# Direct Irrigation Technology

## Transmitting Water **Directly to the Plant**

### How well does it actually work? Look at these two dahlia plants!

- Uses Less Water
- Accelerates  Plant Growth
- Overcomes Drought Conditions
- Does Not Salinate Soil

  **Even When Brackish Water Is Used**.

OSU


The Ohio State University
Daniel K. Struve, Ph. D.
Associate Professor
Department of Horticulture
2001 Fyffe Court
Columbus, Ohio 43210


After two months, the plants grown in your within container watering system were visibly larger than plants grown without your watering system. Also, the plants grown in your system had less signs of water stress (leaf margin burn) than plants grown without your watering system.

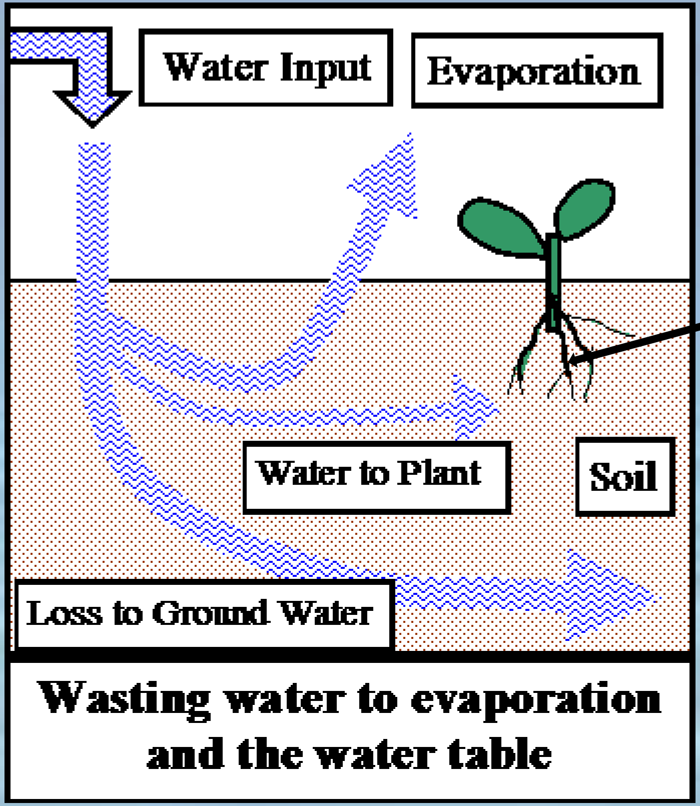
Unretouched photo of dahlias (variety ***Hendra wildfire***) with and without Direct Irrigation. In both cases, the dahlias were properly watered and cared for. The experimental plant on the left shows unusually good growth, quite atypical of dahlias in general, as illustrated by the control plant on the right, which shows typical growth.

**Experiment conducted by Ohio State University Department of Horticulture at our request. Contact Professor Daniel K Struve at OSU for details.**

# *Direct Irrigation Technology*

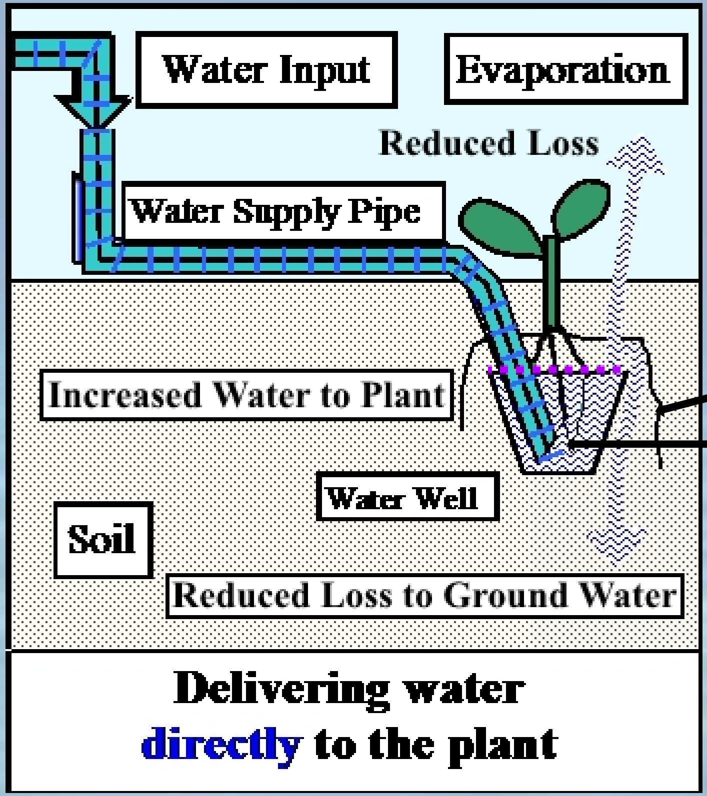
Transmitting Water **Directly to the Plant**

In all other forms of irrigation, water goes first through the soil, and second to the plant




One set of roots in soil only.

In Direct Irrigation Technology, water goes **first** to *Water Well* ™ where plant takes what it needs and a much smaller quantity enters the soil.




Two sets of roots, one in soil, the other in *Water Well* ™ containing plain water

Soil Roots

Water Roots

# How does Direct Irrigation Technology  stimulate growth?

There are four separate but related factors involved here. The *Water Well™* is supplied with ***plain water***, that is, ordinary fresh water from rivers, creeks, lakes, and wells suitable for irrigation. This water should contain minimal concentrations of minerals. Brackish water can also be used, but with special configuration to prevent salination of soil [See Below].

1. The *Water Well™* is kept filled at all times, making it a reliable supply of water. In conventional irrigation or natural rainfall, moisture content of the soil varies with rainfall, time of day, and many other factors making soil an unreliable supply of water.

2. Soil absorbs water by hydrogen bonding with charged and polarized components of the soil releasing a heat of absorption. Energy is required to break these bonds and desorb the water. This energy must be provided by the plant, consuming food that could otherwise be used for growth. This energy is provided via decreasing osmotic potential of interior of plant.

3. Water in soil contains dissolved solutes which exert a negative osmotic pressure working against the process of absorption by the roots.  This is called *static osmotic resistance.*

4. The concentration of solutes in the boundary layer of water around the root hair increases as water flows into the root hair leaving excess solutes behind.  This is called *dynamic osmotic resistance.*

# *Direct Irrigation Technology* bypasses all of these detrimental processes

1. Constant rather than intermittent water availability eliminates periods of shortage.

2. No work of desorption is required since the *Water Well*™ supplies plain water directly instead of from the soil.

3. There are minimal solutes and an optimum osmotic potential in plain water.

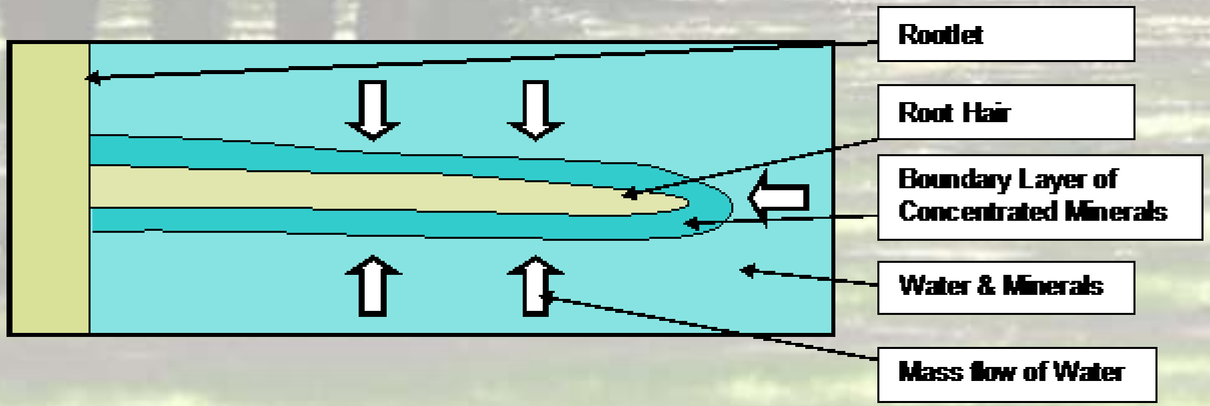
4. The solutes build up much more slowly in *Direct Irrigation Technology* because they are present in low concentration. Regular weekly flushing of the *Water Well*™ restores the solutes to the minimal concentration of plain water.
Thus, the plant obtains all of the water it needs for maximum growth, resulting in large increases in productivity relative to conventional irrigation.

# Why is it so important that plants get all of the water that they can absorb?

Because plant are subject to the phenomenon of photorespiration, a destructive process in which light causes the plant to consume instead of produce food. This counteracts photosynthesis and reduces growth. While modest amounts of photorespiration may be needed for nitrogen metabolism, excessive temperatures make the process antithetical to the goals of the grower.  The evaporation of water from leaves lowers the temperature and reduces photorespiration, increasing yields. In hot conditions, water cannot be absorbed from the soil as fast as the plant needs it to maximize growth. This is true even if the soil is moist.

## What is Osmotic Resistance and How Does It Retard Plant Growth?

Osmotic Resistance is the reduction is osmotic potential caused by the solutes dissolved in soil solution. This is due to the buildup of solutes around root hairs and mycorrhizae. Rapid transpiration results in a bulk flow of soil solution toward the root hairs. This bulk flow entrains soil solutes and transports them toward the root hairs faster than diffusion can dilute them. This diagram shows how solutes, represented by green coloration, build up around the root hairs to form a boundary layer of highly concentrated solutes. Eventually, the osmotic potential of the boundary layer rises to equal the osmotic potential inside the root hairs. At that point, all absorption of water ceases, despite the moisture remaining in the soil. This is the development of dynamic osmotic resistance. The leaves then wilt as the water lost cannot be replaced and turgor decreases. During the night, diffusion, groundwater flow, and possibly rain, ameliorate the boundary layer so that absorption resumes the next day.




*Typical Hot Weather Wilt*

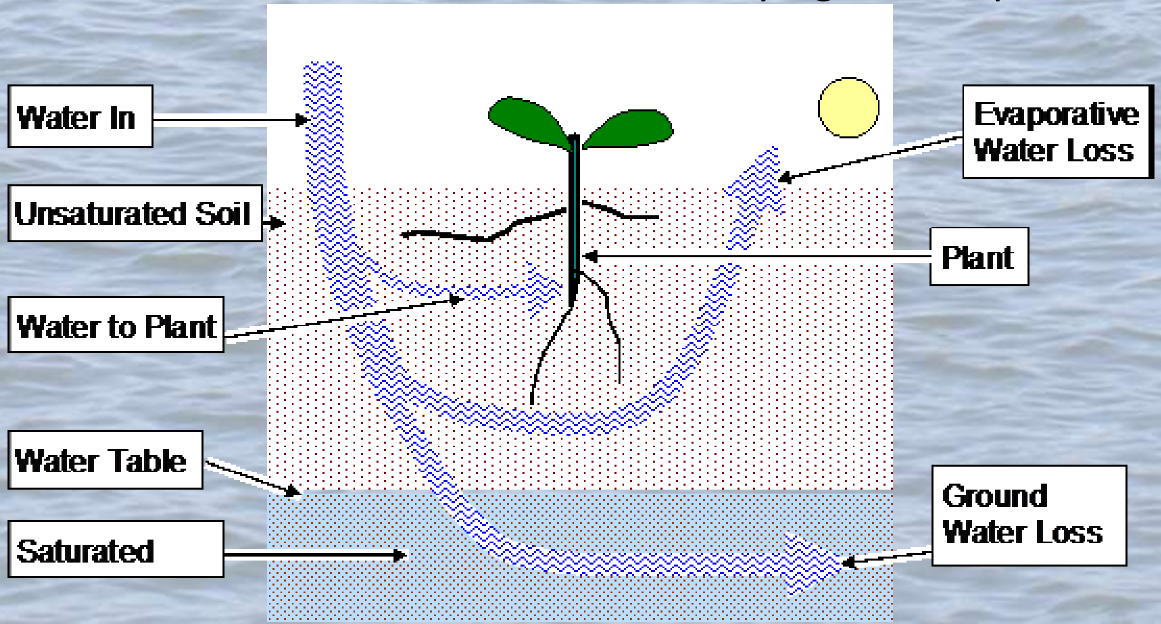
# How Does Conventional Irrigation Technology Waste Water?

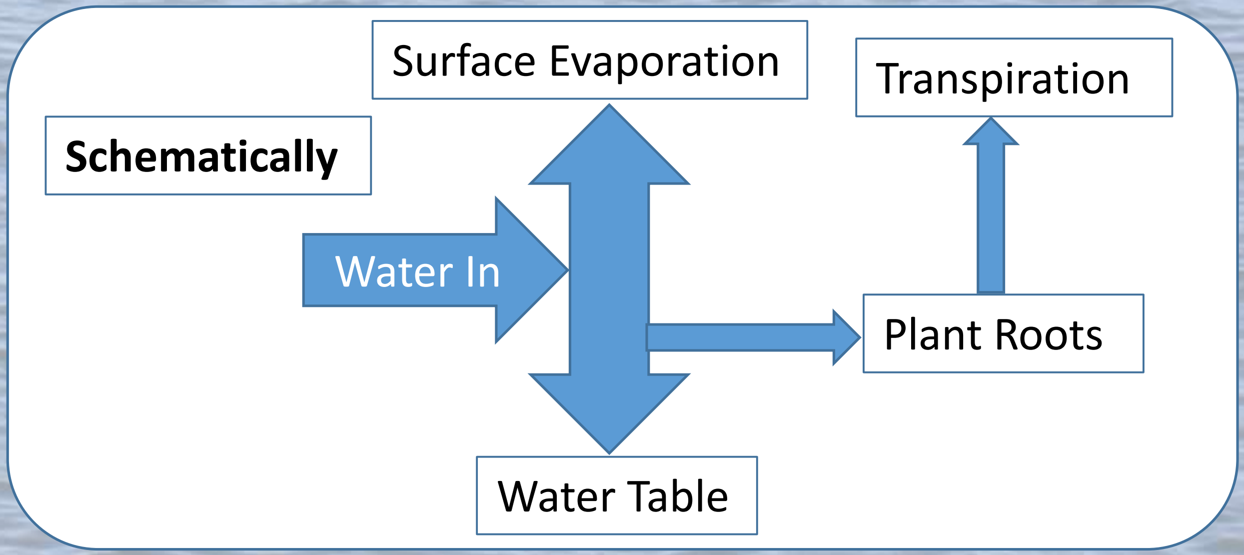
All forms of conventional irrigation ultimately pour water into the soil. The soil is a very leaky container. It loses water both above and below: Above by evaporation; Below by flow into the water table. Only a very small fraction of irrigation water is actually absorbed by the plants, which are the intended recipients. The rest is wasted.

The instant that water touches dry soil it is adsorbed, adhering to the grains, and absorbed, dissolving in the hygroscopic minerals such as clay. It is spread by capillary action, ending up in one of three places:

1. Evaporation from the surface,
2. Descent to the water table,
3. Absorbed by the plants.

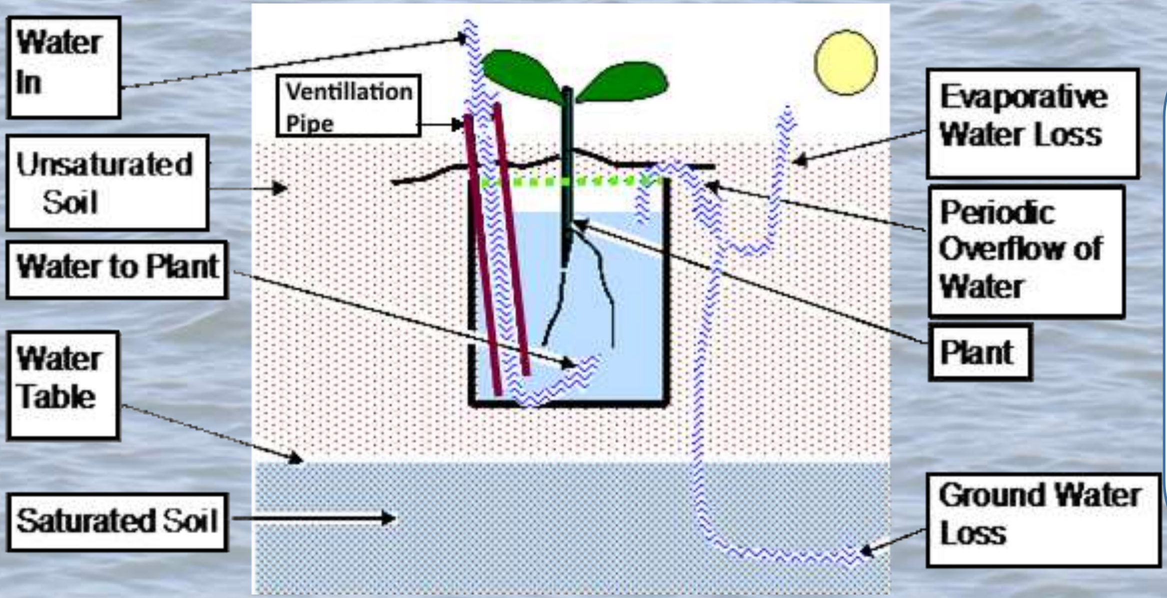
Only the last of these provides direct benefit to the plants. The other routes are mainly waste. Compared to the water table and the overlying air, the plant roots are very small targets. Most of the water misses them.

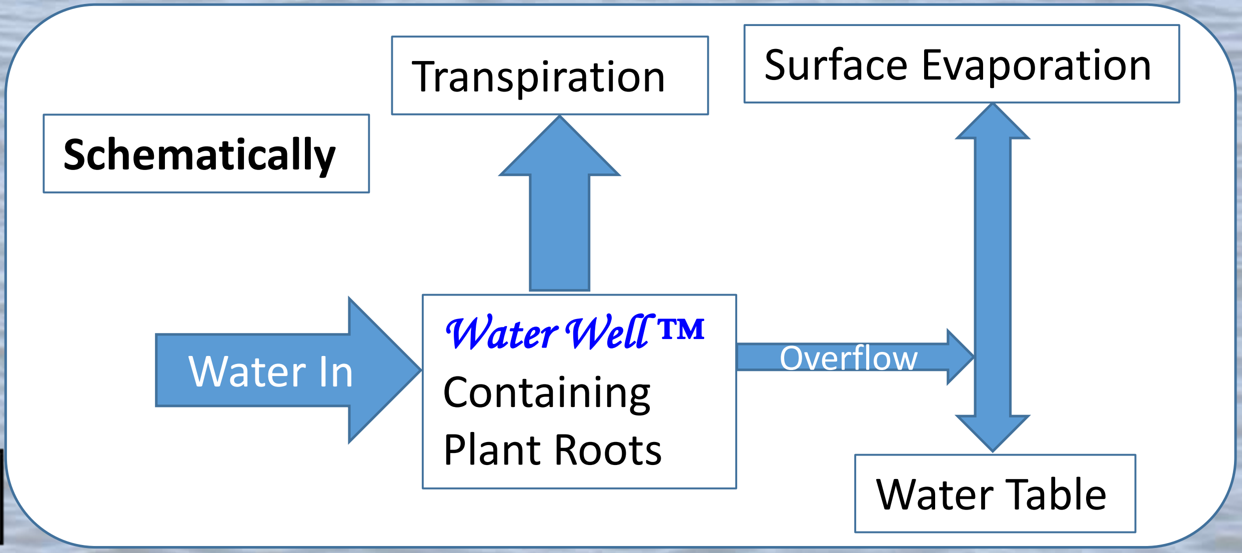


## How Does *Direct Irrigation Technology* Save Water?

In a nutshell, by sending water to the plant **first**. Instead of sending water via the soil, this technology sends water into a *Water Well*™ which contains the **water root system**. Meanwhile, the plant has developed the usual **soil root system,** which absorbs essential minerals from the soil. The **dual root systems** are the heart of the technology. Nothing like them has been developed before. The soil root system functions as usual, anchoring the plant and absorbing minerals. The water root system is the primary entry portal for water. Because the *Water Well*™ is the original destination of the plain water, it is always filled. However, the water is prevented from contacting the soil by a root permeable membrane, shown as a dashed green line. While there is some evaporation, there is no liquid-soil contact, so capillary action cannot occur. Since the plant absorbs (nearly) pure water, the common minerals will gradually build up in the *Water Well*™. To counteract this, the *Water Well*™ is flushed with plain water once per week or so. This also moistens surrounding soil for the soil roots. Thus, the well is kept filled by water containing minimal solutes so that osmotic resistance cannot occur.



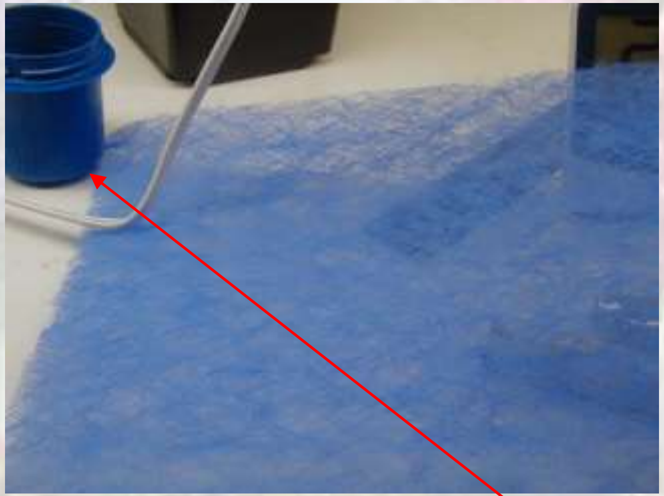
# How does *Direct Irrigation Technology* prevent root rot?

At first glance, it might appear that immersion in plain water would cause the roots to rot, as they do in saturated soil. But conditions are very unlike saturated soil. Roots tend to rot in soil saturated with water because the bacteria in the soil create a large biological oxygen demand that depletes the soil solution of oxygen. Roots thus die of anoxia, not soil saturation directly. In those plants, such as rice, which contain hollow vessels that permit air to flow to the roots, root rot does not occur, which in how rice can be grown successfully in flooded paddies. In *Direct Irrigation Technology*, contact with air is maintained by the **Ventilation Pipe** shown in previous illustration and repeated below for clarity. Therefore, root rot simply does not occur. The Ventilation Pipe is another of the essential features needed for the technology to function properly. The Ventilation Pipe is also used intermittently to deliver water to the *Water Well* **™**.

# How well does *Direct Irrigation Technology* actually work?

Setting Up the Experiment – Part 1

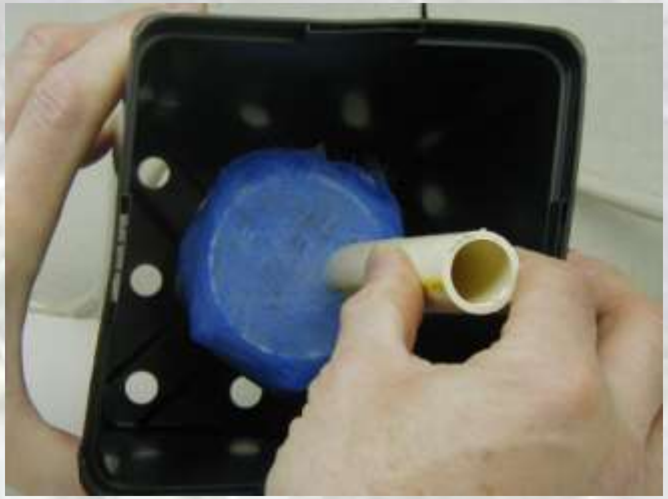
Water well is a detergent bottle lid. Various colors were used. Ventilation pipe is ordinary plastic pipe certified for food handling.



Blue fabric is root permeable membrane available at any garden store. Water well in background (blue).

Water well, ventilation pipe and root permeable membrane combined

# Setting Up the Experiment – Part 2



Water well and ventilation pipe being placed in ordinary plastic flower pot. Apparatus is held in place by soil alone.


Temperature and humidity were carefully monitored by the device above.

Water and soil were handled only with plastic tools, never metal.

# Setting Up the Experiment – Part 3

Illumination was provided by standard fluorescent tubes designed for indoor gardening. Timing was controlled by this timer so that normal day/night illumination was maintained.


Standard, commercially available soil was used throughout.

All plants were obtained from a commercial garden store in matched pairs, of which the experimental plant was selected at random.

Water was added daily in measured amount to both control and experimental plants.


**Complete Experimental Configuration**

# Experimental Results for Spider Plants (*Chlorophytum comosum*)







Clearly, **in every case**, the experimental spider plant grew significantly larger than the control plant. Note the ventilation pipe is hard to see in first two pictures because plants have overgrown it.

More growth above ground was matched by more growth below ground.

# Experimental Results for Violets Part 1



In every case, the experimental violet grew significantly larger than the control plant.
Please note that the control plants thrived in each case, but only in the last two cases (next slide) did the plant manage to peek over the rim of the pot. All eight plants were healthy at the end of the experiment.
Recall that the beige object protruding from the experimental plants is the ventilation pipe, not a plant part.

# Experimental Results for Violets Part 2



In every case, the experimental violet grew significantly larger than the control plant.
Please note that the control plants thrived in each case, but only in the last two cases (this slide) did the plant manage to peek over the rim of the pot.
Recall that the beige object protruding from the experimental plants is the ventilation pipe, not a plant part.


All of the violets grew, but the control plants grew so much less that they are difficult to see from the side. Here is Violet 6, a control plant from above.

# Experimental Results for Kwiatek

Water roots are clearly visible

# How Does *Direct Irrigation Technology* Compare with Drip Irrigation?

*Direct Irrigation Technology* is far more efficient in water use than Drip Irrigation because it does not release the water to the soil. In Drip Irrigation, the soil is an intermediate between the irrigation system and the plant. Most of the water bypasses the roots and is removed by capillarity from the vicinity of the roots. In addition, Drip Irrigation is beset by major clogging problems as the roots attempt to grow into the tiny emitting holes. In *Direct Irrigation* , the root-penetrable membrane and large perforations permit roots to enter the *Water Well* ™ without causing any clogging problems, since there is no constriction of access. Direct Irrigation actually welcomes roots. Finally, water release is controlled by the plants themselves as they lower the water in the *Water Well* ™ and activate the float valve.

Comparison:

| Irrigation Type →<br>Feature ↓ | Direct Irrigation | Drip Irrigation |
|---|---|---|
| Clogging by Roots | No | Yes |
| Water Requirements | Lower | Higher |
| Prevents Wilt in Hottest Weather | Yes | No |
| Stimulates Plant Growth Disproportionately to Water Used | Yes | No |
| Water Use Controlled by Plants | Yes | No |

# How Is *Direct Irrigation Technology* Applied to Row Crops?

This involves no new apparatus or specialized materials. It can be constructed entirely from readily available commercial materials and products. No off-site manufacturing is used.

[This section applies to use of **fresh water only, not brackish water.**]

**Materials required:**

1. Main plastic pipe, approximately 10 to 15 centimeters in diameter, with large holes on the top only. Such pipe is made for use in soil drainage.
2. Ordinary garden sweat hose with microperferations.
3. Plastic screening material.
4. Root permeable membrane found at every gardening shop.
5. Inexpensive mechanical (not electric) plastic float valve.
6. Pieces of small diameter plastic pipe that fits through holes in main pipe, with numerous holes drilled in bottom 6 to 8 centimeters. These pipes ventilate the *Water Well* ™ .

**Installation:** (see figure for details)

1. Dig a **level** trench either under row to be planted, or beside pre-existent row of perennial crop (grape vines, etc).
2. Lay plastic pipe into trench. Pipe must be **level** or water will pool at one end or the other.
3. Insert sweat hose into plastic pipe. Cap distal end of sweat hose.
4. Run supply hose through one of the holes in the plastic pipe.
5. Insert small plastic pipes ventilation, perforated end down, other end well above ground level.
6. Install plastic float valve, connecting input side to water supply and output side to sweat hose.
7. Cap each end with standard caps. Make sure seal is waterproof.
8. Cover main pipe with screen and top with root permeable membrane.
9. Fill trench with soil.

**Operation** [when brackish water is NOT used]

Hookup to water source.

Fill to about ¾ from top.

Adjust float valve to maintain this level.

Plants will lower water level as the consume the water.

Float valve will keep pipe filled ¾ from top.

Plants will find the *Water Well*™ and grow into it.

Plants will remove exactly what they need and leave behind whatever they do not need.

This will result in a slowly increasing concentration of solutes in the *Water Well*™ .

To prevent the development of osmotic resistance, manual valve must be operated periodically to flood the *Water Well*™ to overflowing and replace contents with fresh water.

This will remove solutes, refresh the *Water Well*™ , and moisten the soil.

The amount of water used for flushing is quite small compared to the amount absorbed by the plants.

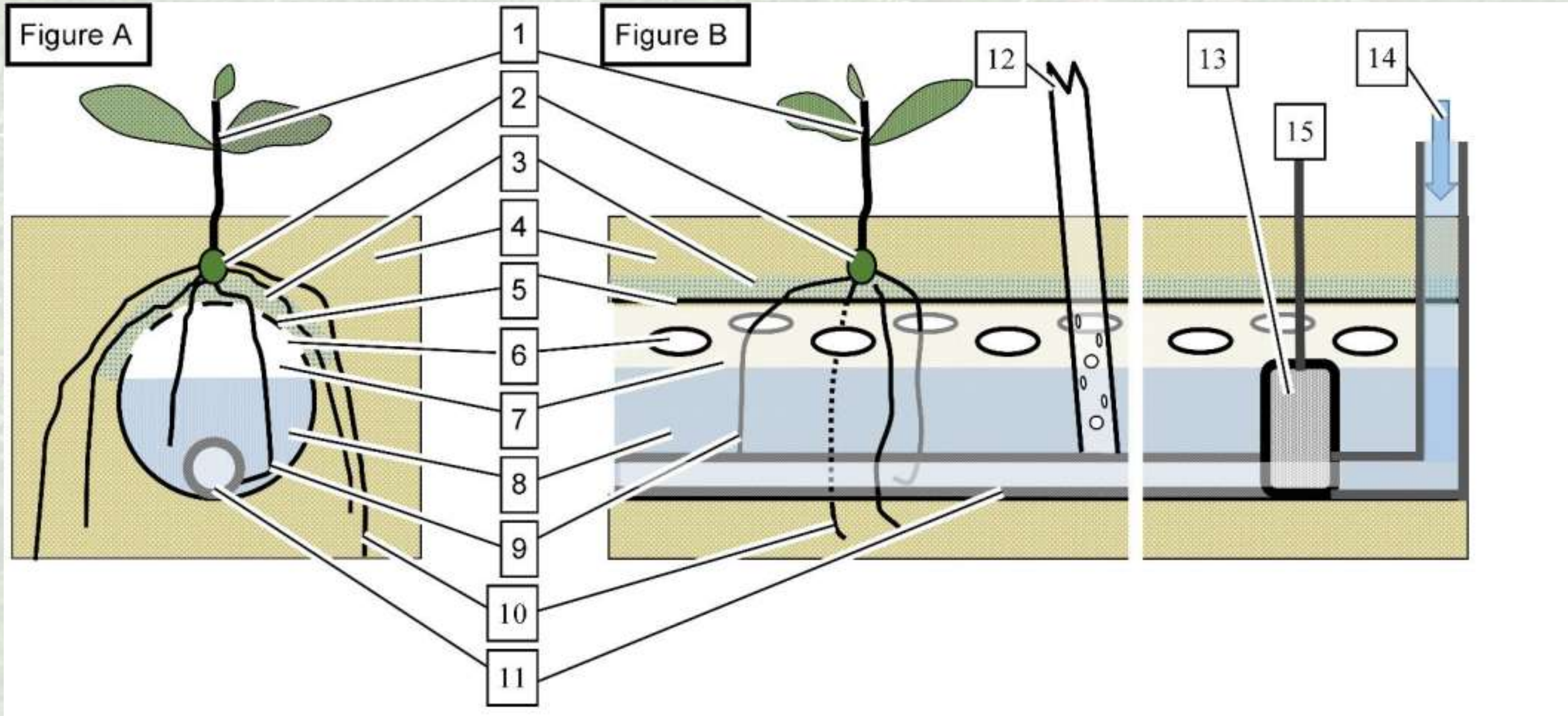
Plants will grow astoundingly fast and large if these instructions are followed.

Crop size will be doubled or tripled. If that result sounds surprising, we were surprised too.

Water use will decrease, since evaporation from the soil and loss to water table is minimized.

Less water will give more crops. That is hard to beat.

Unlike Drip Irrigation, there will be no clogging by roots.

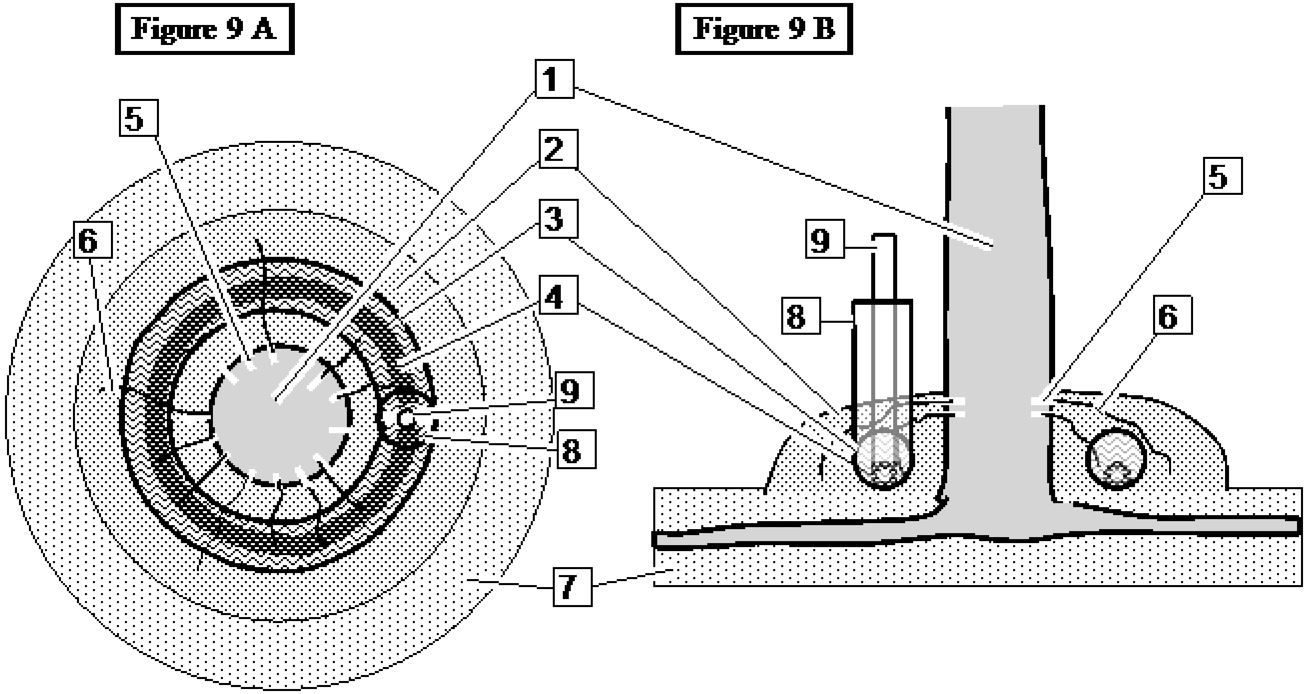



*Legend for Figure A (transverse view) & Figure B (lateral view)*

*1. Plant*
*2. Seed from which plant grew*
*3. Root penetrable barrier over plastic screen (not shown)*
*4. Soil*
*5. Plastic pipe with perforations on top*
*6. Typical hole in top of pipe*
*7. Air space in top part of pipe*
*8. Water in bottom part of pipe*
*9. Water root*
*10. Soil root*
*11. Sweat hose*
*12. Perforated air access pipe to maintain contact with atmosphere*
*13. Float valve*
*14. Water source*
*15. Manual actuator for float valve*

Control Group Used Standard Watering Hose As Shown.
Experimental Groups Grew Over *Water Well™* Pipe As Described Above.
Results Are Robust and Easily Reproducible

# How Is *Direct Irrigation Technology* Applied to Trees?




Legend for Figure 9 A (top view) & Figure 9 B (side view)

1. Tree trunk
2. Soil piled around base of tree trunk
3. Plastic pipe, from 10 to 15 centimeters in diameter, with perforations on top
4. Sweat hose inside of plastic pipe
5. Cuts made in tree bark to expose cambium (exaggerated in drawing for clarity)
6. Soil root growing out of cut into soil
7. Original soil
8. Vertical plastic pipe
9. Vertical water hose connecting with sweat hose

The tree trunk is cut with a thin, sharp knife or a small drill to expose the vascular cambium. A circular plastic pipe with holes in the top is placed in a circle around the base of the tree and constitutes the *Water Well™*. It has large perforations on the top only. Soil must be placed as required to keep the *Water Well™* **level**. A sweat hose with distal end closed by a plastic cover is placed in the pipe. A second plastic pipe is affixed vertically and connected with the circular pipe via a plastic T joint. Then a plastic screen and a root-permeable membrane (discussed elsewhere) are placed on top of the circular pipe to prevent intrusion of soil. Then the entire assembly is covered with soil. The necessity for the sweat hose is twofold.

1. To insure that water enters the pipe uniformly rather than at one end only.
2. To insure that water is flushed uniformly and that residual water does not persist after flushing.

The operation of this setup is simplicity itself. The *Water Well™* is filled from the sweat hose daily. Depth of water can easily be ascertained by dipping a dry stick through the air pipe. An inexpensive alternative to daily filling is the use of an inexpensive toilet filler valve, which will keep water at the desired level automatically.

The circular must be kept filled with water, and overflow must be force at least once per week. The cuts in the bark permit adventitious roots to form from the vascular cambium. These roots then enter the soil around the trunk and enter the *Water Well™*.

The roots are constrained by the shape of the mound from growing laterally, so they are induced to become geotropic. The roots enter the Water Wells and the process of Direct Irrigation begins. The water roots that develop have a very high rate of absorption so the system does not need to be expanded as the tree grows, unless the tree grows so large as to break the circular pipe. If a corrugated stretchable pipe is used, it can expand as the tree grows. Only the frequency of watering needs to be increased with tree growth, unless an automatic level valve is used.

# TRY A NEW EMITTER FOR YOUR GRAPES

By Randy Bailey

*Editor's Note: We receive all types of letters here at Grape Grower Magazine and once in a while one really catches our eye. The following letter was sent to us by Dr. Stefan Ehrlich, the Appointed International Expert of the Food and Agricultural Organization of the United Nations, ret. Ehrlich has created a water saving, sub-surface emitter that he developed over the years during his work in the Middle East; at the Justus Liebig University in Giessen, Germany; and at his home in Columbus, Ohio. Ehrlich is looking for interested researchers and growers to contact him and test his emitter at no charge as long as certain confidentiality observances are honored.*

*Here is the letter we received from Dr. Ehrlich.*

*The Editor*

Dear Editor:

Will you kindly publish the enclosed picture? It shows an aspect of the rooting bed at Mr. Rechsteiner's Willow Hill Vineyards and Winery at 5460 Loudon Street, Johnstown, Ohio 43031. Phone 740-587-4622.

Complete rooting success and lush growth of shoots, some of which extended into vines within a couple of months of planting the cuttings, has become routine for several years, since Mr. Rechsteiner had made and installed a novel subsurface emitter in the rooting bed of his Willow Hill Vineyards.

How could the vines start so early on initially rootless cuttings and so rapidly grow under the sub-optimal sunlight and temperature of Ohio?

Mr. Rechsteiner based his subsurface emitter for rooting cuttings on a general concept of a water-saving subsurface emitter that I developed in studies conducted in the Middle East, Justus Liebig University, Giessen, Germany, and finally in my backyard in Columbus, Ohio.

Plant growth stimulation was an unexpected side effect of the water-saving emitter.

I invite growers, manufacturers of irrigation equipment and Academe to test that emitter on the conditions of my cooperation with Mr. Rechsteiner: 1) A confidentiality agreement; 2) Full exchange of information including photographs; 3) No money changing hands between the cooperating grower and me.

I am especially interested in rooting cuttings on my emitter on a permanent place in an irrigated vineyard, to see the growth and fruiting of my emitter. In tests with other plants my emitter dramatically enhanced flowering under heat stress and without it.

Professor Daniel K. Struve of Ohio State University induced tasseling in sweet corn grown on his embodiment of my water-saving, emitter (it is a general concept that is adapted to various plants) in an overheated greenhouse in summer.

Photo 1

*Virtually rootless cuttings grow rapidly in Ohio's sub-optimal sunlight and temperature thanks to a subsurface emitter.*








*The center plant, used as a control, is grown without the aid of the subsurface emitter.*

The culture was hydroponic, the rooting medium was low-nutrient and the pots were watered with a nutrient solution.

The central plant in photo 2 was a control that was planted without the emitter. Heat stress repressed the induction of the flowering second internode of its stem. Instead, a bunch of vegetative one-internode stems grew. The left plant on the emitter grew two flowering stems as corn does under favorable temperatures. The right plant on the emitter initially grew a bunch of one-internode vegetative stems that were larger than in the control, and then grew a weak flowering stem. I do not now what was the reason. Professor Struve stated that my emitter reduced leaf scorch.

Photo 3 is another demonstration of the induction of flowering by my emitter in heat-stressed plants. It shows a flowering *Dieffenbachia amoena*. It easily flowers in England and there it is termed "spotted lily." It never flowers in this country and is grown here as a foliage plant under the name "dumb cane." *Dieffenbachia* does not tolerate the heat produced by direct sunlight in this country. It is grown in shadow under a cheese cloth and fails to accumulate enough sunlight to induce flowering. In a milder climate of England it is grown under direct sunlight that induces flowering.

My *Dieffenbachia* grew under direct sunlight on my southerly porch during the heat wave of 1996 at 100-110 F daytime temperatures.

With my emitter Norfolk Island pine, *Schefflera*, peace lily, and other shade plants flourished under the heat wave by enhancing seven to 14-fold the root absorption of water. My emitter also stimulated flowering in non-stressed plants grown under optimal conditions.

A test with dahlias made by Mr. Dick Westfall, 16389 Lakewood Lane, Marysville, Ohio 43040, 937-642-9142, retired Head of New Products Department of Scott's, and current Vice President of the Dahlia Society of Columbus. An Inland Dynasty dahlia on his version of my emitter (not shown) began to flower much earlier than the control plant – as it was still small – and flowering slowed down its further growth. A Hendra Wildfire dahlia (in photo 4) on the emitter grew several times larger than the control plant on the right side and developed a purple flower, whereas the control plant on the right side merely developed yellow flower buds that would turn purple as the flowers opened.

These effects of my emitter on flowering make it extremely tempting to grow grapes on it until and during fruiting.

An aboveground model of the emitter may be installed in existing vineyards without harming the roots. Currently in Columbus is a Russian woman who developed in Moscow an above-ground model of the same emitter independently of me. She installed her above-ground emitter on growing tomato plants and dramatically increased and prolonged the fruiting. In contrast to me she did not use water but a special fertilizer solution.


*Dieffenbachia flowering after being grown in 100+ degree weather - an unusual ocurrence.*


***The effect of the subsurface emitter on these dahlias was dramatic and even produced different colored flowers.***

Our emitters eliminate several bottlenecks to water absorption by plants. A fundamental rate-limiting step is demineralization of water by reverse osmosis during its absorption over the cell wall of the root hair. A 2 percent-efficient photosynthesis degrades to heat 98 percent of the solar radiation incident on the foliar surface. The plant dissipates the waste heat of photosynthesis by evaporative cooling by foliar transpiration. The plant absorbs the major portion of water for the sole purpose of its transpiration.

The plant completely demineralizes that water as it passes across the cell wall of the root hair. Without complete demineralization of water, its transpiration would have left behind salts in the leaf. The accumulation of salts would have killed the leaf and forced its shedding. However, the owner of a 10-year-old Norfolk Island pine never complaints that it sheds needles on the carpet. Some needles are as old as the plant itself and still live and function. They were not salinized during their long lifetime. Apparently, the water that they transpired was completely demineralized by reverse osmosis during the root absorption.

Demineralization of water consumes energy and time and thereby restricts its absorption. Demineralization of the major portion of the absorbed water is the price that the plant pays for the presence of the nutrient ions. My emitter liberated the plant from the burden of demineralization of the absorbed water by reverse osmosis. That contributed to the dramatic increase in the root absorption of water that gave the effects shown on the various photographs.

The emitter also eliminated the resistance of the soil sorption of moisture to the root absorption of water from drained soils. To absorb moisture from drained soils the roots exert a force overcoming the absorption of moisture by soil solid surfaces. The rootless cuttings have no mechanism for the desorption of sorbed moisture from the soil.

A high mortality of the rooting cuttings results?

Not necessarily – see photo 1. Apparently, the emitter eliminated the resistance of soil sorption to absorption of water from soil by the rootless cuttings and incipient roots. Rooted plants also benefited from the elimination of the resistance of soil sorption to the root absorption of soil moisture.

Would you like to test the emitter?

Stefan Ehrlich

Stefan Ehrlich, Ph.D., Eng.

Appointed International Expert of the Food and Agricultural Organization of the United Nations (ret.)

*Accompanying Dr. Ehrlich's letter were two signed letters discussing his work. The first was from Daniel K. Struve, Associate Professor, Department of Horticulture, Ohio State University, mentioned in this story. The second letter was from Mahmoud Duwayri, the vice president of the Jordon University of Science and Technology, inviting Ehrlich to Jordon to test the emitter. Both letters are available upon request. Dr. Ehrlich may be reached at 614-451-2519 or you may write him at 1859 Milden Rd., Columbus, OH 43221*

# Mistakes to Avoid

## *Direct Irrigation Technology* Works Fine Provided One Avoids These Errors

### Root Suffocation (Hypoxia)

This can be avoided by making sure that the path between the *Water Well* **™** and the ambient air is large enough and by keeping this path open.

### Dry *Water Well* ™

*Direct Irrigation* works by keeping the roots in constant contact with aerated water. If one does not keep the *Water Well* **™** **filled** with water, the effect is lost. Growers are so used to seeing dehydrated plants that they frequently fail to notice that the *Water Well* **™** is empty. Either a dip stick or some type of water sensor is required to make certain of water level. Automatic watering will help, but in many settings it is not practical, so manual checking of water level is needed.

### Collapse of the *Water Well* ™ from Ambient Pressure

A *Water Well* **™** buried in soil is subject to pressure from above and below as well as from all sides. If the container is insufficiently strong, it will collapse. The best way to prevent this is to choose a container which is cylindrical in shape and either thick walled, or with rigid reinforcement in the walls. Flimsy plastic will simply not work in the real world.

### Cave-In of the Root-Permeable Membrane from the Weight of Overlying Soil

Root-permeable membranes purchased from most stores are not stiff enough to support soil without some kind of grid underneath. The grid should be made of either plastic-coated metal (but NOT bare metal) or stiff plastic. A simple test is to place several bricks on the membrane after mounting it to the grid. If it will support the bricks, it will support the soil.

### Giving in to the Temptation to Use the *Water Well* ™ to Distribute Macronutrients (nitrogen, potassium, phosphorus, calcium, magnesium, sulfur)

Ten years of research have convinced us that putting macronutrients into the *Water Well* **™** retards rather than enhances growth. If this surprises you, it surprised us too, but that is the result that our experiments have consistently shown. If macronutrient distribution is required, a ***Fertilizer Well*** **™** should be used in parallel with the *Water Well* **™**.  Alternatively, fertilizer can be applied to the soil as usual.

# *Direct Irrigation Technology*

## Contact Information

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