SEASONS IN THE SUN

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IEM members at the Cactus Garden, Malaysian Agricultural Park

The Agricultural and Food Engineering Technical Division (AFETD, IEM) organised a visit to the Malaysian Agriculture Park, Bukit Cahaya Seri Alam in Shah Alam, Selangor Darul Ehsan, on 27 July 2003. Twenty-four members made it on that day. The Ministry of Agriculture, Y. Bhg. Datuk (Dr.) Mohd. Effendi bin Norwawi were initiated the idea of the park in 1986. The park is designed in such a way that it gives visitors a total experience of its natural attributes, scientific facilities and agricultural presentations. All these are set within a luscious tropical rain forest in a scenic 1,290-hectare site. Its planners have in mind an open-air 'university' for the dual purpose of recreation and education. Here's a place to learn all about trees by their names. It has permanent display boards, live demonstrations, cultural exhibits, recreational facilities, accommodation, picnic areas, camping grounds, open-air amphi-theatres, natural trails, public amenities and numerous educational opportunities. One needs to spend a whole day walking through the park to appreciate its natural beauty and serenity. It is learned that there are further plans to develop the entire park into a theme park based on an agro-tourism biodiversity research and development concept to challenge the minds of Malaysians.

The highlight of the visit was to the environmentally controlled house. The Four Seasons Temperate Plant House is a brainchild of our former Prime Minister, Y. Bhg. Tun Seri Dr Mahathir bin Mohamad. His idea was forwarded to MARDI; and was later transformed into a technical project brief and turnkey document tender for the construction process. Hydrogarden International Ltd was awarded the contract to build the Temperate Plant House. The house was completed in August 1990.

The Four Seasons Temperate House consists of four components: Growth Chamber Structure, Mechanical Controlled Environment Hardware, Integrated Data Acquisition with Monitoring System and Horticulture Acquisition and Implementation. The house is intended for research on the effects of plant growth over a four-season climate in the tropics, as an education tool for those who have not seen a four-season climate by bringing the seasons to them, and also as a tourism destination. The house simulates are the natural spring, summer, autumn and winter seasons.

The Growth Chamber Structure was built with a portal frame steel structure, metal deck sheet roofing and high quality insulated panel sidewall. The dimensions of the structure, which houses the garden, is 39m long by 23m wide and it is 6m high. There are three important compartments in the structure: the growing beds, the controlled room and the viewing tunnel. Figure 1 shows the floor plan of the Temperature Plant House. The insulated sidewall consists of fire resistant materials made up of 10cm prefabricated Polyurethane (PU). The insulated panel is covered with 0.5mm thick PVC coated steel sheet for maximum strength and long life.

A viewing tunnel 2.4m wide and 2.4m high runs through the middle for a total length of 36m. The tunnel has an entrance door at each end, constructed by using triple glased vacuum tempered glass complete with support structures and heater lines at the perimeter. The vacuum glass prevents condensation and eliminates high air change rates that can damage plants. The vacuum glass provides transparent viewing

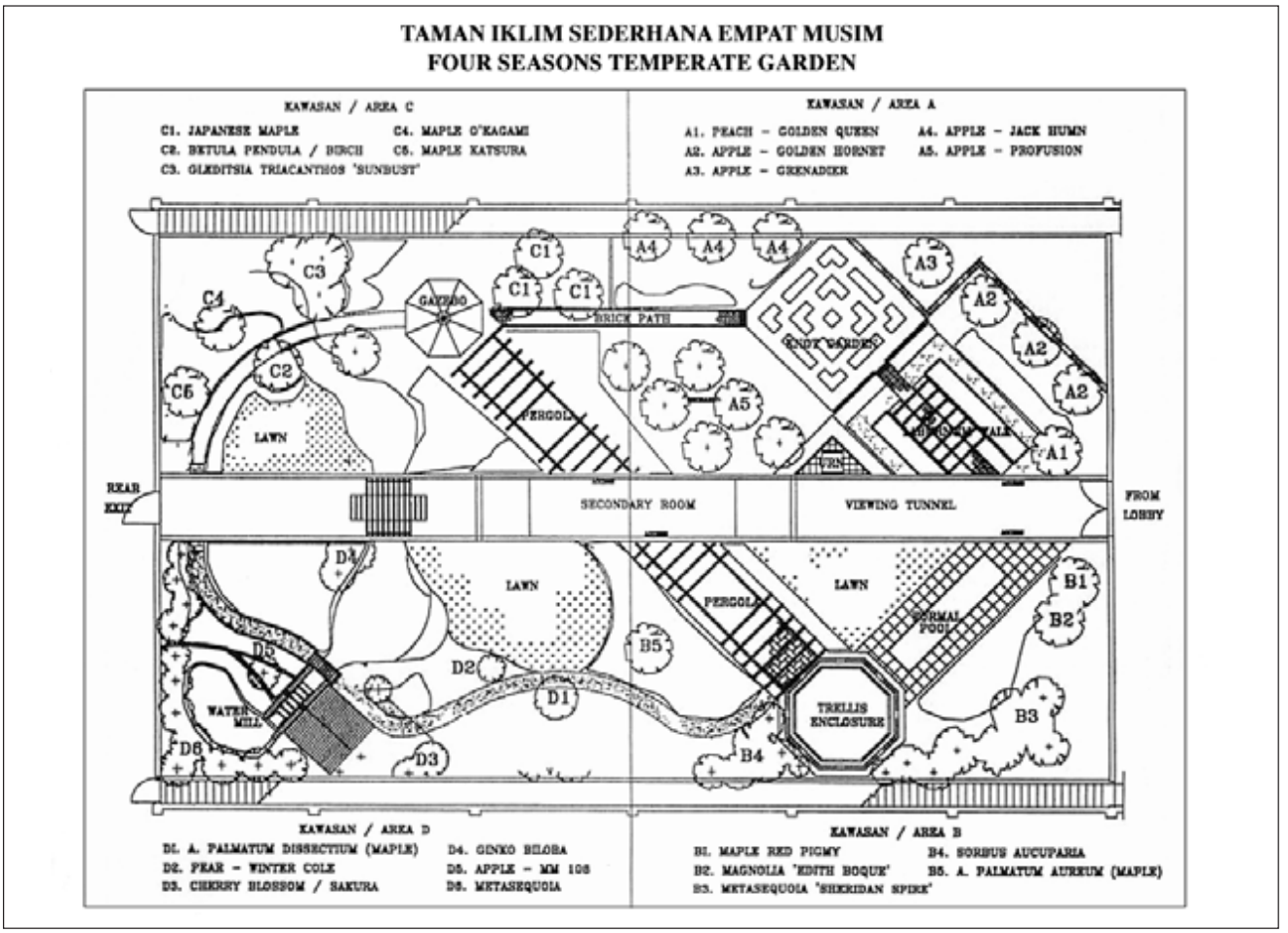

Figure 1: Floor Plan of the Four Seasons Temperate Plant House

Figure 2: Front View of the Four Seasons Temperate House

as no fogging occurs even with rapid changing of temperature and humidity inside the chamber.

There are 6 separate growing beds on each side of the viewing tunnel. Each bed is 10.3m long by 6.0m wide. Each bed has been dug out to allow a fill of 2.0m depth of soil below the ground level. This enable separate plant nutrient feeding in each bed and also prevents the spread of soil disease if it occurs.

A vestibule room is provided at one end of the growth chamber. Its section of 3.0m wide runs along the whole width of the chamber, which gives it a length of 23m. The vestibule portion is 3.0m by 7.0m. Each of the two control rooms is made of 3.0m by 8.0m on both sides of vestibule room. Figure 2 show the front view of the Four Seasons Temperate Plant House.

The Mechanical Controlled Environment Hardware for climate simulation includes a ventilation system provided to let in fresh air. In addition, a CO_2 supply system was also provided. The ventilation system was designed to extract air from the roof by using exhaust fans; and to bring in fresh air from the air inlet at the lower part of the house by pressure relief valves. Cylinder tanks supply CO_2. The capacity of CO_2 per cylinder is 15m3 and the weight of each tank is approximately 30kg. The house requires 20 cylinders per month. This system is regulated and controlled by the integrated data acquisition and monitoring system.

The climate control system was provided to maintain the required

Table 1. Typical Microclimate inside the Four Seasons Temperate Plant House

SPRING (SEPT – NOV)	SUMMER (DEC – FEB)
Temperature: 7 – 12°C Humidity: 65 – 85% Light intensity: 2500 – 3500Wm^{-2} Carbon Dioxide: 350 – 450ppm Day length: 12 – 13 hours Ventilation: 0.004 – 0.006m^3 s^{-1} m^{-2} Irrigation: 0.10 – 0.20litres/m^{-2}	Temperature: 7 – 12°C Humidity: 65 – 85% Light intensity: 2500 – 3500Wm^{-2} Carbon Dioxide: 350 – 450ppm Day length: 12 – 13 hours Ventilation: 0.004 – 0.006m^3 s^{-1} m^{-2} Irrigation: 0.10 – 0.20litres/m^{-2}
AUTUMN (MAR – MAY)	**WINTER (JUNE – AUG)**
Temperature: 12 – 15°C Humidity: 65 – 85% Light intensity: 2000 – 3500Wm^{-2} Carbon Dioxide: 350 – 450ppm Day length: 10 – 12 hours Ventilation: 0.004 – 0.006m^3 s^{-1}m^{-2} Irrigation: 0.10 – 0.20litres/m	Temperature: -5 – 5°C Humidity: 65 – 85% Light intensity: 500 – 2000Wm^{-2} Carbon Dioxide: 350 – 450ppm Day length: 7 – 8 hours Ventilation: 0.004 – 0.006m3 s^{-1}m^{-2} Irrigation: 0.10 – 0.20litres/m^{-2}

Table 2. Hard landscape structures and construction material inside the Four Season Temperate Plant House

STRUCTURE	CONSTRUCTION MATERIAL
Gazebo	Hardwood
Pergola	Hardwood
Walking Path	Interlocking Engineering Brick
Knot Garden	Engineering Brick
Viewing Tunnel	Triple Tempered Glass
Lawn Water mill	Hardwood and Boulders
Pond	Marble and Geotextile Membrane
Trellis Enclosure	Hardwood
Walking Path	Nominal River Aggregate
Mural	High Density Polyethylene Sheet
Arboretum Walk	Marble Slab
Formal Pool	Marble Slab

and desired temperature and humidity ranges. The system was designed to handle a temperature range from –10°C to 30°C based on local ambient conditions. A water-cooled system was used for refrigeration. The refrigeration system consists of water cooled condensing units, evaporators, a cooling tower, a refrigeration piping system, a water piping system and electrical wiring from the central control switch board to condensing units and evaporator units. The total cooling load for all the growing beds of the chamber is approximately 475,695Btu/hr (139,500W) at an operating temperature of –10°C.

Humidifiers were provided so that proper levels of humidity can be maintained for plant growth. Humidity down to approximately 55% RH can be achieved at temperatures down to approximately 22°C. A steam humidification system is used to create a specified humidity condition. The system consists of humidity unit, all-water piping, and electrical wiring from the central control switch.

Artificial lighting system is used to provide a maximum light intensity, equivalent to what one could find at high noon in the brightest regions. This is based on a maximum of 5,000lux. The irradiance for the greenhouse is approximately 24,000mW/m2. Two types of lamps provide the best spectrum for plant growing public viewing: 400W high pressure sodium lamps (108,000mW per lamp) and 400W high pressure metal halide (88,200 mW per lamp).

Plant irrigation, fertilisation and watering systems consist of water sources, nutrient tanks, fertiliser injectors, fittings, fasteners, piping system, filters, valves, dripper nozzles, controllers, EC monitors and pH controllers.

Temperature in the garden can be made to vary from –5°C to 25°C, while the temperature in the public viewing tunnel is kept constant throughout the year for public comfort. Triple glazed vacuum tempered glass is used to separate the public viewing tunnel from the garden so as to provide all-year-round perfect viewing, free of any condensation.

The house also has snow machine. It uses compressed air blasting out of a 'gun', atomising water emerging from an adjacent nozzle. The drop in air pressure causes the atomised water to form snowflakes. The equipment to drive the system includes an air compressor and water pumping systems along with air and water lines.

Table 3. Plants inside the Four Season Temperate Plant House

VARIETY	PLANT SPECIES
Bedding	Aubrietia Royal Red, Tulip Silentia, Ipomoea Heavenly Blue, Strawberry Rapella, Salvia Victoria, Petunia Express Blue Star.
Bulbs	Hemerocallus, Lilium Chinook, Lilium Conina, Lilium stirling Star, Lillium spp.
Climbers	Lonicera Dropmore Scarlet, Hydrangea Petiolaris, Wisteria sinencis Caroline'.
Herbs	Arundinaria Virdistriata, Helenium, Nepeta Nervosa, Alchemilla Mollis, Cyclamen hederofolium, Ligularia Vietchiana
Lilies (Water)	Escarboucle, Froebeli, Marliacea Albida, Moorei, Occidentalis, Paul Hariot.
Marginals (Water)	Caltha Palustris, Glycera Spectabilis Variegatus, Iris Laevigata, Myosotis Scorpyoides, Iris Higo, Typha.
Shrubs	Chaenomeles Cardinal, Cotoneaster Horizontalis, Euonymus Fortunei, Juniperus Horizontalis, Kolwitzia Amabilis.
Trees	Acer Palmatum Dissectum Viridis, Fagus Aylvatica Purpurea, Ginko Biloba Autumn Gold', Thuja Occidentalis Pyrimidalis, Taxodium Distichum, Pear 'Winter Cole', Peach 'Golden Queen', Apple 'Golden Hornet',
Turf	Grasses

The function of the Integrated Data Acquisition with Monitoring System is to understand real time microclimate parameters and to control mechanical hardware to simulate the right microclimate for plant growing. The system consists of computer software programs, data loggers, parameter sensors and hardware actuators. The computer is programmed to automatically set all the environment parameters for each day of the four-season year, following the New Zealand climate. It is used to control air temperature, humidity, ventilation, refrigeration, defrost cycles, carbon dioxide enrichment, artificial lighting, irrigation and fertilisation, and performs data recording and analysis together with alarm detection. The microclimate requirement of Four Seasons Temperate Plant House is shown in Table 1.

Figure 3: Lovely cool spring beginning with beautiful flowers

Hard landscape structures are the non-living elements of a garden landscape. Hard landscape is necessary in order to create a beautiful and

Figure 4: Summer season follows with a sea of colourful blooms

aesthetically pleasing landscape. Some of the structures are listed in Table 2.

The Horticulture Acquisition and Implementation program involves sourcing of plant resources and planting. The main attraction of the Four Seasons Temperate Plant House is the soft landscape that is the colorful and varied temperate plant species. The types of plants include bedding, bulbs, climbers, herbs, lilies, marginals, shrubs and turf. Table 3 shows some of temperate plant species planted in the house. The plants are blended with hard landscape according to a temperate region thematic garden design.

CLIMATE SCHEDULING AND ACTIVITIES

Spring (September – November)

During this season, most of the plants produce colorful flowers and fresh green leaves. The average day temperature is around 12_2C and by night, 7_2C. The light is on for 13 to 21 hours a day throughout this season. Spring is the season in which new growth begins and most plants burst into flower Drifts of yellow Daffodils, Red Tulips and Muscari decorate the border of the lawns. Pink blossoms liven up the leafless

Figure 5: A pictureque temperate summer season in the tropics

rap apple trees. Other flowers such a Hyacinthus, Cytisus, Viburman, Azalea and Dahlia, Pansy, Viola add color to this garden. Figure 3 shows a panoramic view of the spring season inside the Four Seasons Temperate Plant House.

Summer (December – February)

The hottest season of the year, summer is the period for vigorous plants growth. The garden will be lighted for 18 hours a day, to create conditions similar to those in temperate regions. With an average day temperature of around 20°C, the environment in the garden is almost similar to that of the viewing tunnel. During this season all the tress will be full of leaves and colors. Bed of richly colored flowers such as Dahlia, Marigold, Carnation, Lobelia, Candytuff, Viola, Viscaria and Pansy brighten up the whole garden. Figures 4 and 5 show panoramic views of the summer season inside the Four Seasons Temperate Plant House.

Autumn (March – May)

Red and yellow autumn colours dominate during the period between summer and winter, during which the temperature of the house is gradually decreased. The lights will be on for an average from 10 to 12 hours. At night the temperature will drop to 8 – 10°C. During this season, the greenery of spring and summer changes gradually to copper and brown, and some of the leaves will drop off. The leaves of Ginko Biloba and Liquidamber turn into lovely golden and copper hues. Michaelmas Daisy and Chrysanthemum will give a pastel color. The beauty of Autumn is in the base bark of trees and the fallen leaves of marry colours. Figures 5 and 6 show the autumn season at its best.

Figure 6: Late autumn copper and brown colours, a prelude to falling leaves

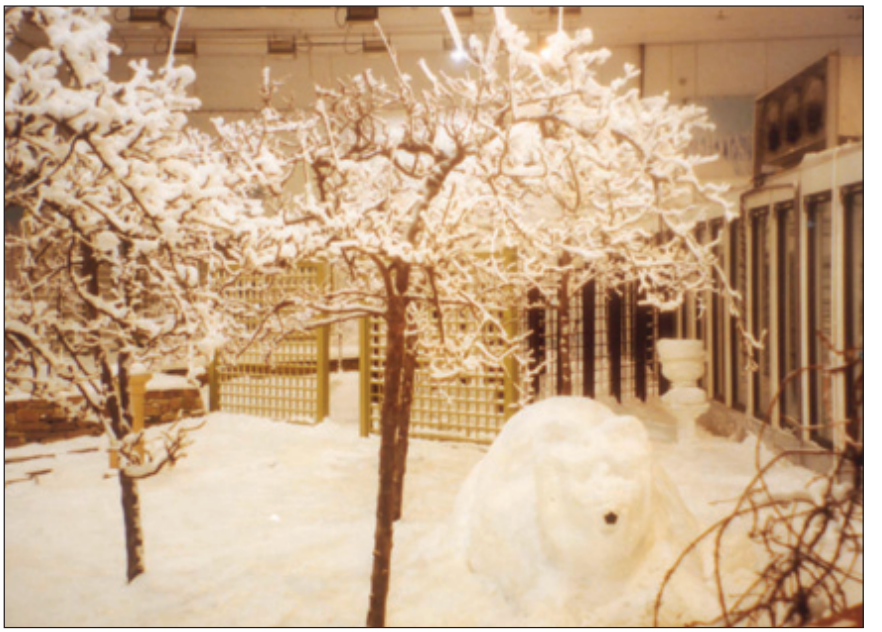

Figure 7: Where else can you get a winter dressed in clothes for the tropics

Winter (June – August)

The most popular season among Malaysians, winter is the coldest season of the year. Winter days are short with less than 8 hours of daylight. The temperatures for both day and night will drop to as low as –5°C and rarely rises above 5°C. The garden will be enveloped in snow for two months. During this period, most of the trees remain dormant. These trees will spring into life again when the winter is over and temperatures get warmer. However, some plants will die, leaving their seeds for the next season. The evergreen Royal Bay trees and Chamaecyparis however will maintain its beauty over winter. The silver barked birches contrasting with the red-stemmed dogwoods adds some colours to the otherwise white Christmas winter scene. The other trees and plants will be covered with snow and remain dormant until the first signs of spring. Figures 6 and 7 show the beautiful cool winter season minus the chilling winds associated with normal winters.

TABLE 4. TYPICAL ANNUAL MAINTENANCE COST

MAINTENANCE COST	RM
Horticultural Management Service	687,500
Mechanical and Electrical	772,800
Civil and Structure	45,000
Computer System	42,000
Miscellaneous	59,700
TOTAL:	**1,607,000**

MANAGEMENT AND MAINTENANCE

Since the Four Seasons Temperate Plant House is a highly complex system, it requires a day-to-day management team. It requires consultants in mechanical and electrical engineering, civil and structure engineering, and experts in horticulture to manage and maintain the house. In addition, a project management team is required to supervise, monitor and certify their works. RM10 million was required to develop the Four Seasons Temperate Plant House. However, maintenance requires RM1.5 million to RM1.8 million annually. The maintenance cost varies, due to replacement or maintenance of imported horticultural plants and mechanical hardware in services. The typical breakdown of annual maintenance cost is shown in Table 4.

The Four Seasons Temperate Plant House draws many visitors, both local and international. Many distinguished visitors have not missed visiting the house. Among

them are local VIPs, ASEAN Ministers of Agriculture, The Ambassador of Poland, Members of the Parliament of Singapore and Thailand, the Foreign Minister of Taiwan, the Minister of Food, Agriculture and Cooperatives of Pakistan, ASEAN Welfares Ministers, the Finance Minister of Sudan, ASEAN Chief Secretaries, the Prime Minister of Fiji, the British High Commissioner, the Prime Minister of Singapore, His Majesty Emperor and Her Majesty Empress of Japan and the President of Republic of Peru.

The Four Seasons Temperate Plant House is a project that is a first of its kind undertaken in the tropics. The house provides facilities for research, education and tourism. The house has proven to be reliable and functional. The initial proposal of having all fours seasons at one go in four different settings seems attractive; we can then have all the temperature seasons at once. It would have been the only spot in the world with this phenomenon. However, the development and maintenance costs of the house are still high. It is also not feasible and not economically viable for temperate plant production. The main cost contribution are energy consumption and maintenance of mechanical hardware. Therefore, further study and improvement of the system are needed in terms of energy saving and of using low-cost controlled environment hardware to achieve a technically feasible and economically viable business in the near future.

The authors would like to thank the Management of the Malaysian Agricultural Park, Shah Alam and the MARDI for their generosity and permission to use their material in this report. ■

Figure 8: Thawing snow soon making way for the first of spring