visited at least once each year. Larger growers in terms of volume may be seen 3 or 4 times. We make many trips into the local areas surrounding each site for local growers. These trips will give us a good overview of what is in production and improve our sensitivity to the market.

How do we assure ourselves of adequate purchases? We do it by knowing the business trends. Are single family or townhouses the trend? Is the area commercial or residential? Will there be new plantings in growth areas like Atlanta and Maryland, or replantings as in Connecticut? We make sure to keep our relationships with our vendors on an even keel. We pay constant attention to the supply side. What is ready now? Should we arrange contract purchasing and, if so, how far ahead? What items should be contracted — specialty items, bread-and-butter, or novelty items? We assure adequate purchases by making our commitments early and taking what we commit to. We do it by making sure that although it's of primary importance to us that we make money, it is also important that our suppliers flourish and make profit.

How can we help the grower? Specifically, I feel we are obligated to pass on market trends, fashion, and changes in customer types. We should work together toward making the market drive production, bringing a sense of order, rather than allowing production to drive the market. When production drives the market, price cutting is the result, which is disastrous for both the grower and the wholesaler.

In summary, in order to forecast purchasing you must know the following:

1. Your business plan.
2. Your market and customers.
3. The current fashion.
4. The available supply.
5. The tools needed to assure adequate purchases.

PLANT MODELING: DEVELOPING AN APPROACH[1]

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WHAT IS PLANT MODELING?

Webster defines a model as information, data or principles which are arranged or grouped mathematically. The algebraic formula $y = mx + b$, which is used to fit a straight line, is a

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simplified form of a model. Basically a model is a means of classifying or categorizing. In order to simplify daily activities, we use models frequently. When meeting a stranger, we may categorize or classify that person based on our previous experience or "models" in our minds. We may classify or categorize how we produce an azalea crop versus a *Pittosporum* or *Ligustrum* from the standpoint of media requirements, pH, and light intensity. The difference with plant modeling is that we are using hard data. We take quantitative values and plug these numbers into a statistical program (equation) to derive a statistical model.

In September, 1985, the American Association of Nurseryman published a list of research priorities that included the need to determine growth dynamics for various nursery crops; that is, to develop mathematical models that could describe environmental treatments and effects on plant responses. The ultimate goal is to increase plant productivity through better understanding of how environmental treatments influence plant growth, characteristics and potential.

Modeling is a *predictive* response. Modeling is accomplished by using equations to help quantify and give us an estimate on the growth response of a plant based on the environmental conditions under which that plant is being manipulated.

Goals of plant modeling. Modeling is designed to have direct application to: 1) predictable plant quality, 2) predictable plant inventory turnover, i.e., minimizing plant residency in the nursery, 3) maximizing people, plant, materials, energy, and scheduling efficiency, 4) customizing growing conditions, and 5) minimizing costs.

In modeling it is necessary to quantify and keep records. It is important that environmental data be collected and quantified so that management decisions can be made based on facts, and not just intuition or guess work. Modeling attempts to take some of the *art* out of propagation and production and make it more of a *science*.

Current usage of plant modeling. There are many examples of plant modeling in use. Growth chambers from small cabinets to large specialized warehouses are manipulated to determine and control environmental conditions for optimum plant growth. In the greenhouse industry modeling is being utilized, particularly in environmental climate-control systems. In Holland there are some 8,000 climate-control computers employed in commercial greenhouse operations (3). In agronomy, degree-heat days are used to predict when corn should be planted and when maturation will occur for harvesting and processing. In fruit crops, chilling-degree hours are monitored to determine dormancy requirements of apples, peaches, and other crops. Once the designated number of hours at 43°F (5°C) is reached, the dormancy requirement, or the ability of that plant's buds to force out has been met. Chilling-hour requirement is a model to help give a rough estimate of when this occurs for a particular plant.

The important area of water relations is also being used for model development. In production of nursery pine seedlings, Weyerhaeuser Corporation utilizes pressure bombs to determine water management programs. The pressure bomb helps to assess leaf water status, which can then be used to determine necessary irrigation frequency to maximizing seedling girth, height and other characteristics. Manipulating the irrigation frequency can also bring seedlings into dormancy in the fall to improve the plant's survivability after the seedlings have been lifted for transplanting. Jackson and Perkins are using pressure bombs to determine water status before digging dormant field rose bushes. Objectives are to correlate water status of rose bushes with optimum survivability of processed rose bushes.

Model user vs. modeler. It is important to differentiate between being a model user versus a modeler. Most of us will use statistical programs (models) that have been designed by researchers and statisticians (modelers) to be used on personal computers. Once suitable models are developed for nursery propagation and production systems, we will see much greater usage on a commercial scale.

Computer usage — monitoring, controlling, modelling. Computer usage in nursery crops currently consists of monitoring, using data loggers or automated weather collection systems. For example, in determining fungicide application programs for apple scab control, data loggers gather information on relative humidity and temperature. The producer can then make more accurate management decisions on most efficient fungicide usage. Controlling climate is another aspect of computer use. And last, statistical equations, or models to determine optimal environmental conditions for plant productivity are slowly being developed and adapted.

In order for modeling to be successful we must first select test model nursery crop species to use. Environmental conditions must be standardized where possible. This is difficult in container production and under open field conditions. However, there are opportunities for environmental control under propagation and greenhouse systems.

Methodology of crop modeling. Methodology of crop modeling in the nursery begins with data collection. Gathering data from a data logger (automated weather collection systems) and compiling it into a computer data base would be one way to collect data. Data analysis consists of utilizing the data collected, quantifying it by using spread sheets such as Lotus 1-2-3®, and then adapting a statistical program such as Plotit® which can be utilized with an IBM PC and other systems (5).

Plant propagation, production, and modeling. Crop modeling can be applied to propagation systems using a statistical technique known as regression. In the mathematical model presented, for seasonal rooting of hardwood rose cuttings, a slope known as the regression line is fitted to the various points that represent the month cuttings were propagated and the subsequent rooting percentage (Figure 1) (2). From this model, or statistical package, one can better understand environmental parameters under which the cuttings were taken and the ultimate predicted success rate in future years.

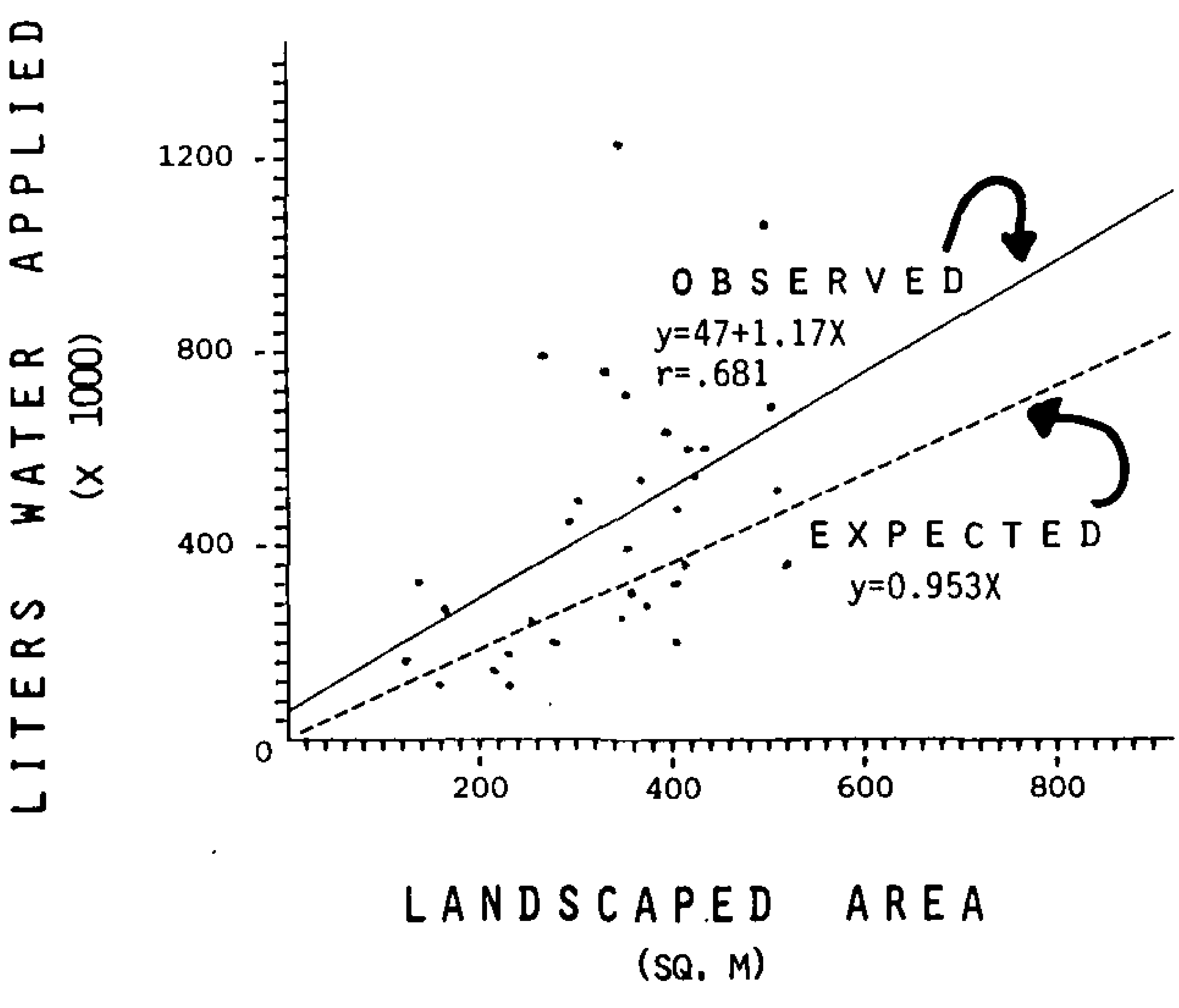

Figure 1. Regression model of propagation date on percent rooting of *Rosa multiflora* hardwood cuttings. $y = 21.196+33.866x-5.143x^2$ $R^2 = 0.22$. [From C.E. Hambrick, 1985, (2)]

Models can also be used as management tools. For example, pan evapotranspiration estimates as a model can be used to predict expected water usage needed to water a consumer's yard and then compared with actual observed water usage that occurs later (Figure 2). From the predicted model (dotted line) versus that of the actual water usage (solid line), one can determine if water is being wasted by the consumer (1). Based on the prediction model, 40% more water is used to irrigate than is needed. This same type of model could be used in wholesale nursery production where frequently more irrigation water is applied than is needed.

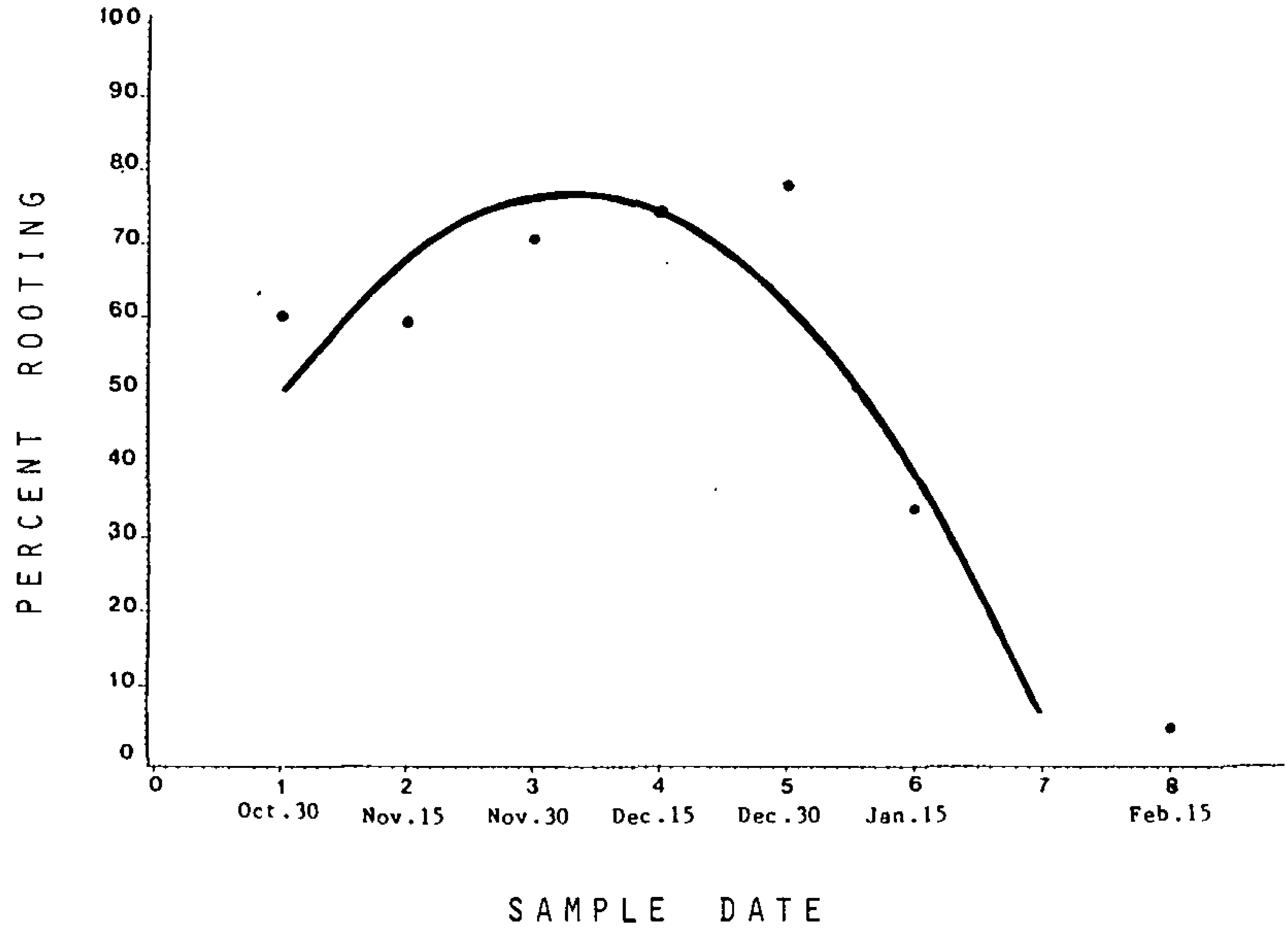

Figure 2. Water application rates on urban landscapes. The effect of landscape size on actual and expected water use. From Cotter and Chavez, 1979, (1).

In England environmental computer control systems are being utilized in commercial plant propagation systems. One method of propagating cuttings in England is to stick conifers during the fall and early winter in trays covered with plastic without intermittent mist. When temperature and light intensity are properly controlled, cuttings root without the detrimental effects of leaching and pathogens often found with intermittent mist systems. A computerized propagation system is used to monitor light intensity, photoperiod, CO_2 levels, temperature, and relative humidity. Acceptable light intensity levels are normally 1.5 to 3 megajeuls/m^2/day, or 100 watts per m^2, for ideal propagation. When light intensity becomes too high, the system triggers automatic shading from the top and sides of the propagation house.

Models could also be used to manipulate temperature of media in rooting cuttings. Some commercial nurseries on the U.S. West Coast are testing temperature responses of propagation beds by recording temperature on data loggers (Campbell Scientific, P.O. Box 551, Logan, Utah 84321), then funneling data onto an IBM personal computer, quantifying the data, and using a statistical program to develop a model. From the model developed, optimal temperature conditions can be determined for future propagation. The advantage of developing a model is that the grower in the future can program his bottom heat to obtain optimum rooting response. In containerized production in quonset houses where growth continues during the spring, winter, and fall months, light intensity and temperature can be manipulated and modeled to determine optimal crop growth responses.

In an open container nursery or field production system, the ability to manipulate environment is considerably more difficult than that found in propagation or greenhouse systems. However, plants can be grouped by growth characteristics. The light intensity, fertilization media, and pesticide programs can be changed accordingly. Examples of outdoor systems available are ARAX (Transwave Corp., P.O. Box 489, Vanderbilt, PA 15486). This is basically a data-logger system used to establish and collect climatology data as well as soil parameters. By quantifying the data from the ARAX system, the grower and producer can determine more accurately irrigation systems, fertility programs, pesticide and fungicide applications.

Plant stress and modeling. Another important goal of modeling is the potential to reduce plant stress. Under commercial production systems in the southern U.S., high container-media temperatures cause plants to undergo summer dormancy and greatly distort root growth and development. Work has been done by Newman and others (4) to study leaf-water status by utilizing pressure bombs based on various high-temperature regimes. By following fluctuations in the water status of leaves and roots, one can establish plant models based on actual growth and development of plants at various temperatures.

Models could also be developed to predict the fate of plants in shipping. It is not uncommon in the south for nonrefrigerated truck cargo temperatures to reach 140° to 150°F (60° to 66°C). This very much influences the longevity and quality of nursery products.

What are the limitations of plant modeling? The noted plant modeler, Dr. Ben Zur of Israel, has pointed out that to date management model programs have only shown us good management techniques already known to good producers. These management model programs may be useful to new and to less successful growers. However, lack of precise knowledge of plant inputs, poor data collection and methodology limit the establishment of accurate predictive models.

The long range benefits of plant modeling. We need to think in terms of propagating and producing plants not just with today's technology but with new systems coming in the next 20 years. It may well be in the next 25 to 30 years that a sizeable portion of retail nursery items will be produced under specialized warehouse conditions where environmental controls are manipulated. Tissue culture and accelerated growth techniques (AGT) of light, fertility, CO_2, and water manipulation are examples of such controlled conditions.

Growers must become more receptive to computer usage in the quantification of data to make better managerial and production decisions. As our ability to take more accurate environmental and plant data improves, the use of more precise models to make management decisions will enable us to be more productive and efficient nursery producers.

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PLANT MODELING — PRACTICAL APPLICATIONS

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A "model" is another term for a set of equations that describe the system in question. Their purpose is to help make decisions. These models can be very simple or complicated and are simply an organized expression of knowedge about the interacting factors in a given system. Models may cover very broad areas or deal with only very specific situations. Vrecenak and Harrington (1) attempted to model the transpiration of trees in urban areas. They concluded that modeling held promise of aiding in urban plant management but noted that