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ECONOMICS OF LANDSCAPING FEATURES FOR CONSERVING ENERGY IN RESIDENCES[1]

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Abstract. **The economic effectiveness of various: 1) shading levels on walls and roofs; 2) exterior colors of walls and roofs; and 3) building orientations for conserving energy in heating and cooling residential buildings is presented. The effectiveness of each landscaping feature is evaluated on the basis of its present worth in terms of energy savings that accrue because of the adoption of the landscaping feature. Present worths are calculated for interest rates ranging from 7.5% to 17.5% and energy cost escalation rates ranging from 10% to 30%. The results are based on the Test Reference Year of 1965 for Jacksonville, Florida.**

The computer simulation results are summarized by evaluating the annual expenditures for cooling and heating a specified house with "low energy" and "high energy" landscaping designs. The "low energy" landscape consists of heavy shade on light-colored walls and roof and an east-west orientation. The "high energy" landscape refers to a house with no shade on dark-colored walls and roof and a north-south orientation. The differences in present worths of the "low energy" and "high energy" landscape for a 20 year life are $3,080, $8,683, and $27,277 for energy cost escalation rates of 10, 20, and 30%, respectively, and for an assumed interest rate of 10%.

Energy conservation in residential buildings is being widely promoted throughout the United States as one means of coping with the problems of rapidly escalating prices of utilities and the uncertain supply of conventional energy sources. A recent report (12) indicates that approximately 32% of the energy consumed in the United States is for heating and cooling buildings occupied by people. The fact that 32% of total energy consumption is for comfort conditioning underscores the need for defining optimal parameters for efficient landscaping designs for residences. Information on design parameters and recommendations for economically conserving energy in heating and cooling residential buildings by using different landscaping features is an obvious void in the literature.

Rather traditional means of energy conservation in residential buildings include retrofitting existing buildings with insulation in walls and ceiling, weather-stripping around window and door frames, and periodic maintenance of the mechanical cooling and heating equipment. Retrofitting of this nature can save 20-25% of the energy used for comfort conditioning buildings (7). In new residential construction, the energy savings that can be realized by incorporating energy conservation principles into the design, construction and operation of a building are approximately 50-60% (8). These energy savings can be realized with little, if any, discomfort to the occupants of the buildings.

Landscaping features of a residential building can be designed to save energy and to increase comfort during both heating and cooling periods of the year. The use of different types of trees, vines, and espaliered plants for protecting buildings from intense solar radiation was presented by Black (3). A discussion of the qualitative means in which plants can reduce energy expenditures for comfort conditioning has been presented by many (3, 6,11).

A quantitative approach on the value of landscaping materials for energy conservation was presented by Buffington (5) who reported on the effectiveness of various shading levels, exterior colors of walls and roof, and building orientations for conserving energy. The computer simulation results indicated a reduction of 27% in the heat extraction rate for a building with desirable landscaping features compared to the same building except with undesirable landscaping features. Heat extraction rate is defined as the rate at which the air conditioner removes heat from the conditioned building. The report focused on the reduction in heat extraction rates that can be achieved by utilizing landscaping features. Although the results are beneficial for design purposes, they cannot be applied directly in economic analyses. The heat extraction results were based on the 2½% design dry-bulb temperature and outdoor daily temperature range for Orlando, Florida. The design day selected was June 21, which corresponds to the date of maximum solar insolation. Parker (10) has reported that a design day of August 6 is more appropriate because it corresponds to the time of maximum ambient temperature and the period of peak energy utilization of residential air conditioners in Miami and probably most of Florida.

The object of this reported research was to determine the economic effectiveness of various landscaping features for reducing energy expenditures for heating and cooling residential buildings. The landscaping features considered were: 1) wall and roof shading; 2) wall and roof exterior colors; and 3) building orientation. Orientation of a building is defined as the direction of the major axis of the building.

Methodology

To experimentally evaluate the effects of different landscaping features on energy expenditures for heating and cooling residential buildings would involve constructing several identical structures with various landscaping features. The energy expenditures for heating and cooling could then be monitored over an extended period of time in order to evaluate the effectiveness of each landscaping design. Such experimental evaluation would be prohibitively expensive and time consuming. Furthermore, if the residential buildings were occupied, then the differences in lifestyles among the various families could easily mask the effectiveness of the landscaping features for reducing energy consumption.

Computer simulation can be effectively used for a detailed analysis of the thermal performance of a residential building as a function of many different structural and landscaping designs.

The computer model for simulating the heat gains and losses of a residential building over a one year period was based in part on the transfer function method as presented in *ASHRAE Handbook of Fundamentals* (1). The transfer function coefficients for walls and roofs of buildings were calculated for the specific construction details of each building section according to the computer program by Mitalis and Arseneault (9). After heat gains and losses through the building were simulated, heating loads, cooling loads, heat

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extraction rates, and heat addition rates were simulated (1). The consumption of utilities was calculated from heat extraction and addition rates on the basis of system performance of the mechanical heating and cooling equipment as specified in Table 1. The utility expenditure was then related to dollars using current price estimates of the utilities. Full details of the application of the transfer function method to the thermal analysis of residential buildings are presented by Buffington (4).

To properly evaluate the thermal performance of any building, it is essential to perform detailed simulations on an hour-by-hour basis over an extended period of time of at least one year (1). It is not sufficient to simply use one summer design day and one winter design day for the analysis, regardless of when the design days are selected to occur. Using a unique design day for each month of the year is also not sufficient to simulate energy consumption for heating and cooling a building.

The weather data set used as input for the simulation model was the test reference year (TRY) as developed by the National Oceanic and Atmospheric Administration (13). The TRY consists of hourly climatic data for a selected reference year to be used to compare the performance of heating and air conditioning systems in the same building or in buildings with different design features (13). The TRY for Jacksonville is 1965. The data from the TRY used in the computer simulation were: dry-bulb temperature, dewpoint temperature, and opaque sky cover. Hourly values of the opaque sky cover data for the TRY were used to relate the incoming solar radiation to the extra-terrestrial radiation according to statistical relationships presented by Bennett (2).

For the purpose of evaluating the various landscaping features, a rather typical Florida residential building located in Jacksonville, Florida (30.5°N Latitude and 81.7°W Longitude) was used as a control house for the computer simulation studies. Details of the control house were:

—Concrete block building on concrete pad
—139 m² (1500 ft²) floor area (9.1 m x 15.2 m) (30 ft x 50 ft)
—2.4 m (8 ft) wall height
—White exterior walls
—Asphalt shingle roof (1/3 slope)
—Dark color roof
—Window area 14.5% of floor area
—Single-pane windows
—1½ ACPH (air changes per hour) building infiltration
—3 ACPH attic ventilation (natural)
—0.61 m (2 ft) roof overhang
—No shade on exterior walls and roof
—Carport on north end of house
—Building occupied by 2 adults and 2 children
—Wall construction
  20 cm (8 in.) concrete block wall
  1.9 cm (0.75 in.) air gap
  1.3 cm (0.50 in.) plaster board
—Ceiling construction
  9 cm (3.5 in.) mineral wool insulation
  1.3 cm (0.50 in.) plaster board
  3.8 cm x 14 cm (2 x 6) joists on 61 cm (24 in.) spacing
—Floor construction
  10 cm (4 in.) concrete slab
  carpet and rubber padding
—Gable construction
  1.9 cm (0.75 in.) siding
  3.8 cm x 8.9 cm (2 x 4) studs on 61 cm (24 in.) spacing
—Roof construction
  asphalt shingles
  building paper
  1.3 cm (0.50 in.) plywood sheathing
  3.8 cm x 14 cm (2 x 6) rafters on 61 cm (24 in.) spacing
—Air handling duct construction
  2.5 cm (1 in.) duct board

The air temperature maintained inside the building was 25.5°C (78°F) during the cooling season and 20°C (68°F) during the heating season.

Floor plan and side views of the control house used in this simulation study are shown in Fig. 1.

In all the computer analyses performed, the energy expenditures were simulated for heating and cooling the control house with different landscaping features. Other energy expenditures for heating water, lighting, powering appliances, etc. were not included in any of the analyses because these energy expenditures were assumed to be independent of landscaping features.

Results and Discussion

Yearly expenditures for comfort conditioning the control house were simulated using the computer model discussed earlier in this paper. Expenses were simulated for required energy for cooling and heating throughout the test reference year of 1965 for Jacksonville, Florida. The energy expenditures for heating and cooling were simulated for current prices of $0.07 per kilowatt-hour for electricity and $0.92 per gallon for No. 2 fuel oil for the mechanical systems as described in Table 1.

Table 1. Mechanical systems for residential building.

Cooling System	Heating System
Air Conditioner (Air-to-air) Energy Efficiency Ratio (EER) 8.6 at rated environmental conditions EER varied as function of ambient temperature Price of electricity is $0.07/Kw-Hr	Direct-fired furnace 75% combustion efficiency No. 2 heating oil (140,000 BTU/gallon) Price of oil is $0.92 gallon

The simulated yearly expenditures for comfort conditioning of the control house and for thirteen different modifications to the control house are presented in Table 2. Whenever a landscaping feature was being evaluated, all other features remained exactly the same as in the control house. For example, when the modification of heavy roof shading was considered, all the features remained the same in the control house as specified, except that the roof was assumed to be under heavy shade. In analyzing the results tabulated in Table 2, one can realize the large impact that various landscaping features can have upon the total expenditures for comfort conditioning.

Light, heavy, and full shade as used in this manuscript correspond to approximately 33%, 67%, and 100% shading, respectively, during the cooling season. During the heating season, the shading levels correspond to 10%, 20%, and 25% shading, respectively. The reduction of shading levels during the heating season is based on the shading being provided primarily by deciduous trees.

To evaluate the economic effectiveness of the various landscaping features being considered, present worths of each feature were analyzed for interest rates of 7.5, 10, 12.5, 15, and 17.5% and an assumed 20 year life. Present worths of each landscaping feature for a 10% annual energy cost escalation rate are presented in Table 3. For assumed energy cost escalation rates of 20 and 30%, present worths are presented in Tables 4 and 5, respectively. The economic

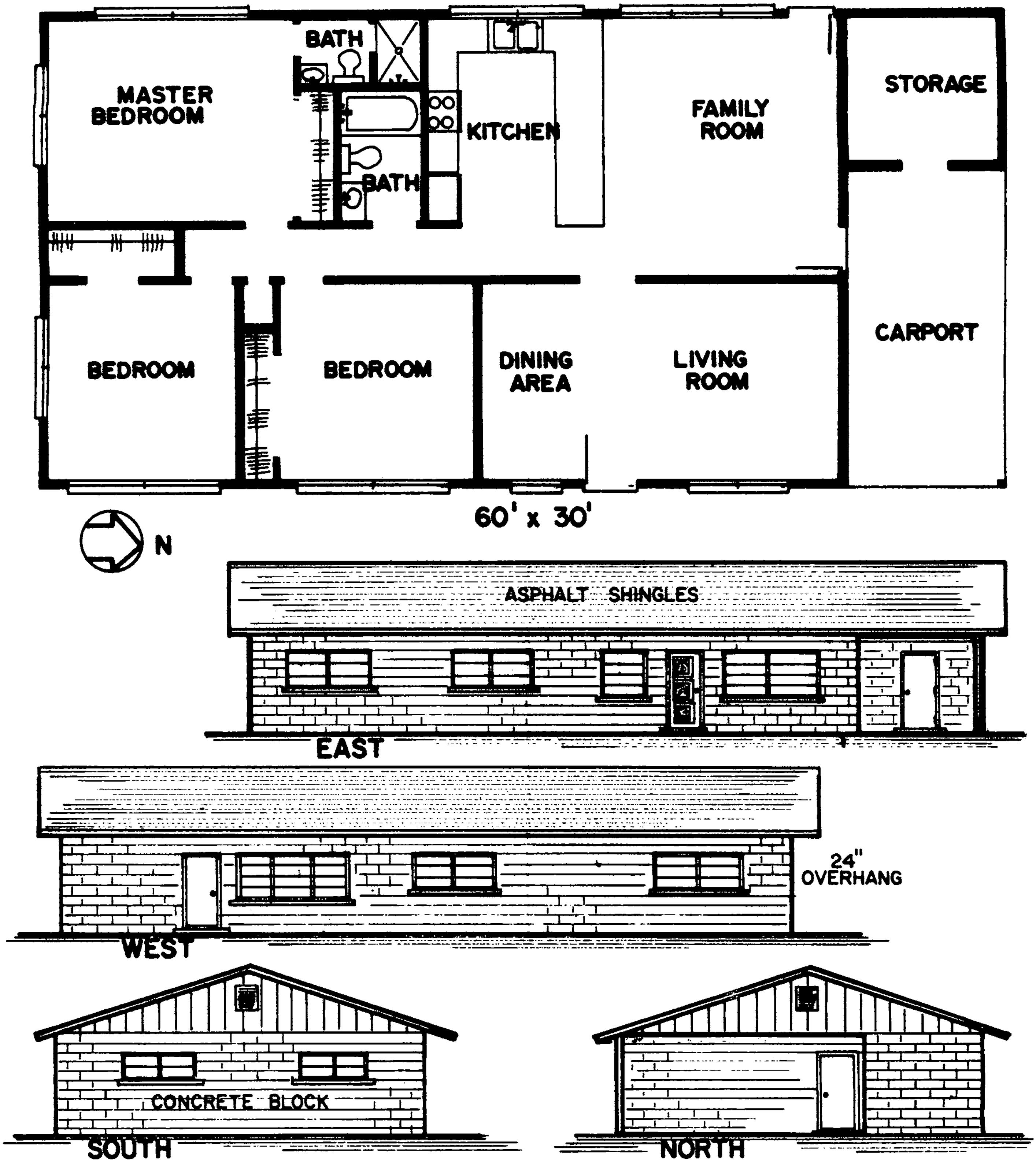

Fig. 1. Floor plan and side views of control house.

concept of present worth is interpreted as the additional present value of one alternative compared to another alternative on the basis of annual monetary savings attributed to the *adoption* of the alternative. For example, the present worth of a residential building with an east-west orientation compared to north-south orientation is $1,340 for an interest rate of 10%, annual energy cost escalation rate of 10% and a 20 year life (Table 3). The interpretation is that one could justifiably spend $1,340 additional for the control house with an east-west orientation compared to north-south orientation on the basis of the amount of money saved annually in utilities for comfort conditioning over the next 20 year period. The data in Tables 3-5 indicate that as the annual energy cost escalation rate increases, the present worth of each landscaping feature also increases. However, for an increase in interest rates, the present worth of each

Table 2. Simulated yearly expenses for comfort conditioning.

	Cooling	Heating	Total
Control House	$535	$179	$714
Modifications			
Orientation			
East-West Orientation	477	170	647
Wall Shading			
Light Shading	493	186	679
Heavy Shading	449	191	640
Roof Shading			
Light Shading	522	181	703
Heavy Shading	510	182	692
Full Shading	496	184	680
Wall and Roof Shading			
Light Shading	480	186	666
Heavy Shading	427	194	621
Heavy Shading on Walls; Full Shading on Roof	414	197	611
Exterior Colors			
Dark-Colored Walls and Roof	591	162	753
Light-Colored Walls and Roof	511	187	698
Overall Comparison			
High-Energy Landscaping	591	162	753
Low-Energy Landscaping	410	189	599

landscaping alternative decreases. The most desirable landscaping feature is obviously that feature which yields the highest present worth for a given interest rate and energy cost escalation rate.

To summarize the results of the economic efficiencies of the various landscaping alternatives, "low energy" and "high energy" landscaping designs were simulated. The high energy landscaping corresponded to the control house with north-south orientation, no shading on the walls or roof, and dark-colored exterior walls and roof. The low energy landscaping corresponded to the control house with east-west orientation, heavy shading on walls and roof, and light-colored exterior walls and roof. For an interest rate of 10% and energy cost escalation rates of 10, 20, and 30%, the corresponding present worths of the low energy landscaping are $3,080, $8,683, and $27,277, respectively, compared to the high energy landscape.

Table 6 summarizes the simulated energy consumption and the mechanical system requirements of these two landscaping designs. Although the low energy landscaping results in higher consumption of oil for heating than the high

Table 6. Comparison of low energy and high energy landscaping designs.

	Low Energy Design	High Energy Design
Electricity Consumption, KW-Hr/Yr	5,864	8,437
Fuel Oil Consumption, Gallons/Yr	205	176
Cooling System Capacity, Tons	3	4.5
Heating System Capacity, BTU/Hr	55,000	55,000

Table 3. Present worths for various landscaping alternatives (10% annual energy cost escalation rate and 20 year life).

Alternatives	Interest Rate 7.5%	10%	12.5%	15%	17.5%
East-West Orientation vs North-South Orientation	$1,721	$1,340	$1,067	$ 868	$ 720
Heavy Wall Shading vs No Wall Shading	1,901	1,480	1,179	959	795
Heavy Roof Shading vs No Roof Shading	565	440	350	285	236
Light Wall and Roof Shading vs No Wall and Roof Shading	1,233	960	765	622	516
Heavy Wall and Roof Shading vs No Wall and Roof Shading	2,389	1,860	1,481	1,205	999
Heavy Wall and Roof Shading vs Light Wall and Roof Shading	1,156	900	717	583	484
Light-Colored Walls and Roof vs Dark-Colored Walls and Roof	1,413	1,100	876	713	591
Low Energy Landscaping vs High Energy Landscaping	3,955	3,080	2,453	1,995	1,655

Table 4. Present worths for various landscaping alternatives (20% annual energy cost escalation rate and 20 year life).

Alternatives	Interest Rate 7.5%	10%	12.5%	15%	17.5%
East-West Orientation vs North-South Orientation	$ 5,162	$3,778	$2,825	$2,159	$1,684
Heavy Wall Shading vs No Wall Shading	5,701	4,172	3,121	2,384	1,860
Heavy Roof Shading vs No Roof Shading	1,695	1,240	928	709	553
Light Wall and Roof Shading vs No Wall and Roof Shading	3,698	2,706	2,024	1,546	1,206
Heavy Wall and Roof Shading vs No Wall and Roof Shading	7,165	5,244	3,922	2,996	2,337
Heavy Wall and Roof Shading vs Light Wall and Roof Shading	3,467	2,537	1,898	1,450	1,131
Light-Colored Walls and Roof vs Dark-Colored Walls and Roof	4,237	3,101	2,319	1,772	1,382
Low Energy Landscaping vs High Energy Landscaping	11,864	8,683	6,494	4,962	3,870

Table 5. Present worths for various landscaping alternatives (30% annual energy cost escalation rate and 20 year life).

Alternatives	Interest Rate 7.5%	10%	12.5%	15%	17.5%
East-West Orientation vs North-South Orientation	$16,932	$11,867	$ 8,472	$ 6,162	$ 4,566
Heavy Wall Shading vs No Wall Shading	18,701	13,107	9,357	6,806	5,043
Heavy Roof Shading vs No Roof Shading	5,560	3,897	2,782	2,023	1,499
Light Wall and Roof Shading vs No Wall and Roof Shading	12,131	8,502	6,070	4,415	3,271
Heavy Wall and Roof Shading vs No Wall and Roof Shading	23,503	16,472	11,760	8,553	6,338
Heavy Wall and Roof Shading vs Light Wall and Roof Shading	11,372	7,971	5,690	4,139	3,067
Light-Colored Walls and Roof vs Dark-Colored Walls and Roof	13,900	9,742	6,955	5,058	3,748
Low Energy Landscaping vs High Energy Landscaping	38,919	27,277	19,474	14,164	10,495

energy landscaping, the extra heating expense is more than offset by the much lower cost of utilities required for cooling. The savings in the purchase of the smaller air conditioner necessary for the low energy landscaping will compensate for some of the expenses required for providing the low energy landscaping features.

Summary

The economic feasibilities of various landscaping alternatives must be shown before a homeowner, contractor, financial lender, engineer, architect, horticulturist, realtor, etc. can most effectively utilize data on the energy savings of various landscapes. The results presented in this paper show the economic feasibilities of the landscaping features of building orientation, wall and roof shading, and exterior wall and roof colors.

The most effective way to educate people of the need to conserve energy is to convince them how they can save money by saving energy. Therefore, the economic feasibility of any energy conserving alternative should always be considered before presenting materials and recommendations to the consuming public.

Planned future research activities will focus on incorporating the purchase price and annual maintenance costs (fertilizer, water, pesticides, etc.) of shading materials into the analysis of the economic feasibilities. Economic analyses will then be presented in the form of effective interest rates earned on the capital investment required to provide each of the landscaping features for various climatic zones within the State of Florida.

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VERSATILITY OF THE MODERN DAYLILY

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Abstract. **The modern daylily, which in more temperate climates is a major perennial, is adaptable for multiple uses in warmer areas. Many evergreen and extra-evergreen cultivars are handsome enough to market as standard pot plants and are, in fact, more likely to succeed having been grown in pots. Some of the more compact growers will succeed as container plants for extended periods and will give repeated bloom. Daylilies offer real potential as cut flowers with their vibrant colors, varied shapes and sizes. Yet, they continue to find their highest beauty in ground plantings, offering a vivid, long-season display of color and increasing in beauty from one year to another.**

In temperate areas of the United States the daylily is one of the most dependable of many colorful perennials. Combined with other perennials such as delphinium, iris, peony, campanula, etc. in a classic herbaceous border, featured in massed beds of daylilies, used as clump plantings with rocks or shrubs, or used as ground cover, it is a highly adaptable and useful plant. The herbaceous border is little used in the lower tip of Florida where lush tropical foliage plantings supersede it. Although most of the plants used in the northern border will fail in this climate, some will adapt. Louisiana iris, for example, in my border combine their blues in a delightful contrast to warm pinks and yellows of daylilies. Pentas give pleasing contrast in color and texture. Shrubs such as *Plumbago capensis* and *Brunfelsia americana* provide both pleasing flowers and background. The variations in size and colors of daylilies, themselves, provide texture and color interest.

Major hybridizers and a host of hobby hybridizers contribute to the beautiful and bewildering bounty of modern daylilies. They vary in size from one and a half inches in diameter to seven or eight inches; likewise the height varies from about ten inches to three or four feet. Colors range through every variation of cream, yellow, gold, orange, pink, rose, red, "melon" and purples; moreover, there are flowers with contrasting eyezone areas, markings not unlike those of brocades, deeper colored edges and rainbow blends of colors within one flower. Shapes may be round and flat, or lily-like and recurved, or triangular, and there may be all sorts of frills and ruffles and even completely double flowers. Textures may be satiny, velvety or puckered, and there is sometimes a shimmering glint of "gold" or "diamond" dust on the surface of the flower. Many are fragrant with scents reminiscent of lilies, narcissus, and tea roses.

A scape, or flower stem, may have from several to fifty or more buds and the graceful, arching foliage may vary in length of leaf, width and stiffness. The basic cultural divisions, evergreen, semi-evergreen and those which are dormant in winter govern general areas where specific cultivars may be grown. This very basic differentiation is not well understood. In general, only strongly evergreen daylilies will succeed in the southern tip of Florida (2). Since