements. Plants grown in stagnant air are more prone to be attacked by scale insects and fungal organisms causing them to deteriorate (Black and Dehjan, 2003). Air circulation under indoor can be improved by opening a window or by turning on a fan at low speed.

2.2.9 Propagation

Bromeliads can be propagated sexually and asexually. Sexual method of propagation is by the use of seeds and asexually by tissue culture methods and by the use of offsets and pups.

Bromeliad production by use of seeds is a long and tedious method (Black and Dehjan, 2003). The seeds require 20-25°C of day temperature with a 5°C drop during the night, 14 hour day light, 80-90 per cent humidity dropping back to 60-70 per cent when ventilation is increased at the two leaf stage. Water spraying is necessary every three to four hour interval continuously for three to four days, then once every morning and evening. Once germinated drying should be allowed in between mistings (Flower, 2001). Large number of plantlets can be produced at a small expense (Black and Dehjan, 2003).

Seed production is either by natural or hand pollination. Naturally pollination is done by insects and humming birds (Killengley, 2000). After germination, the seedlings are left in the propagation container until 3-4 cm tall and then transplanted to small pots. They take about three to six years to reach flowering size (Black and Dehjan, 2003).

Pups are propagating materials produced at the base of the plant inside the sheath of a leaf. Propagation by pups in the most satisfactory method for home gardeners (Black and Dehjan, 2003). Pups are removed using a pruning shear and planted separately when they are about $1/3^{rd}$ of the size the plant.

Thomas (1999) reported that offsets produced at the base of mother plants are another method of multiplying plants. This helps in residential landscape and commercial landscape nursery industry (Ingram, 2003). They are produced when mother plants reach maturity, sometimes before flowering but mostly after flowering, (Margaret and Butchner, 2007). They develop from dormant buds in the axils of basal leaves. They are also produced from the axils of bracts on the flower stem (Paroz, 2005).

Plantlets can be mass produced by tissue culture. An effective plant regeneration system was developed for induced shoot formation from the leaves derived from seedlings of *Neorgelia,* an endemic Bromeliad from Brazil. Shoot development occurred directly from leaf base. Explants excised from 7 week old

seedling culture showed highest regeneration rate (Ceneiro *et al.*, 1998). Initially they will be very small with two to three leaves with some root initiation. After hardening they are packaged in sealed plastic containers containing specially formulated agar media for transporting and supplying to the market.

Growing hybrid bromeliads from seed may not result in plants resembling the parents. Tissue culture plants are produced from a single plant. They are clones similar to parent plant. They also allow rapid breeding of a large number of plants (Stenhouse, 2006).

2.2.10 Planting and maintenance

Epiphytic Bromeliads like *Neorgelia compacta, Achmea nutricalin, A. orlandana* and most of the *Tillandsias* can be mounted on branches of trees while terrestrial bromeliads like *Dyckia* and *Cryptanthus* can be potted.

In pots, a good potting mixture should be provided. It should contain lots of humus in the form of peat or leaf mould but not soil. Potting media consisting of pine bark, peatmoss, peanut shells, rice hulls, charcoal, coarse sand and pertile are used. Charcoal is used in potting media mixes. It acts as a sponge or as a magnet absorbing ammonia released from organic fertilizer added. They also check damping off in seedlings, encourage growth, sweetens the soil, saves fertilizer, open up potting media helping in drainage (Hardy, 2002). A good potting medium must supply air, water and nutrients, which are essential physical properties. Catlan (2005) reported that a good potting mix should have a good soil life. He also reported that a potting mixture containing 15-20 per cent air is required for terrestrial Bromeliads which has more than 20 per cent is the minimum required for epiphytic Bromeliads.

The pots used should have drain holes in the bottom and sides. We should use the pots according to the size of the plant. Clay pots are preferred in humid condition and plastic pots for dry and indoor areas. Planting should not be done too deeply. It should be planted firmly in its container.

Mounting is another method of planting Bromeliads. Mounting can be done using normal offsets and adventitious offsets. Some plants produce only adventitious offsets well before flowering of the parent plant (eg. *Tillandsia viridifolia* as reported by Margaret and Butcher (2007). By this method a 'Bromeliad tree' can be made with the help of nontoxic water proof glue or wiring them to a branch. Decay resistant wood should be used for mounting. The mounted area should be kept free of copper as they are toxic to plants.

Billbergia and *Tillandsia* make attractive clumps. Other genera like *Neorgelia, Aechmea, Canistrums* and *Vriesea* that have stolons will make nice displays (Head, 2007).

Bromeliads can also be planted in bed. The bed should be well drained to prevent rotting. They cannot tolerate clayey soils because of their epiphytic nature. So the soils should be reclaimed by incorporating 3-5 cm of organic matter (Black and Dehjan, 2003).

2.2.11 Nutrition

In their natural habitat, Bromeliads depend on nutrients from the air circulating and those with cups draw their nutrition from leaf excrement, dust, reptiles and insects which fall in to the water reservoirs.

Johnson (1995) reported that adding superphosphate and potash to the potting mixture and top dressing with slow release nitrogen fertilizer as needed has improved the quality of plants. Fertilizers should not be applied in the cup since it leads to accumulation of fertilizer salt that may affect the newly emerging leaves (Black and Dehjan, 2003). It is recommended to fertilize the plants every 6 to 8 weeks. Organic fertilizers are added to the cups during watering (Anderson, 2004).

Bromeliads are plants that have evolved to colonize many nutrient deficient habitats. The plants show slow growth, limited inflorescence size, limited seed set, and limited offset production. However, they do benefit from fertilizer addition (Paroz,

2006). Bromeliads do not require a lot of minerals but they require a balanced supply of macro, micro and trace elements. N, P, K and Mg deficiencies are shown in the older leaves since they are moveable elements and Fe deficiency is observed in the newer leaves, being a fixed element. The benefits of good nutrition are early flowering, larger inflorescences, more number of bracts, more number of flowers and more offsets (Paroz, 2007).

Beyer (2007) reported that except *Tillandsia* and *Cryptanthus*, other Bromeliads should not be fertilized regularly unless to increase the pup production. They respond well to regular fertilizer application. Fertilization reduces the colouration in most bromeliad hybrids that are noted for their colour (eg. *Neorgelia* and *Billbergia*). Liquid soluble fertilizer (N:P:K, 20:20:20 @ 5g/l) can be given as foliar sprays at weekly intervals. Bromeliad plants are well adapted to absorb moisture from foliar application. The trichomes on leaf surfaces and at the base of leaves have evolved to scavenge available nutrients (Paroz, 2005). Reily (2000) reported the use of low salinity water for fertilizer application. Rain water is most suitable for this purpose.

Gal (2007) reported that a fertilizer mixture containing N (3%), Total P (8%), K (25%) may be good for *Neorgelias* and variegated plants as they do not need a lot of nitrogen. Another foliar mixture containing total nitrogen N (7%), total P (9.7%) and total K (20.8%) can be used for *Vriesea* and *Guzmania*. Urea content should be kept in a controlled level when foliar feeding as it will cause leaf burn.

2.2.12 Induction of flowering

Flowering being a crucial developmental stage in the plant life cycle, a number of factors from environmental to chemical trigger flowering. Kerns (1936) mentioned acetylene treatment for *Billbergia* and Foster (1943) reported successful treatments of some Aechmeas with acetylene and ethylene. Mayers (1997) reported that ethylene is used commercially to force Bromeliads into flowering.

Ethylene has been popularly known to induce flowering in pineapple. A sprinkle of acetylene, a precursor of ethylene on top of pineapple plant is quite effective in inducing the pineapple plant to flower (Chomchalow, 2004). It is reported that plants treated with ethylene will flower in approximately 6 to 14 weeks (Black and Dehjan, 2007). The flower spikes may last up to three months in *Aechmea fasciata*. It is important to take good care of the flower spike to maximize the shelf life of Bromeliads. Bromeliads can be induced to flower with small doses of ethylene (25-100 ppm) either in the gas form or at a low concentration of liquid spray (Schoellhorn, 2003). Bromeliads can be made to flower by placing a slice of apple in the vase and commercially by use of ethrel (Pertuit, 1995).

2.2.13 Cut flower production

Bromeliads are valued for their beautiful flowers. *Aechmea* and *Tillandsia* are some of the interesting genera with potential for cut flower production. In *Aechmea servitensis* cv. 'Exigua', *A. leucocarpa* and *A. pubescens* are some of the *Aechmea sp.* suitable for cut flower production. A hybrid cultivar 'Regime' (*A. servitensis* x *A. leucocarpa*), has been released by growing under a low temperature (around 17°C) and high light intensity. Undesirable shortening and broadening of the leaves can be prevented. This cultivar has long stem and well filled flower spikes, the orange flower resembling that of *A. servitensis* (Samyn, 1991; Samyn, 1992). Vissers and Thomas (1997) reported that in *Tillandsia cyanea*, flower production could be enhanced (73%) by the treatment combination of ethaphone at 500 ppm; 22°- 23°C temperature and supplementary lighting.

2.2.14 Mutation breeding

Genetic variability which is the backbone of crop improvement may be induced deliberately by employing ionizing radiation and chemical mutagens. Ionizing radiations can interact with cells to produce a genetic effect in the immediate vicinity of its ionizing track (Muller, 1954). Induction of mutation is an important tool for the production of new varieties in vegetatively propagated species (Broertjes, 1972). He also reported that mutation research has indicated the possibility of improving one or

two characters of a basically good cultivar without altering the other desired characters of the genotype.

Generally gamma rays in lower dosages cause stimulatory effects (Gupta *et al.*, 1982) and higher dosage induces mutagenic changes (Ono, 1971). Genotype of the irradiated plants decides the critical doses of gamma rays. Favourable changes bought about by lower doses of gamma irradiation have been successfully exploited in vegetatively propagated crops (Desai and Abraham, 1974 and Raghav *et al.*, 1988). Mutations induced by gamma rays for creating desirable combination of traits have been reported in many ornamentals like tube rose (Patil, 1975; Younis and Borham, 1975; Abraham and Desai, 1976; Gupta, 1979; Sambandhamurthi, 1983), chrysanthemum (Mabuchi and Kuwada , 1974; Datta and Banerji, 1995; Zhenhua *et al.*, 1995; Neto and Latado, 1997; Banerji and Datta, 2002), gerbera (Jerzy *et al.*, 1997), gladiolus (Buiatti and Tesi, 1968; Banerji *et al.*, 1994), lantana (Datta *et al.*, 1995), rose (Banerji *et al.*, 1996), carnation (D'Amato *et al.*, 1964), iris (Rather and Jhon, 2000) and alstroemeria (Przybyla and Cadic, 2000).

Variegation is a very common phenomenon seen pronounced in Bromeliaceae. It is found in the subfamily, Pitcarnioidea, and is not common in Tillandsioideae. It is common in genera *Guzmania, Vriesea, Aclantaria* and in few species of *Tillandsia.* In the subfamily Bromelioideae variegation is common especially in *Xechmoa, Ananas, Billbergia, Cryptanthus, Neorgelia* and *Nidularium* (Carvalho, 2000). Chlorophyll mutants and mutants with reduced thorns along the leaf margin are preferred in Bromeliads (Lapade *et al.*, 2002).

Materials and Methods

3. MATERIALS AND METHODS

The present investigation entitled "Evaluation of ornamental bananas and Bromeliads for tropical landscapes" was carried out in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during the period 2005-2007.

3.1 MAJOR ASPECTS OF THE STUDY

3. 1.1 Bromeliads

a) Morphological description of Bromeliads belonging to different genera and species
b) Performance evaluation under different light
c) Performance evaluation of Bromeliads in various growing media
d) Effect of ethrel on flowering of Bromeliads under different light intensities
e) Evaluation of Bromeliads for indoor conditions
f) Vase life studies of the inflorescence
g) Induction of variability through irradiation of suckers by gamma rays

3.1.2 Ornamental bananas

a) Morphological description of ornamental bananas belonging to *Musa* and *Ensete*
b) Performance evaluation of ornamental bananas under open and 50 per cent shade in pots
c) Performance evaluation under open in field
d) Pollen fertility and compatibility studies
d) Induction of variability though irradiation of seeds and rhizomes using gamma rays
e) Vase life studies of the inflorescence

3.2 PLANT MATERIALS

The following Bromeliads and ornamental bananas were used for the study.

3.2.1 Bromeliads

Aechmea fasciata

Ananas bracteatus

A. nanus

Billbergia pyramidalis

Bromelia balansae

Cryptanthus bivittatus

C.bromelioides

C. zonatus

Dyckia brevifolia

Tillandsia stricta

Pitcarnea flammea

3.2.2 Ornamental bananas

Musa coccinea

M.laterita

M. ornata

M. rosea

M. rubra

Ensete ventricosum

3.3 METHODS

3.3.1 Characterization

Bromeliads and ornamental bananas selected for the study were morphologically described.

3.3.2 Bromeliads

3.3.2.1 Performance evaluation of Bromeliads under shade and open conditions

The vegetative and floral characters were evaluated under two shade levels viz., 50 per cent, 75 per cent and under open condition. The observations were recorded at monthly interval for seven consecutive months.

3.3.2.2 Performance evaluation of Bromeliads in different growing media

Performance of *Billbergia pyramidalis* and *Pitcarnea flammea* was evaluated in different growing media as follows

a) Tilebits

b) Sand + vermicompost + cocopeat

c) Coarse sand + sand + vermicompost + cocopeat

d) Coconut husk

Observations were recorded on the vegetative characters at monthly interval.

3.3.2.3 Effect of ethrel on flowering of Bromeliads

Ethrel solution was applied to the following Bromeliads

a) *Billbergia pyramidalis*

b) *Tillandsia stricta*

c) *Ananas bracteatus*

d) *A. nanus*

They were grown under two shade levels viz., 50% and 75% and under open condition.

For induction of flowering, ethrel solution was prepared by mixing 25 ppm ethephon, 2% urea and 0.04% $CaCo_3$ in water. 50 ml of the prepared solution was poured into the heart of the plant during dry weather condition. Days taken

for flowering and flower characters under different shade levels and under open condition were recorded.

3.3.2.4 Evaluation of Bromeliads under indoor condition

Bromeliads with attractive leaves like *Billbergia pyramidalis, Tillandsia stricta* and *Pitcarnea flammea* were kept under indoor condition to study their suitability for interiorscaping. *Dieffenbachia amoena* and *Aglaonema commutatum* which are commonly used as indoor plants were used as control. Vegetative characters were recorded at monthly interval.

3.3.3 Ornamental bananas

3.3.3.1 Performance evaluation of ornamental bananas under 50 per cent shade and open condition in pot

Ornamental bananas like *Musa coccinea, Musa rubra, Musa rosea Musa ornata, Musa laterita and Ensete ventricosum* were grown under 50 per cent shade and open condition in pots. Vegetative characters were recorded at monthly interval.

3.3.3.2 Performance evaluation of ornamental bananas under open in the field condition

As the performance of ornamental bananas was poor under shade, they were evaluated under open condition in the field. Vegetative and floral characters were recorded at monthly interval.

3.3.3.3 Pollen fertility

The fertility of pollen grains of ornamental bananas was estimated by acetocarmine staining technique. Pollen grains were collected during the male phase from *Musa ornata* and *Musa laterita.* They were stained with glycerine: acetocarmine (2%) in the proportion of 1:1. Pollen fertility was estimated by counting the fertile and sterile pollen grains separately. Pollen grains which

stained well, looked plumpy, well filled and well shaped were considered as fertile. Unstained, small or shrivelled pollen grains were counted as sterile (Zirkle, 1937). Observation were made under five different microscopic fields. This was repeated using three such slides of pollen of each species. Pollen fertility was worked out as follows.

$$\text{Percentage of fertile pollen} = \frac{\text{Number of fertile pollen grains}}{\text{Total number of pollen grains}} \times 100$$

3.3.3.4 Compatibility studies

Compatibility between *Musa ornata* x *Musa laterita* and *Musa laterita* x *Musa ornata* was studied by artificial pollination. Between 7.30 to 8.30 am, at the time of stigma receptivity, artificial pollination was done by brushing the pollen grains collected from the male flowers on the stigma of the female flowers. This was done till the completion of female phase. After pollination the inflorescence was bagged to prevent cross pollination by insects or by other means.

Hybrid seeds were collected from the ripened fruits of both the crosses and the germination percentage was calculated. Vegetative characters of hybrid seedlings were recorded at monthly interval.

3.3.4 Vase studies in Bromeliads and ornamental bananas

Vase life of the inflorescence of Bromeliads and ornamental *Musa spp.* was studied. Partially opened inflorescence of Bromeliads were collected. In *Musa laterita* and *Musa ornata* inflorescence were collected at the beginning of the female phase. They were collected early in the morning and placed in a conical flask containing measured quantity of water (V_1). The quantity of water left in the flask after the removal of the inflorescence on the last day in the vase was measured (V_2). The difference in the volume of water ($V_1 - V_2$) gave water uptake which was expressed in ml. Days taken for fading of the colour of the first and last bract were also recorded.

3.3.5 Irradiation studies

For the induction of variability by irradiation with gamma rays, the following materials were used.

a) Suckers of Bromeliads viz., *Billbergia pyramidalis* and *Tillandsia stricta*

b) Seeds and rhizomes of *Musa ornata*

They were subjected to gamma rays @ 5, 10, 15, 20, 25 Gy. The irradiated materials along with control were planted in pots filled with potting mixture. They were observed and the time taken for sprouting of suckers and germination of seeds was recorded. The germination percentage of the seeds was calculated.

3.3.7 Management of plants

Bromeliads were grown in pots in potting mixture containing sand, vermicompost and cocopeat in equal proportion. To boost up growth, weekly sprays of N:P:K 19:19:19 @ 5 g/l were given. Watering was done in the shade house and open condition twice daily (morning and after noon) during the summer months. Water was retained in the species having the rosette cup. Good drainage was also provided. Sprays of fungicide and insecticide were given as and when required.

Ornamental bananas were planted in pots under 50% and open condition in a medium containing sand, vermicompost, cocopeat and organic manure in equal proportion. They were also planted in the field. Organic manures and inorganic fertilizers were applied at monthly interval. Irrigation was given during the summer months daily and only on sunny days during rains. Weeding was done at weekly intervals.

3.4 CLIMATE

Vellanikkara is located at an altitude of 22.25 m above MSL and between 10°31'N latitude and 76°10'E longitude. The area enjoys a typical

tropical humid climate. Meteorological data during the period of investigation are presented in Appendix - I.

3.5 OBSERVATIONS

3.5.1 Bromeliads

The following observations were recorded for evaluating the performance of Bromeliads.

3.5.1.1 Vegetative characters

a) Plant height (cm)

Height of the plant was measured at monthly interval from the collar region to the region of start of rosetting and expressed in cm.

b) Spread (cm)

Spread of the plant was taken at monthly interval by measuring the spread in east west and north south directions. The mean value was taken and expressed in cm.

c) Number of leaves

Total number of leaves produced on the plant was counted at monthly interval and recorded.

d) Leaf length and leaf breadth (cm)

Length and breadth of the 4^{th} leaf was measured at monthly interval and expressed in cm.

e) Number of suckers

Total number of suckers produced on the plant during every month was recorded.

f) Presence or absence of spines

Presence or absence of spines in Bromeliads was recorded and described.

g) Colour of leaves

Colour of the leaf was observed and described.

3.5.1.2 Flower characters

a) Nature of inflorescence

Nature of the inflorescence such as erect or semi erect character was observed and recorded.

b) Days to flower

Number of days taken from planting to the emergence of the inflorescence was observed and recorded. In the case of ethrel application for induction of flowering, number of days taken from the date of ethrel application till the emergence of the inflorescence was observed and recorded.

c) Length of peduncle (cm)

Length of peduncle from the point of emergence to the point of attachment of the first bract was measured and expressed in cm.

d) Length of inflorescence (cm)

Length of the inflorescence was measured from the point of emergence of first bract to the tip and was expressed in cm.

e) Number of flowers

Number of flowers produced per inflorescence was counted and recorded.

f) Number of bracts

Number of bracts on the inflorescence was counted and recorded.

g) Length of bracts (cm)

Length of the bract was measured and expressed in cm.

h) Longevity of inflorescence (days)

Number of days from the emergence of the inflorescence to the loss of quality as indicated by symptoms of necrosis and discoloration of the bracts and flowers on the plant was observed and recorded.

i) Longevity of flower (days)

The number of days from the emergence of flower bud to discoloration and appearance of drying symptom while on the plant was observed and recorded.

j) Colour and shape of flower

The colour and shape of the flowers were observed and recorded.

h) Percentage of flowering

The number of plants flowered and total number of plants present was counted and expressed as percentage of flowering after application of ethrel.

i) Symptom of necrosis

The days taken for the appearance of necrosis on the leaves from the day of keeping the plant under indoor condition was observed and recorded.

3.5.2 Ornamental banana

The following observations were recorded for evaluating the performance of ornamental bananas.

3.5.2.1 Vegetative characters

a) Height (cm)

The height of the pseudostem was measured at monthly interval from the ground level to the point of emergence of the first leaf.

b) Girth (cm)

The circumference of the pseudostem 10cm above soil was measured at monthly interval and expressed in cm.

c) Length (cm), breadth (cm) and area (cm^2) of leaf

Length and breadth of the fully emerged second leaf was measured and expressed in cm and leaf area was calculated using the formula (length x breadth x 0.8) and expressed in cm^2. This was taken at monthly interval.

d) Petiole length (cm)

Petiole length was measured from the point of emergence to the base of the leaf lamina was measured at monthly interval and expressed in cm.

e) Number of suckers

Total number of suckers produced in the plant in each month was counted and recorded.

f) Crop duration

Number of days from planting to the completion of the male phase was counted and recorded.

3.5.2.2 Flower characters

a) Days to flower

Number of days taken from planting to the emergence of the inflorescence was counted and recorded.

b) Nature of inflorescence

The inflorescence character whether erect, pendant or drooping was observed and recorded.

c) Number of bracts

Total number of bracts produced on the inflorescence was observed and recorded.

d) Bract length (cm)

Length of the bract was measured and expressed in cm.

e) Bract breadth (cm)

Breadth of the bract in the middle was measured and expressed in cm.

f) Longevity of bract

Number of days the bract remains on the inflorescence was observed and recorded.

g) Duration of female phase (days)

The number of days from the beginning of the opening of the first female bract to the drying of the last female flower was counted and recorded.

h) Female flowers/bract

Number of female flowers produced per bract was counted and recorded.

i) Duration of male phase (days)

Number of days taken from the beginning of the opening of first male bract to the drying of the last male flower was counted and recorded.

j) Male flowers/bract

Number of male flowers produced per bract was counted and recorded.

k) Flower size

The length of the flower was measured and expressed in cm.

l) Flower longevity

Number of days from the emergence of flower to falling off the inflorescence was observed and recorded.

m) Inflorescence longevity

Number of days from the emergence of the inflorescence to the loss of quality as indicated by symptoms of necrosis and discoloration of the bracts and flowers on the plant was observed and recorded.

n) Flower persistent/not

Whether the flower was persistent in the bract or not was observed and recorded.

o) Colour and shape of male and female flower

Colour and shape of the male and female flower was observed and recorded.

p) Bract reflex and roll back

The nature of bract whether it reflexes and rolls back was observed and recorded.

q) Bract persistent/deciduous

The persistent or deciduous nature of the bract was observed and recorded.

r) Bract scar prominent/not

Whether the bract leaves a prominent scar on the peduncle when it falls from the inflorescence was observed and recorded.

3.5.3 Pollen fertility

Number of fertile pollen in each microscopic field was counted and expressed as percentage to the total number.

3.5.4 Compatibility studies

The observations on the following characters were recorded.

a) Number of flowers pollinated

Total number of flowers pollinated in each inflorescence was recorded.

b) Days to fruit set

Total number of days taken for the female flower to turn into fruit after pollination was observed and recorded.

c) Number of hands

Total number of hands formed in the inflorescence was observed and recorded.

d) Number of fruits

Total number of fruits formed in each inflorescence was observed and recorded.

e) Number of seeds

Total number of seeds formed in each inflorescence was counted and recorded.

3.5.5 Vase life in Bromeliads and ornamental bananas

Observations on the following characters were recorded for studying the vase life of Bromeliads and ornamental bananas.

a) Days to colour fading

Number of days from the day of keeping the inflorescence in distilled water in a conical flask to the discoloration of the first bract and to the last bract was recorded.

b) Water uptake (ml)

Water uptake was calculated by taking the difference between the initial volume of water present in the conical flask (V_1) at the time of placing of the inflorescence and volume of water (V_2) after the removal of the inflorescence. This was expressed in ml.

3.5.6 Irradiation

For the various planting materials irradiated for Bromeliads and ornamental bananas, following observations were recorded.

3.5.6.1 Irradiation of suckers

Number of suckers sprouted after irradiation was recorded.

3.5.6.2 Irradiation of seeds

a) Germination percentage

Number of seeds germinated after irradiation was recorded and expressed as percentage of the total number of the irradiated seeds sown.

b) Days taken for germination

Number of days taken from sowing of seeds to germination was recorded.

3.6 STATISTICAL ANALYSIS

The experimental data were analysed using MSTAT package.

Results

4. RESULTS

The results of the "Performance evaluation of ornamental bananas and Bromeliads for tropical landscapes" conducted at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during the period 2005-2007 are presented in this chapter.

4.1 MORPHOLOGICAL DESCRIPTION

4.1.1 Bromeliads

4.1.1.1 Aechmea fasciata/ Billbergia rhodocyanea (Plate 1a)

Common name : Urn plant/Silver vase plant/Living vase plant
Family : Bromeliaceae
Centre of origin : Rio-de-Jeneiro

The plant is 22.00 cm tall with a spread of 39.00 cm. It is a tank epiphyte with rosettely arranged strap like leaves, which are greasy and scaly in appearance with spines in the margins. On an average 10 leaves are produced with a mean length of 46.3 cm and mean breadth of 6.4 cm. An average number of two suckers per plant was produced during the period of observation.

Flowering was observed 130 days after planting. The inflorescence is erect, cylindrical, cone like, measuring 21.3 cm in length with a peduncle of 11.5 cm long bearing ten blue coloured tubular flowers. They emerge in between the pink coloured bracts. They are 21 in number, each with a mean length of 4.5 cm. The longevity of the flower is 2 days and that of the inflorescence is 6 days on the plant under open condition. Fruit formation was not observed.

a) *Aechmea fasciata/ Billbergia rhodocyanea*

b) *Ananas bracteatus*

c) *Ananas nanus*

d) *Billbergia pyramidalis*

e) *Bromelia balansae*

f) *Cryptanthus bivittatus*

Plate 1. Bromeliads-I

4.1.1.2 *Ananas bracteatus (Plate 1b)*

Common name : Variegated red pineapple

Family : Bromeliaceae

Centre of origin : Brazil

Plant is 25.00 cm tall with a spread of 1.1 m. Leaves are rosettely arranged; colourful with creamy yellow, green and pink bands and marginal pink spines. The centre of the rosette is tinted rosy red. An average number of 56 leaves measuring a mean length of 43.5 cm and mean breadth of 3.4 cm are produced. Suckers were not produced during the period of observation.

Flowering was observed on ethrel application after sixty days. Peduncle is 10.00 cm in length bearing the inflorescence, which is 25.00. It bears 28 bracts bearing 20 purple buds. The buds open into purple blue tubular flowers. The inflorescence is topped with a leafy crown. The duration of the inflorescence is 60 days and that of the flower is two days on the plant.

4.1.1.3 *Ananas nanus (Plate 1c)*

Common name : Dwarf pineapple

Family : Bromeliaceae

Centre of origin : Brazil

Miniature ornamental *Ananas* species with recurved, serrate, greyish green leaves with spiny margins. The plant is 4.5 cm tall with a spread of 51.5 cm. An average number of 19 leaves with a mean length of 22.7 cm and mean breadth of 2.6 cm are produced. No suckering was observed during the entire period of observation.

Flowering was observed 173 days after planting. Inflorescence arises in a slender peduncle of length 31.8 cm, bearing the inflorescence, which is 6.8 cm in length. A mean number of 39.8 bracts were observed, bearing 23 red buds resembling a pincushion. The buds open into purple tubular flowers. This inflorescence is topped with a leafy crown. The duration of the inflorescence in 55 days and that of the flower is two days on the plant.

4.1.1.4 *Billbergia pyramidalis (Plate 1d)*

Common name	:	Summer torch
Family	:	Bromeliaceae
Centre of origin	:	Brazil

The plant is 20.3 cm tall and urn shaped with a spread of 49.00 cm. It is a tank epiphyte with rosettely arranged, broad, glossy and apple green coloured leaves, which are very showy without any spines. On an average 20 leaves with a mean length of 21.8 cm and mean breadth of 6.3 cm are produced. Only one sucker per plant was produced during the entire period of observation.

Flowering was observed 52 days after planting. The inflorescence is erect, red, showy and arises from the central cup. It is 13.00 cm long with the pedicel measuring 8.5 cm. Pedicel is mealy white with a head of large bracts, 13 in number, each 7.00 cm in length and with 27 crimson red tubular flowers which are tipped purplish with blue stigma. The crimson red coloured bracts are the most colourful part of the inflorescence. The longevity of the flower is 2 days and that of the inflorescence is 7 days on the plant under open condition. No fruit formation was observed during the entire period of observation.

4.1.1.5 *Bromelia balansae (Plate 1e)*

Common name	:	Pinuela
Family	:	Bromeliaceae
Centre of origin	:	Brazil

The plant is 30.3 cm tall with a spread of 1.5 m. The leaves are greyish green, large, terrestrial rosette, stiff with dangerous hook like spines facing both the directions. On an average 63 leaves with a mean leaf length of 40.1 cm and mean leaf breadth of 3.00 cm are produced. No suckering and flowering was observed during the period of observation.

4.1.1.6 Cryptanthus bivittatus (Plate 1f)

Common name	:	Pink starlite
Family	:	Bromeliaceae
Centre of origin	:	Brazil

The plant is 6.5 cm tall with a spread of 48.8 cm. Leaves are open, rosettely arranged, fleshy, predominantly olive green, crisped wavy and spiny at the sides with the centre tinted carmine red. On an average 16 leaves with a mean length of 21.6 cm and leaf breadth of 3.2 cm are produced. An average number of 2.8 suckers per plant were produced. Plant did not flower during the period of observation.

4.1.1.7 Cryptanthus bromelioides (Plate 2a)

Common name	:	Rainbow star
Family	:	Bromeliaceae
Centre of origin	:	Brazil

The plant is 14.7 cm tall with a spread of 70.4 cm. Leaves are olive green with creamy white marginal bands tinted rose, waxy and spiny at the margins. On an average 22.3 leaf, which are narrow, lanceolate, measuring a mean length of 24.00 cm and mean breadth of 3.2 cm are produced. An average number of 1.7 suckers per plant is produced. Plant did not flower during the period of observation.

4.1.1.8 Cryptanthus zonatus (Plate 2b)

Common name	:	Zebra plant/ Earthstars
Family	:	Bromeliaceae
Centre of origin	:	Pernambuco

Plant attained a height of 2.8 cm and a spread of 18.3 cm. They grow low and parallel to the ground in a star arrangement. The bronzy, long leaves are rosettly arranged and show pronounced silvery to beige cross bandings resembling those of a zebra. An average number of 9 leaves with a mean length of 11.5 cm and mean

a) *Cryptanthus bromelioides*

b) *Cryptanthus zonatus*

c) *Dyckia brevifolia*

d) *Pitcarnea flammea*

e) *Tillandsia stricta*

Plate 2. Bromeliads-II

breadth of 2.8 cm are produced. Only one sucker per plant was produced. Duration was over by 90 days after planting under open and shaded conditions. But the mother plant put forth new suckers under 50 per cent shade during the month of July, when the mean maximum temperature recorded was 30.4°C, average sunshine hour was 0.71 hr/day and maximum rainfall was 1131.9 mm. The inflorescence arises in a cluster and is hidden inside the central portion in between the leaves. Numerous tiny white coloured tubular flowers with a mean length of 1.5 cm are produced from it. The plant is not grown for their flowers but for its beautiful foliage.

4.1.1.9 Dyckia brevifolia (Plate 2c)

Common name	: Miniature agave
Family	: Bromeliaceae
Centre of origin	: Brazil

The plant is 7.1 cm tall, with a spread of 55.6 cm. It is a spiny xerophyte forming a dense rosette of, maroon coloured, spiny fleshy leaves with a dense covering of scales on the underside. The upper side of the leaves are glabrous and glossy. On an average 25 leaves, with a mean length of 24.1 cm and mean breadth of 2.1 cm are produced. A mean number of 20 suckers are produced per plant.

It takes 179 days to flower after planting. The inflorescence is an erect spike produced at the centre of the plant measuring a length of 6.6 cm. Peduncle is 1.8 cm long bearing a mean number of 18 purple coloured tubular flowers. An average number of 4 pale brown bracts are produced. The inflorescence longevity is 62.4 days and that of the flower in 2.6 days on the plant. The bracts are not at all attractive. Fruit formation was not observed.

4.1.1.10 Pitcarnea flammea (Plate 2d)

Common name	:	Pitcarnea
Family	:	Bromeliaceae
Centre of origin	:	Brazil

The plant is 18.6 cm tall with a spread of 42.6 cm. It develops into a clump from the underground rhizome bearing rosettely arranged green coloured, grassy, narrow leaves, which are not spiny. Scales are present on its underside. On an average 48 leaves each with an average length of 16.7 cm and average breadth of 1.4 cm are produced. An average number of 4 suckers were produced per plant.

Inflorescence was produced 216 days after planting. It is unbranched, slender with a semi pendent stalk of 25 cm length. Peduncle is 6.6 cm, bearing 21 slender red coloured tubular flowers. They are pedicellate with no bracts, arising individually from the inflorescence stalk. The duration of the flower is 4 days and that of the inflorescence is 7.8 days on the plant. Fruit formation was not observed.

4.1.1.11 Tillandsia stricta (Plate 2e)

Common name	:	Air plant
Family	:	Bromeliaceae
Centre of origin	:	Brazil

The plant is 25.2 cm tall with a spread of 60.0 cm. Leaves are rosettely arranged, narrow shaped, spiny, tapering to the tip recurving with distinct yellow and green bands. On an average 43 leaves with mean length of 25.8 cm and mean breadth of 1.2 cm are produced .On an average ten suckers were produced, per plant.

Flowering in the plant was observed at the onset of rainfall during the month of July when the mean maximum temperature recorded was 30.4°C, average sunshine hours .71 and maximum rainfall recorded was 1131.9 mm. The inflorescence is a spike on which five yellow leathery bracts are produced. Numerous small creamy yellow fragrant flowers about 1 cm in length are produced in between the bracts. The inflorescence is 5.8 cm in length with a peduncle measuring 3 cm.

4.1.2 Ornamental bananas

4.1.2.1 Musa coccinea (Plate 3a)

Common name	:	Scarlet banana, Flowering Thai banana
Family	:	Musaceae
Section	:	Callimusa
Centre of origin	:	Indo China, Myanmar, Malaysia

Pseudostem : 19.6 cm high, slender, green, with a girth of 5.7 cm.

Leaves : 6 in number, 40.2 cm long, 9.9 cm wide and leaf area 1142 cm^2. Green leaves are devoid of wax, shiny dark green above, paler beneath but not glaucous, midrib green like the lamina above, paler beneath. Petiole upto 7.3 cm in length with narrow erect margin clasping the pseudostem but not becoming scarious.

Inflorescence : Erect, sterile bracts usually 2, they are bright scarlet with green leaf like tips. Basal flowers pistillate, 1-4 clusters or more, upper flowers male.

Male bud : Open at the advanced blooming stage. Bracts oblong, imbricate at the tip, closed portion of the bud ovoid, very firm in texture, bright scarlet on both surfaces, with extreme tip yellow or green.

Male flower : Bright orange in colour with green tip and lobes, 2 flowers per bract, free tepal as long as the compound tepal, narrow, oblong and orange in colour, laterally hyaline and obtuse at the apex.

Female flower: 1-3 per bract, ovary 3-4 cm long, 1.5-2 cm wide, dorsiventrally compressed, orange yellow, compound tepal 3.5 cm long, orange yellow with green lobes, free tepal as long as the compound tepal, dorsally thickened, opaque and orange in colour, laterally hyaline, staminodes short (about 1 cm), style as long as the perianth with a bright orange elevate stigma.

Fruit : 4-6 cm oblong, crowned by the persistent withered perianth, orange yellow at full maturity with a waxy bloom, purple white.

Seeds : Cylindrical, black, 6 mm long and 4 mm in diameter at the centre portion .The surface is marked with longitudinal warty edges.

Suckers : Suckers were not produced during the period of observation

4.1.2.2 Musa laterita (Plate 3b)

Common name	:	Red salmon
Family	:	Musaceae
Section	:	Rhodoclamys
Centre of origin	:	India to Indo China

Pseudostem : 29.6 cm tall, slender, green, devoid of wax, with a girth of 9.2 cm.

Leaves : 7 in number, 39.7 cm long, 14.5 cm wide with a leaf area of 461.2 cm^2; medium to dark green in colour, truncate at the apex, narrowing down rather with a grading acute base. Petiole is 10.1 cm long; its base closely clasping the pseudostem, midrib is flushed red on the lower surface.

Inflorescence : Erect, peduncle is slightly hairy in nature, bracts are brick red coloured, do not reflex and roll back, persistant, leaving a prominent scar with a longevity of 3-4 days. An average number of 34 bracts, each measuring a mean length of 15.2 cm and mean breadth of 5.2 cm are produced. First sterile bract is usually a foliage leaf with a broadened petiole developing red colour, followed by one sterile true bract. Basal flowers are pistillate. The flowers are deciduous in nature.

Bunch : Very compact, erect in nature, 4-5 hands, 4-6 fingers in each hand.

Male bud : Ovate, slightly imbricate and yellow at the tip, bracts are brick red, slightly grooved, 6-10 flowers per bract, biseriate.

Male flower : Orange yellow in colour, 5.2 cm long, compound tepal 4 cm, lobes slightly darker, the lateral lobes 5 mm long with minute dorsal

appendages. Free tepal more than 1 cm long, opaque white, boat shaped.

Female flower: 4-6 in each bract, 7-8 cm long, perianth about as long as the ovary, free tepal ¼ to 1/3 as long as the compound tepal, the latter yellow, its lobes little darker in colour than the rest.

Fruit : Bunch very compact, the fruits almost appressed to the rachis, individual fruit about 8-10 cm long, very short pedicel, turning yellow on ripening.

Seeds : Dull black, irregularly depressed, 4 mm in diameter and 5 mm in length.

Suckers : Profuse suckering was observed. On an average 2.30 suckers were produced which emerge slightly at an angle from the mother plant.

4.1.2.3 Musa ornata (Plate 3c)

Common name	:	Lavender banana
Family	:	Musaceae
Section	:	Rhodoclamys
Centre of origin	:	India to Indo China

Pseudostem : 49.2 cm tall, green, slender, waxy with a girth of 10 cm.

Leaves : 9 in number, 49.2 cm long, 17.8 cm wide with a leaf area of 702.3 cm^2; medium green in colour, truncate at the apex, midrib often flushed with red beneath, petiole 12.4 cm long and clasping the pseudostem at the base.

Inflorescence: Erect, 30-35 cm long. Bracts are lavender pink coloured reflex and roll back leaving a prominent bract scar with a longevity ranging from 3-4 days. An average number of 59 bracts, each measuring mean length of 16.7 cm and mean breadth of 5.5 cm are produced. Sterile bracts usually two, the first, a foliage leaf with broadened and lavender coloured petiole, the second, a fully coloured true bract. Basal flowers, pistillate. Flowers are deciduous in nature.

Male bud : Acute, bracts convolute or slightly imbricate at the tip, pink in colour, yellow at the extreme tip.

Male flowers: Orange yellow in colour, 4-6 flowers per hand in one row, each with an average length of 6 cm. Compound tepal about 4 cm long, orange yellow in colour, free tepal is more or less as long as compound tepal, bowl shaped, tip is more or less smooth.

Female flowers: 3-5 per bract, each with an average length of 6 cm arranged in a single row. Ovary 4 cm long, green, compound tepal 3.5 cm, deep orange yellow, free tepal 3 cm long, transluscent white, ovate oblong with a rather obtuse yellow acumen, staminodes one third to one half the length of the style, style green, 3 cm long.

Fruits : 6-8 cm long, 2-2.5 cm in diameter, green at maturity and bright yellow at ripeness.

Seeds : Dull black, irregular, smooth surfaced, 5 mm in diameter and 3 mm in length.

Suckers : Profuse suckering was observed. On an average two suckers were produced which emerge slightly at an angle from the mother plant.

4.1.2.4 Musa rosea (Plate 3d)

Common name	:	Rose banana
Family	:	Musaceae
Section	:	Rhodoclamys
Centre of origin	:	India to Indo China

Pseudostem : 20 cm tall, green, slender and devoid of wax.

Leaves : 6 in number 35.5 cm long, 7 cm wide and leaf area 199 cm^2, green in colour and shiny, leaf basees symmetric and pointed. Petiole up to 7 cm in length.

Inflorescence: Erect, 30-35 cm, glaborous, medium green. Sterile bracts usually one, red in colour soon shriveling. Basal flowers are pistillate.

Male bud : Narrowly ovoid acute, bractsred, slighty imbricate at the tip. Red in colour, yellow at the extreme tip.

Male flowers: Orange in colour, 2-4 flowers per hand in one row. Compound tepal 3 cm long, orange in colour, free tepal 8 cm long, oblanceolate, transluscent white.

Fruits : Bunch rather lax, individual fruit 7 cm long, 1.5 cm in diameter, green at maturity and bright yellow at ripeness.

Seeds : Dull black, irregularly depressed 5 mm in diameter and 3 mm in length.

Suckers : No suckers were produced during the period of observation.

4.1.2.5 Musa rubra (Plate 3e)

Common name	:	Red banana
Family	:	Musaceae
Section	:	Rhodochlamys
Centre of origin	:	India to Indo China

Pseudostem : 17 cm tall, lower sheaths pale brown, upper green, devoid of wax.

Leaves : 6 in number, 30.5 cm long, 6 cm wide and leaf area 146.5 cm^2, green in colour, oblong lanceolate, truncate at the apex, narrowing down rather with asymmetric base. Petiole 7.1 cm in length, its base closely clasping the pseudostem.

Inflorescence: Erect, peduncle is slightly hairy in nature, first sterile bract is usually a foliage leaf with broadened petiole, developing pale red colour, followed by one sterile true bract. Basal flowers are pistillate.

Male bud : Ovate, slightly imbricate at the tip, bracts pale red, slightly grooved, 6-10 flowers per bract, biseriate.

Male flowers : Compound tepal 4 cm long, orange yellow in colour, lobes slightly darker, the lateral lobes 5 mm long with minute dorsal appendages. Free tepal, long, opaque white, boat shaped.

Fruits : Very compact bunch, erect with 4-5 hands, fruits almost appressed to the rachis. Individual fruit about 8-10 cm long, very short pedicel, yellow upon ripening.

Seeds : Dull black, irregularly depressed 5 mm in diameter and 3 mm in length.

Suckers : No suckers were produced during the period of observation.

4.1.2.6 Ensete ventricosum (Plate 3f)

Common name : Abyssinian banana

Family : Musaceae

Genus : Ensete

Centre of origin : Africa

Pseudostem : 36 cm tall with a swollen base of 59.4 cm circumference at the base, often variably stained purple or purplish brown, with a pale whitish latex which reddens on exposure to air.

Leaves : 13 in number, born on a banana like crown erect or spreading, oblong, lanceolate, 85.4 cm long, 28.4 cm wide, with a leaf area of 2418.3 cm^2 .Leaf lamina bright yellow, green, more or less glaucous beneath. Midribs green purple or brown. Petioles 11.3 cm long.

Inflorescence : Droopy, large hanging head with a massive male bud. Bracts are green coloured, dark within, claret brown, dull claret brown, red, purple, greenish brown, striated pale greenish, lanceolate, oblong subaccuminate or obtuse; slightly imbricate

Male bud : Very massive, male bracts persistent or semi deciduous (rotting away), densely over lapping.

Male flowers : White with orange yellow tipped lobes, outer perianth linear-oblong, 3 lobed, one petal protected by large dark red bract, 5 stamens, produce sticky pollen, anthers violet purple, staminode absent or minute.

Hermaphrodite flowers: Persistent and partially covering the fruits, orange yellow tipped perianth and 3 lobed outer perianth. Two extra acicular lobes internally attached, stamens 1-5, anthers violet to dark purple; pollen yellow or greyish in colour. Staminodes variable in number. Female flowers are without stamens but with staminodes.

a) ***Musa coccinea***

b) ***Musa laterita***

c) ***Musa ornata***

d) ***Musa rosea***

e) ***Musa rubra***

f) ***Ensete ventricosum***

Plate 3. Ornamental bananas

Fruit : Trilocular, 8-15 cm x 45 cm size; mature fruit, bright or yellow orange with orange pulp arranged in clusters.

Seeds : Irregularly subspherical, striated to almost smooth black or greyish brown, 12-18 mm in diameter, upto 40 seeds per fruit.

Suckers : No sucker production was observed during the period of observation.

4.2 PERFORMANCE EVALUATION OF BROMELIADS UNDER DIFFERENT SHADE LEVELS

The results of the performance evaluation of Bromeliads under different shade levels are presented in Tables 1-8 Fig. 1-10.

4.2.1 *Aechmea fasciata*

Plant characters of *Aechmea fasciata* like height (Table 1 and Fig. 1), number of leaves (Table 3 and Fig. 1) and number of suckers (Table 6) showed no significant difference through out the growth period observed between 50 per cent shade and open condition. The spread (Table 2 and Fig. 1) of the plant was found to be the highest (66.16 cm) during the 2nd month after planting. The length of the leaf (Table 4) was found significantly higher under open condition during the 1st(46.00 cm), 2nd (53.33 cm) and 3rd (52.83 cm) months after planting.

From the above results, it can be concluded that *Aechmea fasciata* showed significantly higher plant spread and leaf length under open condition than under shade (Plate 4a & b).

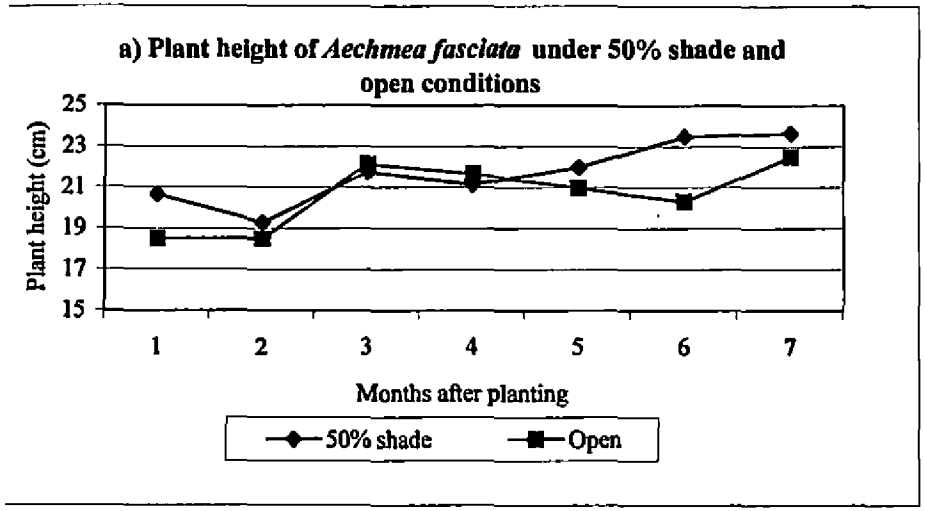
4.2.2 *Ananas bracteatus*

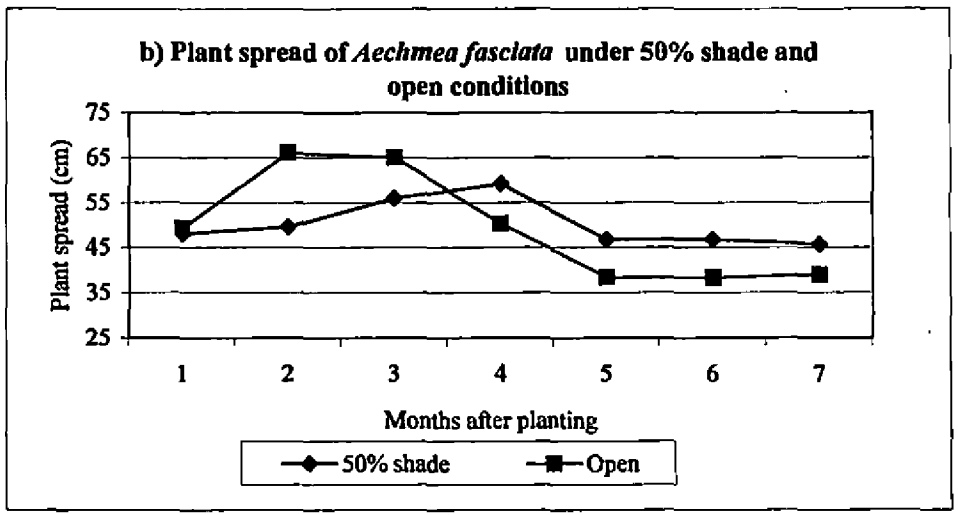
Ananas bracteatus showed significantly higher values in height (Table 1 and Fig. 2) only during the 1st and 2nd months after planting under open condition, 23.00 cm and 22.66 cm, respectively. Spread of the plant (Table 2 and Fig. 2) was found to be significantly higher during the 4th month after planting under 50 per cent shade level (2.26 m). There was significant increase in the number of leaves (Table 3 and Fig. 2) under 50 per cent shade level, and maximum number recorded was 59.66. Length of the leaf (Table 4) was found to be significantly higher during the 4th month

Table 1. Plant height (cm) of Bromeliads under 50 per cent shade and open condition

Sl. No.	Species observed	Height(cm)													
		1st month		2nd month		3rd month		4th month		5th month		6th month		7th month	
		50% shade	open	50% shade	open	50% shade	open	50% shade	open	50% shade	open	50% shade	open	50% shade	open
1	*Aechmea fasciata*	20.67	18.50	19.30	18.50	21.76	22.16	21.16	21.66	22.00	21.00	23.50	20.33	23.66	22.50
2	*Ananas bracteatus*	15.50	23.00	15.66	22.66	16.50	16.16	16.83	16.50	17.58	18.75	20.33	21.50	22.76	25.16
3	*Ananas nanus*	3.16	2.83	5.00	2.33	3.61	2.75	4.13	2.75	5.63	3.21	6.66	4.41	7.06	4.51
4	*Billbergia pyramidalis*	14.50	17.17	15.40	15.83	16.16	16.83	18.76	17.75	18.50	18.61	19.91	18.66	14.21	20.33
5	*Bromelia balansae*	11.25	16.85	12.65	13.50	13.95	17.25	15.33	25.33	15.75	24.40	16.58	27.25	17.83	30.32
6	*Cryptanthus zonatus*	2.25	2.90	2.33	2.90	2.05	2.80	-	-	-	-	-	-	-	-
7	*Dyckia brevifolia*	8.67	8.13	7.85	7.51	7.41	7.38	7.43	7.58	7.30	7.31	6.55	7.36	6.23	7.18
8	*Pitcarnea flammea*	8.25	16.00	14.36	14.75	14.40	14.25	16.50	15.00	18.08	15.66	20.08	17.01	20.48	18.64
9	*Tillandsia stricta*	18.50	15.47	12.91	15.71	16.35	18.98	17.50	21.21	18.66	22.23	13.66	24.25	20.83	25.23
	CD (0.05)	3.65		4.27		5.13		5.38		5.51		7.85		5.84	

Fig. 1. Plant characters of *Aechmea fasciata* under 50% shade and open condition





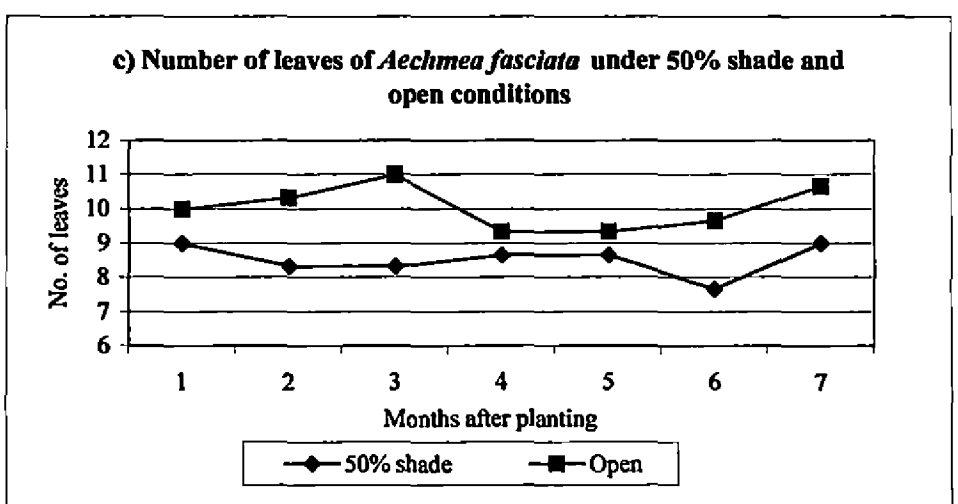
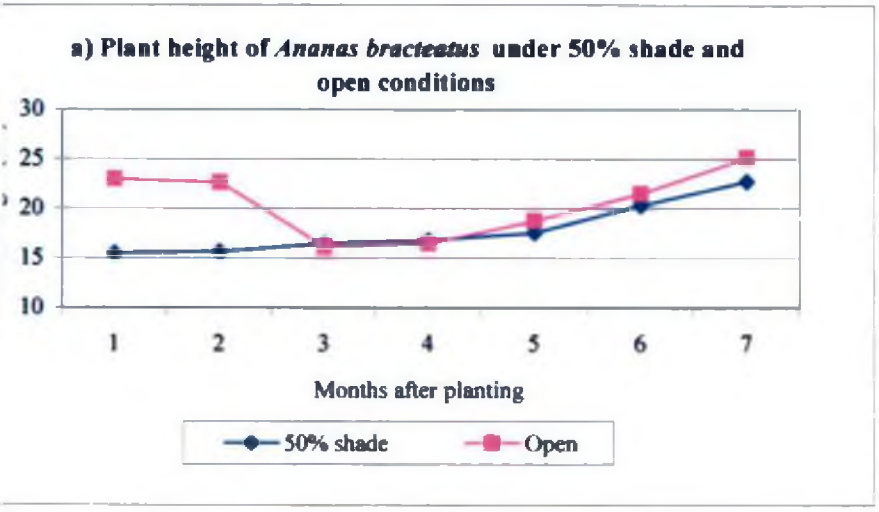
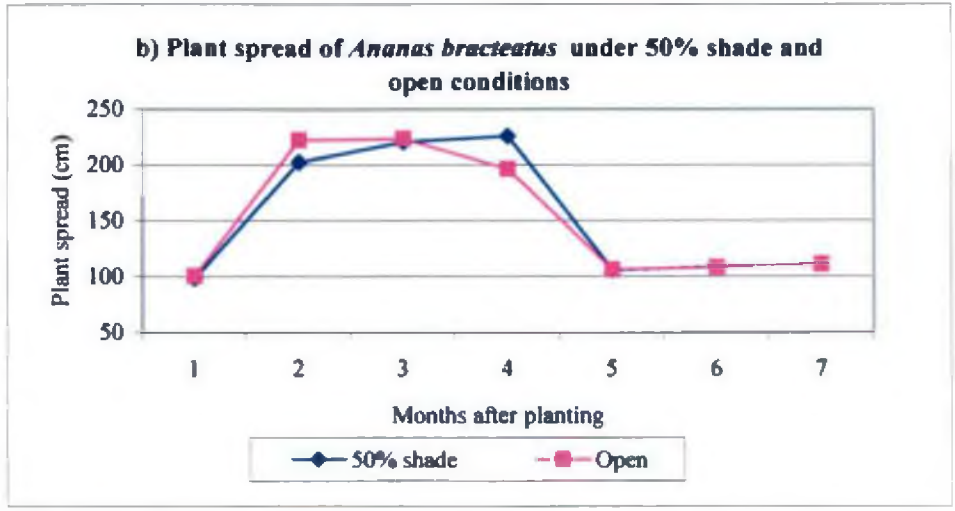
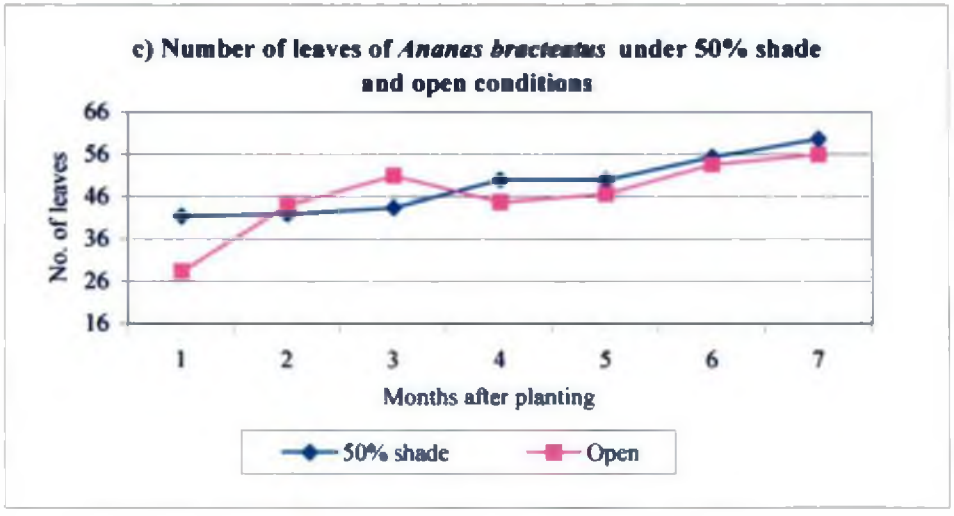


Fig. 2. Plant characters of *Ananas bracteatus* under 50% shade and open condition







a) *Aechmea fasciata* under 50% shade

b) *Aechmea fasciata* under open

c) *Ananas bracteatus* under 50% shade

d) *Ananas bracteatus* under open

Plate 4. Performance of Bromeliads under different shade levels-I

after planting under 50 per cent shade level. Breadth of the leaf (Table 5) was found to be significantly higher under 50 per cent shade during the 4th month after planting and the maximum recorded was 5.30 cm. Number of suckers (Table 6) showed no significant difference between the two conditions during the entire period of growth observed.

From the above data it can be concluded that plant height was significantly higher under open condition. Leaf length was significantly higher under 50 per cent shade than under open condition. The spread of the plant, number of leaves and breadth of the leaves were significantly higher under 50 per cent shade level. Sucker production showed no significant difference between the two growing conditions (Plate 4c & d).

4.2.3 *Ananas nanus*

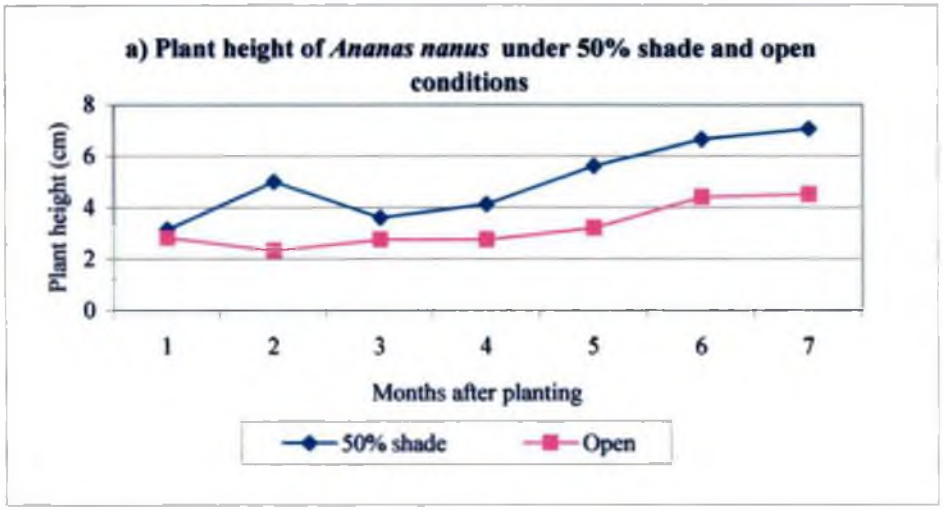
Plant height (Table 1 and Fig.3), number of leaves (Table 3 and Fig.3) and sucker production (Table 6) showed.no significant difference during the entire growth period of observation between 50 per cent shade and open condition. Spread (Table 2 and Fig 3) was found to be significantly higher during the 2nd, 3rd, 5th and 7th month after planting under 50 per cent shade level,being 44.30 cm, 46.00 cm, 56.20 cm and 62.50 cm, respectively. Significantly higher values in leaf length (Table 4) were observed during the 1st, 2nd, 3rd, 6th and 7th months after planting under 50 per cent shade and maximum recorded was 32.20 cm during the 7th month. The breadth of the leaf (Table 5) showed significant increase only during the 4th month after planting which was higher under open condition (2.70 cm).

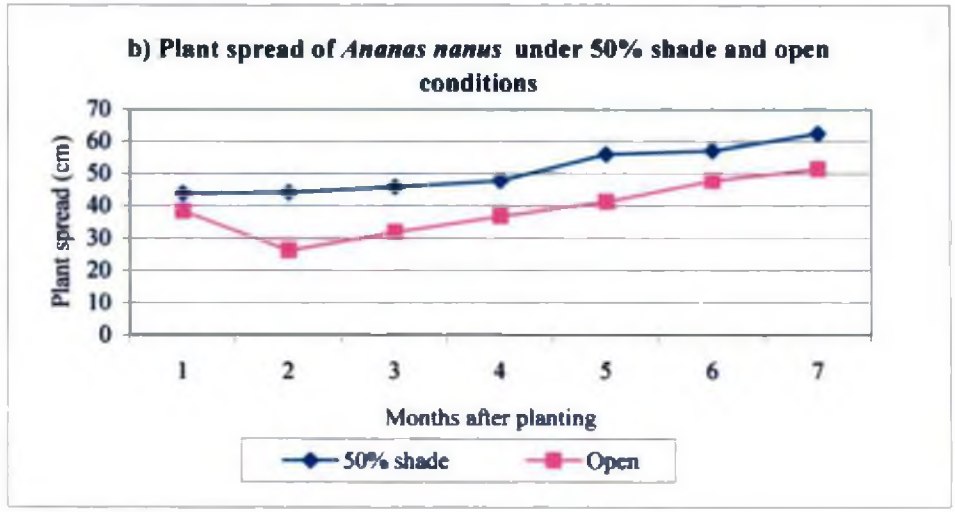
The observations on the floral characters are presented in Table 7. Flowering was observed earlier under open condition (152.00 days) than under shade (173.80 days). Length of the peduncle was higher under 50 per cent shade level (31.80 cm) than under open condition (24.30 cm). Length of the inflorescence was higher under 50 per cent shade level (38.60 cm) and lower under open condition (28.90 cm). Number of flowers produced per inflorescence was higher under open condition

Table 2. Plant spread (cm) of Bromeliads under 50 per cent shade and open condition

Sl. No.	Species observed	Spread (cm)													
		1st month		2nd month		3rd month		4th month		5th month		6th month		7th month	
		50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open
1	*Aechmea fasciata*	48.16	49.33	49.66	66.16	56.08	65.16	59.21	50.33	46.83	38.50	46.83	38.43	45.73	39.03
2	*Ananas bracteatus*	98.50	100.50	202.50	222.50	220.50	223.50	226.00	196.50	106.00	106.28	108.75	108.50	111.75	111.00
3	*Ananas nanus*	44.00	38.50	44.30	26.26	46.00	31.98	47.95	36.92	56.20	41.39	57.25	47.96	62.50	51.55
4	*Billbergia pyramidalis*	40.08	32.16	38.4	39.08	35.58	39.08	34.16	40.31	33.56	39.73	32.75	46.5	38.00	49.08
5	*Bromelia balansae*	88.00	94.50	118.25	103.83	177.37	112.04	115.83	124.50	116.00	145.33	119.00	150.83	126.83	158.75
6	*Cryptanthus zonatus*	17.11	17.75	18.55	20.08	18.00	18.25	-	-	-	-	-	-	-	-
7	*Dyckia brevifolia*	51.16	47.50	53.49	50.90	55.79	52.10	57.80	53.23	56.50	54.51	55.66	54.73	53.36	55.63
8	*Pitcarnea flammea*	45.26	42.58	52.16	45.74	45.12	44.20	47.76	41.20	49.42	36.02	50.42	40.00	52.83	42.62
9	*Tillandsia stricta*	69.33	45.29	53.50	51.87	41.25	52.33	39.50	52.30	39.50	53.56	39.25	51.81	39.50	59.98
	CD (0.05)	9.82		15.76		13.37		12.56		9.92		11.05		9.36	

Fig. 3. Plant characters of *Ananas nanus* under 50% shade and open condition





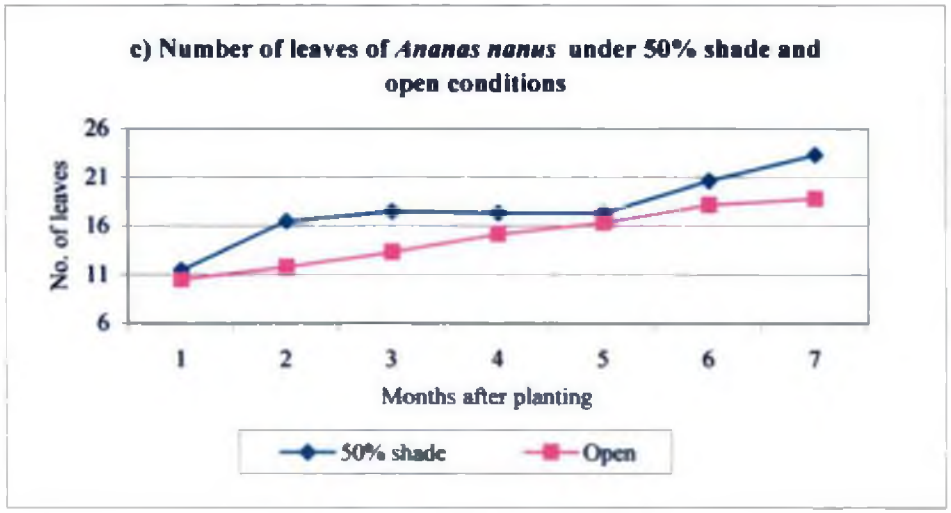
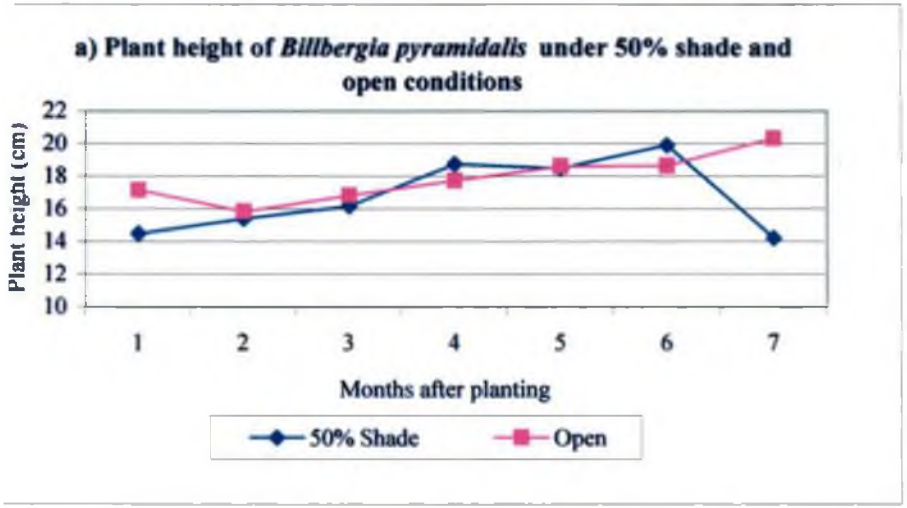
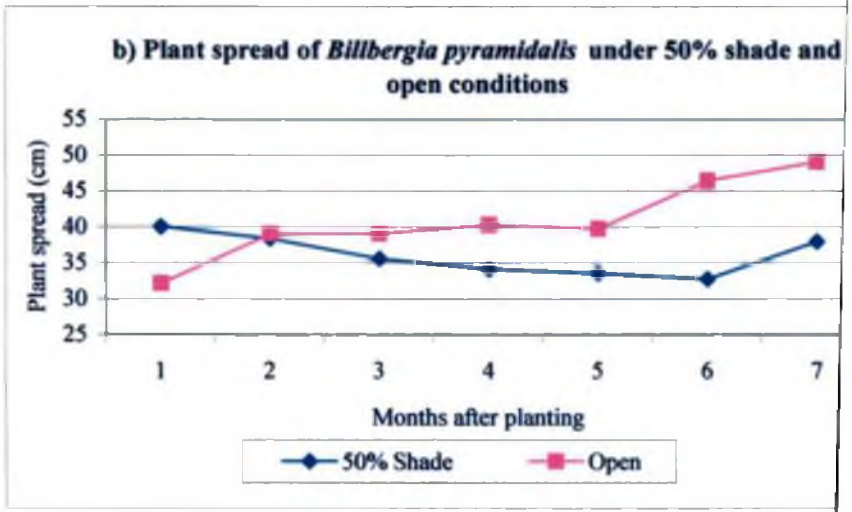
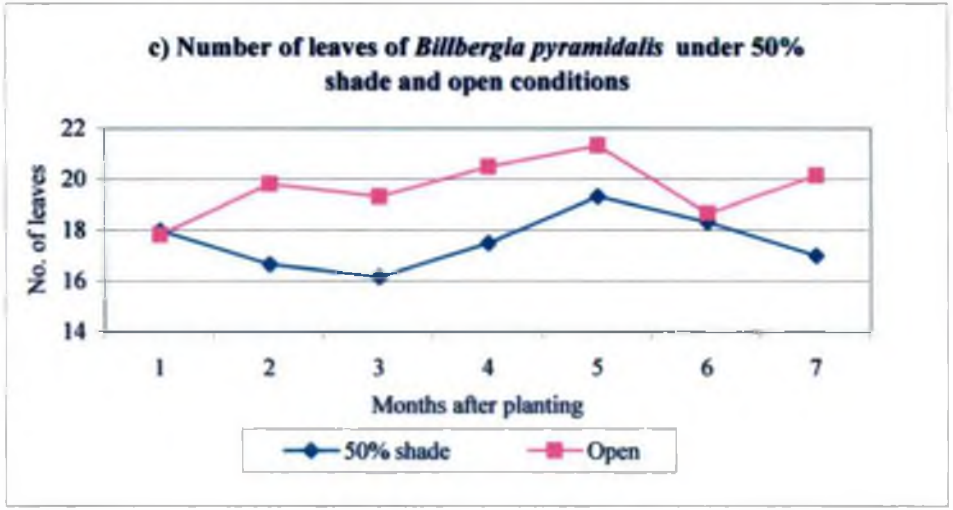


Fig. 4. Plant characters of *Billbergia pyramidalis* under 50% shade and open condition







a) *Ananas nanus* under 50% shade

b) *Ananas nanus* under open

c) *Billbergia pyramidalis* under 50% shade

d) *Billbergia pyramidalis* under open

e) *Bromelia balansae* under 50% shade

f) *Bromelia balansae* under open

Plate 5. Performance of Bromeliads under different shade levels-II

(32.80) and lower under 50 per cent shade level (23.80). Number of bracts produced was higher under 50 per cent shade level (39.80) and lower under open condition (38.80). Longevity of the inflorescence on the plant was higher under open condition (67.60 days) and lower under 50 per cent shade level (55.80 days). Longevity of flower on the plant was higher under open condition (2.6 days) and lower under 50 per cent shade level (2 days).

About the vegetative characters it can be concluded that only leaf breadth was significantly higher under open condition. Plant spread and leaf length showed significantly higher values under 50 per cent shade level than under open condition. Other plant characters like plant height, number of leaves and number of suckers showed no significant difference between the two conditions.

About the floral characters it can be concluded that earlier flowering, more number of flowers, longer inflorescence and flower longevity were observed under open condition. Other characters like length of the peduncle, length of the inflorescence and number of bracts produced were higher under 50 percent shade level (Plate 5a & b).

4.2.4 *Billbergia pyramidalis*

Table 1 and Fig 4 show the plant height recorded under 50 per cent shade and open condition in *Billbergia pyramidalis* during the experimental period. There was no significant difference in height up to the 6th month of planting between the two growing conditions. In the 7th month, height was significantly higher (20.33cm) under the open condition. In the case of spread (Table 2 and Fig .4), no significant difference was observed up to the 5th month between the two growing conditions. But it was significantly higher during the 6th and 7th months under open condition, being 46.5 cm and 49.08 cm respectively. Number of leaves (Table 3 and Fig.4) and length of leaves (Table 4) showed no significant difference under the two growing conditions throughout the growth period observed. Breadth of the leaf (Table 5) showed a significant increase in the 6th month after planting under 50 per cent shade level

Table 3. Leaf number of Bromeliads under 50 per cent shade and open condition

Sl. No.	Species observed	Leaf number													
		1st month		2nd month		3rd month		4th month		5th month		6th month		7th month	
		50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open
1	*Aechmea fasciata*	9.00	10.00	8.33	10.33	8.33	11.00	8.66	9.33	8.66	9.33	7.66	9.66	9.00	10.66
2	*Ananas bracteatus*	41.50	28.33	42.00	44.00	43.50	51.00	50.00	44.66	50.00	46.66	55.50	53.66	59.66	56.00
3	*Ananas nanus*	11.50	10.50	16.50	11.83	17.50	13.33	17.33	15.16	17.33	16.33	20.66	18.16	23.33	18.83
4	*Billbergia pyramidalis*	18.00	17.83	16.66	19.83	16.16	19.33	17.50	20.50	19.33	21.33	18.33	18.66	17.00	20 16
5	*Bromelia balansae*	31.00	32.33	33.33	38.00	35.33	55.33	36.66	70.33	40.00	71.66	43.00	63.66	45.00	63.00
6	*Cryptanthus zonatus*	11.33	11.00	10.33	8.50	10.33	9.50	-	-	-	-	-	-	-	-
7	*Dyckia brevifolia*	13.00	22.83	13.33	24.66	15.16	25.16	14.33	24.33	15.66	24.50	16.16	25.06	12.66	25.66
8	*Pitcarnea flammea*	35.33	45.50	52.03	47.83	51.00	49.83	54.00	56.33	56.33	50.50	57.50	48.83	57.66	47.66
9	*Tillandsia stricta*	18.00	22.50	24.00	31.50	20.50	34.33	25.00	37.50	30.00	40.00	24.50	42.33	24.50	42.83
	CD (0.05)	7.12		8.67		7.77		8.47		8.65		8.13		7.66	

(6.75cm). In sucker production (Table 6), significant increase was observed during the 3rd month after planting in the open condition compared to 50 per cent shade.

From the above results, it can be concluded that plant height and spread were significantly higher under open condition than under 50 per cent shade. Leaf breadth and sucker production showed significant increase under 50 per cent shade level than under open condition. Other plant characters like number of leaves and leaf length showed no significant difference under the two growing conditions (Plate 5c & d).

4.2.5 *Bromelia balansae*

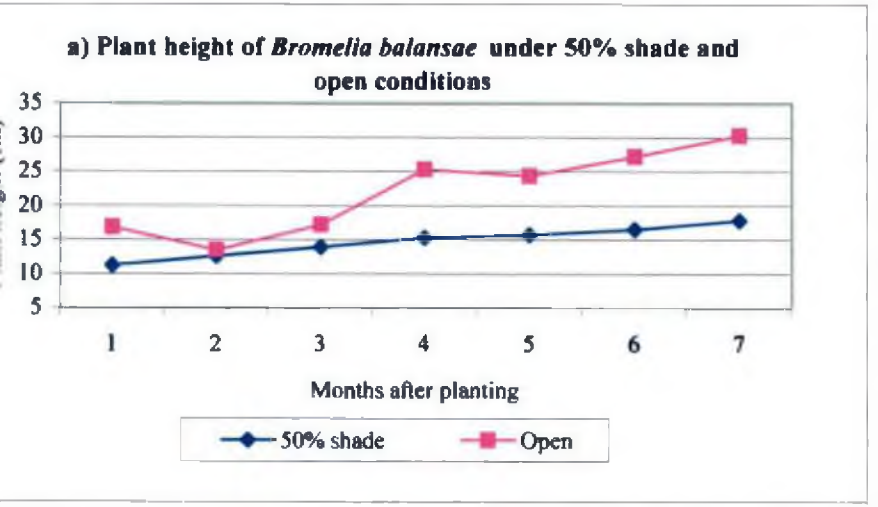
Height (Table 1 and Fig. 5) of the plant showed significant increase under open condition than under shade during 1st, 4th, 5th, 6th and 7th months after planting. Spread (Table 2 and Fig. 5) of the plant was found to be significantly higher under 50 per cent shade level during the 3rd month (1.77m). It was also significantly higher under open condition during the 5th (1.45m), 6th (1.50 m) and 7th (1.58 m) months after planting. The number of leaves (Table 3 and fig 5) showed significant increase from 3rd to 7th month after planting under open condition, highest being 63.00 during the 7th month. Length of the leaf (Table 4) was found to be significantly higher during the 3rd and 4th months after planting under 50 per cent shade level. Breadth of the leaf (Table 5) showed significant increase under 50 per cent shade level during the 3rd, 4th, 5th and 6th months after planting. Number of suckers (Table 6) showed no significant difference between the conditions during the entire period of growth observed.

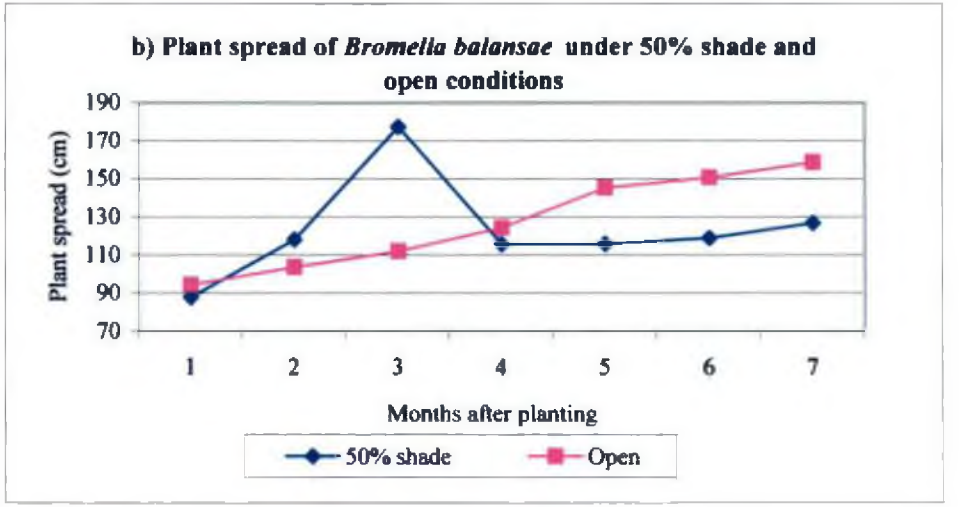
From the above results we can conclude that height of the plant and number of leaves showed significant increase under open condition than under 50 percent shade. Spread of the plant, leaf length and leaf breadth were significantly higher under 50 per cent shade level. Length of the leaf showed significantly higher value under open condition also. Number of suckers per plant showed no significant difference between the two conditions (Plate 5e & f).

Table 4. Leaf length (cm) of Bromeliads under 50 per cent shade and open condition

Sl. No.	Species observed	Leaf length (cm)													
		1st month		2nd month		3rd month		4th month		5th month		6th month		7th month	
		50% shade	open	50% shade	open	50% shade	open	50% shade	open	50% shade	open	50% shade	open	50% shade	open
1	*Aechmea fasciata*	36.43	46.00	40.73	53.33	40.73	52.83	46.50	46.50	39.83	45.33	46.00	44.83	46.90	46.33
2	*Ananas bracteatus*	56.50	52.66	53.75	48.25	47.00	45.25	45.50	39.65	37.16	42.33	30.50	43.50	30.50	43.50
3	*Ananas nanus*	22.03	14.36	24.45	16.96	26.70	20.06	25.03	21.31	22.48	21.91	30.33	20.16	32.20	22.70
4	*Billbergia pyramidalis*	23.33	19.83	21.25	22.91	20.58	23.00	22.05	24.16	23.00	26.15	22.33	19.83	27.25	21.85
5	*Bromelia balansae*	46.25	47.50	47.75	51.60	50.18	37.66	50.50	39.10	45.40	43.16	45.08	39.00	45.25	40.17
6	*Cryptanthus zonatus*	9.75	9.75	11.25	11.25	11.40	11.50	-	-	-	-	-	-	-	-
7	*Dyckia brevifolia*	24.23	25.05	23.40	24.90	24.06	26.13	23.03	25.03	21.16	23.66	20.83	22.73	18.76	24.10
8	*Pitcarnea flammea*	21.13	22.46	20.26	23.18	18.08	22.75	17.42	21.70	16.69	20.25	15.08	19.08	13.50	16.61
9	*Tillandsia stricta*	31.50	30.41	22.25	30.41	16.00	31.83	20.75	32.50	27.00	33.41	20.50	27.00	20.00	25.81
	CD (0.05)	6.35		6.04		6.38		5.82		8.15		8.81		8.94	

Fig. 5. Plant characters of *Bromelia balansae* under 50% shade and open condition





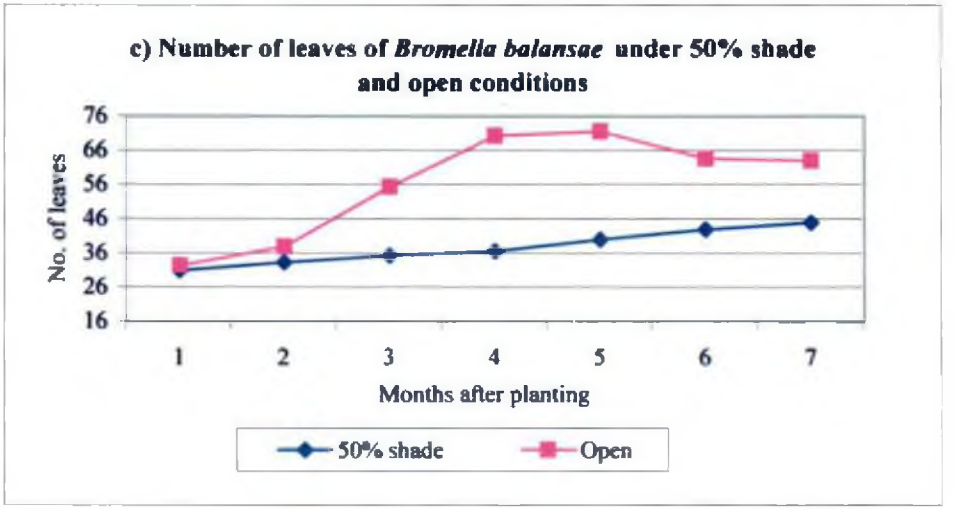


Table 5. Leaf breadth (cm) of Bromeliads under 50 per cent shade and open condition

Sl. No.	Species observed	Leaf breadth (cm)													
		1st month		2nd month		3rd month		4th month		5th month		6th month		7th month	
		50% shade	open	50% shade	open	50% shade	open	50% shade	open	50% shade	open	50% shade	open	50% shade	open
1	*Aechmea fasciata*	6.50	6.43	6.36	6.16	6.36	6.03	6.13	5.86	5.86	6.16	6.16	6.26	6.26	6.43
2	*Ananas bracteatus*	4.91	4.50	5.30	4.55	4.00	4.15	4.20	3.80	3.40	3.86	3.50	3.60	3.90	3.46
3	*Ananas nanus*	2.25	2.41	1.96	2.61	2.16	2.66	1.91	2.70	1.78	2.28	1.91	2.50	2.26	2.63
4	*Billbergia pyramidalis*	5.41	5.93	6.48	6.23	6.76	6.61	6.73	6.58	6.68	6.68	6.75	5.83	6.25	6.38
5	*Bromelia balansae*	3.25	3.20	4.35	4.76	4.30	3.00	4.00	3.16	4.33	3.43	3.68	2.66	3.63	3.03
6	*Cryptanthus zonatus*	3.50	3.00	3.15	3.00	2.90	2.85	-	-	-	-	-	-	-	-
7	*Dyckia brevifolia*	2.56	2.13	2.15	2.15	2.26	2.18	2.06	2.05	2.15	2.01	2.03	2.06	2.03	2.16
8	*Pitcarnea flammea*	1.60	1.48	1.17	1.43	1.33	1.35	1.25	1.40	1.20	1.38	1.25	1.31	1.20	1.40
9	*Tillandsia stricta*	1.40	1.53	1.10	1.36	0.85	1.20	0.90	1.18	0.90	1.16	1.20	1.23	1.20	1.16
	CD (0.05)	6.798		0.9210		0.8195		0.4417		0.6306		0.7904		0.9134	

4.2.6 *Cryptanthus bivittatus*

Data on the evaluation of *Cryptanthus* species under 50 per cent and 75 per cent shade levels are given in Table 8 and Fig .6

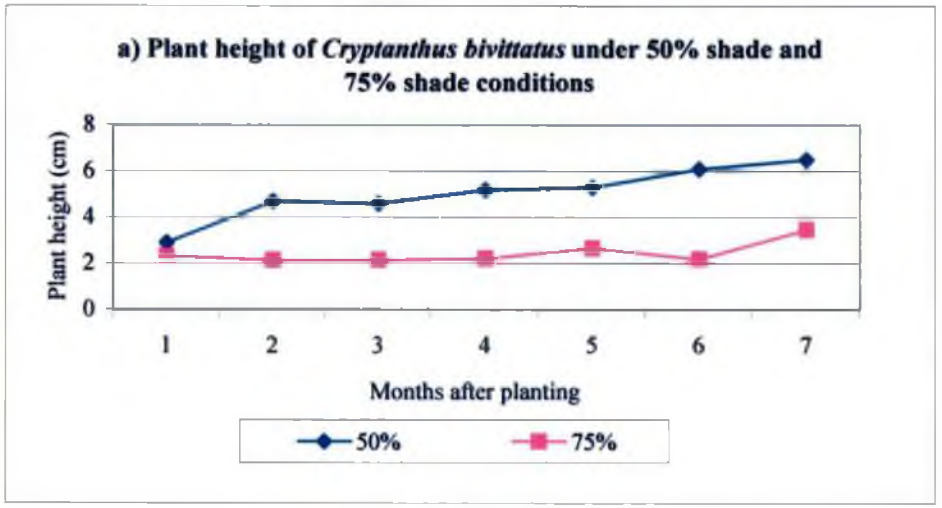
Cryptanthus bivittatus showed significant increase in height under 50 percent shade level during the 2nd(4.70 cm), 4th(5.18 cm) and 6th(6.10 cm) months after planting. In the case of spread there was significant increase under 50 per cent shade level during the 1st(54.86 cm), 4th(41.20 cm) and 7th(48.75 cm) months after planting. The number of leaves (Table 8) was significantly higher under 50 per cent shade level during the 2nd(13.00), 4th(14.83), 5th (16.83) and 6th(17.83) months after planting. Except for the 1st month, leaf length showed significant increase under 50 per cent shade level throughout the growth period and it was recorded maximum (28.68 cm) during the 3rd month. There was significant increase in the breadth of the leaf during the 2nd and 7th months after planting under 50 percent shade level and it was recorded maximum (3.55 cm) during the 2nd month. In the case of number of suckers during the initial period of growth there was significant increase under 50 per cent shade. From the 3rd to the 6th month, sucker production was significantly higher maximum being 4, under 75 per cent shade level. During the last month no significant difference was observed between the two shade levels.

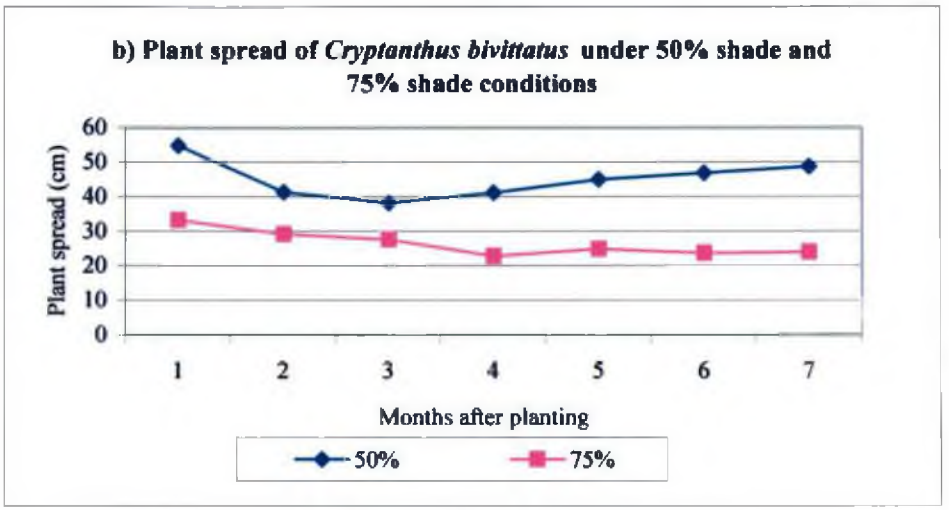
It can be concluded that all the plant characters like plant height, plant spread, number of leaves, leaf length and leaf breadth were significantly higher under 50 per cent shade than under 75 per cent shade. Number of suckers was significantly higher under both the shade levels (Plate 6a, b & c) during the different stages of growth.

4.2.7 *Cryptanthus bromelioides*

Height of the plant showed significantly higher values during the 6th and 7th months after planting under 50 per cent shade level. Under 50 per cent shade levels, spread of the plant showed significant increase during the 2nd, 4th, 6th and 7th months after planting, maximum being (70.41 cm) during the 7th month. Significant increase

Fig. 6. Plant characters of *Cryptanthus bivittatus* under 50% and 75% shade





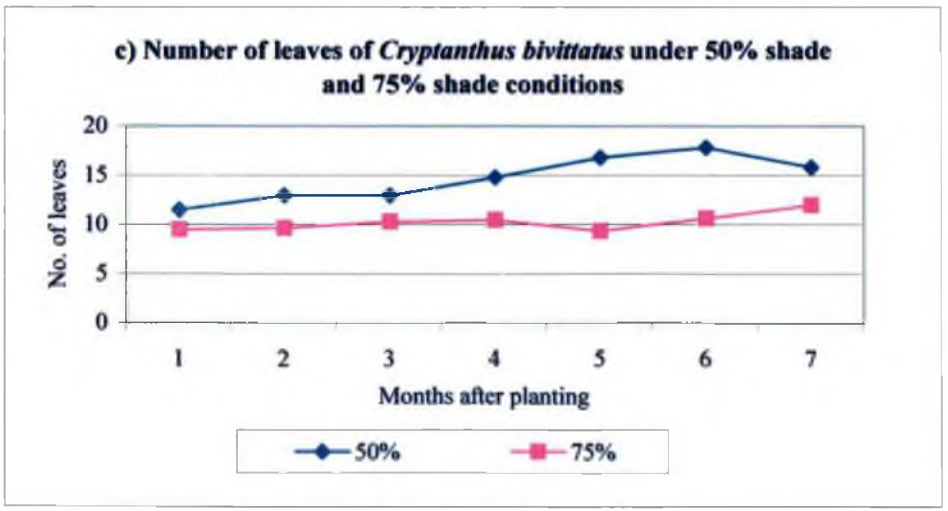
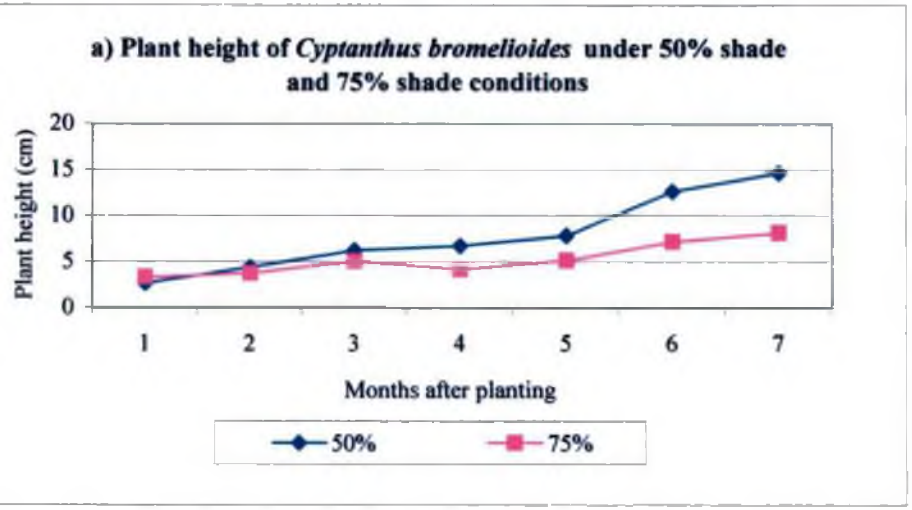
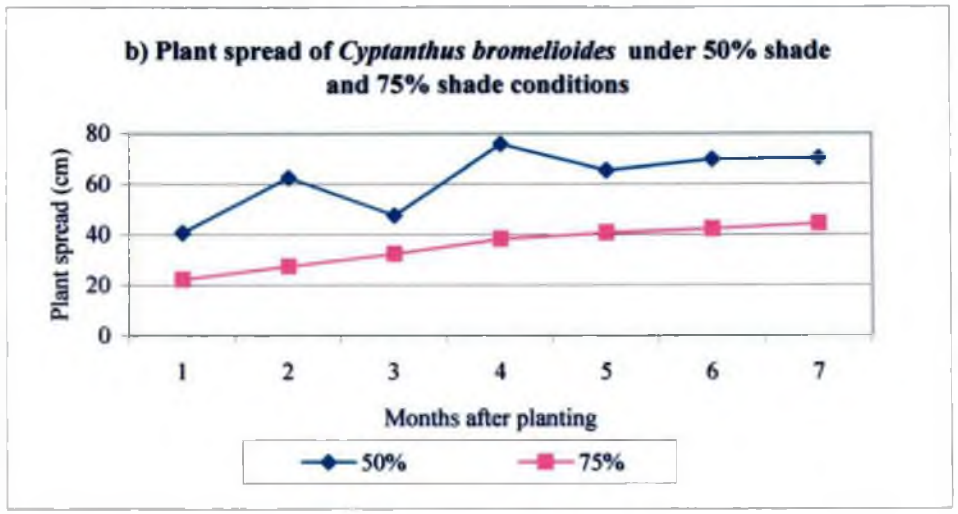
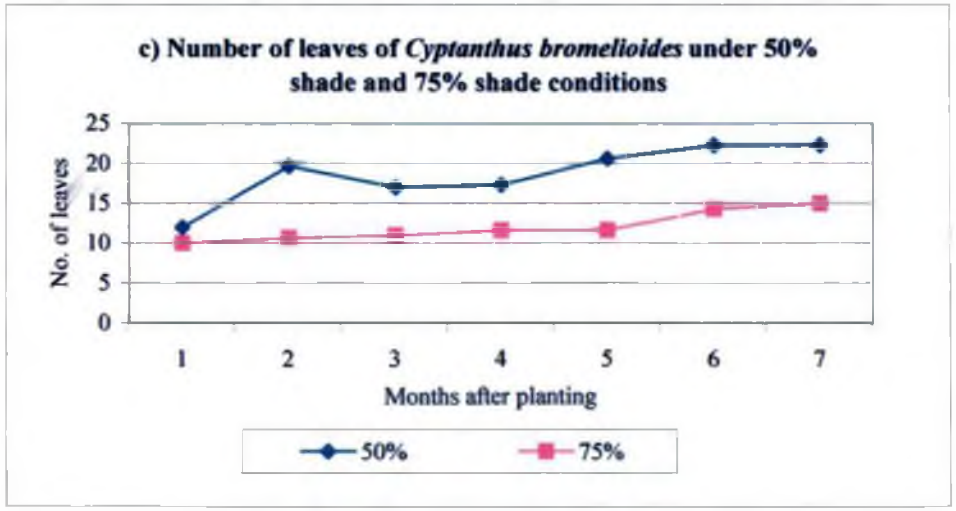


Fig. 7. Plant characters of *Cyptanthus bromelioides* under 50% and 75% shade







a) *Cryptanthus bivittatus* under 75% shade

b) *Cryptanthus bivittatus* under 50% shade

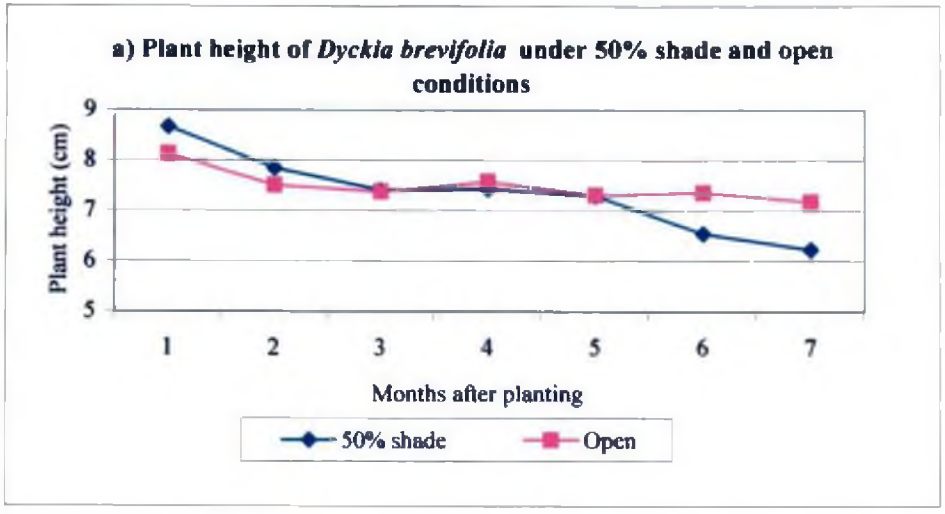
c) *Cryptanthus bivittatus* under open

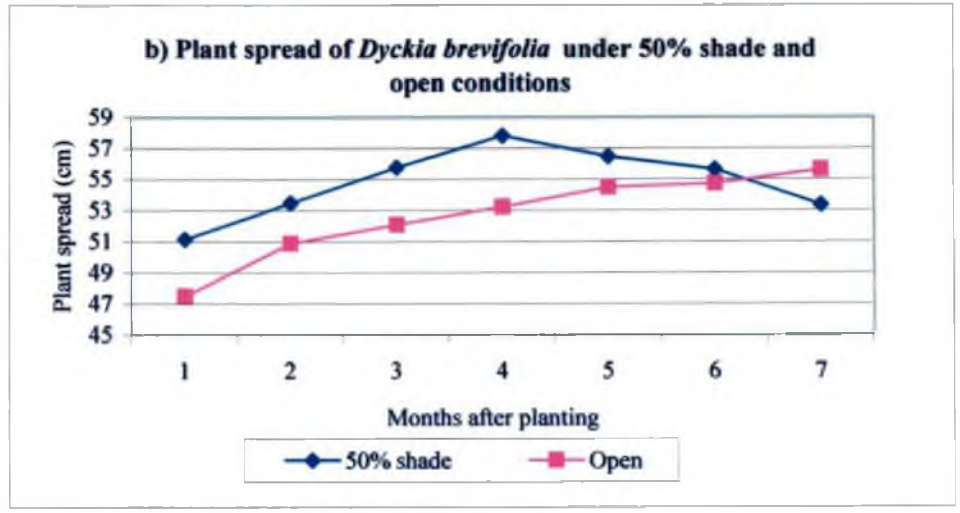
d) *Cryptanthus zonatus* under 50% shade

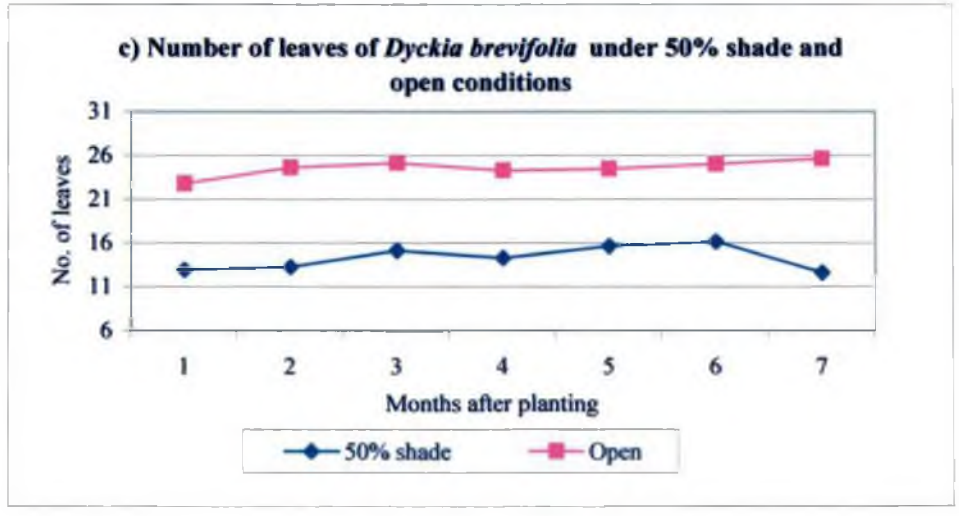
e) *Cryptanthus zonatus* under open

Plate 6. Performance of Bromeliads under different shade levels-III

Fig. 8. Plant characters of *Dyckia brevifolia* under 50% shade and open condition







in the number of leaves was observed from the 2nd to the 7th month after planting under 50 per cent shade level. Lengths of the leaf showed significant increase under 50 per cent shade level (24.00) during the 7th month. No significant difference was observed in the breadth of the leaves during the entire growth period between the two conditions. Significant increase in sucker production was observed under 75 per cent shade level up to the 5th month of planting and during the rest two months, no significant difference was observed. Maximum value recorded was 2.83 under 75 per cent shade level in the 7th month.

From the above results it can be concluded that only number of suckers produced showed significant increase under 75 per cent shade level. Other characters like spread of the plant, number of leaves and leaf length showed significant increase under 50 per cent shade level. Leaf breadth showed no significant difference between the two shade levels (Plate 7 a, b & c).

4.2.8 *Cryptanthus zonatus*

In *Cryptanthus zonatus* no significant difference was observed between open condition and 50 per cent shade level for any of the characters during the entire growth period observed. The plant dried out under both the condition three months after planting (Plate 6 d & e). The observations are presented in Tables 1-6.

4.2.9 *Dyckia brevifolia*

Plant characters observed like height (Table 1 and Fig. 8), spread (Table 2 and Fig 8), length (Table 4) and breadth of leaf (Table 5) showed no significant difference throughout the growth period between 50 per cent shade and open conditions. Number of leaves (Table 3 and Fig 8), showed a significant increase during the 1st (22.83), 2nd (24.66), 3rd (24.33), 4th (25.16), 5th (24.50), 6th(25.06), and 7th (25.66) months after planting under open condition. Number of suckers (Table 6) showed significant increase during the 1st, 3rd, 4th and 5th months after planting under open condition, maximum being 20.00 in the 7th month.

a) *Cryptanthus bromelioides* under 75% shade

b) *Cryptanthus bromelioides* under 50% shade

c) *Cryptanthus bromelioides* under open

d) *Dyckia brevifolia* under 50% shade

e) *Dyckia brevifolia* under open

Plate 7. Performance of Bromeliads under different shade levels-IV

The observations on the floral characters are presented in Table 7.The number of days taken for flowering was higher under open condition (183.40 days) than under 50 per cent shade (179.20 days). The length of the peduncle was higher under open condition (1.94 cm) than under 50 per cent shade level (1.78 cm). Length of the inflorescence was higher under 50 per cent shade level (6.62 cm) and lower under open condition (5.10 cm). Number of flowers produced was more under open (22.20) compared to 50 per cent shade (17.60). The number of bracts produced per inflorescence was higher (6.60) under open condition and lower under 50 per cent shade level (4.40). The longevity of the inflorescence was higher under open condition (67.40 days) and lower under 50 per cent shade level (62.40 days). The longevity of flower was higher under open condition (4.0 days) and lower under 50 per cent shade level (2.6 days).

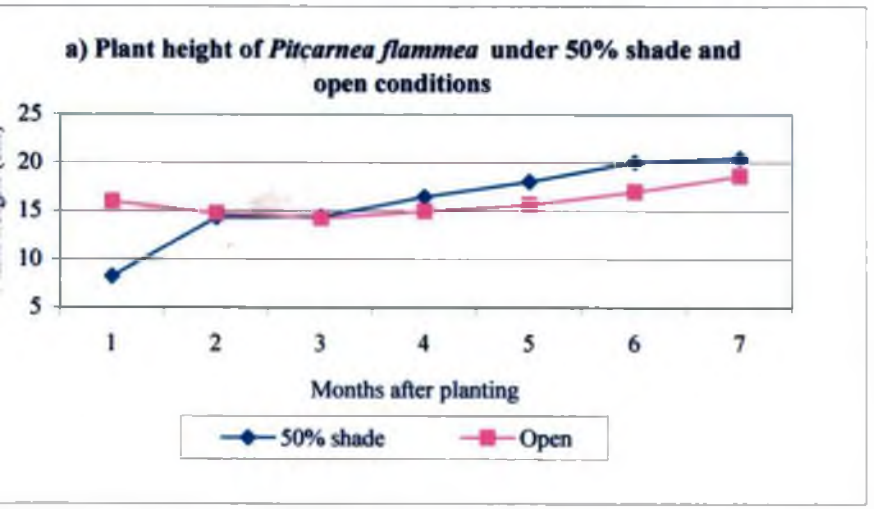
About the vegetative characters it can be concluded that only the number of suckers and number of leaves produced per plant showed significant increase under open condition. Other plant characters showed no significant difference between the two shade levels (Plate 7 c and d).

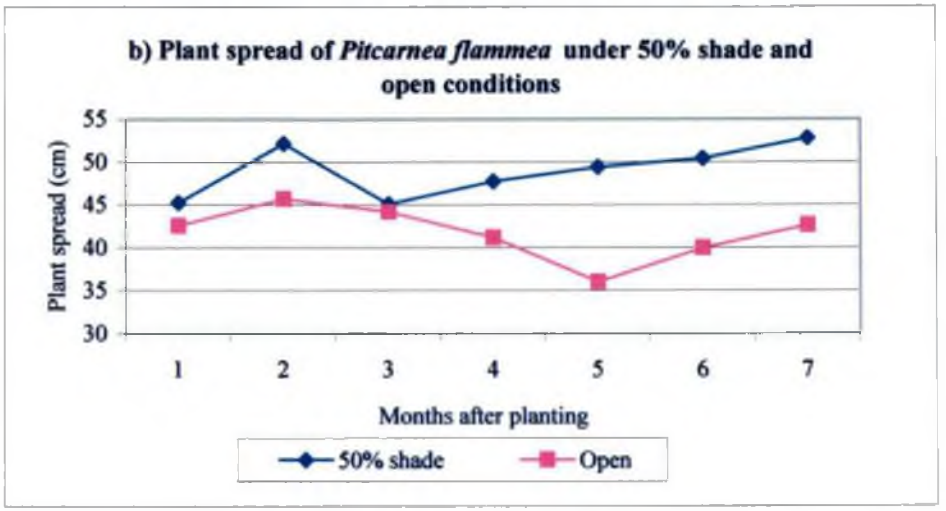
About the floral characters it can be concluded that early flowering was observed under 50 per cent shade level. Other characters like length of the inflorescence, length of the peduncle, number of flowers, number of bracts, longevity of inflorescence and the flower were higher under open condition.

4.2.10 *Pitcarnea flammea*

Plant height (Table 1 and Fig. 9) was significantly higher under the open condition (16.00 cm) only during the 1st month after planting. There was significant increase in spread of the plant (Table 2 and Fig. 9) under 50 per cent shade level during the 5th (50.42 cm) and 7th (52.83 cm) months after planting. Leaf number (Table 3 and Fig. 9) showed a significant increase under 50 per cent shade level during the 1st (45.50 cm), 6th (57.50) and 7th (57.66) months after planting. Length (Table 4) and breadth (Table 5) showed no significant difference throughout the growth period

Fig. 9. Plant characters of *Pitcarnea flammea* under 50% shade and open condition





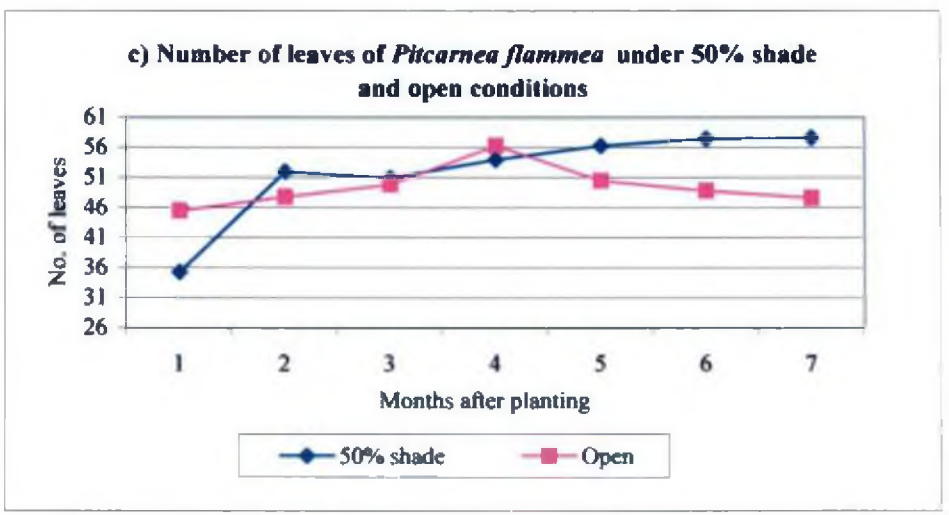
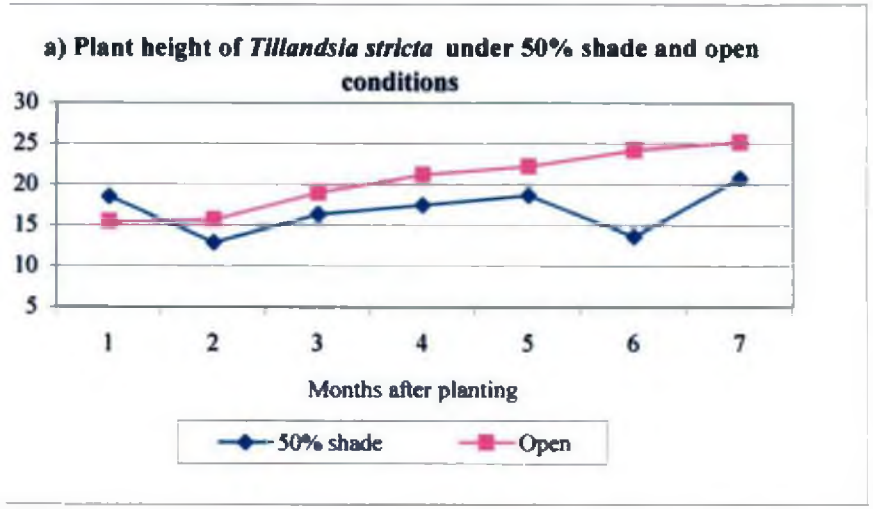
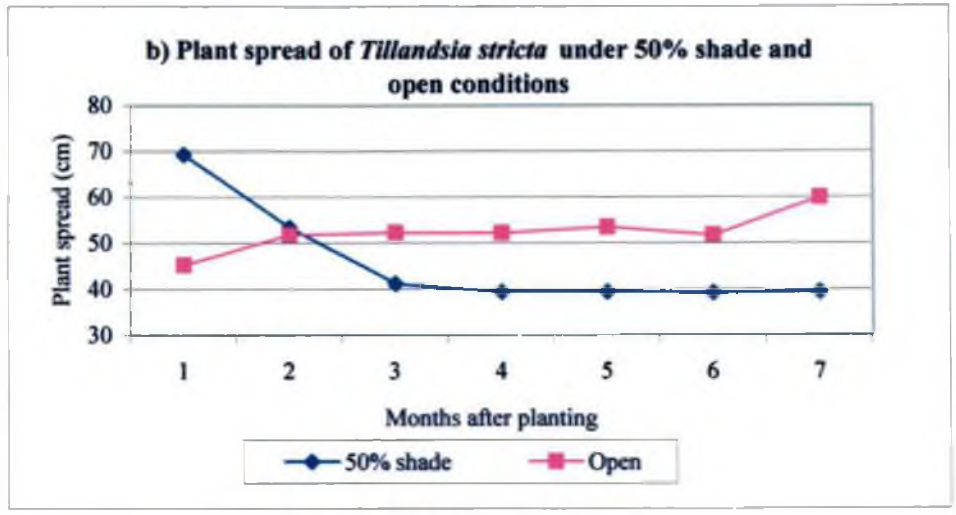


Fig. 10. Plant characters of *Tillandsia stricta* under 50% shade and open condition





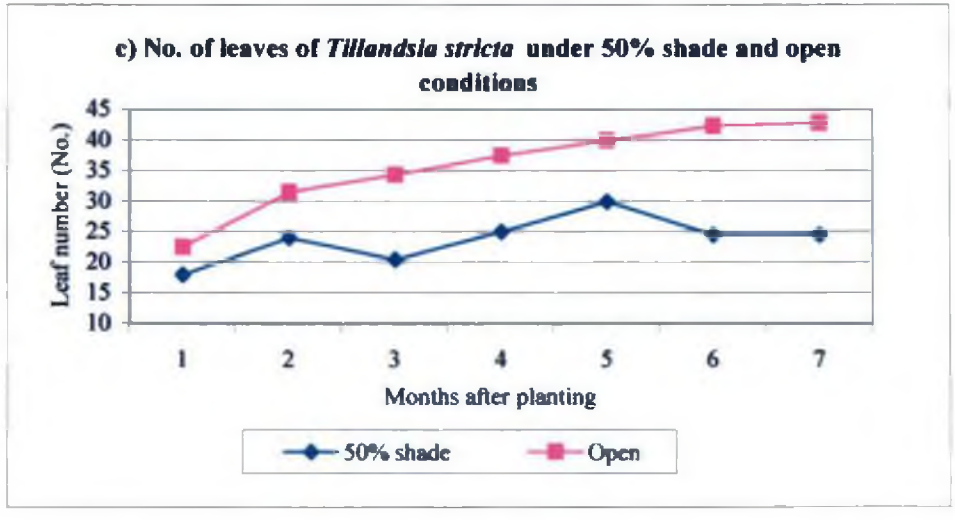


Table 6. Number of suckers of Bromeliads under 50 per cent shade and open condition

Sl. No.	Species observed	Number of suckers*													
		1st month		2nd month		3rd month		4th month		5th month		6th month		7th month	
		50% shade	open	50% shade	open	50% shade	open	50% shade	open	50% shade	open	50% shade	open	50% shade	open
1	*Aechmea fasciata*	0.66 (1.05)	1.33 (1.34)	1.66 (1.46)	2.00 (1.58)	1.66 (1.46)	2.00 (1.58)	2.33 (1.67)	2.00 (1.58)	2.66 (1.76)	2.00 (1.17)	2.66 (1.76)	2.00 (1.58)	2.66 (1.76)	2.00 (1.58)
2	*Ananas nanus*	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.33 (0.88)	0.33 (0.88)	0.33 (0.88)	0.33 (0.88)
3	*Ananas bracteatus*	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
4	*Billbergia pyramidalis*	0.66 (1.00)	0.00 (0.71)	0.16 (0.80)	0.00 (0.71)	1.16 (0.80)	0.83 (1.11)	0.66 (1.04)	0.83 (1.11)	1.00 (1.17)	1.00 (1.17)	1.00 (1.17)	1.00 (1.17)	0.00 (0.71)	1.00 (1.17)
5	*Bromelia balansae*	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
6	*Cryptanthus zonatus*	1.00 (1.22)	1.00 (1.22)	1.00 (1.22)	1.00 (1.22)	1.00 (1.22)	1.00 (1.22)	1.00 (1.22)	1.00 (1.22)	1.00 (1.22)	1.00 (1.22)	1.00 (1.22)	1.00 (1.22)	1.00 (1.22)	1.00 (1.22)
7	*Dyckia brevifolia*	6.83 (2.70)	5.00 (2.32)	8.66 (3.02)	9.16 (3.10)	9.33 (3.12)	12.33 (3.58)	10.66 (3.33)	14.16 (3.83)	12.50 (3.60)	17.50 (4.24)	16.00 (4.06)	18.83 (4.39)	18.50 (4.35)	20.00 (4.52)
8	*Pitcarnea flammea*	4.00 (2.08)	0.00 (0.71)	6.00 (2.53)	2.66 (0.77)	6.50 (2.64)	3.33 (1.94)	7.83 (2.58)	4.00 (2.08)	9.50 (3.15)	4.00 (2.11)	11.16 (3.40)	4.00 (2.11)	12.33 (3.58)	4.00 (2.11)
9	*Tillandsia stricta*	1.00 (1.22)	1.00 (1.22)	1.00 (1.22)	1.00 (1.22)	1.00 (1.58)	1.00 (2.33)	1.00 (1.58)	1.00 (2.60)	1.00 (1.72)	1.00 (2.93)	1.00 (1.72)	1.00 (3.14)	1.00 (1.87)	3.34
	CD (0.05)	0.348		0.2420		0.2876		0.3257		0.2970		.3857		.3551	

Value in parenthesis are square root transformed values

Table 7. Flower characters of Bromeliads under 50 per cent shade and open condition

Sl. No	Species	Days to flower		Length of peduncle (cm)		Length of inflorescence (cm)		Number of flowers		Number of bracts		Longevity of inflorescence (days)		Longevity of flower (days)	
		50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open
1	*Ananas nanus*	173.80	152.00	31.80	24.30	38.60	28.90	23.80	32.80	39.80 (6.34)	38.80 (6.26)	55.80	67.60	2.0	2.6
2	*Dyckia brevifolia*	179.20	183.40	1.78	1.94	6.62	5.10	17.60	22.20	4.40 (2.21)	6.60 (2.65)	62.40	67.40	2.6	4.0
3	*Pitcarnea flammea*	216.00	135.60	6.80	8.60	25.00	28.10	21.00	35.80	0.00 (0.71)	0.00 (0.71)	7.80	9.40	4.0	6.4
	CD (0.05)	2.196		0.8006		1.352		1.961		0.1812		1.624		0.5194	

Values in parenthesis are square root transformed values

Table 8. Plant characters of *Cryptanthus sp.* under 50 % and 75 % shade condition

Species	1 MAP		2 MAP		3 MAP		4 MAP		5 MAP		6 MAP		7 MAP	
	50%	75%	50%	75%	50%	75%	50%	75%	50%	75%	50%	75%	50%	75%
Height(cm)														
Cryplanthus bivittatus	2.90	2.33	4.70	2.15	4.60	2.16	5.18	2.21	5.30	2.66	6.10	2.19	6.50	3.46
Cyptanthus bromelioides tricolor	2.66	3.33	4.40	3.73	6.26	5.10	6.76	4.16	7.83	5.16	12.66	7.16	14.66	8.16
CD (0.05)	4.05		1.46		3.02		2.79		4.29		5.05		5.07	
Spread(cm)														
Cryplanthus bivittatus	54.86	33.27	41.37	29.21	38.20	27.65	41.20	22.83	45.00	24.90	46.86	23.66	48.75	24.00
Cyptanthus bromelioides tricolor	40.75	22.21	62.58	27.50	47.60	32.43	75.91	38.28	65.50	40.83	69.83	42.33	70.41	44.33
CD (0.05)	19.95		14.98		31.44		15.94		11.32		13.62		13.66	
No. of leaves														
Cryplanthus bivittatus	11.50	9.50	13.00	9.66	13.00	10.33	14.83	10.50	16.83	9.33	17.83	10.66	15.83	12.00
Cyptanthus bromelioides tricolor	12.00	10.00	19.66	10.66	17.00	11.00	17.33	11.66	20.66	11.66	22.33	14.33	22.33	15.00
CD (0.05)	5.09		6.92		4.24		4.16		6.22		5.83		5.37	
Leaf length(cm)														
Cryplanthus bivittatus	25.33	22.25	27.13	19.16	28.68	16.43	25.00	14.75	24.31	15.41	25.05	15.50	21.58	15.00
Cyptanthus bromelioides tricolor	18.86	12.96	41.13	14.76	35.56	13.80	87.83	16.16	18.56	15.00	22.00	16.73	24.00	17.33
CD (0.05)	10.06		9.86		9.20		8.61		4.54		6.91		6.34	

Continued

Table 8. Continued

Species	1MAP		2 MAP		3 MAP		4 MAP		5 MAP		6 MAP		7 MAP	
	50%	75%	50%	75%	50%	75%	50%	75%	50%	75%	50%	75%	50%	75%
Leaf breadth(cm)														
Cryplanthus bivittatus	3.31	2.18	3.55	2.18	3.05	2.43	3.32	2.65	3.36	2.76	3.46	2.58	3.16	2.21
Cyptanthus bromelioides tricolor	3.53	2.63	3.10	2.66	2.96	2.53	3.20	2.96	3.00	3.00	3.00	3.50	2.23	3.76
	1.43		1.07		0.864		0.951		1.41		1.371		0.830	
Number of suckers														
Cryplanthus bivittatus	1.00 (1.22)	0.00 (0.71)	1.00 (1.22)	2.66 (1.77)	1.00 (1.22)	3.33 (1.94)	1.33 (1.34)	4.00 (2.11)	1.66 (1.40)	4.00 (2.11)	1.66 (1.46)	4.00 (2.11)	2.33 (1.67)	4.00 (2.11)
Cyptanthus bromelioides tricolor	0.00 (0.71)	0.83 (1.09)	0.00 (0.71)	1.33 (1.34)	0.167 (0.807)	2.33 (1.68)	0.16 (0.307)	2.16 (1.607)	1.00 (1.22)	2.16 (1.60)	1.33 (1.34)	2.33 (1.65)	1.66 (1.46)	2.83 (1.78)
	0.36		0.61		0.297		0.53		0.380		0.447		0.494	

Value in parenthesis are square root transformed values

a) *Pitcarnea flammea* under 50% shade

b) *Pitcarnea flammea* under open

c) *Tillandsia stricta* under 50% shade

d) *Tillandsia stricta* under open

Plate 8. Performance of Bromeliads under different shade levels-V

observed between the two conditions. Number of suckers (Table 6) was found to be significantly higher under 50 per cent shade level throughout the growth period, maximum recorded being 12.33.

Observations on the floral characters are presented in Table 7. Flowering was observed earlier under open condition (135.60 days) than under 50 per cent shade (216 days). Length of the peduncle was higher under open condition (8.60 cm) than under 50 per cent shade level (6.80 cm). Length of inflorescence was higher under open condition (28.10 cm) and lower under 50 per cent shade level (25.00 cm). No bracts were formed under both the growing condition. Number of flowers formed was higher under open condition (35.80) and lower under 50 per cent shade level (21.00). Longevity of the inflorescence was higher under open condition (9.40 days) and lower under 50 per cent shade (7.80 days). Longevity of flower was higher under open condition (6.4 days) and lower under 50 per cent shade level (4 days).

About the vegetative characters it can be concluded that only plant height showed significant increase under open condition compared to 50 per cent shade level. Other characters like leaf number, number of suckers and spread showed significant increase under 50 per cent shade level. Other characters like leaf length and leaf breadth showed no significant difference between the two conditions (Plate 8 a and b).

About the floral characters it can be concluded that flowering was earlier under open condition. All the flower characters were better under open condition .

4.2.11 *Tillandsia stricta*

Plant height (Table 1 and Fig .10) was significantly higher under open condition only during the 6^{th} month after planting, maximum value being 25.23 cm during the 7^{th} month. Table 2 and Fig .10 show the spread of the plant, which was significantly higher during the 1^{st}after planting under 50 per cent shade (69.33 cm). It was also significantly higher during the 4^{th} (52.30 cm), 5^{th} (53.56 cm), 6^{th} (51.81 cm)

and 7th (59.98 cm) months after planting under open condition. The number of leaves (Table 3 and Fig 10) showed significant increase from the 3rd month to the 7th month, maximum being 42.83 in the 7th month under open condition. There was significant increase in length of the leaves (Table 4) under open condition during the 2nd, 3rd and 4th months and maximum being 33.40 cm in the 4th month. Breadth of leaf (Table 5) showed no significant difference between the growing conditions. Sucker production (Table 6) was significantly higher under open condition, maximum recorded being 10.

It can be concluded from the above observations that plant height, plant spread, number of leaves, leaf length and number of suckers were significantly higher under open condition. Leaf breadth showed no significant difference between the two conditions (Plate 8 c and d).

4.3 Performance of Bromeliads in different growing media

4.3.1 *Billbergia pyramidalis*

Data on the performance evaluation of *Billbergia pyramidalis* in different growing media like tile bits (M_1), equal proportion of sand + vermicompost + cocopeat (M_2), equal proportion of coarse sand + sand + vermicompost + cocopeat (M_3) and coconut husk (M_4) for five consecutive months are presented in Table 9 (Plate 9 a, b, c & d).

4.3.1.1 Plant height

The height of the plant differed significantly among the media. The highest height (19.91 cm) was recorded in the medium containing 1:1:1 sand + vermicompost + cocopeat (M_2). The least height was recorded in the medium containing coconut husk (M_4) which was 7.50 cm.

4.3.1.2 Plant spread

During the first three months of growth, the spread of the plant in the media containing tile bits (M_1) and 1:1:1 sand + vermicompost + cocopeat (M_2) was

Table 9. Plant characters of *Billbergia pyramidalis* in different media

Media	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP
Height (cm)					
M_1	12.33	14.33	14.91	14.50	14.83
M_2	16.16	18.76	18.50	19.91	14.21
M_3	13.66	15.16	16.16	17.30	19.08
M_4	4.66	5.61	6.16	7.16	7.50
CD (0.05)	2.92	3.86	3.58	2.89	2.91
Spread (cm)					
M_1	34.87	36.58	38.51	35.08	36.16
M_2	35.58	34.16	33.50	32.75	38.00
M_3	29.63	30.63	30.83	37.33	38.41
M_4	22.45	21.33	21.00	23.33	23.41
CD (0.05)	12.17	12.16	12.16	12.65	10.74
Number of leaves					
M_1	15.16	16.66	18.16	16.83	18.33
M_2	16.16	17.50	19.33	18.33	16.66
M_3	15.66	17.16	18.00	20.33	21.50
M_4	6.00	6.50	7.33	8.66	9.66
CD (0.05)	2.55	2.81	3.24	2.88	3.14
Leaf length (cm)					
M_1	18.76	19.08	19.75	18.91	19.83
M_2	20.58	22.05	23.00	22.33	27.25
M_3	21.00	21.75	22.41	36.16	27.16
M_4	33.83	34.80	36.03	32.66	34.91
CD (0.05)	15.43	15.72	15.90	10.90	9.94
Leaf breadth (cm)					
M_1	5.96	6.10	6.23	6.43	6.73
M_2	6.76	6.73	6.68	6.75	6.25
M_3	7.13	6.90	6.95	6.60	6.08
M_4	3.10	3.33	3.43	3.58	4.25
CD (0.05)	0.600	0.619	0.703	0.040	0.734
Number of suckers					
M_1	0.00 (0.71)	0.00 (0.71)	1.00 (1.17)	0.00 (0.71)	0.00 (0.71)
M_2	0.16 (0.80)	0.66 (1.04)	1.00 (1.17)	1.00 (1.17)	0.00 (0.71)
M_3	0.00 (0.71)	0.33 (0.88)	0.33 (0.88)	0.55 (0.97)	0.55 (0.97)
M_4	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
CD (0.05)	0.386	0.335	0.468	0.349	0.186

Values in parenthesis are square root transformed values

a) M_1 - Tilebits

b) M_2 - Sand + vermicompost + cocopeat

c) M_3 - Coarse sand + sand + vermicompost + cocopeat

d) M_4 - Coconut husk

Plate 9. Performance of *Billbergia pyramidalis* in different growing media

on par. In the later stages of growth, i.e. during the 4th and 5th month after planting, the growth was observed to be on par in tile bits (M_1), 1:1:1 sand + vermicompost + cocopeat (M_2) and 1:1:1:1 coarse sand + sand + vermicompost + cocopeat (M_3). The highest spread (38.41 cm) was recorded in medium containing 1:1:1:1 coarse sand + sand + vermicompost + cocopeat (M_3) in the 5th month of planting and the least spread (23.41 cm) in coconut husk (M_4).

4.3.1.3 Number of leaves

During the period of observation, the highest number of leaves (21.50) was recorded in the medium containing 1:1:1:1 coarse sand + sand + vermicompost + cocopeat (M_3). The number of leaves recorded in the medium containing tile bits (M_1), 1:1:1 sand + vermicompost + cocopeat (M_2) and equal proportion of 1:1:1:1 coarse sand + sand + vermicompost + coocopeat (M_3) were on par. The least number of leaves was recorded in the medium with coconut husk (M_4).

4.3.1.4 Leaf length

The leaf length of the plant showed no significant difference for the entire period of growth in different media.

4.3.1.5 Leaf breadth

For the first two months, the breadth of the leaf significantly differed among the media. It was the highest (6.73) in tile bits (M_1) and lowest in coconut husk. During the later stages of growth the breadth of the leaf in the four media were observed to be on par.

4.3.1.6 Number of Suckers

Number of suckers produced per plant in the four different media was observed to be on par in the first month after planting. In the 2nd, 4th and 5th months a significant increase in sucker production was observed in the medium containing 1:1:1 of sand + vermicompost + cocopeat (M_2) maximum being one in the 5th month after planting. The least number of suckers was obtained in coconut husk (M_4) for the entire period of observation.

It can be concluded that with respect to plant height and number of suckers produced medium containing 1:1:1 sand + vermicompost + cocopeat (M_2) is the best medium. Maximum spread and number of leaves was obtained in medium containing 1:1:1:1 coarse sand + sand + vermicompost + cocopeat (M_3). Maximum leaf breadth was obtained in tile bits (M_1).

4.3.2 *Pitcarnea flammea*

The performance evaluation of *Pitcaenea flammea* in three different media like sand + vermicompost + cocopeat (M_1) which was taken 1:1:1 ration, tile bits (M_2) and coconut husk (M_3) for five consecutive months are presented in Table 10 (Plate 10 a,b and c).

4.3.2.1 Plant height

The height of the plant was observed to be significantly different in all the three media with the highest (20.48 cm) in medium containing 1:1:1:1 sand + vermicompost + cocopeat (M_1) and the lowest (11.90 cm) in coconut husk (M_3), in the 5^{th} month after planting.

4.3.2.2 Plant spread

The spread of the plant was significantly different in all the three media. It was highest (51.66 cm) in tile bits (M_2) and lowest (41.75 cm) in coconut husk (M_3) during the first month after planting. During the 2^{nd} and 3^{rd} months after planting it was observed to be on par. During the later stages of growth i.e. during the 5^{th} month of observation, spread was highest (57.00 cm) in coconut husk (M_3) and lowest in tile bits (M_2).

4.3.2.3 Number of leaves

Number of leaves in the plant, was observed to be on par in the three media during the first month after planting. During the next four months of planting highest number of leaves (57.66) was recorded in medium containing 1:1:1:1 sand +

Table 10. Plant characters of *Pitcarnea flammea* in different media

Media	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP
Height (cm)					
M_1	14.41	16.50	18.03	20.08	20.48
M_2	11.75	12.16	14.00	14.00	14.26
M_3	9.83	8.83	9.50	11.26	11.90
CD (0.05)	3.42	2.29	1.48	3.21	3.52
Spread (cm)					
M_1	45.12	47.76	49.42	50.42	52.83
M_2	51.66	43.75	46.25	46.50	47.75
M_3	41.75	52.26	51.66	53.66	57.00
CD (0.05)	6.28	6.95	8.41	7.31	6.41
Number of leaves					
M_1	51.00	54.00	56.33	57.50	57.66
M_2	39.00	42.50	47.00	52.50	54.50
M_3	37.33	35.66	33.33	39.66	42.33
CD (0.05)	15.83	14.52	12.76	17.77	16.16
Leaf length (cm)					
M_1	19.93	17.42	16.69	16.08	13.50
M_2	18.50	16.50	15.50	17.00	17.25
M_3	18.88	21.86	23.50	21.33	21.00
CD (0.05)	2.12	2.25	2.75	4.11	4.74
Leaf breadth (cm)					
M_1	1.33	1.25	1.20	1.25	1.20
M_2	1.30	1.20	1.20	1.15	1.20
M_3	1.30	1.36	1.50	1.50	1.20
CD (0.05)	0.205	0.154	0.422	0.227	0.235
Number of suckers					
M_1	6.50 (2.64)	4.50 (2.88)	5.50 (3.15)	6.50 (3.40)	8.00 (3.58)
M_2	4.00 (2.08)	7.83 (2.18)	6.71 (2.37)	11.16 (2.58)	12.33 (2.88)
M_3	0.00 (0.71)	0.33 (0.88)	0.33 (0.88)	0.66 (1.00)	0.66 (1.00)
CD(0.05)	0.456	0.601	0.762	0.803	0.663

Values in parenthesis are square root transformed values

a) M_1 - Sand + vermicompost + cocopeat

b) M_2 - Tilebits

c) M_3 - Coconut husk

Plate 10. Performance of *Pitcarnea flammea* in different growing media

vermicompost + cocopeat (M_1) and least number (42.33) of leaves was recorded in coconut husk (M_3).

4.3.2.4 Leaf length

During the first month after planting the leaf length was observed to be on par in all the three media. During the next three months it was observed to be highest in coconut husk (M_3). Leaf length in medium containing 1:1:1 sand + vermicompost + cocopeat (M_1) and in tile bits (M_2) was observed to be on par for 2nd, 3rd and 4th months after planting. During the 5th month of planting it was recorded the highest (21.00 cm) in coconut husk (M_3) and lowest (13.50 cm) in medium containing 1:1:1 sand + vermicompot + cocopeat (M_1).

4.3.2.5 Leaf breadth

Leaf breadth of the plant was observed to be on par in all the three media during the first month after planting. During the next three months it was recorded the highest (1.50 cm) in coconut husk (M_3). In the 5th month of planting it was observed to be on par in all the three media.

4.3.2.6 Number of Suckers

Sucker production in the plant was significantly different in all the three media. It was recorded the highest (12.33) in medium containing 1:1:1:1 sand + vermicompost + cocopeat (M_2) and lowest in coconut husk (M_3) for the entire growth period observed.

From the above observations it can be concluded that parameters like plant height, number of leaves and sucker production were the highest in medium containing 1:1:1 sand + vermicompost + cocopeat (M_1). Other parameters like spread of the plant and leaf length and leaf breadth were the highest in coconut husk (M_3).

4.4 Effect of ethrel on flowering of Bromeliad species under different shade levels

4.4.1 Effect of ethrel on *Billbergia pyramidalis*

The results on the effect of ethrel on flowering of *Billbergia pyramidalis* under 50 per cent and 75per cent shade levels and open condition are presented in Table 11 (Plate 11 a and b).

The number of days taken for flowering after ethrel application was the least under open condition (2.71 days) followed by under 75 per cent shade (6.28 days) and the highest under 50 per cent shade level (15.57 days). The length of peduncle was observed highest under 75 per cent shade level (11.25 cm) followed by 50 per cent shade level (7.12 cm) and the least under open condition (1.21 cm). The length of inflorescence was recorded highest under 75 per cent shade level (19.35 cm) followed by under 50 per cent shade level (11.52 cm) and the least under open condition (1.90 cm). The number of flowers produced on the inflorescence was the highest under 50 per cent shade level (13.57) followed by open condition (7.14) and the least number of flowers under 75 per cent shade level. The number of bracts produced in the inflorescence was observed highest under 75 per cent shade level (10.28) followed by 50 per cent shade level (9.57) and least under open condition (2.00). The length of the bracts was observed to be the same (1.77) under 50 per cent and 75 per cent shade levels and least under open condition (0.286 cm). The longevity of inflorescence was highest under 75 per cent shade (11.57 days) followed by 50 per cent shade (8.71 days) and the least under open condition (1.57 days). The percentage of plants flowered was same (71.42%) under 50 and 75 per cent shade level and least under open condition (14.28%).

Effect of ethylene varied under different light intensities and the performance was best under 75 per cent shade level.

Table 11. Effect of ethrel on flowering of *Billbergia pyramidalis* under different shade levels

Sl.No.	Shade levels	Days to flower	Length of peduncle (cm)	Length of inflorescence (cm)	Number of flowers	Number of bracts	Length of bracts (cm)	Longevity of inflorescence (days)	% of flowering
1	50 %	15.57 (3.57)	7.12 (3.10)	11.52 (3.10)	13.57 (3.32)	9.57 (2.85)	1.77 (1.43)	8.71 (2.74)	71.42
2	75 %	6.28 (2.38)	11.25 (3.08)	19.35 (3.95)	3.85 (2.51)	10.28 (2.95)	1.77 (1.43)	11.57 (3.12)	71.42
3	Open	2.71 (1.24)	1.21 (1.03)	1.90 (1.13)	7.14 (1.35)	2.00 (1.15)	0.286 (0.83)	1.57 (1.00)	14.28
	CD (0.05)	2.04	1.70	2.31	2.16	1.87	0.62	1.82	

a) Inflorescence under shade

b) Inflorescence under open

c) Inflorescence of *Ananas bracteatus*

d) Plant of *Ananas bracteatus* after flowering

Plate 11. Effect of ethrel application on *Billbergia pyramidalis* and *Ananas bracteatus*

4.4.2 Effect of ethrel on *Tillandsia stricta*

Ethrel was also applied on *Tillandsia stricta* under open condition but no flowering was observed.

4.4.3 Effect of ethrel application on *Ananas* species

Ethrel was applied on two species of *Ananas* viz; *Ananas bracteatus* and *Ananas nanus* under open condition. *Ananas bracteatus* flowered 60 days after application (Plate 11 c and d) and none of the plants in *Ananas nanus* flowered.

4.5 Evaluation of Bromeliads under indoor conditions

Species of bromeliads like *Billbergia pyramidalis, Tillandsia stricta,* and *Pitcarnea flammea* were kept under indoor condition to study their suitability for interiorscapes. *Dieffenbachia amoena* and *Aglaonema commutatum* which are commonly used as indoor plants were used as control plants. The observations recorded are presented in Table 12.

In all the three species, the vegetative parameters observed like height and number of leaves were observed to be poor under indoor condition throughout the observation period of three months. In *Tillandsia stricta* 20 per cent necrosis of leaves was observed after 14 days of planting and in *Pitcarnea flammea* 20 per cent necrosis was observed 7 days after planting. In *Billbergia pyramidalis* necrosis symptoms were observed 47 days after panting. During the 3rd month of observation 75 per cent of the leaves of *Tillandsia stricta* and *Pitcarnea flammea* and 50 per cent leaves of *Billbergia pyramidalis* showed necrosis.

The control plants like *Aglaonema commutatum* and *Dieffenbachia amoena* showed steady increase in vegetative parameters like plant height, leaf length and number of leaves, though a slight reduction in breadth of leaves was observed. Leaf necrosis was not observed in the control plants during the entire period of study.

Table 12. Plant characters of Bromeliads under indoor condition

Name of the plant	Height (cm)	Spread (cm)	Number of leaves	Leaf length (cm)	Leaf breadth (cm)	Number of suckers	Remarks
Ist month							
Tillandsia stricta	13.50	41.75	21	24.00	0.10	12	Necrosis after 14 days
Pitcarnea flammea	15.00	46.30	66	24.50	1.80	2	Necrosis after 7 days
Billbergia pyramidalis	23.00	52.50	17	34.50	6.50	2	Good condition
Dieffenbachia amoena	16.00	62.00	3	37.00	17.20	0	Good condition
Aglaonema commutatum	18.00	43.75	12	24.20	6.30	2	Good condition
2nd month							
Tillandsia stricta	12.50	45.76	16	25.00	0.50	18	Leaf number reduced and sucker number increased
Pitcarnea flammea	15.00	48.75	46	20.30	0.80	6	Necrosis increased
Billbergia pyramidalis	18.00	48.00	20	34.50	2.00	2	Necrosis after 47 days
Dieffenbachia amoena	23.50	70.50	5	46.00	14.00	0	Good condition
Aglaonema commutatum	21.00	46.00	9	33.00	5.50	2	Good condition
3rd month							
Tillandsia stricta	10.00	54.00	14	27.00	0.30	18	75% of plant showed necrosis
Pitcarnea flammea	16.00	39.50	32	78.50	0.50	7	75% of plant showed necrosis
Billbergia pyramidalis	17.00	45.00	8	39.00	6.50	2	50% of plant showed necrosis
Dieffenbachia amoena	25.00	75.25	6	48.00	13.00	0	Good condition
Aglaonema commutatum	23.50	47.60	8	36.00	6.20	2	Good condition

4.6 Suitability of Bromeliads for landscapes

The suitability are presented in the Table 13a and visual scoring in Table 13b.

4.6.1 *Aechmea fasciata*

Plant height and number of leaves produced showed no significant difference between 50 per cent shade and open condition. But plant spread was significantly higher under open condition. Flowering was also observed earlier under open condition. But sun scorching was observed in the leaves of the plant during the summer months from January – February when the mean maximum temperature was 34.50-36°C and the average sunshine hours was between 8.2 and 9.2.The plant appeared more attractive with its scaly green leaves under 50 per cent shade level.

So *Aechmea fasciata* can be recommended for open condition if the temperature is less than 34.5°C, otherwise it is more suited for 50 per cent shade level.

4.6.2 *Ananas bracteatus*

Height of the plant was significantly higher under open condition, while the plant spread and number of leaves were significantly higher under 50 per cent shade. Plant appeared more attractive under 50 per cent shade with its variegated leaves. The pink bands on leaves were more prominent under open condition. It can tolerate temperature up to 36°C which was the highest recorded temperature during the period of investigation. So it can be recommended for open and 50 per cent shade level. Flowering was observed on application of ethrel, but the mother plant started drying and lost its attractiveness when the inflorescence dried. But new suckers were produced. So ethrel application can be recommended for the production of new suckers in this plant.

Table 13a. Suitability of Bromeliads for landscapes and interior scapes

Sl. No.	Name	Open	50% shade	75% shade	Indoor
1	*Aechmea fasciata*	X	√	-	-
2	*Ananas nanus*	√	x	-	-
3	*Ananas bracteatus*	√	√	-	-
4	*Billbergia pyramidalis*	x	√	√	√
5	*Bromelia balansae*	√	√		
6	*Cryptanthus zonatus*	x	√	-	-
7	*Cryptanthus bivittatus*	x	√	√	
8	*Cryptanthus bromelioides*	x	√	√	-
9	*Dyckia brevifolia*	√	√	-	-
10	*Pitcarnea flammea*	√	x	-	√
11	*Tillandsia stricta*	√	x	-	√

√ Suitable
x Not suitable
- Not evaluated

Table 13b. Visual scoring of Bromeliads

Sl. No.	Name	Characters (Score out of 10)							
		Colour and pigmentation of leaves		Symptoms of sun scroaching		Overall appearance		Total score	
		50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open
1	*Aechmea fasciata*	7.0	5.0	10.0	2.0	9.0	5.0	26.0	12.0
2	*Ananas nanus*	8.0	8.0	10.0	10.0	3.0	8.0	21.0	26.0
3	*Ananas bracteatus*	7.0	8.0	10.0	10.0	7.0	9.0	25.0	27.0
4	*Billbergia pyramidalis*	8.0	5.0	10.0	5.0	9.0	6.0	27.0	16.0
5	*Bromelia balansae*	9.0	9.0	10.0	10.0	7.0	7.0	26.0	26.0
6	*Cryptanthus zonatus*	4.0	3.0	2.0	0.0	2.0	0.0	8.0	3.0
7	*Cryptanthus bivittatus*	7.0	2.0	10.0	1.0	9.0	1.0	26.0	4.0
8	*Cryptanthus bromelioides*	7.0	2.0	10.0	1.0	9.0	1.0	26.0	4.0
9	*Dyckia brevifolia*	9.0	9.0	10.0	10.0	9.0	9.0	28.0	28.0
10	*Pitcarnea flammea*	7.0	9.0	10.0	9.0	4.0	8.0	21.0	26.0
11	*Tillandsia stricta*	6.0	9.0	10.0	10.0	5.0	10.0	21.0	29.0

4.6.3 *Ananas nanus*

Height of the plant, spread and number of leaves showed no significant difference between the two shade levels. Flowering was observed earlier under open condition and flower characters like number of flowers, flower longevity and inflorescence longevity were observed significantly higher under open condition. Other flower characters like length of the peduncle and length of the inflorescence were observed higher under 50 per cent shade level which resulted in lanky inflorescence that could not stand erect on the plant. It can also tolerate the maximum temperature recorded up to 36°C. So it can be recommended for open condition.

4.6.4 *Billbergia pyramidalis*

Plant height and spread were significantly higher under open condition while the number of leaves showed no significant difference between the two growing condition. The apple green colour of the leaves and the inflorescence appeared more attractive under 50 per cent and 75 per cent shade level than under open condition. Even though the plant flowered earlier under open condition on ethrel application, the floral characters like size of the peduncle, length of the inflorescence, number of bracts produced and percentage of flowering were observed significantly higher under 50 per cent and 75 per cent shade level than under open condition. Under indoor condition necrosis of the leaf was observed only after 47 days. The leaves showed sun scorching under open condition during the peak summer months when the temperature was between 34.5°-36°C.

So *Billbergia pyramidalis* is more suited under 50 per cent and 75 per cent shade level. It can also be used as an indoor plant for 47 days.

4.6.5 *Bromelia balansae*

Height of the plant was observed significantly higher under open condition while other characters like spread and number of leaves showed no significant difference between the two growing conditions. The plant appeared similar in

appearance under both the condition even though there was an increase in height under open condition. So it can be recommended for 50 per cent shade and open condition.

4.6.6 *Cryptanthus bivittatus*

The plant showed sun scorching under open condition during the month of December when the mean maximum temperature was 31.5°C and average sunshine hours was 6.5 hrs. So it cannot be recommended for open condition. Height of the plant, spread and number of leaves were significantly higher under 50 per cent shade than under 75 per cent shade level. The colour of the leaves appeared similar under both the shade levels. So it can be recommended for both 50 per cent and 75 per cent shade levels.

4.6.7 *Cryptanthus bromelioides*

The plant showed sun scorching under open condition during the month of December when the mean maximum temperature was 31.5°C and average sunshine hours was 6.5 hrs. So it cannot be recommended for open condition. Height of the plant, spread and number of leaves were significantly higher under 50 per cent shade than under 75 per cent shade level. The colour of the leaves appeared similar under both the shade levels. So it can be recommended under both 50 per cent and 75 per cent shade levels.

4.6.8 *Cryptanthus zonatus*

The plant showed sun scorching under open and 50 per cent shade levels during the month of March when the mean maximum temperature recorded was 36°C. But the mother plant produced new suckers and flowered under 50 per cent shade on the commencement of rain when the mean maximum temperature recorded was 30.5°C and maximum rainfall recorded was 1131.9 mm. So *Cryptanthus zonatus* can be recommended for 50 per cent shade .

4.6.9 *Dyckia brevifolia*

Plant height and spread showed no significant difference between the shade and open, while the number of leaves produced was significantly higher under open condition. Flowering was observed earlier under open condition. Other flower characters like length of the peduncle, number of leaves, number of bracts, longevity of the inflorescence and number of flowers were significantly higher under open condition than under 50 per cent shade. The leaves are the attractive part of the plant than the flowers. Leaves develop less colour under shade. Plant height and spread were similar under both the conditions. So *Dyckia brevifolia* can be recommended for 50 per cent shade and open condition.

4.6.10 *Pitcarnea flammea*

Plant height was significantly higher under open condition. The leaf number and spread were significantly higher under 50 per cent shade. The colour of the leaves appeared similar under both the shade levels.

With respect to flowering, early flowering was observed under open condition. Other flower characters like length of the inflorescence, number of flowers, longevity of the inflorescence and flower longevity were significantly higher under open condition. This plant can also be used for indoors since necrosis appeared only after 7 days.

So *Pitcarnea flammea* can be recommended under open and 50 per cent shade conditions. This can also be used as an indoor plant, which keeps well for 7 days.

4.6.11 *Tillandsia stricta*

Plant height, spread and number of leaves were significantly higher under open condition. The colour of the leaves with yellow and green bands was more

prominent under open condition. Flowering was also recorded under open condition during the month of July on the commencement of rain, when the mean maximum temperature recorded was 30.4°C, average sunshine hours 0.71 only and maximum rainfall 1131.9 mm. It can also be used under indoor condition since necrotic symptoms appeared only after 14 days.

So *Tillandsia stricta* can be recommended for open condition. This can also be used as an indoor plant, which may need replacement after a fortnight.

4.7 ORNAMENTAL BANANAS

4.7.1 Performance evaluation of ornamental bananas under different shade levels in pot

Ornamental bananas like *Musa ornata, Musa laterita, Musa coccinea, Musa rosea Musa rubra* and *Ensete ventricosum* were planted in pots for evaluation under 50 per cent shade and in the open . *Musa rosea* and *Musa rubra* dried out in the second month itself after planting under both the conditions. *Musa coccinea* survived only under 50 per cent shade but with poor growth. *Musa ornata, Musa laterita* and *Ensete ventricosum* with good growth were subjected to detailed evaluation.

The results of the performance evaluation of ornamental bananas under different shade levels in pot are presented in Table 14 and Fig. 11-13 (Plate 12).

4.7.1.1 Musa ornata

Height of the plant showed a significant increase of upto 63.00 cm under 50 per cent shade level. Girth and number of leaves showed no significant difference between the shade levels during the entire period observed. Leaf length was significantly higher under open condition and the highest value recorded was 82.90 cm. For leaf breadth, significantly higher value was obtained during the 3rd month under open condition. Leaf area showed no significant increase during the first two months but it was observed to be higher under open condition during the 3rd and 4th month after planting. Petiole length of the plant was significantly higher during the 2nd and 3rd month after planting under open condition maximum being, 19.50 cm. There

Plate 12. Performance of Ornamental banana under shade showing lanky growth, reduced leaf size and less robust appearance

was no sucker production during the first two months. During the 3rd and 4th months after planting, suckers were produced and the number showed no significant difference between the two shade levels.

4.7.1.2 Musa laterita

Height of the plant was significantly higher under 50 per cent shade level (35.00 cm). Girth of the plant was found significantly higher under open condition for the first two months, maximum value being (8.84 cm). The number of leaves produced per plant was recorded highest under open condition only during the 3rd month of planting. Leaf length of the plant was recorded significantly higher from the second month onwards under open condition. Leaf breadth and leaf area was significantly higher from 3rd month onwards under open condition. Petiole length was recorded significantly higher from the 2nd month onward under open condition. There was no sucker production during the first two months. During 3rd and 4th months after planting suckers were produced and it showed no significant difference between the two growing conditions.

4.7.1.3 Ensete ventricosum

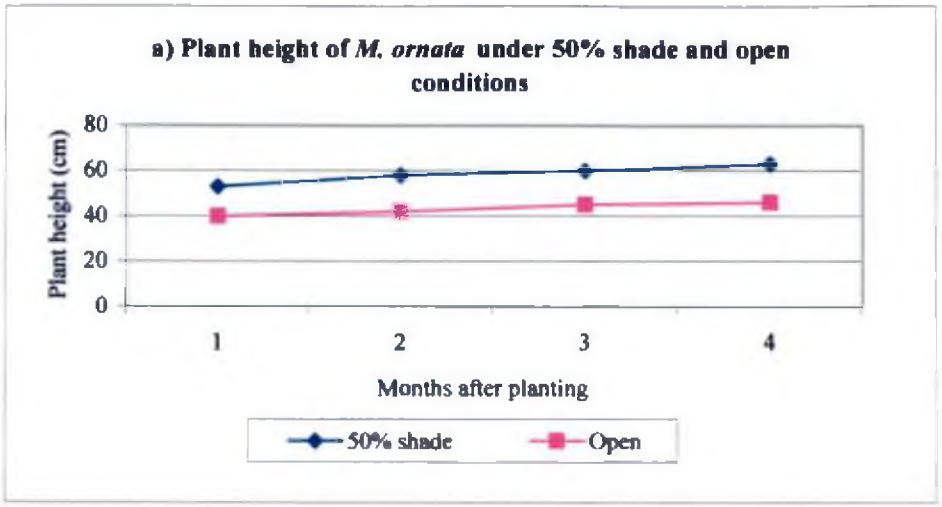
Height of the plant was significantly higher under 50 per cent shade condition, the maximum being 28.00 cm during the 5th month after planting. Girth of the plant was also significantly higher and was recorded highest (29.70 cm) under open condition. The number of leaves produced in the plant was significantly higher during the 2nd, 3rd and 4th months after planting under open condition. Leaf length (68.40 cm) and petiole length (44.10 cm) were significantly higher throughout the period observed. Leaf length was significantly higher under open condition and petiole length under 50 per cent shade level. Except in the 2nd month, leaf breadth of the plant was found significantly higher throughout the growth period under open condition. Leaf area was observed significantly higher under open condition from 2nd to the 4th month. No suckers were produced during the entire growth period.

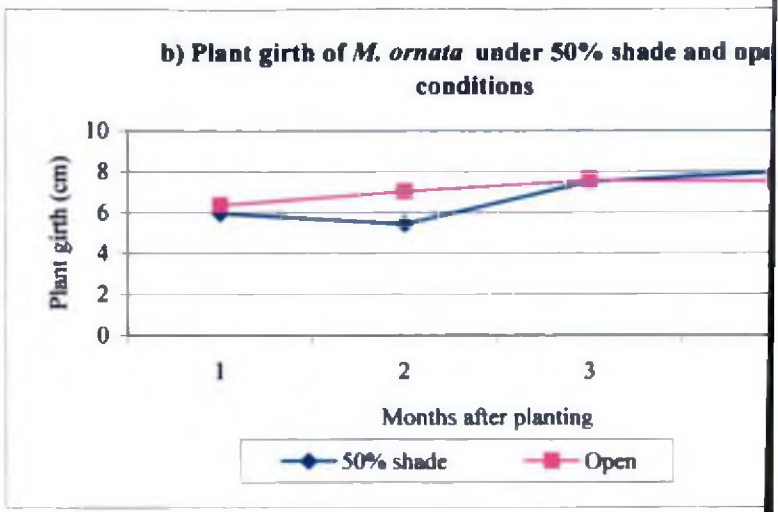
Table 14. Plant characters of ornamental bananas under 50% shade and open condition in pot

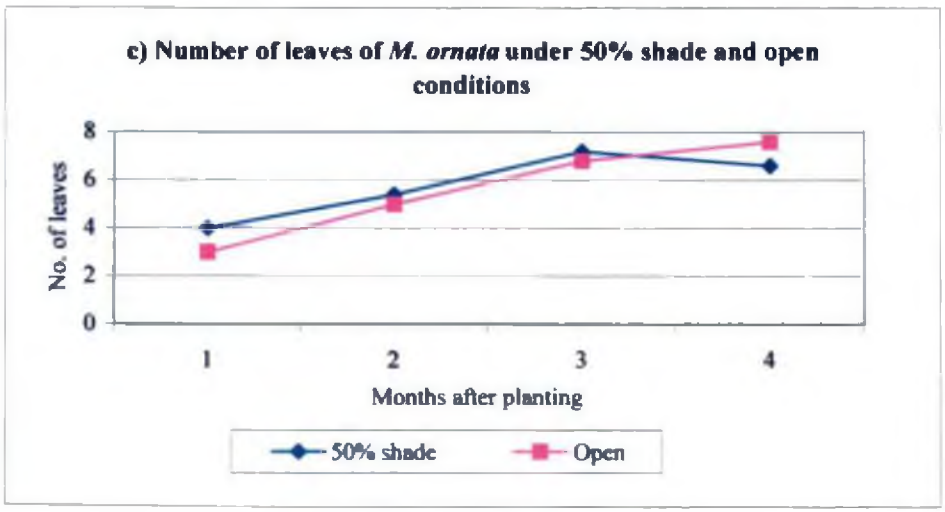
Species	1 MAP		2 MAP		3 MAP		4 MAP	
	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open
Height (cm)								
M. ornata	53	40	58	42	60	45	63	46
M. laterita	26	17	39	20	32	24	35	25
Ensete ventricosum	15	8	20	16	24	23	28	29
CD (0.05)	4.43		8.01		4.58		4.55	
Girth (cm)								
M. ornata	5.96	6.38	5.44	7.04	7.53	7.59	7.97	7.53
M. laterita	6.70	8.32	7.35	8.84	7.98	7.44	8.84	7.58
Ensete ventricosum	6.50	17.10	12.75	21.35	18.20	25.40	22.50	29.70
CD (0.05)	2.084		1.566		2.052		1.567	
Number of leaves								
M. ornata	4.00	3.00	5.40	5.00	7.20	6.80	6.60	7.59
M. laterita	5.00	3.80	5.60	5.40	7.20	10.00	7.40	7.44
Ensete ventricosum	3.40	6.40	6.00	7.60	9.00	8.80	10.00	25.40
CD (0.05)	2.084		1.566		2.052		1.567	
Leaf length (cm)								
M. ornata	35.40	48.50	41.12	51.10	49.90	67.20	48.64	82.90
M. laterita	41.90	50.00	45.30	52.65	42.50	59.30	44.90	69.04
Ensete ventricosum	5.08	49.60	15.15	57.00	20.00	61.60	24.90	68.40
CD (0.05)	8.99		7.71		8.11		7.22	
Leaf breadth (cm)								
M. ornata	10.10	9.77	11.80	10.85	14.00	17.57	15.10	16.50
M. laterita	14.26	16.00	14.90	16.44	14.33	17.70	14.60	19.17
Ensete ventricosum	10.84	17.70	14.30	18.35	15.00	21.10	16.60	23.90
CD (0.05)	3.83		3.19		2.98		2.898	
Leaf area (cm2)								
M. ornata	312.32	394.21	403.48	460.86	580.48	954.14	600.84	1102.12
M. laterita	482.37	639.40	543.52	693.73	490.56	841.08	527.20	1059.29
Ensete ventricosum	43.29	708.48	174.56	843.32	239.20	1047.28	330.24	1315.12
CD (0.05)	177.21		180.79		208.33		214.63	
Petiole length (cm)								
M. ornata	6.80	10.60	8.80	15.76	10.80	17.50	11.50	19.20
M. laterita	6.10	11.40	6.60	14.05	7.00	16.20	6.80	18.15
Ensete ventricosum	25.10	11.10	35.30	15.57	42.30	19.20	44.10	25.37
CD (0.05)	5.621		5.51		5.96		8.14	
Number of suckers								
M. ornata	-	-	-	-	0.40 (0.88)	0.20 (0.81)	1.00 (1.19)	0.80 (1.19)
M. laterita	-	-	-	-	0.80 (1.28)	0.60 (1.01)	0.80 (1.78)	1.00 (1.22)
Ensete ventricosum	-	-	-	-	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
CD (0.05)	-		-		0.335		0.277	

Values in parenthesis are square root transformed values

Fig. 11. Plant characters of *M. ornata* under 50% shade and open condition







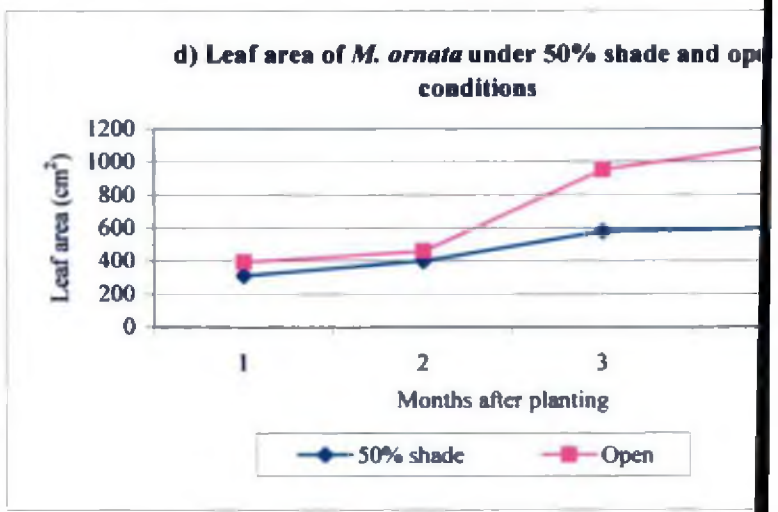
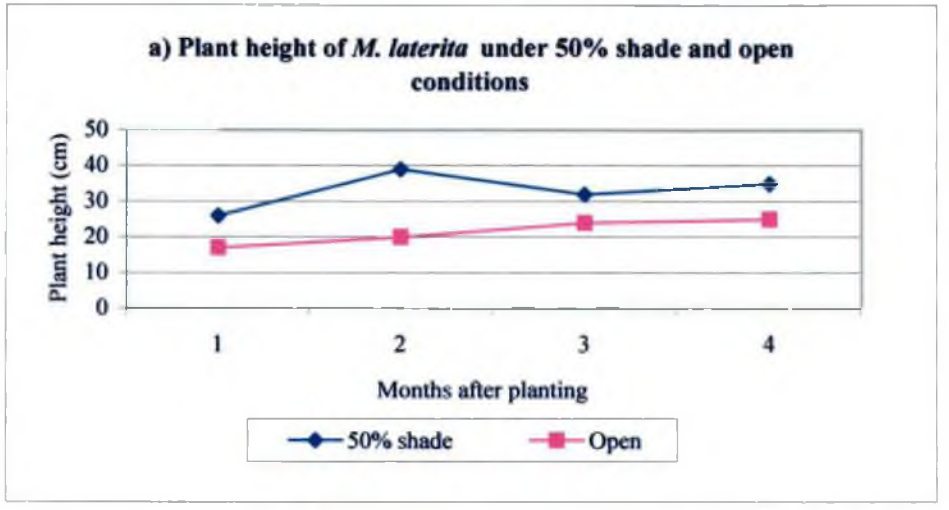
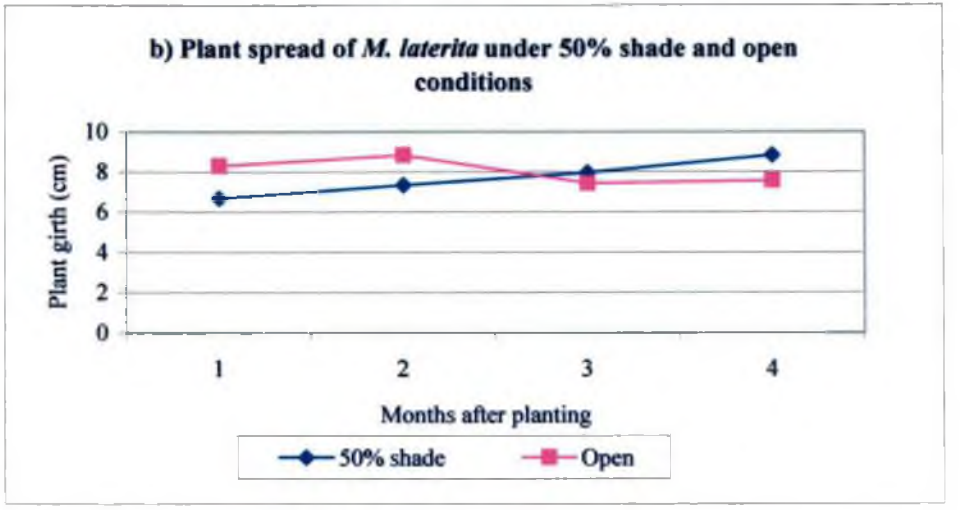
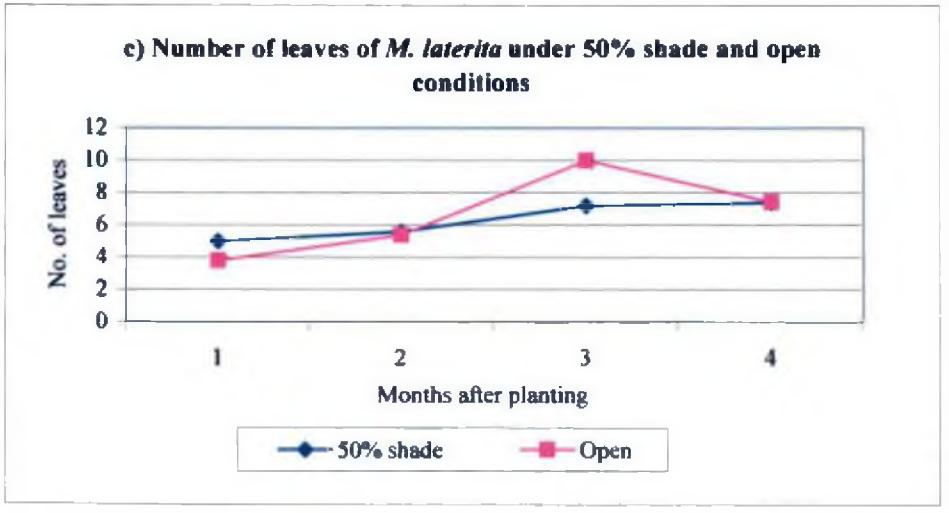


Fig. 12. Plant characters of *M. laterita* under 50% shade and open condition







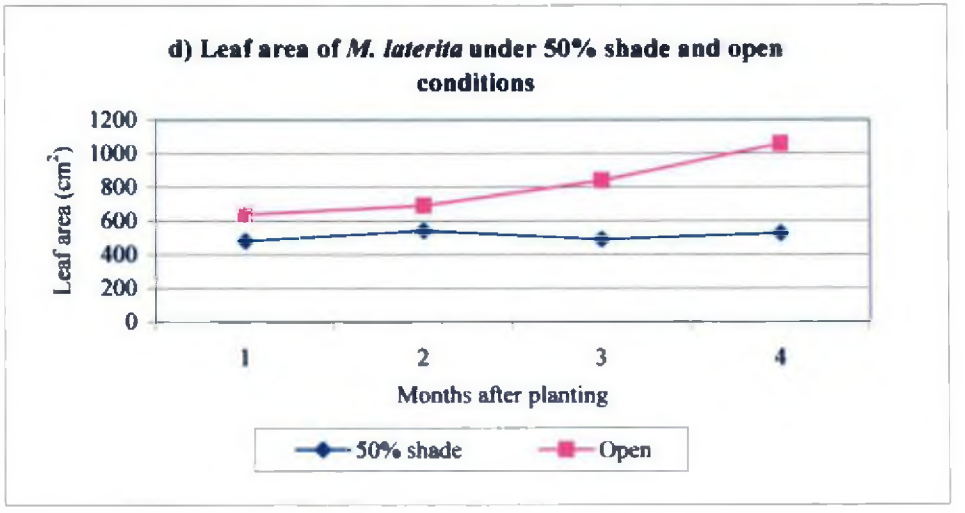
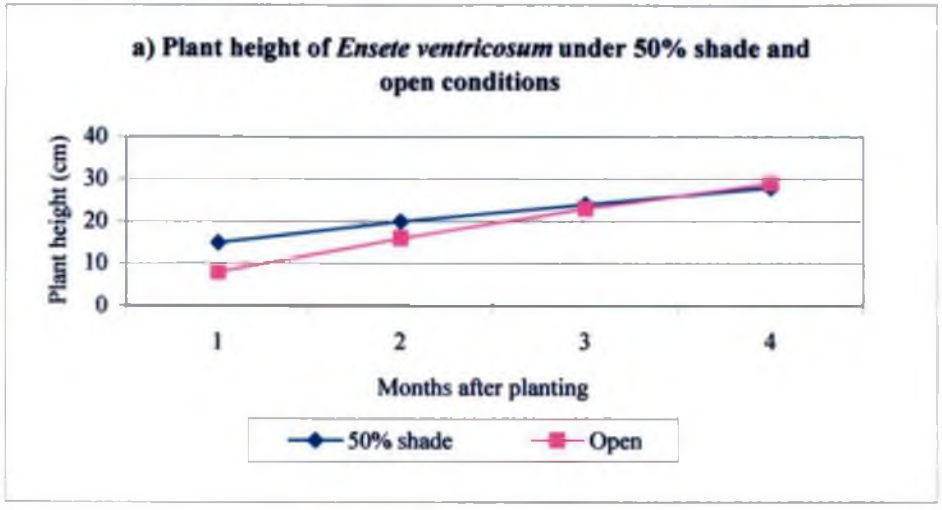
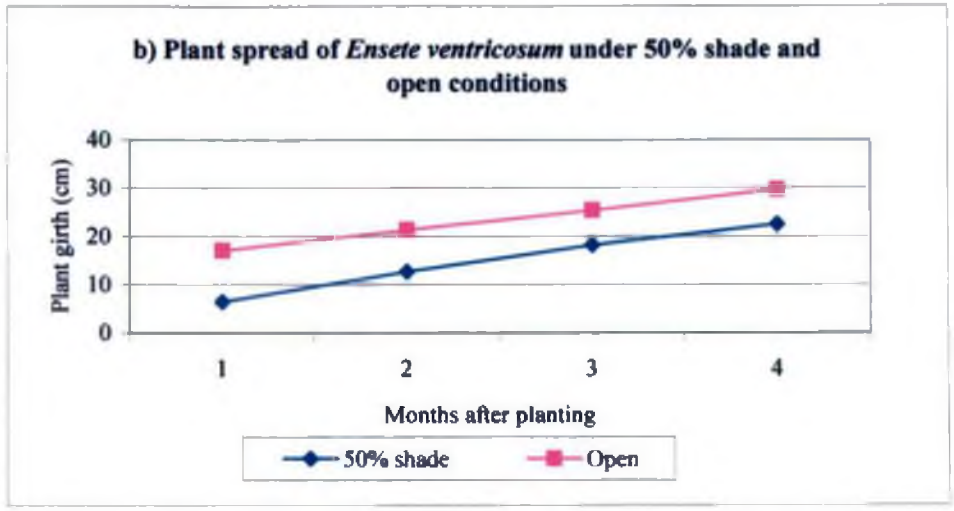
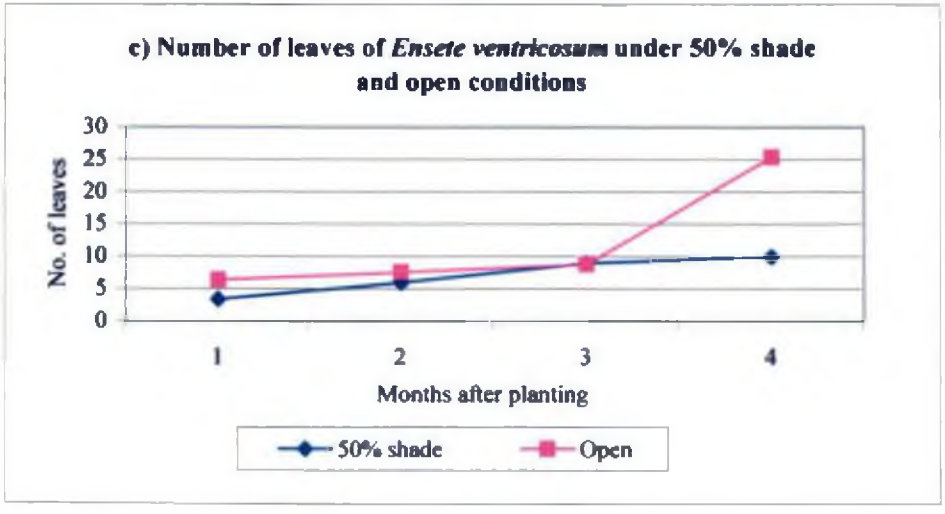
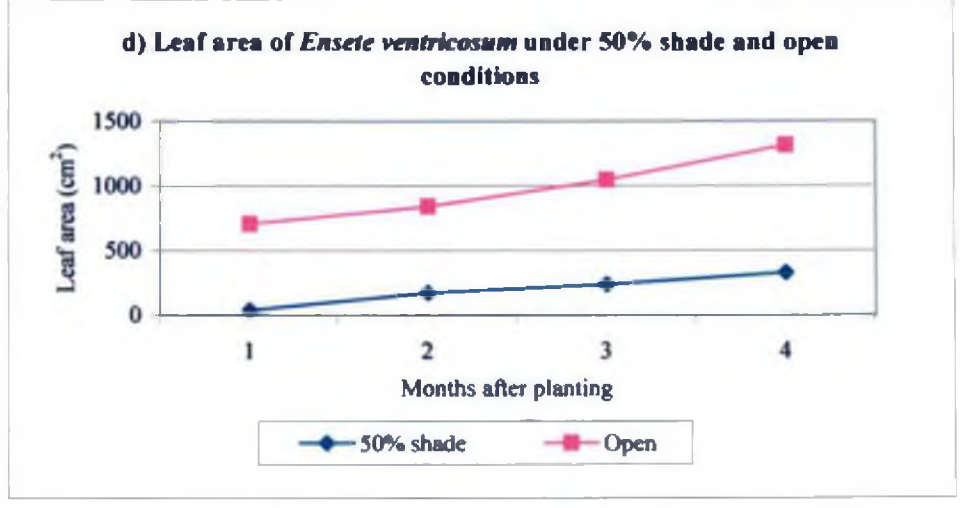


Fig. 13. Plant characters of *Ensete ventricosum* under 50% shade and open condition









4.7.2 Performance evaluation of Ornamental bananas under open condition

Ornamental bananas viz., *Musa coccinea, Musa laterita, Musa ornata,* and *Ensete ventricosum* were evaluated in the open under field condition. *Musa ornata* flowered during the third month after planting and *Musa laterita* during the fourth month after planting. *Musa coccinea* and *Ensete ventricosum* did not flower after the seventh month of observation. The observations on the vegetative characters of ornamental bananas three months after planting are presented in Table15 .

4.7.2.1 Height

Height of all the species varied significantly. It was the highest for *Musa ornata* (49.15 cm) followed by *Musa laterita* (29.60 cm), *Ensete ventricosum* (8.00 cm) and the least for *Musa coccinea* (7.34 cm).

4.7.2.2 Girth

Girth of the plant was on par for *Musa ornata* and *Musa laterita.* It was highest for *Ensete ventricosum* (13.52 cm) and the least for *Musa coccinea* (2.85 cm).

4.7.2.3 Number of leaves

Number of leaves produced per plant was the highest (9.49) in *Musa ornata* followed by 8.20 in *Ensete ventricosum* and 7.60 in *Musa laterita.* The least number of leaves was recorded in *Musa coccinea* (3.60).

4.7.2.4 Leaf length

The leaf length of all the four differed significantly. It was the highest in *Musa ornata* (49.16 cm), and the least in *Musa coccinea* (13.75 cm).

4.7.2.5 Leaf breadth

Leaf breadth was highest in *Musa ornata* (17.81 cm) followed by *Ensete ventricosum* (15.20 cm), and *Musa laterita* (14.47 cm). The least leaf breadth was recorded in *Musa coccinea* (4.01 cm.).

Table 15. Vegetative characters of ornamental bananas under open condition

Sl.No	Ornamental bananas	Height (cm)	Girth (cm)	Leaf number	Leaf length (cm)	Leaf breadth (cm)	Leaf area (cm^2)	Petiole length (cm)	Sucker number
1	*Musa coccinea*	7.34	2.85	3.60 (2.02)	13.75	4.01	45.09	3.79	0.00 (0.71
2	*Musa laterita*	29.60	9.2	7.60 (2.84)	39.69	14.47	461.18	10.31	2.30 (1.66)
3	*Musa ornata*	49.15	9.9	9.49 (3.14)	49.16	17.81	702.28	12.40	2.00 (1.57)
4	*Ensete ventricrosum*	8.00	13.52	8.20 (2.95)	30.00	15.20	307.27	7.66	0.00 (0.71)
		6.18	1.358	0.234	5.057	2.51	97.97	1.51	0.365

Values in parenthesis are square root transformed values

4.7.2.6 Leaf area

Leaf area was the highest in *Musa ornata* (702.28 cm^2) followed by *Musa laterita* (461.18 cm^2) *and Ensete ventricosum* (307.27 cm^2). The least leaf area was recorded in *Musa coccinea* (45.09 cm^2).

4.7.2.7 Petiole length

Highest petiole length was in *Musa ornata* (12.40 cm) followed by Musa *laterita* (10.11 cm) and in *Ensete ventricosum* (7.66 cm). The least petiole length was recorded in *Musa coccinea* (3.79 cm).

4.7.2.8 Number of suckers

In the case of number of suckers produced the highest was recorded in *Musa laterita* (2.30) followed by *Musa ornata* (2.00). In *Musa coccinea* and *Ensete ventricosum* no suckers were produced.

4.7.3 Evaluation of flower characters of *Musa ornata* under 50 per cent shade and open condition

Flowering characters of *Musa ornata* was evaluated under 50 per cent shade and open condition. The results of the experiment are given in Table 16. Characters like bract length, bract breadth, inflorescence longevity, duration of female phase and male phase differed significantly between 50 per cent shade and open condition. Other characters like number of bracts, flower longevity, male flowers per bract, female flowers per bract and flower size did not differ significantly between the two conditions.

The highest bract length recorded under 50 % shade level was 21.00 cm and in the open condition, 16.72 cm. The highest bract breadth under 50 per cent shade level was 10.40cm and in the open condition, 5.46 cm. Longevity of the inflorescence under 50 per cent shade level was 47.80 days and in the open condition, 71.60 days .The duration of female phase under 50 per cent shade level was 5.60 days

Table 16. Flower characters of *Musa ornata* under 50% shade and open conditions

Sl.No	Growing condition	No. of bracts	Bract length (cm)	Bract breadth (cm)	Duration of female phase (days)	No. of female flowers/ bract	Duration of male phase (days)	Number of male flowers/ bract	Flower size (cm)	Flower longevity (days)	Inflorescence longevity (days)
1	Shade (50%)	63.20	21.00	10.40	5.60	2.80	36.20	3.00	5.10	3.20	47.80
2	Open	59.20	16.72	5.46	6.60	3.20	62.30	3.20	5.95	2.80	71.60
	Statistical significance	NS	S	S	S	NS	S	NS	NS	NS	S

S - Significant at 0.05
NS - Non significant

Table 17. Flower characters of *Musa laterita* and *Musa ornata* under field condition

Sl. No.	Ornamental bananas	Days to flower	No. of bract	Bract length (cm)	Bract breadth (cm)	Duration of female phase (days)	Number of female flowers/ bract	Duration of male phase (days)	Number of male flowers/ bract	Flower size (cm)	Flower longevity (days)	Inflore-scence longevity (days)	Crop duration (days)
1	*Musa laterita*	158.90	34.30	15.18	5.24	6.80	4.40	54.30	4.50	4.21	3.50	63.40	220.00
2	*Musa ornata*	141.20	59.20	16.72	5.46	6.50	3.20	62.30	3.20	5.95	3.40	71.60	186.60
	Statistical significance	NS	S	NS	NS	NS	NS	NS	S	S	NS	NS	NS

S - Significant at 0.05
NS - Non significant

and under open condition, 6.60 days .The duration of male phase under 50 per cent shade level was 36.20 days and in open condition, 62.30 days.

From the results given above it can be concluded that the bract size is the highest under 50 per cent shade level. Longevity of the inflorescence, duration of male and female phase were recorded highest under open condition.

4.7.4 Evaluation of flower characters of *Musa ornata* and *Musa laterita* under field conditions

The floral characters of *Musa ornata* and *Musa laterita* were evaluated under field conditions. The results of the experiment are given in Table 17. Flower characters like number of bracts per inflorescence; male flowers per bract and flower size differed significantly in both the species. Other characters like days to flower, flower longevity, bract length, bract breadth, female flower/bract duration of male phase and female phase, longevity of the inflorescence and crop duration did not differ significantly in both the species.

Number of bracts was the highest (59.20) in *Musa ornata* followed by *Musa laterita* (34.20). The number of male flowers per bract was significantly higher (4.50) for *Musa laterita*. The flower size was recorded highest for *Musa ornata* (5.95 cm).

4.8 Pollen viability of *Musa ornata* and *Musa laterita*

The pollen viability of *Musa ornata* and *Musa laterita* was calculated by collecting the pollen grains from the male flowers of both the species. The pollen viability of *Musa ornata* was higher (84%) compared to *Musa laterita* (77%).

4.9 Compatibility studies in Musa sp.

Results of the compatibility studies between *Musa sp.* are presented below.

Table 18. Effect of artificial pollination on ornamental bananas

Musa laterita x *Musa ornata*				
Number of flowers pollinated	Days to fruit set	Number. of hands	Number of fruits	Number of seeds
15	5	3	15	1250
15	5	3	14	1119
15	5	3	13	1988
Musa ornata x *Musa laterita*				
9	4	3	9	560
9	4	3	9	362
13	4	3	11	480

Table 19. Plant characters of hybrid seedlings

Character	*Musa laterita* x *Musa ornata*			
	Months after planting			
	1 MAP	2 MAP	3 MAP	4 MAP
Plant height (cm)	4.3	6.3	8.6	14.16
Girth (cm)	1.0	1.3	1.6	2.2
No. of leaves	2.0	4.6	6.0	8.0
Character	*Musa ornata* x *Musa laterita*			
	Months after planting			
	1 MAP	2 MAP	3 MAP	4 MAP
Plant height (cm)	3.2	4.35	6.65	9.85
Girth (cm)	1.0	1.25	1.5	2.0
No. of leaves	2.0	4.5	6.0	8.0

4.9.1 *Musa laterita* x *Musa ornata*

The results of the cross between *Musa laterita* x *Musa ornata* are presented in Table 18. Altogether 45 flowers were pollinated in three plants. Out of it 42 flowers had set in five days. The ripe fruits contained a total of 3357 seeds. When they were sown, only 50 seeds germinated after 72 days.

The results of the evaluation of hybrid seedlings are presented in Table 19. Four months after germination average height of the seedling was 9.85 cm with a mean girth of 2.00cm. Eight leaves were produced on an average.

4.9.2 *Musa ornata* x *Musa laterita*

The results of the cross between *Musa ornata* x *Musa laterita* are presented in Table 18. Thirty-one flowers were pollinated in three plants. Out of them 29 fruits were set in four days. The ripe fruits contained 1342 seeds in total. They were sown and only 30 seeds germinated after 63 days.

The results of the evaluation of hybrid seedlings are presented in Table 19. Four months after germination average height of the seedling is 14.5 cm with a mean girth of 2.33 cm. Eight leaves were produced on an average.

4.10 Occurrence of pests and diseases

4.10.1 Bromeliads

No attack of insect or other pests was observed during the period of study .In *Cryptanthus sp.* anthracnose appeared during the summer months between February to March when the mean maximum temperature recorded was 34.5-36°C. It appeared as small circular black coloured spots which was caused by *Collectotrichum gloeosporioides*. It was controlled by spraying mancozeb 0.3%.

4.10.2 Ornamental bananas

No attack of pests and diseases was observed during the period of study.

4.11 Vase Life

4.11.1 Bromeliads

In *Billbergia pyramidalis,* when the inflorescence was kept in distilled water the first bract showed drying symptoms on the second day itself and it dried fully by the third day. Water uptake was recorded as 20 ml.

In *Pitcarnea flammea* the first flower showed primary symptoms of drying on the second day and the last flower on the sixth day .The water uptake was recorded as 20 ml.

In *Ananas nanus* the first drying symptom started by the 19th day and the inflorescence fully dried by the 50th day. Water uptake was 100 ml.

4.11.2 Ornamental banana

In *Musa ornata* the bract *showed* primary symptoms of drying on the second day itself and it detached from the peduncle on the second day itself. Water uptake was 20 ml.

4.12 Effect of gamma rays

4.12.1 Bromeliads

Suckers of *Billbergia pyramidalis* and *Tillandsia stricta* were subjected to irradiation @ 5,10,15,20 and 25 Gy.

All the suckers of *Billbergia pyramidalis* except those irradiated with 15 Gy sprouted. The control also sprouted seven months after irradiation. The suckers subjected to 25 Gy resulted in plants having reduced height, leaf length and leaf breadth compared to the others. The results are presented in Table 20.

None of the *Tillandsia stricta* suckers sprouted even seven months after irradiation.

Table 20. Morphological characters of irradiated suckers of *Billbergia pyramidali* (M0)

Sl. No.	Radiation dose (Gy)	Height (cm)	Spread (cm)	Number of leaves	Length of leaves (cm)	Breadth of leaves (cm)
1	10	19	12.2	2	16	3.25
2	15	-	-	-	-	-
3	20	17.5	19.75	2	11	2.7
4	25	13	15	2	13	3
5	Control	19	19.75	3	14	3

Table 21. Effect of gamma rays on germination of seedlings

Sl. No.	Radiation dose (Gy)	Number of seeds sown	Days to germinate	Number of seeds germinated	Germination %
1	Control	10	17	1	10
2	5	10	15	3	30
3	10	10	16	3	30
4	15	10	15	3	30
5	20	10	14	7	70
6	25	10	20	4	40

4.12.2 Ornamental banana

4.12.2.1 Seeds

Ten seeds of *Musa ornata* were subjected to irradiation @5, 10, 15, 20 and 25Gy. The results of the treatment are presented in the Table 21.

The germination percentage varied from 10 per cent (control) to 70 per cent (20 Gy). Days taken for germination varied from 14 days (20 Gy) to 17 days (control).

From the above given data we can conclude that 20 Gy is the best dose resulting in 70 per cent germination taking only 14 days to germinate. Seeds subjected to 25 Gy showed less germination percentage compared to the others.

4.12.2.2 Rhizomes

One month old rhizomes of *Musa ornata* were irradiated at the rate of 10, 15, 20 and 25 Gy. They were observed for 8 months. None of them sprouted and all are remaining healthy.

4.13 Suitability of Ornamental bananas for landscapes

The studies on the suitability of ornamental bananas for different landscapes are described below.

4.13.1 *Musa laterita*

Plant height was significantly higher under 50 per cent shade level, while the girth and number of leaves produced showed no significant difference between the two growing conditions. Leaf area was significantly higher under open condition No flowering was observed under both the conditions in pot. When planted in field, all the vegetative and floral characters were better compared to pot culture. Flowering was observed three months after planting. Sucker production was also higher.

The plant appeared lanky with reduced leaf size under 50 per cent shade level, which is not a desirable character. So with respect to vegetative growth *Musa laterita* can be recommended under open condition in pot. Since all the vegetative and floral characters were observed better under field condition, it is more suitable for landscape planting in the open condition.

4.13.2 *Musa ornata*

Plant height was significantly higher under 50 per cent shade level, while the girth, number of leaves produced and leaf area was significantly higher under open condition. No flowering was observed under both the conditions in pot. Under field condition all the vegetative and floral characters were better compared to pot culture. Flowering was observed four months after planting. Sucker production was also higher.

The plant appeared lanky with reduced leaf size under 50 per cent shade level, which is not a desirable character. So with respect to vegetative characters, *Musa ornata* can be recommended under open condition in pot. Since all the vegetative and floral characters were observed better under field condition, it is more suitable for landscape planting in the open condition.

4.13.3 *Ensete ventricosum*

Plant height was significantly higher under 50 per cent shade level, while the girth, number of leaves and leaf area were significantly higher under 50 per cent shade. Under field condition all the vegetative and floral characters were better compared to pot culture. Even though the plant did not flower, the leaves looked glossier, with pink midrib more prominent.

The plant appeared lanky with reduce leaf size under 50 per cent shade level, which is not a desirable character. So *Ensete ventricosum* can be recommended under open condition in pots. The plant appeared more robust and attractive with its glossy leaves with the pink midrib more prominent under field. So it is more suitable for landscape planting in the open condition.

Discussion

5. DISCUSSION

Results of the "Evaluation of ornamental bananas and Bromeliads for tropical landscapes" carried out at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during the period from 2005-2007 are discussed in this chapter.

The main objectives of the study were to evaluate the performance of ornamental bananas and Bromeliads with respect to various vegetative and floral characters under different shade levels, in order to recommend them for different landscapes and interiorscapes. The possibilities of induction of variability by hybridization and irradiation were also explored.

Nine bromeliads viz., *Aechmea fasciata, Ananas bracteatus, Ananas nanus, Billbergia pyramidalis, Bromelia balansae, Cryptanthus zonatus, C. bivittatus, C. bromelioides, Dyckia brevifolia, Pitcarnea flammea, Tillandsia stricta* and six ornamental bananas viz., *Musa coccinea, M. rosea, M. rubra, M. laterita, M. ornata* and *Ensete ventricosum* selected for the study were morphologically described with respect to their vegetative and floral characters.

5.1 BROMELIADS

Performance evaluation of Bromeliads under different shade levels revealed that in *Aechmea fasciata* plant spread (66.16 cm) and leaf length (53.33 cm) were significantly higher under open condition but the performance of the plant was good under shade with respect to the attractiveness and scaly green colour of the leaf was concerned. Sun scorching was observed during the peak summer months of February to March when the mean maximum temperature recorded was 34.5-36°C. This is because Bromeliads, in general should not be grown in direct sunlight. They grow best in indirect light or good light without sun. This was reported by Hickmann (2006). Symptoms of too much light are yellow leaves, markings that are faded and bleached out, leathery, stressed look to the foliage and in extreme cases sun burn spots and holes. Black and Dehjan (2003) also reported that a general recommendation is to

grow Bromeliads where the light level is approximately 1500 foot candles or where orchids grow well. Most species should not be exposed to the direct rays of sun. A yellowish or pale green plant may indicate that the light level is too high. A darker green than normal, with a more open or elongated shape may indicate low light levels. Flowering was observed only under open condition 130 days after planting. Hickmann (2006) reported that some Bromeliads do not flower if they do not receive enough light, therefore, do not keep them in a dark corner. The inflorescence is a dense spike with pink coloured bracts in which violet blue flowers are produced. Johnson (1995) reported that in Bromeliads the flower is cone shaped or a spike or a lose umbel. No seeds are produced in our climatic condition but Johnson (1995) reported that many Aechmeas produce colourful, attractive seeds, all of which are edible. Russ (2007) also reported that *Aechmea fasciata* is a funnel shaped plant that has leaves that are curved at the top and numerous light blue flowers are born in a dense spike. So if the temperature is low the plant can be recommended under open condition with respect to flowering characters. Plants in the genera *Dyckia, Puyas, Hechtias, Ananas*, and the hard leaved species in *Aechmea* and *Billbergia* grow best at high light levels. This was reported by Black and Dehjan (2003) also.

In *Ananas bracteatus*, height and spread of the plant were significantly higher under open condition. Other characters like number of leaves (41.50), length (45.50) and breadth (4.20 cm) of leaf were significantly higher under 50 per cent shade. The plant appeared more attractive with its pink bands more prominent under open condition. Russ (2007) reported that in variegated pineapple the longitudinally striped leaves turn pink in bright light. Romanowski (2003) reported that banding and diagonal striping on various species such as *Aechmea fasciata* and *Billbergia zebrina* occur due to alternative zones of both heavy and light areas of scale development. Heavily shaded locations should be avoided, especially for those Bromeliads with striped and banded leaves. Such forms when grown under shade will lose their distinctive markings. This was reported by Hickman (2006). Russ (2007) reported that they require strong light, rich soil, regular feeding and plenty of moisture for proper colour development. Black and Dehjan (2003) reported that hard leaved plants in the

genera *Dyckia, Puyas, Hechtias* and *Ananas* grow best at high light levels. Spread of the plant reduced under both the conditions during the peak summer from February–March when the mean maximum temperature recorded was 34.5-36°C due to sun scorching of the lower leaves. The Bromeliads prefer temperature below 36°C, but many tolerate heat if there is good air circulation.

Flowering was obtained in *Ananas bracteatus* on ethrel application under open condition. Chomchalow (2004) reported that a sprinkle of acetylene, on top of the pineapple plant is quite effective in inducing the plant to flower. The induction of flowering in Bromeliads by ethylene is unusual, because the gas inhibits flowering in most other species. The inflorescence is a dense cone. Russ (2007) reported that the plants have a dense rosette of spiny leaves from which the flower develops in to a typical pine-cone shaped fruit. Flowering resulted in the death of the mother plant. So flowering is not desirable as a pot plant. But it is desirable for production of new suckers. Anderson (2007) reported that Bromeliads flower only once and then slowly die. Individual plants that require 18 -30 months of growth before flowering and will die 6-12 months later but will be hidden beneath newly formed plants. Other species flower in shorter periods and produce many plants in 18 months. With respect to the vegetative characters the plant can be recommended under 50 per cent shade and open condition.

In *Ananas nanus* spread (62.50 cm) and leaf length (32.20 cm) were significantly higher under 50 per cent shade level. Flowering was observed earlier (152 days) under open condition and later (173.80 days) under 50 per cent shade. Other flower characters like number of flowers (32.80), longevity of inflorescence (67.60 days) and longevity of flower (2 days) were recorded highest under open condition. The inflorescence arises in a slender stalk bearing the inflorescence with red buds resembling a pincushion. The buds open into purple coloured flowers. Black and Dehjan (2003) reported that *Ananas nanus*, a smaller species commonly grown as an indoor plant has arching, 12 to 15 inch greyish green leaves surrounding a 15 inch spike of red buds resembling a pin cushion. flowers. The buds open into purple coloured flowers followed by a 2' high fragrant edible pineapple. The inflorescence

toppled down from the plant under 50 per cent shade level due to longer peduncle (31.80 cm). With respect to floral characters the plant is suited more for open condition. Anderson (2007) reported that typical pineapple plants get quite large and rarely flower in the home so the dwarf pineapple can be purchased with the fruit already formed.

The height (20.33 cm) and spread (49.08 cm) of the *Billbergia pyramidalis* were significantly higher under open condition. The inflorescence is a dense spike with mealy white coloured pedicel and a head of crimson red bracts. Dallwitz and Watson (2006) reported that the bromeliad flowers are aggregated in 'inflorescences'; in racemes, or in spikes, or in heads (or thryses), the terminal inflorescence unit seemingly racemose. The plant looked more attractive with its apple green leaves and bigger inflorescence under shaded condition. Berry (2000) reported that too much light destroys the colour of spikes in *Tillandsia cyanea*. In addition to light, temperature and humidity are essential factors in colouration of spikes. The deepest colour in the spikes can be developed by reproducing the cool, moist condition of a cloud forest.

In *Billbergia pyramidalis*, the plants flowered earlier under open condition, 52 days after planting. Johnson (1995) reported that some of the Bromeliads need strong light to grow well and produce flowers. On ethrel application flowering was much earlier, within 2.71 days under open condition compared to 6.28 days under 75 per cent shade and taking maximum time, 15.57 days under 50 per cent shade. Russ (2007) reported that bromeliads can be forced to flower by placing the plant inside an airtight plastic bag with a ripe apple for 2-3 days. Depending on the plant type, flowering commences within 6-14 weeks and after flowering the plant dies producing offshoots and pups for steady renewal of the plant. Chomchalow (2004) reported that ethylene releasing substance, called ethephon or ethrel that is commercially available can induce flowering in Bromeliads. Black and Dehjan (2007) reported that Bromeliads can be forced to flower by exposing them to ethylene gas.

In the present study, the size of the inflorescence under open condition was smaller. Longest peduncle was recorded under 75 per cent shade (11.25 cm) followed by 50 per cent shade (7.12 cm) and the least under open condition (1.21 cm). Length of the inflorescence, number of flowers and number of bracts were also higher under shade. The showy portion of the inflorescence is made up of brilliantly coloured bracts born below each flower. Although short lived, the inflorescence is very colourful. This was reported by Anderson (2007). The longevity of the inflorescence was highest under 75 per cent shade (11.57 days) followed by 8.71 days under 50 per cent shade and the least under open condition (1.57 days). Closely related plants like *Billbergia pyramidalis* (Summer torch), *B. nutans* (Queens star) and *B. fantasia* (Marbled rainbow plant) resemble *Aechmea fasciata* but their flowers last only a few days as reported by Anderson (2006). The percentage of plants flowered was the same, 71.42%, under both 50 and 75 per cent shade and least under open condition (14.28%).

In a pot plant the overall appearance of the plant is much valued than biometric characters. With respect to the attractiveness of the plant and floral characters, the plant is more suited for 50 per cent shade and 75 per cent shade levels. It can also be kept indoor for a period of 47 days after which necrotic symptoms appeared. Anderson (2007) reported that in indoors Bromeliads should be placed in east, south or west window where they will receive full sun for 3-4 hours each day. Londers *et al.* (2003) reported that under high humidity, turgour pressure builds up which leads to leaf damage. Many Bromeliads adapt to growing conditions found indoors and therefore, make excellent interior plants for the home. Hardier genera can be used as landscape plants (Black and Dehjan, 2007). Most Bromeliads cultivated for interior use, however are alike without stems and with a central flower spike and strap shaped, leathery, arching leaves arranged in a rosette. Anderson (2007) reported that in general appearance, Bromeliads are considered unusual and exotic house plants by most home gardeners. In fact Bromeliads tolerate interior conditions as well, as any other tropical foliage plant.

In *Bromelia balansae*, height of the plant (30.32 cm), spread (1.58 m) and number of leaves (63.00) were significantly higher under open condition. In March when the mean maximum temperature recorded was 36°C, the lower leaves which add to the spread of the plant dried out under open condition. The Bromeliads prefer temperatures below 36°C, but many tolerate high temperature if there is good air circulation. Length and breadth of the leaf were significantly higher under 50 per cent shade level. The appearance of the plant was similar under both the condition. So it can be recommended for both 50 per cent shade and open condition. The large size and presence of spines in the plant make it suitable for open areas, were it can be used as an ascent plant.

Among the *Cryptanthus sp.* viz., *Cryptanthus zonatus, C. bivittatus* and *C. bromelioides*, sun scorching was observed in all the species under open condition during December when the mean maximum temperature recorded was 31.5°C. *Cryptanthus zonatus* dried out under both the condition, but on the commencement of rain, during the month of July when the mean maximum temperature recorded was 30.4°C, average sun shine hrs/day was only 0.71 and maximum rainfall was 1131.9 mm, the mother plant put forth new suckers under 50 per cent shade and flowering was also observed. Johnson (1995) reported that *Cryptanthus* prefer rich soil with plenty of moisture. They do best under 60 per cent shade. Based on the results of the present study it can be recommended under 50 per cent shade level. The plant is suitable in pots and also as a ground cover.

C. bivittatus and *C. bromelioides* showed significantly higher height, spread and number of leaves under 50 per cent shade level. Leaf breadth was observed to be on par (24.00 cm) under both the condition. But the leaves looked attractive both under 50 per cent and 75 per cent shade level. These plants grow well in bright diffused light as reported by Russ (2007). The solid striped or banded leaves may be green, brown, bronze, silver pink or white. They are terrestrial and grow flat against the ground. They should be grown in rich organic soil. Their compact size make them suitable for dish gardens. They can be grown along with cacti and succulents. They are excellent house plants since they can tolerate low humidity better than most of the

plants and they are easy to water. So with respect to the attractiveness of the plant they can be recommended both under 50 per cent and 75 per cent shade level. Anderson (2007) reported that *Cryptanthus bivittatus* and several of its cultivars are among the most widely grown for use as interior plants.

In *Dyckia brevifolia* number of leaves (25.66) and number of suckers (20.00) were significantly higher under open condition. Flower characters like length of peduncle, length of inflorescence, number of leaves, longevity of inflorescence and longevity of flower were observed to be higher under open condition. Leaves are the attractive part of the plant than the flowers. The maroon colour of the leaves is more developed under open condition, but they develop a greenish marron colour under shade which is also acceptable. Romanowski (2003) reported that plants situated in more exposed positions will be more intensely coloured than those of the same species in more shaded areas. This is because the plant produces more pigment due to the strong UV rays in summer months. He also reported that *Neorgelia* 'Red of Rio' will appear green in low light but develop a vivid red colouration when grown in very bright light or direct sunlight. Due to its attractive leaf colour under both the conditions *Dyckia brevifolia* can be recommended for both 50 per cent shade and open condition. Generally Bromeliad species with hard, thick, grey-green or fuzzy foliage withstand highest light levels, while species with soft, green, thin leaves grow best under low light levels. *Dyckia brevifolia* belong to the first category and they are suitable for rock garden in the open, as a pot plant in trough gardens and window gardens.

In *Pitcarnea flammea*, spread (52.83 cm), number of leaves (57.66) and number of suckers (12.33) were significantly higher under 50 per cent shade. But height of the plant and flower characters like days to flower, length of peduncle, length of inflorescence, number of flowers, longevity of inflorescence and longevity of the flower were significantly higher under open condition. The inflorescence arises on a slender stalk bearing tubular red coloured flowers. Johnson (1995) reported that Bromeliads like *Pitcarnea flammea* need strong light to grow well and produce flowers. Johnson (1995) reported that Pitcarneas are becoming popular; eventhough

the foliage is often grassy and sloppy. Blooms are spectacular by red, orange and yellow colours. They do not have a leaf rosette that traps water. The Pitcarneas are soft leaved species. Black and Dehjan (2003) reported that soft leaved species need a higher temperature, while those with very hard and stiff leaves are tolerant to cold. The plant is attractive with flowers only so it is more suited for open condition. The plant can also be kept indoor for a period of 7 days after which necrosis appeared. *Pitcarnea flammea* has scales on its leaves. Since the plant does not have a distinct cup to collect water, they absorb water from the air through the scaly leaves. Black and Dehjan (2003) reported that in an indoor situation where the humidity is low, they are unable to obtain moisture from air. In a home environment they do best under 21.5-23.8°C during the day and between 15.5-18.3°C at night. Most grow best at a relative humidity of 40-60 per cent. *Pitcarnea* is an inhabitant of damp creek banks and shady locations. The plant seems to enjoy a dormant, dry recess for several months during winter, which forces bloom when watering is resumed (Johnson, 1995). In tropical areas they can be grown in the open to form flower beds.

In *Tilladsia stricta* plant characters like height, spread, number of leaves, leaf length and number of suckers were significantly higher under open condition. On ethrel application the plant did not flower, but flowering was observed on the commencement of rain during the month of July, when the mean maximum temperature recorded was 30.5°C, with average sunshine hour per day 0.71 hour and maximum rainfall 1131.9 mm. All of the Tillandsias need moisture. This was reported by Johnson (1995). Black and Dehjan (2003) reported that Bromeliads require temperature up to 30°C in order to bring young plants to flowering. Bromeliads grow naturally where the humidity is high. Therefore, it is vital to the health of the Bromeliad that a high humidity is maintained.

In *Tillandsia stricta*, the inflorescence is a creamy yellow spike which is very fragrant. Plants in this group have smooth or entire leaf margins, unusual foliage markings and colours. Some species produce fragrant flowers (Black and Dehjan, 2003). The colour of the leaves with its yellow and green bands is more prominent under open condition. Romanowski (2003) reported that position of the plant may also

determine the amount of pigment produced by it. The plants in more exposed positions will be more intensely coloured than those of the same species in more shaded areas. Johnnson (1995) reported that Tillandsias are dry growing, sun loving epiphytes. Those with heaviest coat of peltate scales will survive dry conditions best. It is the mechanism for extracting moisture from air. So it can be recommended under open condition. Under indoor condition, necrosis of the leaf appeared after 14 days.

With respect to the growth under different media, *Billbergia pyramidalis* obtained highest number of leaves (21.50) and number of suckers in the medium containing equal proportion of sand + vermicompost + cocopeat (M_2) and the least in coconut husk (M_4). Plant characters like spread, number of leaves and percentage of flowering were highest in the medium containing sand + coarse sand + vermicompost + cocoa peat (M_3). For Bromeliads the growing medium should contain a lot of humus in the form of peat or leaf mould and not soil. A good mixture would consist of equal parts of fibrous peat and leaf mould with half part of coarse sand as reported by Hickman (2007). Leaves were elongated in coconut husk. Highest leaf breadth (6.73 cm) was obtained in tile bits (M_1) and the least (4.25 cm) in coconut husk (M_4). Due to their epiphytic nature they can also be grown in media like coconut husk and tile bits. Hickman (2007) also reported that both epiphytic and terrestrial Bromeliads possess tiny roots which serve the purpose of anchorage so that these plants can be grown in small pots compared to the overall size of the plants. They absorb nutrients and water through their leaves and the so called vase in the centre of the plant. The plants in their natural habitat grow in hollows and crevices in the bark and branches where water collects during the rains. Eventhough the growth of the plant if better in a medium containing organic matter it can be displayed in coconut husk also.

For *Pitcarnea flammea* maximum height (20.48 cm), number of leaves (57.66) and number of suckers (12.33) were observed in the medium containing equal proportion of sand + vermicompost + cocopeat (M_2). Maximum spread, leaf length and leaf breadth were obtained in coconut husk (M_3). So with respect to vegetative characters M_2 and M_3 are good media. Black and Dehjan (2003) reported that most Bromeliads grow best in a very porous organic medium which permits quick water

drainage and sufficient air circulation around the roots. A well drained medium suitable for all epiphytes is composed of large bark chips, osmunda fibre, large size calcine clay, or tree fern fibre with small amounts of peat moss or vermiculite added to hold some moisture. The growing medium should be as drained as a tree branch as reported by Anderson (2004). The satisfactory growth of the plant in coconut husk is due to this reason.

5.2 ORNAMENTAL BANANAS

Performance evaluation of ornamental bananas in pots under 50 per cent shade and open condition revealed that the performance of *Musa rosea* and *Musa rubra* was not good under both the conditions. The plants dried under both the conditions two months after planting. Even though *Musa coccinea* survived under 50 per cent shade, its performance was also poor. McLaughlin (2006) reported that *Musa coccinea* can take some light shade and has a preference for acidic soils. Like other ornamental bananas, it can be grown in a container usually rich in free draining soil and can be placed as an attractive patio plant. The upright torch like inflorescence is finding increasing use as a cut flower and is readily amenable to container culture. In the present study, tallest plants were produced under 50 per cent shade in *Musa ornata* (63.00 cm), *Musa laterita* (35.00 cm) and *Ensete ventricosum* (28.00 cm) than under open condition. *Musa ornata* and *Musa laterita* produced longest petioles length under open condition. For *Musa laterita* and *Ensete ventricosum* maximum number of leaves and maximum girth were higher under open condition. *Musa ornata* showed no significant difference in the number of leaves and girth of the plant between 50 per cent shade and open condition. Eckstein *et al.* (1997) reported reduced leaf emergence rates under shade. All other characters like leaf length, leaf breadth and leaf area were significantly higher under open condition. Shade caused a reduction in temperature and within a certain temperature range, leaf emergence rate was positively correlated with ambient temperature as reported by Robinson and Nel (1998). Recourse allocation is adjusted in shaded plants, increasing both photosynthetic area and chlorophyll contents to compensate for reduced light fluxes (Nargrove, 2007). Balasimha (1989) reported that *Musa sp.* grown in the understorey of arecanut palms

adapted to lower light levels by producing leaves with higher chlorophyll content, specific leaf area and photosynthetic efficiency. Leaf area was highest under open condition. Lanky and less robust plants with reduced leaf size were produced under 50 per cent shade in the present study.

Suckers were produced two months after planting for *M. ornata* and *M. laterita* but no flowering was observed in the three species under pot culture. Crane *et al.* (2005) reported that banana plants are moderately shade tolerant up to 50 per cent. However, shading delays plant and fruit growth development. Norgrove (2007) reported that the growth cycle was lengthened under lower light flux densities. He also reported that *Musa spp.* exhibited morphological and physiological changes if grown in shade. So with respect to flower characters these three species are not suitable for pot culture under shade. But with respect to vegetative characters, they are suitable for growing under open condition in pots, especially *Ensete ventricosum* with its attractive leaves is suitable for tropical landscapes under full sunlight. Constantine (2006) and Crane *et al.* (2005) reported that two Ethiopean coloured leaf cultivars *E. ventricosum* 'Maureli' and 'Montbeliardii' have found their way into ornamental horticulture. Unlike other bananas *Ensete ventricosum* does not produce suckers. Mc Laughlin (2006) reported that it is possible to induce suckers by removing the pseudostem just above the ground and then scooping out the apical meristem. This should be done at the pre flowering stage. Plants propagated by this way may develop suckers since some meristematic tissue is invariably removed along with the detached shoot.

Performance evaluation of ornamental bananas under field condition revealed that *Musa ornata, Musa laterita* and *Ensete ventricosum* are suitable for tropical landscapes under full sunlight than under shaded condition. Uma *et al.* (2007) reported that ornamental bananas are best grown in full sun. They have fast growing foliage and give long lasting showy floral displays, especially large colourful bracts that subtend the colourful flowers. Due to their inherent beauty, Rhodoclamys members like *Musa ornata* offer enormous scope for commercial exploitation as garden plants. Ploetz *et al.* (2007) reported that Callimusa section of bananas, which includes *Musa coccinea* is having plain bracts which are firm and shiny on the outer

surface. They bear upright flower stalks, variously coloured buds and flowers, and small seedy fruit. They are most important as ornamentals. In Hawai, *Musa ornata* is occasionally grown in botanical and private gardens along the wet, windward coasts .Hakkinen (2007) reported that they were suitable for indoor and greenhouse culture, and also can be grown outdoors during the growing season. *Musa ornata* growing in clumps adds to the beauty of a tropical landscape.

Flowering was observed in *Musa ornata* three months after planting and in *Musa laterita* four months after planting. Maximum height, number of leaves, leaf length, leaf breadth, leaf area and petiole length were recorded for *M. ornata*. *M ornata* produced maximum number of suckers forming a large clump. Long rhizomes producing a more open stand occur in *M. laterita* and *M. iterans*, although this was not obvious in pot grown plants as earlier reported by Constantine (2006). Suckers are routinely pruned off to promote flowering in edible bananas but when grown for ornamental purpose, removal of suckers is not necessary other than for aesthetic reasons (Constantine, 2006). In *Ensete ventricosum*, lateral buds appear to be absent and suckers arise by adventitious shoot formation.

Evaluation of the flower characters of *Musa ornata* in the field under open and shade revealed that the characters varied significantly. Maximum bract length and bract breadth were recorded under 50 per cent shade. Longevity of the inflorescence, duration of male phase and duration of female phase were higher under open condition. Hakkinen (2007) reported that *Musa ornata* is the most widely grown banana in tropics and subtropics. Most of the species in sections Callimusa and Rhodoclamys are characterized by having inflorescences that are erect, at least at the base, with fruit pointing towards the bunch apex. These species also typically have relatively few fruits and are best known for their brightly coloured bracts, a feature that makes them popular as ornamental plants.

The flower characters of *M. ornata* and *M. laterita* also varied significantly under the field condition. Inflorescence with more number of bracts and flower size

was produced by *Musa ornata.* But number of male flowers per bract was higher in *Musa laterita.*

Studies on pollen viability revealed that pollen viability was higher for *Musa ornata* (84.0%) compared to *Musa laterita* (77.0%). Shepherd (1999) reported that the offsprings of *Musa ornata* as female parents are much more fertile than as a male parent.

Compatibility studies between *Musa sp.* revealed that both the species are compatible with each other. Constantine (2006) reported that there is a transition in flower type along the inflorescence that maximizes outcrossing in species, basal flowers being female and distal flowers male. The ability of the *Musa laterita* to hybridize with *Musa ornata* suggests the possibility of a common origin, but they are sometimes erroneously known in tropical horticulture as cultivars of *Musa ornata* (Hakkinen, 2007).

In the cross between *M. laterita* and *M. ornata,* from 42 fruits total number of 3357 seeds were obtained. From the cross between *M. ornata* x *M laterita,* from 29 fruits, 1342 seeds were obtained. Out of 3357 seeds only 50 and from 1342 seeds, only 30 germinated. The days taken for germination varied from 63 to 72 days. Germination can begin in as little as two weeks but a flush of germination after 4-6 weeks is more common (Constantine, 2006) Vegetative characters of the seedlings from *M. ornata* x *M. laterita* was superior compared to those from *M. laterita* x *M ornata.* Seedlings from *M. ornata* x *M. laterita* recorded maximum height of 14.5 cm, girth of 2.33 and 8 leaves and compared to seedlings of *M. laterita* and *M. ornata,* with a height of 9.84 cm, girth of 2 cm and 8 leaves. Silva *et al.* (2007) reported that considerable difference was observed in seed production (quality and quantity) according to the parent varieties.

Vase life studies in Bromeliads showed that longest vase life was obtained for *Ananas nanus* (19 days) followed by *Pitcarnea flammea* (3 days) and minimum for *Billbergia pyramidalis* (2 days). For *Musa ornata* the bracts withered and abscised after two days.

Studies on the effect of gamma rays on Bromeliads revealed that all the suckers of *Billbergia pyramidalis* except those irradiated with 15 Gy sprouted six months after planting. The control plants sprouted 7 months after planting. The Suckers treated with 15 Gy remained healthy .The delayed sprouting in irradiated material is attributed to chromosomal aberrations caused by mutagenic agents which adversely affect the cell division (Sparrow, 1961).Vegetative parameters like height of the plant ,leaf length and leaf breadth decreased with increasing dose in gamma radiation. Reduction in height after irradiation was reported by Sambandamurthi (1983) in tuberose and Banerji *et al.* (1994) and Singh (2002) in gladiolus. None of the irradiated suckers of *Tillandsia stricta* sprouted but all remained healthy. Delay in sprouting due to irradiation was reported by Vasudevan *et al.* (1967) in colocasia and Gupta and Shukla (1971) in rose. The delay in sprouting might be due to the influence of mutagens on hormones and plant growth regulators in higher plants.

Treatment of gamma rays on the germination of seeds in ornamental bananas resulted in higher germination percentage and earlier germination for those treated with 20 Gy compared to others. None of the rhizomes of ornamental bananas sprouted, but all remained healthy even after eight months. Failure of assimilatory mechanism, production of diffusible growth retarding substances (Mackay, 1951) and change in specific activity of the enzymes (Haskins and Chapman, 1956) also could have contributed to the reduced sprouting.

Regarding the incidence of pests and diseases, during the peak summer months of February- March when the temperature was 34.5–36°C there was incidence of anthracnose in *Cryptanthus* species. Black and Dehjan (2003) reported that plants subjected to mechanical injury, insects or sunburn may be invaded by one or many fungi. The invasion usually appears as dark spots on the leaves, either with sunken or water soaked areas and frequently with a radiating yellow area. No attack of pest was noticed. In ornamental bananas no incidence of pests and diseases was noticed during the period of observation.

The results of the present investigation revealed that Bromeliads could be used in tropical landscapes under shade and in the open for their peculiar plant form, leaf colour and attractive flowers. They may be displayed in pots rich in organic matter for robust growth or in coconut husk for growing as 'air plants'. Some of them can be forced to flower by ethrel application and some are suitable as indoor plants and for production of cut flowers.

Ornamental bananas like *Musa ornata, Musa laterila* and *Ensete ventricosum* add to the beauty of tropical landscapes with their attractive leaves and flowers. New varieties could be obtained by interspecific hybridization as they are compatible and produce fertile pollen. The poor germination percentage of seeds could be improved by embryo culture as done in edible bananas. The possibility of evolving new plant forms by irradiation may be further explored.

Summary

6. SUMMARY

Bromeliads and ornamental bananas were evaluated at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during the period from 2005-2007. The main objective was to study their performance with respect to various vegetative and floral characters under different shade levels and in the open, in order to recommend them for different landscapes and interiorscapes. The possibilities of induction of variability by hybridization and irradiation were also explored.

Nine bromeliads viz., *Aechmea fasciata, Ananas braceatus, A. nanus, Billbergia pyramidalis, Bromelia balansae, Cryptanthus zonatus, C. bivittatus, C. bromelioides, Dyckia brevifolia, Pitcarnea flammea, Tillandsia stricta* and six ornamental bananas viz., *Musa coccinea, M. rosea, M. rubra, M. laterita, M. ornata* and *Ensete ventricosum* were selected for the study. They were morphologically described with respect to their vegetative and floral characters.

Performance evaluation of Bromeliads under different shade levels revealed that in *Aechmea fasciata* plant spread (66.16 cm) and leaf length (53.33 cm) were significantly higher under open condition. But the performance of the plant was better under shade with respect to the colour of leaves. Sun scorching was observed during the peak summer months of February to March when the mean maximum temperature recorded was 34.5-36°C. Flowering was observed only under open condition 130 days after planting. So if the temperature is low the plant can be recommended under open condition with respect to the flowering characters are concerned.

In *Ananas bracteatus*, height of the plant was significantly higher under open condition and spread of the plant under 50 per cent shade. Other characters like number of leaves, length and breadth of leaf were significantly higher under 50 per cent shade. The plant appeared more attractive with its pink bands more prominent under open condition. Spread of the plant was reduced under both the conditions during the peak summer from February – March when the mean maximum

temperature recorded was 34.5 -36°C due to sun scorching of the lower leaves. Flowering was obtained on ethrel application under open condition, but it resulted in the death of the mother plant. So flowering is not desirable to use it as a pot plant. But it is desirable for production of new plants. With respective to the vegetative characters the plant can be recommended under 50 per cent shade and open condition.

In *Ananas nanus* spread (62.50 cm) and leaf length (32.20 cm) were significantly higher under 50 per cent shade level. Flowering was observed earlier (152 days) under open condition and later (173.80 days) under 50 per cent shade. Other flower characters like number of flowers (32.80), longevity of inflorescence (67.60 days) and longevity of flower (2 days) were recorded highest under open condition. The inflorescence toppled down from the plant under 50 per cent shade level due to longer peduncle (31.80 cm) and inflorescence (38.00 cm). The plant did not flower on ethrel application under open condition. So with respect to floral characters the plant is suited more for open condition.

The height (20.33 cm) and spread (49.08 cm) of *Billbergia pyramidalis* were significantly higher under open condition. The plant looked more attractive under shaded condition with its apple green coloured leaves and bigger size of the inflorescence. The plant flowered earlier under open condition, 52 days after planting. On ethrel application flowering was much earlier, taking an average of 2.71 days under open condition compared to 6.28 days under 75 per cent shade and taking maximum time, 15.57 days under 50 per cent shade. With respect to the attractiveness of the plant and floral characters, the plant is more suited for 50 per cent shade and 75 per cent shade levels. It can also be kept indoor as potted foliage plant for a period of 47 days after which necrotic symptoms appeared.

In *Bromelia balansae*, height of the plant (30.32 cm) and number of leaves (63.00) were significantly higher under open condition. Spread was recorded significantly higher under open and 50 per cent shade during the different growth periods, but the maximum spread was recorded under 50 per cent shade level (1.77 m). Length and breadth of the leaf were significantly higher under 50 per cent shade level

maximum values being, 50.50 cm and 4.33 cm, respectively. The appearance of the plant was similar under both the condition. So it can be recommended for both 50 per cent shade and open condition.

Among the *Cryptanthus sp.* viz., *Cryptanthus zonatus, C. bivittatus* and *C. bromelioides*, sun scorching was observed in all the species under open condition during December when mean maximum temperature recorded was 31.5°C. *Cryptanthus zonatus* dried out under both the conditions, but on the commencement of rain, during the month of July when the maximum temperature recorded was 30.4°C, average sun shine hrs/day 0.71 and maximum rainfall 1131.9 mm, the mother plant produced new suckers under 50 per cent shade. Flowering was also observed under 50 per cent shade. *Cryptanthus bivittatus* and *C. bromelioides* showed significantly more height (6.10 cm, 14.60 cm, respectively), spread (8.75 cm, 70.41 cm, respectively) and number of leaves (17.83 and 27.33, respectively) under 50 per cent shade level. The leaves looked attractive both under 50 per cent and 75 per cent shade levels. So with respect to the attractiveness of the plant it can be recommended both under 50 per cent and 75 per cent shade level.

In *Dyckia brevifolia* vegetative characters like number of leaves (25.66) and number of suckers (20.00) were significantly higher under open condition. Other flower characters like length of peduncle (8.6 cm), length of inflorescence (22.10 cm), number of leaves (35.80), longevity of inflorescence (67.40 days) and longevity of flower (4 days) were observed maximum under open condition compared to 50 per cent shade. The plant was attractive under 50 per cent shade and open condition. So this plant can be recommended for both 50 per cent shade and open condition.

In *Pitcaenea flammea*, spread (52.83 cm), number of leaves (57.66) and number of suckers (12.33) were significantly higher under 50 per cent shade. But height of the plant and flower characters like days to flower (135 days), length of peduncle (8.60 cm), length of inflorescence (28.10 cm), number of flowers (35.80 cm), longevity of inflorescence (9.40 days) and longevity of the flower (64 days) were significantly higher under open condition The plant is attractive with flowers only so it

is more suited for open condition. The plant can also be kept indoor as potted foliage plant for a period of 7 days after which necrosis appeared.

In *Tillandsia stricta* plant characters like height (25.23 cm), spread (59.98 cm), number of leaves (42.83), leaf length (32.50 cm) and number of suckers (10.00) were higher under open condition. On ethrel application the plant did not flower. But flowering was observed on the commencement of rain during the month of July when the mean maximum temperature recorded was 30.4°C. The colour of the leaves with yellow and green bands was more attractive under open condition. The plant can also be kept indoor as a potted foliage plant for a period of 14 days after which necrosis appeared.

With respect to the growth under different media, *Billbergia pyramidalis* showed highest spread (38.41 cm), percentage of flowering and number of leaves (21.50) in the medium containing equal proportion of coarse sand + sand + vermicompost + cocopeat (M_3). It can be grown in coconut husk for display as in hanging baskets. For *Pitcarnea flammea* a medium containing equal proportion of sand + vermicompost + cocopeat (M_2) is better since maximum height (20.48 cm), number of leaves (57.66) and number of suckers (12.33) were obtained in it. It can also be grown in coconut husk for display as in hanging baskets.

Performance evaluation of ornamental bananas in pots revealed that under 50 per cent shade and open condition, the performance of *Musa rosea* and *Musa rubra* was not good under both the conditions. The plants dried two months after planting. Even though *Musa coccinea* survived under 50 per cent shade, its performance was also poor. Tallest plants were produced under 50 per cent shade, for *Musa ornata* (63.00 cm), *Musa laterita* (35.00 cm) and for *Ensete ventricosum* (28.00 cm). For *Musa ornata* girth of the plant and number of leaves produced showed no significant difference between the two conditions. For *Musa laterita* and *Ensete ventricosum* maximum number of leaves (10.00 and 25.40, respectively) and maximum girth (8.84 cm and 29.70 cm, respectively) were obtained under open condition. All other characters like leaf length, leaf breadth and leaf area were significantly higher under

open condition. Since the height of the plant was more under 50 per cent shade, it resulted in lanky and less robust plants with reduced leaf size. Plants produced suckers but no flowering was observed when grown in pots. *Musa ornata, Musa laterita* and *Ensete ventricosum* can be grown under open condition in pots. *Ensete ventricosum* looks very attractive in pots with its glossy green paddle shaped leaves.

Performance evaluation of ornamental bananas under field condition revealed that *Musa ornata, Musa laterita* and *Ensete ventricosum* are suitable for tropical landscapes for growing under full sunlight than under shaded condition. Flowering was observed in *Musa ornata* three months after planting and in *Musa laterita*, four months after planting.

The flower characters of *M. ornata* and *M. laterita* varied significantly under the field condition. Number of bracts produced was recorded highest in *M ornata* (59.20) followed by *M.laterita* (34.30). Flower size was also recorded highest for *M. ornata* (5.95 cm) followed by *M laterita* (4.21 cm). Male flowers per bract were highest for *M laterita* (4.50) and lowest for *M. ornata* (3.20).

Studies on pollen viability revealed that pollen viability was higher for *Musa ornata* (84.0%) compared to *Musa laterita* (77.0%).

Compatibility studies between *Musa sp.* revealed that both the species are compatible with each other. In the cross between *M. laterita* and *M. ornata*, 3357 seeds were obtained from 42 fruits. From the cross between *M. ornata* x *M. laterita*, 1342 seeds were obtained from 29 fruits. The time taken for germination of seeds varied from 63 to 72 days. Performance of the seedlings from *M. ornata* x *M. laterita* was superior compared to those of *M. laterita* x *M. ornata* with respect to the vegetative characters.

Studies on the vase life of Bromeliads showed that longest vase life was for *Ananas nanus* (19 days) followed by *Pitcarnea flammea* (3 days) and minimum for *Billbergia pyramidalis* (2 days). For *Musa ornata* the bracts withered and abscised two days after keeping in water.

Suckers of Bromeliads and ornamental bananas were irradiated with different doses of gamma rays. In *Billbergia pyramidalis* all the suckers except those irradiated with 15 Gy sprouted six months after planting. The control plants sprouted seven months after planting. Suckers subjected to gamma rays @ 25 Gy produced plants with reduced height, leaf length and leaf breadth compared to others. Treatment of gamma rays @ 20 Gy on the seeds of ornamental bananas resulted in higher germination percentage (70%) and earlier germination (14 days) compared to others. None of the irradiated rhizomes of ornamental bananas sprouted.

References

REFERENCES

Abraham, V. and Desai, B.M. 1976. Radiation induced mutants in tuberose. *Indian J. Genet.* 36:328-381

Anderson, R.G. 2004. Plants for home and office Bromeliad. [On-line] Available: www.ca.uky.edu. [07 August. 2006]

Balasimha, D. 1989. Light penetration pattern through arecanut canopy and leaf physiological characteristics of intercrops. *J. Plantn. Crops.* 16: 61-67

Banerji, B.K. and Datta, S.K. 2002. Induction and analysis of somatic mutation in chrysanthemum. *J. Ornamental Hort* 5(1):7-11

Banerji, B.K., Datta, S.K. and Sharma, S.C. 1994. Gamma irradiation studies on gladiolus cv. White Friendship. *J. Nuclear Agric. Biol.* 23:127-133

Banerji, B.K., Dwivedi, A.K., and Datta, S.K. 1996. Gamma irradiation studies on rose and chrysanthemum. *J. Nuclear Agric. Biol.* 25:63-67

Barfurs, M., Samuel, R., and Till, W. 2002. Generic Delimitation and molecular phylogeny in sub family Tillandsioideae (Bromeliaceae) based on fine cp DNA Markers. In: *Proceedings of the Scientific Seminar on Bromeliad Taxonomy, Diversity, and Environmental Threats* ,15th May 2002. Institute of Botany. University of Vienna., Austria, pp. 45-46

Bayer, R. 2007. Tips on Growing and Enjoying Bromeliads. [On-line] Available: www.bromeliad society houston.org. [05 March. 2007]

Benzing, D.H. 1980. *The Biology of the Bromeliads.* Mad River Press, Eureka,CA USA,300 p.

Berry, D. 2000. Notes on the intensity of colour in spikes of Tillandsias. [On-line] Available: www.neworleans.bromeliadsociety.com. [02 December. 2006]

Black, R.J. and Dehjan, B. 2003. Bromeliads. [On-line] Available: www.bsi.org. [07 August. 06]

Broertjes, C. 1972. Use in plant breeding of acute, chronic or fractional doses of X-rays or fast neurons as illustrated with leaves of saintpaulia. *Agric.Res.Rep.*776:74

Broertjes, C. and Harten, A.M.V. 1978. *Application of Mutation Breeding Methods in the Improvement of Vegetatively Propagated Crops.* Elsevier Scientific Publishing Co., New York,313 p.

*Buiatti, M. and Tesi, R. 1968. Gladiolus improvement through radiation induced somatic mutation. *Laboratorio di Mutagenesi e differenziamento del* 16:35-37

Butcher, D. 1999. Lyman B. Smith and Hybrids. [On-line] Available: http://fcbs.org. [28 January. 2007]

Carneiro, L.A., Araujo, R.F.G., Brito, G.J.M., Fonseca, M.H.P.B., Cosla, A., Crocomo, O.J., and Mansur, E. 1998. *In vitro* regeneration from leaf explants of *Neorgelia cruenta* (R. Graham) L.B. Smith, an endemic bromediad from Eastern Brazil. *Pl. Cell Tissue Organ. Cult.* 55(2): 79-83

Cathcart, D.J. 1995. The importance of maintaining Bromeliad imports. *Fla. Entomologist* 78(1): 16-20

Catlan, J. 2005. Air and potted bromeliads. *Bromeliaceae* 39(2): 19-20

Charley, W.B. 2006. Making an inflorescence last. *Bromeliaceae* 11(3): 42

Cheesman, E.E. 1947. Classification of the bananas. *Kew bull* 2: 97-100

Chomchalow, N. 2004. Flower forcing for cut flower production with special reference to Thailand. AU J. T. 7(3): 137-144

Collingbourne, H. 2000. *Ensete* suckering. [On-line] Available: http://www.rose downmill.co. uk. [02 December. 06]

Constantine, D. 2002. UK Musaceae. [On-line] Available: www.users.globalnet.uk. [02 December. 06]

Constantine, D. 2006. Propagating Ornamental Musaceae. *Plantsman* 8(4):110-113

Crane, J.H., Balerdi, C.F., and Maguire, L. 2005. Banana growing in the Florida Home Landscape. [On-line] Available: http://edis.ifas.ufl.edu. [05 December. 2006]

D'Amato, F., Moschini, E., and Pacini, L. 1964. Somatic mutations in carnations induced by gamma rays. *Caryologis* 17(1):93-101

Datta, S.K. and Banerji, B.K. 1995. Improvement of garden chrysanthemum through induced mutation. *Flora Fauna* 1(1):1-4

de Carvalho, L.F.N. 2000. Variegation in Bromeliads. *J. Bromeliad Soc.* 50(4): 182-185

de Silva, S., da Silva, K.M., de Borger, M., and de Oliverea, R.P. 1999. Pollination and culture of banana embryos. *INFOMUSA* 8(2): 25-26

Delin, W. and Kress, W.J. 2000. Musaceae. *Flora China* 24(4): 297-313

Desai, B.M. and Abraham, V. 1974. Radiation induced mutants in canna. *Proceedings of Symposium on the use of radiations and radioisotopes in studies of plant productivity.* Pant Nagar, pp.214-217

Devouard, H. 2004. Banana taxonomy. [On-line] Available: www.inhibap.org. [05 December.2006]

Eckstein, K., Robinson, J.C., and Fraser, C. 1997. Physiological responses of banana (Musa AAA: Cavendish subgroup) in the subtropics - VII. Effects of Windbreak shading on phenology, physiology and yield. *J. Hort. Sci.* 72: 389-396

Flower, A. 2001. Notes on growing Bromeliads from seed. [On-line] Available: www.anwyl.com. [22 March.2007]

Foster, A. 1996. Pollination and hybridization. [On-line] Available: http://fcbs.org[07 August. 2006]

Foster, S. 1945.cited by Zimmer (2007). Control of flowering in Bromeliads [On-line]. Available: www.actahort.org.[07 August. 2006]

Frogge, M.J. 2005. Bromeliads need strong light, warm temperatures to survive. [On-line] Available: www.lancaster.bind.edu. [27 April. 2006]

*Gardner, C.S. 1984. Natural hybridization in Tillandsia subgenes: *Tillandsia. Selbyana* 7: 380-392

Garrison, D. 1998. Cultural tips: Growing from seed. [On-line] Available:www.bromeliadsocietyhouslon.inc.[07 August. 2006]

Gordon, S.A. 1954. Occurrence, formation and inactivation of auxins. *Ann. Rev. Pl. Physiol.* 5:341-378

Govil, S. and Gupta, S.C. 1997. Commercialization of plant tissue culture in India. *Pl. Cell Tissue Organ Cult.* 51: 65-67

Gupta, M.N. 1979. *Progress in Plant Research.* NBRI Silver Jubilee Publication, Lucknow,75 p.

Gupta, M.N. and Shukla, R. 1970. Mutation breeding of garden roses: Studies on induction of somatic mutations after gamma irradiation of bud wood. *Progressive Hort.* 2(3): 69-83

Gupta, M.N., Laxmi, V., Dixit, V.S., and Srivastava, S.N. 1982. Gamma ray induced variability in *Costus speciosus. Progressive Hort.* 14: 193-197

Hakkinen, M. and Sharrock, S. 2001.In: Diversity in the genus Musa: Focus on Rhodoclamys - Focus Paper IV. *INIBAP Annu. Rep.*. INIBAP, Mont Pellier, France, pp.54-62

Hakkinen. 2007. Ornamental Bananas: Focus on Rhodoclamys. *Chronica Hort.* 47(2): 7-12

Hardy, R. 2006. Charcoal, the forgotten ingredient. *Bromeliaceae* 11(4): 5-6

Haskins, F.A. and Chapman, H.W. 1956. Effects of irradiation, maleic hydrazide, temperature, and age on enzyme activity in seedlings of corn (*Zea mays* L.). *Physiologia Pl.* 9: 355-362

Head, O. 2007a. Mounting Bromeliads. Available: www.bsi.org. [22 March. 07]

Head, O. 2007b. Wonderful world of Bromeliads. [On-line] Available: www. bromeliads ocietyhoston.inc. [02 January. 2007]

Heer, B and Montgomery, T. 2006. CAM metabolism. *Bromeliaceae* 11(3): 45

Hickman, M. 2007. Get growing gardening tip. [On-line] Available: www. devonianvalberta.ca/dbg.html. [28 January. 2007]

Ingram, D. 2003. Landscape plant propagation work book: Unit IV. Propagation by division. [On-line] Available: http://edis.ujais/ujl.edu. [07 August. 2006]

Jerzy, M., Zalewska, M., and Altman, A. 1997. Flower colour recurrence in chrysanthemum and Gerbera mutants propagated *in vitro* from meristems and leaf explants. *Acta Hort.* 447: 611-614

Johnson, C. 1995. Cultural hints for bromeliad growers. [On-line] Available: http://fcbs.org. [07 August. 2006]

*Kerns, K. 1936.cited by Zimmer (2007) Control of flowering in Bromeliads. [On-line] Available: www.actahort.org.[07 August. 2006]

Killengley, E. 2006. Pollination of Bromeliads. *Bromeliaceae* 11(2): 5

Lapade, A.G., Veluz, A.M.Z., Marbella, L.J., Bamida, A.C., and Rama, M.G. 2002. *Status of mutation breeding in vegetatively propagated crops in Philippines.* Papa. Philippine Nuclear Research Institute, Philippines,180 p.

Londers, E. Ceusters. J. Godts. C. Vervaeke, I., De Droft, M.P., Deroose, R., and Deroose, P. 2003. Aechmea (Bromeliaceae) production in mild winter climate implication on leaf quality. [On-line] Available: www.actahort.org.[07 August. 2006]

*Luther, H.E. 1984. A hybrid Pitcarnea from Western Ecuador. *J. Bromeliad Soc.* 34: 272-274

Smith.L.B 1979. Bromeliaceae. *Flora Neotropica* 14(2): 1-3

*Mabuchi, T. and Kuwada, H. 1974. Radiation effects on the shoot tip cultures of chrysanthemum. *Kagawa Daigaku Nogakubu Gakuzyatu Hokokes* 25: 171-177

Macias, M. 2003. Induced suckering in *Ensete*. *INFOMUSA* 12(1): 56

Mackay, J. 1951. Neutron and X-ray experiment in barley. *Hereditas*. 37: 421-464

Margaret, M. and Butcher, P. 2007a. An illustrated guide to asexual reproduction. [On-line] Available: http://fcbs.org. [07 August. 2006]

Margaret, M. and Butcher, P. 2007b. An illustrated guide to mounting Tillandsias. [On-line] Available: http://fcbs.org. [07 August. 2006]

Mayers, A., Newmann, J., Reid, M., and Dodge, L. 1997. New Ethylene Inhibitor could extend flower life. *Perishable Handling. Q. Issue* 92: 9-11

McLaughlin, J. 2006. Looking to accentuate the Tropical? "Ornamental Bananas, Bird of Paradise and Travellers tree".[On-line] Available: http://miamidade. ifas. ufl. edu/ publications.htm. [02 December. 2006]

McWilliam, E.L. 1974. Evolutionary ecology: Bromeliaceae .In: *Flora Neotropica Monograph*. Smith, L.B. and Dows, R.J. (eds.), Hafiner Publishing Co., New York, USA, pp. 40-45

Morris, B. 2007. Problems with breeding and interpreting results. [On-line] Available: http://fcbs.org. [22 March. 2007]

Muller, H.J. 1954. The nature of the genetic effects produced by radiation. In :*Radiation Biology Vol.I I* Vellaender, A.(ed.), Mc Graw Hill, New York, 351 p.

Nelson, S.C., Ploetz, R.C., and Kepler, A.K. 2006. *Musa* species (Banana and plantain). [On-line] Available: www.traditional.tree.org. [08 January. 2007]

*Neto, A.T. and Latado, R.R. 1970. Induction of *in vivo* mutation in chrysanthemum (*Dendranthema grandiflora* Tzvelev) cv. Repin Rosa breeding. *Pesquisa Agropecuaria Brasileira*. 32: 1153-1158

Norgrove, L. 1998. *Musa* in Multistrata system: Focus on shade. *INFOMUSA* 7(2):17-21

Ono, S. 1971. Studies on the radiation breeding in the genus *Mentha* :Effective irradiation techniques to induce mutation in mint. *Sci. Rep. Fac. Agric. Akagama Univ.* 37: 9-15

Paroz, P. 2005. Beginners Guide. *Bromeliaceae* 39(3): 17-18

Patil, A.V., Kale, P.N., and Kaulgud, S.N. 1975. Some observations of gamma irradiation on growth and flowering of tuberose bulbs. *Curr. Sci.* 44: 406-407

Pennisi, V.B. 2006. *Growing Indoor Plants with Success*. Dept. of Cooperate Extension, College of Agricultural and Environmental Sciences, University of Georgia, 60 p.

Pertuit, A.J. 1995. Understanding and Producing Bromeliads. [On-line] Available: http.//hgic. clemon.edu/ [28 January. 2007]

Pierce, S., Winter, K., and Griffithi, H. 2002. The role of CAM in high rainfall for cloud forests an *in situ* comparison of photosynthetic pathways in *Bromaliaceae* 25(9): 1181-1189

Plever, H. 2006a. Does your potting mixture breath ?. *Bromeliaceae* 11(3): 32-34

Plever, H. 2006b. Richters Prescient Vision of Bromeliads as House plants. *Bromeliana* 43(5): 2-4

Prince, M. 2002. Truefull - sun Bromeliads. [On-line] Available: http://fobs.org. [02 January. 2007]

Przyblyla, A.A. and Cadic, A. 2000. Mutagenesis in creation of new *Alstroemeria* genotypes. *Acta Hort.* 508: 351-353

Raghava, S.P.S., Negi, S.S., Sharma, T.V.R.S., and Balakrishnan, K.A. 1988. Gamma ray induced mutants in gladiolus. *J. Nuclear agric. Biol.* 17: 5-10

*Rather, Z.A. and Jhon, A.Q. 2000. Effect of ^{60}Co gamma rays on Dutch iris. *J. Ornamental Hort.* 3(2): 71-74

*Read, R.W. 1984. Natural hybridization: the problem In: *Proceedings of the 1982 World Bromeliad Conference* (ed. Garnder, S.), Mission Press, Texas, USA, pp.98-104

Reilly, B. 2005a. Albino Bromeliads. *Bromeliaceae* 39(5): 34-35

Reilly, B. 2005b. Growing Pitcarnias and Pepinias. *Bromeliaceae* 39(3): 19-22

Relf, D. 1997. Bromeliads. [On-line] Available: www.ext.vt.edu. [27 April. 2006]

Robinson, J.C. and Nel, D.J. 1988. Plant density studies with banana (cv. Williams) in a subtropical climate 1. Vegetative Morphology, Phenology and Plantation microclimate. *J. Hort. Sci.* 63: 303-313

Romanowski, M. 2003. Colour my world.[On-line] Available: www.victorianbromeliadosciety.com. .[07 August. 2006]

Russ, K. 2007. Bromeliads. [On-line] Available: http://hgic.clemenson.edu. [22 March. 2007]

Sambandamurthi, S. 1983. Studies on induced mutations in tuberose (*Polianthes tuberose* L.). Ph.D. thesis, Tamil Nadu Agricultural University, Coimbature, 206 p.

*Samyn, G. 1991. Aechmea a genus with some interesting types of cut flower culture. *Veebonds nieuws-voor-de-Belgische-Sierleelt* 36 (13) 810-812

*Samyn, G. 1992. Cut flower culture of bromeliads, an evaluation of the first practical study of cut flower production with Aechmea leucocarpa Andre (Bromelioideae). *Revue-de-Agriculture* 45(3):490-497

Schmidt, E. 2007. Bananas in Central Florida. Available: www.leugardens.org. [08 January. 2007]

Schoellhorn, R. 2003. Bromeliads; Longlasting Tropical Colour. *Green Products News* 13(2): 8-14

Sharrock. 1997. The banana and its relatives - Focus paper III.In:.*INIBAP Annu. Rep. INIBAP.* Mont Pellier, France, pp.62-70

Sharrok, S. 1996. *Uses of Musa - Focus paper III* In : *INIBAP Annu.Rep.* INIBAP, Mont Pellier, France, pp.52-60

Shepherd, K. 1999. Rhodoclamys and M. flaviflora, their hybrids with AA and BB. In : *Cytogenetics of the genus Musa.* INIBAP, IPGRI, pp.55-56

Simmonds, N.W. 1962. *The evolution of the bananas.* Longmans Green and Co. Ltd., London, 170 p.

Singh, K.P. 2002. Gamma rays mutagenesis in gladiolus. *National Symposium on Indian Floriculture in the New Millenium*, 25-27 February 2002. Indian Society of Ornamental Horticulture, IARI, New Delhi. Abstract: 60

Sparrow, A.M. 1961. Types of ionizing radiation and their cytogenetic effects. *Mutat. Pl. Breed.* 891: 55-119

Stebbins, G.L. 1959. The role of hybridization in evolution. *Proceeding of the Am.Phil. Soc.* 103: 231-251

Stenhouse, R. 2006. Bromeliad tissue culture laboratory comes to Queensland. *Bromeliaceae* 11(6): 34-36

Thomas, P.A. 1999. *Propagating House Plants.* Department of Extension and Management, University of Georgia, College of Agriculture and Environmental Science. 84 p.

Trinklein, D.H. and Rothernberger, R.R. 2007. Caring for house plants. [On-line] Available: www.missowri.edu.xplor. [02 January. 2007]

Uma, S., Saraswathi, M.S., Durai, P., and Sathiamoorthy, S. 2007. Diversity and distribution of section Rhodoclamys (Genus *Musa,* Musaceae) in India and breeding potential for banana improvement programmes. PGR *Newsl.* 146: 17-23

Valmoyer, R.V. and Le Dinh Danh. 2002. Classification and characterisation of *Musella splendida sp. nov. INFOMUSA* 2(2): 24-27

VanGal, P. 2007. Foliar feeding of Bromeliads. [On-line] Available: www.hunterdistructbromeliadsociety. com[07 February 2007]

Vervaeke, I., Deroose, R.,and DeProft, M.P. 2007a. Available: Interspecific and intergeneric hybridisation in Bromeliaceae. [On-line] www.actahort.org. [28 January. 207]

Vervaeke, I., Deroose, R.,and DeProft, M.P. 2007b. Interspecific and intergeneric hybridisation in Bromeliaceae. [On-line] Available: http://www.actahort.org. [05 December. 2006]

Vissers, M. and Thomas, F. 1997. Winter flowering trial for different Bromeliaceae. *Verbondsnieuws* 40(6): 32-33

Watson, L. and Dalliwitz, M.J. 2006. The families of flowering plants. [On-line] Available http://delta-intkey.com.[07 August. 2006]

Wu, C.Y. 1976. *Musella lasiocarpa. Icongraphica Cormophytorum Sini corum* 42(3):52-55

Younis, S.E.A. and Borham, J.H. 1975. The effects of gamma irradiation on *Polianthes tuberosa. Egypt. J. Bot.* 18: 205-217

Zhenhua, P., Shoutte, J. and DeWei, Z. 1995. New chrysanthemum varieties developed by radiation breeding and micropropagation. *Acta Hort.* 404: 128-130

Zirkle, C. 1937. Acetocarmine mounting media. *Science* 85: 528

* Originals not seen

Appendices

APPENDIX - I

Meteorological data during the period of observation

Months/ year	Maximum temperature °C	Minimum temperature °C	Total rainfall (mm)	No. of rainy days	Relative humidity (%)		Average sunshine hours per day
					Morning	After noon	
November 2006	31.7	23.7	79.5	5.0	83	60	6.5
December 2006	31.5	23.6	0.0	0.0	68	45	7.8
January 2007	32.5	22.0	0.0	0.0	37	54	8.7
February 2007	34.5	22.2	0.0	0.0	77	33	9.8
March 2007	36.0	24.4	0.0	0.0	86	39	8.2
April 2007	35.7	25.0	64.0	4.0	85	52	7.6
May 2007	32.8	24.6	240.5	10.0	87	65	6.6
June 2007	30.2	22.1	825.5	23.0	92	76	3.50
July 2007	30.4	21.7	131.9	28.0	94	82	0.71

Collected from the Department of Agricultural Meteorology, College of Horticulture, Vellanikkara

APPENDIX - II

Mass arrangement in the interiors

Mass arrangement in the exterior

Plate 1. Use of bromeliads in landscapes and interiorscapes

A rockery with Bromeliads near a pond

A Bromeliad tree

Bromeliad under shade

Plate 2. Use of bromeliads in landscapes and interiorscapes

Bromeliad as a pot plant

Bromeliad as an accent plant

Bromeliad as flowering plants

Plate 3. Use of bromeliads in landscapes and interiorscapes

Bromeliads in a trophy arrangement

Bromeliads displayed in hanging baskets

Bromeliads in open landscapes

Plate 4. Use of bromeliads in landscapes and interiorscapes

APPENDIX - III

As an accent plant

As a background for flowers

Plate 1. Landscape uses of ornamental bananas

Planted in clumps

Corner planting

Plate 2. Landscape uses of ornamental bananas

Planted in backyard

As a pot plant

Plate 3. Landscape uses of ornamental bananas

EVALUATION OF ORNAMENTAL BANANAS AND BROMELIADS FOR TROPICAL LANDSCAPES

By

HAZMIN. H.

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the
requirement for the degree of

Master of Science in Horticulture

Faculty of Agriculture

Kerala Agricultural University, Thrissur

Department of Pomology and Floriculture

COLLEGE OF HORTICULTURE

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2007

ABSTRACT

Performance of Bromeliads and ornamental bananas was evaluated at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during the period from 2005-2007. The objective of study was to evaluate their suitability under different shade levels and to recommend them for tropical landscapes, interior plantscapes and explore the possibility of production of novel varieties by irradiation and hybridization. Nine Bromeliads and six ornamental bananas were selected for the study.

Results of the investigation revealed that among the Bromeliads, *Aechmea fasciata, Ananas bracteatus, Bromelia balansae* and *Dyckia brevifolia* can be grown under both open and 50 per cent shade. *Aechmea fasciata* looked more attractive under shaded condition, but flowering was observed under open condition only. When the temperature was above 34°C, sun scorching was observed on leaves. In *Ananas bracteatus* the colour of the leaf was more pronounced under open condition but the number of leaves and length and breadth of leaves were more under 50 per cent shade. In *Dyckia brevifolia* the number of leaves and suckers produced was more under open condition. Though maroon colour was more pronounced under open condition it developed an acceptable colour under shade also. *Bromelia balansae* looked attractive both under 50 per cent shade and open.

Ananas *nanus, Billbergia pyramidalis, Cryptanthus zonatus, C.bivittatus* and *C. bromelioides* are suited only under shade with respect to their vegetative and floral characters. In *Ananas nanus* and *Billbergia pyramidalis,* longer inflorescences were produced under shaded condition. In *Billbergia pyramidalis,* it was a desirable character but in *Ananas nanus* it leads to toppling down of the inflorescence.

Performance of *Cryptanthus* species was better under 50 per cent and 75 per cent shade with respect to the vegetative characters and attractiveness of the plant.

The plant looked attractive only under shaded condition. Under open condition sun scorching was observed.

Pitcarnea flammea and *Tillandsia stricta* are suited for open condition than under 50 per cent shade. *Pitcarnea flammea* flowered only under open condition. The plant is attractive with its flowers only. In *Tillandsia stricta* the vegetative characters and the colour of the leaves were better under open condition. Flowering was also observed only under open condition.

Performance of Bromeliads like *Billbergia pyramidalis* and *Pitcarnea flamea* under different media revealed that the growth was better in the media containing equal proportion of sand + vermicompost + cocopeat and coarse sand + sand + vermicompost + cocopeat. These media containing organic matter supplied nutrients and coarse sand provided good drainage revealed that Bromeliads responded well if grown under suitable media. It can also be grown in coconut husk, for display in hanging baskets.

Under 50 per cent shade the ornamental bananas looked lanky, less robust with reduced leaf size. Ornamental bananas like *Musa oranata, Musa laterita* and *Ensete ventricosum* can better be grown in pots under open condition than under shade. *Ensete ventricosum* was the best suitable for growing in pots because of its paddle shaped, attractive, glossy green leaves with pink midrib.

Under open condition the performance of *Musa ornata, M. laterita* and *Ensete ventricosum* were good with respect to vegetative characters. The plants looked robust and flowering was also observed in *Musa ornata* and *M. laterita*. The number of bracts and size of the male and female flowers were more for *Musa ornata* compared to *M. laterita*, but the number of male flowers was produced more in *Musa laterita*. *M. ornata*, *M. laterita* and *Ensete ventricosum* can be recommended as landscape plants under tropical areas.

Under indoor condition *Billbergia pyramidalis* performed better compared to *Pitcarnea flammea* and *Tillandsia stricta.* It can be kept as potted foliage plant for a period of 47 days.

Maximum vase life was recorded for *Ananas nanus* followed by *Pitcarnea flammea* and minimum for *Billbergia pyramidalis*. *Musa ornata* recorded a vase life of two days. Among these *Ananas nanus* can be used in flower arrangements, since it has substantially long vase life (19 days).

With a view to explore the possibility of improvement by hybridization, pollen fertility and compatibility studies were conducted in *Musa sp.* The viability of pollen grains was more for *Musa ornata* (84.0%) compared to *Musa laterita* (77.0%). They were also compatible and hybrid seedlings were also produced which revealed that new varieties can be evolved and they have great potential for use as landscape plants under tropical areas.

Irradiation studies were conducted in Bromeliads and *Musa sp.* for induction of variability. In Bromeliads, suckers of *Billbergia pyramidalis* subjected to gamma rays @ 25 Gy gave rise to plants with lesser height, leaf length and leaf breadth. Suckers of *Tillandsia stricta* did not sprout and all remained healthy. Induction of gamma rays @ 20 Gy on seeds of ornamental bananas resulted in earlier germination. The rhizomes subjected to irradiation did not sprout and all remained healthy even eight months after the treatment.