Comparison of wicking bed media and designs

Research proposal for BSc (Hons)

1. Introduction

Wicking beds are planting containers that have a reservoir of water in the lower portion and a growing medium above. Water from the reservoir wicks up through the growing medium to supply the plants. Figure 1 shows a typical wicking bed design. The beds are a popular way of growing vegetables in home gardens and have been used in some small scale urban farms. Apart from these urban farms, they don't appear to be used to any significant extent in commercial horticulture. Various wicking media such as gravel, scoria, sand, woodchips, soil and plastic frameworks have been proposed for filling the reservoir layer and providing support for the growing media layer while allowing sufficient pore space to hold a useful volume of water. In some designs a layer of geotextile is used above the reservoir layer to prevent the growing medium from mixing with the reservoir. Other common features of wicking beds include an overflow outlet at the top of the reservoir layer to prevent excess water from flooding the growing medium, and a fill pipe that allows delivery of water directly into the reservoir layer.

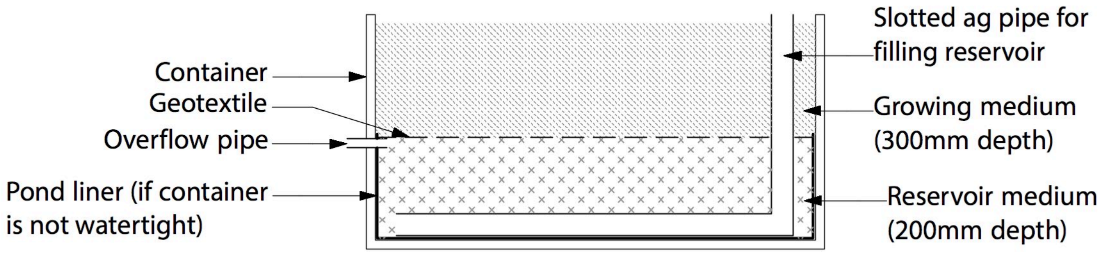

Figure 1 - Cross section of typical wicking bed design showing the major components

Little has been written in the scientific literature about wicking beds but there are many articles about them in the popular press. These range from publishers that may be thought to have some authority, such as ABC's *Gardening Australia*, to people with unknown experience publishing blogs or YouTube videos.

Only two scientific papers describing research into wicking beds have been found. Sullivan, Hallaran, Sogorka, and Weinkle (2015) compared yields obtained from wicking beds and conventional planters in an urban farm. Their wicking bed design used a coil of perforated plastic pipe in the reservoir layer, both with and without geotextile. Though not explicitly stated by the authors, the growing medium would have extended below the water level in the spaces between the coil of pipe and the container walls. Apart from the variation of containers with and without geotextile, they did not evaluate different wicking bed designs. Semananda, Ward, and Myers (2016) investigated the water use efficiency of growing tomatoes in wicking beds of various soil and reservoir depths and compared this with surface irrigated containers. They used a single wicking bed design with a gravel layer in the reservoir but had a column of soil extending through the gravel layer to improve wicking. Other papers dealing with subirrigation of plants in containers in the nursery industry and aspects of hydroponic production may also provide useful guidance for the design of wicking beds. A review of literature about capillary irrigation noted the almost complete lack of published papers on wicking beds and commented that:

> "Due to the lack of research on wicking beds, we contend that there is a specific - and very important - knowledge gap relating to the verification of performance, and of design guidance, of wicking beds." (Semananda, Ward, & Myers, 2018)

Because of the popularity of wicking beds among sections of the gardening community and the variety of unverified designs that are being proposed in the popular literature and social media, there is a need for rigorous research to compare various wicking bed designs. This research proposal has been developed to, at least partially, fill that knowledge gap.

2. Research aims

The main aim of this project is to examine and compare water movement by capillary action in wicking beds using different media in the water reservoir layer in order to determine the best reservoir media for use in wicking beds. At this stage it is anticipated that the media to be evaluated will include; gravel, scoria, sand, sand/gravel mix, crusher dust, coir, woodchips, and various commercial mixes of topsoil, sand, compost and manure.

To achieve this aim, the research objectives are:

1) to determine the rate and extent of upward water movement by capillary action in the various media listed above
2) to compare saturated water holding capacity of common reservoir media. Since one of the reasons for using wicking beds is to increase the time between watering, the amount of water held in the reservoir is an important factor in selection of media to fill the reservoir. The same selection of media as in the wicking capability study will be tested
3) to identify differences in efficiency between different wicking media
4) to assess the impact of wicking bed design on plant development.

3. Proposed methods

3.1. Wicking capability experiment

This experiment will measure the amount and rate of capillary rise of water through the selected media. Clear perspex tubes filled with the media being studied will be stood upright in containers of water and the movement of moisture upwards through the media by capillary action will be periodically measured.

A variety of media that are commonly used in wicking beds and available from commercial soil yards will be tested. The selected media are: gravel, scoria, sand, sand/gravel mix, crusher dust, coir, woodchips, super soil, garden mix and vegi mix. The latter three are various mixes of topsoil, sand, compost and manure available from Corkhill Bros, Mitchell ACT.

Figure 2 shows the equipment for this experiment.

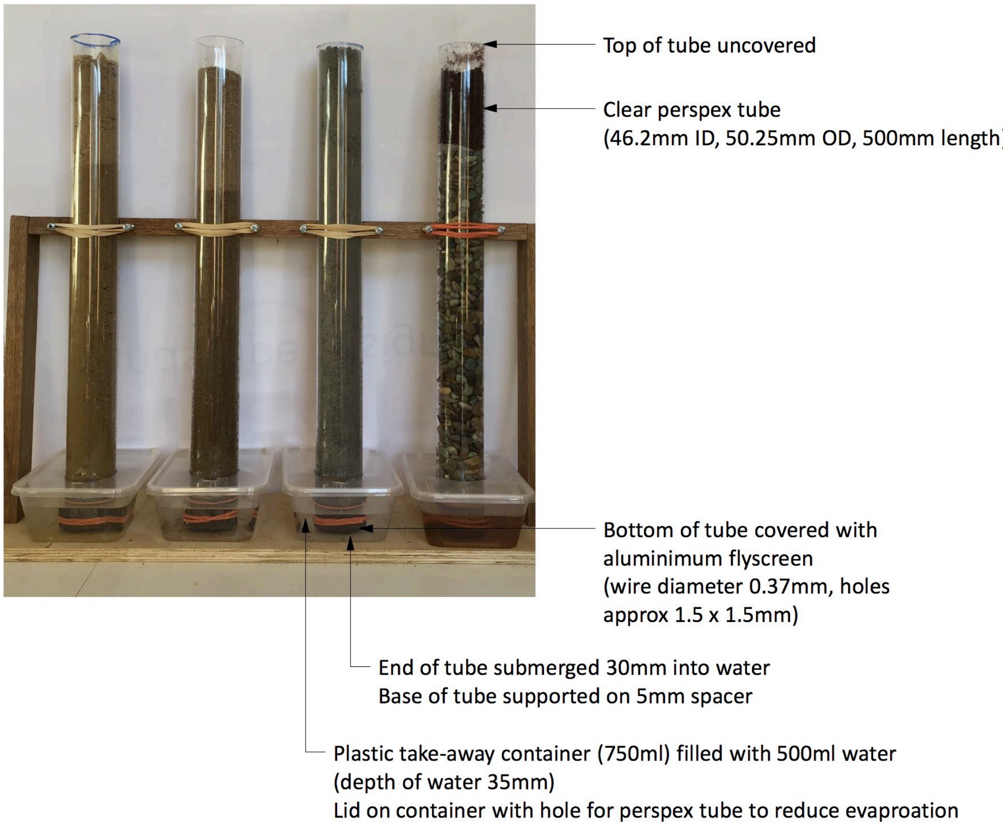

Figure 2 - Equipment for the wicking capability experiment

The perspex tubes will be filled with air dried samples of the selected media. Media will be settled by gentle manual shaking of the tubes as they are being filled but will not be otherwise compacted. The bottom ends of the filled tubes will be placed in the containers of water.

Measurements of the height of capillary rise will be taken approximately twice per day. When capillary rise is comparatively quick, more frequent measurements will be taken. When capillary rise is slow, measurements will be taken daily. The height of capillary rise (wetting front) will be identified by visually identifying a colour change in the media. Measurements will be taken from the surface of the water in the container to the line of colour change in the media. If the rise is not even (the wetting front is higher on one side of the tube than the other, the median level of the water rise will be estimated. Because of the granular nature of some of the media and the difficulty in precisely identifying the wetting front, measurements will be recorded to the nearest 5mm. Measurements will be taken for one week or until the wetting front reaches the top of the tube.

The filled tubes will be weighed before placing in the water. At the end of the measurement period, the tubes will be removed from the containers and any free water will be drained back into the container and the tubes weighed again so that the volume of water absorbed by the tube of medium can be calculated.

The experiment will be performed three times for each medium.

Analysis of the results will identify the average maximum capillary rise, the rate of rise, and the average amount of water absorbed for each medium. Any significant differences between media will be identified.

3.2. Saturated water holding capacity

This experiment will determine the saturated water holding capacity of each medium to allow an estimate of the reservoir capacity of a wicking bed using that medium.

A 750ml plastic take-away container will be filled with an air dried sample of the medium. The filled container will be weighed and then water will be added to the container until the top of the water is level with the top of the medium. The container will be weighed again and the amount of water calculated.

The media used in this experiment will be the same as those used in the wicking capability experiment. Each medium will be tested three times.

3.3. Wicking bed experiment

The wicking bed experiment will measure a number of parameters related to water use and movement in wicking beds with four different media selections. Final selection of media will be confirmed after completion of the wicking capability and saturated water holding capacity experiments but it is anticipated that the following configurations will be used. A brief explanation of the reasons for selecting each configuration is given.

1. **Gravel-filled reservoir covered with a geotextile barrier and a soil/compost growing medium**

   This is the wicking bed design that is most commonly described in popular web sites and YouTube videos. Due to the large pore spaces in the gravel, it is likely that water will not effectively wick up through the gravel to the growing medium layer so it is unclear how this type of wicking bed can work. One explanation I have read suggested that the humid conditions in the reservoir below the soil allows water transfer through a vapour phase. Other possible explanations include that people are keeping the reservoir filled often enough for sufficient wicking to occur, that the beds are being top-watered often enough for the plants to grow, or that the plant roots are growing down through the geotextile barrier into the water reservoir.

2. **Sand-filled reservoir covered with a geotextile barrier and a soil/compost growing medium**

   This is probably the second most common wicking bed design in popular web sites and YouTube videos. The greater wicking capacity of sand compared with gravel makes it seem more likely that this design of wicking bed will be successful.

3. **Wicking bed completely filled with soil/compost growing medium** (The medium in the reservoir layer will be saturated when the reservoir is filled.)

   This is the simplest wicking bed design and is the one promoted by Austin (2011) who claims to have invented the wicking bed concept. Providing the growing media has good wicking capability (which soil/compost mixes are likely to have due to small pore sizes) it is expected that this type of wicking bed will be successful. One criticism that has been made of this design is that a growing medium that is high in organic matter and continually saturated will decompose anaerobically and smell. Personal experience has been that wicking beds filled with a mixture of potting mix and mushroom compost did suffer from this problem after a few years but that wicking beds filled with a 50:50 soil:compost mix do not seem to have this problem. A method of dealing with this problem suggested by Austin is to let the reservoir layer periodically dry out rather than keeping the reservoir continually filled. The time required to investigate this anaerobic decomposition problem and assess the possible solutions is greater than is available for the current project.

4. **Reservoir filled with high water holding capacity medium and columns of soil/compost growing medium extending down through reservoir to bottom of wicking bed**

   This design seeks to combine the expected good wicking properties of the growing medium with the maximum possible water holding capacity in the reservoir. The reservoir medium to be used will be selected after the saturated water holding tests are completed. If there is not a great difference between the water holding capacity of the various media, another option is to use a structure within the reservoir that creates a large void that can be filled with water with sections where the growing medium can extend through the void to provide wicking capability. This structure could be formed by upturned plastic pots, coils of Ag pipe, or a commercially available product such as WaterUps.

All wicking beds will use the same growing medium. The medium to be used will be selected based on the wicking capability experiment results. An amount of fertiliser adequate for growing the crop will be added to each wicking bed. Three replicates of each design will be used.

The wicking beds will be constructed using 1000L IBC containers. Each container will be cut in half and each half will have a waterproof dividing panel installed resulting in wicking beds of approximately 500 x 500 x 1000mm.

The wicking beds will have a reservoir layer 200mm deep and a growing medium layer 300mm deep. These are dimensions that are commonly used for wicking beds. A clear plastic tube from the bottom of the reservoir up the outside of the wicking bed will enable the water level in the reservoir to be visually monitored and measured. The wicking beds will be placed in a 4m x 6m poly tunnel at my property in Bywong NSW.

Before starting the experiment, the reservoir layer in all wicking beds will be filled and the beds allowed to equilibrate for a week. During this time the reservoirs will be kept full.

The wicking beds will be planted with spinach or silverbeet seedlings at a common density used in market gardens. The seedlings will be top watered until they are established (approximately three days). The same volume of water will be applied to all wicking beds during the plant establishment period.

Water will be added to each reservoir when the reservoir is close to empty or the soil moisture in the wicking bed is low. The date and amount of water added will be recorded.

The experiment will continue until the plants are at a stage where they could be harvested for market. Swiader and Ware (2002) give a period to maturity of 50 days for spinach and 60 days for silverbeet. So it is anticipated that the experiment will be run for about two months. If the first experiment is done in spring, there will be time available for the experiment to be repeated in summer.

Soil moisture will be recorded within the growing medium layer. Gypsum blocks will be placed at depths of 50mm, 150mm and 250mm within the growing medium. One electronic tensiometer will also be placed at 150mm depth in each wicking bed as a second source of data. Gypsum blocks will be made using Plaster of Paris and stainless steel electrodes using methods described by Keyhani (2001) and van der Lee (2013). The tensiometers will be constructed using a method described by Thalheimer (2013). The gypsum blocks and tensiometers will be calibrated by comparison with a commercially available tensiometer. Data from the gypsum blocks and tensiometers will be automatically recorded each hour by an Arduino-based data logger.

Other factors that will be measured and recorded are:

- daily maximum and minimum temperature in the poly tunnel
- daily maximum and minimum humidity in the poly tunnel
- reservoir water level in each wicking bed (daily)
- soil EC in each wicking bed (weekly)
- height and leaf area of the spinach (measured weekly using the Canopeo app)

At the end of the experiment, the total above and below ground plant mass in each wicking bed will be measured.

Analysis of the data collected will include the following results for each wicking bed design:

- total water used
- rate of water usage
- soil moisture by soil depth
- frequency of watering
- plant growth rate
- final plant mass

4. Initial results

One test of the wicking capability and saturated capacity of a number of media has been conducted. The results are shown in Figure 3 and Figure 4.

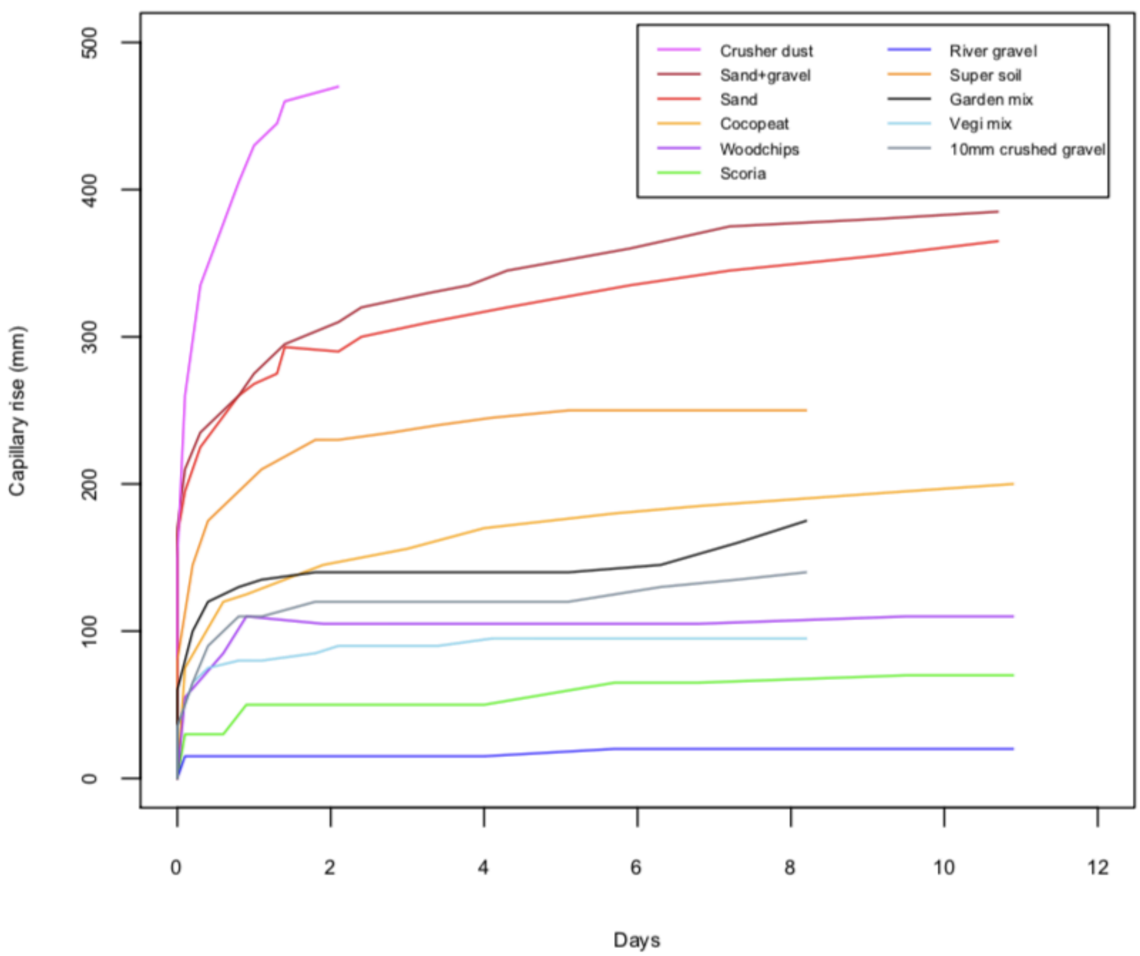

Figure 3 - Rate and extent of capillary rise of water in 50mm diameter perspex tubes filled with various media

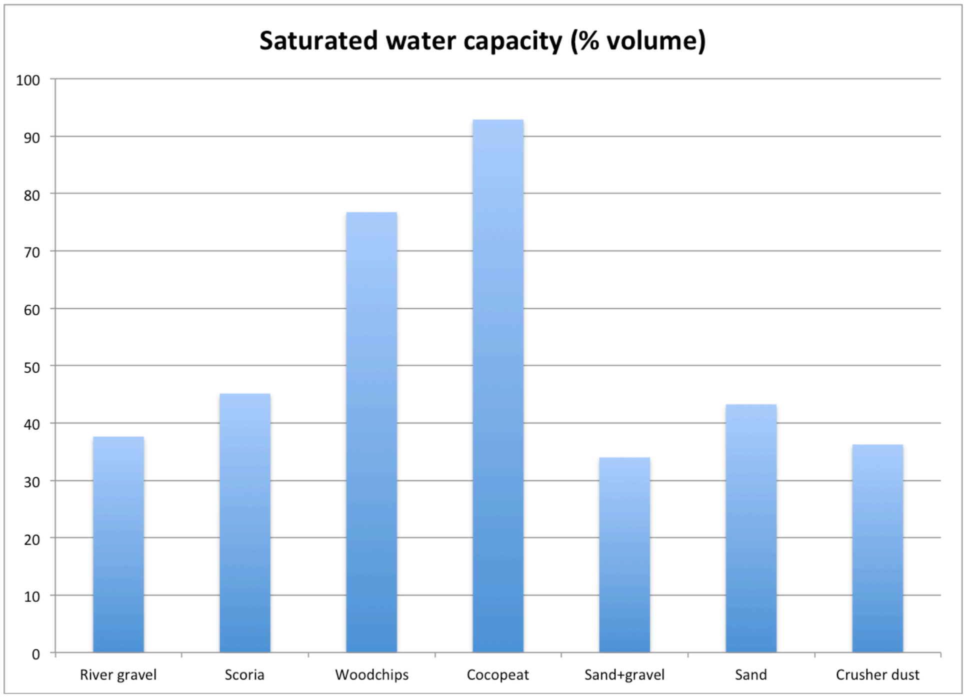

Figure 4 - Saturated water holding capacity by percentage of total volume of various media

5. Key milestones

Figure 5 shows key tasks and milestone dates for the project. Contingency time has been allowed for all major tasks so that delay in any one task should not adversely affect the overall schedule. For example, three months has been allowed for the wicking bed experiments when it is anticipated that only two will be required. There will be time in Autumn 2020 to conduct a third wicking bed experiment and still have the dissertation completed on time should severe problems occur during the first two wicking bed experiments.

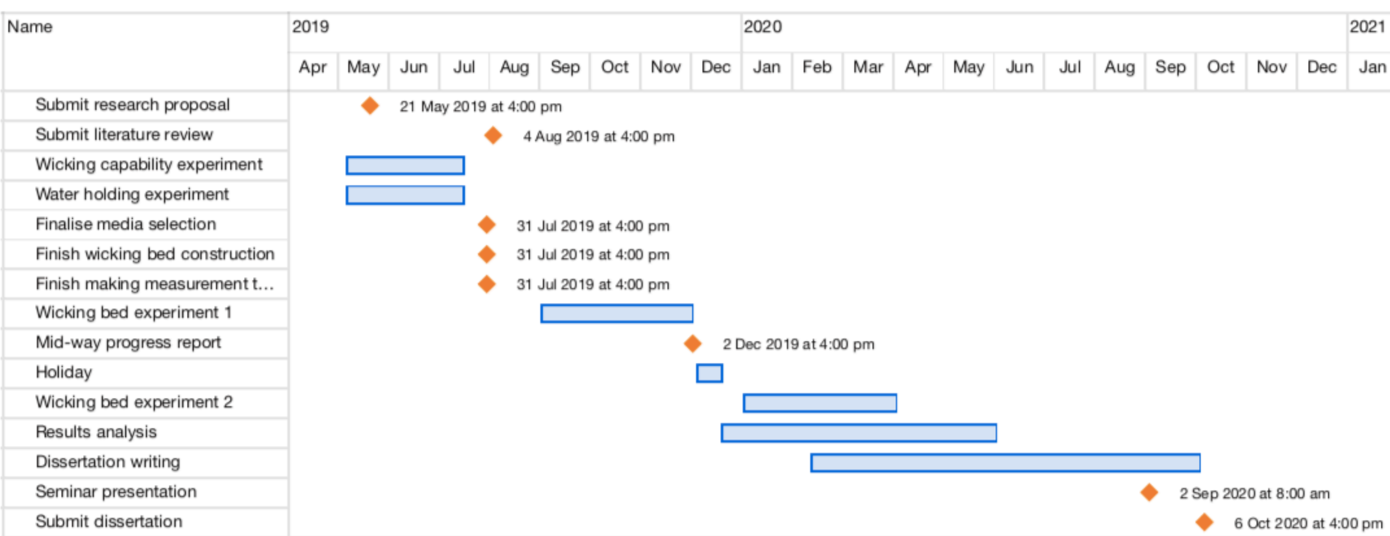

Figure 5 - Project plan for wicking bed research project showing key tasks and milestones

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