ON-LINE MEASUREMENT OF PLANT GROWTH IN THE GREENHOUSE:

- Traditionally, greenhouse environmental control has been relying on feedback from the environmental.
- On-line control and optimization of plant production will require feedback directly from the crop.
- Therefore non-destructive measurements of "plant growth" have been developed and tested.
- For determination of fresh weight and transpiration of plants an electronic balance is used in combination with a hydroponic system.
- The second method, a CCD-camera and an image processing system allows on-line measurement of leaf area.

- An evaluation of the relation between fresh weight and recorded leaf area gives the best accordance with an exponential regression equation.
- The third method is the measurement of net CO2-uptake using the greenhouse as a cuvette or maintaining inside the greenhouse the same CO2-concentration as outside.

OUTLINE OF ON-LINE MEASUREMENT OF PLANT GROWTH IN THE GREENHOUSE

- The use of microcomputers allows to control the climate conditions in a greenhouse according to the plant response.
- This requires information about plant reaction and physiological processes, such as photosynthesis, transpiration, fresh weight and leaf area development in short intervals.
- It is likely that control of plant production will require feedback directly from the crop.
- Three kinds of feedback information from the plants are distinguishable:

1. Potentials, such as leaf temperature, turgor pressure, stem diameter or leaf colour.
2. Fluxes, such as transpiration or assimilation rates. –
3. State variables, such as fresh weight, leaf area or height of plants.

- Unfortunately, direct feedback from the plants is not easy to measure.
- Especially on-line measurement in greenhouses is difficult because of disturbances

MATERIAL AND METHODS

The following methods have been tested under greenhouse conditions.

1. Image Processing system

- The image processing system consists of the image sensor, the image processing unit and the computer system.
- The plant image is recorded by a CCD-camera and converted to a digital picture with at maximum 64 grey levels.
- These are stored in a buffer memory. Digitization logic, D/A-converter and buffer memory are located on the image processing board in the process computer.
- Mouse and keyboard allow corrections and manipulations of the picture. In the same way it is possible to set the grey level, which is a scale for the brightness of the picture.
- To eliminate disturbances caused by short wave radiation a red filter is used cutting off radiation shorter than 700 nm.

- For small plants a two-dimensional measurement of leaf area is sufficient, whereas for higher plants a three dimensional evaluation is necessary using two cameras with different angles.
- The first tests have shown a high fluctuation of measured leaf area during daytime. With changing radiation intensity, the values increase and decrease, while at constant radiation level. e.g. at night, they are relatively constant.
- It could be observed, that at high radiation level the contrast between soil and plant is decreasing. Because the contrast of the image is influenced by the grey level, this must be changed according to the radiation.
- A linear regression has been used to adapt the grey level to light intensity. Thus, the influence of global radiation on the measurement error could be eliminated.
- The main Tash of image processing is to estimate fresh weight. Several regression models have been tested. The best correlation between fresh weight and leaf area gives an exponential equation, which can be expressed by:

  FG = 1.74 * EXP (0.02 *LF)

  (FG = fresh weight; LF = leaf area)

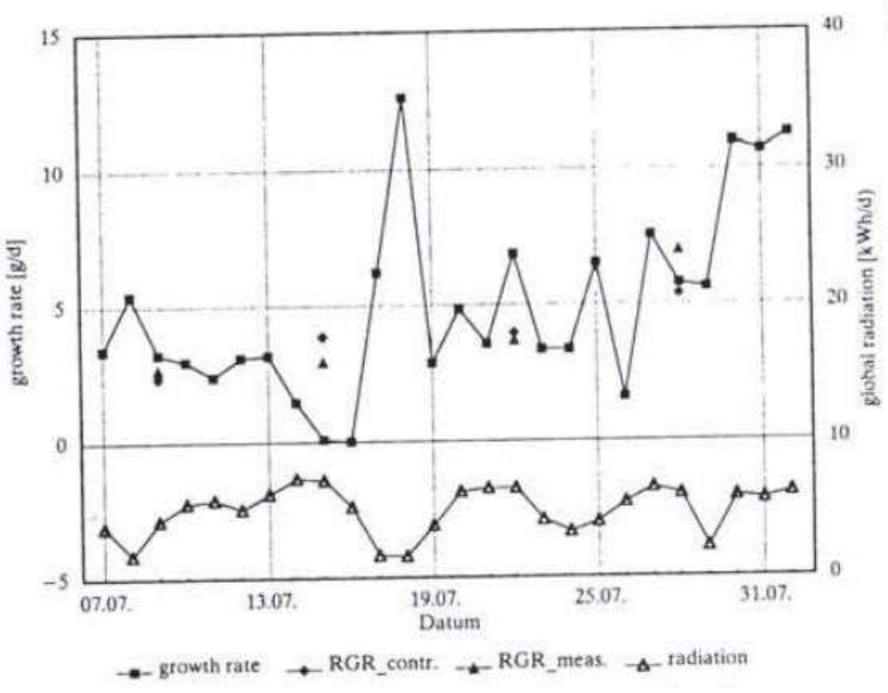

Fig. 1. Growth rate, relative growth rate and solar radiation for the time of 7.7. to 31.7.

- Fig. 1 shows an example for the estimation of growth rate, relative growth rate and solar radiation. The measured growth rate using image processing fits very well into the real growth rate.

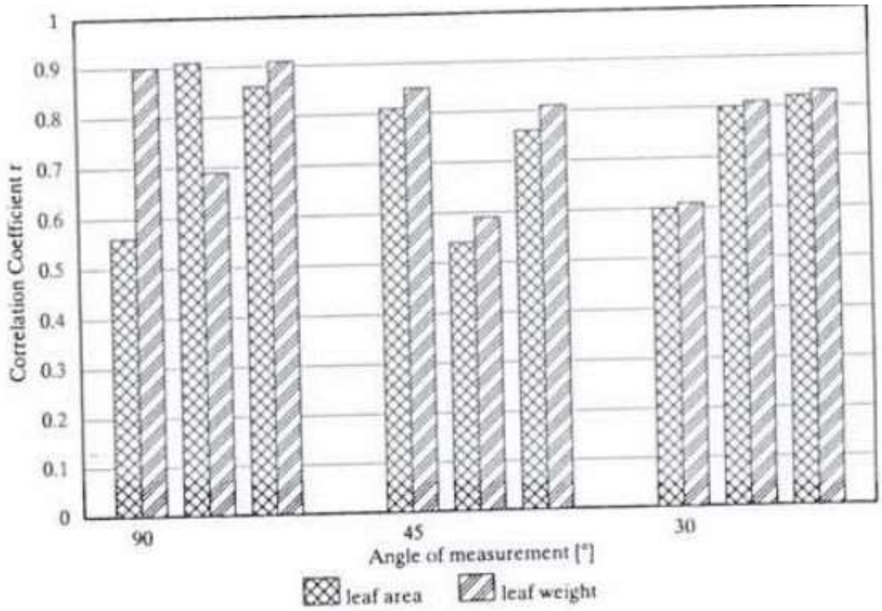

Fig. 2. Correlation coefficients for 1 or 2 cameras and different measurement angles.

- As mentioned earlier, for higher crops (e.g. tomato) a three-dimensional measurement is necessary using two cameras with different angles.
- Fig. 2 shows the correlation coefficient using 1 or 2 cameras and different angles of measurement.

2. Electronic balance and hydroponic system

- This method can be used especially for hydroponic culture.
- The pot with the plant stands on the balance. By means of a controlled inlet nutrient solution is added up to a fixed level.
- At first a run-off system has been used. That means surplus water will be returned ("run-off').
- After a few minutes there is a water balance in the system with always the same defined amount of water.
- For the second period of experiments the system has been changed, using a sensor to detect the level of water in the pot and to switch off the inlet at a fixed level.
- The weight differences between the actual and the preceding adding present the increase of the fresh weight of the plant.
- Until to the next adding the system can be used as a lysimeter and measurements of the evapotranspiration are possible with an interval of one minute.
- The hourly changes of plant fresh weight and evapotranspiration show an antagonistic daily course (Fig. 3).

- The evapotranspiration rate depends mainly on the solar radiation (Fig. 3). That means the minimum is in the night.
- During daytime the evapotranspiration rate increases according to solar radiation. When the transpiration losses exceed the water uptake of the plant, the fresh weight of the plant decreases.
- At night with low transpiration rates the fresh weight increases steadily.

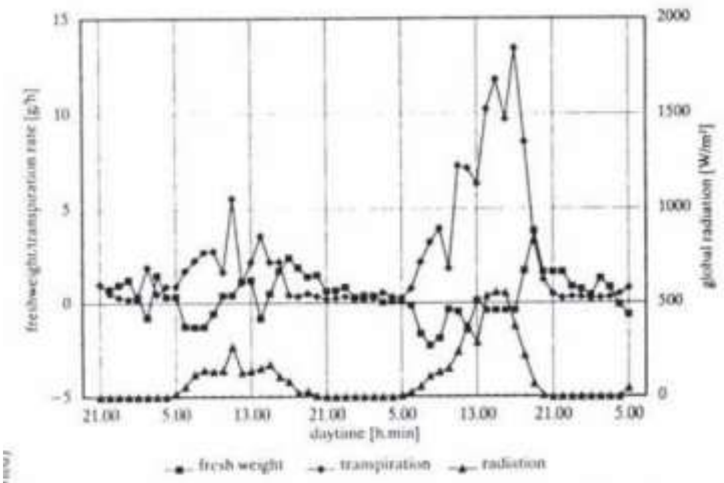

Fig. 3. Daily course of transpiration rate and fresh weight for days with low and high solar radiation

- The experiments have shown that on-line measurement of plant reaction due to a change of climate conditions is possible.
- The described methods allow non-destructive measurements. The accuracy of the measurements is limited.
- For image processing the grey level must be adapted to light intensity.
- The time interval between measurements has to be selected in accordance to the intensity of plant growth.
- For overlapping leaves, fruit or head development a correction of the regression model is necessary.
- For higher plants a three-dimensional measurement, using 2 cameras gives a better correlation.
- Using the electronic balance the information of short term plant reaction is available directly with a high accuracy.
- **A disadvantage** of this method is that it is limited to hydroponic cultivation system and that only a few plants can be measured which must be representative.

MODELS OF PLANT PRODUCTION AND EXPERT SYSTEMS IN HORTICULTURE.

- Expert Systems are intelligent encoded domain specific expert's computer program solutions. Generalized computerized farm management and Expert System have good scope for managing and coordinating optimal production in agriculture.
- Horticultural crops, by improving the income in the rural areas, play a unique role in Indian economy.
- Though these crops hardly occupy 7% of the area and they contribute over 18% to the GDP in the country.
- Litchi is one of them and is called the Queen of the fruits which play a significant role in our national economy. Horticultural crops are affected by insect-pests and diseases causing destruction if mismanaged.
- It is therefore essential that the identification of pests, diseases and disorders and application of suitable remedies.
- For this purpose, application of ES in the management of horticultural crops can be helpful for minimizing losses and thereby increase productivity

Why we need an Expert System?

- The major problem is scarcity of real experts in a particular field, if available then there may be a problem of inaccessibility.
- Consultation may be expensive, and the expert may feel the repetitive job uninteresting, which may affect efficiency.
- The other major problem faced by experts is the memory limitation affecting processing of essential knowledge and information required for decision-making.
- Research and developments in every discipline render relevant and accurate advice available from updated experts, which is not an easy task.
- Experts are subject to limitations, and it is impossible to access all the essential factors, while taking decisions.
- Some factors are always missed and unconsidered.
- This necessitates computer-based tools for assistance, like Decision support system, Decision making system or Expert system to update knowledge and render help in making decisions.

SOLUTION:

- In this respect, ES has been a very useful tool. ESs of today support problem solving activities such as decision making, knowledge fusing, designing and planning, forecasting, regulating, controlling, monitoring, identifying, diagnosing, prescribing, interpreting, explaining or training using different techniques, while future expert systems will support many more activities.
- In the beginning, Expert Systems were developed by the end of 1970s and were operating in the medicine, chemical, education, natural resources and science. ES started to gain popularity in the early 1980s.

EXPERT SYSTEM

- Expert Systems (ES) are intelligent computer program encoded, domain specific knowledge and reasoning of experts to produce solution.
- ES derived its knowledge from experts, supported by literature on application. ES differs from conventional computer program in many ways: uses knowledge rather than data for controlling solutions.
- Knowledge is encoded as an entity separate from the control of the program, it can explain how and why a particular solution is obtained, it uses symbolic representation for knowledge (rules, semantic nets or frames), it often reasons with meta knowledge i.e., knowledge about itself and has self-learning capabilities.
- The rule-based expert system has five components:

(i) the knowledge base, (ii) the database, (iii) the inference engine, (iv) the explanation facilities, and (v) the user interface.

- The basic components of rule-based expert system are shown in fig.1.

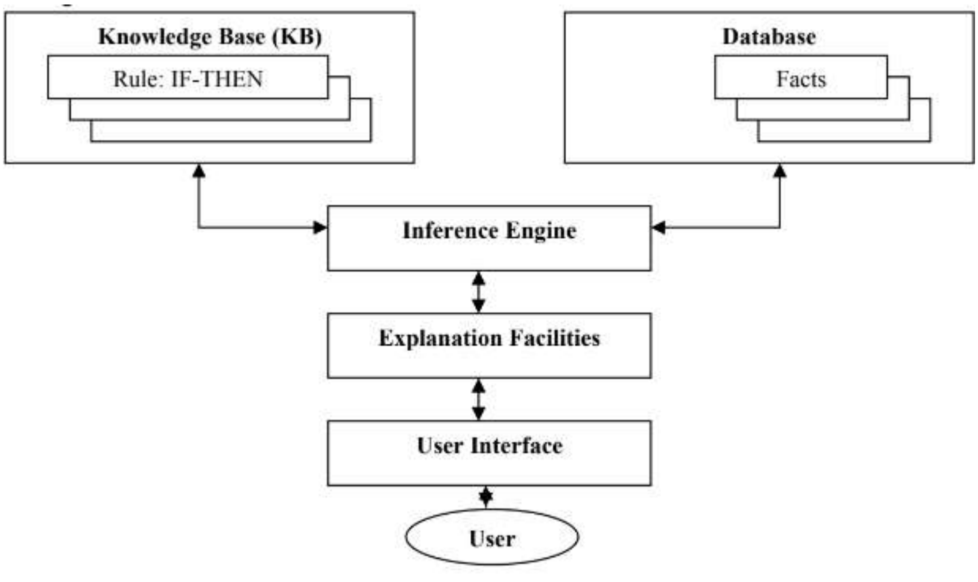

Fig.1 Components of Expert System and User interface

- The expert system developed in the Prolog programming language functions as an inference engine in the backward chaining.

(i) **Knowledge Base:** It is a declarative representation of the expertise, often in IF- THEN rules including such things as simple facts about the domain, rules or constraints that describe relation or phenomena in the domain, and possibly also methods, heuristics and ideas for solving problems in this domain.

(ii) **Database:** It is the data or a set of facts which is specific to a problem being solved used to match against the IF (condition) parts of the rules stored in the knowledge base.

(iii)**Inference Engine:** It carries out the reasoning by interplaying the information or facts obtained from the user with the knowledge stored in the knowledge base whereby the expert system reaches a solution.

(iv) **Explanation Facilities**: It explains about how a particular conclusion is reached and why a fact is needed and explains its reasoning and justifies its advice, analysis or conclusion.

(v) **User Interface:** It provides communication between the user and expert system.

APPLICATION OF THE EXPERT SYSTEM IN HORTICULTURE:

- The agricultural practices as performed by farmers are traditionally based and non-scientific. Computer based general farm management and Expert System can be helpful in providing solutions to the problems in horticulture.
- ES can provide a comprehensive management of orchards. It can help in disease, pest and disorder management of plants. Since, plants and fruits are affected by insect-pests and diseases, which cause considerable loss, if not properly managed.
- So, proper management of orchard for diagnostic purposes can be helpful to increase total production and minimizing losses. Computer based general support and ES can be helpful in creating awareness and giving timely preventive suggestions.
- It can also help in insect identification, monitoring, insecticide selection, and disease management.
- It can be cost effective as users need not wait for experts. By repeated consultations, farmers can develop self- skill and awareness for care-taking and ES can become advisory-cum-training tools.
- The transfer of knowledge from consultants, scientists, researchers and experts to extension workers in any area is very important for the development of agriculture and horticulture.
- The ES technology provides a good platform to facilitate the transfer of knowledge from expert to extension workers or farmers.

- The ES technology around horticulture has been developed especially related with decision-making, pests, diseases, or disorders diagnosis.
- Some of the Expert Systems developed for the horticulture applications are: CUPTEX- for cucumber crop production, TOMATEX- for tomatoes, CITEX- for orange production, LIMEX- for lime production, PLANT/ds- for the disease diagnosis among Soyabean, AMRAPALIKA- for the diagnosis of pests , diseases, and disorders in Indian mango , POMME for apple orchard management
- The application of the ES in horticulture is well justified and many developed countries have developed the expert system for their use.
- Although adoption of this technology in Indian agricultural practices is rather slow in comparison to developed countries, Indian farmers felt the need for such technology to increase agricultural productivity.
- Since, signs and symptoms of the pests, diseases and disorders have due geographical variations, expert system developed for a particular climatic and geographical region does not apply to different geographical region.
- Therefore, it is necessary to develop a new one or modify the existing system for that geographical region. Since, the concept of ES technology in agriculture has enough potential to revolutionize the agricultural practices, its use in India is urgently needed to enhance the productivity.
- ES can also help in finding nutrient status using visual symptoms in the plant and use of proper fertilizers to control the nutrient disorders and preventing damage to that tree.
- The information provided by farmers during consultation can be used to develop database of specific orchard for region-specific agricultural practices and problems. Such database will become valuable research resources in the future.
- In the modern days the concept of agro clinic has come into practice as shown in fig 2. Such clinics are being established near the agricultural land in the rural areas. Obviously, farmers will seek these clinics to get solutions for problems encountered.
- For this purpose, ES can also be installed for consultation in local agro-clinics or like ATM machines where farmers can have direct access. The person managing this clinic will need expert knowledge to help farmers.
- Under such conditions, ES will be highly useful and will attract farmers to these clinics. The ES available at agro clinics in remote area can be linked with central remote sensing center to make predictions about disease spread and weather conditions, enabling advance planning in caretaking of orchards. Such scheme will be highly helpful in

alerting farmers in rural area for taking preventive steps to save crops in adverse weather conditions.

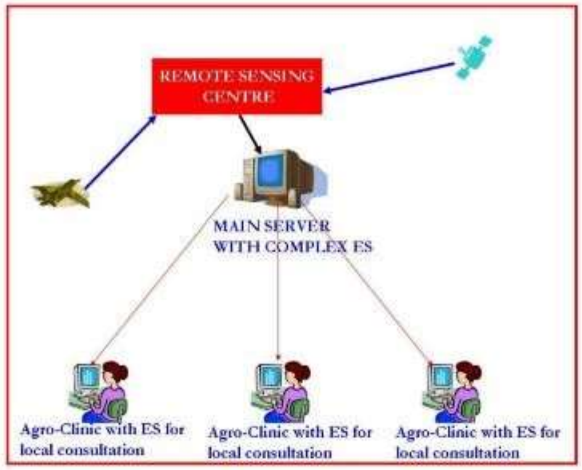

Fig 2. Role of ES in agro-clinics