at Area and One-Day Meetings, almost wihout fail participating in the discussion sessions at these meetings. Recently he has written two books: "Hardy Woody Plants from Seed" (Grower Books) and "Plant Propagation" (Mitchell Beazley).

THE APPLICATION OF MODERN INSTRUMENT TECHNIQUES TO HORTICULTURE

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An instrument is a device that is used in performing an action — a tool or an implement. It, therefore, follows that the term instrumentation refers to the operation or arrangement of one or more instruments. Instruments of an electronic or scientific nature when used in horticulture should be considered as tools or implements and are there as such to perform or assist with a wide range of actions The question is whether we can identify those actions that can benefit from the use of modern instrumentation techniques. The actions being carried out daily within horticulture are no less frequent, diverse, or precise than those found in many other process industries. Indeed, it can be stated with some certainty that many actions related to plant growth continue for 24 hours of every day. Why should it be necessary to consider or seek new aids for the long established industry of horticulture? It is worth remembering that even the simplest tool such as the spade was evolved as a result of identifying those actions that could be assisted by the use of a suitable artifact. Are more sophisticated tools required, perhaps specifically designed for tasks found only in horticulture or, alternatively, is it possible to borrow existing techniques from other industries? Much of the instrumentation already in use within the horticultural industry has been developed primarily for other uses associated for example with medicine, meteorology and geology, whilst research and development has used every available technique. However, over the last 20 years there has been a growing need for the development of specialised equipment both for the grower and the research worker. Until fairly recently many instrument manufacturers considered that the potential sales for their products within horticulture was too small to be of great interest. Of those that did take an active interest there were some who considered that the engineering profession knew what was best for plant production and in some instances this resulted in disaster or, at the very least, great apprehension on the part of the grower when faced with similar equipment at some later date.

Today the term instrumentation is being increasingly associated with the use of sophisticated electronic devices often referred to as silicon chips, integrated circuits, or microprocessors. The news media have repeatedly drawn our attention to the predicted benefits likely to be gained from the application of such devices Can we expect that the present and future generation of electronics will radically change the potential use of instrumentation within horticulture? The evolution of the optical microscope and its early application to science brought about the need for a wide range of supporting techniques and apparatus. The generations of mechanical instruments that followed played a vital part in establishing the knowledge of today. Indeed, large numbers of mechanically based instruments are still in daily use within horticulture; for example, the mercury thermometer, bimetallic temperature recorder, and hair hygrometer The reasons for seeking new and improved techniques for instrumentation must be established in order that it may be used both efficiently and effectively. The most efficient use of such equipment should produce the maximum effect possible for the lowest effort needed to apply it. Those tools that have withstood the test of time are often those that, by due process, have been designed and constructed with simplicity but still effectively carry out the duties required of them. Such an approach is to be recommended at all times.

One possible reason for considering the use of instrumentation is for the purpose of improving the quality of plant production or at the very least to ensure that quality remains constant. The early studies relating plant growth to the environment used many of the meteorological instruments then available. The studies have intensified, the use of such equipment has continued and today monitoring and control of the plant environment is often dependent on systems using the most up-to-date electronic circuits. Such solid state circuiting is not only capable of carrying out a vast number of operations in a fraction of a second but it is also reliable, small and, in real terms, very much cheaper than the somewhat bulky equipment of even ten years ago. The skill of the mechanical instrument maker has, to a certain degree, given way to the skills of the chemist and physicist. The best instrumentation contains the skills of not only those who are concerned with its design and manufacture but above all those who are to benefit from its use.

In today's environmental instrumentation we find that the mercury in glass thermometer and mechanical thermograph are being challenged by the versatility of electronic temperature meters and recorders. Temperature sensors generating electrical signals are available in size from that of a pin head to that having sufficient mass and strength that it can safely be run over by a tractor. The "throw away" age has given us the disposable temperature recorder that is used once to monitor cargo in transit, is discarded leaving behind only the chart for reference. Sensors and interface units are available at modest cost that can instantly convert the electrician's digital test meter into an electronic thermometer The manufacture of temperature sensors and associated monitoring and control equipment has become highly competitive and makes available a wide range of products directly applicable to horticulture.

The hair and sling hygrometers, together with the wet and dry bulb thermometers, are now supplemented with a range of sensors whose electrical characteristics vary directly or indirectly in relation to the relative humidity of the atmosphere in which they are placed. The development of such sensors has been lengthy and not without its problems. However over the last five years very significant progress has been made using both thick and thin film technology and it can be expected that the interest shown by major industries such as those associated with paper, textiles and food processing will result in continuous improvements being made.

The measurement of gas concentration is important, for example, in the glasshouse sector in relation to the enrichment of CO_2 levels, in the mushroom sector to detect excessive levels of CO_2, and also in fruit storage applications. The techniques employed have relied very heavily on equipment developed for the detection of hazardous gases in the mining and chemical industries Although some growers have used such methods, the infrared and conductimetric instruments referred to are primarily research tools. As might be expected the interest being shown in the subject of safety in the working environment is already encouraging the development and manufacture of simpler and cheaper instruments for this purpose. Semiconductor technology has produced a variety of new compounds that are light sensitive thus forming the basis of sensors used not only for radiation monitoring but also energy conversion. The present interest being shown in converting solar energy into electrical power will result in the availability of an even wider range of radiometers. Their small size in relation to sensitivity make them ideally suited for siting within the crop with the minimum of disturbance.

Sensors responding to soil moisture content are based on changes in electrical capacitance whilst the mercury manometer used in soil moisture tension measurements can often be replaced with a silicon strain gauge pressure transducer that produces an electrical signal. The measurement of liquid flow, conventionally accomplished with the aid of displacement piston meters, is now possible using magnetic or ultrasonic sensors clamped to outside of the pipework. Vortex shedding flowmeters are being used with flow and return temperature sensors, and a small microprocessor to determine the input of thermal energy into the buildings. The rotational speed of mechanical cup and vane anemometers is detected by photocoupled or Hall-effect, semiconductor sensors that not only reduce friction but allow remote indication and recording. The measurement of low air speeds is possible using hot wire or thermistor sensors and currently such techniques enable velocities as low as one centimetre/second to be recorded at low cost. The determination of high airflow in ductwork is carried out with the aid of orifice plates and pressure transducers having no moving parts.

A great many other factors not directly related to the plant environment, for example weight, displacement, and colour, can be sensed. These other factors are often related to productivity or efficiency and the use of instrumentation for this purpose should not be ignored. Much is being stated about the possible loss of jobs resulting from the widespread use of the silicon chip. However some form of instrumentation could well be desirable within horticulture to offset difficulties arising from the shortage of skilled labour or to relieve what in other cases might be tedious work. Automation, often electronically based, could release labour that in turn could be used for more appropriate duties. Electronic controls are more sensitive, stable and as cheap as their electromechanical equivalents. In those installations covering a large area it is very convenient for administrative reasons to concentrate the indicating or set value facilities of the instrumentation in a central position.

When carrying out multi-channel measurements it is advisable to connect each sensor in turn to one common indicator or recording instrument. If frequent readings are to be taken then it is preferable to use a multi-channel chart recorder that can be left unattended for long periods. When dealing with dissimilar sensors it is necessary to have a specially adapted recorder or alternatively process the sensor signals such that they all match one preferred range. The latter approach is made easier if battery-powered semiconductor conditioning and transmitter units are used with each sensor. In any multichannel installation it is generally necessary for a minimum of two wires to be connected from each measuring point to the recorder, but if platinum resistance thermometers are used then it may be necessary to use 3-wire or even 4-wire connections. Due to the present cost of copper the overall cable cost in such an installation might account for a large percentage of the whole.

The words computer and microprocessor conjure up visions of units of sophisticated equipment costing large sums of money. The computers of yesterday costing thousands of pounds have been shrunk into what are today no more than electronic components costing merely a few pounds. At our disposal, therefore, are components that when linked into conventional instrumentation systems can form very powerful and flexible aids to the horticultural industry. These components, integrated circuits, microprocessors, are effective both in terms of ability and cost when used to carry out relatively simple operations. As an example, the electrical signal from a solar radiation detector can be integrated against time and upon reaching a preselected value, a set amount of water can be applied to the crop. The microprocessor contains within itself a precision clock and it is, therefore, an ideal basis for that type of instrumentation requiring operations to be carried out at preset times of the day or in sequence. Its capacity and speed of operation is such that it can share its time between a great many incoming signals and commands.

In effect the microprocessor is a small computer and can, therefore, carry out mathematical calculations at rapid speed. Examples of use are for the calculation of relative humidity from wet and dry bulb sensor signals and the linearisation of thermistor characteristics. Not only can the microprocessor receive instructions and carry out subsequent calculations but it can also initiate action or secondary instructions based upon its stored memory. For the larger installation the use of a microprocessor, together with associated display or printer, could prove to be more efficient and as cheap as conventional chart recorders. For instance, a microprocessor data acquisition system could be programmed only to log at preset times of the day or when any particular parameter being monitored deviates beyond set limits. A further development is the distributed system in which a central processor is connected to a large number of smaller satellite units. Each of the satellite units is connected to the central processor via the same pair of wires, thus in a large installation only one pair of wires is installed around the site. Coded signals are transmitted along the pair of wires from the central unit to each satellite, following which the satellite uses the same pair of wires to relay back to the central unit local information received from incoming signals. The central processor may be used to transmit further instructions to the remote units following which it will transmit to the next satellite. Should a fault develop in the central processor then the satellite units may be operated quite independently as local loop indicators or controllers. Not only is such a system more flexible but significant cable costs may be saved.

If automation is desirable for the purpose of consistency, or reduction in labour, then a measurement alone is not sufficient and measurement must be compared with a desired value and if different appropriate action is taken. In the past it was customary for manual readings (e.g. using a thermometer) to be followed by manual adjustment (e.g. using a heating valve). At that time electronic control was often unreliable and costly compared to labour costs. The modern computer enables the human input to be reduced to a minimum once the programme of operation has been established. Various parameters can be scanned and resultant action initiated with consistency and reliability such that optimisation of plant growth can be achieved based upon available knowledge. At least 20 sophisticated computers are in use in the glasshouse sector, each one controlling the environment in several separate areas of the nursery. Not only is temperature and humidity controlled but wind velocity and direction, ventilator position, and incidence of rain is taken into account. Reaction from those using the existing installations is very favourable and already discussions are taking place with a view to applying similar techniques to the mushroom sector.

It would appear that communication within horticulture is such that techniques used successfully in one sector are often not known by another sector. Research and development establishments are, by far, the largest users of instrumentation and perhaps, therefore, it can be argued that it is one of their duties, in conjunction with the Advisory Service, to demonstrate to the industry the full potential of all new techniques. It might be asked whether we are likely to create more problems, not less, by the application of sophisticated electronics within horticulture. Have we sufficient data and experience, it may be asked, with which we may apply and instruct these complicated pieces of equipment and will it, in turn, feed us with vast amounts of data that can only be digested by even more powerful computers? Many within the engineering profession, and it would appear to be particularly so with computer and control engineers, are somewhat puzzled to find that there is still much to be learnt about growing which is very much an art when compared to the manufacture of silicon chips. If horticulture is to benefit from other innovations such as mechanical handling, nutrient film growing, alternative sources of energy, then it is reasonably certain that new forms of instrumentation will be needed not only to apply these new techniques but also to establish facts upon which they may be developed.

Many growers are using up-to-date electronic techniques for purposes other than production. Modern surveillance and security systems scan selected operations and upon detecting a failure or significant deviation automatically transmit a prerecorded message to the grower. In some instances, temperature alarm can be transmitted across the nursery using high frequency signals superimposed upon the normal electrical mains. A single probe inserted into the boiler flue will generate signals to a portable instrument whose digital display will show not only flue temperature and oxygen level but also boiler efficiency.

It can be seen, therefore, that modern instrumentation is a valuable aid to horticulture, particularly for the purpose of acquiring data about processes being undertaken, and to control others within very close limits. It is an aid to the establishment of new techniques, business efficiency and security. The question is whether the use of instrumentation requires in itself support that is not normally catered for within horticulture. The problem of repairs and maintenance to electronic instruments is something that must be considered. It is likely that visual inspection of some mechanical equipment will detect if a fault is present whereas in the case of semiconductor circuitry such as approach is not practical. Indeed it is likely that an electronic instrument will not fail completely but give erroneous or erratic readings. Equally it is wrong to assume that an automatic control system is performing correctly at all times. Although the development of sensors has advanced, the progress made has lagged significantly when compared to the present level of accuracy and reliability of semiconductor devices. Regular checks of sensor calibration against known physical standards is therefore recommmended. Furthermore it is likely, human nature being what it is, that instrument dials and charts will be accepted as being accurate. It is therefore essential for regular checks to be carried out on total system performance if the full benefit is to be obtained. This will mean that accurate test equipment must be made available for use by staff having sufficient technical expertise. Whilst many manufacturers provide excellent repair and maintenance facilities it is true to say that few, if any, can offer a 24-hour service. Those processes or actions that become dependent upon instrumentation must be backed, at the place of installation, with full technical data and necessary spares. Whilst the local watchmaker, may be able to rectify a fault on a thermograph it is unlikely that the local electrician will be able to repair a computer.

Biological research and development by its very nature is slow when compared to the rapid advances being made in the field of electronics Whilst this may have advantages it does raise the question of obsolescence. Providing the purpose for which equipment is purchased does not change radically then its potential life span will not be affected by the availability of updated versions. However rapid electronic development could make repair difficult and, in some cases, impossible due to the obsolescence of component parts, high labour costs, or disinterest on the part of a manufacturer. In many instances it is likely that only a small number of identical or similar instruments will be installed at any one site and, therefore, it may be difficult for the grower to transfer less essential equipment. The practical life span of modern instrumentation may be considered shorter, even though generally more reliable, than was experienced a few years ago. As an example, the electronic part of a heating and ventilating control system might have to be changed as a result of one peripheral item being no longer available. However, there is a clear indication that there is an increasing need for good instrumentation, carefully selected and applied, within horticulture. It will not replace good growing but will prove to be a valuable tool in assisting those engaged in a precise and efficient industry.

J. GAGGINI: Is there any instrumentation to measure aeration and compression of composts?

R. RANDALL: Not to my knowledge. I expect there could be developments as a result of work being done on mushrooms.

J. GAGGINI: Do you think it will be possible to design a simple piece of equipment to measure density?

R. RANDALL: Yes. As now, costs are coming down so rapidly it is possible that a system could be evolved at a reasonable cost.

J. CLAYTON, Chairman: Who can one go to for advice on this modern equipment, that becomes obsolete so rapidly, especially to prevent us from spending thousands today only to find that it is obsolete tomorrow?

R. RANDALL: I would suggest you keep in close touch with A.D.A S. and N.I.A.E They are dong a lot of work on computer control and several manufacturers produce control equipment for the glasshouse market. I can also be contacted on anything I have to date.

PROPAGATION OF SHRUBS USING BLOCKING COMPOSTS[1]

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Abstract. The propagation of tree and shrub cuttings in peat blocks made from fertilized peat (Levington Blocking Compost) has been investigated. It was shown that peat blocks can offer a viable alternative rooting method for many

[1] Levington Blocking Compost, Levington Compose Universal, and Levington Container Compost are Trade Marks of Fisons, Ltd