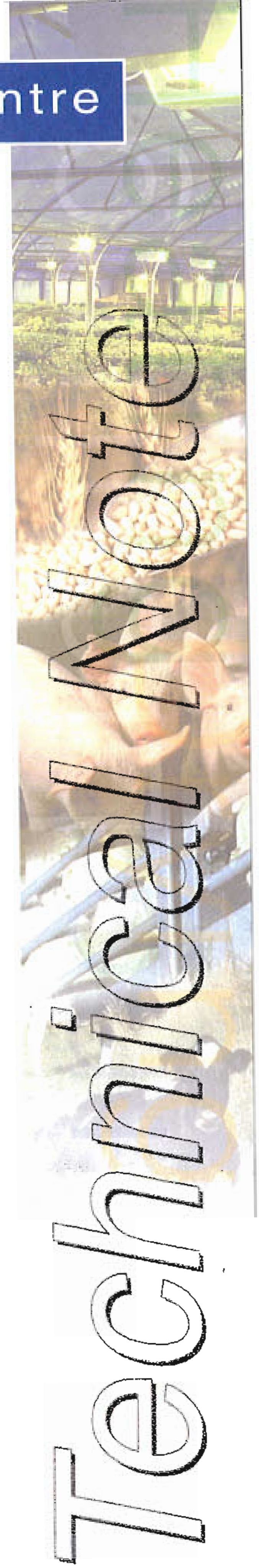

SOIL WARMING IN HORTICULTURE - HEATING CABLE & MAT SYSTEMS

The temperature of soil, or any other growing medium, is a major factor affecting plant growth. Three principal aspects of plant growth and development affected by the temperature of the root zone are:

- seed germination,
- root formation and development,
- root function.

In only a few cases has the precise optimum temperature for the root zone been defined. Results obtained in practice, however have shown the temperature ranges which yield effective performance with a whole range of crops. Suggested optimum bands for some root zone temperatures are given in Table 1.

TABLE 1.

SUBJECT	Temperature Range °C
Vegetable seeds (germination)	
Cabbage, spinach	10
Cauliflower, broccoli, parsnip, lettuce, celery, carrot, chicory, tomato, sweet pepper	15-20
Cucumber, sweet corn, melon	20-25
Flower seeds (germination)	
Cineraria, delphinium, larkspur, antirrhinum	15-10
Aster, carnation, cyclamen, dahlia, lupin, stocks, gypsophila. sweet pea	20
Pansy, iceland poppy, foxglove, lobelia	20-25
Hot bed salad crops	
Lettuce, carrots, celery, endive, chicory, radish	7-15
Soil warming for vegetable seedlings	
Lettuce, celery	18-20
Tomato, sweet pepper	21-25
Soil warming for bedding plants	
All species	20-25
Soil warming for rooting cuttings	
Geraniums, begonias	20
Chrysanthemum	25
All others	21-24

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It is also generally recognized that, if the root zone temperature falls outside a certain band, plant growth will be inhibited.

For most plant species it is advisable to maintain a root zone temperature which is slightly above the set air temperature required for maximum growth. Many people, assume quite incorrectly, that the root zone temperature will follow the temperature of the air above. In practice this is not the case and soil temperatures remain below air temperatures because:

- heat will conduct downwards into cooler soil,
- there is an evaporative cooling effect from the soil surface,
- watering with cold water will cause the soil to cool.

When rooting cuttings it is often desirable to maintain air temperatures which are lower than normal, whilst maintaining relatively high root zone temperatures. This enables the cutting to promote good root formation whilst avoiding moisture stress in the unrooted cutting.

Similar responses can be obtained with the growth of various other crops. For example, with lettuce, by increasing root zone temperatures, satisfactory growth can be achieved at relatively low air temperatures. This technique reduces the need for space heating and therefore reduces the fuel costs required for production.

A highly effective method of root zone warming is by using controlled electrical soil warming equipment.

Such equipment offers the following advantages:

- even heat distribution,
- precise control,
- versatile,
- low capital cost.

CABLE SYSTEMS

Electrical resistance cables with ratings of 10-15W per linear meter run can be used for soil warming purposes.

Two types of cable are available:

(a) Low Voltage Cable

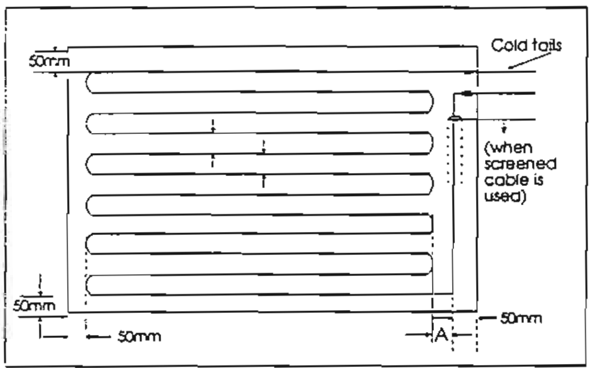
This type of cable was popular with early soil warming equipment because of its inherent safety. However, because most systems ran at voltages of either 6V or 12V, costs were expensive because of the need for a transformer.

(b) Mains Voltage Cable

Lower cost coupled with ease of laying and the availability of screened cable have led to the present popularity of this approach. It should be noted that unscreened mains voltage cables are available but are not recommended on safety grounds.

Screened cables consist of a heater core surrounded by earth braiding and a PVC or cross linked polythene sheath. In sizes up to 1kW there is often a specially constructed cable with a cold return conductor contained within the single core. Terminations are at one end with a connection box thus simplifying connection of the cable. A loop return system should be used when installing a soil warming cable. A typical cable layout is shown in Figure 1.

FIGURE 1.



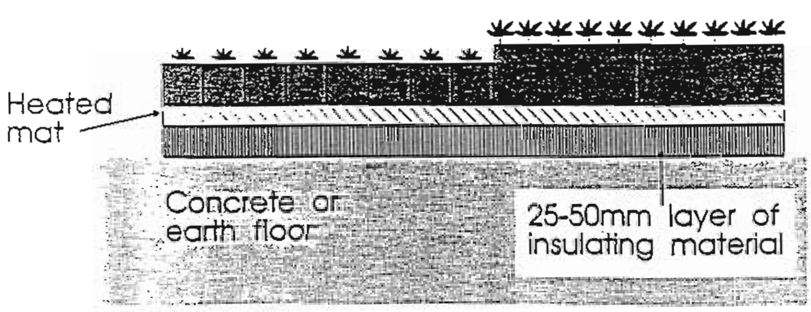
FLEXIBLE MAT SYSTEMS

A number of heating mat systems are available which comprise of a heating element embedded in a non conducting mat. The mat can be laid directly on any convenient flat surface (as shown in Figure 2) or alternatively bedded in sand similar to soil warming cables.

The mats can be made up in various sizes as rectangular sheets or alternatively in strips of up to one metre wide which can then be laid side by side to cover the area required.

Mats are available in either low or mains voltage configurations. Care should be taken when laying to ensure adequate drainage and avoid the formation of pools of water on the mat.

FIGURE 2. TYPICAL INSTALLATION OF SOIL WARMING ON A CONCRETE FLOOR



CONTROLS

Although it is possible to control the temperature of the root zone medium by means of either manual switching or through the use of a time switch, it is much more satisfactory to use thermostatic control.

Electronic thermostats are most suited to soil warming applications for the following reasons:

- accuracy,
- sensor(s) can be inserted in the root zone,
- a number of sensors can be used on large beds,
- can provide modulating control.

As an alternative to electronic controls, both rod type and capillary thermostats are available. Most available thermostats will control electrical loads up to 10 amps. Above this load a suitable contactor is required.

If a heated bed is over $30m^2$ in area, more than one temperature sensor should be used. As a practical guide, temperature sensors should be located away from the edge of the bed and, where possible, at a point half way between the centre and one corner on a diagonal line between two opposite corners. Where several sensors are used, these should be positioned at points along this diagonal line.

INSTALLING SOIL WARMING

Although laying soil warming cables or mats may be carried out by the user, care should be taken to ensure that electrical connections and associated installations are carried out by suitably qualified personnel. The use of a contractor who is approved by the National Inspection Council for Electrical Installation Contracting (NICEIC) is recommended.

For mains voltage soil warming applications, the inclusion of a residual current circuit breaker (RCCB) is recommended for additional protection against electric shock.

All mains voltage soil warming cable is laid in the loop fashion with the cable parallel either to the long or short sides of the bed as is most convenient. When choosing a cable it is first necessary to decide the energy density in W/m^2 for the bed by reference to the appropriate application (Table 2).

Assuming a bed 8m x 2m is to receive $90W/m^2$, then a cable rated at 1440W (ie 8 x 2 x 90) is required. The nearest cable size available is approximately 129m long and rated at 1500W. If the cable is to run parallel to the longest dimension (8m) then the number of passes required to a first approximation is $^{129}/_{8}$ = 16 (this should be an even number) and the spacing is the shorter dimension divided by the number of passes ie $^{2}/_{16}$ = 0.125m (125mm). Cable laid to this general pattern should give an evenly heated area.

If the cable is to be laid in sand or directly in soil the base layer should be firm, but free draining and as level as possible. In the case of soil warmed hot beds, normally prepared top soil should cover the cable. When the cable is to be laid in sand, fine building sand is required, except for mist propagation where a coarse washed variety gives better drainage. When laying cable in concrete, 'fine concrete' ie one part cement to two parts aggregate should be used; the aggregate being not more than 10mm in size. A lightweight concrete (highly suited to benches) which has also a degree of porosity of facilitate drainage, can be made up from a mixture of cement and 'perlite'. Similarly, where very free drainage is required, 'vermiculite' concrete can be used. All concrete mixes should be of a 'stiff' consistency. If the upper thickness of concrete (above the cable) is less than 75mm it must be laid within two hours of that below the cable but, if of a greater thickness, provided it is laid within forty eight hours, an adequate bond will be established.

Some form of permanent or temporary end spacers is recommended which will assist in (a) holding each loop at the correct spacing and (b) tensioning the cable sufficiently to remove any 'kinks'. With longer runs of cable it is also advisable to provide intermediate spacers at 3m intervals made from suitably notched lath or purpose-made plastic strip. Careful covering is necessary to avoid displacing the cable, which might lead to development of hot spots. Moulded connection boxes should also be covered in order to ensure maximum heat dissipation.

TABLE 2.

SOIL WARMING LOADING & DOSAGE

Soil Warming Application	Loading of Bed W/m^2
Hot beds in cold frames	55-65 65-70 for restricted hours
Propagation bench	60-100 for restricted hours 80-150 in unheated house
Warmed propagation beds or floors within the greenhouse. warmed frames or growing rooms.	60-100 in heated house 80-150 in unheated house 80-170 for restricted hours
Mist propagation beds	170 approx

APPLICATIONS OF SOIL WARMING

Soil warming techniques can be used in a wide range of circumstances. These can, broadly speaking, be grouped into the categories shown in Table 2.

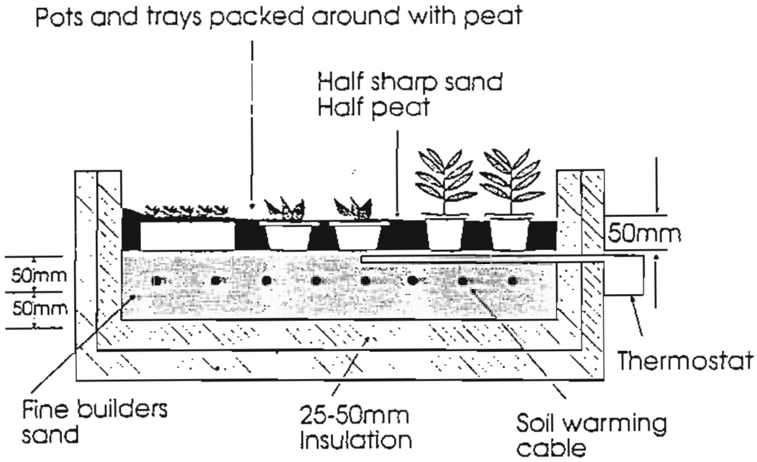
Hot Beds in Cold Frames or Under Cloches

This type of soil warming is used for crops such as early salads, carrots, spring onions or flower bulb crops (for cutting). Remote sensor type thermostatic control is recommended.

Propagation Benches

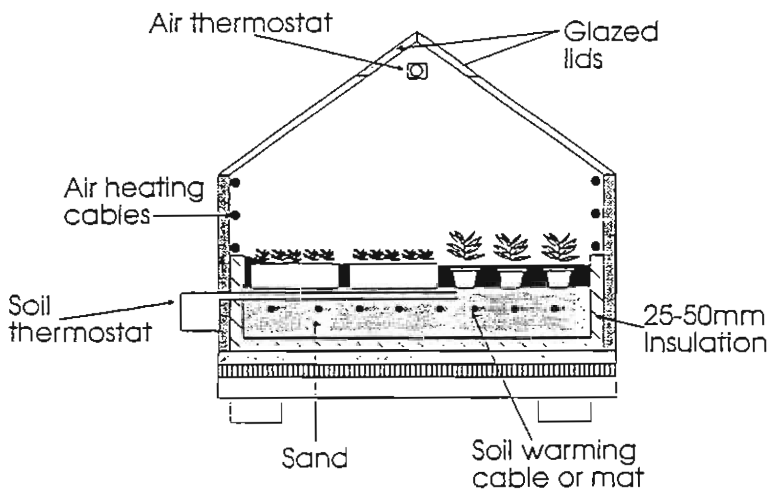
Figure 3 shows a typical propagation bench. This is the most popular and versatile form of soil warming and it can be used for propagating a wide range of species from seed or cuttings. It can be used in both heated or unheated greenhouses.

FIGURE 3.



An adaption of the propagation bench is the heated propagating case (Figure 4). This can be built over a bench and forms a small scale greenhouse within a greenhouse. The propagating case can be run at higher temperatures than the surrounding greenhouse, thus enabling fuel savings to be achieved. Foil mats are particularly suited to this application.

FIGURE 4.



WARMED PROPAGATION BEDS OR FLOORS WITHIN THE GREENHOUSE, WARMED FRAME OR GROWING ROOM

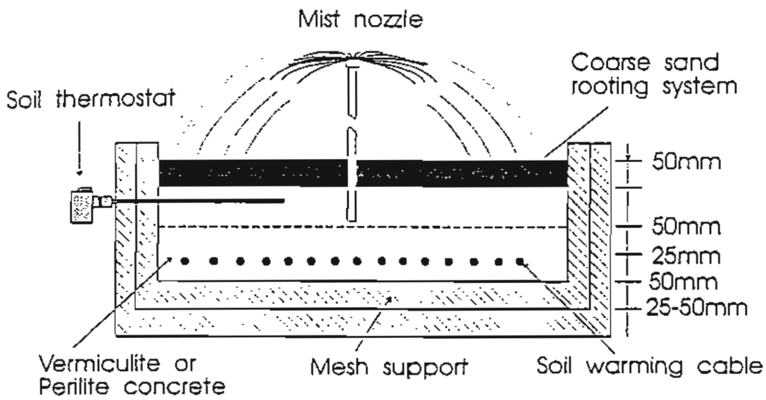
These beds or floors also have a wide range of applications (Figure 4) and are often associated with some form of space heating providing at least frost protection. If sand is used, free drainage below this must be ensured by means of free draining soil or by using hard core or similar material to avoid waterlogging. When warming at higher temperatures, consideration should be given to insulation such as expanded polystyrene or styrofoam sheet (25-50mm thick) immediately below the warmed substrate to prevent heat loss downwards into the ground. The insulating material should be of an impermeable nature or sealed to prevent the ingress of water by sandwiching it between two sheets of heavy-gauge polythene. Under these conditions the bed should be level and drainage provided along the edges.

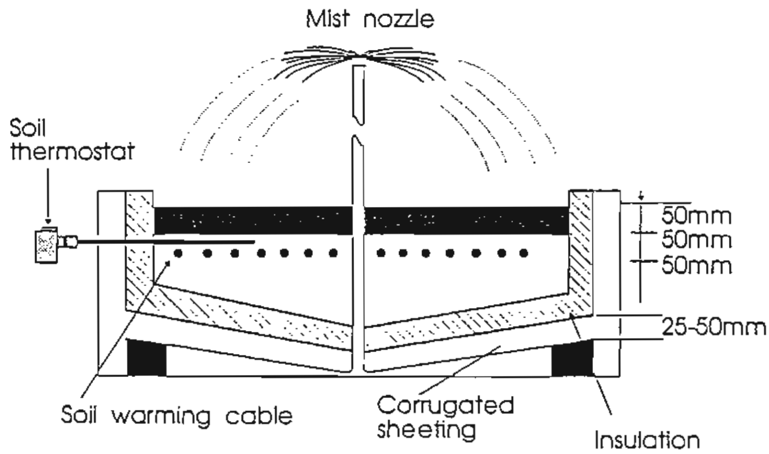
Vermiculite or perlite concrete can also be used as an alternative to sand for the heated substrate. Individual concrete areas should be restricted in size so that their major plan dimension is not more than 10m thus reducing risk of settling cracks and damaged cable.

MIST PROPAGATION BEDS

A typical mist propagation bed is shown in Figure 5. Because of evaporation of moisture from the bed, the heat demand to achieve a given rooting temperature is higher for mist propagation beds. Some drainage is essential and a heated substrate of course sand, vermiculite or perlite concrete is suggested.

FIGURE 5.





Restricted Hour Working

In some circumstances it may be possible to take advantage of off-peak tariff rates for soil warming installations. Advice should be taken from your Electricity Supplier to establish the times of the day when off-peak rates apply. When the duration of these periods is known, consideration can be given to the design of a suitable system.

It is possible to store heat within a heated floor or bed, thus enabling running costs for an installation to be controlled. Alternatively some specialist heat storage materials are available which can be used for this purpose.

The electrical loading of the bed must be selected such that sufficient heat is stored during the off-peak period. For example, if a floor requires a loading of 850 Wh/m^2, and the off-peak period is seven hours, $^{850}/_{7}$ = 120 Wh/m^2 will be required by the bed.

The basic control of heat input is by the use of a time switch. It is however, wise in cases with high loadings to install a thermostat to give overriding control. This thermostat should be set at approximately 5°C above the target temperature to prevent excessive temperatures developing.

ELECTRICITY CONSUMPTION OF SOIL WARMING EQUIPMENT

Estimating the electricity consumption of a thermostatically controlled soil warming system is difficult as it is affected by a number of factors including:

- The difference in temperature between the bed and the surrounding air.
- The rate of heat loss downwards to the ground *.
- The rate of evaporation of moisture from the bed surface.

** This is obviously influenced by insulation levels around the bed and with good insulation, energy consumption can be significantly reduced.*

TABLE 3.

TYPICAL ELECTRICITY CONSUMPTIONS IN SOIL WARMING UNDER THERMOSTATIC CONTROL

Application	Mean temp. differential (bed°C - air°C)** 15° C kWh/m^2.day	10° C kWh/m^2.day	5°C kWh/m^2.day
Soil warmed hot beds (for salad production)	1.5	1.0	0.5
Propagation beds and benches	2.0	1.3	0.6
Mist propagation bed	2.5	1.7	1.0

*** This refers to the average differential between the air temperature and the thermostat setting controlling the heated bench or bed. In assessing consumptions per plant, multiply the figure obtained above by the expected propagating period in days and divide by the number of plants per m^2.*