Meadows, S.A., and the S.A. Woods and Forests Dept. for gifts of potting mix materials, to Australian Gypsum Ltd for samples of gypsum, and to Barbara Graham for technical assistance during some of the experiments.

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GREENHOUSES IN PLANT PROPAGATION: AN HISTORICAL PERSPECTIVE

JOHN FALLAND

Controlled Environment Structures (Australia) Pt. Ltd.
P.O. Box 345
Nuriootpa, South Australia 5355

The growing of plants in covered houses, whether they be greenhouses, conservatories, or orangeries, is essentially a northern hemisphere phenomenon. It is not, however, a new phenomenon, and the first attempts at growing plants under artificial conditions go back to at least early classical times. For countless generations much use has also been made of "shade houses" or natural cover to allow the cultivation of many plants which were affected by excess sunlight.

The Greeks with their "gardens of Adonis" appeared to have had forcing houses in miniature. Plato says that "a grain, a seed or a branch of a tree placed in or introduced to these gardens acquired in eight days a development which could not be obtained in as many months in the open air." Columella, a Roman writer on rural matters, speaks of Rome possessing "within the precincts of her walls, fragrant trees, trees of precious perfumes such as grown in the open air in India or Arabia." The implication of this is that they were not grown in the open air in Rome. It was Caesar Tiberius, however, who, introduced a utilitarian note to these early attempts at covered gardening. Told by his doctor that he needed a cucumber a day to cure an illness, he instructed his gardener to produce a cucumber a day or else! The gardener succeeded in growing cucumbers by cultivating them in pits filled with fermenting dung and covered with frames or lights of talc or mica.

In later Roman times forcing was done my means of specularia, buildings covered with sheets of mica, thinly split. Mainly fruits, cucumbers, and peaches were grown in specularia. Among the ruins of Pompeii a building of this kind was discovered, with

masonry staging for displaying plants and hot air flues in the walls; it was apparently originally glazed with talc or rough glass.

With the decline of the Roman empire the practice of forcing fruit in artificial conditions seems to have been abandoned in Europe, and not until the 13th century do we hear of any attempt to revive it. In 1295 Albert Magnus, a Paduan, is said to have entertained William of Holland, King of the Romans, in a garden maintained in flower and fruit by artificial heat. The wealthy merchants of Venice and Genoa, importers of many luxurious fruits, were probably the next to attempt glasshouse construction.

Further north, the earliest development of the greenhouse appears to have taken place in France: this lead was subsequently taken by the Dutch, when at the height of their maritime empire, and it passed ultimately to Britain. The first covered gardens were orangeries, normally without heat, built for sheltering citrus fruits during the winter months, but by the seventeenth century these had reached a fair degree of perfection. In 1685 Jules Mansard (or Mansart) built the noblest orangery in Europe for Louis XIV at Versailles. It had three arcaded galleries, the central portion of which was 508 ft long, 42 ft wide and 45 ft high. In 1693, Fagon, Superintendent of the Jardin Royal, constructed the famous hothouse which he warmed with "stoves and furnaces for the preservation of tender plants, including the tea plant. The first successful attempt in Britain at greenhouse gardening was made at the Physic Garden at Oxford where the buildings were of wooden construction, very little better than cold frames.

In general, orangeries, which were unheated, came first; these were followed by conservatories, essentially houses for conserving tender plants; the stovehouse which was heated to a high degree came later. The credit for coining the word greenhouse (a house for conserving tender greens) goes to the diarist Englishman, John Evelyn.

In the early days the greatest problems related to heating and all sorts of fantastic methods were used. The Dutch first used freestanding stoves which had to be fuelled from inside the greenhouse. It was fairly soon realized, however, that fumes from the stoves were destroying the plants, and quite a number of gardeners also appear to have been choked to death by these early furnaces. Even more primitive was the portable brazier, filled with burning coals and wheeled to and fro, used to heat the first greenhouses at the Oxford Physic Garden. Subsequent developments involved moving the stove outside and heating the back wall of the greenhouse by means of complicated flues.

At this time the only people who had greenhouses were the very wealthy. In Britain there was no real progress made in glasshouse development until the tax on glass was repealed in 1845. Every gentleman with any self-respect had to have a greenhouse. The

aristocracy really became enthusiastic and a number of structures similar to the Palm House at Kew Gardens were erected, perhaps the most famous being the huge conservatory built by Paxton for the Duke of Devonshire at Chatsworth.

Another major breakthrough occurred when hot water heating for greenhouses was invented. Incredible though it may seem, until 1818 nobody realized that hot water circulated naturally. Once this principle had been understood all manner of boilers were invented, the manufacturers of each one claiming invariably that their boiler presented a larger area of water to the fire than anyone else's and was therefore a more efficient heat exchanger. One wonders what the proud possessors of the first boilers would have thought of a modern small bore, or mini-bore, heating system! The next problem, of course, was how to ventilate the heated greenhouse efficiently, while keeping it at an acceptable temperature to the plants being raised.

Once electricity became available, further advances followed in greenhouse development and as long as it was cheap, many greenhouses used it for heating to high levels. Today, electricity is used mainly for heating to moderate levels, but is essential for the operating of almost everything else in greenhouse mechanics. It is also used for artificial illumination, both so that one can see in the greenhouse after dark and to encourage the growth of plants with long-day requirements, for automatic ventilation and shading, and for air circulation.

Thus, although greenhouses have developed rapidly and have come a long way from the earliest attempts by the Romans in classical antiquity, the basic problems faced by greenhouse designers and engineers today are still the same as they were in those days and, indeed, throughout the whole history of the development of greenhouses, including the heyday of the Victorians. The giant conservatories at Chatsworth House faced precisely the same problems as the 8 by 12 ft greenhouse found so frequently in private gardens today. The difficulty has always been to find an effective balance between heating and ventilating, and between light and shade. Too much heat and the plants boil to death in their own condensation; too much ventilation and it becomes almost impossible to raise the temperature to the desired level; too much light and the greenhouse overheats in summer; too much shade and the plants become drawn and leggy. However, with modern electric and other automatic aids it is now possible to overcome all these problems and to have a greenhouse that is not only more efficiently heated, ventilated, lit, and shaded than ever before, but also to have these elements in proper balance and so automatic in their running that the greenhouse can virtually be left to itself. All the modern greenhouse gardener need do is enjoy his plants.

SITE SELECTION

I assume that some of you will be contemplating building a new complex and where you build and how you build will be uppermost in your minds. Some of you will already have a greenhouse and may not have had a choice on site selection.

The nearer you are to the equator the nearer you are to the sun. If you journey away from the equator the colder it can get. This is important in the winter when heating may be required, and the cost of heating fuel can be one of the biggest costs in running a greenhouse.

Since water stores heat, it is quite often an advantage to build a greenhouse close to the coast to take advantage of the heat radiated back to the air.

Some areas can get extremely hot with 40°C+ temperatures. With modern day cooling equipment, these can usually be easily handled, but again with a running cost.

For the milder climate, roof and/or side venting may be sufficient, and in the high humidity areas it may be the only real way to go. Natural venting does not cost anything to run and is very quickly coming back in favour with many growers.

Depending on the plant you are growing, when you want to grow, and where you want it to grow, it may be that you would need to have cooling and natural venting, with heating as well.

I am not going to enter the debate of whether a greenhouse should face north to south or east to west—there are growers who are adamant that only north to south is correct. Their ideas may well be correct but I believe that Australia has an abundance of light as compared to other countries and it does not make a lot of difference; also, with the use of fiberglass and plastics, the light entering the greenhouse is much more even, thereby minimizing shadows from structures, etc.—more of that later.

THE MODERN STRUCTURE

The present day structure is usually made of hot dipped galvanized steel with a few glazing members of aluminium—all designed to be low in maintenance. The structure will also be slim in its sections to minimize shadows, but yet it has to be strong enough to withstand any adverse weather conditions.

All-aluminium structures are available, but not all that popular since they cost more to manufacture and have no definite advantages in the final performance.

Designed into the structure will be a means of collecting and draining condensation which forms inside the glazing. This will minimize damage to the plants from falling droplets and reduce the likelihood of humidity related diseases which require expensive spray control.

The modern greenhouse will be well sealed to reduce cold drafts and also keep the heated warm air inside—which has cost you money to get. It is also necessary to have the greenhouse sealed for the modern cooling systems which are negative pressure operated.

GLAZING ALTERNATIVES

To glaze the greenhouse, there are so many options that you could be excused for being confused.

If you are thinking of using polythene you probably have more decisions to make than anyone else. There must be at least 10 different polys on the market, ranging in quality and cost with all kinds of performance claims. Some come in a choice of light transmissions and then you need to decide whether you have a single or double skin and how you will fasten it all. In initial cost poly would be the cheapest but can also cause more heartache than either fiberglass or glass. If you count the material and labour cost of frequent replacement and the very real possibility of losing the cover with a crop in a high wind—I suggest it may not be that cheap after all. In fact 50% of our business comes from disgruntled poly users.

The debate continues on the merits of using fiberglass or glass. I prefer fiberglass because it has a host of advantages. It can be purchased in several choices of light transmission, and I don't know of any plant that will not respond better under fiberglass than glass. The light transmission is much softer—much like comparing a soft 40-watt florescent light with a harsh 40-watt incandescent bulb. It reduces heavy shadows from the structure. Tests taken have shown fiberglass will actually allow more light in at the beginning of the day and at the end of the day when compared with glass, thereby lengthening the day. It will not shatter from hailstones or cricket balls and it is much easier and quicker to fix on site which means lower construction costs. Although fiberglass bought in 1986 has protective coatings and is much improved from only five years ago, it still loses its light transmission by about 1% per year. This means that fiberglass bought today at say 90% light transmission will, in effect, be about 80% in ten years time. Now this would possibly not concern too many growers with the abundance of light in Australia. Growers have repeatedly told me that they are growing a better product now than they were when the greenhouse was new. It could well be that we are brainwashed into believing we need all the light possible, from literature obtained or reproduced from overseas where light is not in abundance. It could also be that the grower has gained experience in those years and treats his plants differently.

Glass is the other alternative that requires a mention. For all intent, it will last forever and is not affected by reducing light transmission. Glass by itself lets in a lot of light but with the necessary glazing bars the overall light transmittance is not a lot different from

fiberglass. Hailstones are not the big threat they used to be with the change from 3mm to 4mm in thickness, although a hail guard is still desirable. Glass is harder to fit around doorways, exhaust fans, etc. and as mentioned, field erection times are considerably more with the glazing bars, sealers, and smaller panels. It also seems that its easier to insure a fiberglass house than a glasshouse.

HEATING

There is no doubt that when heating is necessary it is usually the costliest item that occurs in the operation of a greenhouse.

Oil, gas, and electricity are extremely costly and there does not seem to be any reductions of price for growers in the foreseeable future. Maybe this is an area where organizations such as IPPS could do some lobbying.

The success of a greenhouse manager lies, in part, with his ability to maintain desirable and uniform temperatures during the heating season. A properly sealed greenhouse and properly designed, installed, and maintained heating system is a necessity to be able to operate as economically as possible.

There are many heating systems available ranging from hot water boilers, unit heaters, infrared heaters, electrical cables, and electric fan forced units. Depending on the size of the greenhouse, the types of fuel conveniently available and what the grower wants to achieve, will usually determine the type of heating system to be installed.

It is claimed that a thermal blanket system can save 30 to 40% of heating costs, and a fully automatic system would pay for itself in two or three years.

Many experiments have been made with solar heating, and whilst the costs of running are lowered, it is costly to install and a "back up" system would still be necessary for those days when the sun is not releasing enough of that free energy.

COOLING

Prior to the mid-1950's, little was mentioned in texts regarding principles, methods, and equipment used in ventilating greenhouses. Little did an American named Bailey realize, when he wrote in 1900, that some of his 100-word description of ventilation would be the goal of engineers 50 years later. He wrote of ventilation:

> "Theoretically, it is employed also for the purpose of introducing chemically fresh air, but with the opening and shutting of doors, and the unavoidable leaks in the house, it is not necessary to give much thought to the introduction of mere fresh air. Ventilating reduces the temperature by letting out warm air and letting in cool air. The air should be admitted in small quantities and at the greatest distance from the plants in order to avoid

the ill effects of drafts on the plants. Many small openings are better than a few large ones. Ventilate on a rising temperature."

Bailey had made some observations, which are quite correct, but he was not to be aware of the progress that has been made with greenhouse design.

Today's greenhouses have roof and side ventilation which can be opened and closed and, if you wish, are operated automatically by micro-processors.

In 1954, DeWerth and Taska in the U.S., pioneered a new method of ventilating greenhouses. It could be classed as forced ventilation but is commonly known as pad and fan cooling. It took another 20 years, to 1974, before a suitable standard was established for engineers to work on for ventilation requirements.

This standard is now accepted on a world wide basis and gives the grower an environment in his greenhouse that is, combined with other factors, just about as perfect as one could hope for.

The system works best in the hot dry areas and we now see plants, flowers, fruit and vegetables all year round that only a few years ago were simply not available.

CONCLUSIONS

Yes, greenhouses have come a long way in a short time. They have become sophisticated in their design, they can grow almost anything almost all year round; they are also able to do it automatically.

I am told by experts that the horticultural industry is one of the few growth industries (and that is not meant as a pun) in Australia. It has an excellent future, providing we can hold costs to a minimum and keep pace with technology which will produce good, new products for a reward, which gives us incentive to continue.