scores will increase. The average score on these problems sets increased from 91.8 for the last two years prior to computerizing them to an average of 94.8 for the first two years after they were computerized. Students are also free to go back to the lab at any time and rework problem sets in preparation for examinations. Finally, potential errors by the grader either in grading or in adding scores are eliminated because the computer performs these functions. This virtually eliminates grading complaints by the students.

Thus, the cost and educational advantages overwhelmingly favor microcomputerizing student take-home problems for a large class where problems will be required regardless of the class size. Students often give favorable comments about them in class evaluations. Instructors should give this teaching technique serious consideration; it can be very economical and educationally effective.

Microcomputer Simulation of Plant Growth

John Ball

Abstract

Many instructors are examining the use of computers as a means of utilizing simulations. This is especially applicable to horticulture due to the time length required to grow real plants. To increase students' understanding of environmental influences on plant growth, a plant simulation game was developed. Game players can alter light intensity, light duration, day temperature, night temperature, atmospheric carbon dioxide level and soil moisture content in their attempt to grow a taller plant.

Introduction

Most horticulture students are able to enumerate the environmental factors effecting plant growth. However, few are able to comprehend the effect these factors and their interaction can have on plant growth. Understanding environmental factors and their interaction is critical for horticulture workers. It is especially important for greenhouse growers since almost all environmental factors including atmospheric carbon dioxide concentrations, can be under grower control.

Computers are ideal tools for presenting these concepts. Computer simulations can be effective in increasing a student's problem-solving ability (Small and Edwards, 1979). By working with situations involving multiple variables and many acceptable results, a student must reason to obtain the desired outcome. A computer can also compress time, and this ability is useful in teaching biological concepts where time horizons can stretch into months or years (Lehman, 1983). In addition, computer modeling is now being used by the greenhouse industry (Carlson, 1986), and the students should become familiar with its practical application.

To promote a better understanding of envionmental influences on plant growth a computer game was developed. The simulation game permits student teams to set the values for the environmental factors and observe how the plant performs under these conditions. The game's basic assumption is that the plant is in a pot placed in a closed room. Students can adjust light intensity and duration. They can alter the day and night air temperature, atmospheric carbon dioxide content and soil moisture. Values for all factors are selected at the beginning of the game then the total plant growth is computed. No alteration of the values is posible after this point.

Students work out a strategy for producing the maximum growth, type in the value for each of the factors, read the total growth produced from the run, determine how they could improve upon it then try again. To add some additional competitivee interest to the simulation game, when the computer displays the plant height achieved during the last execution it also displays the maximum height achieved during the day.

The computer simulation game is introduced to the students after they complete the lectures on environmental influences of plant growth. Students must have a basic understanding of the environmental factors and how they influence plant growth to fully utilize this sumulation game. In the next lecture period the purpose and rules of the game are explained to the students. Working in small groups of three or four, students discuss strategies and decide the values they will utilize. They may not run the simulation until they explain to the instructor what they are goint to try and why. This procedure is a vital part of the simulation game. It requires students to plan a course of action and predict its outcome rather than just randomly select values and see what happens.

The effectiveness of the game in promoting a better understanding of environmental influences was examined through the use of a randomized control group. Twenty-eight students were given a pretest after the initial lectures on environmental influences. The students were then randomly assigned to two groups, one group utilized the computer simulation, the other continued with just lecture. The following lecture period all students were given a post-test. The scores of the two groups of tests were compared by use of the students's t-test. There was no significant difference between the two groups pretest scores. However, there was a significant difference (p►0.05) between the two group's post-test scores (Table 1). The group utilizing the simulation game demonstrated a better understanding of environmental influences.

In addition, student surveys have showed that most students enjoyed this particular portion of the class. They preferred examining plant growth in an

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Table 1. Comparison of test scores (+ SE) between students utilizing a computer simulation as a teaching aid (group A) and students that utilized review lectures (group B).

Student Groups	Average Test Score	n	t - statistics
Pretest A	71.0 ± 3.0	14	0.285[ns]
B	72.1 ± 2.4	14	
Protest A	81.9 ± 2.2	14	2.320[s]
B	74.8 ± 2.1	14	

[ns]t not significant at 0.05 level
[s]t significant at 0.05 level

interactive style and liked the competitive factor among teams. This was also the first exposure to a computer for many students. Becoming familiar with a keyboard and working interactively with a computer is a step towards computer literacy (Luehrmann, 1982).

Program Development

The environmental factors used in the simulation game were selected because: 1) they can be altered by a grower, 2) they demonstrate important interrelationships. and 3) there was sufficient data available to produce the simulation. Some liberty was taken on the environmental influences and their interactions. The simulation does not account for every possible interaction, but does include the major ones. For example, the computer simulates the interaction of light intensity and carbon dioxide content of the air and the interaction of day temperature and light intensity. The simulated plant isnot patterned after any particular plant but the majority of the data was gathered from studies of vegetable and floral crops growing in controlled environments. These plants have volumes of data generated on their response to various environmental factors. The equations and program were developed from information in Spain (1982).

Two major simulated factors were components of light, intensity and duration. Students were able to select a light intensity between 15,000 and 40,000 lux. While light intensity is no longer measured in lux for scientific purposes (Holmes et at., 1975), the program utilizes these photometric units since many growers still rely on this for measuring light levels. A plant's response to light intensity is not linear (Kozlowski, 1957); hence, the students might not observe a proportional increase in plant height with an increase in light intensity. The plant's response to light intensity is also influenced by the carbon dioxide content of the atmosphere and air temperature (Bidwell, 1974). High light intensty (over 30,000 lux) may not yield a substantial increase in plant growth unless the atmospheric carbon dioxide level is also increased. Increases in temperature may also result in an increase in growth at high light intensities. This relationship continues until about 35°C. Temperatures above this will cause our simulated plant to begin to close its stomata and growth will be reduced.

Generally a plant's photosynthetic activity is proportional to the day length, the longer the day the greater the growth. Students were able to select a day length between 8 and 16 hours. The day length selected had two important consequences: the time period photosynthesis could operate, and the duration day and night temperatures would be used to calculate growth.

Students were able to adjust the day and night air temperature between 10 and 40°C. While many plant processes are temperature dependent, higher temperatures do not necessarily result in more stem growth. For many plants, the optimum temperature range for photosynthesis is approximately 30 to 35°C. while respiration reaches its optimum rate at 40 to 45°C. (Hofstra and Hesketh, 1969). All other conditions being held constant, a student selecting a day air temperature near 40°C would find the simulated plant achieving a lower stem height than if a 30°C temperature was selected. The students were also able to observe the effect high night temperatures have on stem growth. Went (1957) observed that most plants grow more if the day temperatures are higher than night temperatures. High night temperatures, when combined with low day temperatures. can limit stem growth (Munoz and Holley, 1972).

Atmospheric carbon dioxide (CO2) levels can be varied in the simulation from 300 and 1500 ppm. While the current atmospheric level of CO2 is 340 ppm (Witwer, 1983), greenhouse growers use CO2 generators to increase the CO2 content to 1500 ppm (Hughs and Cockshull, 1971). Since CO2 is required for photosynthesis, many plants will increase stem growth in response to the higher than normal CO2 levels. However, unless other environmental factors such as light intensity and temperature exceed certain minimums for photosynthesis, inclusion of additional CO2 will not result in an increase in plant growth (Hanan, 1973).

The final factor under control of the simulation game player is soil moisture content. Students may vary the soil moisture content anywhere between -0.5 and -5.0 bars. The larger the absolute value of the negative number of bars, the tighter the water is held by the soil particles and the more difficult it becomes for a plant to absorb water. Water retained in the soil between field capacity (-0.3 bars) and the permanent wilting coefficient (-15.0 bars) is considered available for plants. It was once thought that soil water was equally available from field capacity to the permanent wilting point and that plants were not affected by the decrease until the permanent wilting point was reached (Veihmeyer and Hendrickson, 1950). However, optimum plant growth occurs when soil moisture is near field capacity (Metwally et al., 1970) and studies have shown that plants may have reduced short growth as the soil moisture content dries beyond -0.1 bar (Wikle et a., 1961).

Hardware Requirements

The simulation was developed on the Apple IIe. This widely used computer utilizes DOS 3.3 for its disk operating system. The program was written in Applesoft BASIC and due to its short length utilizes very little storage. The only hardware requirements are an apple computer and a monitor.

Availability

The program is available to anyone at no charge. It contains less than 200 lines so the program can be easily typed in to an Apple or modified or other systems. For a listing of the program statements and instruction notes, please send a self-addressed stamped envelope.

Literature Cited

Bidwell, R.G.S. 1974. *Plant Physiology.* Macmillan Publishing Co., Inc. New York, New York. 643 p.

Carlson, W. 1986. What computer modeling can do for you. *Greenhouse Grower* 4(2):12-13.

Hanan, J.J. 1973. Ventilation temperatures, CO2 levels, and rose production. Colorado Flower Growers Assn. Bul. 279:1-5.

Hofstra, G. and J.D. Hesketh. 1969. The effect of temperature on stomatal aperture in different species. *Canadian J. Botany* 47:1307-10.

Holmes, M.G., W.H. Klein and J.C. Sager. 1985. Photons, flux, and some light on philology. *Hort Science* 20:29-31.

Hughes, A.P. and R.E. Cockshull. 1971. The effects of light intensity and carbon dioxide concentration of growth of *Chrysanthemum morifolium* cv. Bright Golden Anne. *Ann. Bot.* 35:899-914.

Kozlowski, T.T. 1957. Effect of continuous high light intensity on photosynthesis of forest tree seedlings. *For. Sci.* 3:

Lehman, J. 1983. Mocrocomputers simulations for the biology classroom. *J. Computers in Mathematics and Science Teaching* 2:10-3.

Luehrmann, A. 1982. Computer literacy. *The Computer Teacher* 9(7):24-6.

Metwally, A.W., B.E. Struckmeyer and G.E. Beck. 1970. Effect of three soil moisture regimes on the growth and anatomy of *Pelargonium hortorum.* J. Amer. Soc. Hort. Sci. 95:803-8.

Munoz, F. and W.D. Holley. 1972. JAnother look at temperature effects on carnations. Colorado Flower Growers Assn. Pul. 267:1-7.

Small, J.W. and K.L. Edwards. 1979. Simulating drosophila genetics with the computer. *American Biology Teacher* 81:219-25.

Spain, J.D. 1982. *BASIC Microcomputer Models in Biology.* Addison-Wesley Publishing Co. Reading, Mass. 354 pp.

Veihmeyer, F.J. and A.H. Hendrickson. 1950. Soil moisture in relation to plant growth. *Ann. Rev. Plant Physiol.* 1:285-304.

Went, F.W. 1957. *The Experimental Control of Plant Growth.* Chronica Botanica Co. Waltham, Mass. 343 pp.

Wikle, J.S., H. Davidson, and W.A. Erickson. 1961. Soil moisture studies with container-grown plants. Quant. Bull. Mich. Agric. Exp. Sta. Mich. State University 44 (1):125-8.

Wittwer, S.H. 1983. Rising atmospheric CO2 and crop productivity. Hort Science 18:667-73.

ILLINOIS SURVEY

Microcomputer Usage and Needs In Community College Ag Programs

Fred W. Reneau
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Introduction

Economics, technology, and competition have helped make computers a part of reality. An increase in computers, available at the elementary and secondary level, will provide students at the post-secondary level with a wider range of computer literacy. The post-secondary educator should expect that present and potential students will have varying backgrounds in microcomputer usage.

Purpose of the Study

With the reality of microcomputer acceptance and usage in all areas of agriculture business and education, it has become essential to provide community college agriculture students with microcomputing knowledge and skills. High school graduates have a wide variety of backgrounds and experiences in agriculture microcomputing. Therefore, a vast array of skills and levels of competencies need to be realized by community college agriculture instructors for effective teaching. The community college agriculture instructors need microcomputing competencies, teaching materials, and inservice training (Mottaz, 1982; Leising, 1982; Dickerson and Pritchard, 1981.)

The purposes of the study were to determine the level of microcomputer usage within the Illinois community college agriculture program and competencies needed by community college agriculture instructors.

Research Questions

1. To what extent were Illinois community college agriculture instructors currently using microcomputers in agriculture programs?
2. What types of instructional materials should be developed to aid Illinois community college agriculture instructors in teaching microcomputer usage in agriculture?
3. What microcomputing competencies were perceived as necessary by Illinois community college agriculture instructors?

Instrument Design

The instrument used in this study was a questionnaire that was designed to determine the extent and methods with which microcomputers were used as teaching aids; the microcomputer instructional

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