INTERIOR LANDSCAPE ARCHITECTURE:

THE TECHNOLOGY, ART AND APPLICATION

by

CAROL MARLENE MESSER

A practicum submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements for the degree of

MASTER OF LANDSCAPE ARCHITECTURE.

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ABSTRACT

The purpose of this practicum is to compile a manual of the technology, art and application of interior landscape architecture principles for designers. The objective is to illustrate how the designer may create desert or rainforest imagery within the confines of architecture, while satisfying horticultural requirements.

This was accomplished by examining the natural desert and rainforest environments and identifying the following basic elements: the horticultural factors - temperature, light, precipitation, relative humidity, and soil; and the inherent qualities of the natural landscape and plants - light, scale, colour, form, texture and line. The interior environment was examined and basic elements identified: human comfort - temperature, relative humidity, and light; horticulture - temperature, relative humidity, light, moisture, transpiration, soils, nutrients and gases; and architecture - interior finishes, equipment access and planter design.

The principles of interior landscape architecture technology and art were applied in the development of two prototypes for a lobby area in Winnipeg, Manitoba.

Interior landscape architecture environmental imagery may be created when the following components are included in the design:

1. We are obligated to create environments for people therefore human psychological and comfort needs must be satisfied.
2. The proper horticultural requirements must be provided for the plants selected, especially light, to ensure plant health, growth and maintenance.
3. Through the use of abstracted qualities from the natural plant's environment and the plants themselves, more unified and exciting interior spaces may be created.

ACKNOWLEDGMENTS

I wish to thank the members of my committee, Garry Hilderman, Leon Feduniw and Louis Lenz for their guidance and assistance in the completion of this project. Their advice and input was greatly appreciated.

I also wish to thank Ron Cassels and Tammy Levigne for their patience and perserverance in putting this document together.

Finally, but not least of all, I wish to thank my husband Philip Messer for his moral support and encouragement which made this all possible.

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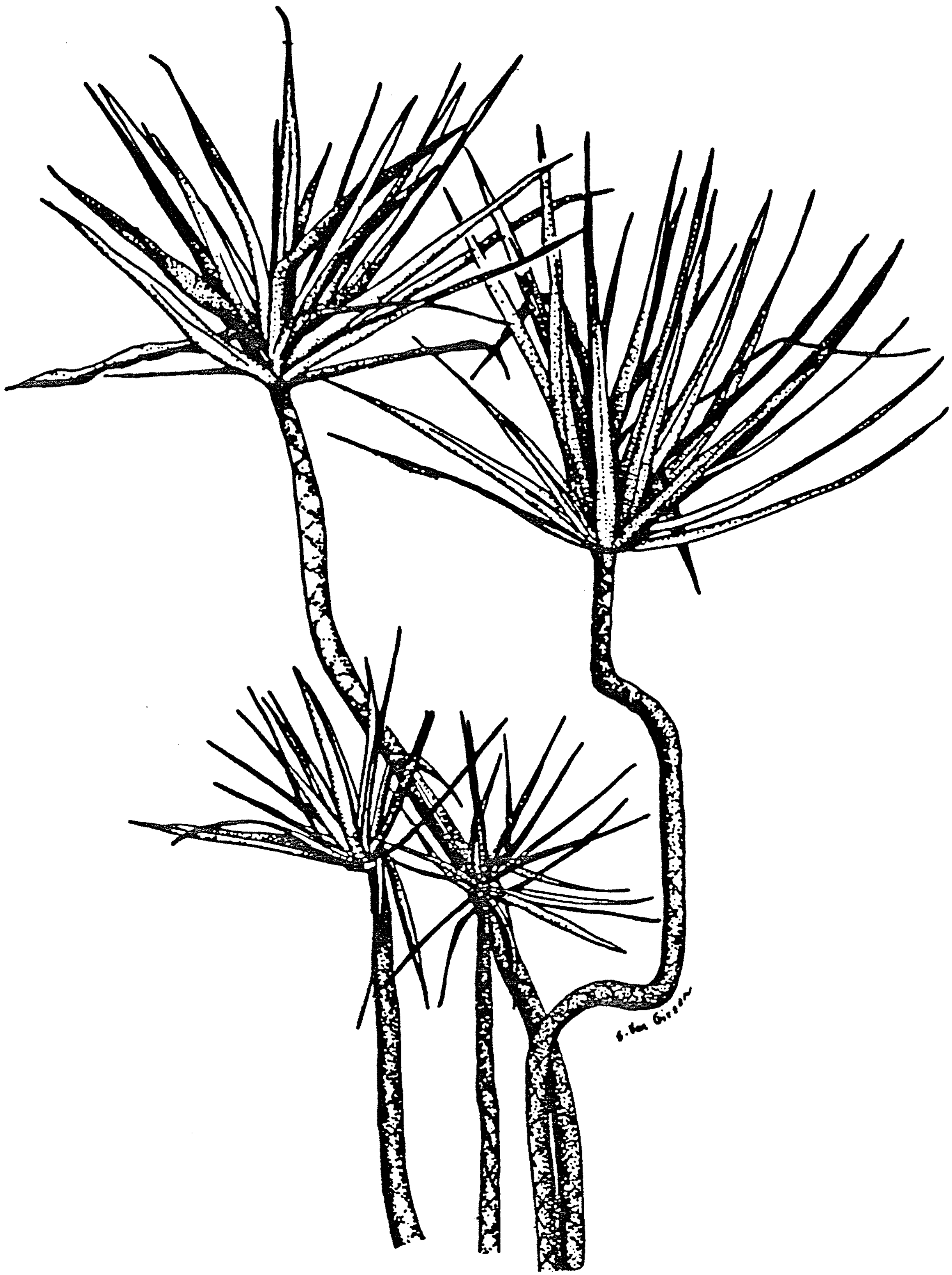


1.1 THE NECESSITY FOR INTERIOR LANDSCAPE ARCHITECTURE

Currently Man exists in two landscapes, the natural and the cultural. The natural can be defined as occurring where ecological forces are dominant. The cultural landscape is identified by evidence of human interaction with nature over time. Humanity is bound by nature's forces and must establish a habitat within nature's balanced and self-renewing environment. Man must understand nature, learn from her and use her as a reservoir of inspiration and discipline.

Since the beginning of time man has had a symbiotic relationship with nature. Man is part of nature and is constantly affected by his physical surroundings. Each of us is dependent on it, not only for the material necessities of life, but for the balanced functioning of our senses and ultimately for emotional well-being. Sounds, light, forms, textures, colors, movement and other living organisms in our environment influence, for better or worse our physical or psychological condition. This is merely another aspect of our participation in nature.

In Man's rapidly changing world where technology continually calibrates, refines and sometimes decimates the world, nature provides support and consolation in her beauty and is of greater value than ever before. Now because of the speed and ability of human beings to change the environment drastically, we should not forget that despite our advanced technology, we are creating environments for human beings and that our emotional and physical needs are much the same as our ancestors thousands of years ago. For centuries, nature has brought beauty, quiet and repose to those who have sought a retreat from the burdens of daily life. In today's cultural landscape this link with nature can be strengthened by including nature in our interior environments.

Interior landscaped spaces are symbols of a defiance of winter in northern climates. Winnipeg is one of many northern cities where winter is a natural phenomenon but through planning and design, the extremities of our winter climate can be softened. If jetplanes can be designed to take passengers in total comfort through high altitudes, why can't the same technology, and designing skills be used to create climatically controlled environments to house year-round tropical oases in high latitudes? "Past generations turned to the technical marvels of their day - hammer and nails, woolen cloth, glass bricks and stoves - to make survival possible in the winter belt. Mere "survival" is not good enough for today's generations, who have seen their lives transformed by planes, television and computers and have for their use miracle technologies previously beyond imagination." [1] No wonder we turn to evolving technology to keep today's well-entrenched expectations of a high quality of life in our northern latitudes competitive with that of warmer climate belts.

In addition to the uplifting psychological and emotional effects of interior plants on the inhabitants of architectural spaces, tropical plants also provide a number of functional and aesthetic duties for the designer. The following examples illustrates these duties:

1. Plants act as visual screens and larger plantings form acoustical barriers between spaces. Plants cleanse the air and refresh the atmosphere through photosynthesis.

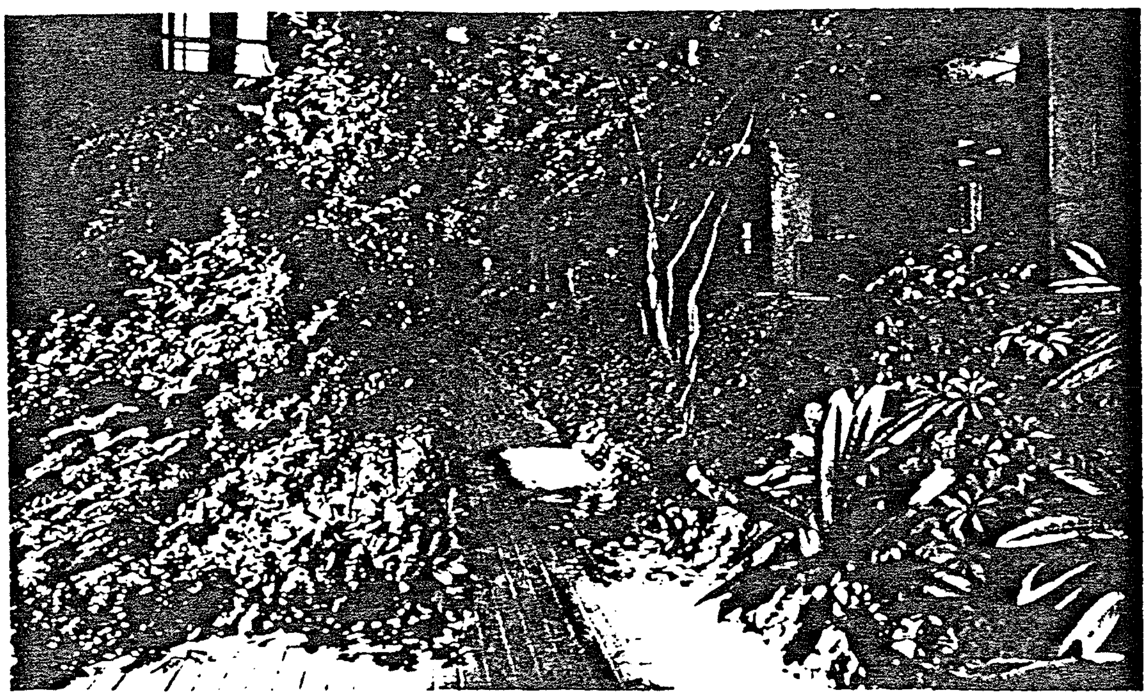


Figure 1.

Source - Ford Foundation Building, New York. Interior Landscape Industry, March 1985, p. 51.

2. Plants help soften hard architectural surfaces and provide texture to nondescript surfaces.

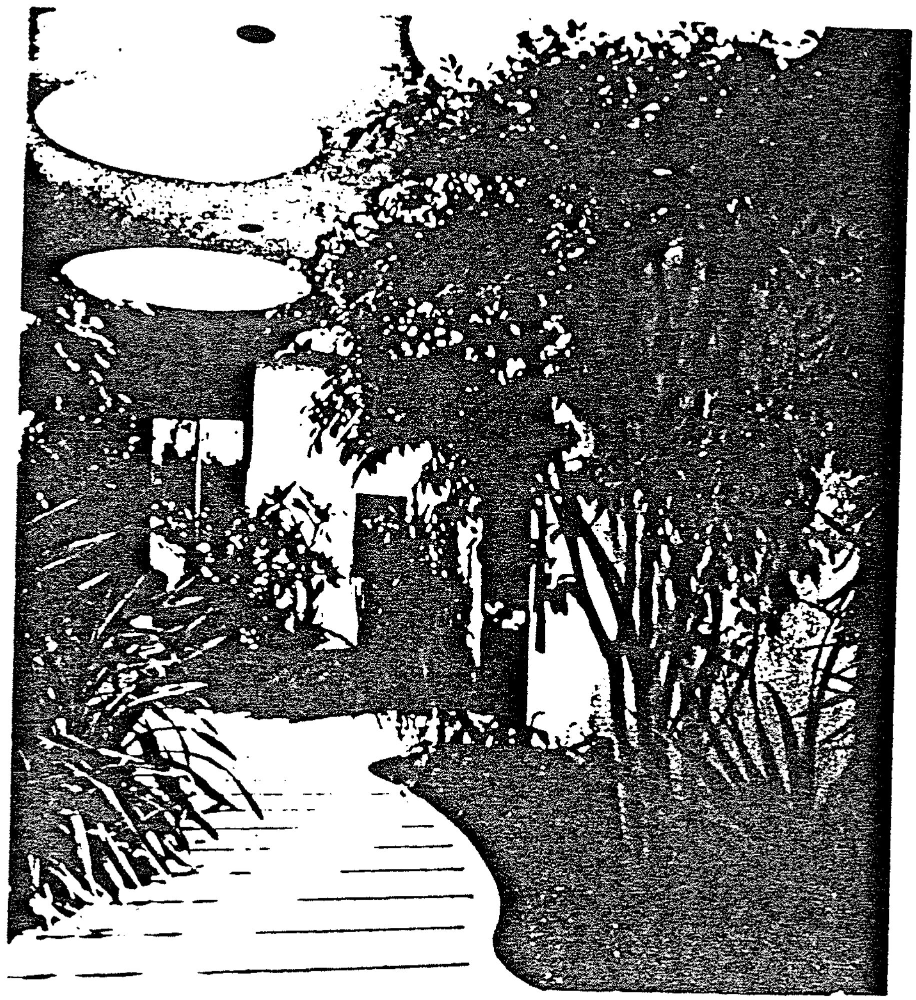


Figure 2.

Source - Residence in Highland Park, Illinois. <u>Interior Landscape Industry</u>, January 1985, p. 51.

3. Plants create and change moods, softening the decor of many modern interiors.

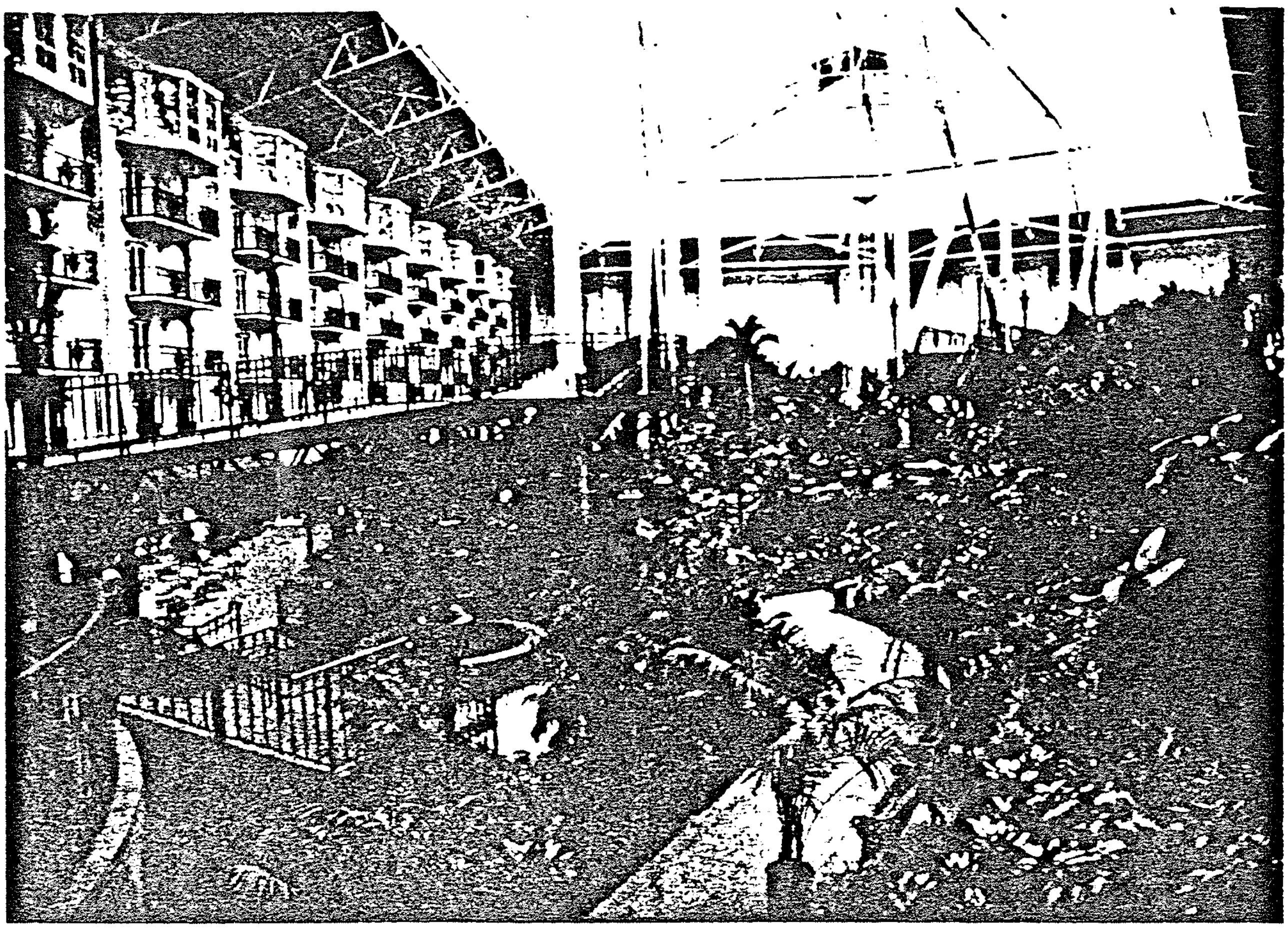


Figure 3.

Source - Opryland Hotel, Nashville. Interior Landscape Industry, October 1984, p. 32.

4. Plants provide a sense of scale and help articulate spatial volume.

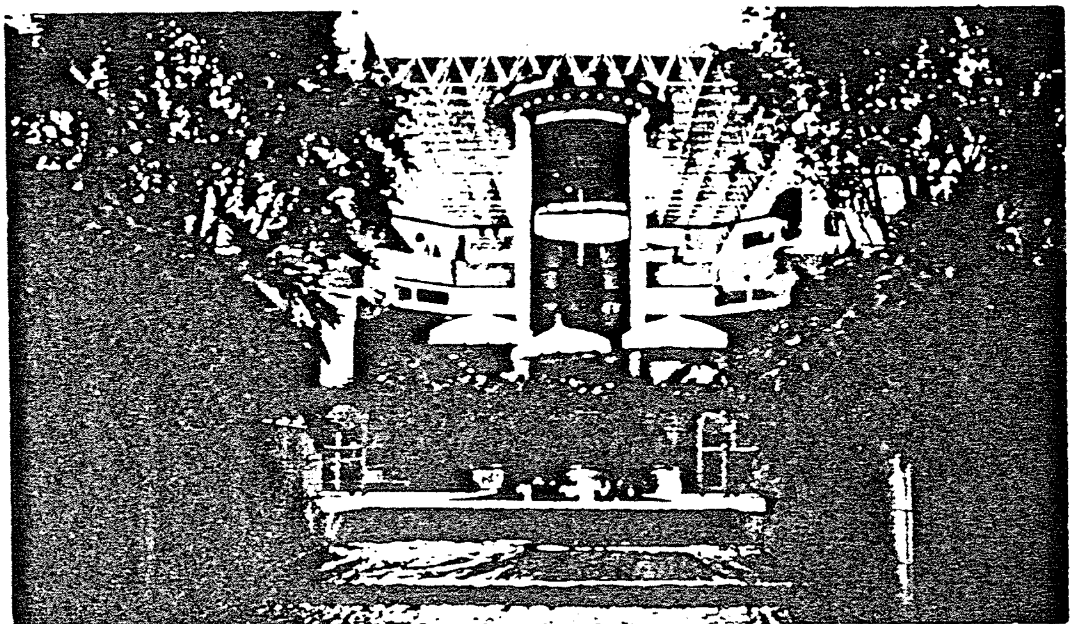


Figure 4.

Source - Hickory Hollow Mall, Nashville. Interior Landscape Industry, October 1984, p. 33.

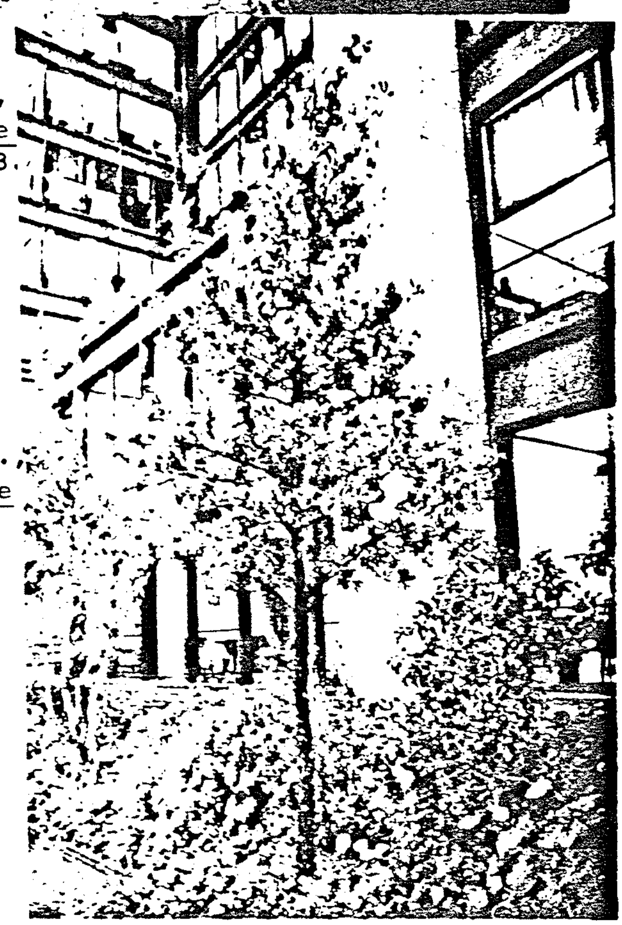


Figure 5.

Source - Ford Foundation Bld., New York. Interior Landscape Industry, March 1985, p. 51.

5. Plants aid in directing traffic circulation.

Figure 6.

Source - ClayDesta National Bank, Prairie View, Illinois. Interior Landscape Industry, October 1984, p. 53.

6. Tropical plants act as a transition between the exterior and interior landscaping.

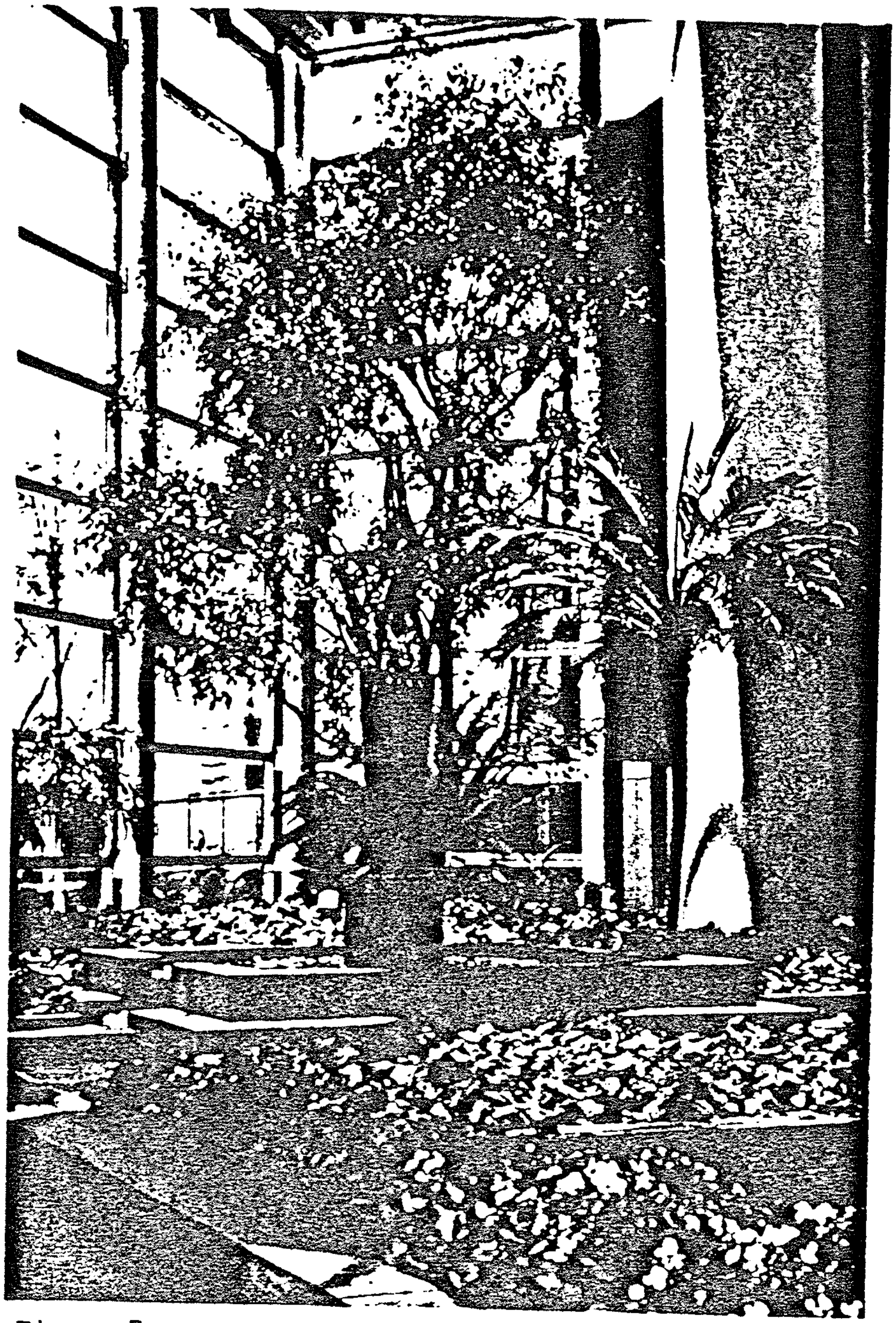


Figure 7.

Source - Crocker Centre, Los Angeles. Interior Landscape Industry, January 1985, p. 61.

7. Plants can be used to indicate a change in floor level, or they can be a colorful treatment of a stairwell.

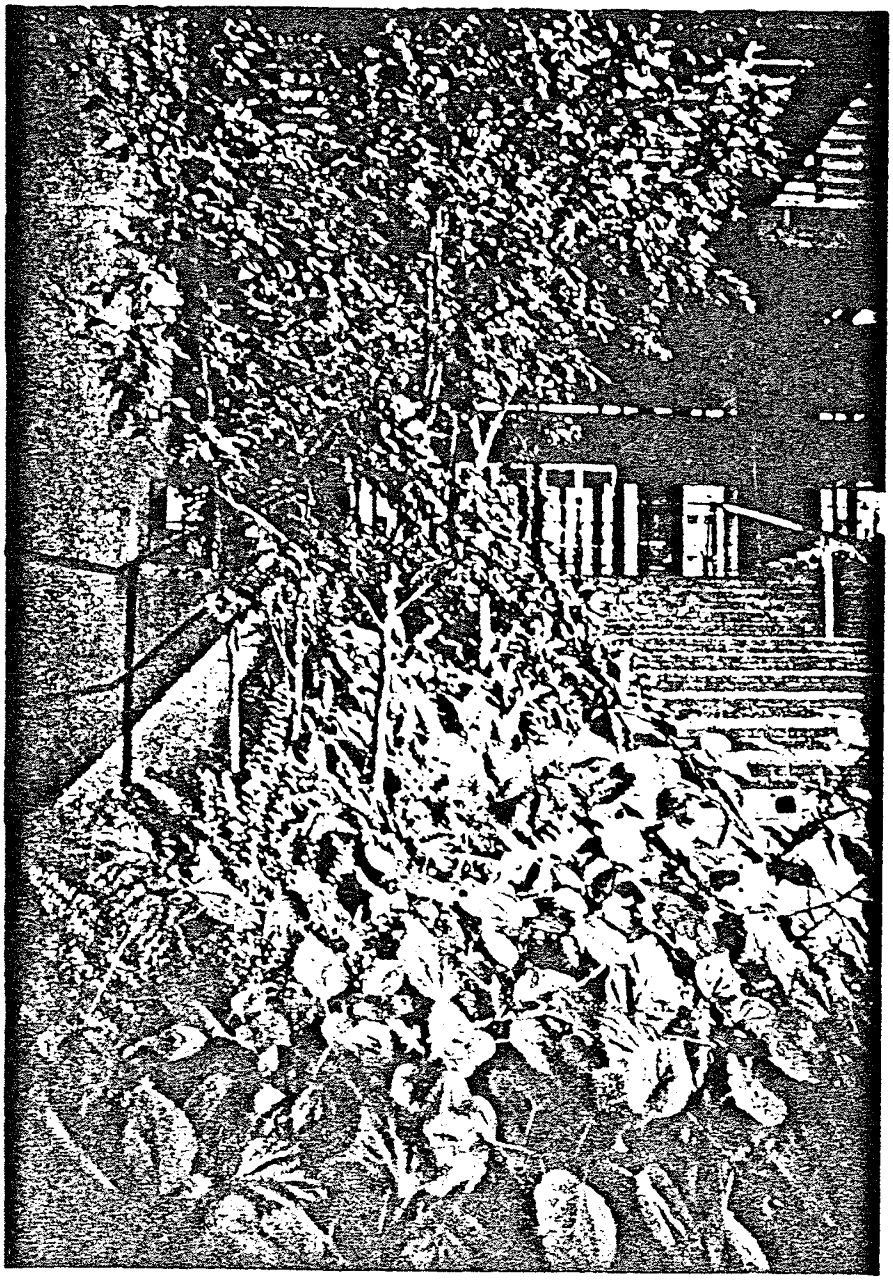


Figure 8.

Source - Ford Foundation Building, New York. Interior Landscape Industry, February 1985, p. 21.

8. Plants are simply aesthetically pleasing, adding color, grace, texture and life to our interiors all year round. Plants can also attract attention to a particular feature of a building such as multi-storey open space.

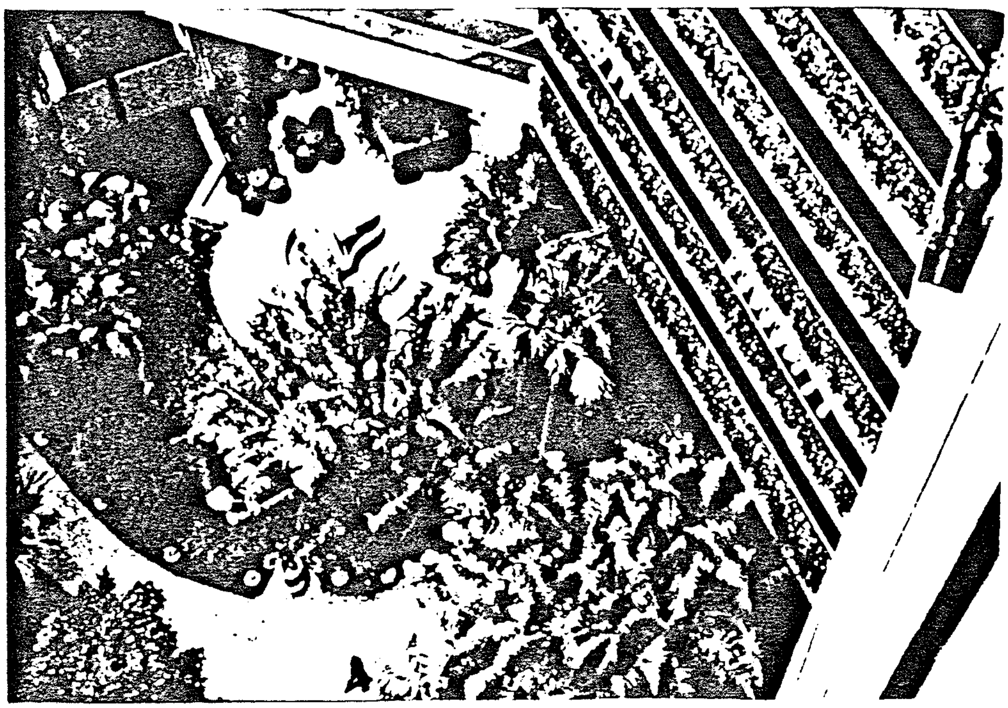


Figure 9.

Source - Grand Cypress Resort, Hyatt Regency Hotel. Interior Landscape Industry, October 1984, p. 52.

9. Plants can be used as objects of art, utilizing their characteristics of form, color, texture and scale.

Figure 10:

Source - Larry Hagman Residence, Malibu. House and Garden, November 1984, p. 186.

1.1.1 The Designer's Role in the Development of Interior Landscaped Spaces

The designer plays a key role in the environmental decision making process of interior landscaped areas. Their task is to provide the skills and knowledge which facilitate the sensible development of interior landscaped spaces. This is accomplished by integrating the art and technology of interior landscaping to create surroundings that stimulate our senses. No one can deny that environments which support active plant growth are far superior to those which only allow tropical plants to merely survive. The art of interior landscaping uses tropical landscapes and plants as inspiration for interior design elements, or to fulfill any of a number of aesthetic or functional uses. Through a cultivated sensitivity to tropical colour, texture, scale, form, line and detail, the designer can create interior spaces which exude pleasure, interest, warmth or pure delight. As a painter uses oil and canvass, the interior landscape designer uses aspects of the natural tropical environment to create art forms. Interior plantings are complex and must be carefully designed for the sake of the plants and those who will benefit from their use. Spaces for plants should be intentionally planned. Plants should not be a decorative afterthought to fill an otherwise useless void. They must be properly designed for ease of maintenance and the plants kept in good condition for a sickly interior garden is worse than none at all. If included at the building concept and design stage, environments can be created that will artfully support the growth of luxurious tropicals.

Design groups consisting of many designers - architects, engineers, interior and industrial designers, as well as scientists, technical experts, contractors, managers and clients - is of vital importance for co-operation, especially in the early stages of planning, is essential in order to avoid mistakes and failures. A professional commitment to understanding the environment, be it exterior or interior, must exist. Proper planning decreases costs of installation, maintenance and replacements resulting in the interior landscaped space that the client, architect, interior designer, landscape architect and landscape contractor had envisioned.

1.1.2 Summary

Exotic plants fulfill many psychological, aesthetic and functional purposes in our interior environments. Landscape designers play a key role in the design and development of interior landscaped spaces by combining the art and technology of interior landscape architecture to create harmonious relationships between tropical plants, the interior environment and people.

1.2 THE HISTORICAL DEVELOPMENT OF INTERIOR LANDSCAPE ARCHITECTURE

1.2.1 Introduction

Man has been growing plants indoors for many centuries, either because of man's natural symbiotic relationship with plants or as a result of his defiance of nature. As man traveled farther afield, he collected unfamiliar varieties and brought back seeds to be nurtured in structures which allowed protection from the cold while allowing light penetration. Advances in technology led to improved interior environments for the cultivation of exotic specimens. Many interiors of modern architecture include interior landscaped spaces which reflect contemporary attitudes towards man's fundamental link with nature.

1.2.2 Historical Development

Plant hunters of the past and present are responsible for the great variety of ornamental plants from around the world. There is evidence that the Roman atrium was well furnished with hanging pots of flowering plants. They built greenhouses of mica to let the sun in and used heat given off by manure to winterforce the exotics collected in their campaigns. The Crusaders brought unfamiliar varieties back to England while Columbus returned from his voyages with seeds found in the New World.

During the 17th and 18th centuries the crews or passengers of colonizing and merchant ships often included a botanist for the purpose of identifying plants of possible value as food, medicine or to accommodate the growing demand for exotics. As new plants continued to be introduced from abroad, along with the Englishman's increasing preoccupation with botany and horticulture, the need for structures to house these exotics in a foreign and hostile environment was realized. This resulted in the building of conservatories where exotic specimens could be raised with special care.

Orange cultivation, especially rare varieties became a noble hobby and the addition of a greenhouse to a mansion was just as important as a membership in a scientific society. Glass rooms known as orangeries in which citrus trees were grown, began to appear in country estates in the early 17th century England. The "orangeries" doubled as banquet halls in the summer when the trees were moved outside. Many of the greenhouses faced north. A few small windows in the structures allowed for light penetration.

The first heating systems were very crude. The open fires and hot flues heated by coal created problems of noxious fumes and uneven heat distribution.[2] The later use of stoves eliminated the smoke problem but localized heat problems remained. The desire to nurture exotic plants in a hostile climate led to the development of the glass house with a sophisticated mechanical climate control device.

In the 18th century, light was generally recognized as healthy for plants. Gardeners, in a quest for light began to use glass, probably due to the decrease in cost of the item, and found that by sloping the walls and roofs of glass, greater sun penetration was obtained. The repeal of duty on glass in 1845 led to the use of larger panes of glass and as thick as possible. But it had problems too, the thickness of the glass acted as a magnifying glass resulting in scorched plants and the weight of the glass led to twisted sash frames. This functional approach to building purpose, created structures varied in form and without historical precedent.

During the 19th century, new inventions and improvements, and the popularity of greenhouses led to many technical advances in greenhouse design and management - automatic thermostats to control ventilators; natural convection circulation of water; ridge-and-furrow roof glazing attempted to provide a more even distribution of light throughout the day for plants. The new construction materials of the Industrial Revolution, iron and glass, in combination with standardization and prefabrication, represented the sophistication of the engineering advances in the 19th century. The tensile strength of iron allowed new designs involving vast enclosed or spanned spaces that were stronger and more fire resistant structures than of preceding centuries. The prefabrication of iron and glass units, permitted the construction of the Crystal Palace, designed by Joseph Paxton, in the unheard of time of six months (Figure 11).

Figure 11.

Source - Crystal Palace, London, 1850-51. Horst de la Croix and Richard Tansey, Art Through the Ages, 6th ed.,(New York: Harcourt Brace Jovanovich, Inc., 1970) p. 713.

During the 20th century, interest in exotic plants waned due to the fact that people had less time and money for exotic plants. Commercial greenhouses on the other hand expanded along with greenhouse technology that automatically monitored heat, light, humidity, water and fertilizer, with little thought given to energy conservation. With increased costs of energy, alternative methods of heating were sought.

The history of interior landscaping has come full circle as many households and institutions recognize the benefits of exotic plants. The conservatories and wintergardens of the last century were popular social centers of their era and not just gardens. They provided seating for people to listen to music played by bands, poetry recited by a reader, or to watch a play acted on Sundays. Many were equipped with a beer garden. An example of a modern day social center and indoor park is the Rainbow Mall Wintergarden, in Niagara Falls, New York (Figure 12). The Wintergarden is a greenhouse-like structure designed by Gruen Associates and M. Paul Friedberg and Partners in 1978. It measures 175 feet by 155 feet and 107 feet high, dividing Fall Street to form east and west pedestrian malls. Inside are 7000 subtropical plants of 200 species ranging in size from 40 foot high palms to smaller trees, shrubs, ground covers and hanging baskets. Plants are tagged with common and botanical names so that visitors can use the Wintergarden as an educational resource as well as attending art classes, listening to classical music or just to stroll among the shops.

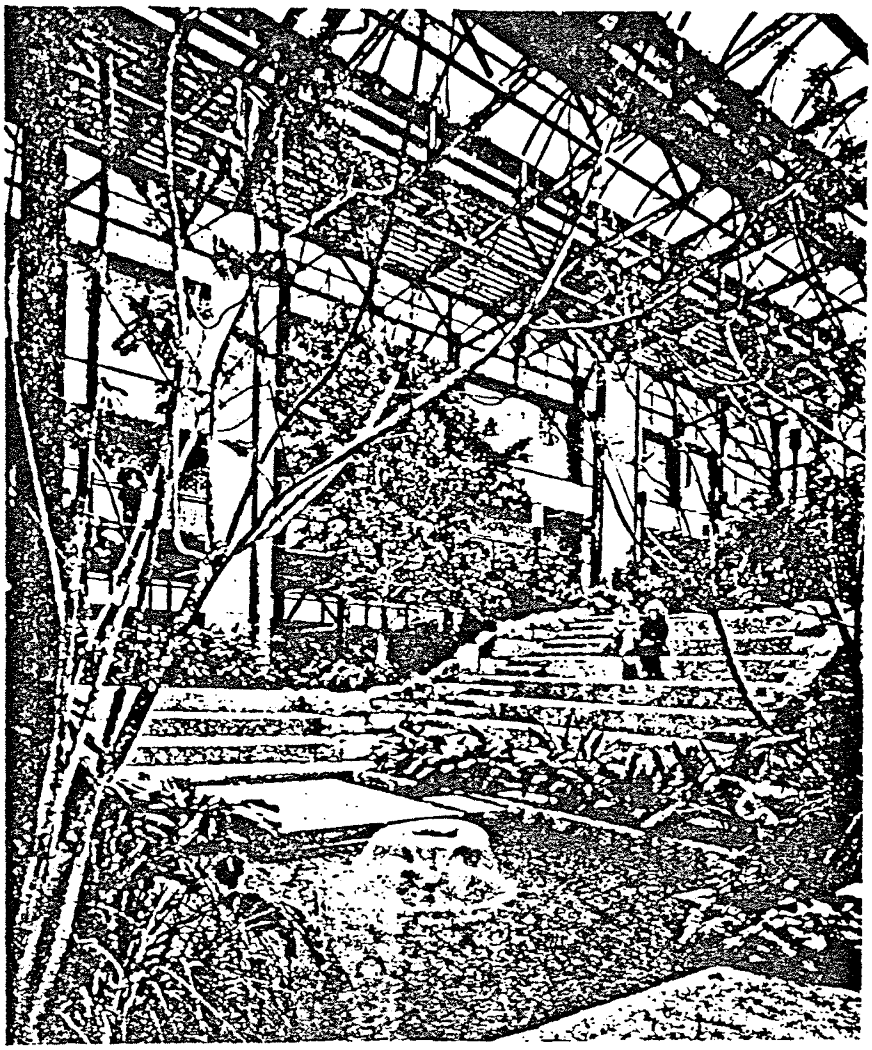


Figure 12.

Source - Rainbow Mall Wintergarden, Niagara Falls. "Gardens On The Inside" Landscape Architecture (January 1980):33.

The West Office Building of Deere and Company has a 11,000 square foot atrium space rising from ground level to a height of 53 feet.[4] (Figure 13). Mirrors throughout the garden reflect people, plants and the panorama. Work spaces of the upper two levels are open to the court while the offices on the lower level are given privacy behind reflective glass. The menagerie of ground covers, flowering seasonal displays, trees, shrubs and hanging baskets provide a daily contact with nature in the work environment. It is the architect's contention that "contact with nature" acts as a spur to the psychological well-being of people. In another of his buildings, Kevin Roche, created a tropical paradise in the greenhouse lobby of the Ford Foundation Building in midtown Manhatten. The indoor garden lends dignity and inspiration to the function of business.

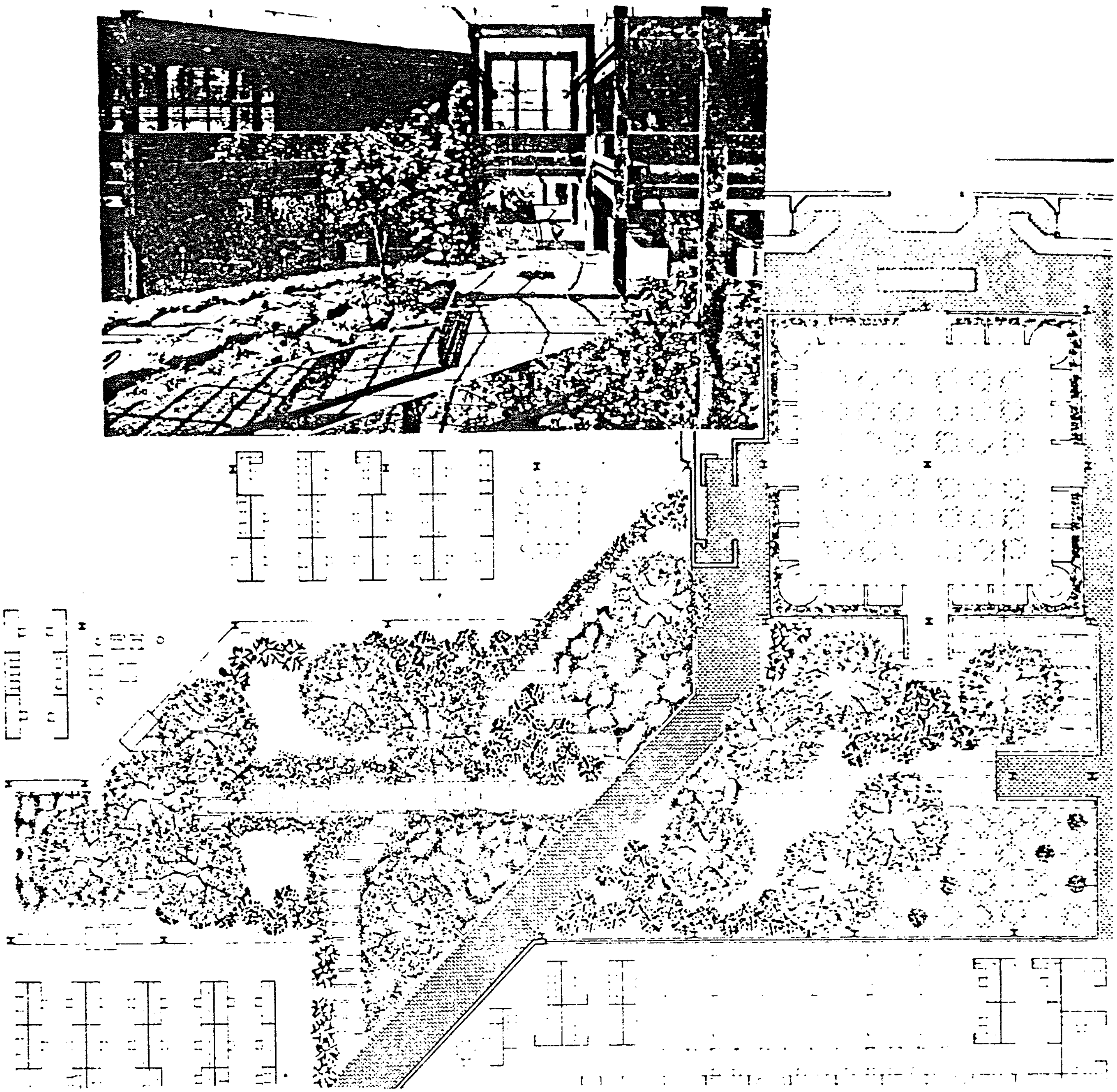


Figure 13.

Source - West Office Building of Deere and Company. Interior Design (April 1979): 211.

The Royal Canadian Mint, built in Winnipeg in 1976, is designed to allow the visiting public to view the money making procedure. The Mint was designed to stand out as a prominent element in the public eye. The landscaped interior courtyard acts as a focal point for the interior spaces. The environmentally controlled garden sports a fountain, bridge and an assortment of tropical and subtropical plants of varying heights. The special feature of the garden is the fact that it can be viewed from many different angles and levels. The strip skylights and extensive windows on the ground plane, flood the space with varying qualities of natural light, changing the mood as the day and outside conditions vary. Supplemental artificial lighting is provided by fixtures on the ceiling and on light standards throughout the garden. The interior landscaping provides a pleasant contrast to the angular and slick structure which houses it.

Tropical plants are also used in buildings such as the Conservatory and Tropical House at the Winnipeg Zoo. These structures are specifically designed and constructed to house plants as well as birds and animals of tropical regions. These spaces serve as educational centers for the public.

Indoor plants and gardens are not only widespread in the contemporary environment, they represent new values and changing attitudes towards their use. What has spawned this revival of indoor plants and gardens?

There are several explanations: First man now has the capability, resources, the freedom of choice and the time to exercise it. Technology combined with North American affluence, has enabled us to coexist with plants in environments originally created for people.

The second explanation is one of economics. Plants are inexpensive interior design elements, continually changing and evoking different moods. They add value and life to the space in which they grow, a residual value which makes plants commercially attractive.

Third, interior tropical gardens represent symbolic values, a defiance of nature in northern climates. Exotic plants add warmth, colour, grace, texture and life to the interior environment all year round.

Fourth, time and choice are more obscure but no less important reasons for growing plants indoors. The enormous increase in the amount of leisure time is creating a kind of personal revolution among us. We search for a broader range of leisure time activities which are individually exciting or gratifying. Interior plants are a close at hand form of leisure art. Our daily lives are structured and competitive so we seek those leisure time activities which are passive, thoughtful, creative, interpretive and highly selective. The result is often a hybrid of recreation, education, culture and entertainment.

Fifth, the cultivation of exotic plants indoors sustains our intellectual interest and fulfills a basic need for life. No one will dispute the fact that the site of healthy, growing plants in interior landscaped areas during winter's cold and snow, lifts one's spirits.

Sixth, plants are an important part of projecting an image by developers, builders and architects. Indoor plants are no longer an optional accessory in building design. They are a necessity. The demand for plants is an integral part of the interior is unquestioned. With this increased demand for interior landscaped spaces, comes the need for higher quality designs. The old theory of simply filling an otherwise useless void with plants no longer fits the bill.

Recent improvements in the field of artificial 'silk' plants creates avenues for their use in locations where live plant material would not thrive. The designer must make a fundamental decision between artificial, real or a combination of both types according to his or her professional and moral convictions. If real plants are the choice, should indigenous plant material from northern climates be selected for indigenous architecture, or plants from tropical regions? Generally, plants from the temperate regions do not thrive well, if at all, under interior conditions because they are conditioned to seasons of cold and heat, or dryness which allows a period of dormancy. Therefore, most of the plants used today in the interior environment are native to the tropical regions, either rainforests or deserts. It is extremely important that the designer realize this in order to understand the horticultural requirements involved in maintaining these plants in a healthy state in the interior environment.

1.2.3 Summary

The history of interior landscaping has evolved throughout the centuries as a result of travel advances in technology, and changes in attitudes towards exotic plant use. Today our climate controlled environments allow us to nurture and enjoy tropical plants where centuries ago our ancestors could not. Interior landscaping is widespread in the contemporary environment, representing symbolic values, economic, and intellectual interests while fulfilling man's psychological link with nature.

PART 2 THE TECHNOLOGY OF INTERIOR LANDSCAPE ARCHITECTURE

2.1 THE DESERT ENVIRONMENT

2.1.1 Introduction

Deserts are characterized by less rain, more wind, more sun, high evaporation, wide daily ranges of temperatures, low humidity and higher temperatures than other regions of the earth. The topography is usually stark and partially shaped by water. Unprotected by vegetation, the soil erodes easily in violent rainstorms and is further eroded by strong winds. Desert vegetation has adapted well to very low levels of precipitation and are either xerophytes or halophytes. The purpose of this chapter is to discuss the Desert environment in terms of climate, description of the environment, vegetation and soils.

2.1.2 Climate

In the Sonoran Desert Arizona, temperatures are consistent from year to year. Temperatures during the summer months are very hot, regularly exceeding 37.7° C. Northern stations and those at higher elevations, occasionally experience freezing. The extreme southern portion of the desert is subject to wide temperature fluctuations from frosts to temperatures of 26.6° C to 32.2° C during the winter months.[4] Extreme diurnal temperature ranges throughout the desert are experienced during the year. Cloudless skies 85 percent of the time attribute to the daily radical temperature fluctuations. Annual rainfall in the Sonoran Desert varies from 203 mm in the western regions to 381 mm throughout the remainder of the desert. Average annual relative humidity is approximately thirty percent.[5] Evaporation is generally great, fifteen to twenty times precipitation, caused by high temperatures, wind and slight cloud cover.

2.1.3 Description of the Desert Environment

The deserts of the world vary in location and are found in low and high latitudes, interiors of continents and on coasts at high altitudes. Deserts can be the result of many local factors:

a) the rainshadow effect next to mountains
b) a lack of rainfall in the summer
c) poor drainage leaving salt deposits on the soil surface
d) Man's efforts of deforestation and farming
e) distance from a large water body, and
f) air currents passing over cold ocean currents absorbing little moisture.

In deserts of the Tropics and Subtropics there is an overall deficit of water in a year, the size of the deficit determining the degree of aridity. Paradoxically, for a region lacking water, the desert's base is primarily shaped by water, eroding the surface during short-lived, high peaked rainstorms (Figure 14). The surface of the desert is relatively impermeable to water with little water seeping into the ground and in combination with a lack of vegetation, contributes to soil erosion and

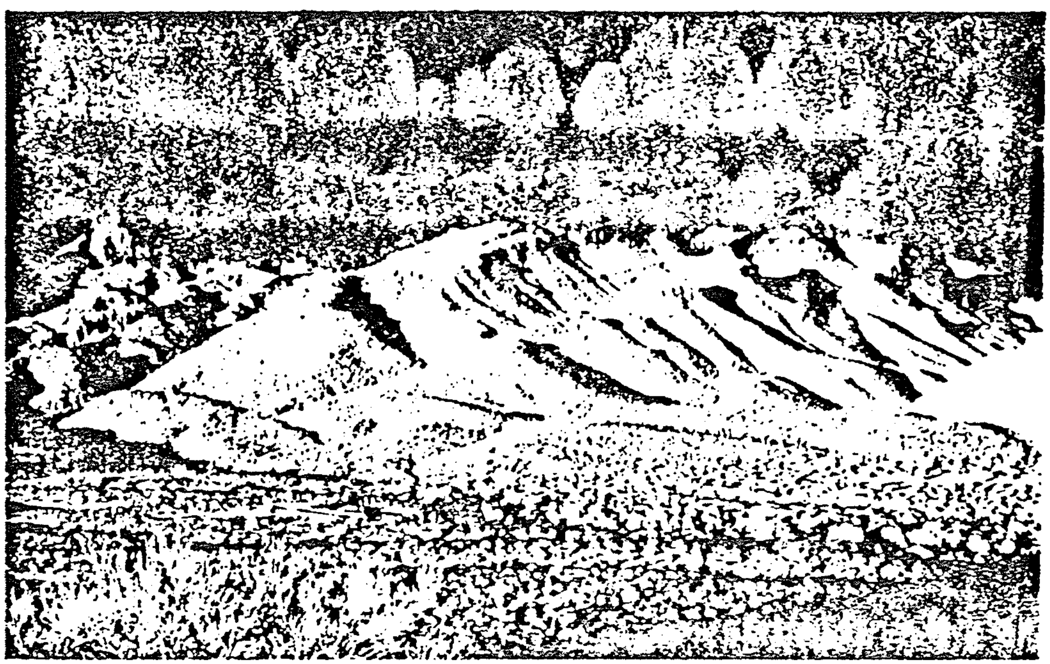


Figure 14 and 15

Source - The Sonoran Desert (Tucson: The University of Arizona Press, 1968), p. 17.

the transportation of debris. Wind also plays an important role in shaping the desert landscape, gusting and whirling without obstruction over the desert collecting, sorting and transporting loose particles, sandblasting everything anchored. Depressions are important features of all deserts.

2.1.4 Vegetation

Because of the random nature of water to the desert, the reproduction of species tends to be opportunistic in nature rather than following a regular seasonal schedule as in other regions with more favorable conditions. Organisms take advantage of temporarily favorable circumstances, reproducing in a very short time. Due to the scarcity of water, desert plant cover varies from nothing to open stands, usually occurring in hollows where available moisture accumulates (Figure 15). Plant biomass, the total amount of plant matter living above and below ground, is a useful indicator of the degree of development vegetation has achieved in an area. Desert's have a low biomass, 10 to 15 centner/hectare when compared to a Tropical Rainforest which has over 5000 centner/hectare.[6] Figure 16 illustrates the openness of desert vegetation.

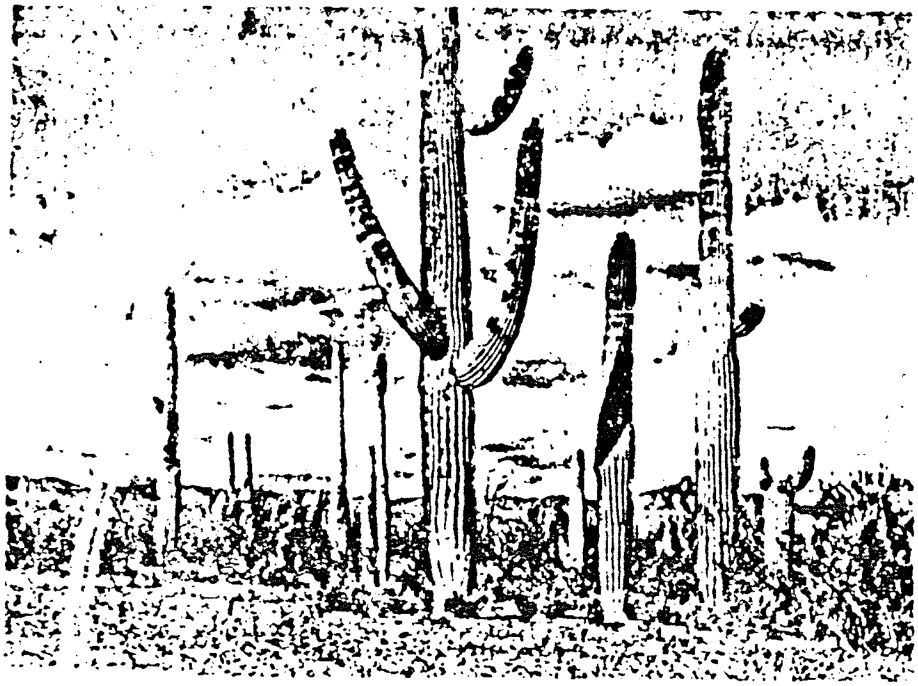


Figure 16

Source - Roger Dunbier, The Sonoran Desert (Tuscon: The University of Arizona Press, 1968), p. 16.

Water is a vital element for plant life and desert plants have adapted well to low precipitation levels. Most desert plants can be classified as xerophytes for they have the ability to avoid drought to some degree. There are two classes of desert vegetation, the annuals or drought evaders, and the perennials or drought resistors. Annuals or ephemerals may form dense stands after rains and produce leaves, flowers and fruit in six to eight weeks, with the seeds waiting for the next year or favorable conditions. Ephemerals make up 50 to 60 percent of all desert plants and are short, small plants with shallow roots.

Desert perennial vegetation is either succulent in nature or woody. The succulents store water within the leaf structure and have a waxy surface or they can be spiny, storing the water in the stem. They close the stomata during the heat of the day and open them at night in order to avoid excessive loss of water. Woody perennials are the dominant plant type of arid regions. There are many morphologically different forms of plants ranging from grasses and woody herbaceous plants to shrubs and trees. They are very hardy, evergreen or deciduous and many are spiny. Their seed germinate only when the seed coat is damaged either by the scraping of stones after a rainfall or by the digestive juices of animals. Stems are especially tough, hard and resistant to drying. Leaves may have a thick cutin layer, a dense covering of hairs, or they may be waxy, leathery or varnished in order to prevent excessive moisture loss through transpiration. Some plants shed their leaves at the beginning of the dry season preventing undue water loss. Roots vary from plant to plant, some having tap roots or root crowns, others having spreading root systems many times larger than the above ground plant mass. Halophytes are salt-tolerant plants which grow in areas with highly saline soils and at the edge of salt lakes. Some halophytes have developed a tolerance to salt conditions while others avoid salt hazard by excluding from entry those ions in high toxic concentrations. Salt evaders regulate their life cycle, growing only during the Wet season, thus avoiding a salt hazard.

2.1.5. Soils

Desert soils are characteristically very poor and in some places do not exist. Due to a general lack of vegetation, therefore little organic matter, and very slow chemical decomposition of minerals, arid-zone soils are nitrogen poor and generally unstable. They are not subject to leaching therefore soluble salts accumulate in the soil profile to the depth of water percolation or to the water table. Often salt concentrations are high enough to be toxic to plants.

2.1.6 Summary

The desert environment is nature's product when the climate produces an overall deficit of water in a year. The desert is characterized by less rain, more wind, more sun, high evaporation, daily wide ranges of temperatures, low humidity and higher temperatures than other regions of the earth. As a result, the desert vegetation has evolved specialized forms to withstand this harsh environment.

By studying the desert environment, the designer acquires a basic understanding of desert plant horticulture. This knowledge can be applied to provide the proper interior conditions of light, temperature, relative humidity, moisture requirements and growing medium for desert plant growth and maintenance in the controlled interior environment of northern latitudes. Desert plants provide a great variety of forms, colors and textures to the interior landscaped space.

2.2 TROPICAL RAINFOREST ENVIRONMENT

2.2.1 Introduction

The tropical rainforests of the world are complex and dynamic systems of diversity and interdependence between plants and animals. They occur in low altitude areas having abundant and well distributed rainfall throughout the year, combined with consistent warm temperatures and length of days. The species-rich forest structure, composed of many layers, is in constant competition for light, moisture and nutrients. The purpose of this chapter is to discuss the tropical rainforest environment in terms of climate, description of the environment, vegetation and soils.

2.2.2 Climate

The species-rich rainforest is possible due to the constant high humidity, and minimal seasonal variations. Mean annual temperature is 26° C with monthly means between 24° C and 28° C. Diurnal temperatures vary from 8 to 10 C degrees. Maximum temperatures rarely exceeds 38° C and minimum temperatures are around 20° C. There are no frosts in this region. (Figure 17).

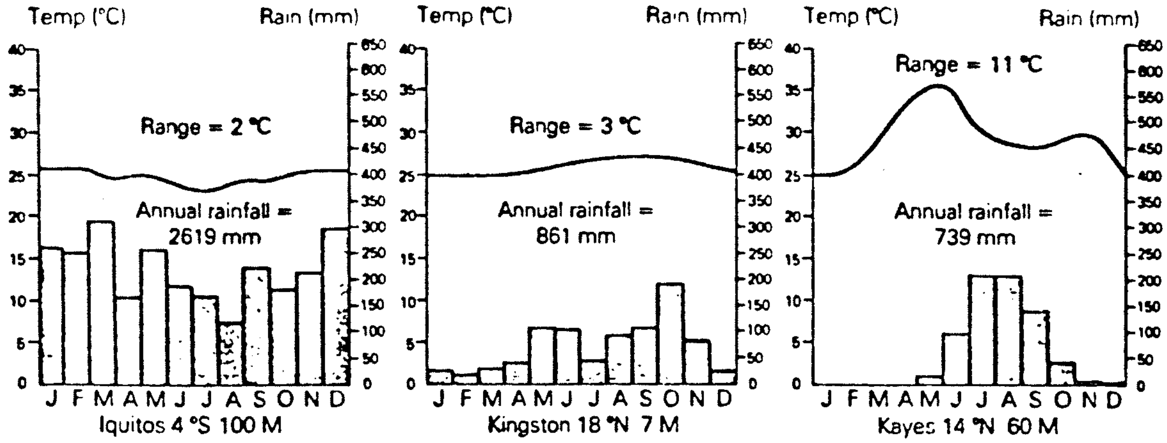


Figure 17.
Source - Temperature and Precipitation in the Tropics. Michael Senior, Tropical Lands A Human Geography (Hong Kong: Longman Group Ltd., 1979), p. 1.

Heavy rainfall occurs throughout much of the year dropping 2,000 to 3,000 mm annually. Rainfall is one of the most influential factors controlling tropical vegetation, often falling in bursts. The crowns of trees, climbers and epiphytes intercept a proportion of the rain. Forty percent runs down the limbs and bark where it is absorbed by the bark, part is evaporated in the forest interior and the rest runs down to the soil. Only one third of the rainfall penetrates through the canopy of the forest. The high evaporation within the forest creates a steambath favoring luxuriant growth.

There is a high level of radiant energy in the tropical rainforest. At noon the sun is more or less directly overhead, thus receiving more energy than any other region on the earth. Some of this energy is absorbed by clouds, therefore the drier regions receive more sunshine. Daylength is 12 3/4 hours for the tops of the trees.

Regional differences in macroclimate caused by trade winds, proximity to, and temperature of ocean currents and the extent and relief of the land masses influence the tropical climate of the rainforest environment.

2.2.3 Description of the Rainforest Environment

Within the complex tropical forest community the microclimate differs between the five layers. Figure 18 illustrates the five forest layers. The uppermost layer A, is composed of the biggest trees which are usually isolated from one another and rarely exceeds a height of 50 meters. The tops of these emergent trees receive exposure to full sunlight equaling that of savanna trees. The crowns of mature trees are usually broader than tall and must be adapted to withstand high temperatures, intense insolation, external atmosphere and considerable wind movement. The uppermost branches are covered with epiphytes such as orchids, ferns, bromeliads, lichens and liverworts which have unique mechanisms whereby water and nutrients are captured for their own use. These semi-parisitic organisms have aerial roots and live in the boughs of the A and B layers. Many climbers reach the canopy and take on the form and size of the tree crowns. Woody stemmed climbers are known as lianes and herbaceous climbers are vines. Stranglers on the other hand start as epiphytes in the tree crowns, sending down roots, which encase the tree trunk and crown, often killing the host tree. Sunlight in the B layer, or the main canopy is decreased to 25 percent of full light intensity. This layer is more humid with a lower temperature than in the A layer. Trees in this layer have straight trunks but the crown in usually tall and narrow. Under the B layer is a lower storey of trees, the C layer. C and D layers only receive three percent of full light available therefore there is strong competition for light. The D layer is composed of woody saplings and the E layer is tree seedlings and herbaceous plants. At ground level only one percent of full light is realized. Contrary to popular belief, the forest floor is not dense due to the extremely low light levels.

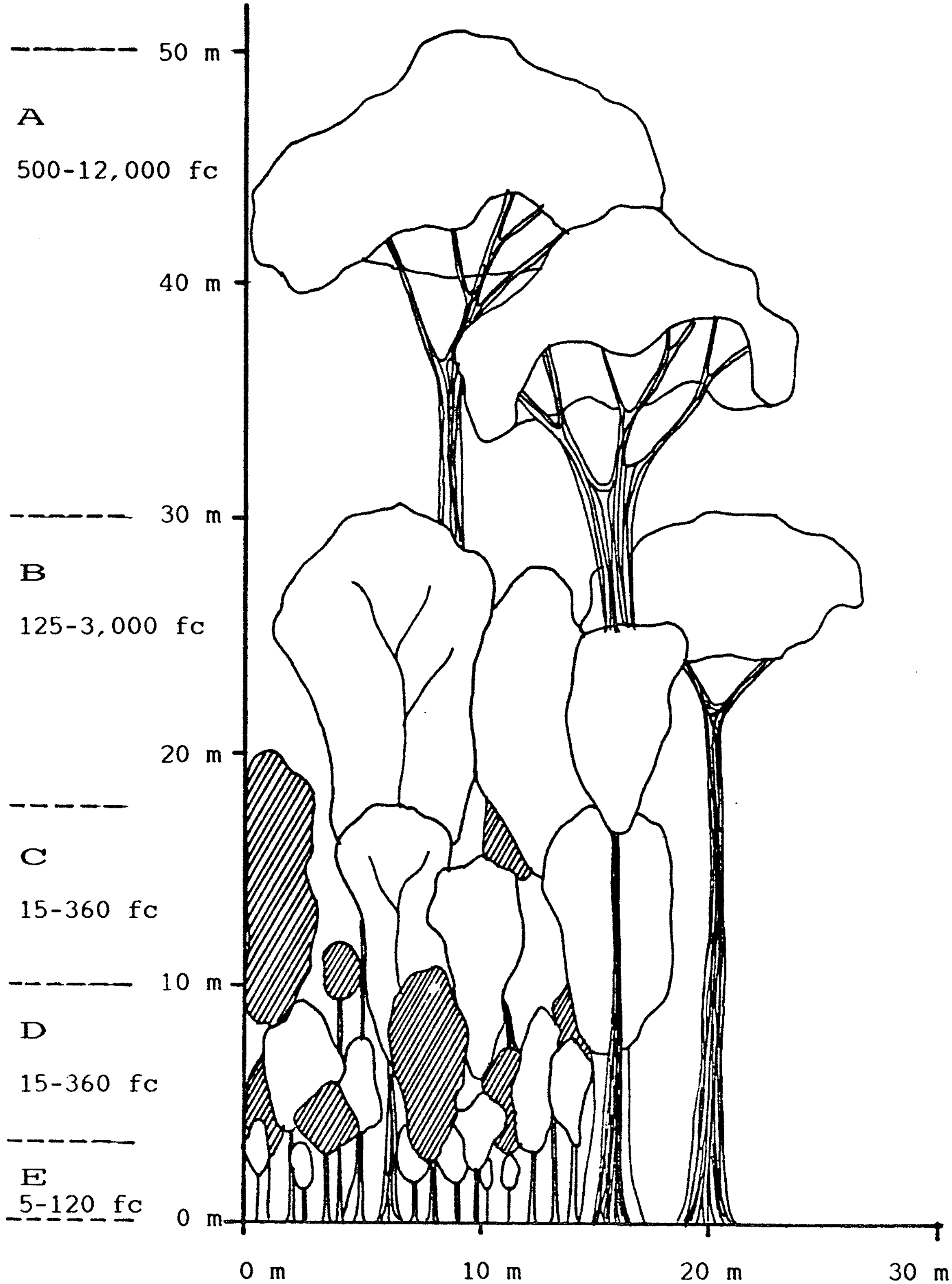


Figure 18. Section through the Tropical Rainforest showing varying amounts of light. Vegetation is dense with strong competition for light.

2.2.4 Vegetation

The climax tropical rainforest is in a dynamic equilibrium with no net gain or net loss of biomass. As old mature trees die, or are toppled by severe winds preceding rainstorms, gaps are created which initiates the three phases of forest development, a) the gap phase, b) the building phase, and c) the mature phase. In the initial phase, the interruption of the upper canopy allows light to penetrate to the lower levels of the forest allowing the development of climbers and vines, and faster growth of tree seedlings. Tree seedlings grown very slowly, one to two inches a year until more suitable light conditions are available when there is a growth spurt during the building phase, filling the gap in the canopy in one to two years.[7] The mature phase of development is achieved when the void, created by the fallen tree, has been filled. Litter decays rapidly due to the high temperatures thus the soil is often bare. Due to the limited light available at the forest floor, undergrowth is sparse. The tangled vegetation that one imagines occurring in the rainforest is rare and only occurs at the edges of the forest or is a result of a gap created in the upper canopy allowing light penetration.

In the tropical rainforest there is fierce competition between plant species for light, moisture and nutrients. Nearly all plants are evergreen in habit, shedding old leaves and growing new ones continuously and simultaneously. The majority of trees have leathery, dark green leaves in order to prevent leaf collapse from the intense insolation and high temperatures at midday. Tree trunks are straight, smooth, slender, often buttressed and reach 25 to 30 meters before expanding to large branches and large leaves in the crown. (Figure 19).

Lower storey trees such as Ficus retusa nitida have adapted to the forest environment. The slightly cupped leaf retains moisture in a light mist, but the tapered point, called the "drip-tip", allows the leaf to shed excess amounts of water easily and dry quickly after storms. Dry leaves transpire quickly and efficiency is important in low light levels.

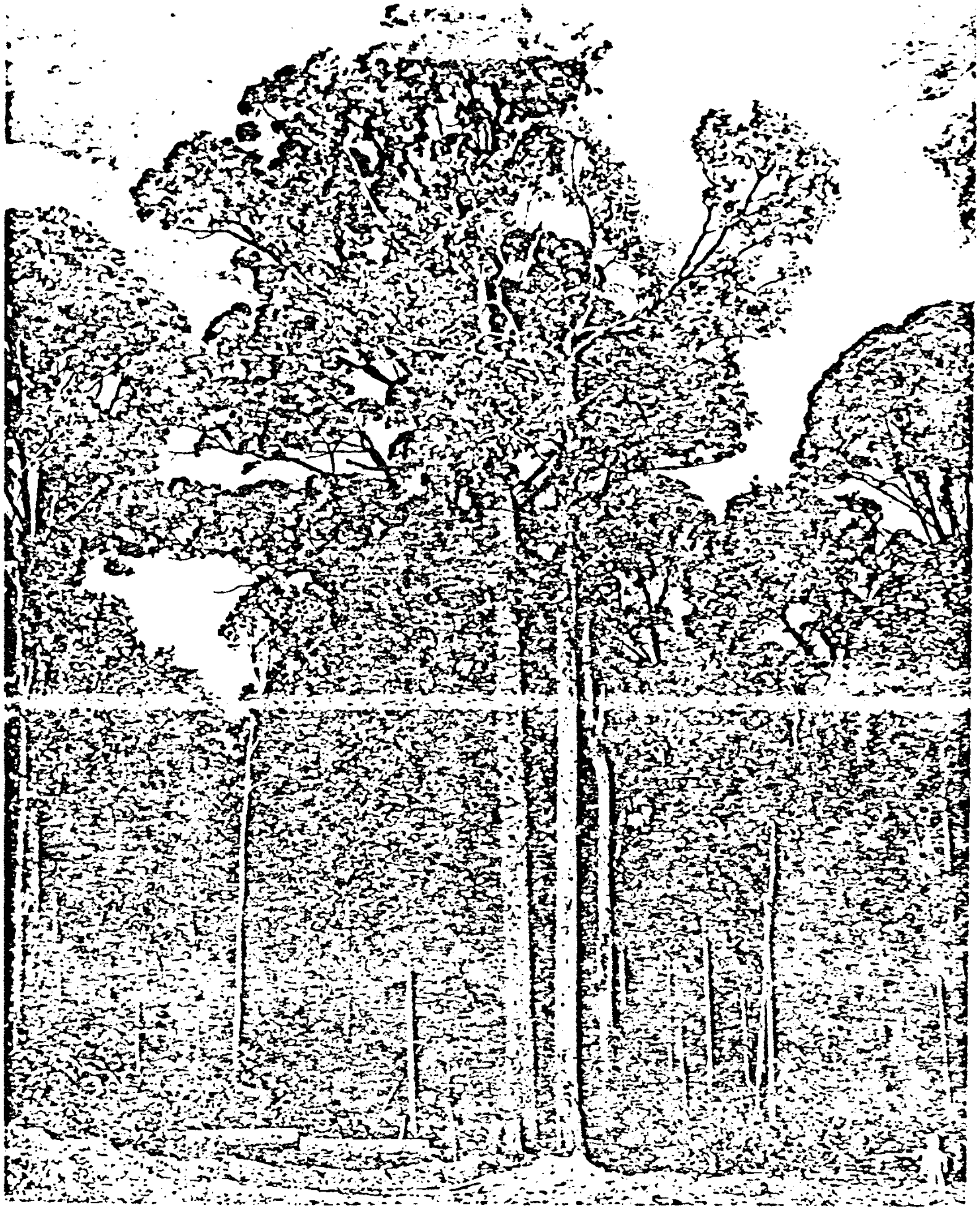


Figure 19.

Source - Tropical lowland evergreen rainforest. T.C. Whitemore, Tropical Rain Forests of the Far East (Oxford: Claredon Press, 1975)

2.2.5 Soils

Contrary to popular belief the soils of the rainforest are not rich in nutrients, nor soft and humousy. The constant high temperatures tend to recycle humus efficiently and quickly and soils are poor and hard as rock. The soils are subject to vigorous leaching and are quite acid in reaction. Consequently the soils are shallow. The ferralitic soils are red in color. Leaching is offset by the fast decomposition thus replenishing the soil minerals. The shallow and extremely dense root system is adapted to catch the nutrients released from the decaying organic matter quickly and almost completely.

2.2.6 Summary

The tropical rainforest is nature's product when the climate enables photosynthesis and decomposition to remain high year round. It is a dynamic community undergoing a continuous sequence of events and ceaseless development. The rainforest occurs in lowland areas having abundant and well distributed rainfall throughout the year, combined with consistent warm temperatures and length of days. The species-rich forest structure, composed of five layers, is in constant competition for light, moisture and nutrients.

By studying the natural environment of tropical rainforest plants, the designer acquires a basic understanding of their horticultural requirements. This knowledge can be applied when making decisions regarding interior conditions of light, temperature, relative humidity, moisture and soil, for rainforest plant growth and maintenance in the controlled interior environment of northern latitudes. Rainforest plants provide great variety of forms, colors and textures to the interior landscaped space.

2.3 THE INTERIOR ENVIRONMENT

2.3.1 Introduction

The success of interior landscape architecture is based on the ability of the interior environment to provide two essential conditions:

a) to maintain human comfort levels of temperature, relative humidity and light; and

b) to provide the horticultural and architectural features which are essential for exotic plant health and ease of maintenance.

The purpose of this chapter is to outline the interior environment in terms of human comfort, horticulture and architectural features.

2.3.2 The Interior Environment - Human Comfort

The most important factors governing human comfort in the interior environment are temperature, relative humidity and light. Seven interior settings were researched in order to obtain the recommended temperature and relative humidity levels for winter and summer, and the typical light levels for these settings. Table 1 outlines these recommended environmental conditions.

TABLE 1.

RECOMMENDED TEMP., HUMIDITY & LIGHT FOR TYPICAL INDOOR SETTINGS

LOCATION	TEMPERATURE C WINTER	TEMPERATURE C SUMMER	RELATIVE HUMIDITY WINTER	RELATIVE HUMIDITY SUMMER	LIGHTING (fc.)	PLANT TYPE Recom. based on Existing Light
DEPT. STORE						
CIRCULATION	21	25.6 max	50	50	10-30	-------
MERCHANDISE	21	25.6	50	50	100-200	LOW to MED
DISPLAY	21	25.6	50	50	150-500	LOW to MED
CHURCHES/ASSEMBLY HALLS						
FOYER	20 to	20 to	40-50		20	-------
HALLS	22.2	22.2			20	
ALTER					100	LOW
SANCTUARY					15-30	-------
OFFICE BLD.						
CONFERENCE RMS	21 to	23.3 to	20-30	50-60	30	-------
TYPING	23.3	25.6			40-50	-------
DRAFTING RM					50-100	LOW
DRAFTING TABLE					100-200	LOW
RECEPTION					10-30	-------
ACCOUNTING					150	LOW
CORRIDORS					20	-------
PRIVATE OFFICES					30-150	LOW
REST & CAFETERIA						
DINING	21.1 to 23.3	23.3 to 25.6	20-30	50-60	5-30	-------
BARS & NIGHT CLUBS	21.1 to 23.3	23.3 to 25.6	20-30	50-60	135-10	-------
AIRPORT TERMINAL	21.1 to 23.3	23.3 to 25.6	20-30	50-60	130-100	LOW
NURSING HOMES						
RAMPS	22	24	50	50	20	
STAIRS & EXITS					30	-------
LOBBY DAY					50	LOW
NIGHT					20	-------
WORK TABLES					100	LOW
DINING					30	-------
PATIENT ROOMS					20-30	-------

* NA - information not available

Sources - (ASHRAE 1982 Applications, Manaker p. 33, Arch Graphics Standards. 6th ed, IES of NA 1977, IES of NA 1981)

To briefly summarize Table 1, the recommended temperatures range from 20° C to 25.6° C. In higher latitudes, building interiors are maintained at a greater temperature than the external air for much of the year, causing the relative humidity to drop. This explains the lower relative humidity levels in winter of 20 to 30 percent, compared to summer with 50 to 60 percent. The recommendations for lighting are based on human tasks performed in those settings and do not reflect levels required for plant health. Lighting recommendations vary from 10 to 500 foot candles.

Exotic plants will thrive in the conditions of temperature and relative humidity recommended for human comfort. Temperature determines the rate at which plant processes occur. Optimum growth occurs when night temperatures are five to eight Celcius degrees cooler than the daylight temperature range of 21° C to 24° C. Plants require a minimum of 35 percent humidity and do well in most buildings with 50 to 55 percent humidity, but an excess of 85 percent can encourage disease pathogens. Therefore, it is evident that exotic plants can coexist with people in their interior environment.

However, light is the limiting factor for plant health in the interior environment, not only in intensity, but also duration and color rendition. Lighting requirements of plants are related to a number of factors including: plant type; level of acclimatization; canopy size; customer expectations relating to canopy density, plant life span and appearance; light source, direction, intensity, and quality. The tropical plants commonly used in the interior environment are grouped according to similar light requirements. Three categories are identified.

1. Low light requiring 50 to 500 fc for plant health growth.
2. Medium light requiring 1,000 to 3,000 fc for plant health and growth, or 100 to 1,000 for plant maintenance.
3. High light requiring 4,000 to 8,000 fc for growth and 500 to 2,000 fc for plant maintenance.

2.3.2.1 Summary

The interior environments of the seven settings provide acceptable temperature and relative humidity levels to support the growth of tropical plants. The limiting factor in each setting is light, thus requiring an increase in light levels if tropical plants are to be used. The increased amount of light required would depend on the type of plant desired for the location. For example: if Brassaia actinophylla, which requires 100 to 1,000 fc (foot candles) for maintenance and 1,000 to 3,000 fc for continued growth, were chosen for a conference room with a typical light level of 30 fc, it would not survive for very long. The light level would have to be increased near the plant a minimum of 70 fc, preferably greater.

2.3.3 The Interior Environment - Horticulture

The processes that determine how a plant grows are controlled by the environment, the factors of which are temperature, humidity, light, moisture, soil, nutrients and gases. All of these factors are interrelated and all effect the height, strength and overall health of the plant. Temperature and humidity have been discussed in section 2.3.2.

2.3.3.1 Light

Light has the most regulating influence on plants. The most efficient and abundant source of light is the sun, and is dependent upon latitude, altitude of the sun, season and cloud cover. Daylight has a higher red content when the sun is low than when the sun is overhead. In most buildings daylight enters through side windows or skylights and is very different in effectiveness. Side windows have a potential to yield only one half to one third of the daylight which is directly overhead. This potential is greatly reduced due to obstructions from other buildings, overhangs or changes in adjacent topography. The total amount of daylight equals the sum of the unobstructed sky view, the external reflected components and the internally reflected components (walls, floors, ceilings, planters, etc.).[8] For calculations see interior landscape model.

Light has three main characteristics: brightness or intensity; the kind of color or light quality; and the length of day.

Photosynthesis is largely regulated by light intensity, the more food the plant produces, the better it will grow. However, there are many exceptions to this. Plants which naturally inhabit shady areas usually have low photosynthetic rates and reach a maximum at low light intensities. These plants survive because they conserve the available energy rather than being efficient at its capture. Plants that originate in dense forests and jungles may overheat causing foliar damage when placed in high light intensities, while those from desert regions require high light conditions. High light levels can cause problems but usually with interior locations, the main concern is with low light intensities. At lower levels, variegated or colored foliage tend to appear less vivid due to the need to produce photosynthetic pigments in preference to color pigments.

The quality of light is not important when plants are grown solely under natural sunlight, but is of considerable importance when artificial light is provided for interior landscapes, for artificial light is quite different from sunlight in color rendition. Light from some lamps, such as mercury vapor is blue, while most incandescent lamps emit light with high red rays. Light with a large amount of red rays tends to produce plants with elongated stems, while plants grown under blue light are short and stocky. When using artificial lighting as supplemental to sunlight, white light, which simulates sunlight, is recommended.[9]

Where artificial light is the sole light source, the lights should be used for ten to twelve hours during each twenty four hour cycle unless some plants grown are sensitive to daylength. A dark period of at least four to six hours is required.

The position of the light source has a marked effect on plant growth. Exterior plants receive some sunlight on all sides throughout the day whereas plants grown in the interior may receive light only on one side, therefore causing the plant to grow towards the light, and possibly losing the leaves on the dark side. Supplemental lighting in the interior would correct the potential growth irregularities.

2.3.3.2 Acclimatization

It is important that foliage plants be acclimatized to the lower light conditions of interior spaces before installation in order to prevent shock causing leaf drop, flower abortion, loss of leaf color or death. Stress is reduced by exposing the plant to short periods of exposure to less ideal conditions over a period of weeks or months, depending on plant variety, allowing the leaf physiology to adjust to new light conditions and lower humidity levels. Only acclimatized plant material should be specified in interior installations.

2.3.3.3 Moisture

Although water is essential for plant life, almost ninety percent of plant material losses are due to overwatering which reduces air circulation in the root zone, causing root suffocation. However, too little water causes water stress and a reduction in growth rate. Water should be at room temperature, therefore a warm-cold blender should be installed at the water source. Chemically softened water should be avoided due to the high sodium content. Fluoride in drinking water can accumulate and cause damage in some species. The symptoms exhibited are leaf tip dieback or dead patches on the main leaf blade. Filters at the water source will purify the water and prevent any potential problems.

2.3.3.3.1 <u>Manual Watering</u>

Watering by hand is highly labour intensive. It is recommended as an alternative to automatic integrated systems. It is suitable for small installations and scattered plantings where automatic systems are not appropriate. Water sources should be supplied as often as possible and always a minimum of one per building floor.

2.3.3.3.2 <u>Integrated Watering Systems</u>

It is recommended that a drip system be used whenever possible especially for large plantings or inaccessible locations. The automatic systems reduces labour and human error. The system should be equipped with a non-return valve to prevent water from being drawn back into the water supply causing a health risk. Drip emitters release water through a number of exit units allowing a slow, steady and exact amount of water to be supplied to a specific area. Another type is a spray system providing coverage in either a fan or circular shape. Irrigation systems can be controlled in one of three ways. Manual control relies on the human element to initiate the operation as a result of personal observation. A time clock can standardize the operation but adequate drainage is essential. Automatic control through the use of moisture sensing devices connected to an alert system allows for effective irrigation control.

In addition to either manual or automatic watering of the plant material, a regular hosing down of the foliage is recommended to clean foliage, reduce insect infestation and improve appearance.

2.3.3.4 Transpiration

Plants lose water by transpiration through the stomata and to a lesser extent by the cuticle. Transpiration is dependent upon the quantity of light and therefore occurs during periods of light. Due to low radiation levels, most interior plants have characteristically low rates of transpiration. Many interior plants are unable to transpire rapidly and are susceptible to sudden exposures to direct sunlight. Transpiration is most intense in conditions of high temperatures, low humidity, high light and fast air movement resulting in the wilting of the plant if the rate of water uptake is exceeded.

2.3.3.5 Soils

The soil is a medium whereby the root system provides anchorage for the entire plant. It is a mixture of ingredients which sustain plant life performing three main functions: a) as a reservoir of plant nutrients which is affected by temperature of the substrate; b) supplies water to the roots, and c) is a source of oxygen necessary for root respiration. It is important to maintain a proper balance in the soil between the solid, gaseous and liquid phases. If there is too much water in the soil, toxic levels of carbon dioxide can build up resulting in a decline in the efficiency of water uptake. Plants can lose turgidity and wilt even in the presence of water. Water logging of the soil also inhibits root growth increasing susceptibility to disease attack. A continuous application of hard water can raise the soil pH and similarly where high concentrations of sodium chloride exist in the water there is risk of toxic salt levels. The soil should be loose and not packed even after long periods of time. It should contain only moderate amounts of nutrients because highly fertile media can be very detrimental. For example, desert vegetation requires light, nutrient poor soil, whereas rain forest vegetation requires richer soil. Soil mixes should contain varying amounts of sphagnum or peat moss, vermiculite, perlite, limestone and sandy loam in appropriate combinations for the plants selected.

2.3.3.6 Nurtrients

Fertilization programs are needed to keep plant materials healthy but must be implemented properly. Liquid feed, slow release either organic or inorganic in origin are recommended. Water soluble fertilizers minimize the risk of leaf and root burning if properly diluted. Slow release fertilizers which are usually organic based are released as a result of bacterial activity. The rate of release is dependent upon temperature and the availability of moisture. Organic fertilizers are more efficient than inorganic fertilizers which are subject to leaching. Of the elements comprising most commercially available fertilizers, nitrogen promotes foliar growth, potassium promotes flowers and phosphorous stimulates root growth. The planting medium should have a pH between 5.5 and 6.5.

2.3.3.7 Gases

The gases in the air in inhabited buildings are adequate to support good plant growth. Phytotoxic gases in building interiors usually arise from the incomplete combustion of organic compounds such as oil, coal and natural gas. The most serious pollutant, ethylene occurs naturally in plants cells where it monitors leaf senescence and root formation, however, when supplied from the environment even in the smallest of quantities, wilting, premature leaf drop and flower abortion occurs. Carbon monoxide has similar effects as ethylene but is only harmful at 5,000 times the concentration, at which point it is also toxic to humans. Chlorine in high concentrations, due to accidental release, usually affects old tissue first. Chlorine in the air next to swimming pools is not in sufficiently large concentrations to be phytotoxic. Vapors from strong cleaning chemicals, often containing ammonia and carbon tetrachloride, can cause foliar damage, turning leaves black. Adequate ventilation should prevent potential problems of phytotoxic gases in buildings.

2.3.3.8 Summary

By providing the proper horticultural conditions of temperature, humidity, light, moisture, nutrients and soil for exotic plant groups in interior environment, their health and growth in ensured. They will thrive and add beauty to the interior of buildings for long periods of time, five years or more.

2.3.4 The Interior Environment - Architectural Features

The following architectural features must be carefully considered in order to properly maintain exotic plants in the environmentally controlled interior: interior finishes, large equipment access and , planter selection and design.

2.3.4.1 Interior Finishes

Surfaces adjacent to plant areas must be carefully selected for ease of maintenance, safety and inherent design qualities. Preference should be given to surfaces that are water and stain resistant, non-slip and unaffected by increased humidity levels. Design qualities of color, texture and pattern are important features to be considered.

2.3.4.2 Large Equipment Access

Provisions should be made to allow the access of large equipment on site in summer and winter for the installation, pruning or spraying of large specimen plants.

2.3.4.3 Planters

Planters as containers for tropical plants, should fulfill the following functions:

a) be of appropriate size to contain the roots and soil required for the plant(s)

b) provide drainage for excess water

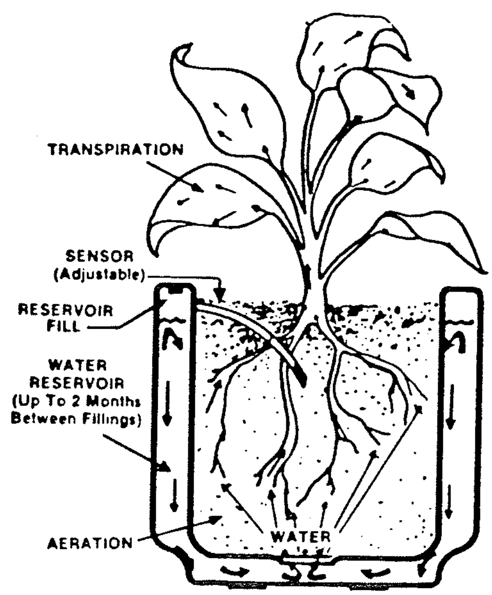
c) should be waterproof and not leak to surrounding surfaces

Planters used in most interior locations are either prefabricated plastic, metal or are built insitu. Small prefabricated pots have the advantage of being relatively light and therefore do not require special structural considerations, as well as easily positioned, unlikely to leak and are available in many shapes, sizes and colors. Plants can be double potted or planted directly in the decorative pots. Insitu planters are best suited for large displays of foliage plants.

2.3.4.3.1 Reservoir Systems

Reservoir systems are based on capillary action and are labor saving. Containers may not need refilling for up to two months freeing up valuable time of the maintenance person to clean and keep plants looking attractive. Sensing devices in the soil detect the soil moisture content and delivers water at room temperature to the plant when needed. The time between refills depends on the size and type of plant, lighting, heat, humidity and season. Reservoir systems are advantageous in hard to reach locations such as balconies, ledges or where accessibility is poor. They also reduce salt buildup and eliminates soil compaction from overhead watering.

Natural Spring Self Controlled Watering Planter by Planter Technology.



2.3.4.3.2 <u>Insitu Planters</u>

There are several advantages and disadvantages to their use in large interior situations. The advantages: a) they look most natural, b) they are not limited by container size therefore large specimens can be used, and c) the roots of plants are not restricted to a pot and therefore they are able to spread out.

The disadvantages: a) Plants are grown directly in the planter and cannot be turned around or rotated, in such cases supplemental lighting away from windows is important to ensure that plants grow straight and not towards the window; b) plant replacements are more difficult especially in the case of large specimens. It is important to select plants that have similar cultural requirements if they are to share the same space.

The drainage of medium is critical. A slope of 1:40 at the base of the planter to the outlet should be allowed for water drainage.

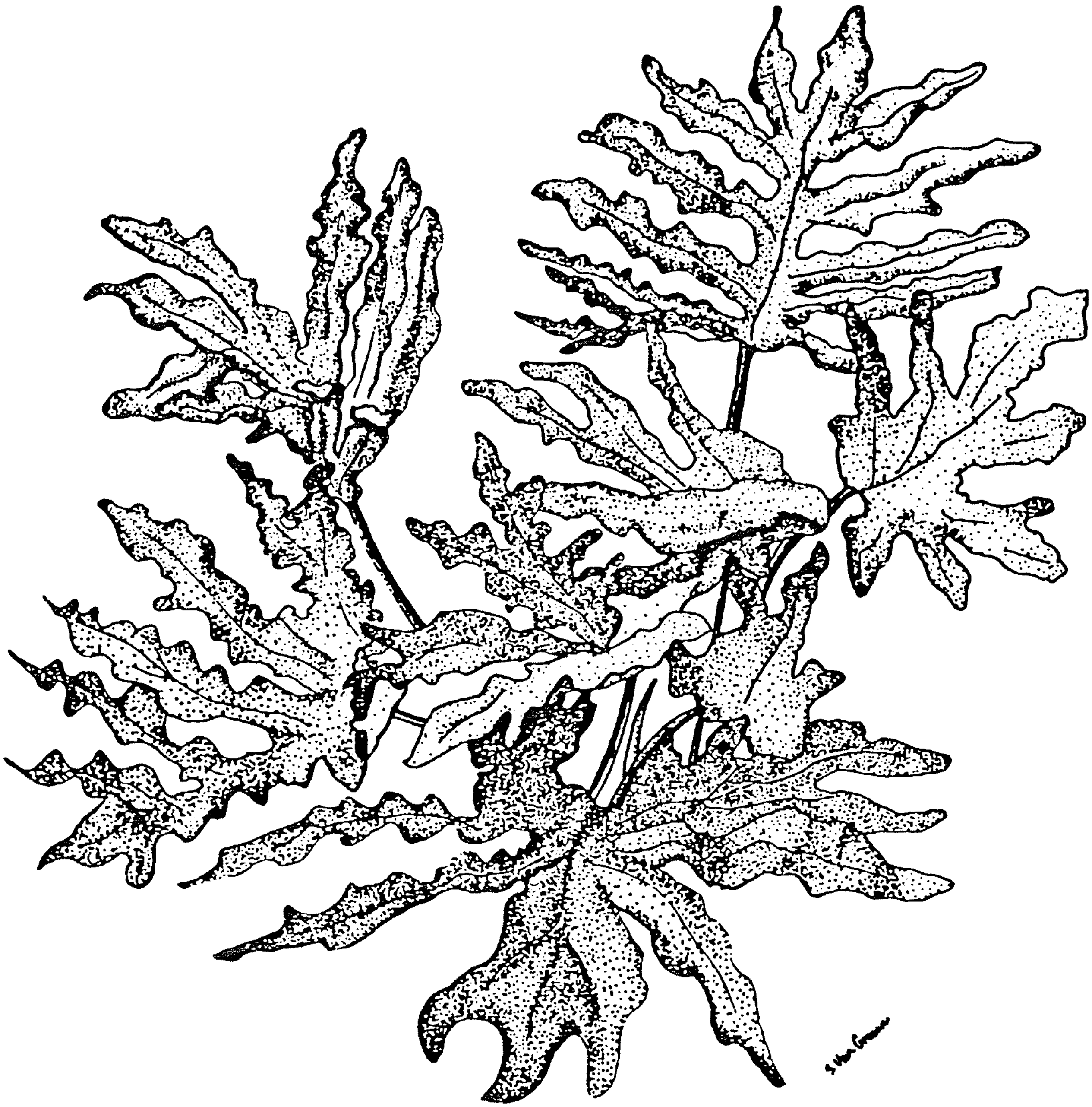
The drainage layer should consist of gravel and be 15 to 20 percent of compost layer. The filter layer should be composed of a tightly woven synthetic material which must resist root penetration located between the compost layer and the drainage layer. Drains linked to building drainage systems must be equipped with a silt trap to prevent particles from entering the building water system.

Buildings must be structurally sound to accommodate the added weight of the planter, soil (dry and wet) and plant material. Point loading of large specimens may be required.

2.3.4.4 Summary

The careful selection of interior finishes for ease of maintenance, safety and design characteristics is important. Provisions should be made for the access of large equipment required for plant maintenance. The selection and design of planters is a prominent architectural feature that the designer must take into consideration.

PART 3 THE ART OF INTERIOR LANDSCAPE ARCHITECTURE



3.1 THE CONCEPT

The aim of interior landscape architecture is to create a better interior environment by satisfying man's emotional and physical needs while fulfilling the horticultural requirements of tropical plants. To accomplish this, the technology and art of interior landscape architecture must be integrated in order to create higher quality designs in the future.

As previously outlined, tropical deserts and rainforests are unique in climate, landscape and vegetation. In order to capture the essence of these tropical environments, the designer of the interior must take inspiration from tropical indigenous landscapes. These environments need to be re-examined to identify the desirable landscape and plant qualities, abstract them and introduce these qualities to the total interior space in order to create images of the native environment. This selective process must be done at the building concept stage. The goal of this fundamental approach to interior landscape architecture is not to imitate nature within the confines of architecture, but to create environmental imagery.

Roberto Burle-Marx, a Brazilian artist and landscape designer, took a similar approach to landscape design. He recognized the inherent qualities of tropical plant form, texture and colour. He used plant material as a means to an end, not wishing to imitate nature, but to improve nature though art. Every plant was chosen for a particular quality it possessed and would contribute to the final design. Trees were chosen for their sculptural characteristics and flowers for size, shape, color or season of bloom. Plants were abstracted from nature to satisfy any of a number of final design qualities: colour; texture; shape; or scent.

In a similar manner, the interior landscape designer can abstract the inherent design characteristics of tropical landscapes and their indigenous plant material, and transform those qualities into interior design elements. Seven qualities of tropical environments have been identified:

1. descriptive words and feelings
2. light quality
3. scale
4. colour
5. form, shape and mass
6. textures
7. line

Through a cultivated sensitivity of these qualities, the designer can utilize them through design and detail as an integral part of the total interior architecture and decoration.

The following section examines the tropical desert and rainforest environments in terms of desirable design qualities of the landscape and vegetation. It also suggests possible uses in interior design and architecture. It should be noted that not all qualities found in native tropical environments are easily abstracted and transformed into interior design form, nor may it be desirable to use all qualities in one space. Discretion is up to the designer.

3.1.1 THE DESERT: INTERIOR DESIGN IMPLICATIONS

1. Descriptive Words and Feelings

Landscape - barren, dry, hot, stark, bright, desolation, vast, lonely, windy open

Plant - prickly, sensuous, ugly, unique, fleshy

Interior Design - minimal furnishings and accessories, detail in textures

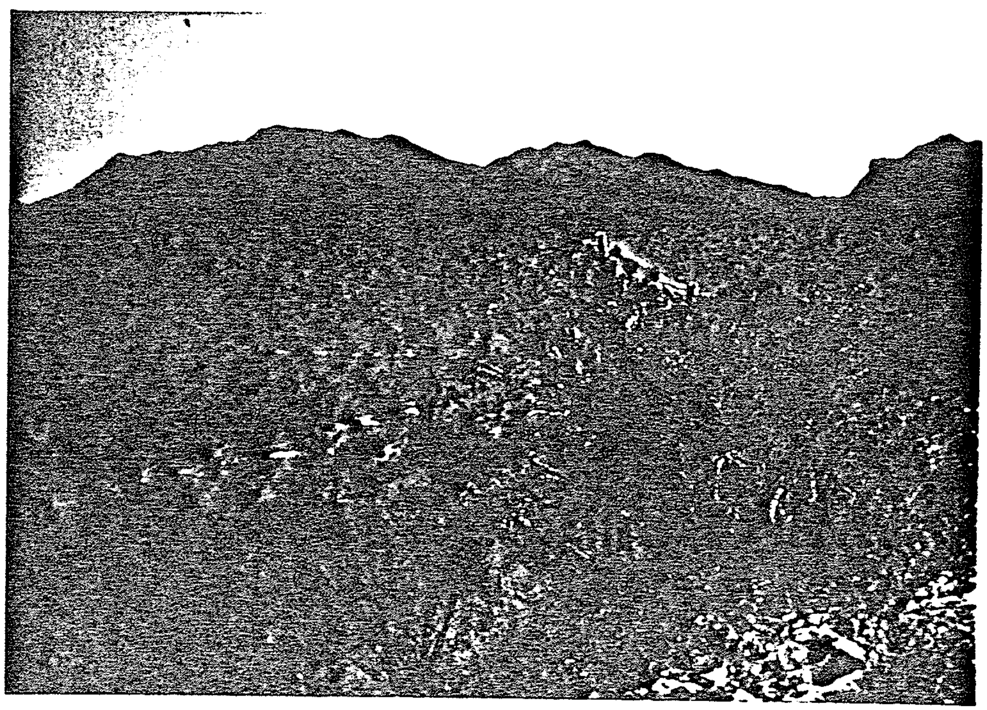


Figure 20.

Source - Desert in southwestern United States. Photo courtesy of Patrick McIsaac.

2. Light Quality

Landscape - strong, brilliant, uniform, few shadows, difficult to determine depth and distance, two dimensional

Plant - few shadows on plants so vegetation appears two dimensional or flat

Interior Design - even light distribution throughout interior, minimal shadows, no accent lighting

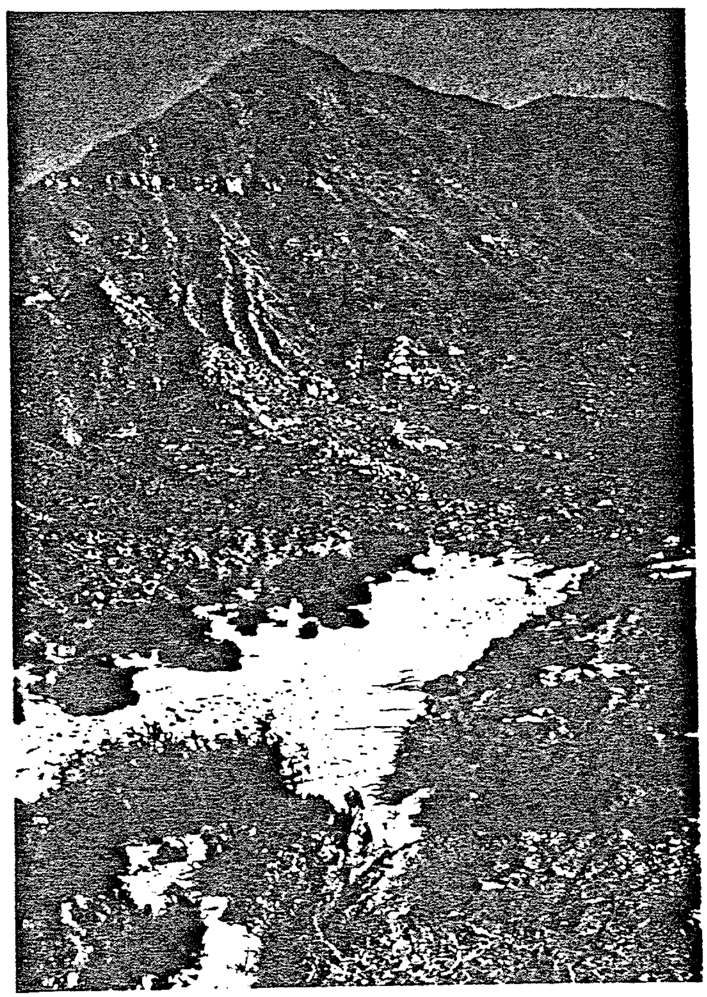


Figure 21.

Source - Desert in southwestern United States. Photo courtesy of Patrick McIsaac.

3. Scale

Landscape - intimidating, vast, open

Plant - wide range of plant sizes from tiny rosettes to larger upright forms

Interior Design - flat low surfaces, high ceilings, stark furnishings

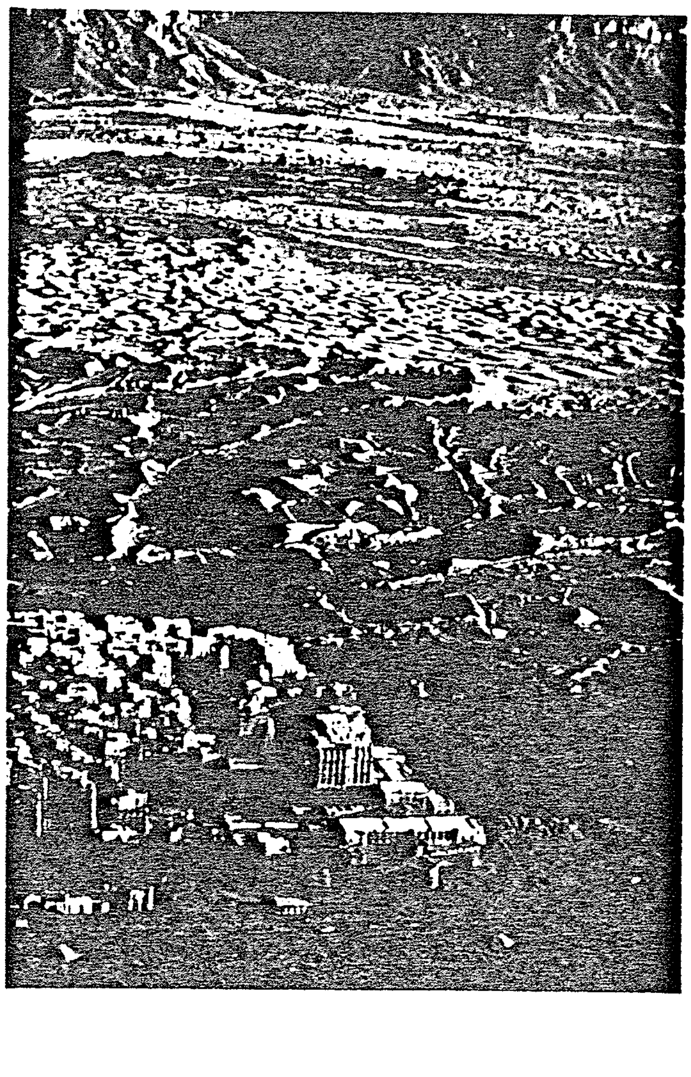


Figure 22.

Source - Shiban, Saudi Arabia. National Geographic, October 1985, p. 477.

4. Colour

Landscape - soft browns, beiges, terracotta, muted tones, brilliant blue sky

Plant - variety of colour from yellow greens to blue greens, brightly coloured flowers

Interior Design - use plant or landscape colours as a basis for colour scheme

Figure 23.

Source - Huntington Desert Garden, California House and Garden, November 1984, p. 168.

5. Form, Shape and Mass

Landscape - flat to undulating, soft sensuous curves

Plant - dictated by shape of stems, dense plant forms, sensuous shapes

Interior Design - sinuous curves in walkways or planting beds, rounded or columnar shapes, "heavy" or dense furnishings

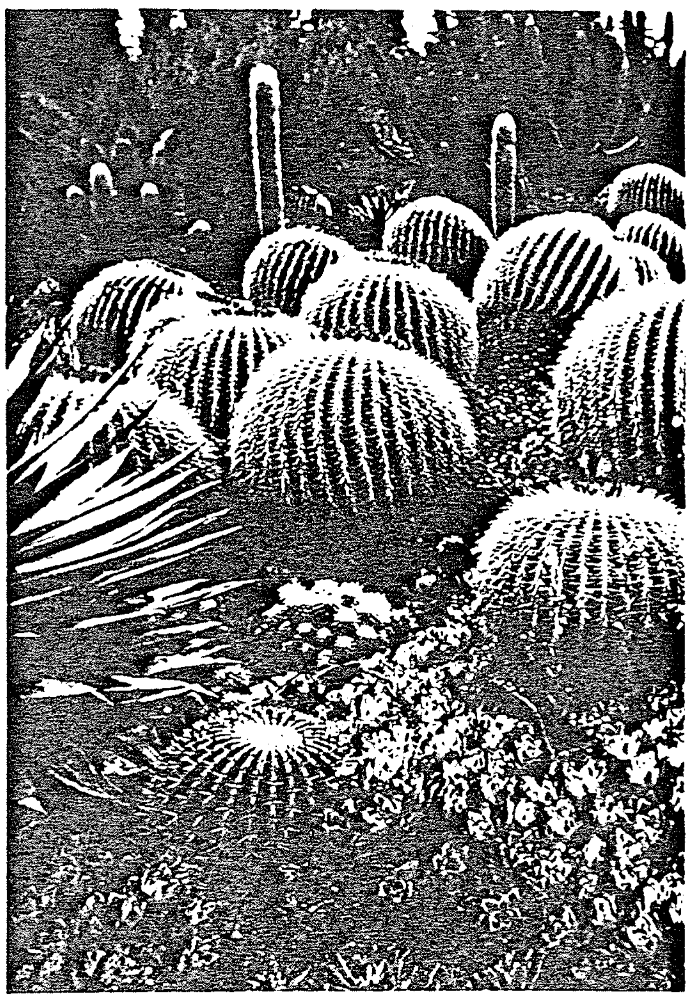


Figure 24.

Source - Barrel cacti, Huntington Desert Garden. House and Garden, November 1984, p. 162.

6. Texture

Landscape - varies from fine sand to coarse rock

Plant - smooth to rough, - spiny, hairy, prickly or aborescent

Interior Design - variety of surface qualities - rough stucco to smooth tiles, "visual" textures or patterns in furnishings and flooring

Figure 25.

Source - Huntington Desert Garden. House and Garden, November 1984, p. 169.

7. Line

Landscape - predominantly horizontal lines, sinuous, minimal verticals

Plant - curving lines, round outlines

Interior Design Form - strong use of low horizontals in window arrangements, furnishing or wall treatments, simple outlines, restful and relaxing lines

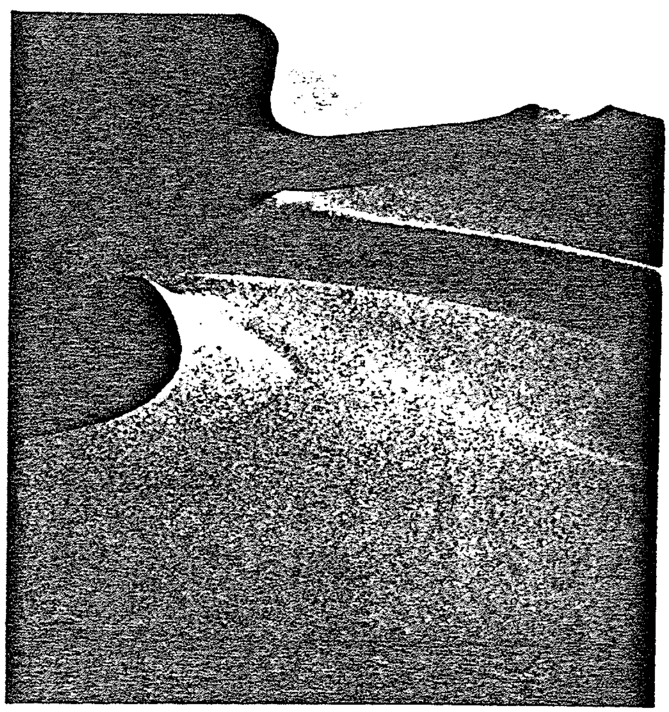


Figure 26.

Source - Gobi Desert. National Geographic, February 1985, p. 263.

3.1.2 THE RAINFOREST: INTERIOR DESIGN IMPLICATIONS

1. Descriptive Words and Feelings

Landscape - lush, green, humid, fragrant, stimulating, dark, refreshing, jungle

Plant - lush, green, large, overgrown, great variety

Interior Design - open and enclosed spaces, high or tall spaces

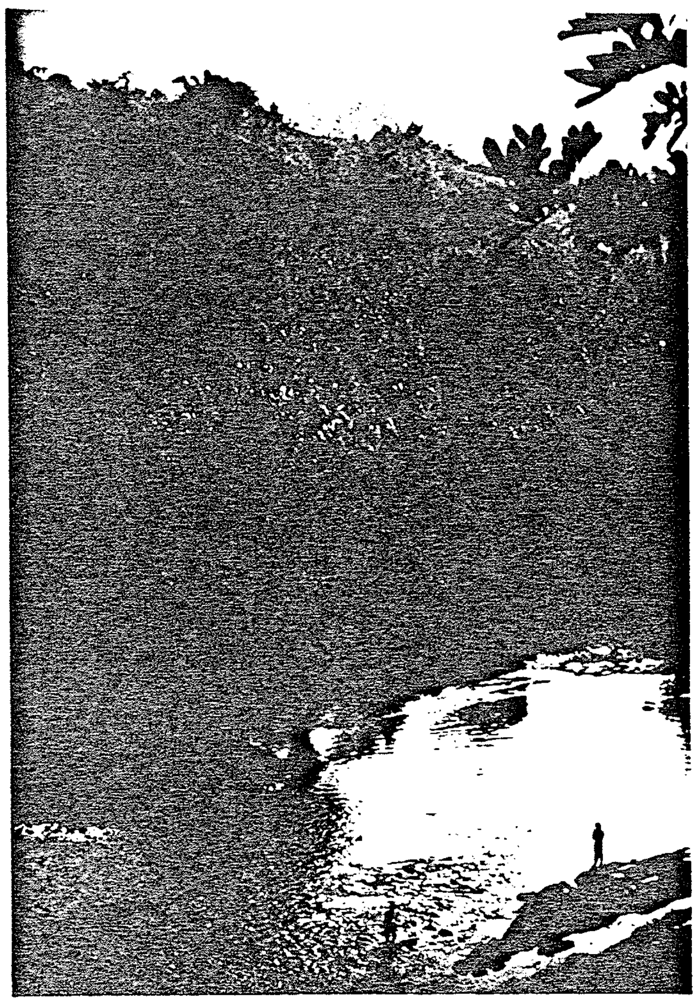


Figure 27.

Source - Rio Grande River, Jamaica. Equinox, September/October 1983, p. 51.

2. <u>Light Quality</u>

Landscape - dark interior to bright open gap areas, many shadows

Plant - interplay of light and dark surfaces

Interior Design - varying qualities of light from bright to dark, use of accent lighting, open and enclosed areas

Figure 28.

Source - Rainforest, Venezuela. National Geographic, September 1985, p. 333.

3. Scale

Landscape - from a distance scale does not appear much different from temperate zones, however when in the forest the vegetation dwarfs man

Plants - towering, awesome, wide variety in size

Interior Design Form - very high ceilings and large plant material, elongated and vertical shapes

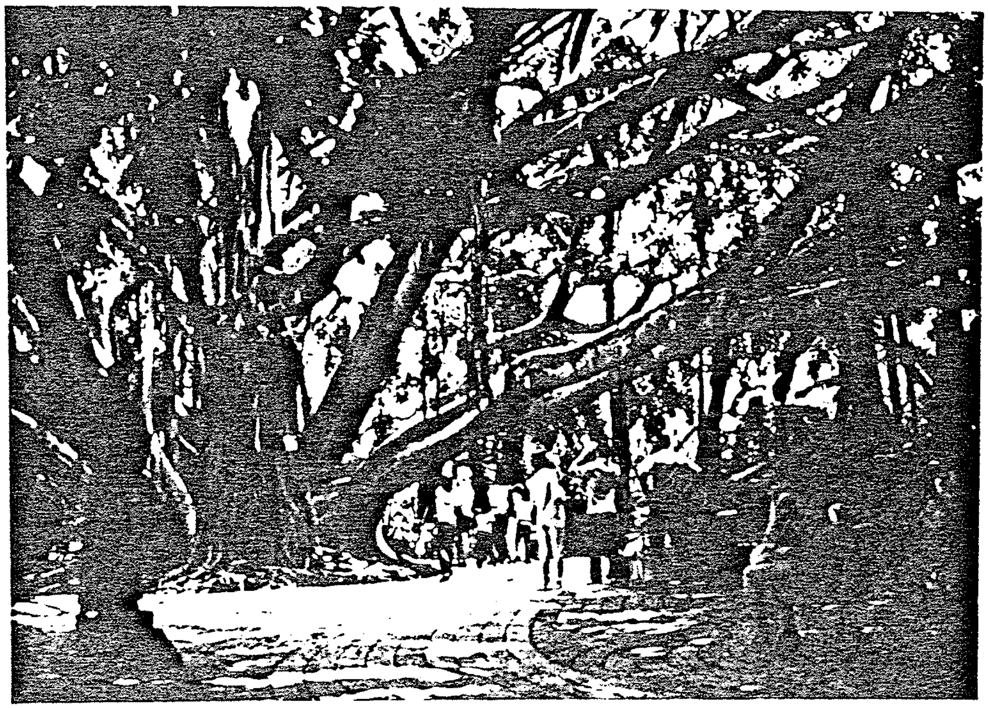


Figure 29.

Source - Banyan tree in Barbados. Photo by author.

4. Colour

Landscape - many variations of green, grey, beige, blue (sky), blue green (water), and red soil

Plant - predominantly yellow, yellow green foliage and some multi-coloured, brilliant flower colours of red, yellow, pink, purple, etc.

Interior Design - base colour scheme on plant or landscape colours

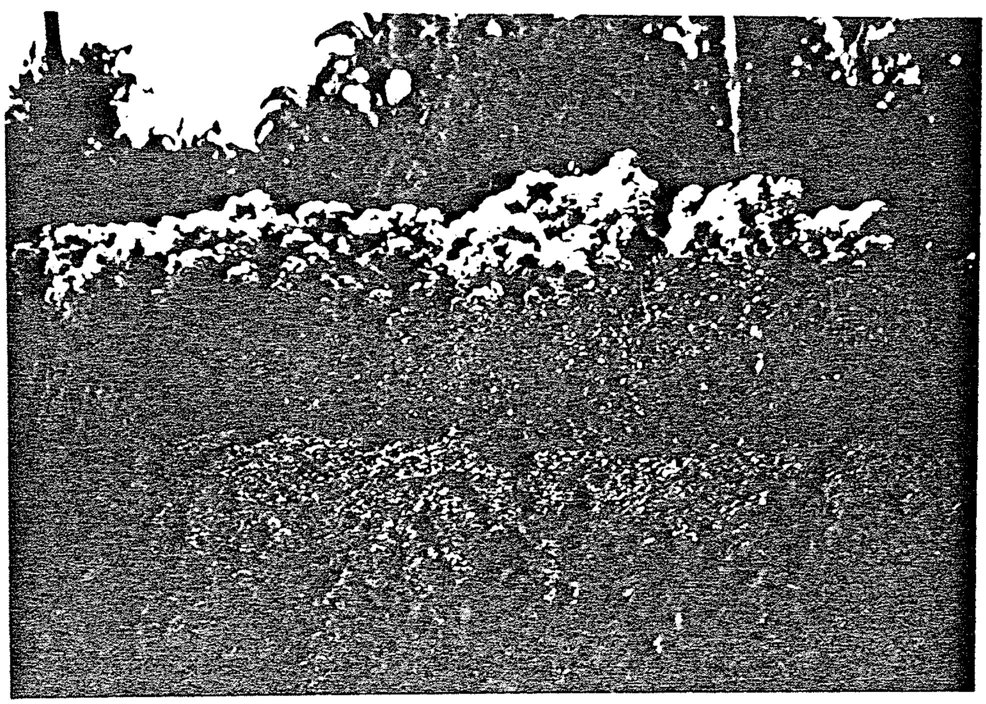


Figure 30.

Source - Tropical gardents in Barbados. Photo by author.

5. Form, Shape and Mass

Landscape - flat to angular landscape

Plant - determined by branching habit, variety in leaf arrangement and size, strong verticals

Interior Design - vertical spaces, delicate patterns in fabrics and finishes

Figure 31.

Source - Rio Grande River, Jamaica. Equinox, September/October 1983, p. 51.

6. Texture

Landscape - delicate, smooth

Plant - smooth to coarse, hairy, must consider leaf shape surface quality, leaf spacing, leaf size and the absence of petioles

Interior Design - predominate use of smooth surfaces

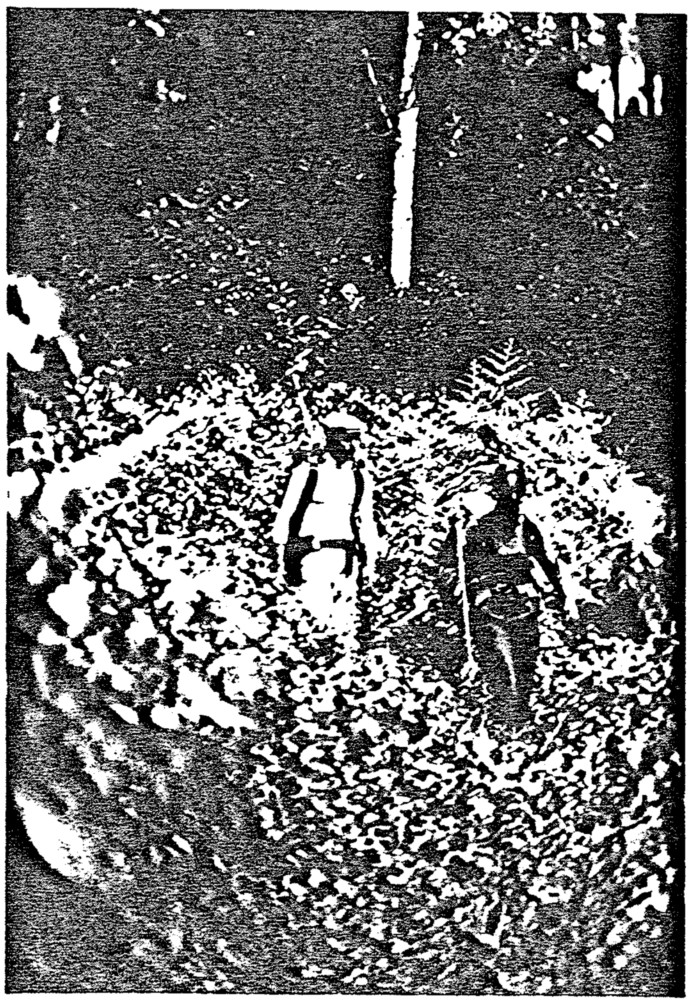


Figure 32.

Source - Tropical forest of Mount Kilimanjaro. Equinox, January/February 1985, p. 64.

7. Line

Landscape - graceful, undulating

Plant - graceful, upleafing, curving, predominantly vertical lines

Interior Design - vertical lines in window divisions, mouldings, graceful lines

Figure 33.

Source - Tropical forest, Columbia. Equinox, November/December 1982, p. 66.

3.1.3 Summary

Desert and rainforest imagery may be created by abstracting the desirable qualities from the natural environment and vegetation, and introducing them in the interior as design elements. Plants are chosen for their particular qualities of colour, texture or form making a significant contribution to the final design. The design process is one of creating three dimensional art form, as opposed to a horticultural exercise.

PART 4 THE APPLICATION OF TECNHOLOGY AND ART

4.1 INTERIOR LANDSCAPE ARCHITECTURE MODEL

4.1.1 Introduction

The following prototypes demonstrate the application of the principles, and methodology required to produce an interior landscaped environment in Winnipeg, Manitoba. Two different approaches have been taken: Prototype A, using the desert landscape for inspiration; and Prototype B, taking inspiration from the rainforest environment.

4.1.2 Site Examination

The following example illustrates the method by which the available light can be calculated for an interior situation in Winnipeg, Manitoba. At the 50th parallel, the potential for available annual sunshine in Winnipeg is 4483 hours. On average only 51.8 percent or 2321.4 hours is experienced. The month of July averages the most available sunshine with 315.6 of a possible 492 hours, or 64.1 percent realized. November registers the least with an average of 33.3 percent.[10]

The setting demonstrated is a reception area of an office building, at ground level. The calculations shown are for an overcast sky at 10:00 a.m., March 21 or September 21. For a more thorough picture of light levels throughout the year, and under varying conditions, further calculations are necessary. The environmental conditions for the reception area are as follows:

Location:	Winnipeg, Manitoba	50° N. Latitude
Room size:	20 ft by 30 ft	
Ceiling height:	14 ft	
Window area:	11 ft high by 30 ft long	
Window type:	Triple glazed, R 3.13	
Window orientation:	South	
Reflectance of interior finishes.		
WALLS:	30%	
CEILING	75%	
FLOORS:	30%	
Reflectance of outside materials:	Vegetation mean value 25% (APPENDIX III)	

Recommended Temperatures.	Winter	21.1 to 23.3° C
	Summer	23.3 to 25.6° C
Recommended Relative Humidity.	Winter	20 to 30%
	Summer	50 to 60%
Recommended Lighting levels.	10 - 30 fc	

To determine the amount of daylight available to the interior, the Daylight Factor must be calculated.

Daylight Factor = Sky Component + External Reflected Component + Internal Reflected Component

Where the

Sky Component is the measure of direct light from the sky reaching any interior point.

the External Reflected Component is the light reaching a point after reflecting from external surfaces, and

the Internal Reflected Component is the light reaching a point after reflection from internal surfaces such as walls, floor and ceiling etc.

Sky Component

- Sky luminance is 1180 footlamberts (see Appendix II)
- Illumination at a vertical window is one half that of the sky therefore it is 590 footlamberts.

External Reflected Component

- to calculate the luminance reflected by the vegetation the sky luminance is multiplied by 25 percent for a value of 295 footlamberts. However, a vertical window receives illumination from a uniformly bright ground equal in footlamberts to one half the ground brightness for a value of (295 x 1/2), 147.5 footlamberts.

Internally Reflected Component

The equation to calculate the internally reflected components is:

Ep = Ei x Aw x Ku x Km

Ep* = workplane illumination at point P (lumens/ft^2 or footcandles, fc)

Ei = illumination from sky or ground incident on vertical windows (fc)

Aw = gross area of fenestration (ft^2)

Ku = utilization coefficient which includes the effect of fenestration design, daylight controls, interior reflectances and room geometry (Appendix IV)

Km = light loss coefficient (Appendix V) (clean area, vertical window a value of .9)

* Since the work-plane illumination varies with the distance from the window, coefficients are determined for three points on the work-plane in a line at right to the middles of the window (Appendix IV).

E max is 5 feet from the window

E mid is the midpoint of the room, and

E min is 5 feet from the inner wall

For each point, separate calculations must be made for sky light and ground light with the results added to obtain the total work-plane illumination at that point.

E max (sky) = 590 x 330 x .00122 x .9 = 213.78 fc

E max (ground) = 147.5 x 330 x .0054 x .9 = 236.56 fc

E max (total) = sky + ground
= 213.78 + 236.56 = 450.34 fc

E mid (sky) = 590 x 330 x .00076 x .9 = 133.17 fc

E mid (ground) = 147.5 x 330 x .00048 x .9 = 21.03 fc

E mid (total) = 133.17 + 21.03 = 154.20 fc

E min (sky) = 590 x 330 x .00042 x .9 = 73.60 fc

E min (ground) = 147.5 x 330 x .00041 x .9 = 17.96 fc

E min (total) = 73.60 + 17.96 = 91.56 fc

For the 3 points in the 20 x 30 foot room the Daylight Factor may be calculated.

Daylight Factor = Sky Component + External Reflected Component + Internal Reflected Component

For point E max the Daylight Factor
= 590. + 147.5 + 450.34
= 1187.84 fc

For point E mid = 590. + 147.5 + 154.2
= 891.7 fc

For point E min = 590. + 147.5 + 91.56
= 829.06 fc

From these calculations it is evident that the light levels would support the growth of tropical plants in the low and medium light categories. The light levels would obviously change with the seasons, time of day and amount of cloud cover.

4.1.3 Prototype A - The Desert

The natural environment was examined to determine the desirable qualities which best capture the essence of the desert landscape. Plant and landscape characteristics were identified and abstracted to create the basis of the interior design scheme.

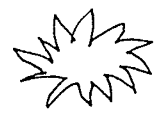
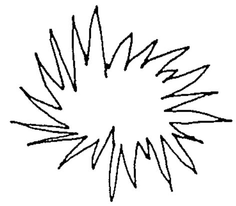
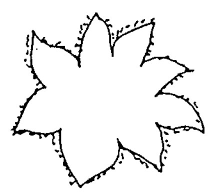
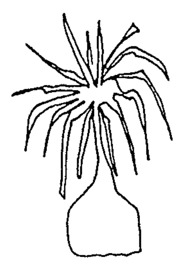
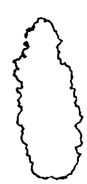
Fifteen desert plants are listed describing three inherent characteristics of colour, texture, and form as well as plant light requirements. It should be noted that texture was determined in three categories as follows:

fine, plant surface smooth or covered with few spines; medium, an even distribution of smooth surfaces and surfaces with spines; and course, plant surface covered in spines.

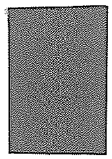
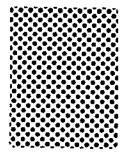
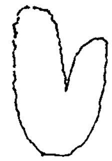
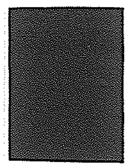
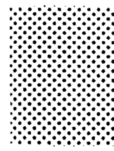
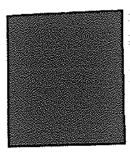
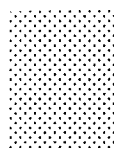
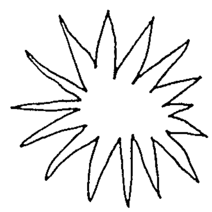
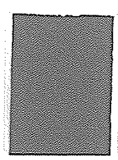
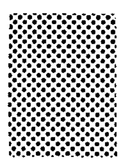
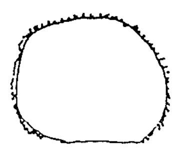
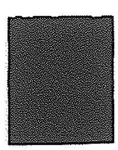
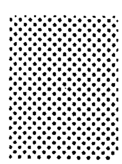
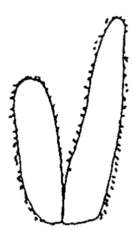
The plants and their characteristics are summarized in Table 2.

Table 2.

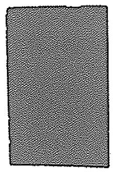
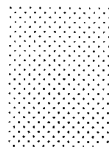
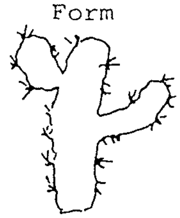
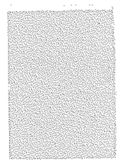
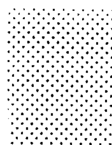
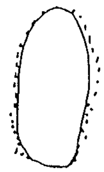
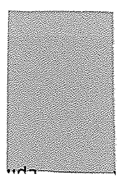
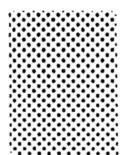
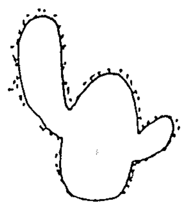
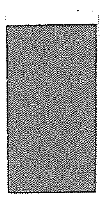
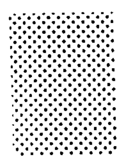
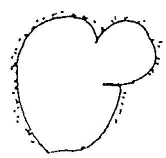
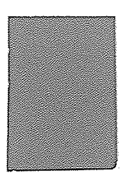
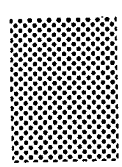
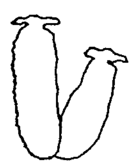
DESERT PLANTS

Plant Name	Colour	Texture	Form	Light
Abromeitiella brevitolia				High Full Sun
Agave americana				High Full Sun
Aloe cristata				High Full Sun
Beaucarnea recurvata				Medium
Cereus peruvians				High Bright

DESERT PLANTS

Plant Name	Colour	Texture	Form	Light
Cleistocactus hylacanthus				High Full Sun
Cochemiea poselgeri				High Full Sun
Dudleya brittonii				High Full Sun
Echinocactus grusonii				High Full Sun
Espostoa lanata				High Full Sun

DESERT PLANTS

Plant Name	Colour	Texture	Form	Light
Euphorbia flanaganii 'Cristata'				High Bright
Lemaireocereus marginatus				High Bright
Myrtillocactus geometrizans				High Full Sun
Opuntia microdasys				High Bright
Trichocereus theleganus				High Full Sun

The following desert landscape characteristics were identified and described in terms of their interior design opportunities.

Light - The even light quality of the desert can be exemplified in the interior through the use of fluorescent lighting. The lighting levels as described for the site would allow desert plants to be maintained, however for their health, higher levels are preferred.

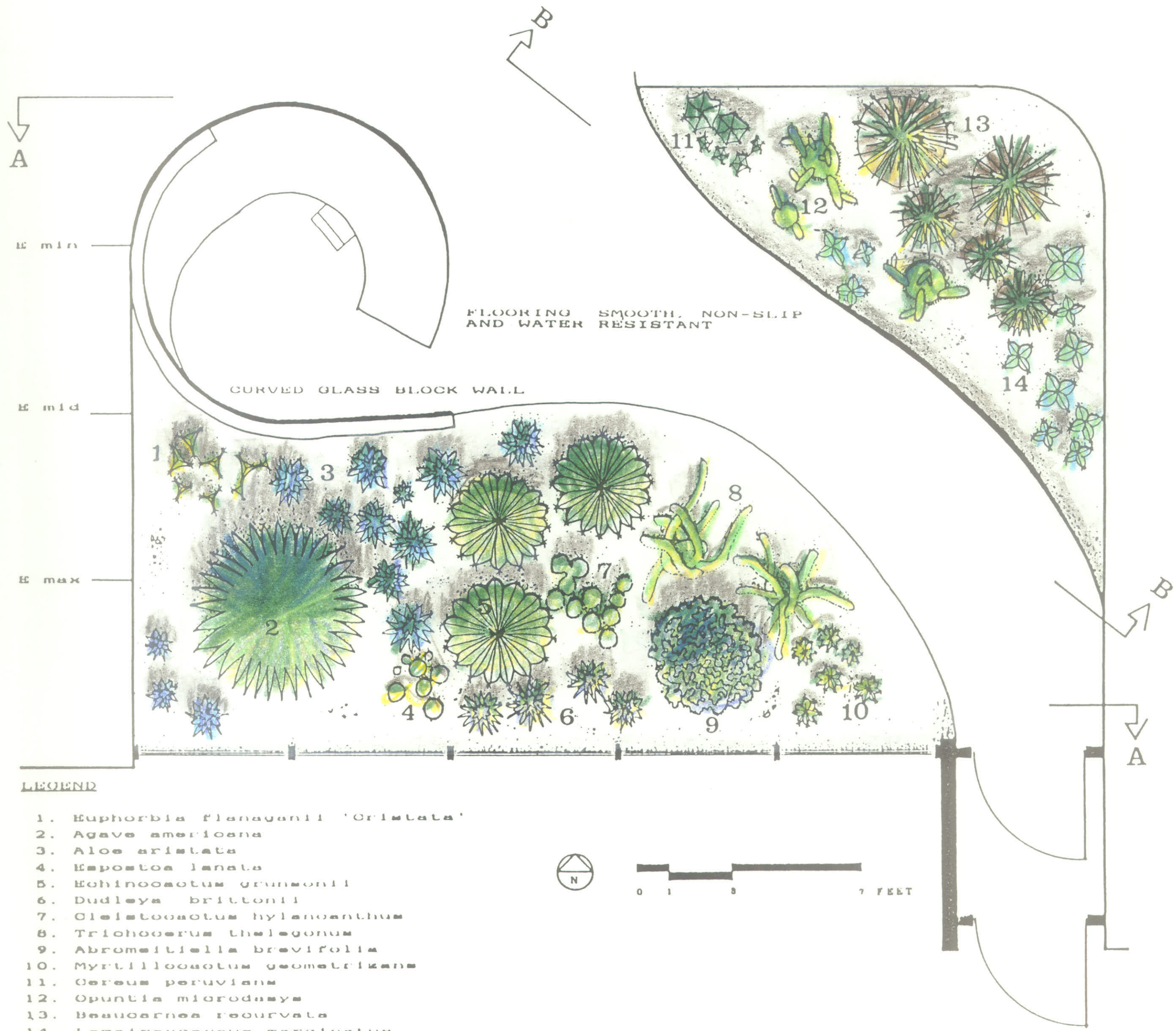
Scale - The high ceilings in combination with a predominance of horizontal lines, and low flat surfaces will help create an image of vastness.

Texture - Textured wall surfaces impermeable to water, and hard, smooth floor surfaces reflect the variety of textures found in the desert environment.

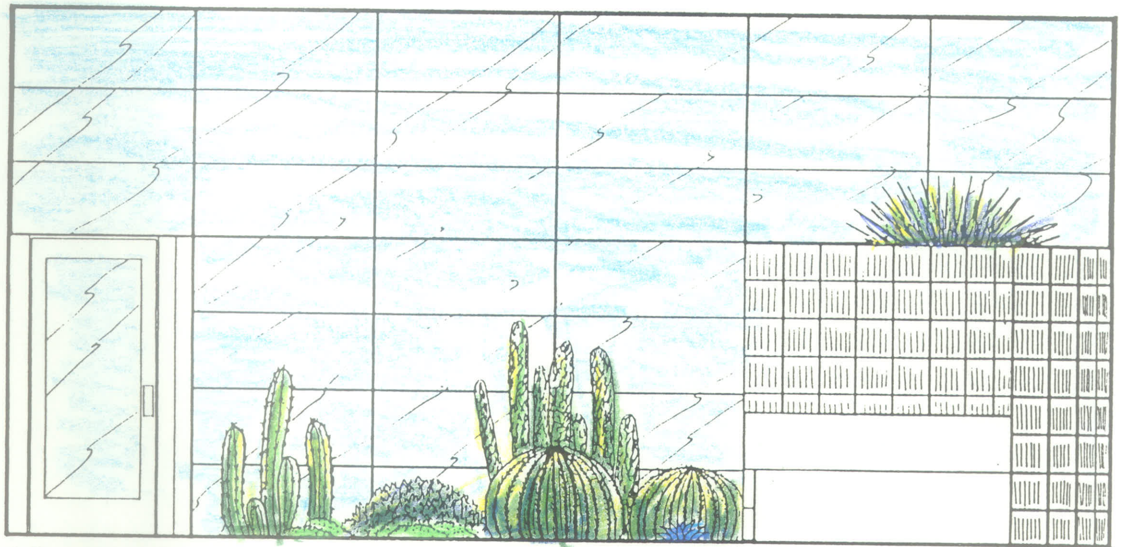
Line - Sinuous curves and rounded shapes in the interior project the variety of soft lines found in the desert.

Colour - The colour scheme is based on the desert plant colours in the Yellow-Green to Blue-Green range and their complimentary colours in the Red-Orange to Red-Violet range.

The following plan and elevations illustrate the Desert Prototype for the Winnipeg site.



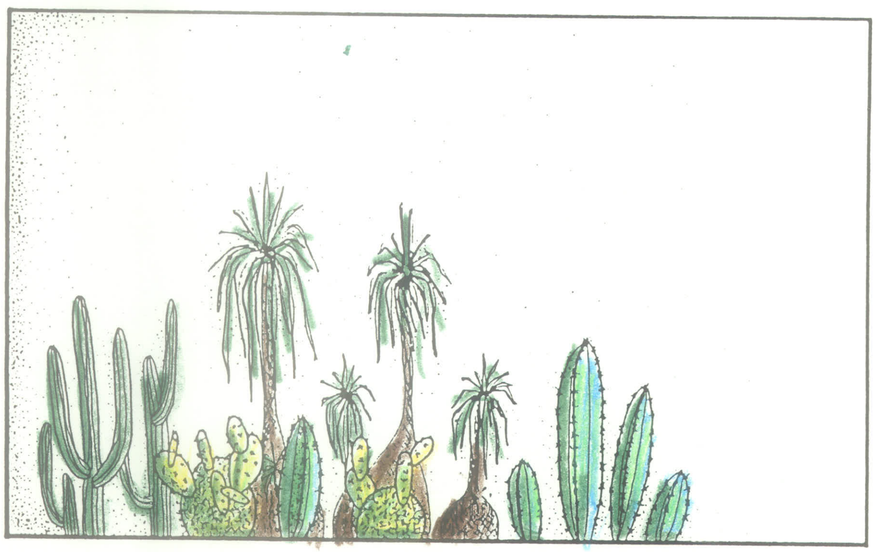
PROTOTYPE A - THE DESERT



SECTION A-A

CEILING HEIGHT 14'

WINDOW SECTIONS EMPHASIZING
THE HORZONTAL



SECTION B-B

WALL SURFACES ROUGH
AND WATER RESISTANT

PLANTING BEDS 6" BELOW
FLOOR SURFACE

0 1 3 7 FEET

4.1.4 Prototype B - The Rainforest

The natural environment was examined to determine the desirable qualities which best capture the essence of the rainforest landscape. Plant and landscape characteristics were identified and abstracted to create the basis of the interior design scheme.

The methodology utilized was similar to that used in the Prototype A - The Desert. In the case of the rainforest plants, the overall texture of the plant was determined by the size of the leaf in relation to the overall plant proportions. Three categories are identified; fine, medium and coarse.

Fine, leaves very small to small in relation to overall plant proportions,

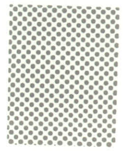
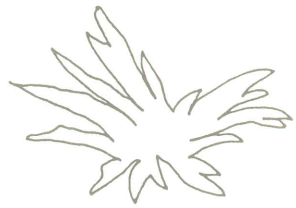
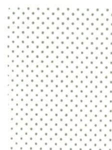
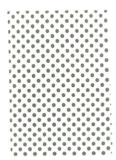
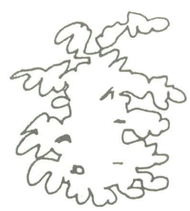
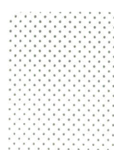
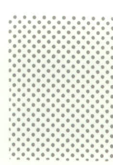
medium, leaves neither small nor large in proportion to the plant

coarse, leaves large in comparison to stem and plant proportions.

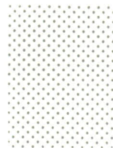
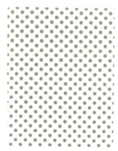
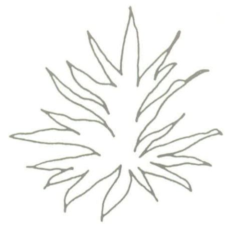
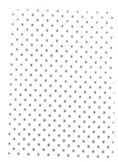
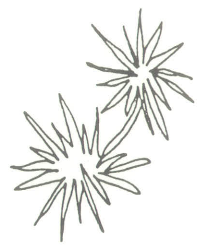
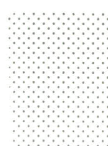
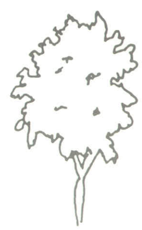
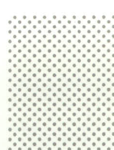
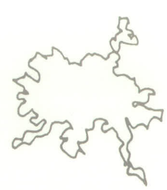
The plants and their characteristics are summarized in Table 3.

Table 3.

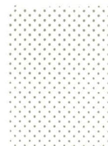
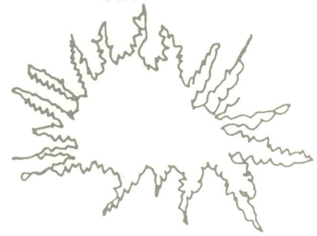
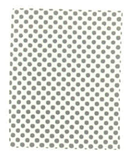
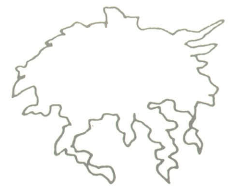
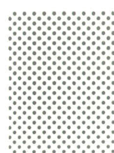
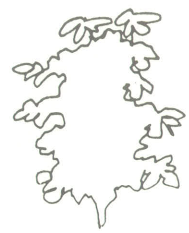
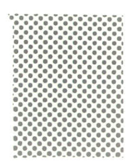
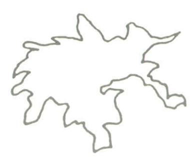
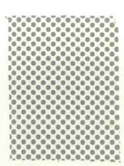
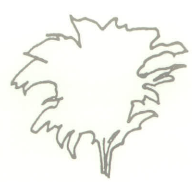
RAINFOREST PLANTS

Plant Name	Colour	Texture	Form	Light
Aglaonema commutatum				Low
Asparagus densiflorus				Low
Brassaia actinophylla				Medium
Chrysalidocarpus lutescens				Low
Cissus rhombifolia				Low

RAINFOREST PLANTS

Plant Name	Colour	Texture	Form	Light
Dizygotheca elegantissima				Low
Dracaena dermensis 'Warneckii'				Low
Dracaena marginata				Low
Ficus benjamina				Medium
Hedera helix				Medium

RAINFOREST PLANTS

Plant Name	Colour	Texture	Form	Light
Nephrolepis exaltata				Low
Philodendron scandens				Medium
Schefflera arboricola				Low
Scindapsus aureus				Low
Spathiphyllum 'Clevelandii'				Medium

The following rainforest landscape characteristics were identified and described in terms of their interior design potential.

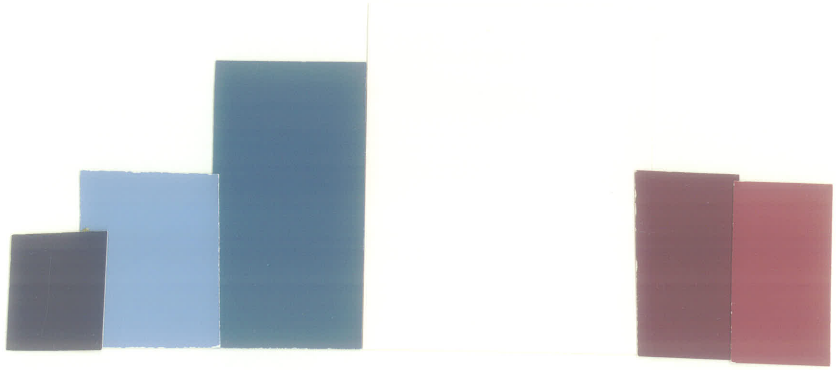
Light - To create an image of light and dark spaces found in the rainforest, the interior environment must present a series of overhead openings and enclosures which filters the available light.

Scale - The predominant use of tall, narrow elongated forms will create images of the rainforest.

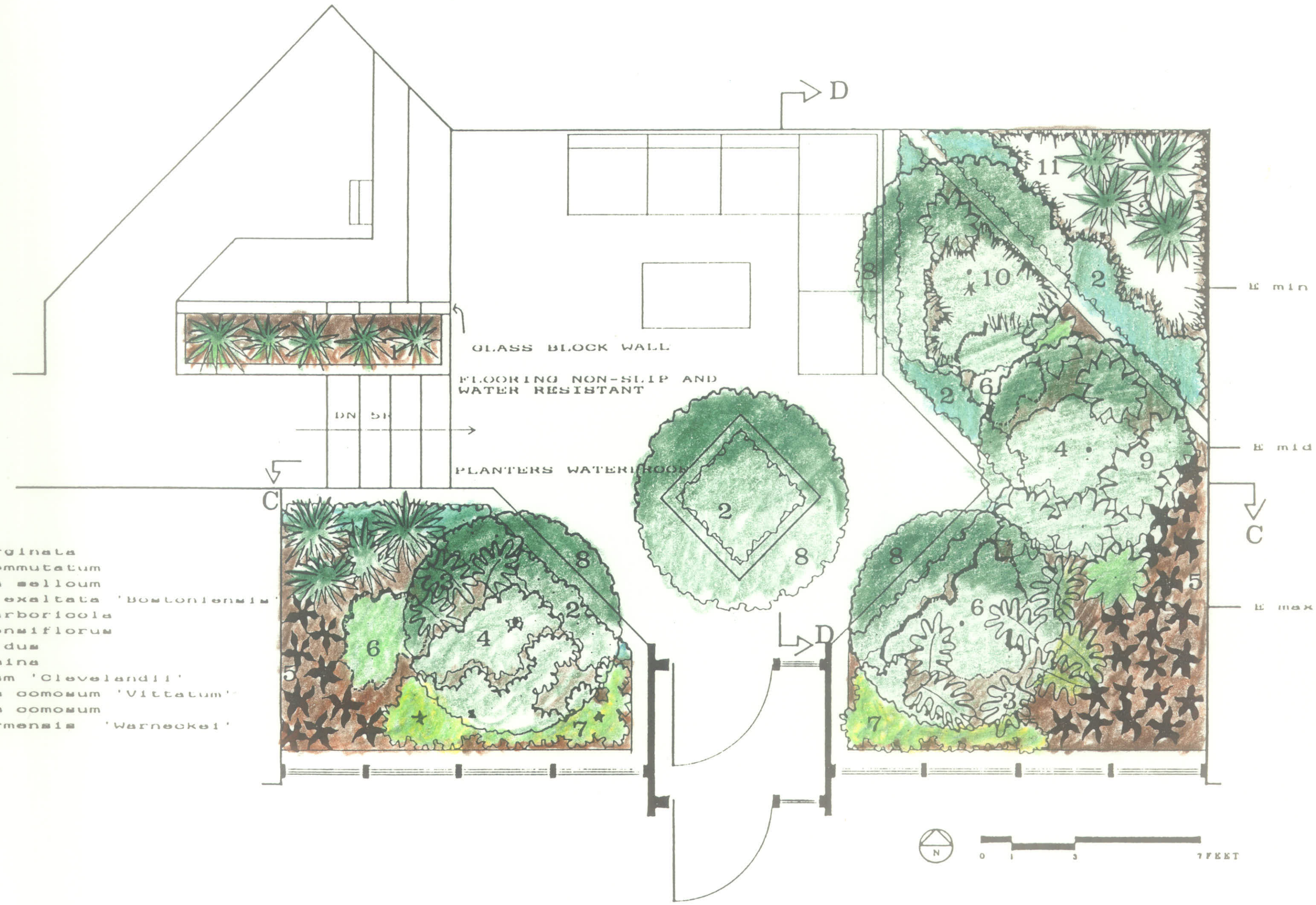
Texture - The use of smooth and finely textured surfaces will reflect the subtle variety of textures found in the rainforest environment.

Line - Vertical lines, gentle upward sweeping curves and delicate shapes are reminiscent of rainforest vegetation.

Colour - The interior colour scheme is based on the rainforest plant colours in the Yellow-Green to Green range. Using a tetrad colour scheme, the other colours are Orange, Red-Violet and Blue.



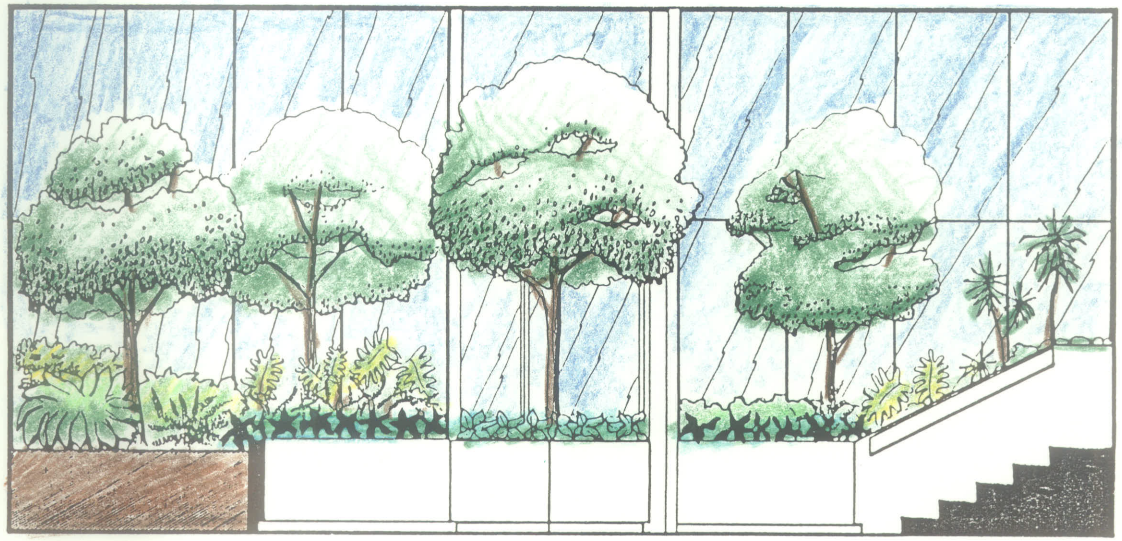
The following plan and sections, illustrate the principles of adapting the rainforest environment to a Winnipeg site to create environmental imagery.



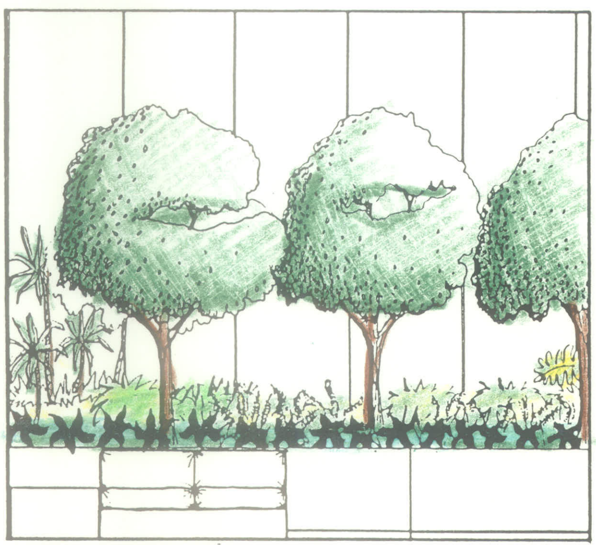
LEGEND

1. Dracaena marginata
2. Aglaonema commutatum
3. Philodendron selloum
4. Nephrolepis exaltata 'Bostoniensis'
5. Schefflera arboricola
6. Asparagus densiflorus
7. Asplenium nidus
8. Ficus benjamina
9. Spathiphyllum 'Clevelandii'
10. Chlorophytum comosum 'Vittatum'
11. Chlorophytum comosum
12. Dracaena dermensis 'Warneckei'

PROTOTYPE B - THE RAINFOREST



SECTION C-C



SECTION D-D

4.1.5 Summary

The two prototypes illustrate two different approaches of interior landscape architecture to the same site. The native desert and rainforest environments are unique from one another in climate, character, vegetation and horticulture, therefore they should be treated differently in the interior. Plants were chosen for their inherent characteristics of colour, texture, and form while satisfying their horticultural requirements for light. Landscape characteristics were chosen for those qualities which best captured the essence or feeling of the native environment.

Due to the inherent differences in horticultural requirements between the desert and the rainforest plants, they should not be combined in the same interior environment. However, many variations within each plant group are possible, combining the varying qualities of colour, form and texture while satisfying similar horticultural requirements. The end result is limited only by the imagination of the designer.

4.2 CONCLUSIONS

At present, interior landscaped spaces do not live up to their potential. Often they are a result of poor planning combined with a limited understanding of tropical plant horticultural requirements. Often too, they are included in the interior, after the fact, to fill an otherwise useless void, instead of being included in the building concept and design stage, resulting in interior landscaped spaces which are less than ideal. To correct this situation, designers must apply their skills and knowledge to create interior environments which integrate the technology and art of interior landscape architecture. Interior landscaped spaces must include the following, for each point is important and necessary to create environments that artfully support the growth of luxurious tropicals.

- Plants add life to the interior while satisfying man's psychological link with nature.
- Satisfy the human comfort levels of temperature and humidity.
- Provide the proper horticultural requirements of light, temperature, humidity, soil, and moisture.
- Create environmental imagery of tropical landscapes within architecture.
- Provide the appropriate architectural features which support plant health and ease of maintenance.

The following recommendations are outlined to assist designers in creating exciting interior landscaped spaces.

- Interior landscape planning should begin at the building concept stage.
- Plants thrive within the human comfort levels of temperature and humidity. However, light is the most limiting factor within architecture for exotic plants therefore increased lighting levels must be provided to ensure plant health, growth and ease of maintenance.
- Through a selective process, the desirable qualities from tropical landscapes may be extracted and abstracted to create environmental imagery.
- Plants should be selected for their inherent design of qualities of colour, texture and form as well as for their horticultural requirements.

Future Research Possibilities.

- Interior landscaped water gardens researching the types of tropical aquatic plants and their potential for use in the interior.
- Study the possibility of combining interior landscape architecture and recreation.
- Study the feasibility of interior landscaped spaces as a form of year round recreation and therapy for the elderly.
- Interior landscaped spaces as an educational tool for children giving them a "hands on" approach to understanding plant physiology while obtaining a greater appreciation for nature.

FOOTNOTES

1. John C. Royle, "Liveable Winter City - Coming Faster Than You Think, <u>Housing Ontario</u> 24 (November/December 1980):12.

2. Stephen Scrivens, <u>Interior Planting in Large Buildings</u>, (London: Architectural Press Ltd., 1980), p. 7.

3. "West Office Building of Deere and Company" <u>Interior Design</u> 50 (April 1979): 208

4. John Balfour et al., "Sonoran Desert", p. 1.

5. Ibid. p. 1.

6. Andrew Goudie and John Wilkinson, <u>The Warm Desert Environment</u> (Cambridge: Cambridge University Press, 1977), p. 23.

7. S. R. Eyre, <u>Vegetation and Soils A World Picture</u>, (London: Edward Arnold Publishers Ltd., 1963), p. 204.

8. Stephen Scrivens, <u>Interior Planting in Large Buildings</u> (London: Architectural Press Ltd., 1980), p. 32.

9. Thomas C. Weiler "How Much Light is Enough?" <u>Interior Landscape Industry</u> (November 1984): 21

10. Leon Feduniw, "Factors of the Winnipeg Climate". p. 64.

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APPENDIX I

Tropical Plant List Grouped According to Similar Light Conditions.

Low Light. 50 - 500 fc

Aglaonema commutatum	
Asparagus densiflorus	Asparagus Fern
Aspidistra elatior	Cast-iron plant
Beaucarnea recurvata	Ponytail
Calophyllum inophyllum	Laurelwood
Chlorophytum comosum	Ribbon Plant
Cibotium chamissoi	Hawaiian Tree Fern
Cissus rhombifolia	Grape Ivy
Clusia rosea	Balsam Apple
Crassula argentea	Jade Plant
Dichorisandra reginae	Queen's Spiderwart
Diefenbachia amoena	
Dizygotheca elegantissima	False Aralia
Dracaena dermensis 'Janet Craig'	
Dracaena dermensis 'Warneckei'	
Dracaena draco	Dragon Tree
Dracaena fragrans	
Dracaena fragrans 'Massangeana'	
Dracaena marginata	Madagascar Dragon Tree
Dracaena sanderiana	Ribbon Plant
Fatsia japonica	Japonese Aralia
Ficus elastica	Indian Rubber Plant
Ficus lyrata	Fiddleleaf Fig
Ficus retusa	Chinese Banyan
Philodendron miduhoi	
Philodendron scandens	Heart Leaf Philodendron
Philodendron selloum	Lacy Tree-philodendron
Philodendron x 'Red Emerald'	
Platycerium alcicorne	Elkhorn Fern
Polyscias fruticosa	Ming Aralia
Sansevierias	
Scindapsus aureus	Pothos
Syngoniums	
Tolmiea menziesii	Piggyback Plant
Tradescantias	Inch Plants
Palms - Acoelorrhaphe wrightii	Everglade Palm
Caryota mitis	Clustered Fishtail Palm
Chamaedorea elegans	Parlor Palm
Chamaedorea erumpens	Bamboo Palm
Chamaedorea seifrizii	Reed Palm
Chamaedorea humilis	European Fan Palm
Chrysalidocarpus lutescens	Areca Palm
Hedyscepe canterbuyana	Kentia Palm
Phoenix chinensis	Chinese Fan Palm

Phoenix roebelenii	Pygmy Date Palm
Ptychosperma elegans	Solitaire Palm
Ptychosperma macarthurii	Hurrican Palm
Rhapis exelsa	Large Lady Palm
Washingtonia robusta	Mexican Fan Palm

Medium Light Plants. 1,000 to 3,000 fc
100 to 1,000 fc for maintenance

Araucaria heterophylla	Norfolk Island Pine
Asplenium nidus	Birdsnest Fern
Aucuba japonica 'Variegata'	Gold Dust Plant
Begonias	
Brassaia actinophylla	Umbrella Tree
Bromeliads	
Caladiums	
Calathea codiaeum	Prayer Plant
Codiaeum variegatum pictum	Crotons
Cycas revoluta	Sago Palm
Ficus benjamina	Weeping Fig
Hedera helix	English Ivy
Hoyas	
Nephrolepis exaltata	Boston Fern
Pandanus utilis	Common Screw Pine
Schefflera arboricola	Hawaiian Schefflera
Spathiphyllum 'Clevelandii'	Peace-lily

High Light Plants. 4,000 to 8,000 fc
500 to 5,000 fc for maintenance

Abutilon	Flowering Maple
Arecastrum romanzoffianum	Queen Palm
Cactii	
Codiaeum variegatum pictum	Crotons
Euphorbia pulcherrima	Poinsetia
Euphorbia splendens	Crown of Thorns
Garcinia mangostana	Mangosteen
Gardenia jasminoides 'Fortuniana'	Cape Jasmine
Kalanchoes	Succulents
Mimusops elengii	Spanish Cherry
Ptychosperma elegans	Alexander Palm
Strelitzia alloa	Great White Strelitzia
Strelitzia caudata	
Strelitzia nicolai	
Yucca elephatipes	Spineless Yucca

Source - Alfred Byrd Graf, Exotic Plant Manual 2 ed. (East Rutherford: Roehrs Company, 1970)

APPENDIX II

Table 2. Equivalent sky luminance in footlamberts for average overcast day

Latitude	8 A.M. 4 P.M.	9 A.M. 3 P.M.	10 A.M. 2 P.M.	11 A.M. 1 P.M.	Noon
			December 21		
30° N	420	740	1020	1210	1270
32	350	700	960	1150	1200
34	320	650	910	1100	1140
36	260	600	840	1020	1070
38	230	550	790	940	1000
40	190	500	740	900	930
42	150	450	660	820	860
44	100	380	600	760	790
46	60	340	550	680	730
48	40	290	470	630	650
50	0	240	420	560	580
			March 21 or September 21		
30° N	910	1320	1710	2010	2140
32	880	1290	1650	1940	2070
34	860	1250	1600	1870	1980
36	840	1220	1560	1800	1900
38	800	1200	1500	1740	1840
40	790	1140	1460	1670	1760
42	760	1120	1410	1600	1690
44	740	1080	1340	1540	1620
46	710	1030	1229	1470	1550
48	690	990	1240	1410	1480
50	650	940	1180	1330	1400
			June 21		
30° N	1270	1730	2250		
32	1280	1730	2240		
34	1290	1730	2220		
36	1290	1730	2200	2960	
38	1290	1720	2160	2840	
40	1290	1700	2120	2650	3060
42	1300	1690	2080	2540	2860
44	1290	1670	2050	2430	2660
46	1290	1640	2010	2330	2520
48	1290	1620	1960	2250	2400
50	1260	1590	1900	2160	2280

APPENDIX III

Table 5. Reflectances of building materials and outside surfaces

Material	*Reflectance, per cent*	*Material*	*Reflectance per cent*
Bluestone, sandstone	18	Glass (cont.)	
Brick		Reflective	20-30
Light buff	48	Tinted	7
Dark buff	40	Asphalt (free from dirt)	7
Dark red glazed	30	Earth (moist cultivated)	7
Cement	27	Granolite pavement	17
Concrete	55	Grass (dark green)	6
Granite	40	Gravel	13
Marble (white	45	Macadam	18
Paint (white)		Slate (dark gray)	8
New	75	Snow	
Old	55	New	74
Glass		Old	64
Clear	7	Vegetation (mean)	25

Table 11. Coefficients of utilization for sidelighting for rooms with a ceiling reflectance of 75 per cent and a floor reflectance of 30 per cent

0.8 ratio of net transmission area to gross window area—80 per cent transmittance of clear glazing medium—no other daylight control

K_u	Room Length in Feet	Room Width in Feet	Light from Clear Sky				Overcast Sky				Uniform Ground			
			Ceiling Height in Feet				Ceiling Height in Feet				Ceiling Height in Feet			
			10		14		10		14		10		14	
			Wall Reflectance in Per Cent				Wall Reflectance in Per Cent				Wall Reflectance in Per Cent			
			70	30	70	30	70	30	70	30	70	30	70	30
Max.	20	20	.00191	.00165	.00149	.00123	.00210	.00223	.00197	.00176	.00147	.00109	.00096	.00070
		30	183	163	139	126	239	216	185	173	142	116	94	71
		40	194	162	139	120	254	223	189	172	138	115	92	71
	30	20	.00133	.00118	.00104	.00087	.00167	.00154	.00137	.00122	.00103	.00098	.00087	.00054
		30	123	113	93	87	165	150	128	121	98	90	65	56
		40	127	115	91	85	171	155	127	121	94	78	63	59
	40	20	.00102	.00094	.00080	.00070	.00125	.00121	.00102	.00095	.00082	.00062	.00053	.00044
		30	87	86	67	67	120	114	93	91	78	72	50	44
		40	93	88	66	65	126	118	94	92	73	70	49	43
Mid.	20	20	.00128	.00091	.00114	.00081	.00122	.00097	.00120	.00102	.00112	.00084	.00092	.00062
		30	65	50	66	47	39	41	51	48	64	46	66	43
		40	46	27	47	28	34	20	38	24	40	28	47	31
	30	20	.00081	.00072	.00071	.00062	.00078	.00071	.00077	.00076	.00083	.00066	.00068	.00049
		30	50	40	50	37	37	33	47	39	48	38	50	36
		40	35	24	38	24	27	18	37	22	32	26	38	29
	40	20	.00070	.00060	.00062	.00052	.00062	.00059	.00062	.00062	.00065	.00056	.00083	.00041
		30	36	34	37	31	24	27	30	32	38	33	39	31
		40	26	20	26	21	20	15	22	18	23	20	27	23
Min.	20	20	.00085	.00056	.00084	.00050	.00059	.00043	.00073	.00051	.00083	.00058	.00082	.00054
		30	42	25	42	25	23	16	29	18	38	19	45	22
		40	29	12	26	12	18	07	19	08	20	13	28	17
	30	20	.00064	.00045	.00063	.00041	.00044	.00035	.00051	.00042	.00065	.00045	.00083	.00041
		30	36	21	36	21	21	14	26	15	29	18	38	19
		40	25	11	23	11	14	07	15	08	18	09	23	12
	40	20	.00054	.00040	.00053	.00036	.00034	.00030	.00042	.00035	.00053	.00037	.00051	.00034
		30	25	19	25	19	15	12	18	13	24	18	29	18
		40	19	10	18	10	11	06	12	07	15	06	20	10

APPENDIX V

Table 7. Typical light loss factors for daylighting design

Location	Glazing position		
	Vertical	*Sloped*	*Horizontal*
Clean areas	0.9	0.8	0.7
Industrial areas	0.8	0.7	0.6
Very dirty areas	0.7	0.6	0.5