target species, particularly in the absence of potential pathogens

The optimum pH for the growth of ferns in this experiment was 5.96 to 6.41 and that of *P. cadierei* was equal to, or in excess of 6 57. Recommendations for the optimum medium pH vary widely. Baker (4) recommends a pH of between 5.5 and 6.5 for growing most plants while Bunt (5) recommends a pH of between 5.0 and 5 5 for growing most plants in medium high in organic matter. Hipp and Morgan (6) recommend a pH of 4.5 for growing *Nephrolepsis exalata* 'Rooseveltii'. This is contrasted to the pH of 6 7 recommended by Hoshizaki (7) for fern culture. The pH of a medium has a large effect on the availability of nutrients in potting medium as does the organic matter content (4). The different nutrient regimes and media used by these writers probably accounts for most of the differences in optimum pH for the growth of ferns under different environmental conditions Nurserymen should be aware that pH can have a large effect on the growth of plants and it may be worthwhile for them to do experiments under their own conditions

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RAPID PROPAGATION OF CITRUS IN CONTAINERS

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Abstract. Closer spacing of citrus trees, rapid expansion, and a more dynamic situation means that the need is for a cheaper and faster method of propagation A method is described of producing citrus on a rootstock in containers in less than one year The work was done with *Poncirus trifoliata* It was grown immediately from seed throughout the winter, microbudded, the scion induced to grow and material was ready for early summer planting This method is compared with another which produced material in one year where the rootstock was grown during the summer and the scion induced to grow during the winter months This produced better quality trees The estimated costs of production are presented Alternative methods, advantages and disadvantages, are discussed in the context of the whole system of citrus production

INTRODUCTION

The work was initiated in 1971 when we realised that the cost of new citrus trees was likely to be a limiting factor in the move towards closer plantings to improve efficiency in citrus production (10). Also, we recognized the need to provide planting material quickly, especially in periods of rapid expansion or in periods of change-over to other cultivars. Another factor that should be taken into account is the increased use of sophisticated irrigation systems. The use of trickle or under-tree sprinklers, especially where nutrients are supplied through the water, would enable citrus growers to "grow-on" young trees "in-situ" rather than in the nursery. Thus growers could make use of small budded stocks with a considerable saving in cost. Some nurserymen produce citrus trees in containers, but there is buyer resistance to this because the small containerized trees are less suited to planting out under conditions of relatively primitive irrigation systems (i.e., furrow irrigation with infrequent application). We have, therefore, considered likely changes in grower demand resulting from technical improvements.

THE PROPAGATION SYSTEMS

The traditional system of producing citrus trees is outlined in Figure 1, as well as the two systems we have developed:

System A Rapid propagation in small containers,

System B Propagation in 12 months in plastic bags which produces a plant more similar in size to open-field produced trees.

All our work was done with *Poncirus trifoliata* rootstock, which will normally go dormant in winter, and 'Valencia' sweet orange scion. Three experiments were carried out using 500 trees in each case. All propagation procedures took place in a glasshouse.

(a) **Seedling Production.** To save time (in System A) seed was extracted from fruit as soon as it ripened in the autumn (March). Large quantities of seed could be extracted by crushing the fruit, washing the pulp, then subjecting it to an enzyme treatment (1). The product would be improved by grading seed for size as variation in seed size could be the cause of variations in the initial size of seedlings. Seed germination is often slow and variable so we soaked the seed in 1000 ppm gibberellic acid for 24 hours to improve germination (2). Seed

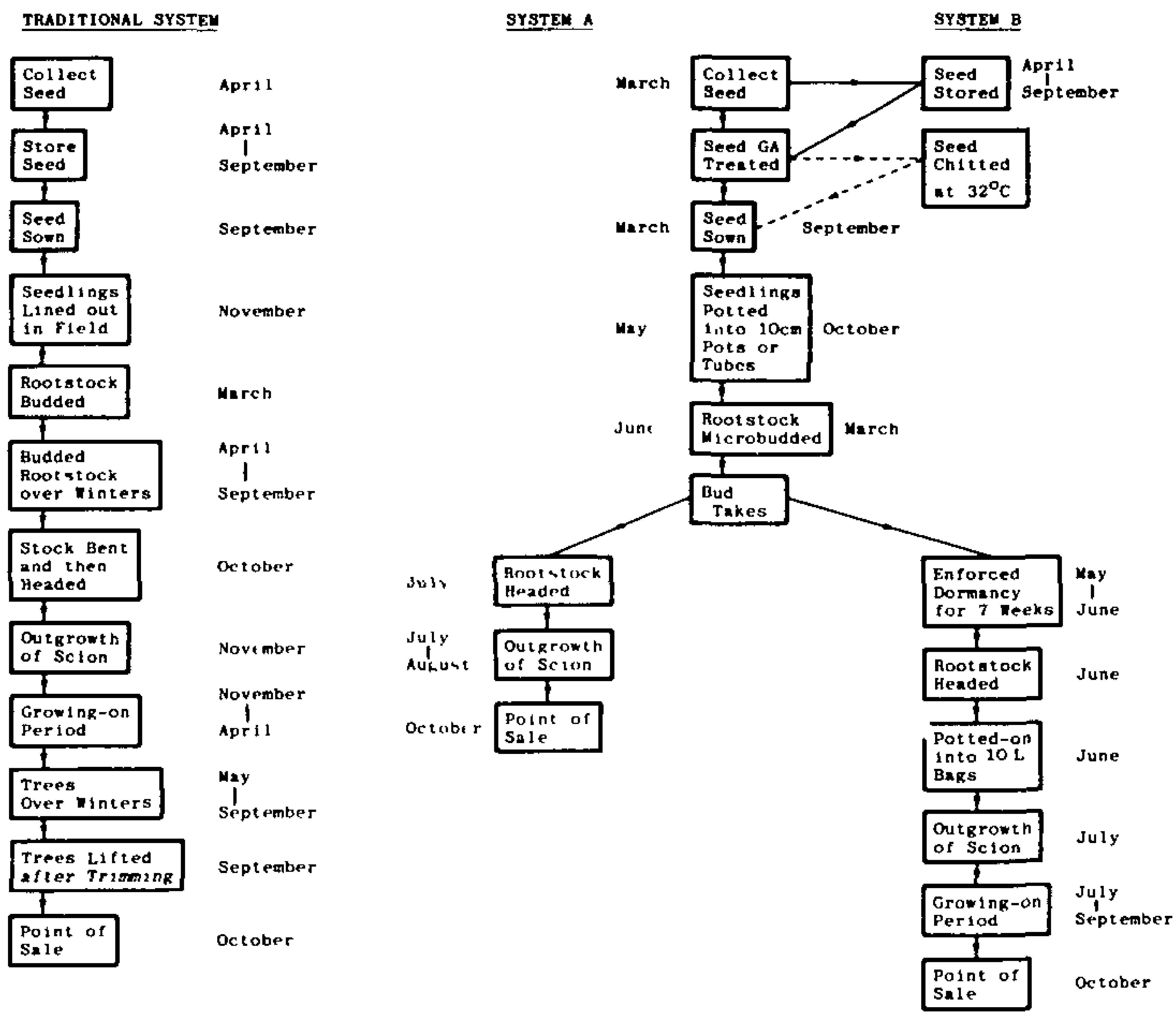

Figure 1. Comparison of three citrus propagation systems

can be heat-treated prior to germination if there is any risk of disease contamination. Another way to speed germination would be to chit the seed by keeping it moist at 32°C and sow at the onset of germination.

We sowed seeds in sterilized sand mixed with peat in "washing-up bowls" 35 × 30 cm with drainage holes. These containers hold 250 to 500 seeds and are 13 cm deep so they do not restrict root growth initially. Polystyrene grape boxes also would be suitable containers. At a minimum temperature of 25°C it took about two months for the plant to reach the transplanting stage. We did not observe any check in growth when the stocks were transplanted.

(b) **Growing-on the Rootstock**

(i) *Containers*. We used standard 10 cm plastic pots, but have tried other containers. A type sold in the USA for tree seedlings is a tapered plastic tube with three antispiral ribs on the inside (Figure 2). The largest of this type of tube is 215 mm long by 40 mm diameter at the top and holds 160 ml of medium (*cf.* the pots hold about ½ l). The standard Australian tube is unsuitable because the container must be large enough to take the stock to the size suitable for microbudding, that is 50 cm high with a stem diameter about 7 mm at 150 mm above the soil level.

Figure 2. Tapered plastic tube suitable for citrus rootstock production.

For System A the container must take the plant through to the planting-out stage. A tapered tube with a volume of at least 330 ml and a height of 250 mm would be best for System A.

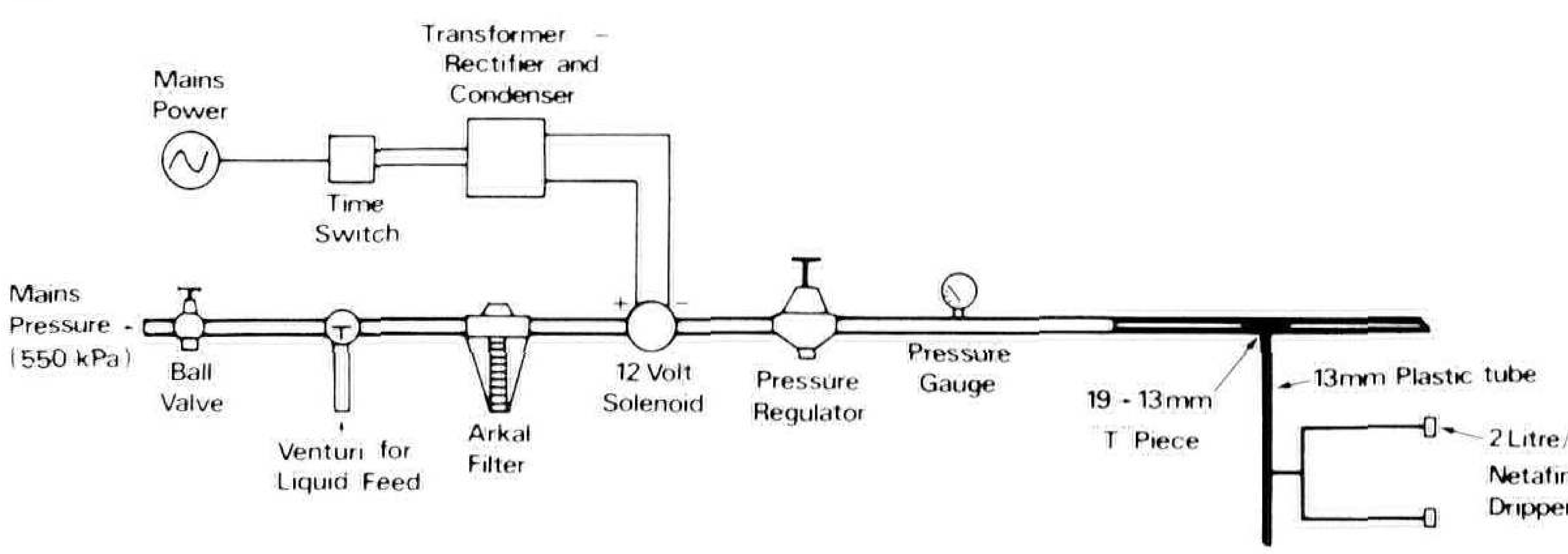

Figure 3. Diagram of the automatic watering system used in System B.

(ii) *Medium.* We used ⅓ loam, ⅓ sand, and ⅓ composted red gum sawdust. The pH was adjusted to 7. MagAmp slow-release fertilizer was added at the rate of 60 g per 10 l bag in system B. We had problems with this mixture — the pH fell rapidly at times and growth ceased, but this was easily corrected with additional lime. We suggest that a cheap, inert medium with liquid feeding might be better.

(iii) *Watering.* This was provided by individual pot drippers controlled automatically (Figure 3). In System B we hand watered up to the stage of potting on. Although we did not feed through the drippers we feel that the greatest advantage of the dripper system is the ability to do this and therefore gain almost total control over the nutrition of the plant

(iv) *Growing Technique. Poncirus trifoliata* has a short-day photoperiodic response which stimulates leaf abscission and winter dormancy Dormancy was prevented by providing photoperiodic lighting to 18 hours and maintaining a minimum temperature of 15°C. Other citrus rootstocks, while not having this dormancy mechanism, are stimulated to better growth with extended photoperiod (12). Below 15°C the plant will become dormant because the critical daylength is dependent on night temperature. In System B we did not extend the photoperiod because the rootstock was grown during the summer months Maximum growth rate would be achieved if the night minimum was kept at 25°C, but we doubt if this would be economic unless it enabled two batches to be produced each year With System B we potted-on the budded rootstock into 10 liter bags after two months, although we now feel that the seedlings could go straight into bags

(c) **Budding.** This was done as soon as the stock was large enough to take a microbud at a minimum height of 15 cm (13) This was achievable 8 weeks from potting-on of the rootstock seedling in System A. In System B budding was done 4½ months from the first potting Plastic tape was used for tying in the bud, and was removed 12 days later because under greenhouse conditions there is the danger of the bud callusing over if the tape remains for too long. The bud take was at least 95% in all experiments.

(d) **Growing the Budded Stock.** Outgrowth of the "taken" bud is one of the major bottlenecks in the system A number of experiments were carried out to make the bud grow without the need for heading the stock (Table 1) None of the environmental or gibberellic acid treatments caused the buds to grow out quicker A similar experiment using ringing, bending and removal of leaves and apical buds was tried earlier and also failed (5) In System B we deliberately induced dormancy for 7 weeks by turning off the heat and leaving the ventilators open during winter (May and June). This was also economically advantageous as it saved considerable heating costs Upon recommencement of greenhouse heating the stocks were headed and uniform sprouting of the buds occurred We feel that a night temperature below 10°C is needed to predispose the bud to grow out because a period at 15/10°C did not achieve the same effect (Table 1) Perhaps treatment of the scion by defoliating prior to taking the budwood, or treatment of the buds with growth regulators such as cytokinins might achieve a more rapid outgrowth (11). With System A small plants were ready for planting out 8 to 9 months from commencement. These are shown in Figure 4. In System B the greenhouse was evaporatively cooled, but we do not feel that the extra cost can be justified by a small increase in growth. Shading during mid-summer and ample ventilation are necessary to prevent excessively high temperatures, maybe requiring the use of fogging jets.

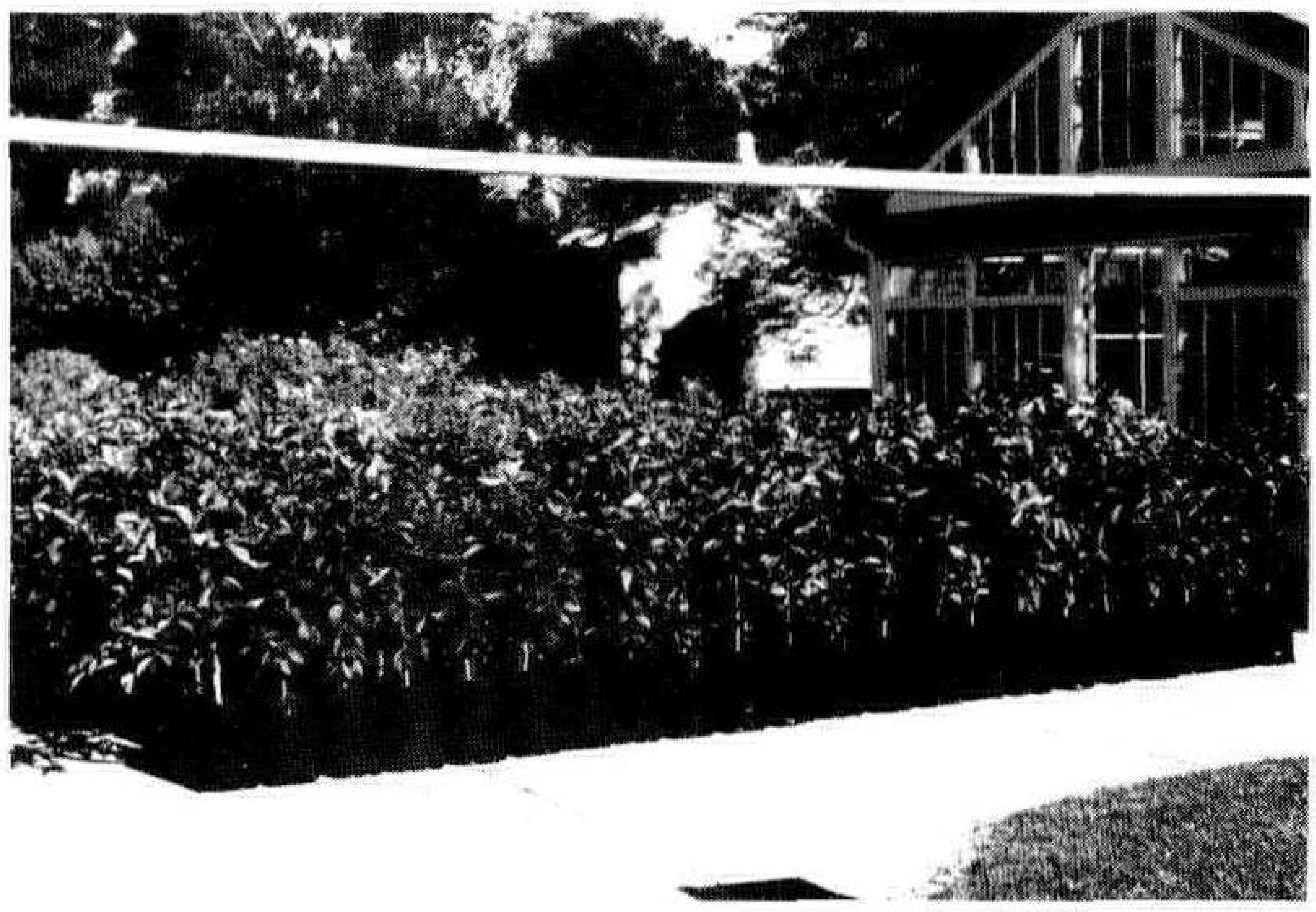

Figure 4. Finished citrus nursery plants in plastic bag containers propagated by System B, standing outside ready for sale.

Table 1. Details of treatments carried out on budded *Poncirus trifoliata* rootstocks to try and accelerate scion growth without the need for heading.

No.	Initial Treatments day/night temp.	photoperiod	Following treatments	Further treatments
	°C	hr		
1	15/10	8	After 4 weeks to 27/22°C	After 4 months
2	15/10	16	with 8 hr photoperiod	foliage lightly trimmed
3	21/16	8		After 5 months, each
4	21/16	16		treatment split — (a) Plants dipped into 100 ppm GA (b) Not dipped
5	27/22	8	After 4 months to 18/13°C	
6	27/22	16	for 6 wks then to 27/22°C with 16 hr photoperiod	After 5 months lightly trimmed

ALTERNATIVE SYSTEMS

In Figure 1 our systems are described along with a few alternatives. There are also some fairly major changes that could be considered:

(a) **Production of Budded Stock in Tubes.** The rootstock could be budded in the tube and upon "take" of the bud could be sold at that stage. This would enable a very rapid turnaround of about 4 to 5 months. As mentioned in the Introduction, acceptance of such material would depend upon the use by the grower of a controlled irrigation technique where individual trees are watered and receive nutrients. Once the buds have started growth, tubes smaller than 10 cm would need spacing apart and would not be suitable for more advanced plants

(b) **Rootstocks Propagated from Cuttings.** There is some opposition to cuttings as it is believed they do not develop a normal root system, but studies on this have failed to note differences (3), or cuttings yielded better than seedlings (6). The main difficulty is obtaining large quantities of suitable cuttings at the right time. Rootstock material could be budded prior to rooting or afterwards (7). It would be much quicker to bud cuttings at the bench than to bud material in pots or in the field Citrus cuttings take about 6 weeks to root under mist at 30°C We estimate the use of rooted cuttings would save 6 to 8 weeks in our two systems.

(c) **Tip Grafting.** Here a small shoot or actively growing tip is cleft-grafted onto the rootstock, secured with tape or mastic and covered with a plastic envelope under plastic covers and shade (or in a mist propagator) until the graft has taken. It would save considerable time in growing because the stock would not have to be so large for budding, and there is little or no delay in growing out as with a bud. We estimate it would save some two months This technique has been described for use with sour orange rootstock which has a problem in that the bark does not always easily "slip", making budding difficult at times (9), and for other rootstocks (8) The disadvantages of this technique are that it is relatively slow to perform compared with budding, and that the right stage of the stock has to coincide with having suitable material for grafting Budwood trees might have to be pruned to get sufficient material of the right type available in time. Also it uses more budwood material than budding. We think it more profitable to improve the budding technique rather than to develop the micro-grafting method

(d) **Use of Inert Growing Media.** Rootstocks could be grown in rockwool cubes on capillary matting receiving nutrient solutions This would save on containers and make transplanting quicker and easier. Where containers are used with drip irrigation then an inert material (such as crushed scoria) could be used in place of compost and nutrients fed through the drip system

(e) **Use of Hydroponics.** In special circumstances citrus cuttings, rootstocks, or budded rootstocks could be grown using the nutrient film technique, and put into containers later on. We do not know how well such material would transplant but this method has been mentioned for hardy nursery stock (4). With this technique it is cheap and simple to warm the root-zone and would enable a further improvement in growth rate. This method might be used in the production of disease-free material for export if such a market were created.

ADVANTAGES OF THE CONTAINER SYSTEM

1 The greatest advantage is the avoidance of pests and disease It is possible to propagate virus-free material under our system if required.
2. The time from ordering trees to planting is reduced considerably and it facilitates contract propagation and gives more flexibility to the system.
3. It enables a quicker turnover of stock.
4. It takes up less land.
5. The work, especially budding, is less arduous than in the field
6. Planting material could be produced much cheaper.
7. The container material is easier to plant out and does not receive a check in growth if adequately watered after planting.

DISADVANTAGES

1. Buyer Resistance to Containerised Material. In the Murrumbidgee Irrigation Area, citrus growers do not like using containerised citrus probably because of the use of furrow irrigation One hundred trees produced from system A were planted out in a field situation and did not grow well. This was apparently due to inadequate watering from furrows, and they were not able to use available soil moisture initially. This would have been less of a problem with trees produced in System B which were similar to presently available material, and had a large root volume As mentioned above, small containerized trees (as produced in System A) are most suitable for use where there is drip or micro sprinkler irrigation.
2. The capital cost of producing citrus trees in this way is high.

COST OF THE SYSTEM

We have costed out the two systems:

A, production of small trees in 10 cm tubes in 8 months, and

B, production of larger trees in 10 liter bags in 12 months.

We used a modern glasshouse with piped heat, but feel that the capital cost of this would be too high for this venture. Therefore, we have assumed the use of a 4 m × 20 m doubleskinned plastic tunnel, with gas heating and automatic watering. The layout for the System B (10 liter bag) is shown in Figure 5. The tunnel would hold 1140 10 liter bags or 4560 10 cm pots.

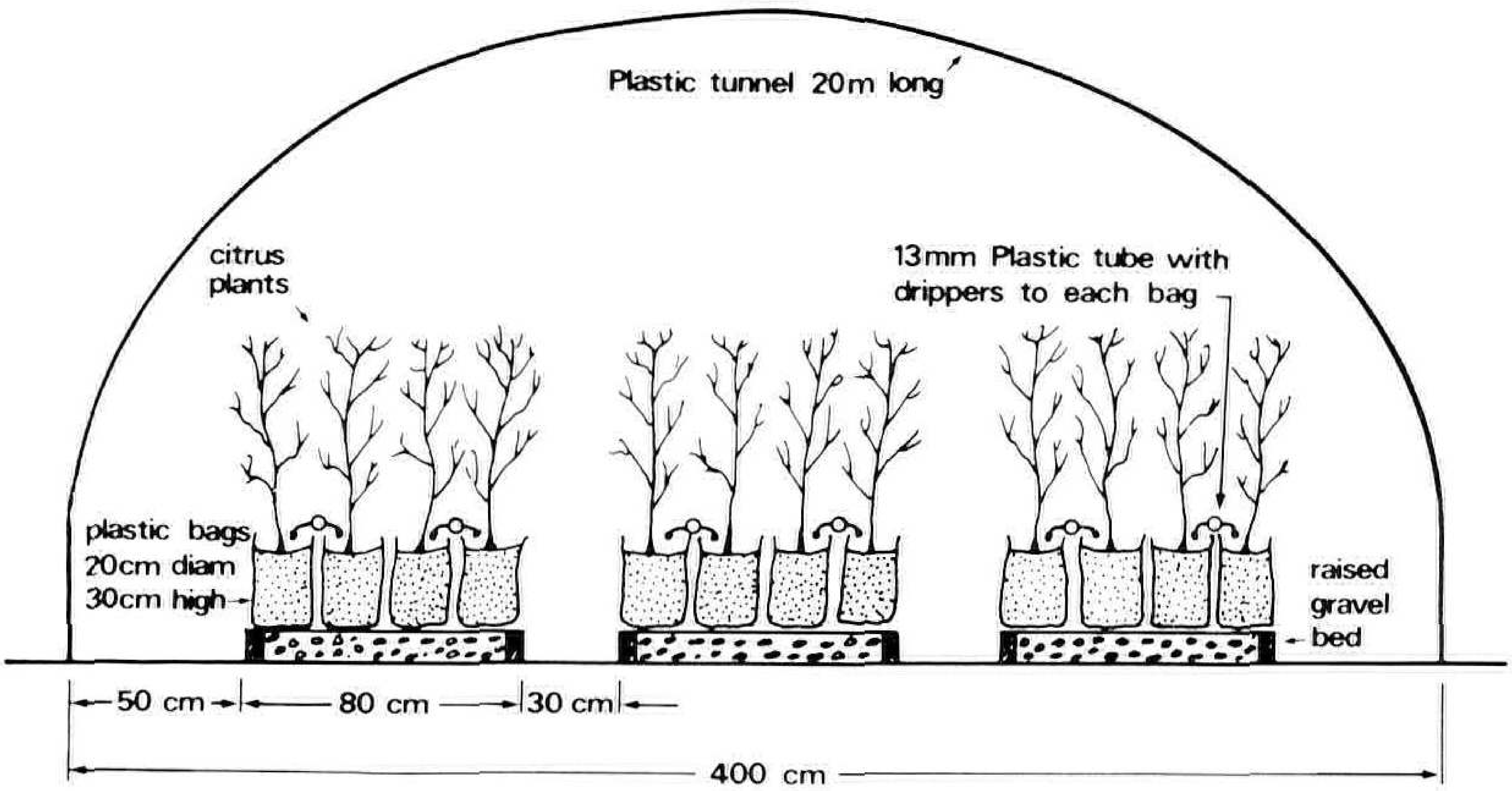

Figure 5. Layout of System B in a plastic tunnel.

The capital cost and depreciation is given in Table 2: depreciation is based on straight line depreciation over 5 years. The outer plastic cover would need to be replaced each year and the inner cover every other year. Indirect costs (Table 3) are based on 12½% interest and 10% land rent on the value of the land plus an estimate for rates.

Table 2. Investment costs of Setting up a Plastic Greenhouse for Citrus Propagation.

Item	Investment Total $	Investment per M² of bed $	Depreciation Total $	Depreciation per M² of bed $
Double-skin plastic greenhouse 4m × 20m	500	10.96	192	4.21
Site works and errection	100	2.19	20	0.44
Raised gravel beds	100	2.19	20	0.44
Gas heater with thermostat	600	13.16	120	2.63
Lights + time Switch + connecting costs. System A only	150	3.29	30	0.66
Irrigation system:				
System A. 4560 pots	2611	57.26	522	11.45
System B. 1140 pots	832	16.25	166	3.64
TOTAL SYSTEM A	4061	89.06	904	19.83
TOTAL SYSTEM B	2132	46.75	518	11.36

Table 3. Indirect Costs for Citrus Propagation Systems per 4m × 20m Plastic Greenhouse

Item	Annual Cost $	Cost per M^2 of bed $
Interest on investment at 12½% System A	495	10 86
System B	254	5.57
Interest on operating costs		
System A, 4560 units for 9 months	465	10 20
System B, 1140 units for 12 months	273	5 99
Land area utilized = $120m^2$ Estimate for rent (10% value of $10,000/ha) plus rates	24	0 53
TOTAL System A	984	21 59
TOTAL System B	551	12 09

Table 4. *Direct Costs Involved in Propagating Citrus in Containers* — per 1000 Units

(a) Seedling Raising

ITEM		COST $
Seed (allow 50% wastage)		10 00
Gibberellic acid treatment		1 00
Containers (Allow 3 years use)		2 70
Medium (sand/peat)		4 00
Labour		3 00
Greenhouse heating to 25°C		2 16
	TOTAL	22 86

(b) First Potting

ITEM		COST $ SYSTEM A	SYSTEM B
10 cm pot or tube (3 years use in B)		65	22
Medium		30	30
Labour		50	140
Greenhouse heating to 15°C		134	16
Greenhouse lighting		30	—
Fertiliser (liquid feed)		60	—
	TOTAL	369	208

(c) Budding

ITEM		COST $
Buds		42
Labour		100
Tape		10
	TOTAL	152

(d) Growing on (System B)

ITEM		COST $
10 liter plastic bags		150
Medium		300
Labour of potting-on		120
Fertiliser		30
Greenhouse heating (15°C)		386
	TOTAL	986

Direct costs for each part of the system are given in Table 4. Labour was costed at $12 per hour and the estimates are based on how long it took us to do the various operations. Heating was calculated for Griffith on the average minimum temperature for each month, heating for the non-daylight hours only and on the use of L.P.G. It may therefore somewhat over-estimate the heating requirements.

Total cost calculations are in Table 5. They do not include a figure for overheads or for management costs The relatively lower cost per unit of system A is due to smaller containers so that four times the number of units occupy the same space. Indirect costs and depreciation account for 40% of the costs and there would be scope for savings in this area. For example, in System A, capillary bed watering would no doubt be more cost effective than drip irrigation. Simple gas burners could be used for heating saving about $500 but there would be less efficient use of gas without a thermostat. If the trees produced from System B sold at $2.80 each, it would give a sales:investment ratio of 1.42. We feel that one person could manage 10 such plastic tunnels with system B which would give approximately $30,300 worth of sales per employee. The profit would be 20% of capital costs.

Table 5. Total Costs Incurred in Propagating Citrus in Containers Excluding Overheads — per 1000 Units

SYSTEM A		
STAGE		*COST $*
Seedling raising		23
Potting-on stage and onwards		369
Budding		152
Indirect Costs		216
Depreciation		198
Allow 5% wastage		48
	TOTAL	1006
SYSTEM B		
STAGE		*COST $*
Seedling raising		23
First potting		208
Budding		152
Growing-on		986
Indirect costs		483
Depreciation		454
Allow 5% Wastage		115
	TOTAL	2421

CONCLUSIONS

1 Aceptable citrus planting material has been economically produced in one year and it has been shown possible to produce material in 8 months at a considerable cost saving.

2. We feel that there is considerable scope for development and improvement of containerized citrus tree production in such areas as.
   (a) A better container, i.e , one that is small enough to improve the density of plants, but not restrict growth. However, at a greater plant density than we achieved with 10 cm tubes, then a cheaper method of automatic watering would have to be used.
   (b) Perhaps the use of budded rootstock-cuttings rather than seedlings.
   (c) Some improvements to the potting medium, such as the use of inert materials
   (d) The initial growth of the bud after it has "taken" needs to be improved.
3. We would like to re-emphasize that developments in the nursery production of citrus requires the adoption of more modern techniques of citrus production in the field, especially closer spacings, and the use of controlled irrigation methods.

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EXPERIENCE WITH SHADE HOUSE CONSTRUCTION USING NEW KNITTED TYPE SHADE CLOTH

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There are several different brands and qualities of shade cloth on the Australian market and I have used most of them over the years. It was in late 1978 that the newest type of knitted shade cloth came to my attention and I was quite impressed with its characteristics. These were mainly·

1. The ability of the cloth to be stretched tightly when being fixed to a structure, due to the fact that the fibres are claimed to not be affected by expansion or shrinkage, to any major degree, by weather changes.

2 The cloth which I used was black and was claimed to have a 2% ultra-violet inhibitor built-in (carbon black) which had shown in accelerated tests to lengthen the life span of the cloth by as much as 20%

3. Because of the knitted nature of the cloth it can be cut at random in any direction without the cloth laddering or coming unravelled along the edge

4 The cloth is available in either 6 or 12 foot widths, which gives added advantages on large construction.

5. The knitted pattern allows the effective use of fixing clips of various types without risk of pulling or fraying

In our first application, a retail display shadehouse, the new cloth was used on both the walls and roof of a wooden structure approximately 75′ long by 30′ wide (23 m × 9 m) One third of the roof was covered with 50%, another third with 70%, of the knitted shade cloth, and the remainder with 30% woven cloth. The reason for this was to give varying degrees of shade for the diverse range of plants on display

Knitted shade cloth (50%) was also used around the walls of the structure and, in all areas, was stretched as tight as possible before fixing down with timber battens on the roof and slotted hoop iron around the walls Where necessary, the knitted cloth was cut with a trimming knife around doorways