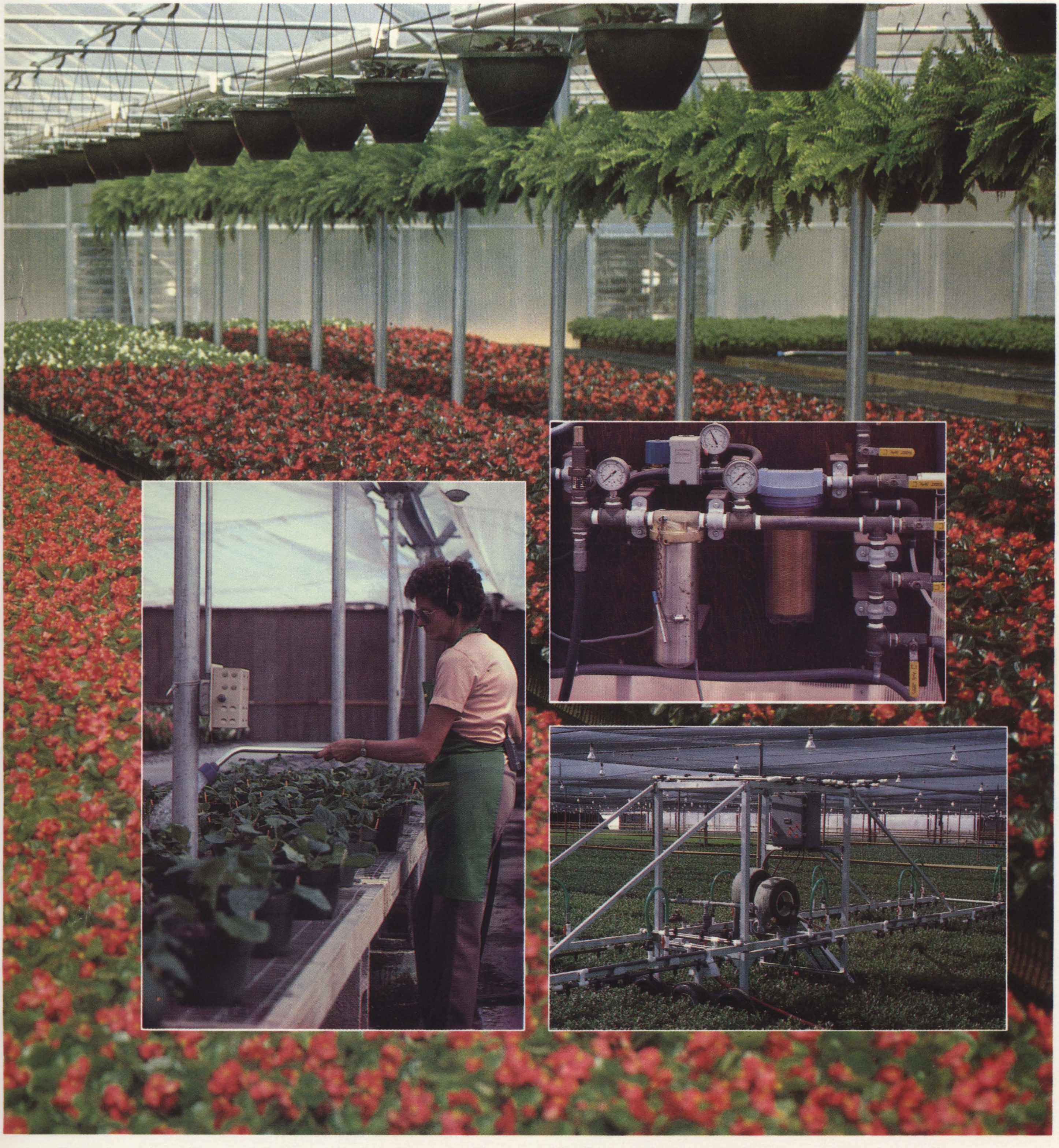
Texas Agricultural Extension Service

Don - My suggestions for revision are marked inside

Water Management Guidelines for the Texas Greenhouse Industry



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Water Management Guidelines for the Texas Greenhouse Industry

A guide for protecting and conserving our natural water resources

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INTRODUCTION TO WATER QUALITY MANAGEMENT

Texas Greenhouse Management Handbook

The use of fertilizers and pesticides is a very important aspect of the commercial production of high quality greenhouse crops. In the United States alone, agricultural applicators have increased the use of nitrogen fertilizers from 2 million tons in 1955 to more than 12 million tons in 1990. Pesticide use has more than tripled since 1964, with approximately 1.5 billion pounds per year now being applied. These significant increases indicate the many benefits derived from the use of fertilizers and pesticides. However, these chemicals also pose a potential threat to our fragile environment.

Runoff from rain or irrigation can concentrate fertilizers and pesticides at collection points where they may enter surface and groundwater reserves. The continued, largely unregulated, use of such chemicals could potentially contaminate lakes, streams, ponds, wells and groundwater.

Injurious effects such as fish kills, reproductive failures in birds and acute illnesses in humans and animals have been correlated with contaminated water. However, the exact source(s) of these damaging chemicals is not always apparent. Because we have a poor understanding of the results of long-term exposure to chemicals, the exact identification of hazards is difficult.

At present, half of the population of the United States relies on underground sources for drinking water. Rural residents are even more dependent on these natural water resources. More than 90 percent of rural water is now being retrieved from groundwater sources. But of all the groundwater withdrawn each year, only a small amount is used strictly as drinking water.

Most groundwater (82 percent) is used for agricultural irrigation. The availability of large volumes of high quality irrigation water is an important factor in the production of greenhouse crops. It is extremely important to protect and conserve this natural resource. A significant quantity of this irrigation water will reenter the water cycle to replenish groundwater supplies. Therefore, fertilizers and pesticides must be used wisely.

The following guide has been compiled to provide growers both with recommendations for optimum growth and with *production alternatives* to help reduce the use of fertilizers and pesticides. A balanced approach which combines traditional cultural practices with a concern for the environment will be an important key to protecting our natural water resources and the future growth of the Texas greenhouse industry.

MONITORING THE QUALITY OF IRRIGATION WATER

Texas Greenhouse Management Handbook

Irrigation water is a key factor in the production of nursery and greenhouse crops. Therefore, it is important to monitor water quality frequently to avoid potential problems.

Often growers are unfamiliar with the many factors measured in a routine water test. This makes interpretation of the results somewhat difficult. Following is a brief summary of these quality factors, as well as guidelines for determining their effect on plant growth.

? Specific conductance or

Electrical Conductivity (EC) is a measure of the total salt content of water based on the flow of electrical current through the sample. The higher the salt content, the greater the flow of electrical current. EC is measured in mho/cm, which is the opposite of ohms of electrical resistance. Since the conductivity of most water is very low, EC is generally reported in thousandths of an mho or millimhos/cc.

Carbonate + Bicarbonate ($CO_3 + HCO_3$) are salts of carbonic acid (the acid formed when carbon dioxide dissolves in water). In combination with calcium and/or magnesium ($CaCO_3$, $MgCO_3$) they have an alkalizing effect. This effect is generally mild because these are slightly soluble salts of moderately strong bases and weak acids. A stronger alkalizing effect may occur in the presence of sodium (Na_2CO_3) because this is a highly soluble salt of a strong base and weak acid. Carbonates and bicarbonates are reported in milliequivalents/liter.

Calcium and Magnesium (Ca, Mg) are cations (positively charged ions) which are present in water. In most cases the sum of Ca and Mg are reported in milliequivalents/liter. Together Ca + Mg may be used to establish the relationship to total salinity and to estimate the sodium hazard.

Sodium (Na) is another cation occurring in most irrigation water. Along with Ca and Mg, Na content usually exceeds 0.1 percent. Sodium is often responsible for salinity problems when linked to chloride (Cl) or sulfide (SO_4), but seldom when linked to Ca or Mg.

Sodium is expressed in terms of the sodium absorption ratio (SAR), calculated as follows:

$$\frac{Na^{+}}{\sqrt{\dfrac{Ca^{++} + Mg^{++}}{2}}}$$

are expressed
where Na^+, Ca^{++} and Mg^{++} are expressed
in ~~milliequivalents~~/l
in milliequivalents/l

Chloride (Cl) is an anion (negatively charged ion) which frequently occurs in irrigation water. Cl determinations are used to establish the relationship to total acidity and to indicate possible toxicities to sensitive crops.

Acidity/Alkalinity (pH) is caused when acids mix with water and ionize into hydrogen ions (H+) and associated anions. The stronger the acid the greater the amount of ionization. Weak acids (such as those in irrigation water) generally ionize to less than 1.0 percent. The H+ ion activity of these acids is stated in terms of the logarithm of the reciprocal of H+ ion activity or pH.

Interpreting Water Quality

The quality of irrigation water is dependent on total salt content, the nature of the salts present in solution and the proportion of Na to Ca, Mg, bicarbonates and other cations. The following table presents guidelines for interpreting water quality factors.

Table 1. Water quality standards for the production of greenhouse and nursery crops.

Quality	Electrical conductivity ECX10^{-3}(millimhos)	Total soluble salts (ppm)	Sodium content (% salts as Na)	SAR	pH
Excellent	0.25	175	20	3	6.5
Good	0.25 - 0.75	175 - 525	20 - 40	3 - 5	6.5 - 6.8
Permissible	0.75 - 2.0	525 - 1400	40 - 60	5 - 10	6.8 - 7.0
Doubtful	2.0 - 3.0	1400 - 2100	60 - 80	10 - 15	7.0 - 8.0
Unsuitable	>3.0	>2100	>80	>15	>8.0

For approximate conversion of EC to parts per million use the following calculations:

Millimhos

$$\text{ppm} = (\text{EC} \times 10^{-3}) \times 670$$

Micromhos

$$\text{ppm} = (\text{EC} \times 10^{-6}) \times 0.67$$

TREATING IRRIGATION WATER

Texas Greenhouse Management Handbook

Water quality is one of the most critical factors affecting the production of nursery and greenhouse crops. This is particularly true in Texas, where growers must combat a variety of water quality problems. In the past, producers were forced to use the water they had available, regardless of quality. Today, however, the use of treated irrigation water is increasing.

Generally speaking, there are three major water characteristics that Texas growers may modify. These include pH, alkalinity and soluble salts.

Alkalinity and pH largely determine the efficacy of pesticides and plant growth regulators. However, these properties most often affect the solubility of fertilizer in the growing medium, particularly the micronutrients and magnesium.

What is pH?

pH is a measurement of the concentration of hydrogen ions (H^+) in a solution. Since this represents a logarithmic expression, H^+ concentration at pH 6.0 is 10 times greater than at pH 7.0 and 100 times greater than at pH 8.0. In this relationship, pH has no direct effect on plant growth. However, pH does affect the form and availability of nutrient elements in irrigation water, fertilizer solutions and the growing medium.

The pH of irrigation water usually should be within the range of 5.5 to 6.5. This level enhances the solubility of most micronutrients and prevents a steady increase in the pH of the growing medium. This pH range also optimizes the solubility of nutrients in concentrated fertilizer stock solutions.

pH and Alkalinity

pH is often described in terms of acidity. This is based on the ability of certain acids to dissociate or ionize into H+ ions and associated anions.

$$H_2SO_4 \xrightarrow{\qquad\qquad} \underset{\text{H+ions}}{2H} \quad + \quad \underset{\text{Anions}}{SO_4\text{-}}$$

Alkalinity is a measure of a water's capacity to neutralize these acids. Chemically, this is expressed in parts per million (ppm) of calcium carbonate equivalents ($CaCO_3$). Bicarbonates, carbonates and hydroxides are the primary chemicals that contribute to the alkalinity of water.

Sound confusing? Well, simply stated, alkalinity affects the ability to reduce pH by neutralizing added acids. A more graphic example of this relationship is presented in Table 1.

Table 1. Amount of acid required to reduce pH to 5.0.

Sample	Existing pH	Alkalinity ppm $CaCO_3$	Acid required
A	9.3	71	1.2*
B	8.3	310	6.0

*Number of ml of 0.1N H_2SO_4 / 100 ml water.

As you will note, sample B is a full pH unit lower than sample A, but because of the neutralizing effect of $CaCO_3$ alkalinity, it requires five times more acid to lower the pH to 5.0. High alkalinity can cause the precipitation of nutrients in concentrated fertilizer solutions, increased pH of the growing medium (which in turn reduces the availability of micronutrients), reduced efficacy of pesticides and growth regulators, and, in severe cases, foliar residue.

Adjusting the pH of Irrigation Water

To optimize fertility and combat the other adverse effects of high pH/ alkalinity, irrigation water can be treated by injecting acid. Phosphoric and nitric acids have some application, but sulfuric acid is the most commonly used. There are several "acid compatible" injectors on the market. Their prices range from \$200 to \$300 into the thousands, depending upon your needs. Some of these systems consist of a flow meter, injector and pH meter to automatically adjust the amount of acid used.

The first step in evaluating acid injection is to have your water tested (for information contact your county Extension agent). In addition, a good quality pH meter is essential. To calculate the amount of acid required to achieve the desired pH, first fill a 5-gallon bucket with irrigation water, then slowly add the type of acid you wish to inject and stir the water to ensure complete mixing. Measure the pH of the water and continue until the desired pH is obtained. The quantity of acid required may be quite small; as little as 0.5 ounces of sulfuric acid may be required to reduce the pH from 7.0 to 4.0.

When the quantity of acid required to correct the pH of the sample has been measured, it is a simple operation to calculate the amount of acid to inject into the system, assuming the amount of water passing into the system is known. (The Texas Agricultural Extension Service Soil and Water Testing Lab has recently established a titration process to assist in determining the amount of acid required. Contact your county Extension agent for more information.)

Acid should be injected into the irrigation system up-line from the nutrient injection point. This will increase the solubility of fertilizer running through the system. Also use acidified water to mix all fertilizer and pesticide solutions.

Soluble Salts

The presence of high soluble salts in irrigation water is one of the most limiting factors in the production of nursery and greenhouse crops. Although certain management techniques may be used to deal with some of these problems, sometimes more drastic action is needed.

Many producers are now using water treated through a process known as reverse osmosis (RO) to remove potentially harmful salts. RO water is cheaper than distilled or deionized water and the overall quality is the same. While it is possible to purchase an RO system, most units now in operation are under lease.

Unfortunately, the use of RO water does not solve all the problems associated with soluble salts. In fact, it can create some very unique situations that are, in many respects, more difficult to correct. Growers generally take for granted the micronutrients present in irrigation water. This source of essential elements is extremely important in supplementing a basic fertility program. When micronutrients are eliminated from irrigation water through the RO process, plants may be subject to a wide range of nutrient deficiencies because of a low supply of a particular element or because of an imbalance between nutrients. Identifying and correcting deficiencies can be tricky in these "super clean" systems.

As a possible solution to this problem, many growers now blend their RO water with other sources (i.e., well, city, river, etc.). By mixing their treated water with the normal source, growers can supply many of the needed nutrients and still reduce soluble salts to an acceptable level. At present a 50-50 mix seems desireable, but further reductions in the percentage of RO water used may be feasible. An additional benefit to this approach is that the cost per gallon is considerably reduced.

Although the use of RO water has some significant limitations, it also has tremendous potential where high soluble salts are a problem. Reverse osmosis will not solve every problem, but used wisely it can be a valuable tool in producing quality crops.

Although the costs of treating irrigation water are substantial, increased quality and reduced losses often offset the required investment. If growers are to maintain profitability, they must continue to evaluate improved cultural techniques for production.

AIR, WATER AND MEDIA... PUTTING THEM ALL TOGETHER

Texas Greenhouse Management Handbook

The relationship between growing medium, air and water is one of the least understood aspects in the production of greenhouse and nursery crops. As a result, a significant amount of plant loss may be related either directly or indirectly to an improper match between these cultural elements. A basic understanding of the factors that mediate this relationship can be valuable in developing sound management practices.

Pore Space

Growing medium consists of solids (i.e., peat moss, bark, perlite) and pore space. Pores are created by the spaces between the solid components of the medium. Therefore, a mix which contains coarse aggregate has fewer but larger pores than one made up of fine aggregate. The size and distribution of pores is one of the most critical factors in developing a growing medium with optimum physical characteristics.

Most soilless growing media contains 60 to 80 percent total pore space. A portion of this space is occupied by air. Plant roots require oxygen for growth so adequate aeration of the medium is necessary. As roots take up oxygen they also give off carbon dioxide. This exchange of gases is primarily by diffusion through the pores of the growing medium.

Although total pore space is a measure of a growing medium's ability to hold air and water, pore size determines the rate of drainage and gas exchange. Large pores permit air to re-enter the medium following irrigation. Since growing medium in containers holds a relatively large quantity of water, the percentage of pore space filled with air is reduced. Therefore, an adequate distribution of large and small pores is essential. On average, most mixes contain 10 to 30 percent air following irrigation.

Water is also held in the pore space of a growing medium. The availability of this water for plant growth is largely determined by how tightly it is held by the solid component of the medium. The closer a water molecule is to a solid, the more tightly it is held through the forces of adhesion and cohesion. Therefore, a fine mix may hold more water than a coarse mix, but less of it is available to the plant. In general, the amount of unavailable water is relatively high in soilless growing medium.

Drainage

Drainage is affected by pore size and the shape of the container. Water occupying large pores is held less tightly because the molecules are not as close to the solids in the medium. As a result, this water is more available to the plant and also drains at a faster rate than water occupying smaller pores.

The length of the soil column also influences the rate of drainage. The taller the container, the greater the force of gravity on the water occupying the pore space. This results in increased drainage. Shorter columns of an equal volume of medium hold more water, drain more slowly and contain less air.

Compaction is another factor that affects drainage. Packing growing medium into a container can significantly reduce the number of large pores. When this occurs, less water is available to the plant, aeration and gas exchange are reduced, more water is held and drainage is decreased. In smaller containers the effect of compaction can be even greater.

Water Holding Capacity

Establishing a balance between the water holding capacity of a medium, aeration and drainage is a key to optimum plant growth. The cost of irrigation often forces growers to use a medium that holds excessive amounts of water. This frequently results in increased crop time, reduced root growth and poor plant quality.

The amount of water a medium holds is dependent on the components used, pore size and distribution and the shape of the container. Most soilless mixes should hold approximately 60 to70 percent water after drainage.

Putting Them All Together

Developing an effective plan for irrigation management requires a careful match between the needs of the plant and the growing medium. Although growers are most frequently concerned about the lack of water in the medium, research now indicates that the potential hazards from overwatering may be much greater.

Although aeration is an essential requirement for optimum plant growth, the pressure to conserve water is forcing growers to use mixes that hold large volumes of water. An understanding of the relationship between growing medium, air and water can be extremely helpful in developing sound management practices.

Table 1. The effect of container size and medium compaction on air and water.

	Container size		
Degree of compaction	**4-inch**	**6-inch**	**1-gallon**
Light compaction			
Available water	2	48	45
Unavailable water	22	25	24
Air space	19	23	25
Medium compaction			
Available water	53	50	48
Unavailable water	21	23	24
Air space	12	17	22
Heavy compaction			
Available water	49	45	42
Unavailable water	29	31	28
Air space	8	12	19

A 2:1 v/v bark:sand medium was used for this example.

DEVELOPING OPTIMUM FERTILITY REGIMES

Texas Greenhouse Management Handbook

Maintaining adequate nutrition is one of the most critical aspects of producing greenhouse crops. At present, most growers use a liquid feed as their primary source of plant nutrients. Liquid feed may be supplemented by adding granular or slow release fertilizers to the growing medium.

The frequency of fertilizer applications also influences plant growth. In some cases it is important to supply nutrients at peak periods of vegetative or reproductive growth. However, it is generally accepted that feeding soluble fertilizer at each irrigation is the best way to optimize plant growth.

A "constant feed" program may be modified so that nutrients are applied at every other irrigation. This approach may be necessary when water is high in soluble salts.

The balance of plant nutrients is important in producing vigorous, efficient plants. When nutrients are out of balance severe deficiencies or toxicities may occur. Therefore, it is important to consider both the source and amount of fertilizer used.

Selecting Fertilizers

Several "complete" fertilizers are available from commercial sources. These provide N, P and K in the balance desired (i.e., 15-16-17, 20-20-20, etc.). However, many growers "custom blend" fertilizers from several different sources to achieve the best balance for plant growth. Tables 1 and 2 provide a quick guide to several of the most commonly used fertilizer materials and show the amounts required to make up desired concentrations.

Selecting the type of fertilizer to be included in a nutritional regime is a key to optimum plant growth. The following is a brief description of the nutrients frequently used:

Nitrogen (N) is often thought of as the most important element in a nutritional program. However, it is only one of several essential elements. The most common sources of N used in liquid feed programs include ammonium nitrate, calcium nitrate and potassium nitrate. Generally speaking no more than 50 percent of the total N supplied to the plant should be in the ammonium form.

Phosphorus (P) is another element required in relatively large quantities, but too much P may render other nutrients insoluble and, therefore, unavailable to plants. Phosphorus is generally supplied by phosphoric acid in liquid feed or by superphosphate incorporated in the growing medium.

Potassium (K) or potash is used by the plant in a number of ways, but is primarily required in water relationships. Poinsettias are notably heavy K feeders. The most common source of K in liquid feed programs is potassium nitrate; however, other sources may be used.

Secondary and micronutrients also are necessary to a complete nutritional program. These two classes of elements generally include calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), boron (B), molybdenum (Mo) and chloride (Cl). Many of these may be supplied by the growing medium; others require supplemental application.

Secondary and micronutrients may be included in a liquid feed program. However, many growers pre-incorporate these elements into the growing medium. Dolomitic lime is perhaps the most common source of Mg used in this manner. There are also several commercial blends of micronutrients which may be incorporated into the growing medium.

Summary

The primary method of supplying nutrients to greenhouse crops is by means of a liquid feed program. This can be supplemented with the addition of secondary and micronutrients to the growing medium.

Constant feed programs supply optimum quantities of nutrients for plant uptake, but the level of nutrition must be based on the presence of soluble salts. Complete fertilizers containing N, P and K in desired ratios may be used for greenhouse crops, or fertilizers can be custom blended to meet the needs of the plant.

Table 1. Parts per million (ppm) of a nutrient element in solution when the specified fertilizer compound is dissolved in 1 gallon of water.

Fertilizer	Fertilizer and element percentage	Amount per gal	N	P	K	Ca	Mg	S	Cl
Potassium nitrate	13.75-0-44.5 (36.9K)	1 g	36	97					
Potassium sulfate	0-0-50 (41.5K, 17S)	1 g			110			45	
Muriate of potash	0-0-60 (49.8K,45 Cl)	1 g			131				119
Mono pot. phosphate	0-22.8-28.7	1 g		53	75				
K-Mag or Sul-Po-Mag	0-0-22 (18K, 11Mg, 22S)	1 g			48		29	58	
Mono cal. phosphate	0-46-0 (20P, 13Ca)	1 g				34			
Calcium nitrate	15.5-0-0 (19Ca)	1 g	41			50			
Ammonium nitrate	33.5-0-0	1 g	88						
Ammonium sulfate	21-0-0 (24S)	1 g	55					63	
Urea	46-0-0	1 g	121						
Nitric acid	70% HNO_3 (15.5N)	1 g	41						
Diammonium phos.	18-46-0 (20P)	1 g	47	53					
Phosphoric acid	75% H_3PO_4 (.363g.P/ml)	1 ml		96					
Gypsum (cal. sulfate)	18.6Ca, 14.9S)	1 g				49		39	
Epsom salts	(9.9Mg, 13S)	1 g					26	34	

Note: For all practical purposes 3.5 ounces of fertilizer dissolved in 100 gallons of water yields the same ppm of element in solution as that given for 1 gm/gallon. (28.35 gms = 1 ounce).

Table 2. Fertilizer sources for greenhouse crops.

	Analysis	
Name and formula of material	**N-P-K**	**Others**
Ammonium chloride NH_4Cl	25-0-0	0
Ammonium nitrate NH_4NO_3	33.5-0-0	0
Ammonium phosphate (di) $(NH_4)2HPO_4$	21-53-0	0
Ammonium phosphate (mono) $NH_4H_2PO_4$ 2.6% S	11-48-0	1.4% Ca
Ammonium sulfate $(NH_4)2SO_4$	20-0-0	24% S
Calcium nitrate $Ca(NO_3)_2$	15-0-0	37% Ca
Sodium nitrate $NaNO_3$	16-0-0	0
Urea $CO(NH_2)_2$	45-0-0	0
Urea-formaldehyde	38-0-0	0
Superphosphate $CaH_4(PO_4)_2$	0-20-0	18% Ca 12% S
Treble phosphate $CaH_4(PO_4)_2$	0-42-0	12% Ca
Phosphoric acid H_3PO_4	0-52-0	0
Potassium chloride H_3PO_4	0-0-62	0
Potassium chloride KCl	0-0-62	0
Potassium nitrate KNO_3	13-0-44	0
Potassium sulfate K_2SO_4	0-0-53	18% S

(Continued on next page.)

	Analysis	
Name and formula of material	**N-P-K**	**Others**
MagAmp-Magnesium Ammonium phosphate	7-40-6	0
Magnesium sulfate $MgSO_4 7H_2O$	0 10%	Mg
Magnesium nitrate $Mg(NO_3)_2 6H_2O$	0	9.5% Mg
Gypsum $CaSO_4 2H_2O$	0	23% Ca
Manganese sulfate $MNSO_4$	0	28% MN
Boric acid H_3BO_3	0	17%B
Copper sulfate $CuSO_4 5H_2O$	0	25% Cu
Iron sulfate $FeSO_4 7H_2O$	0	20% Fe
Iron chelates	0	Various % of Fe
Ammonium molybdate $(NH_4)6Mo7O_{24}2H_2O$	0	53% Mo
Zinc sulfate $ZnSO_4 7H_2O$	0	36.4% Zn

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MANAGING SOLUBLE SALTS

Texas Greenhouse Management Handbook

The accumulation of excessive soluble salts, perhaps the most limiting factor in the production of greenhouse crops, results from the use of poor quality irrigation water, over fertilization, or the use of growing media with an inherently high salt content. Although soluble salts can inhibit plant growth, when managed properly their effects may be reduced.

Salt Injury to Plants

Plant injury from excessive soluble salts may first occur as a mild chlorosis of the foliage; later this progresses to a necrosis of leaf tips and margins. This type of injury is largely attributed to the mobility of soluble salts within the plant and their accumulation at the leaf tips and margins. Once the salts reach a toxic level they cause the characteristic "burn" associated with excessive salts.

Roots also may be injured by the presence of soluble salts. This often pre-disposes the plant to a wide range of root diseases (i.e., phythium, fusarium, etc.). Extreme injury may also interfere with water uptake and cause excessive wilting. It is important to inspect the root systems of plants on a regular basis in order to monitor the effects of soluble salts.

Irrigation Water

Irrigation water is a major contributor of soluble salts to the growing medium. Water contains primarily salts of Na, Ca and Mg, although others may be present.

Soluble salts in irrigation water are measured in terms of electrical conductivity (EC). The higher the salt content the greater the EC. In general EC values exceeding 2.0 millimhos/cc are considered detrimental to plant growth. Water quality should be monitored frequently in order to prevent potential problems.

Fertilizers

Fertilizers are forms of salts and therefore contribute to the total soluble salt content of the growing medium. Depending on the salt content of the irrigation water used, fertility levels must be adjusted to avoid salt accumulations.

Fertilizers are often classified by the amount of total salts they contain. This "salt index" can be used to determine the amount of salts contributed to the growing medium. Table 1 presents the salt index of a number of commonly used fertilizers.

Growing Media

Growing media can be formulated from a variety of components such as peat, perlite, vermiculite, pine bark and others. These materials do not usually contain excessive quantities of soluble salts, but it is important to monitor the quality of media components carefully.

In some cases it is necessary to leach a medium thoroughly before using it. This is particularly important for seed germination and other forms of propagation. Media can be leached by running water through individual pots or trays before planting or through the entire volume of bulk medium.

For a quantitative evaluation of this process the electrical conductivity of the leachate may be determined. When the EC is less than 2.0 millimhos the medium is free of excessive salts.

Managing Soluble Salts

Managing soluble salts requires an approach which integrates the type of growing medium used, irrigation frequency, water quality, fertility regime and plant tolerance.

Growing media should contain many large pores to facilitate good drainage. Such media are easily leached to reduce the potential for soluble salt accumulation. When irrigating, it is important to apply enough water so that large quantities drain out of the container. Approximately 15 to 20 percent more water than the container can hold should be applied at each irrigation if the salt hazard is high. Water pressure must be adjusted to avoid overflow.

Since the concentration of soluble salts in plant tissues increases as moisture levels decrease, it is important to monitor the water content of the growing medium. In the presence of excessive soluble salts, growing media should not be allowed to dry out. Maintaining adequate moisture levels can be difficult in porous growing media and requires careful attention.

Providing adequate fertility is important in maintaining optimum plant growth. However, over fertilization can increase the injury from soluble salts. The amounts of nutrients to use must be based on the quality of the irrigation water as well as the fertilizer's salt index. Most fertility regimes used for potted greenhouse crops apply between 150 and 350 ppm (N). Higher levels create a potential for injury.

Perhaps the most effective means of managing soluble salts is to avoid producing salt sensitive plants. Each plant species has a distinct response to salt accumulations and growers often can select those with tolerance. Among the plants with a known susceptibility to soluble salts are chlorophytum, African violets, calceolaria, chrysanthemums, geraniums and petunias.

Table 1. Relative salt index for several fertilizers.

Fertilizer	Salt index
Sodium nitrate	100
Potassium chloride	116
Ammonium nitrate	105
Urea	75
Potassium nitrate	74
Ammonium sulfate	69
Calcium nitrate	53
Magnesium sulfate	44
Diammonium phosphate	34
Concentrated superphosphate	10
Gypsum	5

Sodium nitrate was arbitrarily set at 100. The lower the index value the smaller the contribution the fertilizer makes to the level of soluble salts.

Pesticides and

Perlinter rel

DEVELOPING A MANAGEMENT PLAN FOR IRRIGATION RUNOFF

Texas Greenhouse Management Handbook

Floral and nursery producers rely heavily on fertilizers and pesticides for producing high quality crops. Runoff from rain and irrigation can concentrate these chemicals at collection points where they can enter surface or ground water. Fish kills, reproductive failures in birds and acute illnesses in humans and animals have been correlated with chemical contamination of water.

Many growers are facing the challenge of developing management plans for handling contaminated irrigation runoff. This is no small task, considering that non-compliance with state and federal water quality standards can result in fines of up to $10,000 per day per discharge site. Unfortunately, few growers take the time required to develop such plans until their operations are found in violation. When this situation occurs, time is usually critical and costly decisions are often made in haste.

A management plan is relatively inexpensive to develop, and implementation costs can be phased in over a period of time. These plans can be extremely flexible, and as simple or as complex as needed. Whatever its characteristics, having a plan will be a clear indication that you are working toward managing runoff. The plan will serve as a useful tool in developing control measures.

Monitoring Water Quality

Federal and state standards for irrigation runoff are not always easy to identify or understand. The Environmental Protection Agency has established basic water quality guidelines, and in many areas this agency is responsible for regulating surface and groundwater for the state. In some states, however, water commissions, boards and districts serve as the primary regulatory agencies.

The first step in developing a management plan is to determine what standards apply to your location(s). Direct inquiries through your county Extension office, commodity association or Soil Conservation District.

Once you have this information, it is advisable to submit runoff samples for analysis. A simple test for nitrates, as well as other nutrients, is usually inexpensive. A complete analysis—including pesticides—can be costly.

If you decide to conduct a thorough analysis, first inventory the chemicals used in your operation and then determine the chemicals to include in the analysis. Be aware that the sampling technique, as well as the analytical methodology, can affect the results. Consult your state water testing lab or state chemist if in doubt.

After reviewing test results and local water quality standards, it should be apparent whether or not you have a problem. Excessive nitrates and phosphorus are the most common problems. Check pesticide concentrations carefully to determine if any are above acceptable limits. Monitor on a regular basis and maintain careful records to track water quality.

Developing Cultural Practices

Many of the production techniques used for floral and nursery crops can be easily modified to reduce the potential for contaminated runoff. Most of these decisions will have to be made on a case-by-case basis, but the following are some general suggestions that may be implemented.

Capturing and recycling runoff requires careful management and can be very expensive. Toxic levels of salts and pesticides can accumulate in surface basins, so careful monitoring is essential. Many operations must also be equipped to capture up to the first 2 inches of runoff from rainfall.

Improvng irrigation management reduces runoff by reducing the volume of irrigation water used. This can be accomplished by adjusting irrigation frequency or installing a drip irrigation system (which uses less water than overhead systems).

Optimizing fertility regimes means reducing excessive fertilizer applications, an important means of managing runoff. Carefully evaluate the role of soluble and slow release fertilizers and the sources of raw materials from which they are formulated. Determine the fertilizer concentration that provides optimum plant quality.

Reducing pesticide applications involves applying pesticides only as needed and eliminating routine or maintenance applications. Rely on close inspection and scouting to determine when pesticides are needed. Be familiar with chemicals before using them (read the label) and stay at the low end of recommended rates when possible. Alternate pest control products to avoid insect resistance and try to use resistant plant varieties if available.

Improving application techniques can make the most of the chemicals you apply. Direct pesticide applications to the target area as precisely as possible. Be sure all sprayers are calibrated correctly and that chemicals are mixed accurately. Avoid spills and back siphoning into water supplies. Dispose of empty containers and chemical wastes properly.

Many of these activities are probably already a part of your cultural program, but document them carefully in the management plan, along with those changes to be implemented.

Categorizing Pesticides

The Soil Conservation Service has developed a data base that estimates the potential hazard of various pesticides to water resources. Although these figures aren't precise, they can be used as a guide for developing a management plan. The following factors were considered in classifying pesticides:

Formulation type refers to the physical form of a pesticide (i.e., emulsified concentrate, wettable powder, etc.) The long-term (weeks to months) life of a pesticide is a function of its physical properties and persistence, but its initial life (hours to days) is strictly a function of its formulation. For example, about 30 times more wettable powders than emulsified concentrates will be lost if both are applied immediately before rain or irrigation.

The solubility of pesticides in water at room temperature is given in parts per million (mg/1). This is the solubility of pure active ingredient and not the formulated product. Solubility is a fundamental property of a chemical and strongly affects the ease of washoff and leaching through soil. In general, pesticides with solubilities of 1 part per million or less tend to stay at the soil surface and are washed away in runoff.

Half-life, given in days, is the time required for pesticides in soils to be degraded so that their concentration decreases by one-half. Pesticide degradation can be fairly acurately described by assuming that each successive half-life decreases the pesticide concentration by half. For example, a period of two half-lives reduces a soil concentration to one-fourth of the initial amount. "Persistence times," often reported in scientific literature, are the times required for a pesticide to degrade to the point that it is no longer active.

Soil sorption index is measured by the Koc value. The Koc measures a pesticide's tendency to be strongly attached, by chemical or physical bonds, to soil particle surfaces. Higher Koc values (1,000) indicate a stronger attachment to soil and a lesser tendency for the pesticide to move, except with sediment movement. Conversely, pesticides with lower Koc values tend to move with water and can percolate deep below the root zone or be carried away in runoff water.

Runoff potential indicates the tendency of a pesticide to move with sediment in runoff. A large rating means the pesticide has a high tendency to move with sediment, while a small rating means the pesticide has a low potential to move with sediment.

The leaching potential indicates the tendency of a pesticide to move in solution with water and leach below the root zone. The ratings of large, medium, small and total use, shown in Table 1, describe the potential for leaching. A large rating means the chemical has a high potential for leaching. The total use rating means the pesticide shouldn't leach with percolating water.

Unfortunately, little is known about the leaching capacity of most pesticides in soil mixtures or soilless growing media. Since a portion of applied pesticides will first move through these substrates, it is important to consider their interaction.

Producers should try to reduce their use of pesticides with high surface loss and leaching potentials. This is not to say that these chemicals should be eliminated from the inventory, but that their use be limited to an "as needed" basis. The Soil-Pesticide Interaction Ratings Matrix and other information available from the Soil Conservation Service can be used to determine the overall potential for pesticide loss to surface runoff or leaching.

Common Sense is the Key

Many aspects of dealing with runoff are really nothing more than common sense. But organizing your thoughts in a water management plan can help identify areas where more than just good judgement may be required.

Water quality is a sensitive, emotional issue that will become increasingly important. Developing sound management practices for your operation *now* may prove to be a much more efficient use of time than responding to a crisis later.

Table 1. Surface loss and leaching potential for commonly used greenhouse pesticides.

Common chemical name	Trade name/ formulation	Solubility (ppm)	Half life (days)	Sorption ratio (Koc)	Surface loss potential	Leaching potential
Acephate	Orthene WP	650000	3	100	small	small
Aldicarb Temik	10G	6000	30	30	small	large
Ancymidol	A-Rest	650	20*	120	medium	medium
Azinphosmethyl	Guthion 50WP	29	40	1000	large	small
Benomyl	Benlate WP	2	100	2100	large	small
Carbaryl	Sevin WP	40	7	229	medium	small
Carbofuran	Furadan 10G	350	30	29	small	large
Chlorothalonil	Daconil WP	0.6	20	1380	large	small
Cyromazine	Trigard WP	11000	90	10**	small	large
Daminozide	B-Nine SP	100000	7	10**	small	medium
DCNA (Dicloran)	Botran WP	7	10*	5000	large	small
DCPA (Chlorthal-Dimethyl)	Dacthal WP	0.5	30	5000	large	small
Demeton-S-Methyl	Metasystox C	33000	30**	51	medium	large
Diazinon	Knox-Out EC	40	30	85	medium	large
Dicofol	Kelthane WP	1**	60*	8000000	large	small
Dimethoate	Cygon C	25000	7	8	small	medium
Dinocap	Karathane WP	4*	20**	630*	medium	small
Disulfoton	Di-Syston 15G	25	4	2000	medium	small
Diuron	Karmex WP	42	60	400	large	medium
Endosulfan	Thiodan EC	0.3	43	200000	large	small
Ethephon	Florel	1000000*	5**	10000	medium	total use
Ethion	Ethion EC	1	350	15400	large	small
Etridiazole	Terrazole WP	50	20**	10000*	large	small

(Continued on next page.)

Common chemical name	Trade name/ formulation	Solubility (ppm)	Half life (days)	Sorption ratio (Koc)	Surface loss potential	Leaching potential
Fenbutatin oxide	Vendex WP	0.005	20**	100000	large	small
Fenvalerate	Pydrin EC	0.1	50	100000	large	small
Ferbam	Carbamate	120	20**	300	medium	medium
Fluvalinate	Mavrik C	0.005	50*	1000000	large	small
Lindane	Isotox EC	7	90	1100	large	medium
Malathion	Malathion EC	145	1	1797	small	small
Mancozeb	Manzate WP	0.5	35 1	000	large	small
Maneb	Maneb	0.5*	12	1000**	medium	small
Metalaxyl	Subdue EC	7100	7	16	small	medium
Metaldehyde	etaldehyde	230	10**	240	medium	small
Methomyl	Lannate SP	57900	8	28* small	medium	
Methyl parathion	Penncap-M	60	5	5100	medium	total use
Monocrotophos	zodrin	1000000	30	1	small	large
Naled	Dibrom EC	10**	10**	1000**	medium	small
Oxamyl	Vydate C	280000	7	1	small	large
Oxydemeton-methyl	Metasystox EC	1000000	20**	1*	small	large
PCNB	Terraclor WP	0.44	21	10000	large	small
Permethrin	Pounce EC	0.2	30*	10600	large	small
Phosethyl-Al	Aliette WP	120000	10**	10000**	large	small
Piperalin	Pipron EC	10**	20**	1000**	medium	small
Propargite	mite EC	0.5	20**	8000*	large	small
Trichlorfon	Dylox WP	154000	27	2	small	large
Triforine	Funginex EC	30	21	500*	medium	small

* Value is estimated.

**Value is probably off by a factor of 2-3.

INTEGRATED PEST MANAGEMENT FOR GREENHOUSE CROPS

Texas Greenhouse Management Handbook

Integrated pest management for greenhouse crops is a complex matter, and each problem or production objective is accompanied by a wide range of potentially acceptable solutions. Pesticide products must be used in accordance with instructions on the labels. The *user* of any pesticide is always responsible for his or her own actions.

A sound pest management program is based on the following principles.

Determine Your Objective

Pest management programs should be designed to meet a specific production objective. In greenhouse production, this objective is usually to produce pest- and damage-free plants. However, in some situations the objective may be to maintain healthy plants. This would allow for some tolerance of minor insect or mite pest damage. There also may be a preference for the use of non-toxic or low-toxicity pesticides. This is particularly important in regard to the potential contamination of surface and groundwater. Financial constraints also play a role in determining the overall objectives of an IPM program. All of these factors significantly affect the management tactics to be implemented.

Sanitation Practices

The first steps to take in a program to manage plant pests are preventative, and starting with a clean production area is essential. Greenhouses can be fumigated or otherwise treated prior to establishing a new crop to help eliminate pest problems from previous crops. However, where plants of different growth stages or species are grown in the same area, pests should be treated before establishing the next crop. Eliminating weeds and other alternate hosts of plant pests will also help prevent problems on the new crop.

Start With Pest-Free Plants

Selection of uninfested plants, plugs, cuttings or transplants is critically important. Carefully inspect all plants brought into the production area and discard or treat those found to be infested. When possible, pest-resistant or tolerant plant species or cultivars should be used to reduce the need for pesticides. Becoming knowledgeable about the susceptibility to pests of a plant species and/or cultivar will help you anticipate problems throughout the production cycle. Use of preventative treatments, such as applying systemic insecticides to the growing media at or shortly after planting, may protect young, rapidly-growing plants if pest pressure at planting time is high.

Maintain Optimum Cultural Practices

Plants under stress are more attractive to and can withstand less injury from pests. Use optimum fertilization and irrigation practices to help reduce the stress which predisposes plants to infestation. Temperature, humidity and light also may affect both pests and the use of certain pesticides.

Early Detection is the Key to Good Management

Once plants are established, there are several methods for monitoring pest problems. Yellow sticky traps placed around the production area can be used to detect early movement of adult whiteflies, thrips, adult leafminer flies, fungus gnats and aphids. Plants also should be inspected regularly, paying particular attention to the undersides of leaves. Beating portions of the plants on off-white paper will dislodge pests. This method is useful for detecting small, hard-to-see pests such as spider mites and thrips. Regularly inspecting plants that are highly attractive to certain insect pests can be useful for detecting low populations of pests. Control programs should be implemented when significant numbers of pests, or related damage, are first detected.

Recognize Damage and Define the Problem

Insect damage is largely caused by the manner in which they feed. Learn to recognize damage produced by major arthropod pests and always attempt to estimate the population density of the pest prior to selecting a control method. Many of the insect and mite species seen in greenhouse operations are not harmful. Some are even very beneficial (parasites and predators). Become familiar with beneficial insect species and consider their fate when making management decisions. Avoid using pesticides for "ghost" pests or unsolved problems.

Consider All Management Tactics

Many producers conduct a preventative program in an attempt to eliminate any and all potential pest problems. This approach can be economically and environmentally harmful. With integrated pest management the emphasis is on first monitoring plants regularly to identify pest problems, and then carefully selecting the correct control measure for the situation. When making that choice, keep in mind the economic, toxicological (worker safety and pesticide residue) and environmental implications of each approach. Non-chemical methods should be used when possible. However, if pesticides are necessary, compare the mode of activity, the cost and the application methods for each registered product. When using a product for the first time on a new plant or in a new mixture, apply it to a small number of plants first and observe possible phytotoxic reactions.

MANAGING AND DISPOSING OF PESTICIDE WASTES

Texas Greenhouse Management Handbook

Management and disposal of pesticide wastes are a major problem for greenhouse and nursery producers. Improper handling of these chemicals poses a real threat to the environment, as well as to the health and safety of laborers. Excess application of chemicals, or the improper disposal of "left over" mixtures, undiluted chemicals or even pesticide containers, can lead to potential contamination of surface and groundwater. However, the risk of a serious incident can be reduced if proper management and disposal techniques are used.

Hazardous agricultural wastes are defined in the 40 Code of Federal Regulations (parts 261.31 - 261.33) as having one of the characteristics of a hazardous waste. Pesticide wastes which are regulated are those which 1) contain a hazardous sole active ingredient, 2) are hazardous mixtures, 3) are acutely hazardous waste or 4) are hazardous waste as identified by an EPA number.

In most areas, pesticides are called hazardous, acutely hazardous or regulated wastes if they require specific disposal procedures. Usually a Uniform Hazardous Waste Manifest must be completed before these chemicals can be shipped off-site for treatment, storage or disposal. This can be costly, so it is important to minimize amounts of hazardous waste.

The first step in minimizing chemical waste is to determine the optimum means for pest control. Integrated pest management (IPM) techniques, such as the use of biological control alternatives, provide plant protection with reduced use of chemical pesticides. If a pesticide must be used, follow these management practices to minimize waste disposal problems:

1. Select the appropriate pesticide
2. Read the label carefully
3. Apply the pesticide properly
4. Clean up thoroughly
5. Store the pesticide securely
6. Dispose of containers safely

With these basic guidelines in mind, several waste minimization techniques can be implemented.

Labels

Once the need for a pesticide product has been determined, carefully review the label. It will contain mixing and spraying directions, the amount to be used over a specific area, equipment requirements, registered crops, spray timing, mixture specifications and other useful information. This information is extremely important and should be reviewed before each use. The label also provides some guidelines on pesticide storage and container disposal.

Storage

Pesticides should be stored in a locked, dry, cool, well ventilated area. This will ensure that the chemical remains active during storage. Safe storage also will help prevent non-authorized personnel from coming into contact with potentially harmful materials. The storage area should be equipped with clean-up supplies, such as clay absorbents, in case a spill occurs. Water, food or feed should not be stored in the same locked areas as pesticides. Safely storing pesticides will help minimize wastes by preventing spills and loss of chemical activity from degradation by heat, sunlight or other environmental factors.

Application

Improper pesticide application can create serious waste management problems and limit a product's ability to control the target pest(s). As a result, additional pesticide applications might be required. These subsequent applications significantly increase the potential for contamination. Overestimating the volume of pesticide required represents another waste management problem. Before application accurately calculate the amount of pesticide needed for a specific area. This will help prevent having excessive left over mixture to dispose of.

Application equipment should be tested frequently to determine if it is in proper working order. A trial run with water can be used to determine the spray pressure needed to cover a specific area at the labeled rate. Check all nozzles to make sure they are dispersing similarly. Clogged nozzles or an improperly pressurized boom will cause uneven distribution, resulting in over or under application.

Cleanup

All remaining mixture should be disposed of according to label instructions. For specific information on the state regulations in your area contact your local Extension office. Storing excess mixture is not recommended. Many pesticides degrade more quickly when mixed with water or oil, and may become weak or even completely inactive when such mixtures are stored. Also, these mixtures are more subject to degradation by temperature and sunlight. Stored mixtures also present spill and leakage hazards.

All equipment should be triple rinsed both inside and out to minimize pesticide residues. If equipment is rinsed on a loading pad, a closed storage system could be used to collect rinsate. If a closed system is not available, storage tanks or containers may be used to catch the rinse water. If this material is stored, keep accurate records on the content of each tank. Never store assorted wastes in the same tank.

The rinse water should be applied to an area where it will do some good in controlling the target pest(s) but will not create a contamination hazard. Do not apply rinse water to areas previously treated because this could increase the potential for contamination or result in longer persistance of the pesticide in that area.

Container Disposal

In many areas there are specific requirements for the disposal of pesticide containers. Check with your county Extension office for state regulations. Typically, all containers should be triple rinsed with a solvent capable of removing any remaining pesticide, and the rinsate disposed of according to the disposal instructions on the label. Empty containers should be punctured, crushed or otherwise rendered incapable of holding liquid. These containers can then be disposed of at a sanitary land-fill or returned to the manufacturer or formulator.

Summary

Managing pesticide wastes properly can help reduce potential hazards to the environment and to employees. Although most of these practices are nothing more than common sense, we often tend to "cut corners" when time is short. However, careful attention to detail in this area is critical if we are to comply with the increasing regulations concerning the environment. Developing an effective waste management program can be relatively painless if you follow these basic guidelines:

- Use IPM techniques to help minimize pesticide applications.
- Be aware of alternative products which might be less toxic or even nonhazardous.
- Store pesticides correctly to maintain their activity.
- Carefully estimate the amount of mixture required for a specific area.
- Accurately calibrate pesticide application equipment to avoid over or under applications.
- Read pesticide labels carefully and know how and where to apply products for optimum results.
- Clean equipment inside and out and dispose of left over mixture and rinsate according to label instructions.
- Triple rinse empty pesticide containers and dispose of them properly.

TREATING AND RECYCLING IRRIGATION RUNOFF

Texas Greenhouse Management Handbook

The potential contamination of surface and groundwater from irrigation runoff presents a major challenge for the greenhouse industry. Growers rely heavily on the use of fertilizers and pesticides, as well as water, to produce quality crops. As a result, these operations can pose a threat to our natural water resources. Collecting, treating and recycling greenhouse effluent is one of the best solutions to this environmental problem.

Many states now require a water discharge permit to control irrigation runoff. These permits regulate the level of discharge that flows into surface and groundwater reserves. In many situations quantitative discharge standards are vague and each case is determined by the best professional judgment of the regulatory agency.

Although these permits differ somewhat from state to state, there are some common features:

- *The permit is usually good for 3 to 5 years.*
- *All irrigation runoff must be retained.*
- *All or part of storm runoff must be retained (usually the first 2 inches).*
- *Irrigation runoff must be disposed of.*
- *No pesticides can be discharged.*
- *Nitrate and ammonia discharge must be less than 2 ppm.*
- *The pH of discharge must be between 6 and 9.*
- *The discharge must contain acceptable levels of suspended solids.*

Monitoring is very important in the overall process of managing greenhouse runoff. Knowing what contaminants are present and their relative concentrations is the basic information required for developing a management plan. Nitrates, salts, pesticides and pathogenic organisms are the principal contaminants to be on the lookout for. Many of the tests for these materials are quite expensive to run. The sampling technique, handling and analytical methodology can affect the test results and interpretation. Table 1 provides a list of labs that are currently conducting runoff analysis.

Table 1. Labs currently conducting runoff analysis.

Millipore
P.O. Box 255
Bedford, Mass 01730
(617) 275-9200

HACA Company
P.O. Box 389
Loveland, CO 80539
(800) 227-4224

National Testing Laboratories
6151 Wilson Mills Rd.
Cleveland, OH 44143
(216) 449-2524

Minimizing runoff
The best method of managing runoff is to use production practices which reduce irrigation water volume. Obviously, the less runoff you have to deal with the less problem it creates. In addition, these techniques are usually much more economical to implement than large scale treatment and disposal procedures. The following are some basics to consider:

Use Efficient Irrigation Systems
A well designed, efficient irrigation system is the foundation of a good water management program. Drip and sub-irrigation do an excellent job of delivering water to the container and are quite efficient. Overhead systems increase the potential for disease and insect problems and create large volumes of runoff. Growers must work towards adapting new irrigation technologies to their production systems to help lower costs and reduce runoff volume.

Reduce Overwatering
Watering is perhaps the least precise of all cultural inputs. Growers frequently rely on the "eyeball" method of determining when plants need to be irrigated. As a result, many crops receive excessive amounts of water, which creates runoff. Researchers in both Europe and the U.S. are now working towards identifying optimum irrigation regimes based on the water status of the growing medium. These systems will become increasingly important as growers work towards reducing runoff.

Implement Integrated Pest Management
IPM is a common sense approach to controlling pests. This management technique is based on getting the most from chemical pesticides, and also incorporates the use of biological controls where feasible. IPM is not only the most economical system for pest control but it also significantly reduces the volume of chemicals that can potentially reach surface and groundwater reserves.

Optimize Fertility
Plants require sufficient nutrition, but since fertilizer does not represent a significant production cost many growers use excessive amounts to ensure optimum plant growth. This practice contributes to high levels of nitrates in irrigation runoff. Researchers now estimate that most greenhouse crops receive 5 to 10 times more fertilizer than they require.

Many growers are also evaluating the benefits of slow release fertilizers to help limit nitrate contamination. These materials alone, or in combination with soluble fertilizers, can provide optimum nutritional levels while minimizing the risk to our natural water resources.

Reducing Storm Runoff
Many growers are required to capture storm runoff from production areas, which can be a significant volume of water to divert and hold. Therefore, growers should use space efficiently and eliminate as much wasted surface area as possible. Vegetative cover helps limit runoff, so work towards eliminating hard surface areas.

Since up to the first 2 inches of storm runoff must be collected, reservoir capacity should be designed on the basis of predictable storm events. Data on rainfall duration and frequency for your specific location are available from meteorological information sources (i.e., Weather Bureau, Extension Service, etc.). Based on the maximum rainfall/hour, annual rainfall and exposed surface area, the reservoir size can be calculated. Most designs also allow for enough freeboard to handle unpredictable storm events. Reservoirs should be designed to prevent seepage (another potential source of groundwater contamination).

Disposing of Greenhouse Runoff

Once you have captured runoff it must be disposed of. There are many commercial water disposal systems available; the one best suited for a specific situation may represent a combination of the following:

Evaporation ponds have not been a viable disposal solution. The quality of the water and sediment left behind after evaporation is extremely poor, which creates an even more challenging disposal problem.

Land use is one means of disposing of runoff. Many operations irrigate tracts of land with irrigation runoff. As much as 3 to 4 inches of water per day can be applied to these areas, depending on soil type and vegetation. However, secondary runoff must be avoided. Overhead irrigation is the most feasible application system for this use.

Constructed wetlands are now being evaluated for their ability to clean up runoff. These shallow gravel beds, filled with selected vegetation (i.e., cattails), serve as a biological filter for removing chemical pesticides and fertilizers. There is still a great deal of work to be done in this area but it looks promising.

Runoff can be discharged into *municipal treatment systems*. However, discharge is usually restricted to off-peak hours, the size of existing sewers can be limiting and user fees are typically high. Since most treatment facilities are quickly becoming overloaded, this approach represents a short term solution to runoff disposal.

Treating and Recycling Runoff

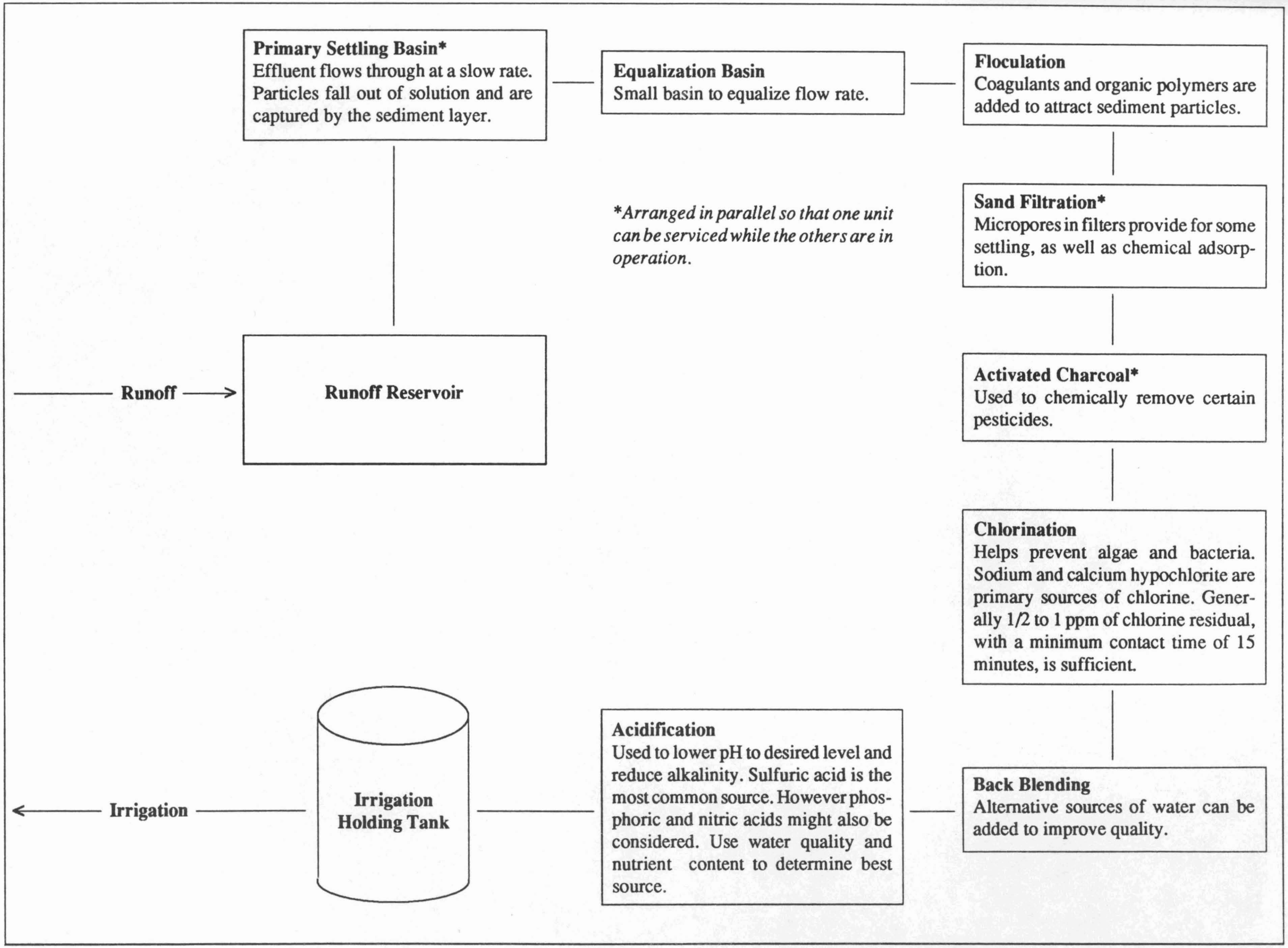
Reuse or recycling of runoff is rapidly becoming a common practice. Careful monitoring of salts, chemicals, nutrients and pH is critical in managing this water resource. Treating recycled runoff is an important part of this process. A sample treatment system is illustrated in Figure 1. Any or all of these procedures can be incorporated into a treatment facility. The order in which water passes through each component of the system can be rearranged to produce the highest water quality required.

Reverse Osmosis

Many growers are now using water treated through a process known as reverse osmosis (RO) to remove potentially harmful salts. These systems are relatively expensive but work well as a source of water for back blending. RO water has virtually no nutrient value and growers have experienced micronutrient deficiencies when plants have been sustained on this water source for extended periods of time.

Like most environmental problems, preventative measures are much more effective than large scale cleanup operations. Common sense is often all that is required to implement cultural practices that reduce runoff, as well as improve water quality. However, where more than commmon sense is required, growers must work towards adapting new technologies for water treatment and recycling.

Figure 1. Typical water treatment and recycling system.



Primary Settling Basin*
Effluent flows through at a slow rate. Particles fall out of solution and are captured by the sediment layer.

Equalization Basin
Small basin to equalize flow rate.

Floculation
Coagulants and organic polymers are added to attract sediment particles.

Sand Filtration*
Micropores in filters provide for some settling, as well as chemical adsorption.

Activated Charcoal*
Used to chemically remove certain pesticides.

Chlorination
Helps prevent algae and bacteria. Sodium and calcium hypochlorite are primary sources of chlorine. Generally 1/2 to 1 ppm of chlorine residual, with a minimum contact time of 15 minutes, is sufficient.

Back Blending
Alternative sources of water can be added to improve quality.

Acidification
Used to lower pH to desired level and reduce alkalinity. Sulfuric acid is the most common source. However phosphoric and nitric acids might also be considered. Use water quality and nutrient content to determine best source.

**Arranged in parallel so that one unit can be serviced while the others are in operation.*

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