Water Management

The Key is Understanding Irrigation, Media and Fertilization

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Current problems with water and fertilizer runoff or percolation from greenhouses are the result of basic cultural practices which have been used for over two decades. Methods that made good sense in the mid 1960's when they were developed are no longer good enough. Taking the time to understand the basis for our current methods can help us to identify ways to deal with runoff.

Watering Practices

Several important developments occurred during the late 1950's and early 1960's that dramatically influenced greenhouse production. We often hear how the development of plastic films changed greenhouse structures. The development of plastics also lead to the production of new irrigation systems. Spaghetti tube drip systems for pots and spray lines for beds made rapid application of large volumes of water very easy.

With the new irrigation systems, watering required less labor. There was also less grower control over the volume of water applied. Some of the systems developed did not make uniform applications of water. The lack of uniformity of application was often compensated for by watering until the driest spot was wet.

Development of totally automated irrigation systems became a priority and the question of what was the best way to schedule irrigations was addressed. Much like today, media moisture content could be measured with a tensiometer, plants could be put on a scale with built in switches, or light levels could be monitored and used to determine watering frequency. At that time, however, the method chosen to automate irrigation was to water at a regular time interval with time clocks. This was the easiest and most efficient method for the largest number of growers.

Root Media was Key

The key to the success of timed irrigations was that the root media had to be well drained so it could not be over watered. Well drained root media made it easy for even untrained growers to grow crops as long as large amounts of water were applied regularly. The well drained root media also benefitted greenhouse operations still using hose watering because it was harder to over water. Pots that did not dry uniformly could all be watered and brought to a uniform moisture level.

The porous root media made use of components like peat, vermiculite, perlite and sand. Perlite and sand which were often added to increase drainage had little or no nutrient holding capacity. Root media components like peat and vermiculite appeared to have a high cation exchange capacity (CEC) but not in comparison to the field soil being replaced.

The nutrient holding capacity of peat compared to soil is a point that often confuses many students. It is important to realize that the values for CEC are often expressed per unit of weight. This hides the fact that a pot of peat:vermiculite has about half the nutrient holding capacity of a pot of soil. Peat:vermiculite has seven times the nutrient holding capacity of field soil per unit of weight. However, since the peat has such a low density, when equal volumes are compared there is twice the nutrient holding capacity in a pot of soil. This is an important point when we consider what happened to fertilization practices as soilless media were adopted.

Nutrient Holding Capacity

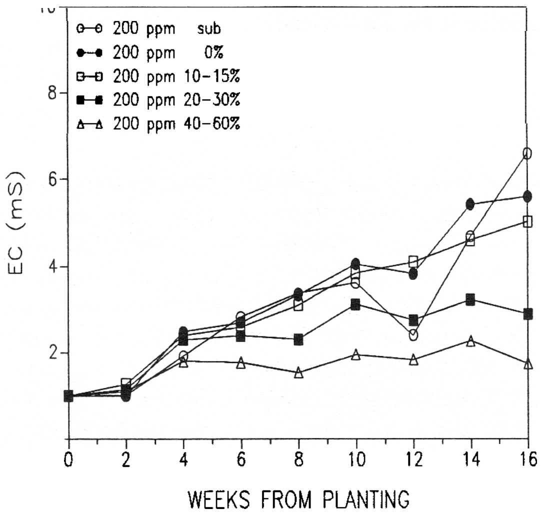
	Field Soil	Peat: Vermic
CEC meq/100 gm	20	141
gram/cubic cm	1.3	0.1
cubic cm/pot	1250	1250
CEC meq/pot	325	176

Fertilizati

At the same time our current watering and media recommendations were developed, it was determined that frequent applications of water soluble nutrients were needed to compensate for the high volumes of water applied and the low CEC of the root media. High levels of fertilizer were needed to maintain an adequate level of fertility. Frequent applications of fertilizer were also due to the increasing use of fertilizer injectors and water soluble fertilizers. Fertilization was easy, as it should be, but this lead to unnecessary applications.

Growers were taught to apply fertilizer and water in excess of container capacity to reduce the potential for soluble salt accumulation and nutrient imbalances. Applying excess and leaching was easier in general than testing the media to see if nutrients were present. It is interesting that the rates of leaching that were recommended, 10 to 20%, have had little effect on preventing soluble salt accumulation in our research. As many growers found out it takes 40 to 60% leaching with constant liquid fertilization of 200 ppm or more to keep fertilizer levels from increasing. (See Figure) In some cases 300 ppm or more were being recommended so even greater leaching was needed. Recommendations for leaching were not refined to account for differences in water quality. Everyone leached to avoid problems.

The irrigation and fertilization practices and the root media that evolved over the last 25 years have helped many greenhouse operators be successful. They have also created a potential problem of water and fertilizer runoff and percolation from greenhouses. The key point is that



The effect of 200 mg/liter N & K applied to 6 inch poinsettias at various leaching fractions on root media EC.

watering, media and fertilization are obviously related to each other. Only through understanding the relationships between irrigation, fertilization and root media can we work to solve the runoff problem in a timely and economical fashion. The goal of every greenhouse operator should be to develop economical irrigation and fertilization methods that optimize the root zone <u>and</u> are environmentally sound.

There are many different methods to manage water, fertilizer and media. Some of the methods are very simple and low cost while others require significant investments. Subirrigation can eliminate the runoff problem, but many greenhouse operations are not ready for subirrigation. The first step in water management for these operations is to limit or eliminate the waste or runoff so there is little or nothing to collect and recycle.

Irrigation Scheduling

Scheduling irrigation frequency based on environmental conditions and careful control of the irrigation duration will control water and fertilizer runoff. Most greenhouse operations do not currently have the ability to automatically control irrigation based on environmental conditions. However, a variety of computers and irrigation schedulers with this capability are available and easy to use. Cost seems to be the major constraint. Labor savings should be considered as well as the limited availability of qualified labor when considering investments in irrigation systems.

If you can't buy a system to control irrigation, or you don't think you are ready for sophisticated technology, there is an easier way. The most common way of determining when to water is to lift a few pots and check the weight. However, when a pot should be watered is strongly influenced by individual opinion and the general rule of thumb is often when in doubt, water.

The inexpensive solution is to buy a portable scale. No matter how little experience they have, our starting students have been able to learn how to tell when to water by simply weighing a few plants. All they have to do is learn how to let plants dry out to the target weight. The target weight is determined by weighing several plants that are at the point of requiring watering. This point can be moist or dry depending on the grower's preference, but now it can be reproduced regularly. The drier the plant, the fewer the number of irrigations over time. Another method of setting a target weight is to let some established plants dry out to very near the wilting point and check the weight. The difference in weight between a watered plant at container capacity and the weight of a plant near wilting is an estimate of the available water in the pot. If the goal is to minimize irrigation frequency, most plants should be watered when 60 to 70% of the available water is used. The target weight may have to be increased as the crop grows, but not much. A simple scale can make irrigations more predictable the same way a ruler works for taking the guesswork out of height control.

Controlling the duration of application to limit leaching can be accomplished in every greenhouse with minimal investment. The key is to realize that <u>seconds</u> of irrigation time, not minutes, are important when it comes to limiting water use. Use some method to measure the length of time the plants are watered.

Root Media Selection

Root media can be selected for higher water holding capacity. For example, rockwool adds water holding capacity when blended with peat. Growers must remember however that higher water holding capacity means the frequency of watering must be reduced. The media should be allowed to dry out or we will be back where we were 30 years ago.

Leaching must also be minimized if there is to be any advantage. One media may hold up to twice the available water of a second media. This could cut the number of irrigations needed in half. However, the amount of runoff will be the same if the leaching fraction is kept at 30 or 40%. Leaching must be minimized.

In some cases, just filling the pot more or filling them thoroughly and uniformly will increase water holding capacity and decrease irrigation frequency. Careful watering to reduce media shrinkage will also help. Hose watering goes faster with higher flow rates, but more water and media end up in the pot with slow flow rates. The person on the end of the hose becomes even more important. Remember that sometimes high flow rates are

used to get a fertilizer injector to work properly. Make sure the injector works properly at lower flow rates. In some cases a mixing tank may be need.

There is not very good information about cation exchange capacity of soilless potting media and how much effect it can have on fertilization requirements and runoff. This is an area that needs work. Higher nutrient holding capacity may not be needed if fertilizer is applied regularly at low levels and with reduced leaching, or if resin coated fertilizers are used.

Fertilize When Needed

Why should growers leach? Many times applying clear water with no leaching can allow time for the fertilizer in the media to be used by the plant rather than washed away. In many cases in the United States, water quality is good enough that leaching should almost never occur. If salt levels are high due to fertilization, stop fertilizing. Recognize that there are greenhouse operations that would be out of business if they stopped leaching because of poor water quality. How do you know what to do? Water and media analysis.

Many growers do not know the level of nutrients available in the root media. It has become easier to leach heavily with a known concentration then to test the media and find out what is needed. The lack of media analysis in the greenhouse is possibly a result of too little time and labor to do the job or a lack of expertise in how to do it. Educating growers about media analysis methods should be one of our highest priorities for the coming year.

To use the example of our beginning students again, they could not be a very effective grower without a soluble salt meter. Weekly media analysis for pH and EC is one of the first things they learn. It is a tool they can use to know how much fertilizer is present and whether more is needed. Fertilizing only when needed based on root media analysis and graphical tracking of EC can greatly reduce the amount of fertilizer applied, and make better crops.

Our research indicates in many cases too much fertilizer is applied. We have worked mainly with bedding plants and poinsettias, but have data on Easter lily also. These crops require relatively little fertilizer as long as nutrient levels are maintained in the media at the proper level. The key is regular application, controlled leaching, and weekly analysis of media EC. Weekly checking pH and EC will prevent most nutritional problems growers experience.

One of the other problems we face, however, is that current recommended root media analysis levels may be too high. Some growers are working very hard to reach levels recommended on a soil test. Not only are the high levels recommended not needed, but with heavy leaching they may never be attained. Not even with 400 ppm nitrogen applied constantly.

Poinsettias are often referred to as "heavy feeders". We have completed seven experiments over three years and in each case poinsettia production required very little fertilizer. As long as some nutrient charge is present in the root media (60-100 ppm N, 5-10 ppm P, 100 to 150 ppm K, 50-100 ppm Ca, 30-50 ppm Mg by saturated media extract), watering in with fertilizer concentrations of more than 100 ppm is a waste of fertilizer. Watering with little or no leaching and clear water the first week has given us excellent results. Levels above 200 ppm nitrogen should rarely be needed during production if applied regularly. Our poinsettias for classes will be fertilized primarily with 1/4 pound potassium nitrate and 1/4 pound ammonium nitrate (calcium nitrate and phosphoric acid later) per 100 gallons started one week after planting. (We have high alkalinity water with 80 ppm Ca^{++}.) The poinsettia can require large amounts of water under some conditions and the leaching that occurs can make it seem like more fertilizer is needed.

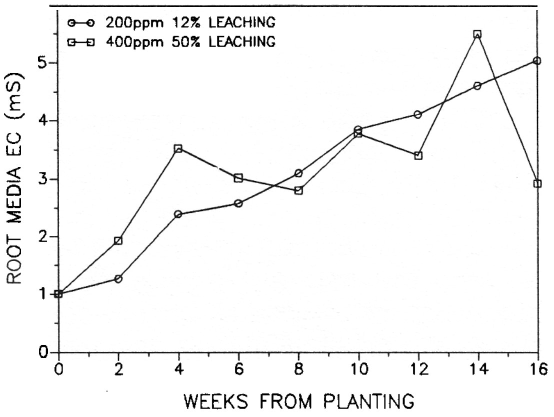
Reducing Leaching

Excess leaching can be avoided with a variety of techniques. Irrigation systems need to be designed to provide uniform pressure and water flow at all locations. With uniform water application, pulsed application of water, for example 2 applications of 1 minute instead of 1 application of 3 minutes, will use less water and reduce or stop leaching. Low volume drip applicators will help if water quality is acceptable and the drippers do not plug. Use of wetting agents to assure rapid wetting of dry root media and to reduce channeling of water down the sides of pots can also reduce leaching and the volume of water applied.

Fertilizer concentrations can also be reduced so less leaching is needed. Another way of looking at this is that if the leaching is reduced, the amount of fertilizer will have to be reduced. The root media availability of nutrients and soluble salts is a function of both the concentration and the volume leached. In one experiment, we applied 200 ppm N with 12% leaching (ex: 16 fluid ounces applied and 2 ounces leached) or 400 ppm N with 50% leaching (ex: 40 fluid ounces applied and 20 ounces leached) to six inch poinsettias. The difference was 5 times as much fertilizer applied. Both strategies resulted in a similar EC level in the root media (see Figure) and still provide more than what was needed to grow a good 6 inch poinsettia. Only 100 ppm with 12% leaching was needed.

If water quality is poor or saline, EC $>$ 1.25 mS, instead of or in addition to leaching, try to lower irrigation water EC by changing water sources, using rain water, blending water sources, or water treatment like reverse osmosis. More growers need to consider collecting and using rain water, particularly when alkalinity is a problem.

Water collection trays can be used with overhead irrigation systems or hand watering. These trays provide a type of subirrigation and greatly increase the efficiency of overhead irrigation. This is a low investment approach which can have a major impact on water and fertilizer use. Remember that leaching is reduced and so should fertilizer concentrations.



Low Cost of Water and Fertilizer

Since water and fertilizer costs make up only a small percentage of total costs, conservation has not been considered economically important. The actual cost of fertilizer is less than 1 to 2% of total production cost per pot in most cases. Small savings in water and fertilizer cost can mean significant increases in profit per unit however. A savings of 1 cent per pot is a 10% increase in profit if you only make 10 cents per pot. The environmental and regulatory costs of excess water and fertilizer use must also be considered.

Not all greenhouses have problems with fertilizer runoff. My observation is that for smaller greenhouse operations, the cost of a bag of fertilizer is a significant cost. Fertilizer is used sparingly, when it is needed, based on the appearance of the plants. Larger greenhouse operations that buy fertilizer by the pallet or truck load tend to use fertilizer more liberally. Fertilizer cost is not that important to them. These operations usually fertilizer regularly based on recommended rates.

Collecting and Recycling Runoff

Most of the suggestions so far have been directed at limiting runoff or the need to collect excess water. For most greenhouse operations it will be more economical to limit runoff then to collect it and reuse it. Runoff can be collected when possible and the water reused. The type of watering system and greenhouse floor will determine how excess water is collected.

With very porous soils that allow water to percolate quickly, cement floors would probably be required. Cement floors are not economically feasible for many greenhouse operations. If floors are going to be poured, they should be floors suitable for subirrigation and runoff will no longer be a problem. With heavy, clay subsoils, field drains can be used to collect runoff into a central location. The water holding area can be an earthen pond, a vinyl lined pond, or an in ground cement reservoir similar to a manure holding tank. Above ground water silos are available but would require pumping and lifting the water. Only a limited number of greenhouse operations are currently collecting runoff in an open system. Occasional testing of the water may be needed.

Based on the limited information available to me, there has not been the problem of rampant disease spread that is often expected with open collection of runoff water. Where the water goes and how it is collected will determine the potential for pathogen problems. The temperature and aeration level during storage also is probably important.

Some form of water treatment may be desired when the water is recirculated. At least two very large horticultural operations have chosen to treat the recirculated water with chlorine. The other alternative that is available and used by some greenhouses is the bromine biocide, Agribrom. Agribrom has been shown to be safe to plants and when used properly will kill algae and other organisms in recirculated water. There are some growers in Michigan treating fresh, nonrecirculated irrigation water with Agribrom. Heat treatment of water is another alternative that is being tried in Europe.

Subirrigation

Rather than using open systems that allow for contamination of the water, the use of subirrigation with recirculated solutions provides the most efficient and thorough method of controlling water and fertilizer runoff. Several methods are available, the main ones being flood benches, flood floors, and flowing water in troughs. There is no doubt that they work, but cost can be a real barrier. We have done experiments with subirrigation of poinsettias, Easter lilies, chrysanthemum, geranium, and bedding plants. Despite the many advantages, investment in these systems should only be made with careful planning to cover the cost. Flood floors may be the affordable answer for many growers.

Summary

The bad news is that many of the new ideas being suggested are contrary to what has been recommended for the past 20 years. Implementing these ideas will require training growers and greenhouse workers. The good news is that there are several areas for improvement with our current approaches to fertilization and irrigation.

John Biernbaum is an Associate Professor in the Department of Horticulture at Michigan State University. The information in this handout is not to be reproduced or published without the consent of Dr. John A. Biernbaum, Department of Horticulture, Michigan State University, East Lansing, MI 48824. This research has primarily been funded by the Michigan Agriculture Experiment Station and the American Floral Endowment. Additional support has been provided by The Bedding Plant Foundation, The Gloeckner Foundation, The Western Michigan Bedding Plant Association, Greenhouse operators supportive of MSU research, and manufacturers and suppliers of greenhouse products. The research reported is largely the work of Renee George, Mark Yelanich, and Bill Argo, graduate research assistants.

Soil Test Interpretation and Recommendations

The information within this article was developed to serve as a quick reference for interpretation of floriculture soil tests by the University of Minnesota. In addition to supplying the recommended ranges for the various factors quantified in the soil test, some recommendations for common problems are also supplied. Specific recommendations for your situation can be obtained by calling me, John Erwin, at (612)-624-9703. Making sure you have both a recent water test as well as the soil test are recommended. It is very possible that you may receive the 'voice mail' system when you call. This means that either I am out of my office or am on another line. Always leave a message! I will return your call as soon as possible.

Test Parameter or Nutrient	Recommended	Acceptable	Toxic
pH	6.2-6.8	5.8-7.2	>7.6
Soluble Salts (SS)	80-140	50-150	>150
Nitrates (N03)	150-250	100-350	>400
Ammonium (NH4)	0-10	0-15	>15
Phophorus (P)	10-15	5-20	>80
Potassium (K)	50-100	30-120	-
Calcium (Ca)	50-200	25-300	-
Magnesium (Mg)	30-50	20-60	-
Sodium (Na)	10-40	5-60	-
Iron (Fe)	0.20-0.50	0.10-0.70	-
Manganese (Mn)	0.50-1.50	0.30-1.75	-
Zinc (Zn)	0.10-0.50	0.05-0.75	-
Boron (B)	0.05-0.25	0.02-0.50	>1.00

Typical Problems

High pH - High pH is by far the most common problem in greenhouse media in the upper midwest. The best solution is to amend the water and/or fertilizer solution before it is applied to the pot! If pH is high, a one time quick method to drop the pH is recommended. The easiest way to do this is by adding acid to your water and drenching the media. The exact amount of acid which is needed to drop your media pH is difficult to determine; it varies with water source, and media and fertilizer composition. However, a 'rule of thumb' which has worked is to add 2.0-3.5 ounces of 75-85% phosphoric acid to 100 gallons of water (final solution) as a 1 time drench. In general, this will drop the media pH 0.5-1.0. Do not add more than this! Test media before attempting to adjust further.

High Soluble Salts - The easiest way to solve a high soluble salts problem is to 'leach' the media. Leaching is simply watering with clear water for an extended period of time. Remember that your pH will probably increase since water pH in the upper midwest is generally high.

High Ammonium - High ammonium levels can result in ammonium toxicity. High ammonium often results from using fertilizer which contains ammonium during a period of the year when both light levels and temperatures are generally lower. Ammonium toxicity is prevalent from October 15 to March 15. Ammonium tends to build up more easily in media which contain soils. Ammonium toxicity is aggravated by high pH, low potassium, and cool temperatures. If ammonium levels are high 1) stop using fertilizers which contain ammonium, 2) leach the media, 3) lower pH, and 4) increase the potassium content of the media.

Low phosphorus - Phosphorus levels can be increased rapidly by applying a 'starter' fertilizer high in phosphorus as a 1 time application. Generally if phosphoric acid is being injected into the water to modify pH, the phosphorus requirements for plant growth are met.

Low Potassium - Potassium deficiency is characterized by a yellow 'speckling' on the leaves. Increase the amount of potassium nitrate which is in your fertilizer mix. A potassium deficiency is aggravated by nitrate levels more than 3 x's that of the potassium level. Always try to maintain a potassium level 1/3 of that of the nitrate level.

High Calcium - High calcium usually suggests high water alkalinity. High calcium is usually not detrimental, however, it can aggravate a magnesium deficiency. Therefore, make sure that magnesium levels are as close to 1/3 that of the total calcium levels in a crop.

Low Magnesium - Magnesium leaches readily from a medium. Therefore, it is often necessary to add magnesium through continuous feeding or with regular single drenches. Drench a minimum of 1 time each month with magnesium sulfate (Epsom salts, $MgSo_4$) at a rate of 8 ounces/100 gallons. Alternatively, apply 2 ounces $MgSO_4$/100 gallons water in a continuous liquid feed program. Do not mix magnesium sulfate and calcium nitrate together; they will react in the stock tank.

Low Iron, Manganese, and Zinc - Add a micronutrient source to your regular feed program or drench with a micronutrient source. A good time to do this is in combination with the monthly magnesium sulfate drench.

High Boron - High boron often results from a high boron content in your water source. Have the water source tested. It may be necessary to eliminate any micronutrient applications and/or use reverse osmosis to 'clean' your water. Leach with water.