Part 1 Vision for wicking beds

Colin Austin 4 Aug 2013

Nutritional food

The car analogy

Let me use the analogy of a car. The vast majority of the input to a car is in fuel which provides the energy and is used up by driving the car.

But a car needs other inputs to ensure it keeps on running sweetly, oils of various sorts, water, brake pads and if you are like me and have the car serviced when the mechanic has just received his tax bill - resonators for the double down draught woofenbergers which you have no idea what they are but cost $165 each and your car needs eight of them – so never get your car serviced at tax time.

Bodies need energy and nutrition - Energy and nutrition

It is the same with our bodies – our food should give us both energy and maintenance. Energy typically comes from relatively simple compounds like sugars, glucose and hydrocarbons and we probably get too much. Nutrition to maintain and repair our bodies is more complex and needs a whole variety of other food components, both a wide range of minerals and complex molecules, to maintain our bodies if we are to remain healthy. These two types are often labelled energy and nutrition.

Science and energy production

Science has done a fantastic job in understanding the production of plants to provide energy, we have an in depth, widely scientifically accepted, understanding of soil chemistry, physics and plant genetics which has led to the abundance of food which now most of us enjoy.

But this success with energy is not matched by improvements in the maintenance or nutritional side of food.

Mega corporations

I do have some concerns about how the technology is managed. Our food production system is dominated by a handful of mega corporations and under the rules of our system are pressurised to maximise their profits for the benefits of shareholders. We cannot winge about this; this is the system we live under and delivers many benefits. The snag is that there is more money to be made by selling energy foods rather than food which maintains our bodies.

The history of mankind

I have noticed that anthropologist have been continuously extending their estimates of how long mankind, in our present form, has been on the earth, the last estimate I saw was 350,000 years – a long, long time anyway. During that time we were preoccupied with running away from lions and tigers which would eat us or running to catch antelope and kangaroos for us to eat - all of which takes a lot of energy.

There is very little high energy food in the natural world so natural selection has meant that we were and still are, obsessed with getting enough energy to eat. But the other side of food, the nutrition to replace our body parts was less important, probably a wolf, tiger or infections would knock us off before we reached forty, so we needed lots of kids – the first disposable society.

Nowadays our maximum need for energy may be finding the remote control or bottle opener that has fallen down the crack in the sofa and modern medicine is keeping us alive for at least double the historic average. This has changed the whole basis of our food needs - our current foods are awash with energy that we want but don't need yet short on the nutritional side to maintain our bodies.

Food industry, energy and profits

It is too simple to blame the food industry with providing us with food with too much energy and not enough nutrients, the food megaliths are not our mummy looking after us, they are in the business of making profits which they do by supplying us with what we want to buy.

The fact is that the science of food production for energy is very solid. The molecules that make up energy are simple, glucose, sugars, fats etc. and the science of producing high energy foods is mature. Laboratory tests, which have stood the test of being independently duplicated and peer reviewed have taught us how to produce high energy food. For example pulsing irrigation water containing dissolved N,K,P directly to the roots of the plants every 15 minutes give dramatic increases in productivity as is easily measured by tonnes per hectare.

Such technology is irrefutable or solid as scientist like to say.

The science of taste is also mature so the food industry can and does produce large quantities of sugary, fatty salt laden food which is full of energy and tastes really good. And let us not hide the fact that they do this because we, the public buy it and so makes it profitable for the food industry to produce.

For most of us food is readily available and brimming with energy, the food production industry has done a fantastic job in the efficient production of energy rich food packaging sugars, starches, hydrocarbons, salt etc. into a wide variety of food products which really taste good.

Nutritional foods

However the picture for the nutrition or maintenance aspect of food is much more complex. It is easy to experiment with plants to find out what they need to grow, if

you want to know the effect of say cadmium on productivity it is straight forward to design a test varying cadmium levels and measuring plant weight.

It is much more difficult to experiment with real people. For example there are indications that selenium is important to maintaining the integrity of DNA but this is difficult to test scientifically. It would be difficult to find volunteers for a control group to be fed inadequate selenium to show this deficiency causes humans to mutate while still in their twenties of thirties.

Plants and animals have evolved together over millions of years and developed symbiotic relationships. Plants only need access to a limited range of elements for the plants to be healthy, but they will absorb a much wider range which they will incorporate into complex chemicals which appear to have no immediate benefit for the plant but which are highly beneficial to animals.

Our needs, as animals are much more complex than the needs of plants, yet the plants produce an incredible range of complex chemicals which are beneficial to our health. I can only assume is because of the symbiotic relation between plants and animals in which plants depend on animals to spread their seeds.

However generally it is difficult to prove, in the strict scientific sense, the importance of certain elements or complex chemicals.

Sometimes the natural variability of soils results in sound evidence. For example there are regions in the Himalayas where there is an iodine deficiency which leads to retarding brain growth. Simply by showing that this can be resolved by adding iodine to the soil (or providing vegetables grown in soil containing iodine) provides clear proof of the need for iodine in our diet.

Finding these complex relationships between soil, plants and health is a very difficult subject requiring the close interaction of many disciplines (which with the reductionist approach of modern science is difficult to achieve).

No doubt over time scientist will work out ways of identifying and verifying the actions of these complex chemicals which appear to play a crucial role in maintaining health. But what do we do in the mean time?

Grow your own

It is apparent that even National Governments have limited power to control multinational corporations but people can easily protect their own interests by growing some of their own food. We may not fully understand the mechanisms as yet but there is little practical doubt that growing food in soil rich in minerals and soil biology to release the minerals is beneficial to our health. It is not necessary or practical for most people to grow all their own food but it is practical to supplement the energy rich food that is commercially available with home grown produce to provide a more balanced diet.

Many people see the benefits of the wicking bed technology as a way of saving or storing water and more complex and expensive wicking bed system have been developed and marketed, often at prices over $200 for a small bed. To my mind this

is missing the key point of wicking beds. The key benefit is that they provide a cheap and simple way for people to grow their own food supplements in nutrient and biologically rich soils. Most people are working and just do not have time for gardening during the week and many people live in apartments with no garden.

The real benefit of wicking beds is that they allow these people to enjoy a more balanced diet with minimal effort and at low cost.

This is a major issue for society, we are suffering from obesity, diabetes, heart attacks and diet associated diseases on a grand scale. As Kevin would say this is one of the great moral health issues of our time.

If it seems a bit farfetched that growing your own food could become the norm just look back to the food revolution that occurred in the UK in the war. Virtually the entire non-combatant population was involved in some form of food production, aided by various Government schemes. The amount of food produced by these often unskilled home gardeners was staggering, some hundred million tonnes per year. (see Green and Pleasant Land - How England's gardeners fought the second world war by Ursula Buchan).

They were assisted by the British Government who took the approach of letting the farmers produce the bulk food while the home gardeners focused on supplementary food. One of the features of the German blockade was that vitamins in such imports as lemons and bananas were no longer available so the British Governments encouraged people to grow salad, onions, carrots and other vitamin rich food. They also provided training and a support structure to help novice gardeners. This is very similar to the approach I am promoting some seventy years later with the coach scheme.

You don't need too dry a sense of humour to note that encouraging the British to adapt wide scale home gardening was one of the few occasions when Hitler and the British Government cooperated although the motives and methods and aims were totally different.

Enthusiastic home gardeners have done a great job in adopting and promoting wicking beds however the potential for improving global health is far greater.

The mechanics and construction of wicking beds is now a mature technology, the critical issue now for the production of food with high level of nutrition is the soil composition and the soil biology.

Part 2 Response to technical questions

Let for the benefit of reader let me first repeat the questions raised in your message

Dear Colin,

Premila forwarded your email to me (I am her principal supervisor; Baden and Richard, CC'd above, are her two co-supervisors). We are grateful for your offer and would be very interested to know how you would like to assist in the project.

We met with William Mansell earlier this year and he helped us shape Premila's experimental design, by indicating a few of the major unknowns with wicking beds - especially lack of scientifically tested data on:
1. Minimum and maximum soil depths;
2. Minimum and maximum reservoir depths;
3. Whether a gravel reservoir is necessary at all (we understand you are not in favour of these but the majority of "practitioners" seem to include them);
4. Accumulation of salts in the soil and/or reservoir.

Currently Premila is performing experiments studying the hydraulics of capillary rise (how fast and how far water moves through a soil column), to investigate #1 and #2 above for a range of different soil and reservoir types. She is also studying the drawdown of water in a gravel-filled reservoir between refills. These experiments should lead to practical benefits in terms of optimal design of wicking beds.

Future work is intended to study the water use efficiency of vegetation grown in wicking beds, to possibly verify the claim that this is a highly efficient irrigation system. We hope that there will also be an opportunity to study salt accumulation and nutrient dynamics in the soil and reservoir, particularly when using water of low quality (such as greywater or recycled water).

We look forward to hearing your thoughts on this project.

Warm regards,

James Ward.

Part 2 Responses

Reservoir and soil heights

First on heights of reservoir and soil depths. All my recent beds have a variable drain height, either by the rotatable drain or simply folding the liner back. This is an important feature as different plants have different water requirements at various stages of growth. Some plants (such as Bok Choi) are particularly prone to fungal attack if the water reservoir is too high while others such as water cress just love it wet. I try and maintain the top of the water level at just below the roots. This may mean that I will virtually fill the bed when seeding then just leave it so as the roots grow they lower the water table. Very lazy but effective.

Gravel reservoirs

There seems to be a widespread misunderstanding of the mechanics of water movement through the soil, there are a variety of mechanisms which get broadly lumped as wicking but may be nothing to do with surface tension which is true wicking.

I did a very interesting experiment cum demonstration some twenty years ago. I simply made a hole in the ground which I kept filled with water then put small holes (pencil size) into the ground radiating out from the reservoir. The ground was dried out lawn with brown dried up grass.

Hydraulic flow

They were three distinct zones. In the first zone the holes were filled with liquid water which dropped in height the further from the water source. This was clearly classic hydraulic flow. The horizontal flow would be controlled by Darcy's law of flow through a porous medium and would drop off with distance from the source while the vertical component would be controlled by gravity so I expect that the liquid profile was something like a parabola. After a metre of so from the water source there was no visible liquid water. This zone could be called the hydraulic zone.

Hydraulic flow can be the most powerful of the mechanisms for water transport in the soil. I was once involved in a major research program on subsurface irrigation. Like many experiments they didn't work out as expected and I ended up pumping water directly into the soil. This created a shear plane at the base of the root level which fractured the soil; this literally created a giant pimple in the ground about 300mm high and several metres in diameters. When I walked on this pimple it was like walking on a water bed. I can see no practical benefit for this observation but it surely shows the power of hydraulic flow in soil.

Wicking flow (surface tension)

The next zone was clearly wicking flow, there was no liquid water in the holes but the soil was clearly moist as seen by shining a touch down the holes. Again this zone was barely a metre in width after which the soil appeared dry. This was exactly as I expected from the laws of physics. This could be called the wicking zone.

Wicking is a relatively low power mechanism and will only raise the water level some 300mm.

Other mechanism for water movement through the soil

However what blew me away was that the grass, previously brown as brown could be now turned green even though the soil looked totally dry.

This zone was not a little zone which could be explained as edge effects, it was probably larger than the other zones so was obviously a real and significant effect.

The question was what were the mechanisms. I could see several and I believe they were all acting together.

Dynamic condensation and evaporation

The first mechanism was that there was a certain amount of water vapour in the soil and the roots were able to pick up this water. It is well known that some plants like the epiphytes and some orchids depends entirely on water vapour in the air so there was a reason to think that grass roots were able to absorb some moisture directly from the subsurface air even though the soil appeared dry.

But water vapour is in dynamic equilibrium with molecules continuously evaporating from the water source while others are condensing and re-evaporating on all other surfaces. If these surfaces are dry and has the right surface characteristics e.g. hydrophilic they will continuously absorb the water vapor - in effect transporting water.

This would be increased by the diurnal effect as the water condenses at night – a sort of underground dew.

These I think are relatively small effects.

Plants transporting water

In the day time the plants are extracting water from the soil. Many people say this is wicking but surface tension effects are really quite small and simply not strong enough to raise water to any height. The mechanism is well understood. Water enters the root system by osmotic pressure and form a continuous line of water to the leaves.

Water has a peculiar molecular structure such that each molecule has strong connections to the surrounding molecules. In effect this give water the property of tensile strength, just like a steel wire, so as the water evaporates from the leaves water is literally pulled up to the top of the plant. This is a very powerful effect; a large tree can pump some thousand litres a day from the soil up tens of metres, the sort of performance you would expect from a fire pump, all solar powered by the sun evaporating water from the leaves.

However at night there is no force pulling the water from the soil and some will drain back to the root system. But there is no reason why the water should follow the route it took going up, so some water will go down to roots further from the water source in effect transporting the water from one point to the next.

The capacity of plants to pump water is very high, probably only second to high pressure hydraulic flow so I believe is a significant effect.

Mycorrhizal fungi

There is also another effect I did not know about at the time and that is the ability of mycorrhizal fungi to transport water from one plant to the next. If one plant is deep rooted and has access to water and is linked into a mycorrhizal mat water can be transported from the deep rooted plant to surrounding shallow rooted plants.

Using plants for water and mineral mining

Trying to understand the mechanics of water movements in not just pedantic, it enables us to design better systems.

I am experimenting with exploiting the amazing ability of plants to pump water from the soil and am using this in a form of companion planting. My favorite plant for this is Senna Alata which is a bit like an extreme version of our Acacias.

It has an extremely aggressive and powerful root system which seems able to bore though many things. I have grown these in polystyrene boxes and the roots go straight through the base to get at the water below. More practically it can bore through heavy clay layers to break it up. It is a legume and very efficient at extracting mineral from the soil so makes an excellent soil regeneration plant.

I use them in conjunction with mycorrhizal fungi. For example I am growing citrus fruit on heavy clay, I have planted the Senna alongside the citrus so they mine the water and minerals which the fungi can transfer to the citrus. I have to prune the Sennas regularly which provides a good source of organic material.

I also use them in some wicking boxes, the power of the Sennas to pump water is much more powerful than surface tension or wicking effects so you can make the wicking bed any depth you like and the Sennas will pump up the water. You do have to be a bit vicious with the pruning though or they will take over.

Gravel beds

Now let me talk about gravel. I just do not think that surface tension wicking forces play a significant role in moving the water. You can do a simple experiment of putting sand and gravel in a glass tube with water at the base and simply watch.

The water in the sand will wick up 100 to 200mm without problem while the water in the gravel will only rise a few mm. The stones are simply too coarse to have any significant wicking action, but I accept that gravel works reasonably well so the question is what are the mechanisms?

I think that the evaporation and condensation mechanisms I described for my outer ring above are at work but I would have thought that these mechanisms would not account for significant water movement, so I set up some experiments in a glass box so I could see what was going on. I had a layer of cloth, as many people use, suspended over a water reservoir with plants in the soil layer above. The cloth was naturally absorbent and so would be effective in capture water vapour.

But I noticed that very fine hair roots would come through the cloth into the water reservoir area. I know that roots are supposed to suffer from air pruning when they enter an open cavity but I think that if the cavity is full of water vapour they will grow quite happily in space without air pruning.

Certainly in my experiment the plants grew very vigorously and the roots went right down to the liquid water surface. I can't say that this happens in other peoples gravel beds but I suspect it might be. I also may have under-estimated the condensation of water on the cloth.

This is not an area I have decided to devote much research into as it seems to me that is totally missing the point of what wicking beds are all about which is producing phytochemical for our health. This requires good soil with a well-developed biology. If you get the soil right you get plenty of water movement without gravel which does nothing for the soil biology.

If you focus on developing the microbiology the soil has a much higher water holding capacity, worms just riddle the soil with holes which increase the water holding capacity and water transport.

If your only interest is to increase the volume of water stored then simply use bigger pipes, after all a 90mm pipe holds almost 7 litres per metre. I notice that many people who use gravel use small diameter pipes, this is just bad technology.

To summarise on gravel, I am not actually against gravel and accept that it does work from the point of view of water storage, but the aim of wicking beds should be to improve our health by increasing the phytochemicals in our diet. This requires mineral rich soils and biology. If you focus on these then gravel has little to contribute and could be negative. There is nothing simpler than using large diameter pipes and just filling the wicking beds with the right soil.

Irrigation efficiency

Some years ago I developed a system of adaptive (or anticipatory) irrigation which is essentially a predictor corrector scheme. (It is on me web).

You (or the computer) would guess an effective crop factor and based on evaporation would predict how much water to apply.

(I use the term effective crop factor to include all losses from evaporation and water leakage and ideal crop factor for plant transpiration.)

Naturally at first this would be wrong so sensors would detect the error (in soil moisture content or irrigation depth) the computer would then correct the effective crop factor for the next irrigation. (I used a damped Newton iteration corrector in the software which proved very effective)

The effective crop factor includes transpiration plus all losses, e.g. evaporation and leakage can then be compared with the true crop factor based only on transpiration to measure the irrigation efficiency.

It is very easy to do this with the wicking bed as all that needs to be done is to measure the amount of water applied over a number of irrigation to get the effective crop factor. It is easy to eliminate surface evaporation by covering the surface (essentially making the wicking bed into a do it yourself lysimeter) to get the theoretical irrigation efficiency.

To me this is not a very valuable exercise as what really matters it to compare the water used with conventional practise - one of the advantages of the wicking bed is that it provides an automatic scheduling system and there is an awful lot of water wasted by poor scheduling.

Wicking bed users have told me that they have cut their water use by up to 50%. This could indicate that wicking beds are very water efficient, in reality it indicated that conventional irrigation scheduling as widely practised is very wasteful.

Salinity

In the adaptive irrigation software I also incorporated a salinity monitor, you simply entered the initial EC, and recorded the EC of irrigation water. The computer would then calculate the amount of water and hence salt flushed from the system and the residual EC.

The principles of controlling the EC in a wicking bed is exactly the same as in normal saline land. Set a minimum and maximum value for the EC, let the EC in the bed rise until the maximum EC is reached then apply enough water to flush the system down to the minimum EC level.

This means that only water at the maximum EC is flushed which gives the most efficient flushing and is far more efficient than the common practise of applying a small flush every irrigation which means that water with a low EC (and hence low salt content) is flushed out.

In normal use I have never had a problem with EC, luckily my water is good and we have rare but heavy rains which automatically flush.

I have however experimented with using grey and black water. Initially I used a cascading system with non edible plants in the first beds until the water was cleaned up. I believe that you use a similar system down in SA. I aborted these trials as being a bit of a pain and now use waste water to grow plants (like the Senna's and Arrow root lilies to produce organic material for my main beds. I am working on the assumption that the plants will not absorb toxic elements into their leaves which I compost. I have no scientific evidence for this but it seems likely and I have been doing it for years and am still alive.

Part 3 Final comments

In my view the mechanics of wicking beds are now quite mature and we have a good understanding of how they work. I accept that many people have tried to develop so called improved systems but they seem to do this with limited understanding of the basic mechanics of water movement through the soil. All they have achieved is making the system more complicated for no real benefit. I also know that various commercial companies have launched wicking bed boxes that are ridiculously expensive. Both have hindered the adoption of the wicking bed system and are contrary to my aim of having a cheap, easy to use system so normal busy people can readily grow nutritional food supplements.

I developed the original wicking bed while working in Africa trying to develop a system of providing sustenance food in time of drought. As the typically peasant farmers only earn $2 per day they had to be very low cost. The original beds only used a film of plastic in a trench and used weeds in the base as a nutrient source and water reservoir. This is an extremely low cost system and works extremely well.

Since then I have experimented with using gum leaves as a replacement for the plastic film (based on the lakes on Fraser Island). This is a virtually zero cost

solution (and does not suffer from the problem of damage to the plastics, simply put a few more gum leaves over the damaged area).

To my mind the two key areas for further research are;-

Soil and soil biology

Refining the soil composition particularly the husbandry of the soil biology; - there is plenty of information on the specific species of the soil biology but there seems a dearth of information on how to care for the complex web needed. (For example local farmers have experimented with mycorrhizal fungi with very poor results, when deep burrowing worms were added there was a much better spread of the fungi.) We need a better understanding of how to care for the soil biology as an integrated system with multiple complex relations.

The food to health chain

We need a better understanding of the complete chain from the soil to human health. There is a mass of research information conducted by agricultural scientist on how to increase crop production. There is less but still significant research information from the medical and nutritional scientist relating human health to consumption of fruit vegetables, fortunately these include studies using crops grown by conventional agriculture and crops grown using traditional methods.

There seems a chronic shortage looking at the complete chain from soil to human health so we can learn how to improve the soils, the soil biology, plant husbandry and cooking.

There are two counter non-scientific views, if it tastes good it must be healthy or if it tastes horrible it must be healthy. There is a vast industry providing nutritional supplements most of which are probably worthless.

Having a better holistic understanding of how to manage and selects soils, soil biology, plants, cooking and consumption patterns is critical for human health.