Using Computer Technology to Improve Irrigation Uniformity

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INTRODUCTION

The application of computer technology as an aid in the process of selection and design of irrigation systems has been growing rapidly in recent years. Previously, sprinkler spacings were based on "rule of thumb" guidelines established by the sprinkler manufacturers themselves. With overlapping sprinklers, phrases such as "head-to-head spacing" or "50% of diameter" were often used by manufacturers to assist customers in making the right decisions. These recommendations were based on previous experience and did not assure that uniformity of water applied would be acceptable. And to compound the problem, different crops had different requirements for acceptable uniformity. A pecan orchard in Willcox, Arizona, for example, required far less sprinkler uniformity than container-grown plants in Southern California because of the extensive and deep-rooted nature of the crop. Many resulting installations have applied extra water in order to adequately irrigate the driest areas. With today's increasing water shortages and increasing emphasis on applying fertilizers and chemicals through irrigation systems, there is a need for making decisions based on science rather than art, especially for new installations.

To this day, almost all sprinkler manufacturers still publish information on each sprinkler device in terms of flow rate and the distance of throw at a given pressure. Most customers still use this information as the only factors in making their decisions on how to space the sprinklers in order to achieve a desired precipitation rate and uniformity. Many other customers contact the manufacturer for recommendations. As the Technical Services Manager at the Agricultural Division of Rain Bird, I have been asked this question for a variety of applications including field crops, vegetables, trees and vines, wastewater, and nursery irrigation using a variety of irrigation products. All of these applications have a similar design goal of achieving acceptable uniformity and precipitation rate using the appropriate device for the application.

The appropriate device for an irrigation application includes many factors which must be considered by the customer before a final decision is made. Some of these factors include:

- Ease of maintenance
- Trajectory height
- Susceptibility to clogging
- Pressure requirements
- Effects of wind (for outdoor use)
- Durability and reliability
- Cold weather operation
- Cost

Many devices have been tried and failed because of one of the above factors in addition to poor uniformity. Poor uniformity may not be the fault of the sprinkler, but rather inappropriate spacing. This is where the computer can help us make more informed decisions. However, in order for the computer to simulate the real world, its results must be based on real world information.

PROCESS

In addition to flow and distance of throw, many manufacturers also test their sprinkler devices in a zero-wind environment for either single-leg catch can distribution or grid catch can pattern. In the case of rotating sprinklers, a single-leg distribution catch can test is normally sufficient to establish a "signature curve" detailing the sprinkler's precipitation rate radially from the sprinkler. For fixed spray devices and small micro sprinklers a grid pattern of catch cans are placed around a device to establish the signature pattern in two dimensions. This is necessary because most of these devices will not have a similar radial precipitation rate at different angles. Each of these tests are performed at a given pressure, riser height above the catch cans, and nozzle size. Many of these tests are performed at the Center for Irrigation Technology, an independent testing facility in Fresno, California. Rain Bird also has a similar test facility in Glendora, California and many hundreds of tests have been performed on a wide variety of sprinkler products, from large-volume guns flowing over 1000 gpm to small spray devices at less than 1 gpm.

First, lets look at rotary sprinkler distribution testing. Each sprinkler to be tested must be representative of production so that tests results will be valid for field installed units. Then a matrix of common values for pressure, riser height, and nozzle size are established to determine the number of tests required. As is always the case, there are many applications outside of this matrix, but many will be relatively close to these setup parameters. Catch cans are then evenly spaced (usually 1 or 2 ft apart) in a radial fashion away from the test sprinkler device. All parameters are setup in accordance with American Society of Agricultural Engineers (ASAE) Standards for sprinkler testing. After operating the sprinkler for a period of time, each can volume is recorded and entered into the computer as raw data for that particular combination. After all tests have been completed, analysis can begin for a wide variety of applications.

Although this type of testing has been performed for many years, it wasn't until recently with the advent of personal computers, that we could put this information to widespread use in irrigation design. A software program called SPACE (Sprinkler Profile And Coverage Evaluation) is now commercially available from the Center for Irrigation Technology (CIT), which is capable of overlapping this sprinkler in virtually any spacing desired. Most exciting of all is the ability to graphically present the resulting distribution in a "densogram", a dot density shading technique illustrating relative distribution within the given spacing.

Briefly, the program calculates the contribution from all nearby sprinklers in every square foot of the spacing area and then performs various uniformity calculations before presenting the densogram. Along with the densogram are presented three yardstick uniformity parameters CU, DU, and SC:

- **CU is** (Christiansen's) **Coefficient of Uniformity (%) defined as:**
  CU = 100(1 - average of all deviations from average value/average value)
- **DU is Distribution Uniformity (%) defined as:**

DU = 100 (average low-quarter depth/average depth)

- **SC is Scheduling Coefficient defined as:**
  SC = average depth / average depth of a window 1, 5, or 10% of total sprinkler spacing area

CU is still widely used because of its familiarity since its establishment in 1942. Unfortunately, it does not put a heavy weighting on inadequately watered areas allowing dry spots with relatively high numerical values. Because of this, both DU and SC are important, especially for container-grown plants where dry spots have a direct effect on plant growth, since there is no chance for soil moisture movement to even out poor distribution. It is the densogram though that tells the story most clearly regarding the expected uniformity of water placement.

Before an actual analysis is run some final questions must be answered. Some bed widths are narrow and a single row of sprinklers or microsprinklers may be all that is required whereas larger bed widths may require overlap from opposing lateral sprinklers in a rectangular or triangular placement. Finally, the desired precipitation rate must be approached by adjusting the flow rate of the sprinkler in question at the spacing desired. In many cases, not all this information is known and several combinations must be tried before a final decision is made. The decision will be an informed one though.

EXAMPLES

To best illustrate this process lets look at some real world examples. In a recent case, a large wood products company planned to setup a fully automated tree seedling establishment block which required frequent, short-cycle irrigations. Bed widths were 36 ft. A small droplet size was desired for a gentle application so higher pressures were analyzed. A low trajectory was also desired to reduce wind effects. A SideWinder™ sprinkler model (SW200-HF) recently introduced and tested at CIT was chosen as a candidate for its adjustable trajectory, (9° setting) and faster rotation speed. Figure 1 illustrates the single leg profile curve of that particular sprinkler operating at 40 psi and 1.38 gpm with catch cans 1 ft below the sprinkler. Looking at the curve does not tell us how well this sprinkler will do when spaced

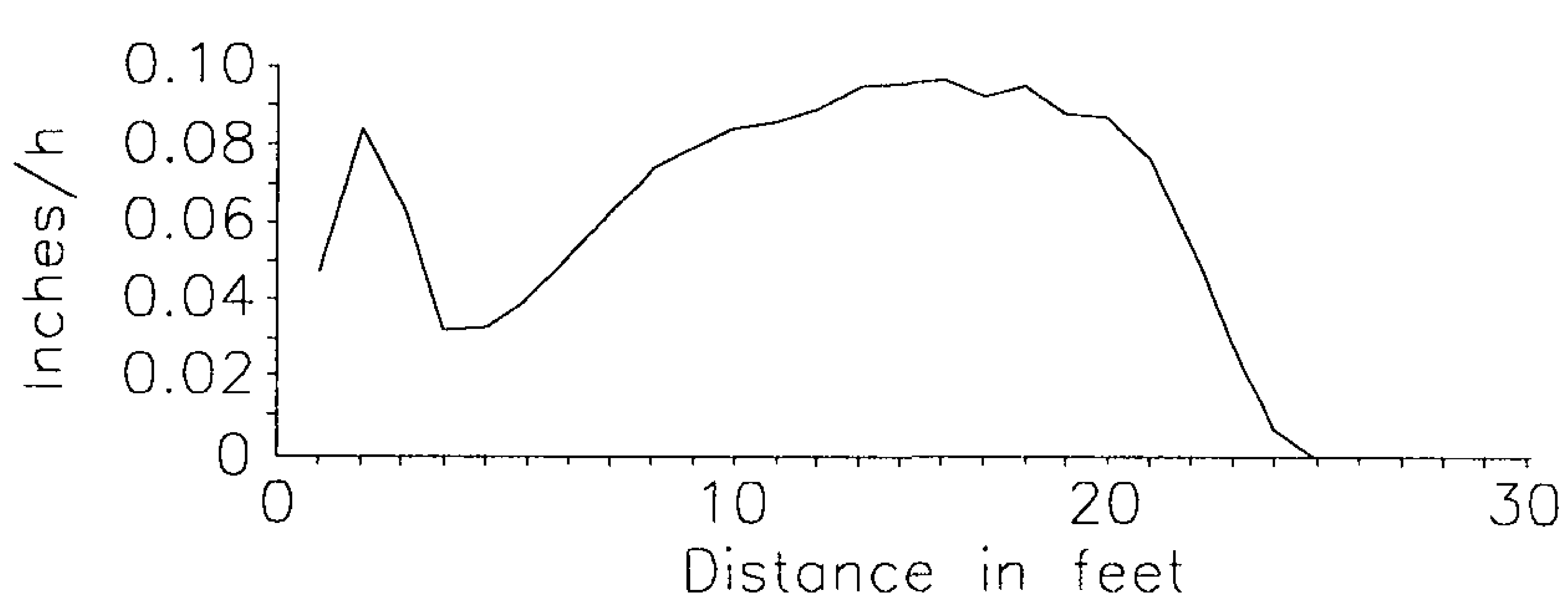


Figure 1. Example 1: Single leg distribution curve.

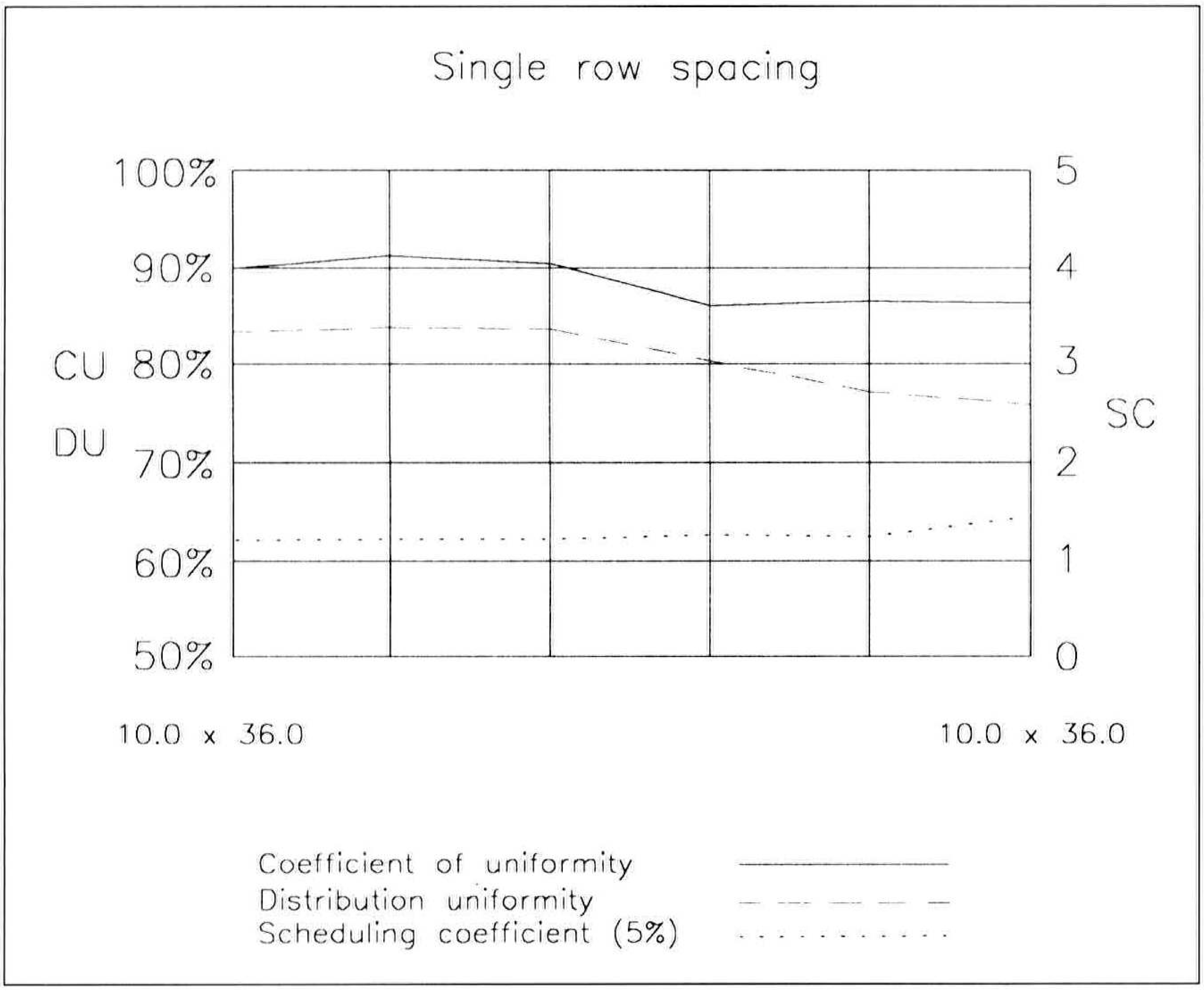


Figure 2. Example 1: Multiple spacing uniformity graph.

in a single row down the middle of the bed. First, a multiple spacing of sprinklers down the single row is run and uniformities are plotted (Fig. 2) for sprinkler spacings from 10 to 20 ft apart. It is noticed from this plot that uniformity begins to worsen beyond 14-ft spacing. A densogram is then run at the 14-ft spacing (Fig. 3). The densogram illustrates where relatively more water is applied in the darker

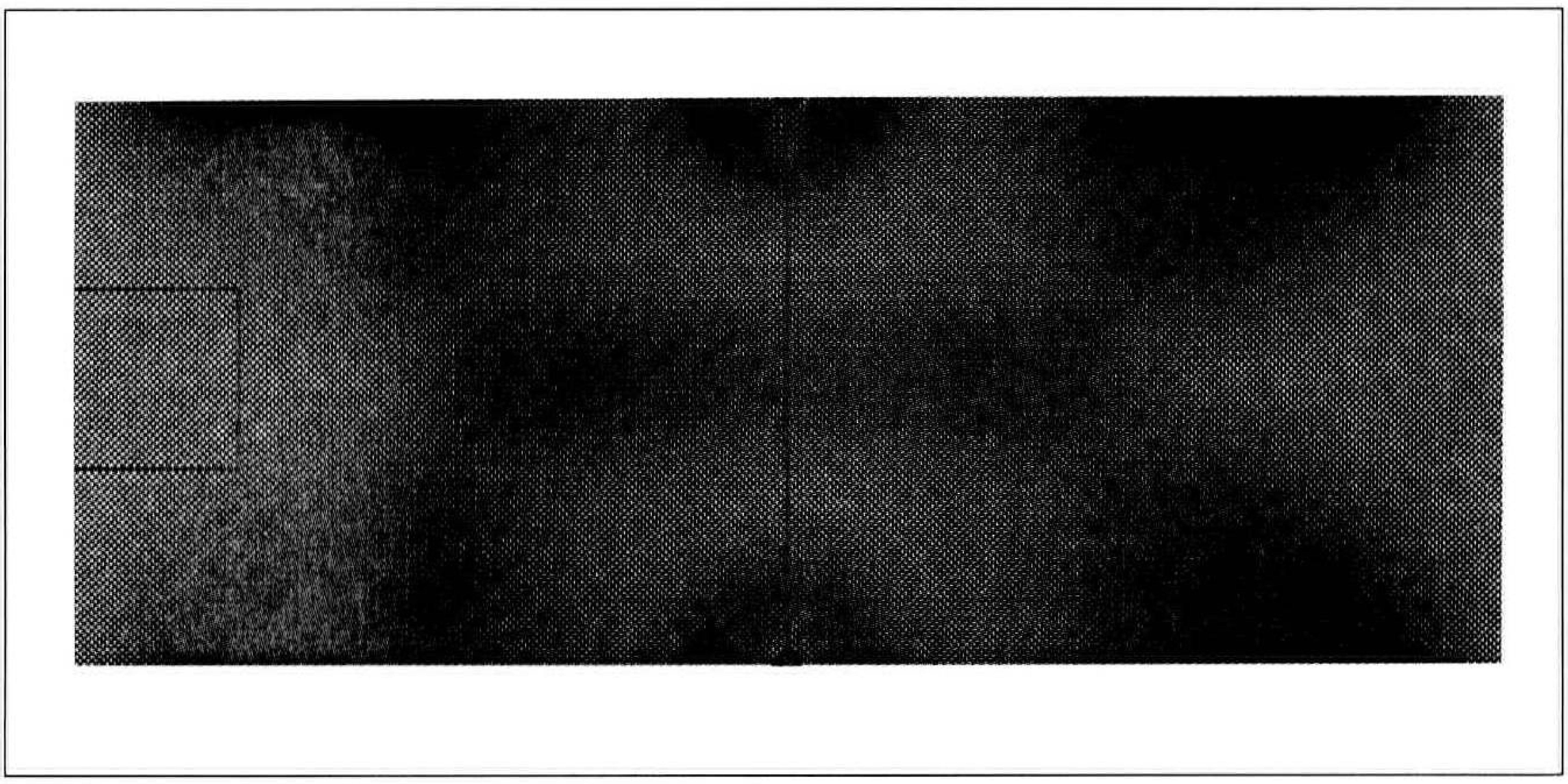


Figure 3. Example 1: Densogram for single row spacing.

areas. The window highlighted by a black box in Fig. 3 pinpoints the lightest application area (5% of the total area shown). It is decided that not only is the uniformity acceptable (CU of 90% or greater) but precipitation rate is near the desired .25 inches/h. The whole process usually takes less than an hour even after several nozzle and pressure combinations are reviewed.

It should be noted that this procedure may not prove adequate for some applications. Outdoor locations with mild to high winds will have sprinkler distributions which vary significantly from the assumed zero wind environment. Conversely, special installations with sprinklers mounted upside down indoors may need to be tested in their actual settings with grid catch can tests verifying uniformity. One such example is at La Verne Nursery in San Dimas, California where Sidewinder sprinklers were tested indoors in an inverted position. A special nozzle orientation was also adjusted to improve distribution. Catch cans were placed in a grid at one-ft spacing 6 ft below the heads. Catch values were recorded and uniformity calculated according to Christiansen's formula. Results verified that uniformity was over 85% and plant growth has been exceptionally uniform according to the grower since the installation was completed.

FUTURE

The SPACE program is not the only program that allows an irrigation designer to perform this type of "what if" analysis. More manufacturers are developing technical software of their own to provide this type of graphical analysis illustrating field uniformity. PCTAPE™ is a software tool provided by our company to irrigation designers of drip tape systems. It provides graphical presentation of field

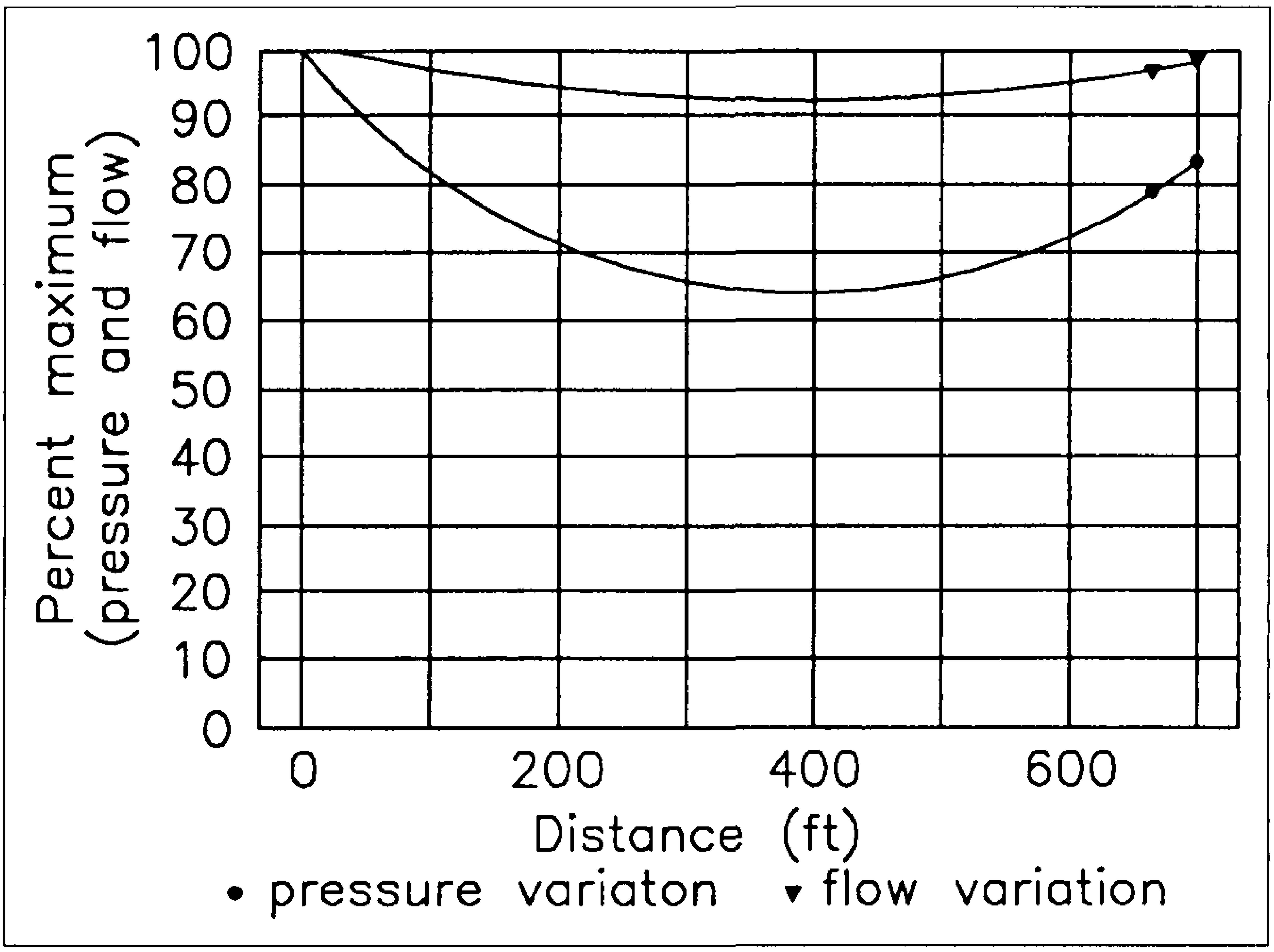
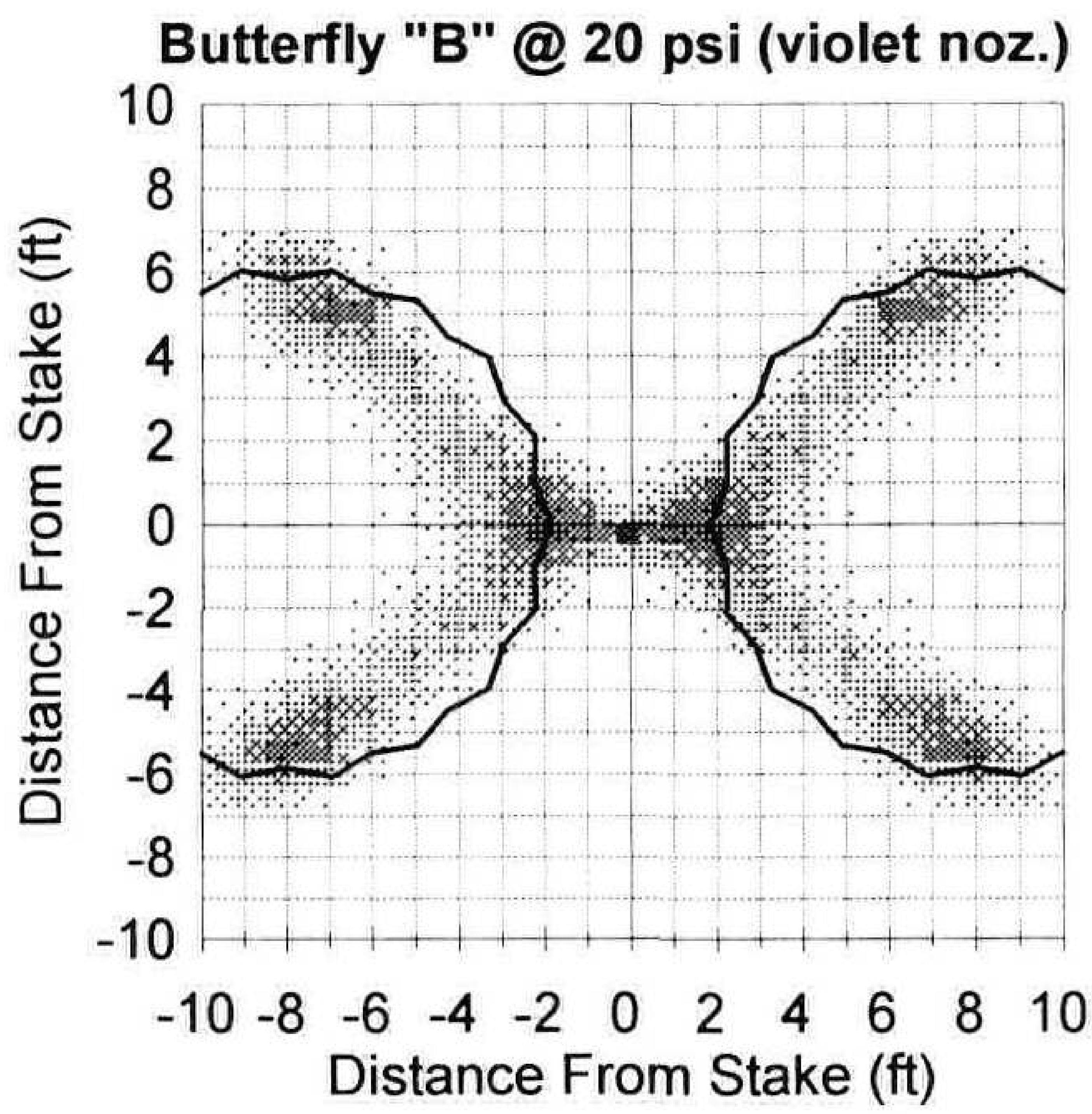


Figure 4. Sample PCTAPE analysis of drip tape uniformity.

pressures and relative distribution of water (Fig.4) even for undulating terrain. As drip tapes become more commonly used in nursery applications this will help verify performance.

Another software tool recently introduced is a program called TREE-GRAM. This program has the capability of overlaying a tree canopy with a micro-spray pattern. The user is able to change tree and row spacing as well as the placement of the Micro-Quick™ pattern as illustrated in Fig. 5. Although this program was primarily developed for tree crops, future releases of the program will allow overlapping the micro-spray patterns, a common practice in the nursery industry.

As you can see, the gap between making more informed decisions versus decisions based only on past rules of thumb is narrowing. As manufacturers provide product performance testing for use in the above software tools we will be able to further reduce water consumption while encouraging more uniform plant growth. This is truly a win-win proposal.



Tree Canopy Diameter (ft.) --->	12
Tree Spacing (ft.) --------------->	16
Row Spacing (ft.) ---------------->	18
Stake Offset From Tree (ft.) ->	8
Rect. or Tri. Spacing (R or T) ->	R

Figure 5. Sample TREE-GRAM analysis of micro-spray pattern.