Factsheet 01/06

Hardy Nursery Stock

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Capillary irrigation of container grown nursery stock

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Growers are under increasing pressure to improve water efficiency and reduce losses of fertiliser to the environment. Low level irrigation systems that harness the principles of capillary watering, combine efficient water use with enhanced crop quality and minimal environmental impact. This factsheet explains the principles, management and benefits of low level irrigation and considers the main systems of application.

Background

Environmental concerns, rising costs of mains water, supply limitations and more stringent legislative requirements are leading growers to review their water management practices. In comparison to overhead irrigation, systems of irrigation that apply water from beneath the container better match the needs of the crop, reduce nutrient leaching and pesticide run-off, and minimise labour costs as there is less need for hand watering.

Despite advances in low level watering systems and commercial pressures, industry uptake has been slow. Many growers continue to rely heavily on overhead irrigation, which can use three times more water than well managed, drained capillary systems.

1 Efford type sand beds produce more uniform plants whilst reducing water consumption, labour costs, moss and liverwort growth and foliar disease incidence

Benefits of low level watering systems

Well managed and correctly installed low level watering systems provide growers with significant benefits:

- More **efficient water use**; 30% of the consumption of some overhead systems. Capillary uptake also overcomes problems associated with crop canopy obstructions.
- **Enhanced weed control** with less moss and liverwort on the surface of the growing media.
- **Reduced labour costs** associated with hand watering, weeding and management of overhead systems.
- Where capillary sand beds are used, much more **uniform crop growth** is achieved through a more even distribution of water to plants during the growing season.
- **Reduced disease incidence** due to less leaf wetness and good drainage of the growing media.
- More **efficient use of fertilisers** through less nutrient leaching.
- Less potential for pH rise and so **better nutritional balance**.
- **Enhanced foliage quality** due to reduced lime-scale deposits from hard water.
- Where flood & drain systems or capillary sand beds are used, **better quality root growth** is achieved through good drainage of free water away from containers in the winter.
- The potential for **automatic watering** and reduced labour inputs.

- An **improved environmental profile** with less potential for groundwater contamination from the leaching of nutrients, especially nitrogen or, growing media incorporated pesticides.

- Potential to link efficiently with **water recycling systems** to further reduce water costs and pollution concerns.

Recent progress on controlling plant growth with controlled water stress ('Regulated Deficit Irrigation' or RDI) and current advances in electronic control technology for irrigation as featured in the HDC Horticulture LINK project HNS 97 (Improving the control and efficiency of water use in container grown hardy ornamental nursery stock) have highlighted further potential opportunities for water savings.

However, this approach is more suitable for use with drip and overhead irrigation rather than capillary watering where essential capillary contact may be broken when drying pots down. Capillary sand beds and matting need to maintain a reasonably constant pot water content without large extremes of wetting and drying to function properly. However, RDI may have potential for use with flood & drain systems (where greater wet/dry cycles can be imposed) although this has yet to be established.

Principles of capillary watering

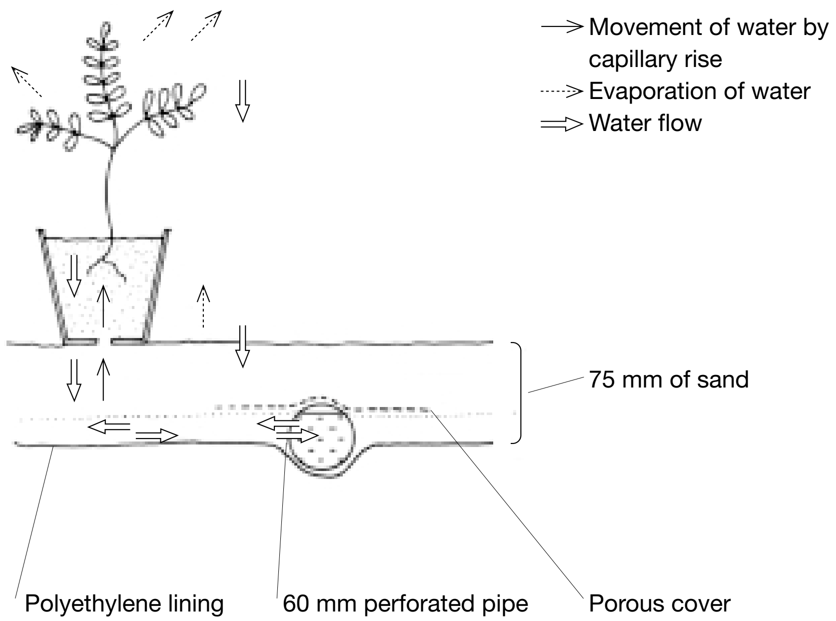
Although there are various methods of low level watering they each share a common principle. This is the upward or sideways movement of water by capillary action from the point of application into the container and root zone.

The upward movement of water or capillary attraction as it is known, from comparatively wet zones to dryer zones takes place slowly and is greatest within the range of smaller pore sizes. In a growing medium, there is a range of pore sizes and so the capillary rise varies. A well-structured growing medium maintains a suitable balance between smaller pore sizes filled with water and larger pore sizes that contain air and provide drainage.

The air-water ratio and moisture content of the growing medium will vary at different levels in a pot, the growing medium at the top being dryer than at the bottom. If there is an excess of free water in the pot, or the growing medium contains lots of small particles and so is very fine, all the pore spaces will be filled with water and anaerobic conditions will occur leading to poor root growth. Disease infection may follow. If the free water level is too far from the plant roots, or the growing medium comprises of mostly large particles, insufficient water will be available to the plant. Thus, with watering systems that rely on capillary action, the vertical distance between the free water level and the pot is critical.

Once capillary contact has been established, the water lost by transpiration and evaporation from the plant or pot is replaced by vertical and horizontal movement of water through the sand or base on which the pots are stood.

Diagram 1 Movement of water in a capillary sand bed



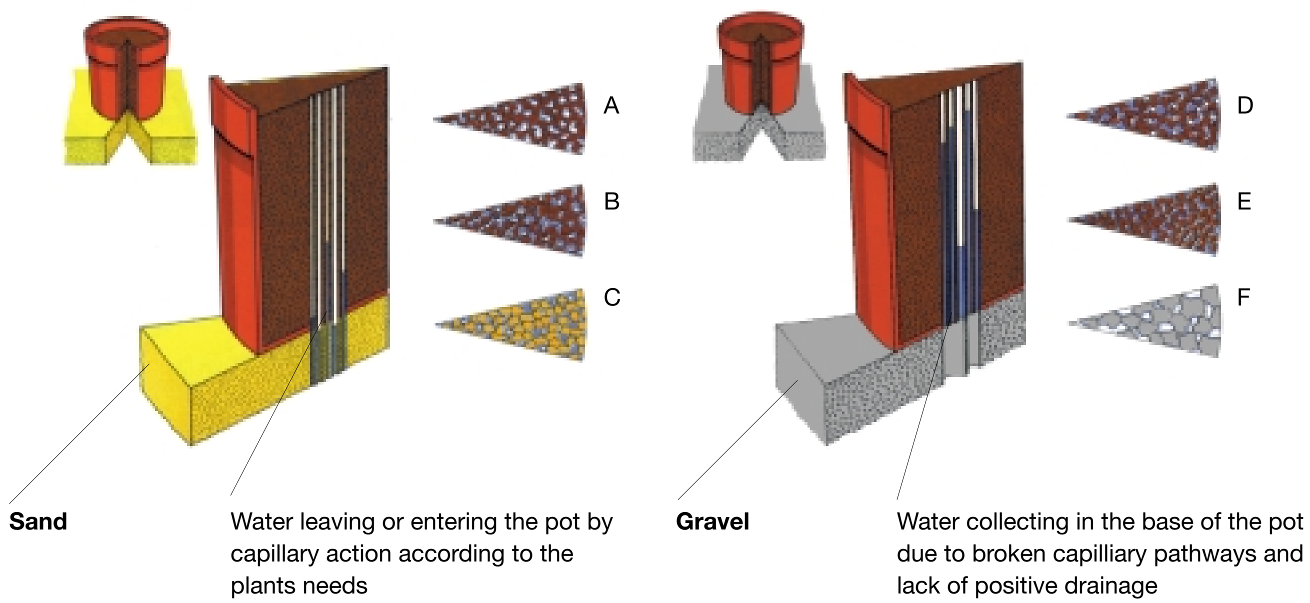
Bed material and its effect on capillary action – sand versus gravel

The free water level is determined by the type of base on which the pots are stood. The upward and sideways movement of water by capillary action is excellent in sand in comparison to gravel.

In addition, pots stood on sand have very good contact between the growing medium in the base of the pot and the sand in the sand bed. This enables continuous capillary pathways between the sand and the growing medium to be formed. This results in excellent capillary lift of water into the pot and excellent drainage from the pot back into the sand bed. In essence, the sand bed becomes part of the container system.

In contrast, pots stood on gravel have more limited contact between the growing medium in the base of the pot and the gravel. Whilst the gravel pieces are larger and water drains from them quickly, the spaces in between the gravel are quickly filled by air and capillary pathways are broken, thus limiting water movement from and into the pot. Capilliary lift into the pot, and drainage away from it, are therefore more restricted.

Diagram 2 Effect of bed material on capillary action (sand or gravel)



Excellent capillary lift of water into the pot and drainage from the pot when plants are stood on sand.

A. Very well drained but reserves of water held around the growing medium particles.
B. Growing medium adequately drained.
C. Sand base with small pores which form continuous capillary pathways with pores in the growing medium.

Poor capillary lift of water into the pot and more limited drainage from the pot when plants are stood on gravel.

D. Growing medium adequately drained with good balance between air and water in pores.
E. Water remains trapped as continuity of draining between small growing medium pores and large gravel pores is broken. Growing medium waterlogged during wet periods.
F. Large pores of gravel base drain freely but cannot pull excess water from the growing medium in the container.

Methods of low level watering

Most low level watering systems rely on capillary action to take water into the container; these include systems based on sand beds, capillary matting and, flood & drain (syn. ebb & flow) irrigation. Each of these watering methods can be used either at ground level or on benches. Benches ease handling operations and mobile systems improve space utlilisation, however they also involve extra cost.

Sand bed systems also work well under protection and though drainage requirements are less exacting, the other advantages remain. Capillary matting systems are better suited to indoor production; they can be used outdoors but have a shorter lifespan and must be linked to an efficient drainage system to remove excess water in winter.

1. Capillary sand beds

Using header tanks

This system comprises two essential components; 60 mm diameter perforated pipes which are installed in the bottom of the bed and a header tank in which the water level is kept constant by a ball-cock valve or similar device. For this system to work, the sand bed must be level. During the summer, the pipe is kept sufficiently full of water so that lateral movement of water from the pipe(s) through the sand bed maintains a relatively constant supply against depletion by capillary rise into the growing media and evaporation losses.

The water level in the pipe and hence water table within the bed itself can be adjusted during the season to achieve the correct watering regime. To a degree, the drier the bed is the better the results providing plants are still able to draw up water by maintaining the capillary link with the growing medium. A dry surface of the pot does not necessarily indicate a need for water. However, if sand doesn't stick to your hand after you place it firmly on the sand bed surface then it is probably too dry. Likewise capillary matting should feel damp. If the bed is kept too wet, this will damage root systems and encourage the development of moss, algae and liverwort. Plants will also become more 'stressed' when removed from 'wet beds'. Rooting through of container stock is also more likely to occur.

During the winter months, the water supply is switched off and the pipework used for sub-irrigation, doubles up to provide a drainage network for the rapid removal of excess water. The drained sand (minimum depth of 75 mm) underneath the container is critical to achieving the water tension needed to withdraw surplus water from the growing media at the bottom of the pot. This contrasts with pots stood on a gravel base that may be free draining but does not have a capillary link to the growing media. In winter, media at the base of the pot stood on gravel can remain saturated as a ‘perched water-table’, resulting in root death.

Using low level irrigation

This system relies on water being applied to the sand by a system of low level irrigation. Various types of proprietary irrigation tubing can be used such as perforated lay-flat tubing or ‘seephose’, laid on the surface of the sand bed. Alternatively, various systems of ‘leaky pipe’ submerged within the sand bed can be considered. Sand beds irrigated intermittently in this way will, with an efficient control system and good management, work on slopes of up to 1 in 75.

The supply of water to the beds is usually controlled by solenoid valves linked to a sequence controller, time clock or other device that measures the moisture content of the sand. The beds usually contain drainage pipes to allow the removal of excess water during the winter.

Whilst cheaper and easier to set up than beds with header tanks, the supply of water is less constant and so more time consuming to manage. The intermittent nature of the system also creates a series of wetting and drying cycles that require careful management if the beds are not to become too wet or too dry. Such extremes can lead to crop problems and uneven growth.

2 Capillary sand beds fitted with header tanks are the most water efficient. However, to maintain a constant water supply and appropriate ‘water table’, beds must be level

3 Waterlogged growing media within the lower half of containers is a major cause of winter losses. Plants overwintered on sand beds (left) have a much healthier root system than those on waterlogged standing areas (right)

Diagram 3a Sand bed header tank assembly for constant water supply

Drained sand bed

1. Levelling sand
2. Timber frame
3. Polythylene lining
4. Minimum 75 mm depth, of firmed, clean, sharp lime free sand
5. 60 mm slotted drainpipe, wrapped or covered with fabric

Header tank assembly

6. Header tank
7. Ballcock valve maintaining constant level of water in tank and pipe
8. Water level (may need adjustment)
9. Connectors linking pipe to tank. Note: Single pipe assembly has been drawn. On wide beds there will be a header pipe connecting several drainpipes to one header tank.
10. Overflow pipe just above water level prevents flooding
11. Drain-tap. Tank emptied in winter to allow 60 mm pipe to drain fully.
12. Firm base for tank
13. Blocks to raise tank to required level
14. Cover to prevent contamination from debris and algae
15. Drainage channel

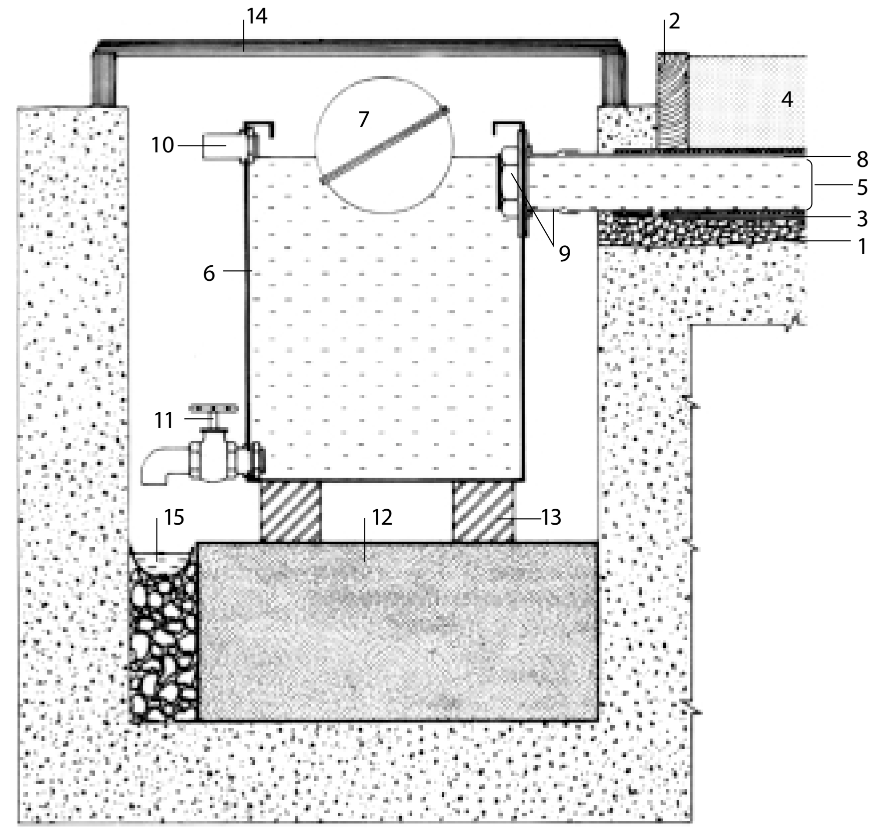
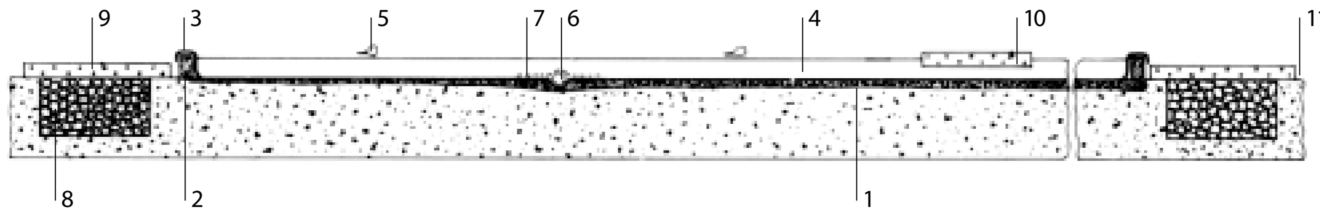


Diagram 3b Sectional end view of wide drained sand bed



1. Levelling sand
2. 75 x 25 mm pressure treated timber side boards prevent loss of sand
3. 500g black polyethylene completely enclosing bed
4. Minimum 75 mm depth, of firmed, clean, sharp, lime free sand
5. Low level irrigation system, eg seephose (may not be necessary if irrigation via drainpipe proves practical
6. 25 mm perforated pipe with 5 mm drainage holes drilled through both walls
7. Porous material strip (30 mm) such as Terram or capillary matting prevents pipe from blocking
8. Soak-away trench approx. 400 mm wide x 200 mm deep filled with rejects
9. Outer pathway slab covers soak-away trench
10. Access pathway
11. Ground level

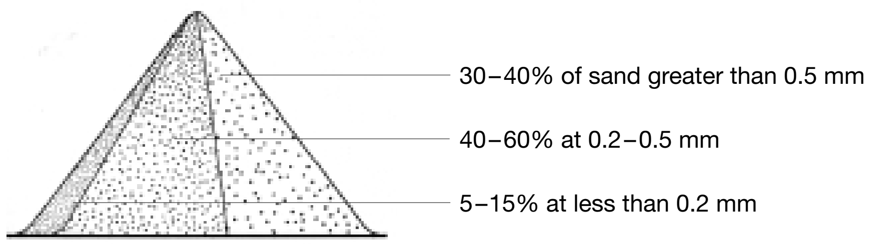
Sand

The correct grade of sand is essential if the right balance is to be struck between water retention and drainage. Within limits, a relatively wide range of particle sizes are suitable but the sand must be a good mixture of fine and coarse grades. It must also provide a reasonably stable surface on which to stand the pots once firmed up. Sand specifications falling within the range illustrated in diagram 4 have been successfully used in capillary irrigated and drained sand beds.

A slightly coarser grade of sand (up to 65% in the greater than 0.5 mm size grade) can also work well provided it is balanced with enough fines (at least 10% in the less than 0.2 mm size grade) to ensure adequate water retention.

If the sand is too fine it will hold too much water and drainage will suffer. Lime free sand is preferred but not always easily obtained. It is not essential for sand beds even with Ericaceous crops as the calcium does not usually move into the pots. The final minimum recommended depth of sand is 75 mm although deeper beds will improve drainage, particularly outdoors and where finer sands have to be used. It is vital to firm the sand well before use and so prevent a 'quick sand' effect when water is applied.

Diagram 4 Sand grain size by percentage required for sand bed construction



Construction notes for capillary sand beds

For capillary sand beds to work efficiently they must be constructed correctly and the following practical points are especially pertinent.

- Beds fitted with header tanks to maintain a constant water supply or 'water table' must be level.
- Where water is supplied intermittently through low level irrigation with an efficient control mechanism, a slope of 1 in 75 is acceptable.
- Ensure the land which the beds are constructed on is firm, adequately drained, free from perennial weeds ie couch grass or creeping yellow cress both of which can puncture membranes and spread through the sand.
- The site should also be adequately sheltered from strong winds as this will reduce evaporation from the bed and prevent pots blowing over.
- For the bed framework, treated timber will last up to ten years but concrete block or brick will last much longer and is more suitable for long term constructions.
- Use 125 micron (500 gauge) polyethylene sheet to line the beds and 'blind' the soil surface with sand first to ensure the ground sheet is not punctured by stones or pebbles etc. With concrete or brick constructions, take the lining up over the sides of the beds taking care to minimise the amount of exposed polythene, which will degrade quickly in direct sunlight and looks unsightly. Where timber frameworks are used, the lining should be folded back and stapled to the inside top edge of the framework where the sand infill will protect it from degradation.
- Permeable membranes laid over the surface of the sand bed can be considered to provide weed control and help keep the beds (and pots) clean. They can be disposable and renewed after a growing season or, more permanent and treated to prevent rooting through. Prior to using such membranes, water quality should be checked as high levels of soluble salts and bicarbonates can reduce the efficiency of some types of material.
- Ensure pipe work or irrigation tubing laid within the sand bed is 'weighted down' before the sand is used. This will ensure it does not 'float' to the surface over time. Usually this is achieved by using a strip of permeable membrane 500 mm wide.
- For best results, use internal drain-pipes to ensure speedy removal of excess water in winter. If the bed is to be used for sub-irrigation, use 60 mm perforated or slotted coiled pipe. As a guide, use one pipe for every 2.5 m of bed width. Wrap the pipes in permeable fabric to ensure they do not fill up with sand. Capillary matting, 'Terram' or a similar permeable fabric is fine.
- Ensure the pipe-work is placed in the bottom of the bed and before the sand is laid. Where the pipes are to be used solely for drainage, one end needs to be capped inside the bed and the other taken out from the bed through the lining to connect with the site drainage system. During the summer, this end also needs to be capped to retain water. During wet periods and in winter, these caps are removed. Where the 60 mm pipe forms the sub-irrigation system, one end will be connected to the header tank and this itself fitted with an overflow pipe just above the drain pipe height, discharging into a suitable soak-away.

2. Capillary matting

Good quality capillary matting has the potential to increase the efficiency of water use of container grown plants by a) reducing the amount of water applied and b) improving the uniformity of water distribution.

Such systems are relatively portable and quick to set up but require periodic renewal. However, they are cheaper than sand beds to set up and easy to water with drip tapes. Although some of the newer more robust types of capillary matting can be considered for outdoor use in well drained situations, they can sit too wet in winter and so are mainly used with container stock grown under protection.

A reasonably level surface is required for them to work efficiently. However, a 2% slope is acceptable with good quality mats provided the total fall across the width or along the length of the bed does not exceed the capillary lift limit of the matting. Otherwise, the top end of the bed will remain too dry and the lower section too wet. The efficiency of capillary mats also depends on how they are managed and the quality of matting used. HDC project PC 166 (Protected ornamentals: The efficiency of water use in different production systems) highlighted the value of 'little and often' water application on capillary systems.

Water application

Water is usually supplied to the capillary matting via trickle irrigation or drip lines at a spacing that will ensure even water distribution between irrigation cycles; a spacing of 0.75 m–1.2 m usually provides constant moisture with trickle irrigation lines. The matting is usually laid over a base sheet either at floor level or on benches. Thicker grade matting is preferred for use at floor level.

Membrane covers

Permeable membranes are frequently used to cover the matting. These help to keep it clean, minimise weed problems and prolong the life-span of the matting. They also help reduce rooting through of container stock.

However, HDC project HNS 107 (Container HNS: Use of capillary matting under protection) found that covering matting with geo-textiles such as woven polypropylene (eg Mypex), or non-woven fabrics (eg Tex R™) could have a detrimental effect on their ability to maintain capillary contact with the pots and hence efficient water movement into the growing medium. Small pots (eg 9 cm) were more adversely affected than larger pot sizes such as 3 litre containers because of their lighter weight. An irrigation schedule to ensure capillary contact between pot and matting is maintained therefore becomes even more critical where a separate geo-textile layer is used.

Lightweight membranes made from perforated polyethylene are widely used under protection, particularly for pots on benches. Such covers are usually disposable and changed between crops to maintain good hygiene.

Capillary lift

Project HNS 107 assessed several capillary matting materials for their capillary lift and water holding capacity (WHC) properties. WHC (usually expressed as litres/m^2) provides an indication of the volume of water per unit area that a matting could hold when wetted to field capacity in a horizontal position. Capillary rise (usually expressed as vertical capillary lift in cm) is an indication of the material's ability to move water upwards against gravity.

The capillary lift characteristics of a capillary mat bear some relation to its ability to redistribute water throughout the mat from the point of water application. This is important; good capillary action is necessary to prevent excessive drainage of the mat on a slight slope and for good water distribution over a bed surface with minor humps and hollows.

Several discrepancies were found between published values and those observed in project HNS 107. Some of the better types of matting were taken forward in the development of a prototype capillary flow bed system whereby water is supplied by trickle lines to the top and middle of a gently sloped bed. With this system, by sloping across (rather than down) the length of the bed, constructing a 50 mm fall over a 2.5 m wide bed is equivalent to a 2% gradient (a 2% slope has been shown to be suitable for several types of matting). The correct gradient balances improved water distribution by gravity with sufficient water retention by the matting. The slope also aids drainage of surplus

4 Good quality capillary matting increases water efficiency – matting with ground cover sheet and central drainage channel below

5 Permeable membrane covers help keep capillary matting clean and weed free

water (eg from any occasional overhead watering needed or rainfall when used outdoors). Normally, however, there should be little or no run-off if the capillary irrigation schedule is correctly set and the growing medium not too wet. For wider beds or areas, either a more gentle slope is needed, or the runs of capillary matting should be separated with short gaps and treated as 'sub beds'. This breaks the capillary link within the (wide) bed and so helps to maintain the uniformity of wetting over the bed.

6 Construction of prototype capillary flow beds which have potential for use in the UK

Management of capillary beds

Capillary beds need to be regularly maintained. Keeping the beds clean and weed free is essential; permeable membrane covers reduce weed problems and help to keep pots clean. Alternatively, certain residual herbicides can be considered between crops but some products are very soluble and so unsuitable. Contact herbicides can be considered to clean up weeds between crops.

'Rooting through' into sand or capillary matting beds can be a problem particularly with vigorous subjects and involve extra work when handling and cleaning pots prior to despatch. Permeable covers can reduce, but not eliminate, the problem. Copper impregnated bed covers (eg Tex R™) are more costly but can be very effective, with a claimed 3 or 4 year longevity.

Periodically, the sand bed should be raked or skimmed to remove weeds and debris. Level with fresh sand if necessary. Plants should be stood down on a lightly raked surface to help ensure adequate capillary contact between the sand and the base of the pot. Overhead irrigation is usually required during the initial post-potting period to establish capillary contact.

Capillary matting will need replacing periodically particularly in outdoor situations although the use of appropriate permeable membrane will prolong their life-span.

It is important not to allow capillary matting to dry out, otherwise it can be difficult to re-wet. Good quality irrigation water that does not contain high levels of salts or bicarbonates is also important otherwise the matting will quickly become hard and hydrophobic, repelling and resisting the capillary uptake of water. Note: new matting often appears very dry and hydrophobic initially and should be wetted up before use. In hard water areas, capillary matting will perform better for much longer if the irrigation supply is acidified to neutralise most of the bicarbonate. This can be done economically with an in-line injector system following a water analysis to determine the correct acidification dose.

Salt accumulation in both the growing medium and standing base from controlled release fertilisers or liquid feeds can occur over time, particularly in summer. To prevent crop problems, containers, sand beds and capillary matting should be flushed through with plain water periodically.

Not all pot sizes are suitable for use with capillary systems; the maximum acceptable height to ensure adequate capillary 'lift' of water into and through the container, is about 20 cm (ie pot sizes of 5–10 litres max.), particularly where more open structured growing media are used. For pot sizes larger than this, drip-point irrigation is recommended. Sand beds are ideal for liner crops.

3. Flood & drain (syn. ebb & flow)

Essentially, ebb & flow flood irrigation is a closed system that harnesses the principles of capillary watering and can be used on benches or at floor level. The water level around the base of the pots is raised periodically to 'flood' the beds and then lowered. The system combines uniform watering in summer with good winter drainage and the pots are always kept moist whilst the foliage remains dry.

Installation and operation

Installation costs are high and true flood/drain systems require laser levelled sites to work efficiently. They are usually of permanent construction but low cost portable 'roll out' systems which use capillary matting are available. Water quality is very important; salt accumulation can be an issue with constant recycling, as can disease spread although both problems can be overcome; routine crop inspections and water analyses are essential. Slow sand filters provide effective disease control.

Adequate shelter is also important to prevent pots blowing over prior to the next 'flood' session. It is important too that there is adequate capability for handling the large volumes of water that need to be applied and drained considering that storm waters will also be collected. Health and safety issues also need to be addressed as the wet concrete base (following flooding) can be a slip hazard.

Benefits

Such systems are popular on the continent where they are frequently linked to water recycling systems. Water efficiency is very good and environmental pollution via leaching of nutrients or pesticides is virtually eliminated. Whilst more costly than sand beds to set up, they are easier to manage and maintain, and enable increased throughput and improved crop handling.

7 Flood & drain floor systems provide high levels of water efficiency and reduce environmental pollution

4. Sand in-fill beds

It is widely acknowledged that inefficient overhead systems, where water is not recaptured, can use over three times the amount of water as drained sand bed systems, underlining the potential for savings in water bills by making more efficient use of water. Adapting gravel bed systems to achieve more efficient water use, by sand in-fills provides the opportunity to reduce water use and limit nutrient/pesticide leaching into ground or surface water supplies.

HDC project HNS 38 (Water use under different hardy nursery stock container systems) investigated the potential of improving water efficiency of overhead irrigated gravel beds by in-filling with 25 or 50 mm of sand and comparing their performance against standard gravel and drained sand bed systems.

The principal finding of this work was that the use of sand in-fill to existing gravel beds has genuine potential for improving their efficiency of water use providing a non-permeable lining is used in the base. This is important to prevent water being drawn out of the bed down into the drier soil profile beneath. Mypex linings under gravel are widely used to improve drainage away from the beds, but non-permeable polythene linings would be required if sand in-fills were being considered as a means of improving water utilisation. In trials, a 25 mm and in particular a 50 mm depth of sand in-fill to an existing 25 mm gravel bed did improve the efficiency of water use.

A further finding from this work confirmed that species with similar water requirements do need to be grouped together to ensure differential watering regimes can be applied, thus avoiding over and under watering. Overall in the trial, the drained capillary sand bed still provided the greatest savings in water use and winter drainage capability. The full potential of sand in-fill beds needs further investigation over a dry season before the system can be considered for commercial uptake.

Choosing the right system

Irrigation systems are frequently a low priority in nursery planning but growers should consider how to reduce their wastage of water and fertiliser. The first steps are to a) improve existing irrigation systems where practical and b) carefully plan future developments. Many European growers are now reducing water and fertiliser use by the adoption of low level irrigation and 'closed' production systems which recycle water. Re-circulating systems waste very little water and fertiliser but require higher investment costs. Non re-circulating systems can be modified or treated differently to improve water and fertiliser use efficiency. HDC project PC 166 (Protected ornamentals: The efficiency of water use in different production systems) highlighted several key practical points that should be considered when planning and choosing irrigation systems:

- Ebb & flow and trough track systems should be designed with built-in re-circulation. Water / feed tanks should be allowed to run down to low levels before emptying out.
- Capillary systems should apply water 'little and often' and ensure the use of high quality matting.
- Drip irrigation systems offer good water saving potential but drip nozzles must be regularly checked and periodically cleaned.
- Hand-watering systems can be efficient if supplemented with capillary matting and careful water application by trained staff.
- Overhead spray-lines are frequently difficult to improve and inherently inefficient. However, careful choice of nozzles can help to reduce the loss of water onto paths.
- Gantry systems provide well targeted water application. Shutting off nozzles irrigating hard surfaces can reduce wastage.

When considering which capillary watering system to use, take full account of the following:

Your site

Accurate site levelling is essential for sand beds irrigated by header tanks and laser levelled sites are essential for flood & drain systems of irrigation. Sloping sites are usually costly to level or terrace and are best avoided. However, slopes of 1 in 75 have worked satisfactorily with sand beds where the water is supplied intermittently via low level irrigation lines. A 2% slope is acceptable with good quality capillary matting. Sites should also be well sheltered, drained and free from perennial weeds.

Your budget

Any system adopted by growers must be financially viable and when budgeting, water efficiency benefits must be balanced with financial considerations. Sand bed systems and those based on flood & drain principles are the most expensive to construct, particularly on sites which are not naturally level. For example, likely start up costs for capillary sand beds are £8–12/m^2, those fitted with header tanks being the more costly but water efficient. However, the pay back period is relatively short (with sand beds, typically 3–5 years) in terms of water savings and improved crop grade out. They also have a considerably longer economic life than over-head watering systems, usually more than 20 years if correctly installed and managed.

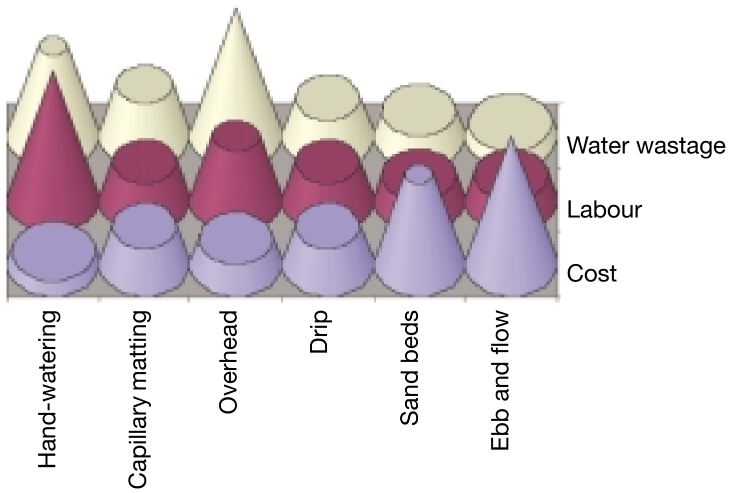
Capillary matting systems provide a cheaper and more convenient alternative to sand beds (<£6/m^2 including irrigation tape) but have a shorter economic life, typically less than 5 years depending on situation (outdoor/indoor), the quality of the matting and the standard of maintenance. Better quality mats will last longer under protection if carefully managed.

Permeable ground cover matting/ over-head watering systems are cheaper still (<£2.50/m^2 excluding gravel) but require greater labour inputs, need more frequent replacement (typically, at 5 year intervals where matting alone is used, longer if well maintained) and, use more water.

The chart opposite shows a comparison between a range of different irrigation systems in terms of their capital costs, water efficiency and labour requirement for nursery stock. The higher the cone the higher the cost in terms of wasted water, labour and materials/installation.

8 Ebb & flow and trough track systems should be designed with built-in re-circulation facilities

Graph 1 Efficiency, labour requirement and capital cost of a range of different irrigation systems



Your crops

Whilst capillary watering is the preferred method of irrigating container grown nursery stock, it is particularly suited to high value and moisture sensitive species requiring careful water management and good drainage. Good examples include varieties of *Acer palmatum, Camellia, Ceanothus, Choisya, Cordyline, Cytisus, Phormium, Senecio* and *Skimmia*. It is also the preferred method of irrigation for subjects which are known to be highly susceptible to foliar diseases such as *Hebe, Garrya, Lavandula* and *Vinca*.

Sand bed systems are ideal for pot liner production where the emphasis must be on uniformity and the speedy establishment of robust root systems. Heather crops and high value ericaceous subjects such as *Rhododendron, Azalea* and *Pieris* also respond well to capillary watering.

For the volume production of many commodity shrub lines, the greater capital costs may be more difficult to justify; well managed overhead watering systems are satisfactory and often considered more cost effective although water consumption is considerably greater. However, with rising water costs and increasing restrictions on availability, this option may not be as cost-effective in the future.

Costs

Costing estimates for ten different systems for protected ornamentals were produced for project PC 166 and are presented as a guide in Table 1. When considering such data, it is important to recognise that systems of irrigation vary considerably between nurseries and in order to make this exercise comparable, a number of assumptions were made:

1. All systems are supplied by the water mains into a galvanised water tank direct to the glasshouse.
2. Water is costed at 0.66 pence per m^3. Mains water costs will vary considerably from region to region and this should be taken into account when budgeting.
3. Any filtration and acidification of the mains water occurs before entering the glasshouse, unless specified for the system.
4. Adequate pressure is available to drive all systems.
5. All systems are fitted into a 1 acre (4047 m^2) 6.4 m Venlo glasshouse. A total of 12 bays, 52 m long with a central path running the length of the glasshouse.
6. Construction labour charged at £244 per man day.
7. Watering labour charged at £56 per man day.
8. Materials costs are based on summer 2000 list prices updated to 2005.
9. Glasshouses are used for 40 out of the 52 weeks of the year.

Full details of these costings can be

Table 1 Summary of set-up and annual running costs of a range of irrigation systems

System	Set up cost per (£/m²)	Annual running cost (£/m²)
Ebb & flow floor (recirculated)	30.95	0.55
Ebb & flow floor (to waste)	30.09	1.21
Ebb & flow benches (recirculated)	36.03	0.51
Ebb & flow benches (to waste)	35.05	1.08
Gantry	25.09	0.72
Overhead	1.85	1.09
Hand-watering	0.50	1.49
Capillary matting	2.42	1.10
Drip	3.16	0.42
Trough track	28.82	0.90

found in Appendix XX of the final project report for PC 166 available from the HDC and Table 1 should be read in conjunction with this.

Notes

- The figures in the table are for illustrative purposes to provide the reader with guidance on the relative costs of different systems.
- Costs will vary depending on the type of glasshouse, crops grown and utilisation. When considering installing a new irrigation system, an irrigation specialist or company should be consulted to plan specific needs accurately.
- The ebb & flow floor system costing was based on a greenhouse concrete floor used for pot plant production.

Action points

- Prepare sites thoroughly when installing capillary watering systems; accurate site levelling is essential for sand beds irrigated by header tanks and, flood & drain systems. Laser levelled sites are essential for flood & drain systems of irrigation.
- Ensure the land on which capillary beds are to be constructed is firm, adequately drained and free from perennial weeds.
- Use the correct grade of sand (capillary sand beds) with a minimum depth of 75 mm. Ensure the bed is firm enough to walk on before use.
- Consider using permeable membranes over sand beds or capillary matting to maintain hygiene, keep pots clean, reduce rooting through of container stock and control weeds.
- For best results with capillary sand beds, use drained sand beds fed by a header tank to maintain a constant water table for container plants to draw on as required. Use 60 mm coiled and slotted pipe. Such systems also ensure rapid removal of excess water in winter.
- Flush sand beds and capillary matting through with plain water periodically to reduce the build up of salts particularly under protection. Avoid using water which is ‘hard’ or contains high salt levels with capillary matting.
- Keep beds clean and weed free. Use permeable membrane covers or use appropriate herbicides with care to control weeds. Periodically, rake sand beds to remove debris and level with fresh sand. Apply overhead irrigation to newly potted container crops to establish capillary contact.
- Choose capillary sand beds for quality production of pot liners and moisture sensitive crops.
- Consider flood & drain systems for maximum water efficiency. Such systems virtually eliminate environmental pollution from nutrient leaching or pesticide run-off.

9 Prepare land thoroughly when installing capillary watering systems including accurate levelling of your site

Further information

HNS 38 – Water use under different hardy nursery stock container systems

HNS 88/88a/88b – Slow sand filtration development projects, workshops, and grower guide

HNS 97 – Improving the control of efficiency of water use in container grown hardy ornamental nursery stock

HNS 107 – Container HNS Irrigation: Use of capillary matting under protection

HNS 107a – Container HNS: Improving water management within growing media

PC 166 – Protected ornamentals: The efficiency of water use in different production systems

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