SOME COMPARISONS BETWEEN PLASTIC AND GLASS GREENHOUSES

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INTRODUCTION

The acceptance of plastic materials for greenhouse construction has been much slower in New Zealand than elsewhere. Worldwide statistics on greenhouses suggest that generally the area of plastic greenhouses is three times the area of glasshouses. The reasons for this lag behind worldwide trends are undoubtedly very complex, but nurserymen and propagators in New Zealand are using a higher ratio of plastics to glass than greenhouse growers generally. The current emphasis on expansion of horticultural production in New Zealand and the general shortage of planting stock is causing many propagators to consider expanding their businesses. This involves difficult decisions on how best to do so. These decisions are not made easier by the wide range of alternative greenhouse covers already offered in New Zealand and the range of new material coming onto the market here and already available overseas (see Table 1).

Table 1. Plastic alternatives to glass for greenhouse use.

	Material	*Trade Names*
(a)	**Currently available in New Zealand**	
	UVI polythene film 125 um thick	GARNITE Greenhouse
	UVI polythene-ethyl vinyl acetate copolymer film 125 um	(NIPPOFLEX (AGPAC Greenhouse PERMAFLEX
	UVI polyvinyl chloride film 300-450 um thick	NYLEX Agricultural PVC
	Polyvinyl chloride rigid sheet	NOVAROOF
	Glass reinforced plastic rigid sheet	DUROLITE fibreglass
(b)	**Available overseas**	
	polyvinyl chloride film 125 um	many brands
	polyvinyl chloride rigid thin sheet	
	UVI double polythene rigid sheet	CORFLUTE
	UVI double acrylic rigid sheet	(ACRYFLUTE (STEGDOPPELPLATEN

The decision on whether to expand plastic or glass greenhouses has to be made objectively from the business point of view on the basis of greenhouse operating costs per unit area and per unit product. The greenhouse operating costs per unit product itself depends on the amount of yield produced under the various greenhouse covers, but it is possible to compare costs on the assumption that yields are equal with all types of greenhouse.

Estimates of the most important greenhouse operating costs are given in Table 2. Greenhouse operating costs per unit area do not accurately reflect costs per unit production which are dependent on the yields actually obtained. Table 3 shows how the profit margin per unit product can vary by a factor of about three times as a result of variations in greenhouse operating costs and yield using tomatoes as an example.

Table 2. Estimated fixed operating costs for greenhouses. All costs in dollars per sq. meter.

Greenhouse types	Tunnels *Single PE*[1]	*double PE*	*PVC*[2]	Small *glasshouse*	Levin *PE*	Multibay *Rigid PVC*	Large *glasshouse*	*GRP*[3]
Capital cost	11	13	12	45	10	16	30	43
depreciation[5]	0.55	0.65	0.60	2.25	0.50	0.80	1.50	2.15
interest[6]	1.10	1.30	1.20	4.50	1.00	1.60	3.00	4.30
recovering	2.00[7]	4.00	0.84[8]	—	1.67[7]	0.50[9]	—	0.63 [9]
maintenance	—	—	—	0.50	—	—	0.50	—
basic operating costs $m2 year	3.65	5.95	2.64	7.75	3.17	2.90	5.00	7.08
heating cost[10]	3.24	2.37	2.57	3.56	1.60	NA	2.85	2.85[11]
ventilating cost[12]	0.63	0.63	0.63	1.00	0.63	NA	1.00	1.00
TOTAL	7.52	8.95	5.84	12.31	5.40	—	8.85	10.93

NOTES:

[1] Polyethylene

[2] Polyvinyl chloride

[3] Fibreglass on steel trusses.

[5] Depreciation over 20 years

[6] Interest on capital at 10%

[7] Annually

[8] Every three years

[9] After fifteen years

[10] Heating costs based on 10,000°C hours below heating set point each year

[11] Heat loss from fibreglass greenhouses under NZ conditions is not known but assumed to be the same as for glasshouses.

[12] Ventilating costs, an arbitrary figure is given dependent on the known variation in fan capacity required for glass and plastic houses.

NB: The use of thermal screens could reduce heating costs by 20 to 30% in all types of greenhouses.

Table 3. Effect of yield and greenhouse operating costs on tomato profit margins.

Yield	Sales	Labour & Variables	Low cost greenhouse Cost	Margins		High cost glasshouse Cost	Margins	
kg/m^2	*\$/m*^{2}	*\$/m*^{2}	*\$/m*^{2}	*\$/m*^{2}	*\$/kg*	*\$/m*^{2}	*\$/m*^{2}	*\$/kg*
15	+30	−20	−5.40	4.60	0.31	−8.85	1.15	0.08
20	+40	−25	−5.40	9.60	0.48	−8.85	6.15	0.31
25	+50	−30	−5.40	14.60	0.58	−8.85	11.15	0.45
30	+60	−35	−5.40	19.60	0.65	−8.85	16.15	0.54

YIELD COMPARISONS

It is difficult to reliably compare yields in plastic and glass greenhouses. Yield in any situation is a result of the environment provided throughout the growing period and the environment itself is greatly modified by different greenhouse types. Some understanding of the physics of the greenhouse environment is required to appreciate the magnitude of the effects of different greenhouse covers and it must be realised that the newer structures all offer the grower a greater opportunity to control the environment than is available under glass. Plastic and glass greenhouses differ particularly in their effects on light, heat, humidity and air change rates in the greenhouse environment and all these factors affect yields.

Modifications to the light environment. As a general rule fewer structural components are required to support plastic greenhouses than glass roofs and this allows a greater light penetration into the structure. The situation however is confused by the fact that most film plastic greenhouses have curved tunnel roofs rather than traditional even spans and also by the fact that most plastics diffuse light more than glass. Diffusing covers an east-west orientated tunnel greenhouses at high latitudes and low sun angles can result in a light trap situation but the diffusing covers probably do not increase total light intensity in north-south greenhouses or under cloudy conditions and reduce light intensities at high sun angles. I am not aware of any experimental evidence showing whether diffusing or clear greenhouse covers would be best in New Zealand. I suspect that, in general, growers use what is available to them, for example at our latitudes in Japan glass-clear PVC is the most widely used plastic material, but in Europe and North America this material is not available and more diffusing polythene covers are most common. The choice of cover may also affect spectral composition of light within the greenhouse and research is in progress with pigmented films, some of which are claimed to have increased yields under certain conditions.

Condensation, particularly in large drops on plastic greenhouse covers can reduce light transmission considerably but this problem can be avoided by using plastics which wet easily so that condensation forms as a film rather than droplets or by treating the plastics with certain surface active agents. The subject of light intensity in plastic greenhouses is thus very complex but, as a general rule, it is safe to assume light transmission is higher under plastic covers than under glass and should therefore benefit production.

Temperature environment. Plastic greenhouses can be thermally much more efficient than glasshouses particularly when double-skinned. Their thermal characteristics are highly dependent on the plastic material used and particularly on its transparency to long-wave infra-red radiation. All the materials at present in use are more transparent than glass when dry and so lose more radiant heat than glass but they are often covered by condensation which is an efficient infra-red absorber, reducing the radiant losses to levels very similar to that of glass. The greater radiant energy loss is largely offset by lower air change rates through plastics than glass roofs and by the smaller effect of wind in increasing heat loss.

Heat loss from greenhouses is surface area related and hence types of greenhouses such as tunnels which have a large surface to floor area ratio lose much more heat per unit floor area than do multi-bay structures with low surface to floor area ratios. It is also relatively easy to decrease heat loss by using two layers of plastic separated by still air.

Unventilated plastic greenhouses tend to be warmer by day than most glasshouses. When heating is required to maintain ideal thermal environments some plastic greenhouses are more expensive to heat than glasshouses but double skin polythene film houses are much cheaper to heat than glasshouses.

Humidity in the environment. Most growers recognise the effect of aerial humidity on plant disease but it is also important to realise that humidity has effects on yield. Well-built plastic greenhouses should have very much lower air change rates than glasshouses and this results in a far greater proportion of the water evaporated from the crop and soil being retained in the greenhouse. This does not necessarily result in high relative humidities though humidities normally tend to be higher in plastic than glass greenhouses. The relative humidity in a plastic greenhouse without any air change is related to the difference between plant and soil temperatures and skin temperature, which in single skin houses, is normally close to outside air temperature. Warm moist air within the greenhouse is cooled at the inner skin surface to close to skin temperature and hence causes condensation on the skin whenever its wet bulb temperature is above skin temperature. Natural convection maintains continuous air movement within the glasshouse and the wet bulb temperature of the air as a whole thus approaches skin temperature. Relative humidity is proportional to the difference between dry and wet bulb temperatures and so relative humidity in greenhouses is automatically regulated by the difference between greenhouse air temperature and skin or outside temperature. Thus, as a general rule, humidities will be high when inside and outside temperatures are similar and low when there is a large difference betwen inside and outside temperatures. Improving greenhouse insulation by double skinning has the effect of increasing the difference between outside air and skin temperature and hence also has the effect of increasing relative humidity within the greenhouse. Since there is little or no air change in unventilated plastic greenhouses, the moisture lost from the crop is retained as condensation on the skin. Provided that the humidity in the greenhouse is not high enough to cause disease and the condensation remains on the skin no harm results but, unfortunately, drips from the skin to the crop do create a disease risk. Walls and roofs with steep angles do not drip, but wind flap (which can be prevented) causes dripping or showering of moisture onto the crops.

Another risk factor is dew on the crop. This risk is again much higher in plastic than glasshouses and is likely to occur in unventilated houses soon after dawn when solar heating quickly warms the air and sets up vigorous transpiration to increase absolute humidity of the air while, at the same time the crop warms up more slowly, thus providing an additional surface below air wet bulb temperature for condensation.

Recently published research from Japan suggests two possibilities providing better control of atmospheric humidity in plastic greenhouses. One possibility is to ventilate with relatively dry outside air and use a simple heat exchanger between outgoing and incoming air streams to recover heat from the exhausted air and warm the incoming air. The other possibility does not require ventilation but simply pumps warm moist air through pipes below the soil surface to provide both soil warming and condensation of moisture from the greenhouse air. Both possibilities have obvious applications to the nursery and propagation situation.

Carbon dioxide in the environment. Yield in all green crops is dependent on the process of photosynthesis, the rate of which is directly proportional to light intensity, temperature and $C0_2$ supply. A normal glasshouse is continuously supplied with $C0_2$ by leakage of fresh air into the glasshouse through gaps in the glass, etc. The rate of air change is itself partly dependent on inside/outside temperature differences so that in a closed glasshouse, as solar radiation intensity increases through the day, air temperature differences, the rate of photosynthesis, and the supply of $C0_2$, all increase in a self compensating manner. This is not true for plastic greenhouses where the $C0_2$ supply is limited by the volume of the greenhouse when ventilation is not given. There is, therefore, a very serious risk that crops in plastic greenhouses may be short of $C0_2$ quite frequently in periods of bright, sunny and cool weather. There is little published information on actual rates of $C0_2$ uptake by greenhouse crops. Uptake rates of 1.3 to 4.7 g of $C0_2$ per square meter per hour have been measured in tomato houses but tomatoes are known to take up more $C0_2$ than many other crops. Luckily, data has been published for roses and it is possible to calculate theoretical CO_2 concentrations in greenhouses cropped with roses according to light intensity and temperature. Such calculations suggest that on a typical New Zealand winter day the CO_2 concentration would remain close to ambient (about 340 ppm) in a rose glasshouse but that in a polythene tunnel the rose crop would consume all the available CO_2 (reducing the concentration to about 150 ppm) by about 10:30 am," thus effectively limiting photosynthesis and growth for the remainder of the day unless ventilation were given. Ventilation on a temperature basis alone would not, however, be justified at that time as the temperature is still below the optimum for roses.

The use of CO_2 enrichment, however, would enable optimum CO_2 and temperature conditions to be maintained throughout the day providing that humidity considerations did not require ventilation. The economics of CO_2 enrichment should be much better in plastic greenhouses than in glass since the temperature difference related leak rate of glasshouses causes considerable wastage of applied CO_2 under optimum temperature conditions in winter.

Total environment effect on yield. New Zealand growers are very competent in crop production in glasshouses where temperature is the most important and most easily controlled environmental factor. By contrast plastic greenhouses exert a greater modification on temperature, humidity and CO_2 environment and hence make their control both easier and more vitally important if high yields are to be obtained. The exact nature of the changes in management practice required are still poorly understood.

THE RISK FACTOR

The plastic materials in current use all have considerable inherent strength particularly against well distributed loads. All the better materials retain this strength for at least one year's use, when manufactured to the proper standards, and properly installed. The materials can be punctured or torn by flying debris during wind storms, but glass would also break in these conditions. There has been some under-estimation of structural loads on plastic film structures, and adequate design of the structure of plastic greenhouses is essential. Tunnel houses built to the specifications of the more recent Lee Valley Experimental Horticultural Station recommendations probably present little if any greater risk than the average New Zealand glasshouse.

Many current greenhouse practices are designed to reduce the risks of crop failure, disease or poor timing or quality through elaborate environmental control as a consequence of the high value of greenhouse crops. Risks in these areas are associated with the reliability of environmental maintenance equipment rather than the structure. The lower capital cost of plastic greenhouses can free more money for investment in this area. The risk of structural and skin damage in absolute terms is similar for plastic and glass houses but less in capital terms for plastic structures. Financial institutions should be most willing to lend on plastic structures, as hopefully small borrowing and greater profit margins should lead to quicker repayment.

CONCLUSIONS

Operating costs for traditional glasshouses and some rigid plastic roof greenhouses are nearly double that of the cheapest modern plastic structure. The plastic greenhouses all provide greater control of temperature, humidity and $C0_2$ concentration and offer cost savings where these factors are controlled. Light intensities in all plastic structures are believed to be better than in glasshouses and this should contribute to greater yield potential. However, achievement of this potential yield in plastic houses requires management practices which control (or at least recognise the greater requirements for control) temperature, humidity and $C0_2$ concentration. Differences in management practices between glass and plastic greenhouses are at present poorly understood but the difficulties in this area are not unsurmountable. Developing techniques in energy conservation and in solar heating are more likely to be more easily applied in future to thermally efficient plastic houses than to greenhouses and so I believe that in the long run glass must be displaced by plastics as the principal component of greenhouses.

PROPAGATING EUCALYPTS BY GRAFTING

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Our aim in grafting eucalypts is to eliminate variability in flower colour and tree type. Grafting will enable us to produce trees true to colour and probably trees in full flower in containers. With *Eucalyptus ficifolia*, for example, we have trees with red, orange, scarlet and pink flowers. Another advantage of grafting is that, because the scions are from mature trees, plants immediately grow into round-headed, multi-branched bushes which are ideal for container sales.

For successful grafting, significant factors seem to be to use fast-growing seedlings for rootstocks and to obtain scions from current season's growth free of diseases and insect injury. Seedlings from October-November (spring) sowing are ready for grafting in late January or early February (late summer). At this time the scionwood is at a suitable stage of growth. Scionwood should be mature with no bud development in the axils of the leaves. Scions with two leaves are best. The leaves are removed