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FUEL ECONOMY IN THE PROPAGATION BENCH

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Efford Experimental Horticulture Station (EHS) is part of the Ministry of Agriculture Fisheries and Food's Agricultural Advisory and Development Service and has responsibility for work with propagation and container production of hardy nursery stock. Work on propagation has been in progress for 4 years and has considered aspects of fuel economy, improving speed of rooting, and maintenance of cutting quality. The scope of this paper reviews the work aimed at reducing electricity fuel costs for heat-assisted winter propagation. Economy measures investigated can be categorised under four headings:

1. Efficient heat control.
2. Efficient heat transfer to rooting medium.
3. Reduction of heat loss.
4. Plant requirements.

EFFICIENT HEAT CONTROL

Most nursery stock is propagated in trays stood on the heated base; the important temperature to consider is that at the base of the cutting within the rooting medium. The advent of electronic controllers with probes which can be inserted into the rooting medium has provided a more accurate means of control than rod thermostats which can only control from a fixed point in the sand base. Optional temperature read-out scales linked into the electronic system provides an important, easily monitored, temperature check. Where rod thermostats are used compost temperatures need checking by thermometers inserted into the tray, and the thermostat must always be covered by a tray, otherwise temperatures will be very different from those desired.

EFFICIENT HEAT TRANSFER

Usually there is no problem in achieving the required temperature in the rooting medium, but efficiency of heat transfer from the base can markedly influence fuel usage. The greater the contact of the rooting medium with the heated base the less heat required to maintain a given temperature, and the most efficient system was by use of cell pack units. However, these take up more space than trays; reasonable results can be obtained with standard polypropylene seed trays, though their performance could have been improved by increasing size and number of holes in the base.

REDUCTION OF HEAT LOSS

The three major areas of heat loss are: into the surrounding air, from the base of the bed, and from the structure itself. The comparative work on these aspects was undertaken in unheated polythene clad tunnels with ground level heated propagating beds.

Propagation under polythene covers. Propagation under low polythene covers provides a major fuel economy measure for winter propagation, since the necessity to continually heat cold mist applications is avoided. Work at Luddington EHS (1) demonstrated that during an August/September period, for every 100 units of heat used by a misting system, only 36 were required under a polythene cover. At Efford EHS the polythene (38μ) is supported just above foliage height by hoops across the bed, allowing easier management for regular inspections (Figure 1). Clear polythene is used in the winter, changing to opaque white, with shading as necessary with increasing light intensities. A routine fungicide programme at 10 to 14 day intervals, together with removal of plant debris, maintains health status.

Bed Insulation. Insulation of beds using sheets of expanded polystyrene has produced significant savings in fuel consumption. The sheets are either wrapped or sealed in polythene to prevent loss of efficiency from water logging; it is also important to line sides and ends of beds as well as the base, since 10 to 15% heat can be lost here from narrow beds (1.25m). Results given in Table 1 show fuel savings achieved at different thicknesses of insulation, with the potential of 50% economy from a 50 mm thickness, which is now the general recommendation. However, on narrow beds, reducing to 25 mm on the sides and ends will avoid too great a loss of effective bed area.

Poor drainage of insulated beds is avoided by cambering the polystyrene sheeting on ground level beds (Figure 1), allowing drainage from the edges. Benching is more difficult and polystyrene sheets must not be fitted in too tightly so water can drain between the sheets. Additionally, a drilled alkathene pipe laid on top of the polystyrene has provided excellent

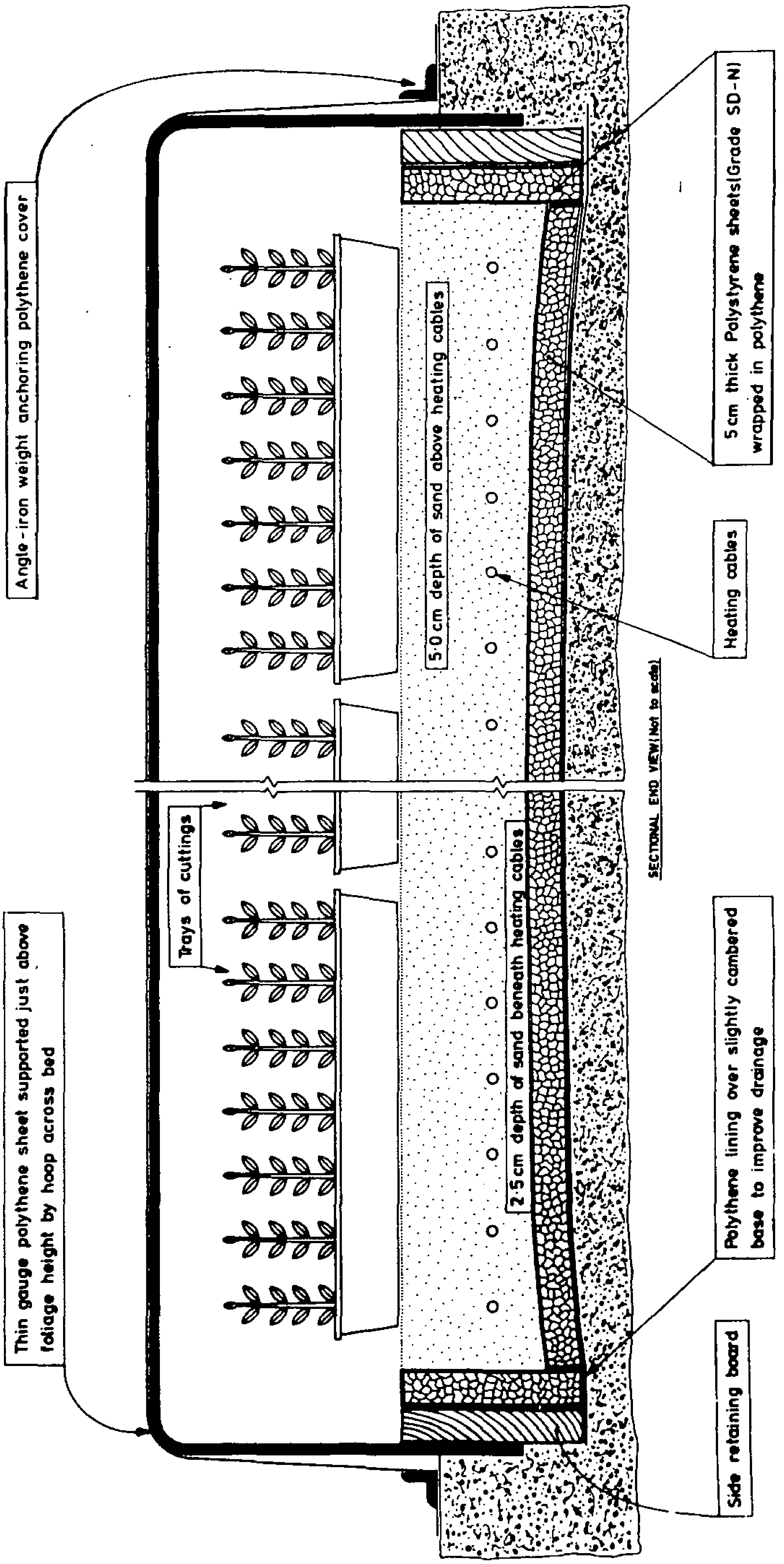

Figure 1. Insulated propagation bed

Table 1. Effects of bed insulation on electricity consumption.

Insulation (polystyrene sheets)	Electricity used kwh/day/m^2	Percent saving over uninsulated bed
1979 (March-April)		
Single Clad Tunnel		
Uninsulated bed	1.2	—
25mm insulation, base only	0.8	32%
25mm insulation base, ends and sides	0.5	49
50mm insulation, base only	0.7	42
1980/81 (Nov-Jan)		
Double Clad Tunnel	2.03	—
Uninsulated bed		
25mm insulation base, ends and sides	1.35	34
50mm insulation base, ends and sides	0.97	53

drainage from 75 mm of sand above. Covering the polystyrene and drain pipe with a layer of fabric (capillary matting) has prevented escape of the sand.

Use of Thermal Covers. Having minimised heat loss from the base of the bed, further fuel savings can be achieved by use of thermal covers over the bed to reduce loss to the air. Both an aluminised polyster cover, which has to be removed during the day, and a bubble polythene (Pillosol) left on permanently, have been compared over beds already insulated with 50mm polystyrene sheeting. Use of the bubble polythene gave the potential for a further 15% fuel savings, while the aluminised polyster cover over the clear polythene cover at night produced a 10% saving (Table 2). There is concern, however, that light levels may be becoming limiting for some species under the bubble polythene and further trials are in progress to monitor rooting response of a range of species.

Table 2. Effects of thermal covers on electricity consumption under a double clad polythene structure. (All beds have 50mm polystyrene sheet insulation)

	Single clear polythene	Bubble polythene	Single clear polythene + Aluminised Polyster sheet (night)
Electricity used, Dec-Apr. (kWh/day/m^2-1981/82)	0.94	0.75	0.83
Percent saving over clear polythene cover	—	15%	9%

The economics of thermal covers needs careful consideration, the fuel saving needing to more than compensate for their costs, although their useful life should extend over several seasons.

Reduction of Heat Loss from Structures. A structure used very successfully at Efford for propagation has been an unheated 4.25 × 14m tunnel clad with two sheets of 500g (125μ) polythene sheeting blown apart by a small fan sited in the middle of the tunnel. Using air from within the tunnel minimises internal condensation since it collects mainly on the colder interface of the outer sheet, running to the base inside the air gap. Since the structure is by no means air tight, consisting of sheeting merely wrapped round lath and nailed to a base batten, water escapes easily. Our original covers are now in their fourth season of use and stand up particularly well in wind gales, the air between the sheets merely displacing from one area to another, preventing their buffeting against the hoops as happens on the single clad structures.

The insulating air gap has provided up to 5°C frost protection compared with a single clad structure, as well as reducing fuel consumption in the propagation beds by up to 30%.

Table 3. Electricity consumption under single and double clad polythene tunnels (beds lined with 50mm polystyrene sheeting)

	Single clad tunnel	Double clad tunnel
Electricity used in beds, Dec-Apr. (kWh/day/m^2-1981/82)	1.33	0.94
Percent saving over single clad tunnel	—	29%

The extra sheet cuts out a further 15% light and while this has not affected rooting at Efford, where winter light is reasonable, it could be a consideration further north. In this situation the mobile thermal screen developed for tunnels by the Lee Valley E.H.S. (2) could be worth considering since it could be drawn back on its internal hooping during the day.

PLANT REQUIREMENTS

The work presented so far has been concerned with ways of reducing energy consumption while maintaining a "standard" compost temperature (18°C). However, running concurrently with this work were detailed environmental studies to determine air and base temperature requirements for propagation of a range of species and their effects on electricity consumption. These trials were in compartmented glasshouses on insulated benching. Over the four year period, cuttings taken in December have been rooted under low polythene covers. Results for the four years follow a similar pattern and are discussed in respect to plant requirements for air and compost temperatures and duration of the base heat.

Air Temperatures. Providing propagation is under polythene covers, air temperatures can be reduced to a *minimum* with no apparent adverse effect on rooting. In fact, results indicated that better rooting was achieved at a 5°C air minimum compared with 10°C and, in 1980/81 and 1981/82, equally good results were achieved where the only heat input was for "frost protection." (Table 4). While costs of heating the bench increase at the lower air temperature, theoretical calculations suggest that cost of actually heating the house would be greater than the extra cost involved in heating the bench.

Table 4. Percent rooting at different air temperatures. The base (compost) temperature was 15°C.

	1980		1981		1982	
Air Temperature	5°C	10°C	"Cold"	5°C	"Cold"	5°C
Hypericum calycinum	96%	96%	89%	87%	—	—
Pyracantha 'Orange Glow'	90	84	—	—	87%	98%
Elaeagnus pungens 'Maculata'	—	—	—	—	98	100
Chamaecyparis pisifera 'Boulevard'	71	48	98	93	100	100
Camellia 'Donation'	90	91	91	98	100	84
Units of electricity used /m^2 (averaged over all species)	81	34	88	72	88	71

Compost Temperatures. Results over the four years have shown conclusively that high compost temperatures of 18 to 21°C are unnecessary for successful rooting of a wide range of species and could, in fact, adversely affect rooting of some (Table 5). In addition, quality of rooting of some species was reduced at the higher temperatures which led to poorer establishment and early growth on potting (*Hypericum*, conifers). *Botrytis* was a greater problem at the higher temperatures. In general, a compost temperature between 12 and 15°C appeared suitable for most species and cost less than half that required to maintain the 18 to 21°C regime. Whether heat assistance is necessary has been questioned and results showed that, as

Table 5. Effects of compost temperature on rooting percentage. (1980 — minimum 5°C air; 1981 and 1982 — air only "frost-protected")

	1980		1981			1982			
Compost Temperature	15°C	21°C	Cold	15°C	18°C	Cold	12°C	15°C	18°C
Hypericum calycinum	96	93	91	89	100	71	98	87	97
Pyracantha 'Orange Glow'	90	71	—	—	—	—	—	—	—
Elaeagnus pungens 'Maculata'	—	—	—	—	—	100	98	89	98
Chamaecyparis pisifera 'Boulevard'	71	84	38	98	96	100	98	100	93
Camellia 'Donation'	90	85	2	91	93	67	100	100	100
Units of electricity used /m^2 (Averaged over species)	81	222	—	88	168	—	61	88	106

expected, this varied with species and season. On the average, some base heat appeared beneficial for winter propagation for all but the easier and faster rooting species. Rooting was considerably slower without base heat.

Duration of Base Heat. For the majority of species used in the trials, limiting the duration of heat input to an 8-hour night period (2300 to 0700) gave equally good results to the continuous regime (Table 6), with only a slight delay in speed of rooting of the slower species (*Camellia*) in the poorer seasons. Thus manipulation of duration of heating appeared to be a means of achieving further fuel savings without adverse effects on results. Monitoring the proportion of heat used in the day/night periods of a continuous regime indicated that 60% was used during the day-evening (16 hours) with 40% used in the cheaper night period (8 hours).

Table 6. Effects of limiting duration of base heat on rooting percentage (1980 — minimum 5°C air, 15°C base; 1981, 1982 — air frost protection only, 15°C base)

	1980		1981		1982	
Duration of Base Temperature	24h	8h	24h	8h	24h	8h
Hypericum calycinum	96%	93%	89%	91%	—	—
Pyracantha 'Orange Glow'	90	83	—	—	87%	100%
Elaegnus pungens 'Maculata'	—	—	—	—	89	96
Chamaecyparis pisifera 'Boulevard'	71	61	98	100	100	100
Camellia 'Donation'	90	88	91	100	100	100
Units Electricity used /m² (averaged over species)	82	72	88	94	88	65
Costs/m² (using current tariff prices appropriate to each year)						
Standard tariff	£3.43	—	£3.92	—	£4.30	—
Economy 7 tariff (on continuously)	—	—	£3.17	—	£3.45	—
Off Peak tariff	—	£1.29	—	£1.83	—	£1.35

1982 tariff prices: "Standard": 4.88p/unit (24 hours continuous)
"Economy 7": 1.09p/unit (7 hours night); 5.24p/unit (17 hours)
"Off-Peak": 2.06p/unit (8 hours night only).

In England, where an 8-hour "Off-Peak" tariff is available between 2200 and 0800 hours, costs of heating were considerably reduced, even though in 1980/81 this regime appeared to use as much or even more electricity to bring the bed back up to temperature after it had been off for 16 hours. In the 1981/82 winter the propagating house itself was thermal lined and screened and, despite a very cold period, the "Off-Peak" treatment used consistently less electricity than the continuous regime. However the "Off-Peak" tariff is only available at night whereas the "Economy 7" package offers the greater flexibility of 7 hours cheaper heat at night with the option of 17 hours at a more expensive rate, which could be used for a few hours boost during the day if required.

DISCUSSION

Results from the four year's trials support the old adage "warm roots/cool tops" for propagation and, in terms of energy saving, it was encouraging that the combination of low temperature regimes (minimum air, 15°C compost) produced the best overall results. While only relatively easy rooting species have been used in the trials they have included a range of fast to slower rooting species, as well as conifers. However, other species such as *Rhododendron* may well have high temperature requirements. Nevertheless, the results underline the magnitude of savings possible by taking the measures discussed and, compared with the old 'standards' of non insulated beds at 18°C - 21°C compost and 10°C air, savings approaching 75% are possible. In addition, improved rooting is achieved since the higher temperatures appeared to have been too high for best results. For winter propagation the "economy package" includes:

1. Propagation under low polythene covers
2. Beds lined with 50 mm polystyrene sheet insulation, including sides and ends for maximum benefit
3. Use of thermal covers over beds
4. Propagation under double clad polythene tunnel or thermal screened glasshouse.
5. Accuracy of temperature control
6. Efficient heat transfer to rooting medium from heated base.
7. Reduction of house temperature (air) to a minimum (frost protection). This is only possible when propagating under polythene covers which create a microclimate less influenced by external factors.
8. Reduce compost temperature (15°C)
9. Limit duration of heat input.

While this experimental programme used electricity as the heat source, the same principles would apply to other heating systems.

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MASS PROPAGATION OF FRUIT TREES IN ITALY BY TISSUE CULTURE: PRESENT STATUS AND PERSPECTIVES

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Abstract. The present status of mass fruit tree micropropagation in Italy is reported. Information is given concerning species, clones, and the amount of trees of various rootstocks and cultivars produced by several laboratories. Methods, materials, and main characteristics of the laboratories, as well as perspectives of this technique are discussed.

In recent years plant tissue culture techniques have been adopted to an increasing extent for the commercial propagation of plants. The success of these techniques is due to important well known advantages over the traditional methods of vegetative propagation.

The tremendous number of studies carried out in a short time on this subject have revealed many improved technical methods and physiological phenomena. Thus, much information is now available on the media and environmental requirements, so the number of species and cultivars currently propagated *in vitro* is continually increasing.

In Italy, as in other countries, tissue culture is a commercially applied practice for propagating a large number of species such as medicinal plants, ornamentals, vegetables, forest and fruit trees. Progress in micropropagation of fruit trees over the past 2 to 3 years has been remarkable.

The satisfactory results obtained by preliminary experience have increased interest in this technique. Today hundreds of thousands of fruit trees are being produced by micropropagation.

The economic and agronomical consequences resulting from the application on a commercial scale of this technique may be of great value for both nursery and fruit-growing activities. In this paper an estimate of the situation concerning fruit tree micropropagation in Italy is made as well as of its perspectives.