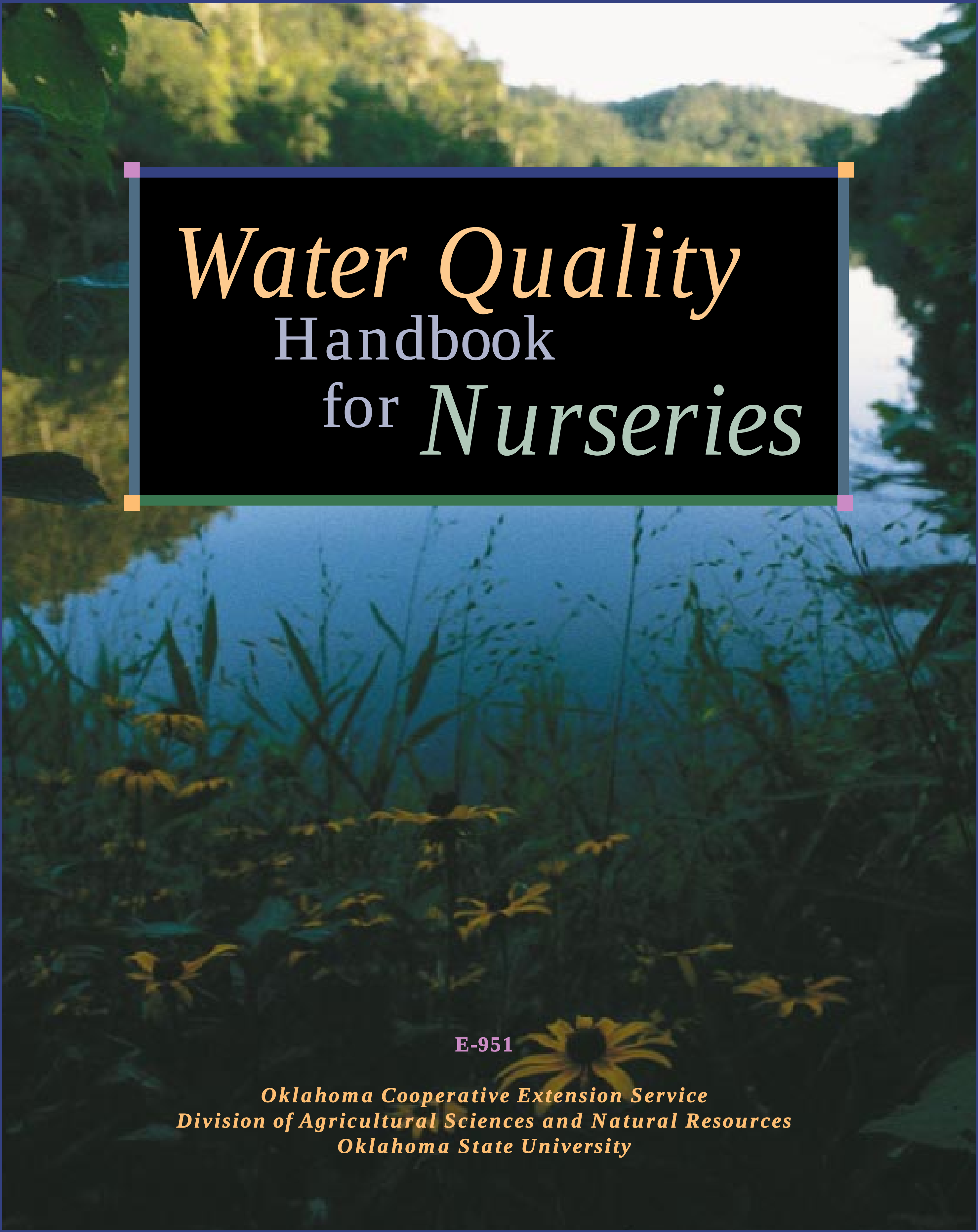

Water Quality Handbook for Nurseries

E-951

Oklahoma Cooperative Extension Service
Division of Agricultural Sciences and Natural Resources
Oklahoma State University

Water Quality Handbook for *Nurseries*

Circular E-951

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Table of Contents

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Preface

Growers work in an environmentally conscious climate where they must appropriately manage irrigation water that contains nutrients and pesticides, while attempting to grow and sell a quality plant at a profit. This handbook was written to challenge nursery personnel who may not be currently using best management practices to consider using BMPs and other actions to be successful toward both these goals.

Acknowledgments

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- Sunshine Nursery, Clinton - Steve and Sherry Bieberich, owners.
- TLC Florist and Greenhouses, Oklahoma City - Charles and Linda Shackelford, owners.

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1. Water Quality

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Introduction

Propagating and maintaining high quality plants requires large amounts of water, fertilizer, and pesticides. These high inputs, however, increase the potential for both surface and ground water pollution. Therefore, nursery producers have an important role to play in protecting water quality.

The purpose of this handbook is to provide nursery managers with tools and information to protect water quality. These tools are called best management practices, or BMPs.

Organization of This Handbook

Chapter 2 of this handbook presents three stages of a BMP program that can be employed in a nursery to protect water quality. Stage I includes practices that can and should be implemented in any nursery. Stage II includes practices that require some effort and expertise, and Stage III includes BMPs that require substantial investment, commitment, and/or advanced training.

Chapters 3 through 6 provide background on fertilizer management (Chapter 3), irrigation management and ground water protection (Chapter 4), integrated pest management (Chapter 5), and management of pesticides (Chapter 6).

In Chapter 7, the author discusses capturing and recycling water in container nurseries–an innovative technique that greatly reduces pollution.

The environmental audit located in Chapter 8 can be photocopied or removed from the handbook and used to evaluate potential environmental risks and opportunities for pollution prevention.

Environmental Regulations

Few regulations govern nursery impacts on water quality; therefore, voluntary efforts are needed to protect water quality. When or if this situation will change is open to speculation, but some regulations are in place in California, Oregon, and Texas. Being proactive is highly recommended.

Producers can reduce their environmental impact by making educated management decisions based on a firm understanding of the relationship between their operation and the environment.

The Potential Exists for Pollution...

Where does water go and what are the implications when it runs off a production area or through a ditch in a nursery? *Where* may seem obvious for surface water, but not so obvious for ground water.

All water not used by plants must go somewhere. Some is lost to evaporation, some may enter a nearby lake by way of ditches or storm sewers, or some may percolate to ground water. The real concern is not the water, but the dissolved or suspended materials it carries.

Despite the fact that water is used on a daily basis, its protection is sometimes overlooked. When it becomes contaminated, it may become unusable or it may become a vehicle to carry pollution off the nursery. What is out of sight is often out of mind, but water quality should be at the forefront of pollution prevention planning.

What Materials Are Considered Pollutants?

Pollutants may be loosely defined as any material that degrades the environment. Typical pollutants released by a nursery or greenhouse include:

- Fertilizers
- Pesticides (herbicides, insecticides, fungicides)
- Cleaning products and disinfectants
- Sediment (eroded soil)

Fertilizers. Fertilizers promote growth of algae and aquatic vegetation beyond what is naturally sustainable. This growth reduces water clarity, often covering the entire surface of a pond or lake. Such a "bloom" of algae consumes oxygen, causing fish kills.

Excess nitrate levels from fertilizer can contaminate drinking water supplies. This is particularly a problem in ground water.

Pesticides. Many pesticides are harmful to aquatic organisms, and some are dangerous to humans as well. Insecticides are a particular concern because of their effects on aquatic insects, which many other organisms rely upon as a food source. Pesticides also may be leached into soil and even ground water, posing expensive cleanup costs and health concerns.

Cleaning Supplies and Disinfectants. Many everyday products such as cleaning supplies and disinfectants can also be damaging to the environment. A slug of such material can wreak havoc if spilled in a small stream. In quantity, they may even damage sanitary sewage treatment systems. Care is necessary when disposing of such materials.

Sediment. Many people don't think of sediment as being a pollutant. It is, however, the most common nonpoint source pollutant in Oklahoma and across the nation. Its presence above naturally occurring levels has serious implications to the health of the aquatic environment.

Erosion produces excess sediment that clogs streams and ditches, often causing flooding. Sediment can interfere with the feeding and reproduction of fish and aquatic insects, disrupting the food chain. Phytoplankton (microscopic algae that form the base of the food chain) are also affected when water clarity is reduced.

Sediment is doubly a concern because of its role as a carrier of other pollutants such as phosphorus and pesticides.

Pollution Prevention in the Nursery

Pollution prevention in the nursery is accomplished through careful management and common sense, using an approach that consists of three parts:

- Water Management
- Fertilizer Management
- Integrated Pest Management

Water Management—The First Step in Pollution Prevention. Water has a dual nature; it is both the medium we are trying to protect and a potential pollution carrier. Contaminated water from a nursery operation is a perfect, mobile taxi for pollutants. It is considered the universal solvent for a reason!

Considering water as a contaminant transport system might be a new way of thinking. Take a look

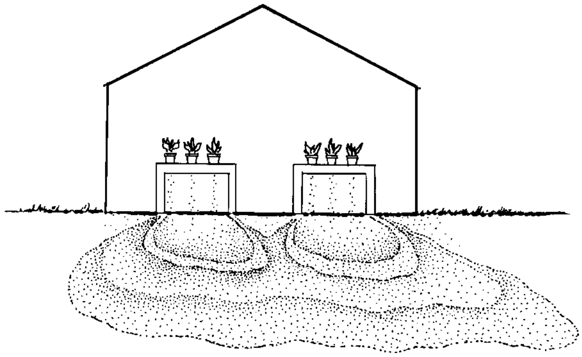

Figure 1. Contamination plume developing under a block of containerized plants.

at water flow during irrigation periods and give some thought to where the water is going. It has many routes to escape into the environment. It can percolate through plant beds, run off into a storm drain, run directly into a lake or stream, or disappear into a sanitary sewer. Whatever its destination, water can carry pollutants into the environment. **Figure 1** illustrates a situation where continual pesticide application has led to growth of a contaminant plume beneath a block of containerized plants. Because the pesticide is being delivered to the soil faster than natural breakdown occurs, the pesticide moves through the soil profile and may eventually reach ground water.

What if this occurred year after year? The soil beneath the nursery could become a hazardous waste site. The legal implications and liabilities are worth thinking about. Managing water resources and chemicals wisely can prevent any occurrence as frightening as this from happening.

Irrigation Management. Irrigation scheduling should be based on plant demand and water requirements. Overirrigation could be likened to pouring money down the drain. When overwatering occurs, fertilizers and soil-applied pesticides leach out of containers into the soil below. This not only leads to pollution, but also reduces product effectiveness and increases cost.

Irrigation management involves matching the amount of water precisely to plant needs. Adjusting irrigation frequency through careful scheduling and application efficiency with hand watering or drip irrigation can reduce water use and reduce or eliminate water pollution.

Choose a watering system that minimizes water loss, such as drip irrigation. Drip irrigation delivers water directly to the roots, minimizing evaporation loss. Using drip irrigation in conjunction with slow-release fertilizers is particularly effective in controlling nutrient loss to the environment. Also, drip irrigation virtually eliminates disease spread from splashing water.

The ultimate form of reducing water loss to the environment is found in systems where runoff water is recycled and reused. These can range from small subirrigation systems such as ebb-and-flow in greenhouses, to large capture-and-recycle systems, where runoff is collected en masse and stored in holding ponds.

Fertilizer Management. Simply put, overfertilizing is polluting. Anything that can be done to reduce the amount of fertilizer protects the environment and saves money. Nutrition is one of the most important aspects in producing healthy, marketable crops. Optimize fertilizer use to produce healthy plants, but avoid excessive use with high losses.

Optimizing fertility means providing nutrients in the right quantities at the right times. Providing the right balance and amount of nutrients requires some thought. Remember to account for nitrogen and phosphorus in irrigation water.

When fertilizer is supplied with the irrigation water in an overhead system, there are two ways that fertilizer can be wasted: 1) when fertilizer solution falls between the plants, and 2) when too much fertilizer solution is used. To minimize these problems, apply only enough fertilizer to meet plant needs, watering separately as necessary.

Use of slow-release fertilizer is an effective way of reducing the amount of fertilizer-contaminated runoff. Several Oklahoma nurserymen have switched almost entirely to slow-release fertilizer throughout their nurseries and are pleased with the results.

Finally, ensure that your application equipment is properly calibrated. Even with the best intentions, overapplication is possible if the application equipment is not maintained.

Integrated Pest Management. Harmful effects of pesticides in the environment are well documented. Pesticides pose not only a risk to the environment, but also to human health. They must be treated with intelligence and respect to avoid environmental and health-related problems.

Reducing the quantity of chemicals used should be a top priority. This can be done by adopting integrated pest management (IPM) and improving pesticide application techniques. IPM is described in detail in Chapter 3 and pesticide usage in Chapter 4.

Examine all application techniques and calibrate all sprayers. Good intentions can be counteracted if equipment isn't functioning properly.

Pesticides vary significantly in efficacy, leachability, and toxicity. Choose pesticides that are recommended for the specific problem at hand. If more than one pesticide is available, choose the one least likely to harm the environment.

Plant disease diagnosis can be a complicated matter, but it is essential to avoid unnecessary or inappropriate use of a pesticide. Be sure to rule out environmental factors before turning to pesticides. If the cause isn't clear-cut, send a sample to a plant disease diagnostic laboratory. (The Plant Disease Diagnostic Laboratory at OSU can be reached by calling 405-744-9961). Getting an accurate diagnosis can save money and protect the environment.

Environmental Audit

Finally, an environmental audit is a process that can help any nursery. The process helps identify problems before they become serious and establishes a good environmental record. Identifying and addressing environmental risks improves your public image and facilitates your pollution prevention program.

The audit in Chapter 8 is a checklist to help identify areas needing attention. After auditing, the report can become the basis for an effective pollution prevention system. Use this system in conjunction with the tips in this handbook and a cleaner environment is sure to result!

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2. Best Management Practices (BMPs) for Nurseries to Protect Water Quality

Sharon L. von Broembsen, Extension Plant Pathologist
Mike Schnelle, Extension Ornamental Floriculture Specialist

This water protection program has been divided into three stages for ease of implementation. Stage I should be implemented wherever feasible by all nurseries. Stage II is strongly recommended for implementation whenever physically and financially possible, whereas Stage III illustrates the ideal in water quality management. The specific recommendations for protecting water quality have been broadly categorized into the following three management areas: irrigation, fertilization, and pest and pesticide management. Justification for implementing the prescribed BMPs and their relevance to protecting water quality can be found in appropriate chapters of this manual.

I. Irrigation Management

A. Backflow Prevention

Stage I

- Install backflow prevention devices.
- Train personnel to keep the end of the filler hose above the spray tank's water level, leaving an air gap between the water and the hose.
- Ensure that someone is near the spray tank during all filling and mixing operations.
- Fill tanks with water first, then move the tanks away from the water source to add pesticide or fertilizer.
- If well water is used on site for human consumption, have the well water tested regularly for contamination.

Stage II

- Check backflow prevention devices at least once a year and record the date and result of this check.
- Move fuel tanks, pesticide storage bins, or any other chemical storage units to sites at least 100 feet away from wells or other water supplies.

Stage III

- Fill and seal any nearby abandoned wells according to the specifications of the Oklahoma Water Resources Board.

B. Runoff and Storm Water Management

Stage I

- Become familiar with all regulations regarding irrigation runoff and find out if a water discharge permit is required.
- Determine where and how much irrigation runoff leaves the nursery.
- Test and record the quality of irrigation water and runoff. Compare lab results against local and Oklahoma water quality standards and regulations.
- Develop a plan to deal with off-site storm water retention and runoff from the nursery.
- Keep records of rainfall or utilize Mesonet data for this purpose.

Stage II

- Use drip irrigation or intermittent (pulse) irrigation to reduce wasted water.
- Adjust individual sections of the irrigation system to avoid excess watering in some sections.
- Group plants with similar water needs together to improve irrigation efficiency.
- Establish plant buffer zones between production areas and ditches, creeks, ponds, lakes, or wetlands.
- Convert paved or bare soil areas to vegetation that will retard runoff (turf grasses or other comparable plant materials) wherever possible.

Stage III

- Install and use moisture sensors, such as tensiometers, for more accurate scheduling of irrigation.
- Capture runoff water on site and then recycle it onto crops, blending it with fresh water as necessary.

II. Fertilization Management

Stage I

- Test irrigation water sources three times a year for salt levels, bicarbonates, and pH. Review the results before any fertilizer is added.

- Test field soils annually to account for carry-over of nitrogen and other nutrients that might be present. Use this information to determine fertilization levels.
- Purchase pH and EC meters and use them to monitor pH and EC (soluble salts) of the media, soil, and irrigation source water.
- Relocate fertilizers that are stored within 100 feet from water sources.

Stage II
- Initiate transition from the use of soluble fertilizers to controlled-release fertilizers.
- Whenever feasible, spread out applications of controlled-release fertilizers and use split applications of soluble fertilizers over the growing season.
- Reduce routine leaching of crops.

Stage III
- Eliminate routine leaching of crops.
- Use only controlled-release fertilizers except when special circumstances warrant the occasional use of soluble formulations.

III. Pest and Pesticide Management

A. Integrated Pest Management

Stage I
- Discontinue routine spray programs for pests. Apply pesticides only when needed.
- Map the nursery to document plant locations. Use this plant map to methodically inspect the nursery weekly and record pest problems.
- Identify specific pest problems to determine appropriate control options.
- Use action thresholds based on acceptable levels of infestation or disease to decide when to treat.
- Use traditional chemical pesticides effectively.
- Start using some of the many highly effective, softer pesticides that are much less toxic to the environment, e.g., horticultural oils or soaps.
- Make careful pest control notes in the field and transfer them to permanent records upon returning to the office.
- Evaluate and record the effectiveness of previous control strategies during weekly inspections.
- Identify changes in cultural practices that might reduce specific pest problems.

Stage II
- Begin growing and selling pest-resistant (low pesticide input) plant materials.
- Identify biological control agents that can replace chemical pesticides.
- Develop procedures for applying pesticides directly on or around the plant, rather than using broadcasting or widespread spraying, which unnecessarily exposes soil.

Stage III
- Assign one person to be an IPM manager, with responsibility for coordinating all pest management actions.
- Use more bio-intensive control options, such as biological control and improved cultural practices.

B. Preventing Contamination from Pesticides

Stage I
- Know the soil type and depth to ground water at the nursery site. Porous soils and shallow water tables require special care.
- Store pesticides in a facility with an impermeable floor and no floor drain situated at least 100 feet from any well, stream, or pond.
- Mix pesticides at least 100 feet from any well, stream, or pond.
- Use up all mixed pesticides on suitable plant material. Don't store or dump them.
- Triple rinse or pressure rinse used pesticide containers and then spray rinse water over a production area.
- Do not get rid of unused pesticides by washing them down drains or throwing containers into farm dumps.
- Follow prescribed precautions carefully when applying soil-based pesticides. Do not overapply foliar-based pesticides.
- Do not apply pesticides or other agricultural chemicals when rainfall is imminent or heavy irrigation is scheduled.
- Do not spray pesticides around sinkholes.

Stage II
- Draw up an emergency action plan to contain pesticide spills in mixing and storage areas and to clean up pesticide spills in production areas. Instruct all personnel in the use of this plan.
- Utilize hazardous chemical collection days to get rid of old chemicals. Return empty pesticide containers to dealers.
- Keep records of soil and water tests as a reference for making future pesticide application decisions.

Stage III
- Compare the leaching and surface runoff potentials of alternative pesticides and use those with the lowest potential to contaminate, i.e., low leaching potentials for porous soils and shallow water tables or low runoff potentials for sites near surface water bodies.

3. Nutritional Management in Nurseries

Mike Schnelle, Extension Ornamental Floriculture Specialist
Cody J. White, Graduate Student, Environmental Sciences

Numerous fertilizer products and recommendations are available to help produce healthy plants. However, information in this chapter is primarily related to protecting and preserving water quality. Because of the porous nature of soilless media, a large amount of water and fertilizer can percolate out of drain holes in nursery containers. With growing public concern and the possibility of environmental regulations, it is prudent to consider practices to reduce fertilizer losses from container systems and field settings.

Some types of container-grown stock may be fertilized once in the spring and remain aesthetically acceptable throughout the growing season. Other types may require fertilizer at planting and supplementation throughout the growing season for optimal growth. Monitoring plant response is recommended with each additional fertilizer application. Choosing only to fertilize "by the calendar" may be particularly meaningless, given Oklahoma's erratic weather patterns and the wide array of plant materials grown.

Regardless of the method chosen, fertilize in an environmentally responsible manner. Use enough nutrients to satisfy the plant's needs, produce an aesthetically saleable plant, and minimize fertilizer loss out of the bottom drain holes. With any fertilizer strategy used, it is usually appropriate to incorporate preplant amendments in the growing mix. These amendments primarily consist of dolomitic limestone and a full complement of micronutrients **(Table 1)**.

Dolomitic Limestone

Dolomitic limestone provides calcium (Ca) and magnesium (Mg) while neutralizing the acidity (raising the pH) of the growing mix. The incorporation of dolomitic limestone depends on several factors, including the irrigation water alkalinity, the initial pH of the mix, and the species of interest. Dolomitic limestone is unnecessary if irrigation water has an alkalinity exceeding 100 parts per million (ppm) and has acceptable Ca and Mg concentrations (5-15 ppm).

Dolomitic limestone amendments of six pounds per cubic yard will create a pH of 6.0 to 7.0 for a mix of two parts pine bark: one part peat: one part sand (by volume) within a month after application. Dolomitic limestone is effective for a minimum of one year after application.

Keep in mind that some plants, such as hollies, azaleas, and other acid-loving species (ericaceous-type stock), prefer an acidic environment of pH 5.5 to 6.2. However, many plants prefer a pH of 7.0 or higher (neutral or basic), necessitating the addition of limestone.

Table 1. Essential chemical elements (nutrients) for plant health.

Macroelements:
- Nitrogen (N)
- Phosphorus (P)
- Potassium (K)
- Calcium (Ca)
- Magnesium (Mg)
- Sulfur (S)

Microelements:
- Iron (Fe)
- Manganese (Mn)
- Zinc (Zn)
- Copper (Cu)
- Boron (B)
- Sodium (Na)
- Chlorine (Cl)

Elements not supplied by fertilizers but by water and air:
- Carbon (C)
- Oxygen (O)
- Hydrogen (H)

Micronutrients

Micronutrients, also called trace elements or minor elements, are mandatory in small quantities for proper plant growth and survival. They are as important as major or macronutrients such as nitrogen (N). (See Table 1 for a listing of essential macro- and micronutrients that must be present during plant production.) Regardless of the commercial formulation selected, micronutrients should be applied according to the label rate. Micronutrient additions are effective for one year or longer. Micronutrient considerations are less important for field-grown nursery stock. Except for high pH soils (which are common in western Oklahoma) and certain acid-loving species, micronutrients may not have to be monitored or supplemented. However, iron, zinc, and other micronutrients may need to be supplied. Micronutrients can become unavailable to species when pH exceeds 7.0 in certain situations; therefore, the soil's pH may need to be lowered. When pH is below 5.0, micronutrient toxicities can occur. Extremes in pH are usually deleterious to plants in relationship to micronutrient status of the soil. Your county Cooperative Extension educator can help should you suspect a micronutrient deficiency or need assistance in field soil testing. Micronutrient deficiencies are mentioned since they are commonly misdiagnosed as a N deficiency. Adding N needlessly can pose a potential threat to the environment.

Macronutrients

Nitrogen

The following research was based on liquid fertilizers and values would probably read lower had CRF been considered. Researchers have shown that nitrogen (N) supplied to woody plants at 100 to 200 ppm is the ideal range for most species. However, lower amounts of N may be adequate when using a controlled-release fertilizer (CRF), since the higher range is based on liquid fertilizer (LF) which is easily leached away. When using CRF, a continuous supply of N is available to roots. Therefore, a lower concentration of N is sufficient for optimal growth. Although N can be supplied in either nitrate or ammonium forms, plant growth is best when the majority of a fertilizer has a nitrate-N source.

For field-grown stock, a rule of thumb is to apply 3 lbs. actual N/1000 square feet or 130 lbs. N/acre. When CRF is not used, divide applications of soluble N to reduce leaching losses. Because nitrogen is mobile, top dressing with N is the ideal way to optimize plant growth rather than deep root feeding. Plant roots responsible for nutrient uptake are located in the top 12 inches of the soil. Therefore, it is important to avoid deep feeding, which may waste N and result in greater pollution.

Phosphorus

About 5 to 15 ppm is the ideal range of phosphorus (P) for plants. Since a complete fertilizer (N-P-K) is typically applied to woody stock, do not use superphosphate in the container medium pre-mix. The container mix is easily saturated with P, allowing it to leach rapidly. In fact, up to 86 percent of the P from superphosphate may leach from containers in just the first three weeks! Phosphorus poses a major threat to water quality. Therefore, plants should be supplied P at low concentrations, along with other nutrients in fertilizer formulations throughout the growing season. Furthermore, field-grown stock is unlikely to require additional P, since it binds strongly to soil particles and does not tend to leach away. Please note that most field-grown stock require anywhere from 15 to 50 lbs. P/acre for proper growth.

Potassium

For woody species, potassium (K) should be supplied at 25 to 75 ppm. When N and P levels are high, the K level should also be high for a favorable N-P-K ratio. For field-grown stock, adding K will likely be unnecessary unless soils are very sandy. When testing field soil, K should be at least 60 to 150 lbs./acre for favorable growth.

N-P-K Ratio

Optimum growth rates for woody stock are obtained when N-P-K ratios are 3-1-2 when considering N, P_2O_5, and K_2O, respectively. Use these ratios when custom blending your fertilizer. Because P and K are often needed in small amounts or not at all, custom blending helps avoid waste. When applying the proper amount of a balanced (N-P-K) fertilizer to obtain sufficient N, P and K nutrients are often wasted in the process.

Fertilizer Application Methods

When balancing environmental considerations, the best means of supplying proper nutrition to nursery stock is the addition of controlled-release fertilizers (CRF) either once or periodically throughout the growing season. Another option is fertigation—delivering a liquid fertilizer solution (LF) through the irrigation system. Some growers have found a combination of both CRF and LF is a compromise which still produces quality plants. The frequency of application and concentration can be tailored to the growth medium and type of nursery stock grown. However, most of Oklahoma's production areas currently utilize overhead irrigation systems. The use of fertigation with overhead sprinklers is not recommended because up to 80 percent of the water falls between containers. Thus, a large amount of soluble fertilizer is washed away to surface or ground water.

Liquid fertilizer (LF) is best reserved for trickle irrigation systems (Chapter 4). With these systems, water can be precisely applied, so very little water or fertilizer is lost to the environment. It is important to note that emphasis has been placed on using CRF. However, CRF, like any fertilizer, can pollute the environment if mishandled. *Choices made concerning irrigation type, frequency of applications, etc., will be just as critical for observing good water quality standards (Chapter 6).*

Controlled-release fertilizers are designed to supply critical plant nutrients for an extended period of time (3-12 months). Fertilizer formulations vary in release mechanisms and rates. Some may release at a more uniform rate than others. However, regardless of formulation, nutrients are released slowly and steadily (theoretically) over time. Still, you may need to supplement additional CRF or LF later in the season. It is ideal to amend the container mix with CRF prior to planting as opposed to applying fertilizer to the container mix's surface, because surface-applied fertilizers are more likely to wash or blow away. Be sure to handle CRF carefully to avoid cracking or breaking the prills when blending the product(s) in the container mix.

Container mix that has been blended with CRF should be used promptly to avoid excessive salts (released fertilizer from the prills) in the bulk mix. Otherwise, fertilizer will be released before plants are actually growing in the mix. To protect water quality, apply surface fertilizers only when containers are pot to pot, too heavy to tip, or secured to avoid toppling over. Otherwise, fertilizer granules may spill, miss the targeted container altogether, or wash away. Adopting this policy alone will reduce fertilizer waste and runoff at nursery and/or garden centers.

Application Rate

Strive to minimize leaching by applying the least amount of fertilizer required for the desired growth rate or aesthetic appearance. Rates of CRF will vary, depending on the formulation, species, and container size. Regardless of these variations, a few rules are applicable for any production method. First, apply fertilizer only when warranted. As earlier stated, a fertilizer ratio of 3:1:2 (nitrogen, phosphorus, and potassium, respectively) is appropriate. Also, a CRF with N, P, and K throughout the container mix at a rate of 3 to 4 pounds of N per cubic yard of container mix should provide ample nutrition for nine months to a year. During cooler months such as early fall, apply half the maximum label rate. Plants not growing vigorously will not use the maximum label rate. Therefore, a greater chance exists for fertilizers to leach and contaminate the environment. During the winter, no fertilizer applications are necessary for outdoor stock.

Monitoring Container Medium Nutrient Status

Environmental conditions ultimately dictate the longevity of fertilizer availability and release. Due to Oklahoma's hot summers and irrigation/rainfall patterns, nutrients may be released more quickly than anticipated. Because environmental conditions fluctuate, regular monitoring of the medium's nutrient status is essential. A lack of essential elements will result in slow and aesthetically unacceptable growth. Conversely, excessive nutrient concentrations will result in root injury, hindering the plant's ability to absorb water and nutrients. This in turn increases the potential for environmental contamination.

It is important to sample your growing mix for nutrient concentrations from time to time because optimum growth may not occur, even in the absence of symptoms such as yellowing and distorted or stunted growth. Excessive nutrient levels may be the result of inadequate irrigation frequency, the composition of the medium, the fertilizer formulation, or the application method selected. Likewise, poor nutrition can result from applicator error or, more likely, excessive irrigation or possibly rainfall. Too much moisture results in rapid leaching before root systems can adequately absorb and utilize chemical elements.

Media used for multiple season crops, such as woody plants, should be sampled at least monthly to check electrical conductivity (EC). Knowing the EC will help gauge nutritional status of the growing medium.

Collect leachate from more than one container and combine them to obtain a representative sample. One straightforward means to measure soil fertility is the leachate collection method. *You must not mix leachate solutions from pots of different species.*

Leachate Collection Method:

1. Wait two to three hours after irrigation to allow the medium to thoroughly drain.
2. Position the container on a collection pan so the bottom of the container is perched above the bottom of the pan.
3. Apply distilled water in a circular motion to the growth medium surface to obtain 50 to 100 ml (1.5-3.0 ounces) of leachate (liquid) from the container. Do not wipe the bottom or sides of the container before collecting leachate.
4. Collect leachate from 5 to 10 containers in each production area to obtain an average value that will accurately reflect the growth medium's nutritional status.
5. Send collected leachate to a private lab or test with an EC meter.

The leachate collection method allows for quick and accurate determination of EC, pH, and concentrations of individual elements.

Table 2. Recommended nutritional levels in growth medium for containerized plants with moderate to high nutritional requirements. Levels are based on the leachate collection method described earlier.

	Solution and Controlled-Release (CR) or Solution Only			CR Fertilizer Only (Ideal)
	Low	Ideal	Very High	
pH	< 5.0	5.5-5.8	> 6.5	5-6
EC, dS/m (mmhos/cm)	< 0.5	0.5-1.1	> 3.0	0.2-0.5
Nitrate-N, mg/l	< 40	65-85	> 150	15-25
Phosphorus, mg/l	< 3	8-12	> 18	5-10
Potassium, mg/l	< 10	20-50	> 80	10-20
Calcium, mg/l	< 10	20-40	> 100	20-40
Magnesium, mg/l	< 10	15-20	> 60	15-20
Manganese, mg/l		0.3		0.3
Iron, mg/l		0.5		0.5
Zinc, mg/l		0.2		0.2
Copper, mg/l		0.02		0.02
Boron, B mg/l		0.05		0.05

Container medium nutritional levels in **Table 2** can be used for interpreting levels obtained with the leachate collection technique. Ranges provided in **Table 2** are appropriate for most nursery stock. However, salt-sensitive species may be better off with 25 to 50 percent lower levels than listed. *Please note that levels should read much lower when controlled-release fertilizers are used alone. (Read the far right column in **Table 2.**)* Since most fertilizers are salts and media concentration of salts is directly related to EC, this can be used as an indicator for the need of additional fertilizer or for the need to leach out excessive salts from the growing medium. Be sure to measure the EC of the irrigation water. It will contribute to overall EC of the medium and perhaps affect your decision-making process.

What to Monitor

Growing media can be tested for individual elements (nutrients) or EC. A number of laboratories can check collected samples. (See the list of testing laboratories at the end of this chapter.)

It is inexpensive to measure EC. Electrical conductivity meters indicate the total dissolved fertilizer in the solution, but not the specific elements that are present. Electrical conductivity meters can be purchased for well under $100 for a pocket pen version, making it easy to check any container mix on the spot. Look for EC meter values ranging from 1.0 to 2.0 mmhos/cm. This range indicates nutritional levels that are ideal for optimal (aesthetically superior) growth for most species.

Recently, it has become more affordable for growers to begin testing for specific ions (elements or nutrients such as N). Cardy meters (hand-held electrodes) and paper test strips can give a measure of NO_3-N, for example, and can be used to estimate the amount of N in the irrigation water. Regardless of whether you check just EC or go a step further for specific nutrients, the information will allow you to adjust fertilizer use for optimal performance and minimal leaching. Taking this extra step will help produce the highest quality plants possible and grow them in an expedient and environmentally conscious manner.

Adding Supplemental Fertilizer Throughout the Growing Season

In most cases, growers find the need to apply additional fertilizer after plants are containerized or transplanted. This is done by placing fertilizer on top of the medium or by fertigation (adding fertilizer directly to irrigation water). If fertigation is used with overhead irrigation systems, collect the runoff so it doesn't go off site and degrade water sources (refer to Chapter 7). Surface-applied fertilizer (the more common approach in Oklahoma nurseries) should ideally be used on small groups of plants at each application to avoid excessive nutrient loading of runoff water. Refer earlier in this chapter to tips on top dressing plants.

Blocking Plants with Like Nutritional Needs

Blocking plants according to their nutritional requirements facilitates management of fertilizer and reduces costly runoff. For example, plants that require high N should be segregated from those that don't need or are injured by high levels of N.

Foliar Analysis

Foliar analysis may be used to diagnose deficiencies or determine the elemental status of plant tissue in the fall prior to the spring flush of growth. Plants cultured under the same conditions can be treated as one group, but samples from different species and possibly even different cultivars should not be mixed. For example, an acre block of plants all treated in the same fashion would require only one to three composite samples. However, plants of the same species grown differently should be sampled separately for accurate results.

To conduct foliar analysis, sample the uppermost mature leaves or shoot tips on woody plants with nonexpanding leaves. Take the samples just before an anticipated flush of new growth occurs. Each

Table 3. Optimum tissue nutrient levels for field-grown nursery stock.

		Deficient	Low	Sufficient	High
		Percent*			
N	(evergreen)	0-1.0	1.5	3.5	5.5
	(deciduous)	0-1.5	2.0	4.5	7.0
P		0-0.1	0.2	0.6	1.0
K		0-1.0	1.5	2-2.5	5.0
Ca		0-0.2	0.5	1.0-1.5	4.0
Mg	(evergreen)	0-0.1	0.2	1.0	2.5
	(deciduous)	0-0.2	0.3	1.0	2.5
		Parts per million (ppm)			
Mn		0-20	30	50-100	300
Fe		0-30	40	150	500
B		0-20	25	30	100
Cu		0-4	5	10-20	200
Zn		0-25	30	75	150
Mo		0-0.4	0.6	1.0	20

**Percent based on leaf dry weight*

sample should contain 20 to 30 uppermost mature leaves randomly collected from the block of plants. When sampling for diagnostic reasons, obtain three samples of tissue that are the same age from sickly as well as healthy tissue. Samples representing different stages or severity of the abnormality should be collected separately to determine whether the elemental content of tissue changes as the aberrance becomes more severe. Samples should be forwarded to a private laboratory (see the list at the end of this chapter). Refer to **Table 3** for elemental ranges for uppermost mature leaves of woody ornamentals. The values listed in **Table 3** are merely guidelines. Healthy plants may deviate from these values from time to time.

It is important to note that the nutritional needs for many genera have not been researched nor a foliar content for any given chemical element (such as nitrogen) established for every species. For some, trial and error must occur. Ultimately, the decision to adjust or maintain a fertilizer schedule must be based on experience and sound judgment as well as "what the numbers say." Keep good records because they are imperative when making future fertility management decisions. Foliar analysis is just one more tool to help make more informed fertilizer choices. By making good decisions and avoiding unnecessary fertilization, water quality can be protected.

Summary

1. Become familiar with plant nutritional requirements.
2. When possible, group plants by their nutritional needs.
3. Measure the electrical conductivity (EC) of the growing media on a monthly basis.
4. Use personal testing equipment or establish a good working relationship with a private lab for soil and water sample testing.
5. Use proper irrigation practices, which are as critical in protecting water quality as good fertilizer practices.
6. Keep detailed fertilizer application records.
7. Controlled-release fertilizers can pollute the environment. They must be managed properly.

Laboratory Testing Services

A&L Southern Agricultural Laboratories
1301 W. Copans Rd., Bldg. D #8
Pompano Beach, FL 33064
Phone: 305-972-3255
Fax: 305-972-7885

Scotts Testing Laboratory
6656 Grant Way
Allentown, PA 18106
Phone: 215-395-7105, 800-743-4769
Fax: 215-395-0322

Soil & Plant Laboratory, Inc.
P.O. Box 153
Santa Clara, CA 95052-0153
Phone: 408-727-0330, Fax: 408-727-5125

Soil & Plant Laboratory, Inc.
P.O. Box 6566
Orange, CA 92613-6566
Phone: 714-282-8777, Fax: 714-282-8575

Soil & Plant Laboratory, Inc.
P.O. Box 1648
Bellevue, WA 98009-1648
Phone: 206-746-6665, Fax: 206-562-9531

The Scotts Company
14111 Scottslawn Rd.
Marysville, OH 43041
Phone: 513-644-0011, 800-543-0006
Fax: 513-644-7679

Wallace Laboratories
365 Coral Circle
El Segundo, CA 90245
Phone: 310-615-0116, 800-473-3699
Fax: 310-640-6863

4. Irrigation in the Nursery

Mike Kizer, Extension Agricultural Engineer
Mike Schnelle, Extension Ornamental Floriculture Specialist

Irrigation Methods

Ideally, one of the most experienced individuals in the nursery should be responsible for irrigating or supervising the irrigation of crops. But, despite the critical nature of this position, few growers can spare the time or resources to actually experiment with different sources of irrigation methods. Choices made in irrigation systems can also directly or indirectly help maintain or improve water quality standards. Numerous container studies have demonstrated that drip irrigation systems consistently save water over more traditionally utilized overhead systems. Drip irrigation applies water precisely to root systems where it infiltrates quickly **(Figure 1)**. However, with overhead irrigation, all areas of the soil must be irrigated to "hit" the containers below. With Oklahoma's hot weather, evaporation of water could be in excess of 30 percent, delivering an application efficiency of 70 percent or less. This means that 70 percent or less of the water enters the soil, with an even smaller fraction of that water actually delivered to the containers and not the surrounding ground/floor area. Evaporation is significantly reduced with drip systems, with application efficiency of 90 to 95 percent in most situations. It has been shown that water used for drip systems ranges from 4,000 to almost 10,000 gallons per acre, while overhead irrigation uses more than 36,000 gallons per acre! About four times the number of plants could be irrigated using drip practices.

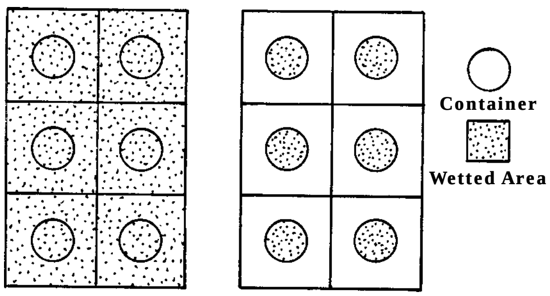

Figure 1A. Water distribution pattern of overhead and trickle irrigation.

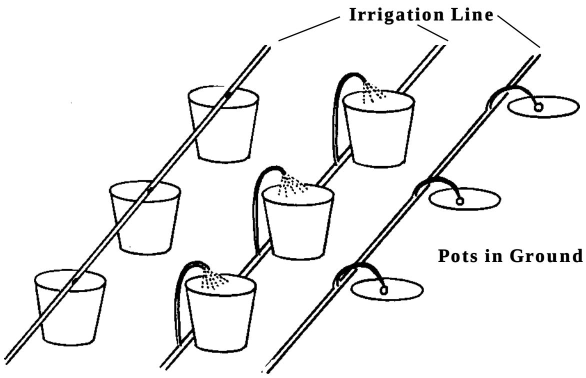

Figure 1B. Irrigating nursery container crops using trickle/microirrigation. a) Individual emitters online over containers. b) Spray stick emitters on a feeder line. c) Spaghetti tube/weight emitters in in-ground pots.

Microirrigation (trickle, drip, or mist irrigation) refers to the frequent application of small quantities of water at low flow rates and pressures. Rather than irrigating the entire field surface as with sprinklers, trickle irrigation is capable of delivering water precisely at the plant where nearly all of the water can be used for plant growth. Little water is wasted in supporting surface evaporation or weed growth because very little water spreads to the soil between the containers. The application of water is not affected by wind because it is applied at or below the ground surface. A well designed and maintained microirrigation system is capable of achieving an application efficiency of 90 percent or better.

Irrigation Components

Microirrigation systems can be arranged in a number of ways. The arrangement of components in **Figure 2** represents a typical layout. Variations in pressure within the system due to changes in elevation and pressure loss within the pipes will affect the discharge of individual emitters. For a system to irrigate satisfactorily, the application of water must be uniform at all emission points. There should be no more than a 10 percent variation in discharge between the emitters with the lowest and highest output. To achieve this, pipes and tubing must be sized correctly. Laterals should run across slope, following contour lines, or run slightly downhill. Areas of a system at markedly different elevations should operate as separate subunits with separate pressure regulators.

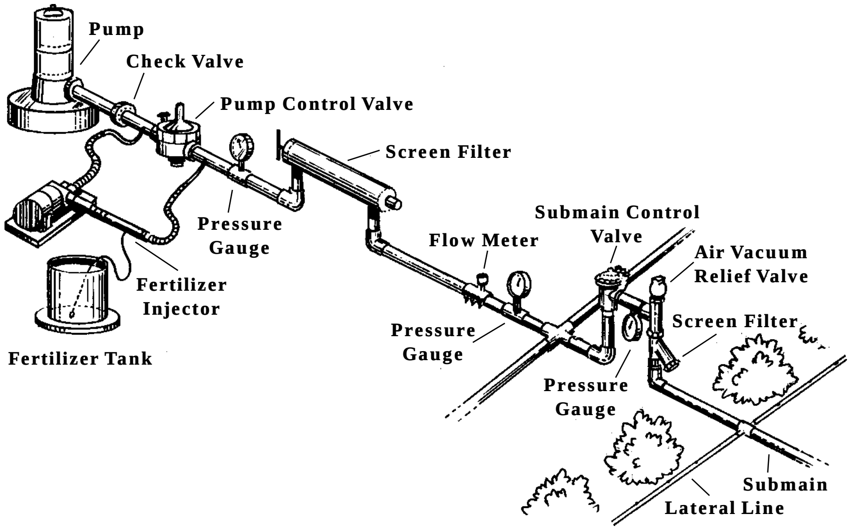

Figure 2. Components of a microirrigation system.

Trickle irrigation laterals can be divided into two categories: line source emitters and point source emitters. Line source emitters are used when plants are closely spaced within a row, with rows several feet apart as with most vegetable crops. The preferred emitting device for vegetable crops is a tubing with closely spaced perforations. The volume of soil irrigated by each perforation overlaps with that of the perforations next to it, resulting in a long, narrow block of irrigated soil that surrounds the roots of the entire crop row **(Figure 3)**.

Point source emitters are used when widely spaced point sources of water are needed, as in the case of large containers or orchard crops where the trees are spaced several feet apart in each direction. In this type of system, one (or more) emitting device is attached to a pipeline at or near the base of the plant, irrigating a single container or a bulb of soil surrounding the root mass of one plant **(Figure 3)**.

Point source emitters for permanent plantings should be located to provide balanced root development. While a single, small capacity emitter may be sufficient during the early years of plant development, a higher flow rate will be needed as the plant matures. This large flow should be divided between several emitters spaced around the trunk within the canopy dripline. The dripline is simply the line marking the extent of the tree canopy coverage on the ground surface.

Pressure Regulation

Since trickle irrigation systems operate at relatively low pressures, even small variations in pressure can have a significant effect on how uniformly the system applies water to the crop. For this reason, pressure regulators are often used, especially on steeply sloping sites. The pressure on water in a pipe will increase 1 pound per square inch (psi) for every 2.31 feet of elevation fall. For every 2.31 feet of elevation rise the pressure decreases 1 psi. So, if a site has a variation of 10 feet in elevation from the highest to the lowest point, the emitters at the lowest point will be operating at a pressure more than 4 psi greater than the highest emitter. In a system which may have a design operating pressure of only 8 to 12 psi, that is an extremely large variation.

Variations in pressure due to elevation change can be handled by using pressure regulators or pressure compensating emitters. Regulators are devices which maintain an outlet pressure that is virtually constant as long as they are driven by an input pressure higher than their output pressure. Sites with elevation variations must be broken into sections with only slight variations of elevation within each sec-

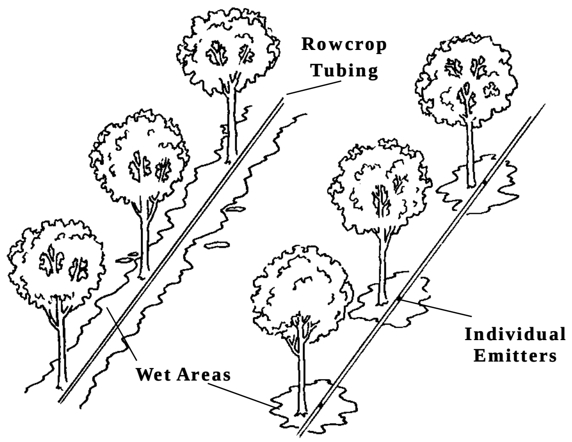

Figure 3. Water distribution patterns for line source and point source emitters.

tion. A pressure regulator would be placed at the inlet to each section and the delivery system pressurized to maintain adequate pressure to the regulator in the section with the highest elevation. All sections with lower elevations would have their increased pressure reduced by regulators, and a reasonably uniform application of water would result.

Pressure compensating emitters are application devices which maintain virtually constant discharge as long as their operating pressure stays within a certain range. Most pressure compensating emitters maintain an acceptable uniformity of discharge in the operating range of 10 to 30 psi. Pressure compensating emitters require no pressure regulator, but are substantially more expensive to purchase than ordinary emitters. However, they allow uniform application of water in locations where it is difficult to divide an irrigation system into subunits of constant elevation.

Water Quality and Filtration

Water quality and filtration are probably the most serious concerns when considering microirrigation. In order to discharge very low flow rates, the diameter of the emitter orifices must be very small. This results in the emitters being blocked easily by even the smallest contaminants in the water supply. Of particular concern are suspended solids such as silt and sand, minerals that precipitate out of solution such as iron or calcium, and algae that may grow in the water. Virtually every drip irrigation system must include a filtration system adequate to prevent plugging of the emitters. A system with poor quality water and poor filtration simply will not function reliably enough to warrant the maintenance requirements needed to keep it in operation.

Suspended solids will normally be less of a problem when ground water is used than when surface water is used for irrigation. Emitters will typically be rated by the manufacturer with regard to the degree of filtration required to prevent plugging by particles. This will normally be expressed in terms of a screen mesh number or as the diameter of the largest particle capable of passing through a filter. The relationship between the two sizing methods is given in **Table 1**.

Table 1. Filter size conversions.

Mesh Size	Width of Opening (inch)	Width of Opening (microns)
40	0.0150	380
60	0.0100	260
80	0.0070	180
100	0.0060	140
140	0.0041	105
200	0.0029	74
400	0.0011	27

Filters may be constructed of stainless steel or plastic screens that are reusable and require periodic cleaning. They also use disposable fiber cartridges. For water with a heavy load of large contaminants, a separator which uses centrifugal force to remove most of the particles may be used. Water with large amounts of fine silt and clay in suspension normally requires filtration with a media filter. Media filters use graded layers of fine sand to remove sediment. They are effective filters, capable of handling large flow rates, but they are relatively expensive to purchase and maintain.

The precipitation of minerals in irrigation water is usually a problem only with ground water sources. Dissolved minerals may come out of solution with a change of pH or temperature or when aeration occurs. If calcium is the problem, injecting acid into the water to lower the pH will prevent precipitates from forming. Sometimes, there is not sufficient calcium to precipitate out of solution, but enough to form a lime crust over the openings of emitters after the system is shut off and the components dry. If this situation causes frequent blockage of emitters, injection of acid into the system for the final few minutes of operation before shutdown should eliminate the problem. If iron is the problem, oxidizing the iron by chlorination or aeration and then filtering the water will be necessary. Injection of chemicals such as fertilizers or pesticides into the water may cause precipitation of minerals. Consequently, any filtration should take place after chemical injection has been done.

Growth of algae within the irrigation system is seldom a problem, since most algae require sunlight to grow and virtually all system components are made of opaque materials. However, if surface water is used to irrigate, algae often exist in the water supply. Pumping unfiltered water from an algae-laden source will result in frequent blockage problems, so adequate filtration is important. Treatment of ponds with algae problems by the addition of copper sulfate will greatly reduce the filtration load if the pond is used for trickle irrigation. Occasionally, a bacterial slime may develop in systems where the water has considerable organic matter. Routine use of a 2 ppm chlorine rinse at the end of each irrigation set will normally prevent slime development. If a slime problem does develop, a 30 ppm chlorine treatment will clean the system.

The use of high quality water and an adequate filtration system cannot be overemphasized. Use of poor quality irrigation water in a trickle irrigation system can result in so many maintenance problems related to emitter plugging that any labor savings you would expect relative to other irrigation methods will be eliminated. Maintaining the filtration system satisfactorily, chemically treating the water if necessary, and frequent flushing of the system will go a long way toward eliminating these problems.

System Capacity

The hours of operation needed to meet the irrigation requirement will depend upon the flow rate of the emitting device, the irrigation interval, and the rate of consumptive use by the plants being irrigated. In no case should the system be designed to operate more than 18 hours per day. This will allow some time for drainage of the plant root zone for proper aeration, time for system maintenance, and some excess capacity for catchup in case of system breakdown. In nursery applications, a common practice is to design the irrigation system with sufficient capacity so that it can maintain satisfactory plant water conditions when operated only during normal employee working hours. This reduces the number of hours available for system operation and increases the size of the water supply required, but it ensures better system oversight when irrigation is taking place.

Summary—Irrigation Methods

Microirrigation can be an extremely versatile production tool in horticultural enterprises. It can stretch a limited water supply to cover much more area than a typical sprinkler system. It can reduce the incidence of many fungal diseases by reducing humidity and keeping foliage dry. It allows automation of the irrigation system, reducing labor requirements. It delays the onset of salinity problems when irrigation water of poor mineral quality must be used.

Microirrigation requires careful water treatment to prevent emitter blockage problems. Frequent inspection of the system is necessary to ensure that it is functioning properly. Improper design and component sizing can result in a system with poor uniformity of application and a much lower than expected application efficiency.

A properly designed and installed microirrigation system is normally more expensive than a sprinkler system *initially*. However, the lower operating cost and higher efficiency of these systems can quickly justify the added expense in some horticultural situations. For more information on the design of microirrigation systems, refer to OSU Extension Facts F-1511, Trickle Irrigation for Lawns, Gardens, and Small Orchards.

Although drip or trickle irrigation has been emphasized, there are certainly other viable means of irrigation, depending upon the size of the nursery, the crops grown, and a myriad of other factors. Hand watering and traditional overhead irrigation are still appropriate in certain cases. Pulse irrigation, where water is applied in small amounts at frequent intervals, also may be a solution to avoiding runoff in the nursery and its related environmental concerns.

Water Supply Protection

In addition to the irrigation delivery system, the water source and its quality must be considered. The irrigation water supply must be protected from contamination. The driving force to move contaminants from the land surface to ground water is surface water that percolates through the non-saturated zone of the soil. Of course, around irrigation wells, a major source of the water that can transport contaminants is the applied irrigation water itself. The design and control of the irrigation system should be done so that water is not over applied. Excess water application in the wellhead area can leach nutrients, pesticides, and other contaminants out of the crop root zone and into the ground water. This not only contributes to the degradation of the environment, but also wastes water and costly production inputs. To minimize the risk to the environment, make sure your irrigation system is designed to apply water at a rate appropriate for your soil conditions.

Irrigation Wells and Contamination

A water well not only provides a path for ground water to be pumped to the ground surface for use, it can also provide a path for pollution from the ground surface to reach the ground water supply. The well punctures the protecting layers of soil that cover the aquifer, eliminating all filtering effect. Even though the water from an irrigation well might not be used for drinking water, contamination from it can affect the quality of water from nearby drinking water wells. For this reason, it is important to make sure that all wells are properly constructed and protected as much as possible.

Wellhead Protection Area Defined

Wellhead area refers to the area in which surface water recharges the ground water supply that feeds a well. There are a number of steps in protecting a wellhead area. One of the first steps is to determine the size and shape of the wellhead area. This can be a complex process, affected by the geology and topography of the area, the rate of pumping from the well, and the time frame for needed protection.

As water is pumped from a well, ground water flows from the surrounding aquifer into the well. This causes a cone-shaped depression in the ground water surface around the well where the water has been pumped out. If the water in the aquifer were not moving, this cone of depression would be a circle.

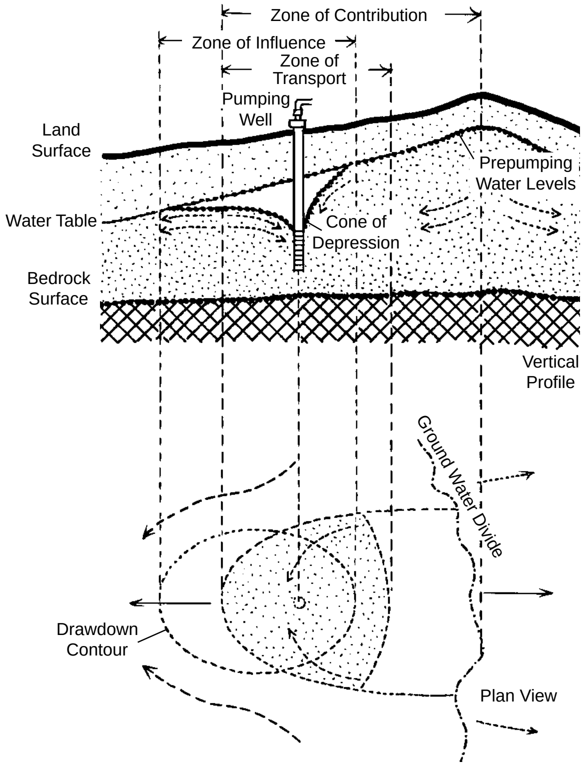

Figure 4. Diagram of ground water flow and zone of contribution around a pumping well.

However, ground water is usually flowing very slowly, and, as a result, the water table is usually sloped slightly. The slope of the ground water surface generally follows the slope of the ground surface, with ground water flow from highland areas toward river valleys, lakes, and the ocean. Because of this flow, the cone-shaped depression in the ground water surface around a pumped well is usually distorted **(Figure 4)**.

Once you get far enough downhill from the well to escape the zone of contribution, water and contaminants carried by surface water percolating into the ground are carried away from the well by the natural ground water flow and will not affect your well. Directly uphill from the well, however, nearly all contaminants will eventually reach the well because of the natural movement of the ground water. The closer the contamination occurs, the more quickly it will reach the well, because the time of transport from points close by is shorter than from points farther away.

Because ground water moves very slowly in most aquifers, sometimes just a few inches per day, a spill of contaminants a few hundred feet from a well might take a year or more to reach the well. During that time, contaminants are constantly being decomposed and diluted; therefore, their effect on the well will be reduced. The change in the contaminant depends on its makeup and conditions in the subsurface environment. Some contaminants break down in a relatively short time, while others may be unchanged over a period of many years. Products which break down very slowly have a long life and should be avoided or used with extreme care in the zone of contribution of water wells.

Well Location

Location determines, to a great degree, a well's potential for ground water contamination. If there are possible sources of contaminants in the area, the well should be located uphill from these sources. Locating the well uphill means the natural flow of ground water will reduce the chance of leached contaminants being in the water pumped by the well. The uphill location also ensures surface water runoff will carry contamination from possible pollution sources away from the well.

Moving high-risk activities outside the wellhead protection area will reduce the risk of well contamination. However, if spills or other accidental releases of contaminants occur, the contamination can still reach the ground water and cause pollution in neighboring wells. Separation from sources of contamination is important to protect wells from pollution. If a well is a long distance from a source of pollution, the contaminant may degrade a great deal due to exposure to air, sunlight, and biological activity before it reaches the well. Any degradation and dilution of the contaminant reduces its potential as a health or environmental hazard.

Well Construction

Proper well construction is an important factor in protecting the ground water supply from contamination. Regardless of what kind of pollution potential exists at the ground's surface, a properly constructed well can prevent many contaminants from rapidly reaching the aquifer through the borehole.

The first step in good well construction is to properly case the well. A good well casing which extends all the way to a protecting layer of clay or rock, or at least 10 feet below the minimum water level of the aquifer, is the first feature of proper well construction **(Figure 5)**. In areas where a water-bearing formation of fractured sandstone or limestone is very near the ground surface, it is common practice to extend the well casing only a short distance below ground. Since the rock formation is stable, there is no danger of the borehole collapsing. However, this practice can allow surface water and contaminants to rapidly enter the borehole after passing through only a few feet of topsoil. Casing the well to a greater depth means that surface water must follow a longer

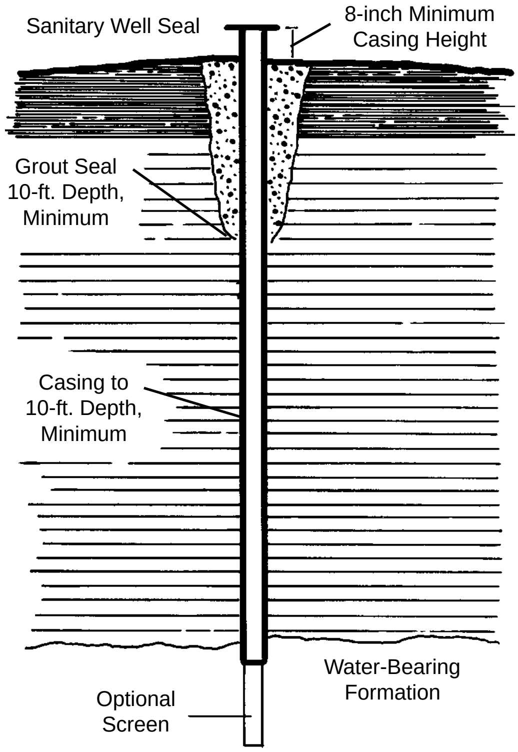

Figure 5. Diagram of typical irrigation well showing required features for proper sanitation protection.

flow path before it can enter the well, resulting in more filtering. Casing the well to 10 feet below the minimum water level can improve the quality of water pumped from wells. Some contaminants, such as petroleum products, are lighter than water and will migrate to the top of the aquifer. Pumping from the bottom of the aquifer will reduce the amount of these contaminants in the water delivered by the well.

The casing should extend at least 8 inches above the original ground surface to prevent any standing surface water or flood water from overtopping the casing and leaking inside the well. The ground surface around the well should be shaped so that it slopes away from the wellhead. This will prevent surface water from collecting near the wellhead and seeping down the outside of the well casing.

The well casing must be securely sealed to the surrounding soil by grouting the area around the casing from the ground level to a depth of at least 10 feet. The grout mixture should be a neat cement mixture (with no aggregates) or a cement-bentonite mixture with no more than 6 percent bentonite. The grout must be made with no more than 6 gallons of water per sack of cement. Using too much water in the mix can result in a poor seal, because the grout mixture will shrink as it cures, causing it to pull away from the casing.

Housekeeping Around Wells

It is important to keep the wellhead area clean and environmentally safe. There are many products that may be used around irrigation wells which can potentially cause contamination and rapidly enter the ground water through a damaged well casing or through coarse topsoil overlying a shallow water table. Well houses are often seen as convenient places to store items such as fertilizer bags and pesticide containers. In no case should the well house be used as a storage area.

If an accidental release of a contaminant occurs in the wellhead area, it should immediately be cleaned up as completely as possible. If the contaminant is allowed to remain in the soil of the wellhead area, much of it will eventually be carried into the ground water by rain and surface water percolating through the soil to recharge the ground water. From there it may be pumped out in the irrigation water or drinking water of your well or a neighboring well.

Backflow Prevention

Many operators use irrigation systems to apply fertilizer and chemicals, a practice called chemigation. Certain precautions must be taken to prevent contamination of the irrigation well should an unscheduled shutdown of the irrigation pump occur during chemigation. If the pump stops while chemical products are within the irrigation pipeline, backflow of contaminated water into the well can contaminate the ground water supply. Backflow prevention devices are required by federal law when toxic chemicals are applied through irrigation water. The main device required is a chemigation check valve. This consists of a spring-loaded, positive-seating, chemically resistant check valve with an atmospheric vacuum breaker and a low-pressure drain. The chemigation check valve is placed in the irrigation pipeline between the pump and the point of chemical injection, preventing backflow of contaminated water into the well.

An approved alternative backflow prevention device is a gooseneck pipe loop. This is a loop in the irrigation pipeline which rises at least 24 inches higher than the highest outlet in the irrigation system and has an atmospheric vacuum breaker at the top of the loop. The rise in the loop prevents backflow due to the back pressure in the sprinkler system, and the vacuum breaker prevents formation of a siphon down to the bottom of the well.

Irrigation systems using public water supplies for their water source must have specialized backflow preventers if they are used for chemigation. A reduced pressure zone device—a double-check valve with a vacuum breaker located in between—is the recommended backflow prevention device. For further information about chemigation safety equipment, refer to OSU Extension Facts F-1717, Safety and Calibration Requirements for Chemigation.

Nutrient Management

Many nursery personnel carefully apply fertilizers to reduce production costs and protect the environment, but few think about the nutrient value of their water. Irrigation water should be tested occasionally for its nutrient content. High nitrate is a problem in the ground water in some parts of Oklahoma. However, if the nitrogen in irrigation water is included in the nutrient budget, it can help improve profitability by reducing fertilizer costs and reducing nitrogen leaching and runoff.

For every 1 mg/l of nitrate-nitrogen in the water, 0.00834 pound of nitrogen is applied with every 1000 gallons of irrigation water. If your water has 10 mg/l of nitrate-nitrogen, you would apply about 1/12 pound of nitrogen when applying 1000 gallons of irrigation water. This may not sound like much, but when considering the amount of water applied in an entire nursery operation throughout the course of a growing season, it adds up.

Water Management

Use some type of irrigation scheduling system that responds to the actual water needs of the crop. This might include soil water measuring devices such as tensiometers or electrical resistance blocks. It is possible to schedule the application of water using a soil water budget and crop water use estimates based on current weather information. Weather data from the Oklahoma Mesonet can be used to schedule the application of water based on crop water needs. This avoids applying water when crop growth conditions don't warrant it and reduces the loss of water, nutrients, and pesticides from the crop root zone.

Good irrigation water management includes metering the amount of irrigation water applied. This may include accurately measuring the discharge from emitters, sprinklers, or watering nozzles and controlling the time of application to meet the needs of the plants being irrigated. With sprinkler irrigation systems, the use of rain gauges can give relatively accurate estimates of the amount of water actually being applied.

When applying fertilizers or pesticides by chemigation, don't overirrigate. Each chemical product will have the specified amount of water to apply listed on the label. Apply only the minimum amount of water required to distribute the product effectively. Overirrigation may cause it to leach below the root zone, which could lead to ground water contamination.

Summary

Irrigation is a necessary tool in profitable nursery management. It has great potential for producing reliable supplies of quality plants. However, when not properly designed and managed, it also has the potential to create numerous environmental problems. Be sure your irrigation system receives proper maintenance and management to keep your operation trouble-free and profitable.

5. Using IPM to Prevent Contamination of Water Supplies by Pesticides

Gerrit Cuperus, IPM Specialist
Sharon L. von Broembsen, Extension Plant Pathologist

Integrated pest management (IPM) is a key to preventing pesticide contamination of water supplies by ornamental nurseries. Pesticides must be prevented from entering water supplies; there is no acceptable tolerance for pesticides in irrigation runoff leaving nurseries. The main ways to prevent pesticides from contaminating nursery runoff are 1) to reduce pesticide use, and 2) to select and apply pesticides appropriately. Reduction in use of pesticides is an important goal of all IPM programs, and this chapter will focus on IPM practices and their implementation in nurseries, outlining appropriate methods for using pesticides to prevent pollution of water supplies.

The IPM Approach

IPM, an effective and economical management strategy for controlling crop pests, helps to protect the environment and human health. IPM involves monitoring pests, establishing action or economic thresholds, and selecting appropriate management methods. To do this, the habits and life cycles of pests and the interaction of pests with plant systems must be understood. Pests include insects, mites, vertebrates, plant pathogens, and weeds. IPM focuses on understanding pest ecology and factors that regulate pest population dynamics, then establishing a system that integrates control tactics with management practices. Finally, IPM focuses on ecologically based approaches, e.g., the use of resistant cultivars, improved cultural practices, the newer "soft" pesticides, and biological control.

Understanding ecological and developmental factors that regulate pest abundance is a critical first step. Disease, insect, and weed populations are regulated by moisture/relative humidity, temperature, predators/parasites, and other factors. Most pests have specific requirements for either relative humidity or moisture in the soil or on leaves. Bacterial diseases are often stimulated or spread by splashing water, and many fungal diseases tend to spread and reproduce more in humid conditions. Most insects and diseases have specific temperature requirements. Understanding these factors can allow the manager to select pest management practices that will be effective.

A. Host Plant Resistance. The first line of defense in any pest management program is to raise plants that have inherently few pests and, therefore, require a minimum amount of pesticides. Genetic resistance to pests is an advantage in any management program. Producing and marketing well-adapted resistant species and/or cultivars will also ensure satisfied customers.

B. Inspection of Incoming Plants. One of the most effective pest management practices is to keep key pests out of the nursery. Incoming plant material should be carefully inspected to make sure that it is pest free. Examples of excludable pests are fire ants, Japanese beetles, or tomato spotted wilt virus. *Never* accept infested nursery stock.

C. Detecting and Monitoring Pests. Decisions as to what pest management practices to use should be based in part on pest detection and monitoring results. This requires careful, systematic searching for signs of pests and for conditions that favor pest buildup. Monitoring over a period of time may help you detect pests and determine sources of infestation and patterns of spread. Monitoring is also helpful in evaluating the effectiveness of management programs. Pest populations take time to build to damaging levels. By understanding the factors that regulate population development, managers can see development occurring and take action before populations get out of hand.

Visual Inspection. The purpose of visual inspection is to find evidence of pests or pest-prone situations. During an inspection, look for 1) conditions that favor pests; 2) signs of pest damage, entry, or presence; and 3) the pest itself. Weeds and insects may be more concentrated near the edge of a nursery, so these should be the places to look first.

When doing an inspection, it's helpful to prepare a diagram of the nursery and keep track of problem areas over multiple years. Observe any conditions that may cause problems during pest management operations. Note areas you were unable to inspect because they were inaccessible. Show the locations of trees, shrubs, garbage storage, water sources, and other features of the surrounding area that may attract or harbor pests or foster pest buildup.

Detection and Monitoring Devices. Simple hand lenses help identify some insects and plant diseases. Special devices and tools are available to detect and monitor insects in some crops. These include pheromone traps and other attractants, light traps, and sticky traps. Pheromone traps are available for key nursery insects, including pine tip moth and Japanese beetle. Traps should be checked regularly—once or twice per week at a minimum—and the number of target insects removed from traps should be recorded each time they are checked. This will allow detection of changes in the insect activity, help determine when to treat, and verify the success or failure of pest management measures.

Disease diagnosis may require sample testing to determine which pathogen is present. This may include use of on-site kits such as ELISA or, more typically, sending diseased samples to a diagnostic clinic. The Oklahoma State University Plant Disease Diagnostic Laboratory in the Department of Entomology and Plant Pathology accepts disease samples (telephone: 405-744-9961).

D. Establishing Thresholds for Action. Pest management decisions should be based on the abundance of pests and the plant's tolerance to damage. Ultimately, the decision depends on the cost versus the benefit of treatment. Thresholds are often available to help make decisions on what type of management is needed and when it should begin. Thresholds vary according to the specific objective at hand, but they have a common goal of limiting pest development to what is acceptable overall.

- Cosmetic thresholds limit the pest numbers to prevent significant cosmetic or aesthetic damage.
- Action thresholds are pest levels at which action should be taken to prevent a sizable accumulation of pests that could cause damage.
- Economic thresholds are levels of pest abundance at which the potential economic loss caused by pest damage is expected to be greater than the cost of managing the pest.

E. Biological Control. Biological control includes the integration of parasites, predators, nematodes, and microbial organisms to manage pests. If managed correctly, biological controls can help suppress pest populations. Key factors are to recognize important naturally occurring biological control organisms, conserve beneficial organisms, understand their role in pest population dynamics, and continue to develop a system that optimizes their impact on pest populations. Insects such as aphids and thrips often are maintained at low levels because of predators and parasites.

In most nursery situations, conservation of naturally occurring biological control organisms is emphasized. Weeds have few natural enemies and must be managed differently. However, effective biological controls are available for some soilborne fungal pathogens. The commercial preparations contain antagonistic bacteria or fungi and are incorporated into planting mixes to control root pathogens. Crown gall, a disease which affects the roots and stems of a wide range of nursery crops, can be prevented by treating exposed root systems or pruned surfaces with a specific biocontrol product.

F. Water Management. Careful use of water is critical to minimizing the risk of contaminating water supplies with pesticides. Reduce runoff by more desirable irrigation methods such as drip irrigation or hand watering for small blocks. Determine where runoff goes and how it might be contained on site. Consider using capture and recycle systems in part or all of the nursery. For more information on irrigation, refer to Chapters 4 and 7.

G. Managing Pesticides. Pesticides are important tools of conventional pest management systems. They can maximize plant survival and growth, but can also pose a risk to the environment. For example, pesticide contamination of aquatic invertebrates can disrupt food chains. When using IPM, pesticides are applied only when economically justified. Integrated pest management does not eliminate pesticide use, but it encourages responsible use which generally results in reduced applications.

Each pesticide has characteristics that determine its mode of transport in the environment and its impact on the ecosystem. The characteristics that regulate movement include formulation, application timing, runoff potential, and leaching potential. Considering these properties can help protect the environment. For more information, refer to Chapter 6 about selecting and using pesticides to protect water supplies.

Implementation of an IPM Program to Protect Water Quality

1. Develop a long-term pest management plan that considers the full range of management options.
2. Carefully consider site features such as slope, drainage, and entry of off-site storm water that can lead to pesticide runoff.
3. Build up a reference library of information resources on pests and pest management.
4. Establish an ongoing employee IPM training program.
5. Select appropriate management actions based on routine inspection and monitoring. This process includes:
   a. Knowing the pest and treatment history of the nursery.
   b. Examining representative plants for pests in a methodical way.
   c. Recording the results (counts and diagnosis of pest problems).
   d. Using action thresholds to determine if action is warranted.
   e. Selecting the best management action for each situation.
   f. Identifying other practices that might limit future pest problems.
6. Develop management options that integrate worker safety, economics, and environmental issues.
7. Keep detailed records of plant location, production, and pest management practices, especially pesticide applications.

6. Pesticides and Water

Jim Criswell, Pesticide Specialist

Oklahoma has numerous lakes to provide water. However, rural residents and small communities usually receive drinking water from ground water sources.

Pollution affects about two percent of ground water in the U.S. An increasing amount of surface water is also becoming somewhat contaminated (EPA 1990).

Agriculture accounts for two-thirds of the more than 4.5 million pounds of pesticides used in the U.S. yearly. Nursery and greenhouse production systems are included in this figure. The home and garden sectors used 135 million pounds of pesticides in 1995 (EPA 1997).

Water contamination is directly related to the degree of pollution in our environment. As a result, the hydrologic cycle **(Figure 1)** may be affected on many levels. After airborne pollution is flushed from the sky by rainwater, it is washed over land before running into rivers, underground aquifers, and lakes. Since drinking and irrigation water come from surface and ground water, any chemical used may pollute water supplies **(Figure 2)**.

While some materials that endanger water quality come from agriculture, most result from urban and industrial activity. Improper application, handling, or disposal of pesticides can lead to pollution, whether in agricultural application or urban environments. For example, a nursery operator must understand how to properly use pesticides to avoid human exposure to pesticides and to protect water sources.

Pesticides used in nursery settings should be selected not only to control the pest, but also to limit its ability to run off or leach into the soil/media surface. In order to achieve this balance, the applicator must be knowledgeable of a pesticide's efficacy and water solubility. The latter can be obtained from the pesticide's label and material safety data sheet (MSDS). Additional water data may be obtained from the Oklahoma Department of Agriculture, from Oklahoma State University, and the chemical company.

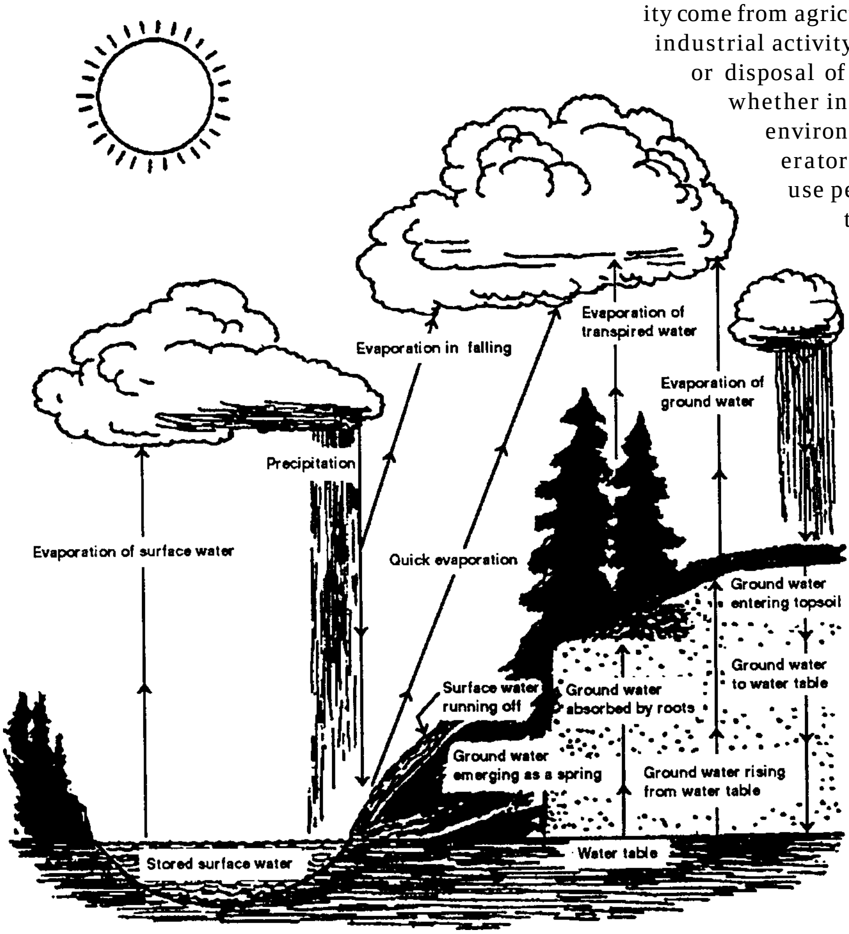

Figure 1. The hydrologic cycle.

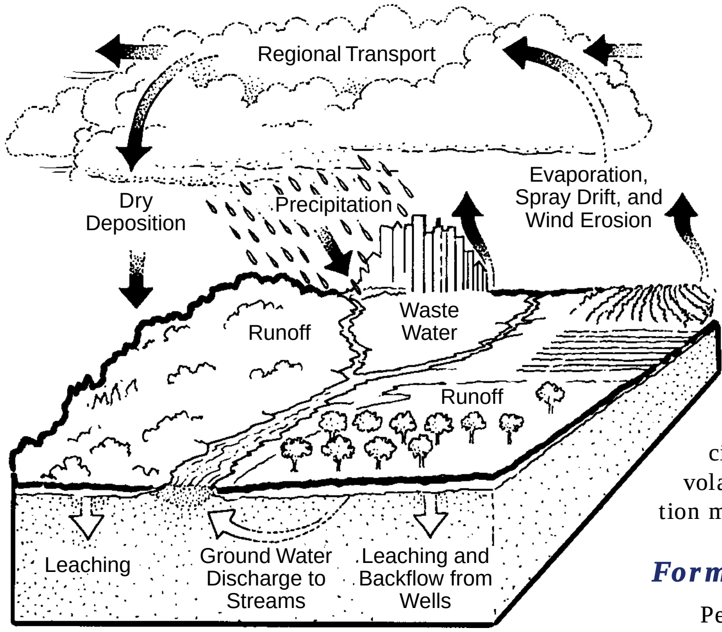

Figure 2. Pathways of pesticide movement in the hydrologic cycle.

Ways to Contaminate Water

Overapplication or misuse of pesticides can allow them to enter the surface and/or ground water. For some newer pesticides, drift from soil/media particles treated with the pesticide is a potential source of water contamination. These pesticides are often active at low concentrations. When bound to soil/media particles, the pesticide may be picked up by wind and moved over surface water. When deposited in water or a waterway, these particles can then move into the surface water. This is generally not a major problem unless large amounts of contaminated particles are moved and deposited in the same area or the pesticide is active on other target species.

Improperly cleaning pesticide containers and sprayers often leads to pesticide runoff or contamination of the soil/media at the mixing/loading site. Pesticide sprayers should be loaded and cleaned on an impervious pad. This eliminates concern about spills causing runoff or leaching problems, avoiding potential contamination of wells from constant small spillages at the same site.

When filling any sprayer, either an anti-back siphoning devise or an air gap should be used. This prevents back siphoning of the pesticide mix into the water line if water pressure is lost. If using anti-back siphoning devises, be sure to periodically inspect the device to ensure it is functioning correctly. Mechanical back siphoning devices have been known to stick in the open position.

Pesticide containers should be triple or pressure rinsed immediately after emptying to rinse all the excess pesticide from the container. The rinsate is to be rinsed directly into the sprayer so the rinsate can be sprayed on the labeled site. This provides a clean container which can then be recycled.

Pesticide Properties

It is important that the applicator knows the type of pesticide and its properties prior to purchasing and using the pesticide. The pesticide's formulation, persistence, volatility, solubility in water, and its soil adsorption must be known.

Formulation

Pesticides come in several physical forms or formulations. Common formulations include emulsifiable and flowable concentrates, wettable powders, granules, and water dispersible granules. Granules, water dispersible granules, and emulsifiable concentrates tend to be more water soluble than wettable powders and microencapsulated formulations.

Persistence

Persistence describes how long a pesticide remains active. Half-life is one measure of persistence. The half-life of a substance is the time required for that substance to degrade to one-half its original concentration. In other words, if a pesticide has a half-life of 10 days, half of the pesticide has been broken down or lost 10 days after application. After this time, the pesticide continues to break down at the same rate.

The half-life of a pesticide is not an absolute factor. Soil/media moisture, temperature, organic matter, microbial activity, soil/media pH, and sunlight all affect the breakdown rate. In general, the longer a pesticide persists in the environment, the more likely it is to move from one place to another and be a potential water contaminant.

Volatility

Many pesticides, including several herbicides and soil fumigants, can escape from soils/media as gases. Some can be drawn from the soil/media and enter the atmosphere with evaporating water. Pesticide particles in the atmosphere can come back to earth in rain, snow, or dust fall. They then can leach into ground water or be carried by runoff into surface water.

Soil Adsorption

Soil/media adsorption is the tendency of materials to attach to the surfaces of soil/media particles. If a substance is adsorbed by the soil/media, the substance stays on or in the soil/media and is less likely to move into the water system unless soil/media erosion occurs. A soil/media's texture, structure, and organic matter content affect the soil/media's ability to adsorb chemicals.

The K_{oc} describes the relative affinity or attraction of the pesticide to soil/media material and, therefore, the pesticide's mobility in soil/media. Pesticides with small K_{oc} values are more likely to leach than those with high K_{oc} values.

Water Solubility

The water solubility of a pesticide determines how easily it goes into solution with water. When a pesticide goes into solution with water, the pesticide will move where the water goes. Solubilities are usually given in parts per million (ppm) or as milligrams per liter (mg/l). These are equivalent. It tells the maximum number of milligrams that will dissolve in one liter of water.

Simply being water soluble does not mean that a pesticide will leach into ground water or run off into surface water. However, solubility does mean that if a soluble pesticide somehow gets into water, it will probably stay there and go where the water goes.

Water solubility is one indicator of the pesticides mobility in water. Water solubility and adsorption to soil/media particles are inversely related for most compounds. However, like most rules, there are exceptions. Water solubility greater than 30 ppm indicates that significant mobility is possible if the K_{oc} value is low (less than 300-500). Pesticides with a solubility greater than 30 ppm and K_{oc} values less than 100 are considered a concern in sandy soil by the EPA.

Pesticides with solubilities of 1 ppm or less are believed to have a higher likelihood of runoff. Likewise, pesticides with high K_{oc} values are more likely to run off than leach. Pesticides with K_{oc} values of 1,000 or higher have a strong soil/media attachment.

How Pesticides Enter Surface and Ground Water

Pesticides can enter water through surface runoff, leaching, and/or erosion. Water that flows across the surface of the land, whether from rainfall, irrigation, or other sources, always flows downhill until it meets a barrier, joins a body of water, or begins to percolate into the soil/media.

Wind and water can erode soil/media that contain pesticide residues and carry them into nearby bodies of water. Even comparatively insoluble pesticides and pesticides with high soil/media adsorption properties can move with eroding soil/media. A number of the sulfonylurea herbicides have warning statements regarding movement of treated soil/media.

With increasing frequency, soil/media-applied pesticides also are being found in ground water where the water table is close to the soil/media surface or the soil is a sand.

Point and Nonpoint Sources

Pesticides that enter water supplies can come either from point sources or from nonpoint sources **(Figure 3)**. Point sources are small, easily identified objects or areas of high pesticide concentration, such as tanks, mixing/loading sites at wellheads, containers, or spills. Nonpoint sources are broad, undefined areas in which pesticide residues are present.

Water Quality Protection

Most pesticide contamination does not come from normal, correct usage. Problems arise from misuse or careless handling. A checklist is provided to use when applying any pesticide. Use this guideline to help safeguard water sources near your nursery operation.

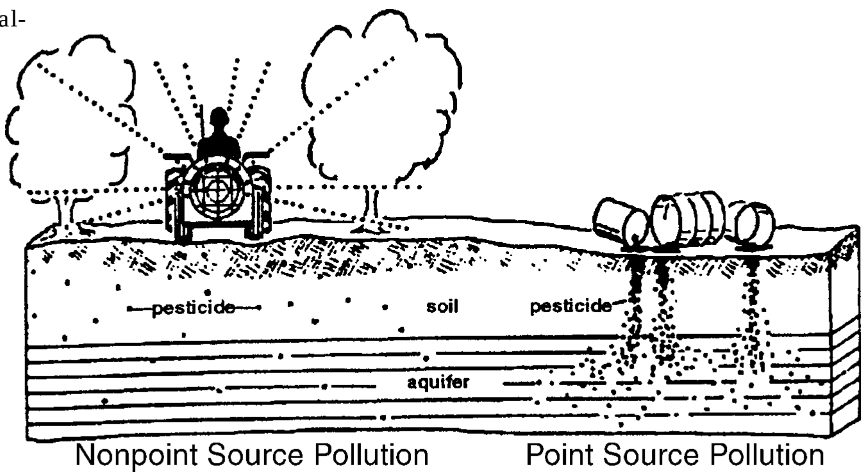

Figure 3. Pesticides can enter water supplies from point sources or from nonpoint sources.

When Applying Pesticies...

- ☐ Consider the vulnerability of the site; be sure that weather and irrigation will not increase the risk of water contamination.
- ☐ Evaluate the location of water sources.
- ☐ Read and follow pesticide label directions.
- ☐ When possible, use the pesticide with the least potential for surface runoff and leaching.
- ☐ Store pesticides properly.
- ☐ Make sure pesticide containers do not leak.
- ☐ Use IPM practices.
- ☐ Calibrate all pesticide application equipment after at least every third use.
- ☐ Prevent backflow during mixing operations by use of a mechanical anti-siphoning device or an air gap.
- ☐ Triple or pressure rinse pesticide containers upon emptying and pour rinsate into spray tank.
- ☐ Always mix, handle, and store pesticides at least 100 feet from water wells.
- ☐ Do not apply pesticides when conditions are likely to produce runoff or excessive leaching.
- ☐ Do not spray pesticides on windy days (winds in excess of 10 mph).
- ☐ Prevent pesticide spills and leaks from application equipment.
- ☐ Leave buffer zones around sensitive areas such as wells, irrigation ditches, ponds, streams, drainage ditches, septic tanks, and other areas that lead to ground or surface water.
- ☐ Do not water pesticide-treated areas immediately after application unless indicated on label instructions.
- ☐ Dispose of excess pesticides by applying them to labeled sites.

Glossary

Adsorption characteristics (K_{oc}). The K_{oc} describes the relative affinity or attraction of the pesticide to soil material and, therefore, its mobility in soil. Pesticides with small K_{oc} values are more likely to leach than those with high K_{oc} values.

Bioaccumulation. The storage or accumulation of materials in the tissues of living organisms.

Carcinogenic. A property that makes a material more likely to cause cancer in humans or animals that are exposed to that property.

Degradation. Degradation occurs due to sunlight, soil microorganisms, and chemical reactions in the soil. Soil temperature and moisture can greatly affect degradation.

Degradation rate is quantified in terms of degradation half-life, the time required for 50 percent of the pesticide to decompose to products other than the original pesticide.

The EPA considers a pesticide with soil half-life of greater than 21 days as having a potential for causing water concerns due to the pesticide's longevity.

Ground water. A region within the earth that is wholly saturated with water.

Leaching. Dissolving and transporting of materials by the action of percolating water.

Persistence. The ability of a substance to remain in its original form without breaking down.

Soil permeability. Permeability is a function of soil texture, structure, and pore space. Highly permeable, coarse, sandy soils have large pores that allow water and pesticides to move rapidly between soil particles during rainfall or irrigation. In medium- and fine-textured soils, water moves more slowly, allowing more time for pesticide adsorption and degradation. Each layer of soil can have a different permeability, but the overall permeability is determined by the most restrictive layer.

Soil permeability increases when there are macropores, large channels produced by plant roots, earthworms, soil cracks, and the burrowing of smaller animals.

Soil organic matter. Soil organic matter helps to bind pesticides, especially those with high K_{oc} values, and promotes degradation.

Soil texture. Texture is determined by the proportion of sand, silt, and clay.

Soil pH. The pH of the soil is a measure of its degree of acidity or alkalinity. pH affects the degradation rate of pesticides and the adsorption characteristics and mobility of ionic pesticides.

Slope and landscape. Areas with high runoff capability will have less of an impact on water infiltration than areas which are flat or have a concave slope.

A landscape which encourages runoff will minimize leaching. Landscapes which hold water may increase leaching potential or may provide organic matter which assists in "holding" the pesticide.

Water solubility. Solubility is measured in mg/l of the pesticide in water at room temperature (20 or 25°C). It is generally the solubility of the pure (active ingredient) that is measured, not the formulated product.

Water table. The upper limit of the saturated level of the soil.

Volatilization. Volatilization is evaporation. Volatilization increases with air temperature and the vapor pressure of the pesticide formulation. It occurs more rapidly in wet than in dry soils.

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Table 1. Persistence of biological activity at the usual rate of herbicide application in a temperate climate with moist, fertile soils and summer temperatures.[1]

1 Month or Less	1-3 Months	3-12 Months[2]		Over 12 Months[3]
Acifluorfen	Bifenox	Alachlor	Fluometuron	Borates
Acrolein	Bromoxynil	Ametryn	Fluridone[4]	Bromacil
Amitrol	Butachlor	Atrazine	Hexazinone	Chlorates
AMS	Butylate	Benefin	Isopropalin	Chlorsulfuron
Barban	Chloramben	Bensulide	Imazamethabenz	Fenac
Bentazon	Chlorpropham	Buthidazole	Imazaquin	Fluridone[5]
Benzadox	Cycloate	Chlorimuron	Imazethapyr	Hexaflurate
Cacodylic acid	Desmedipham	Clomazone	Metribuzin	Imazapyr
Chloroxuron	Diallate	Clopyralid	Monuron	Karbutilate
Dalapon	Diphenamid	Cyanazine	Napropamide	Picloram
2,4-D	EPTC	Cyprazine	Norflurazon	Prometon
2,4-DB	Linuron	DCPA	Oryzalin	Tebuthiuron
Diclofop	Mecoprop	Dicamba	Oxyfluorfen	Terbacil
Diquat[6]	Methazole	Dichlobenil	Pendimethalin	2,3,6-TBA
DSMA	Metolachlor	Difenzoquat	Perfluidone	
Endothal	Naptalam	Dinitramine	Pronamide	
Fluorodifen	Pebulate	Diuron	Propazine	
Glyphosate	Prometryn	Ethalfluralin	Simazine	
Fluazifop	Propachlor	Fenuron	Sulfometuron	
Fenoxaprop	Proham	Fluchloralin	Trifluralin	
Metham	Pyrazon			
Methyl bromide	Siduron			
MCPA	TCA			
MCPB	Terbutryn			
Molinate	Thiobencarb			
MSMA	Triallate			
Nitrofen	Vernolate			
Paraquat[6]				
Phenmedipham				
Propanil				
Sethoxydim				

[1] These are approximate values and will vary as discussed in the text.
[2] At higher rates of application, some of these chemicals may persist at biologically active levels more than 12 months.
[3] At lower rates of application, some of these chemicals may persist at biologically active levels for less than 12 months.
[4] In water.
[5] In soil.
[6] Although diquat and paraquat molecules may remain unchanged in soils, they are absorbed so tightly they become biologically inactive.

Table 2. Insecticide water quality data.

Systemic Insecticide Common Name	Relative Runoff Potential	Relative Ground Water Leaching Potential	Half-Life in Days
Diazinon	Medium	Large	30
Acephate	Low	Low	3
Chlorpyrifos	Large	Small	30
Dimethoate	Small	Medium	7
Dicofol	Large	Small	60
Carbaryl	Medium	Small	10
Malathion	Small	Small	1
Propargite	Large	Small	56

Table 3. Herbicide water quality data.

Herbicide Common Name	Relative Runoff Potential	Relative Ground Water Leaching Potential	Half-Life in Days
Diquat	Small	Small	
Glyphosate	Large	Small	47
Pendimethalin	Large	Small	90
Napropamide	Large	Medium	70

Table 4. Fungicide water quality data.

Fungicide Common Name	Relative Runoff Potential	Relative Ground Water Leaching Potential	Half-Life in Days
Chlorothalonil	Large	Small	30
Etridiazole	Large	Small	103
Ferbam	Medium	Medium	17
Fenarimol	Medium	Small	360
Manozeb	Large	Small	70
Metalaxyl	Small	Medium	70
Propiconazole	Medium	Medium	100
PCNB	Large	Small	21
Thiophanate-methyl	Small	Medium	10
Triforine	Medium	Small	21
Triadimefon	Medium	Medium	26
Vinclozolin	Medium	Medium	20

7. Capturing and Recycling Irrigation Water to Protect Water Supplies

Sharon L. von Broembsen, Extension Plant Pathologist

The preceding chapters describe irrigation, nutrient, and pest management practices for reducing nutrients and pesticides in runoff water leaving a nursery site. This chapter presents a different approach in which water quality is protected by retaining irrigation runoff on the nursery site and then reusing it within the nursery. This capture and recycle strategy may have significant advantages for some nurseries.

The runoff standards that nurseries must meet vary with geographic location. Those located near outstanding resource waters or large population centers are likely to bear the most scrutiny. Since 1990, the Oklahoma Department of Agriculture has been monitoring nutrients and pesticides in runoff from ornamental nurseries in the Illinois River Basin (an Oklahoma designated Scenic River) to establish baselines for nursery effluents. More importantly, it has also been working with these nurseries to reduce effluent contamination to acceptable levels through a voluntary compliance program. This program has been very successful—the cooperating nurseries have made the management changes necessary to achieve the target levels and have shown the public that they are doing their part toward protecting water quality. Although no statewide standards have been set for nursery effluents so far, the Illinois River Basin studies would allow realistic levels to be set for Oklahoma nurseries.

Most nurseries have found it difficult not to exceed the discharge limits occasionally—mistakes, miscalculations, and accidents do happen. Some nurseries have found that certain pollution prevention practices do not fit their production methods. In such cases, the most reliable pollution control may be achieved by capturing and recycling runoff. In this way, potential contaminants are totally contained on site. With the capture and recycle approach, runoff is captured in retention basins, mixed with fresh water as appropriate, and recycled onto crops.

The design of a system to capture and recycle irrigation water must be site specific. The number of retention basins needed to capture runoff depends on the topography of the nursery. Sites with only one major gradient might only need one retention basin, but most nursery sites have more than one gradient and require more retention basins. In the basic system, runoff is captured at low points in the nursery, then pumped to a storage pond at a high point for redistribution. Captured runoff water can be treated before or during transfer to storage to eliminate plant pathogens or improve water quality. The quality of captured runoff can also be improved by mixing it with fresh water before reuse.

During storm events, retention basins may not be able to retain all the runoff from a nursery site, particularly if it receives off-site drainage. Provisions should be made to hold a minimal amount of storm water before discharge occurs. This is important because the pollutant levels in the first flush of storm water through a system can be high. After this initial phase, however, the concentration of pollutants in discharged water is usually much lower than in normal irrigation runoff because dilution occurs. Although no retention limits have been set for Oklahoma, other states require that 1/2 to 1 inch of storm water be retained before discharging. Most rain events do not produce enough storm water to exceed these retention limits and so do not result in discharge. Discharge of storm water is governed by a different set of permitting regulations than normal day-to-day runoff from irrigation.

Capturing and recycling runoff is not a substitute for good pollution prevention practices. These management practices should be well established before implementing the capture and recycle strategy. Most existing nurseries adopting the capture and recycle strategy choose to phase in the installation process over a period of years. Different parts of a nursery may be placed under the capture and recycle approach, starting with those that lend themselves to this most easily or those with the most serious water quality problem. By phasing in capture and recycle technology, the capital outlay can be spread over a number of years and adjustments in management practices made gradually.

Other Advantages of the Capture and Recycle Strategy

In addition to protecting the environment, the capture and recycle strategy has many other important advantages. In fact, many nurseries had already adopted capture and recycling systems to deal with their specific needs even before the current emphasis on environmental protection. For some nurseries, the most important reason to adopt capture and recycle methods has been that using recycled water can result in major savings on the cost of water. For others, the most compelling reason has been to assure that an adequate supply of sufficiently high quality water would be available when needed during production.

Water costs vary greatly depending on the source. Water may have to be purchased from an expensive community water supply. It may need to be pumped a significant distance from underground or surface supplies, entailing high electrical costs for pumping. Source water may require treatment—e.g., by flocculation, filtration, acidification, or decontamination—before it can be used for crop production. All these factors contribute to the final cost of irrigation water. For many production systems, a significant portion of that cost is lost when runoff leaves the nursery. Some nurseries cannot be sure they will be able to acquire enough good quality water for their needs at any cost. Water supplies may be unavailable, restricted, or poor quality during drought periods when production need is great. Capturing storm water and irrigation runoff and storing it for later use is advantageous in these situations.

Some nurseries faced with tightly managing nutrients and pesticides to keep these constantly below effluent limits have switched to the capture and recycle strategy. This allows more flexibility in the use of different forms of fertilizers for different stages of plant growth, in scheduling applications, and in meeting emergencies such as disease outbreaks. For example, soluble fertilizers can be used for propagation and for pushing the growth of certain crops, and slow-release fertilizers can be used at higher levels without concern about spikes of nutrients in effluents. The capture and recycle method also acts as a safety net in case of an accident, mistake, or miscalculation, particularly with regard to pesticides. Finally, the capture and recycle strategy demonstrates to the public a clear effort to protect the environment.

Disadvantages of the Capture and Recycle Strategy

There are several disadvantages to the capture and recycle strategy. The most obvious is the cost of retention basins, storage ponds, and additional pumping capacity. These costs can, in many cases, be recovered through savings in water costs. New types of management skills will be needed to manage a recycling system, with the inevitable learning curve of any new technology. There has also been some fear that recycled herbicides could damage sensitive crops, but this can be avoided with proper management. Likewise, buildup of salts in recycled water can be effectively managed by dilution with fresh water if this becomes a problem.

However, the main disadvantage of the capture and recycle strategy may be the possibility that waterborne pathogens recycled back onto crops will increase disease problems and force nurseries to decontaminate recycled water. Studies have shown that plant pathogenic fungi such as *Phytophthora* and *Pythium* spp. are present in nursery runoff at relatively high concentrations and can sometimes be detected in recycled irrigation water at the point of delivery to crops. Since there are no scientifically derived thresholds for levels of pathogens in irrigation water, it is easy to see why growers may feel compelled to decontaminate recycled irrigation water before reuse. On the other hand, many nurseries have been recycling irrigation water for years without decontaminating and have not experienced increased disease problems.

Managing Plant Pathogens in Recycled Irrigation Water

When it comes to managing plant pathogens in recycled irrigation water, every nursery situation is unique. But an important first step in any situation is to determine if pathogens are present in irrigation water and to what extent. Once this is done, various management practices can be considered to reduce contamination.

Samples should be taken at the irrigation water source, at points of runoff, and at points where recycled water is delivered back to plants. These samples can be analyzed by a diagnostic laboratory for pathogens of importance, such as *Pythium* and *Phytophthora* spp. Another practical way to sample irrigation water is to use plant parts—e.g., lemon or rhododendron leaves—to "bait" these pathogens out of the water. For more information on sampling and testing irrigation water for plant pathogens, contact the Plant Disease Diagnostic Laboratory, Department of Entomology and Plant Pathology, Oklahoma State University, Stillwater, Oklahoma.

The risk of using recycled irrigation water can best be evaluated by looking for pathogens in recycled water at the points of reuse. Even where pathogens are present in runoff water at relatively high concentrations, there may be few or no pathogens detectable at the points of reuse. This results because there are natural processes acting in the system to reduce pathogens. Plant pathogens tend to settle to the bottom of retention basins and storage ponds during even limited storage. Natural biological and physical processes, such as microbial degradation or unfavorable water conditions, destroy many plant pathogens or render them unable to infect. Finally, if captured water is mixed with fresh water before reuse, any remaining pathogens will be diluted even further.

Crops that are highly susceptible to waterborne pathogens such as *Phytophthora* spp. (e.g., rhododendron, citrus, Lawson cypress, dogwood) should be grouped together in the same part of the nursery. That way, pathogen-free fresh water can be reserved for these areas and for propagation. Where recycled water is used with no treatment other than settling, holding, and dilution, it should be used only for hardier or more mature plants that are relatively resistant to waterborne pathogens. By following these strategies, nurseries may find that decontamination of recycled water is not necessary. However, if large parts of the nursery contain crops highly susceptible to waterborne pathogens, decontamination of recycled water may be warranted.

Another consideration in devising any overall disease management strategy which is often overlooked is the need to test the irrigation water source for plant pathogens. Ground water drawn from properly constructed wells and water for human consumption should be pathogen free. However, water drawn from surface sources such as lakes and rivers may contain waterborne pathogens and may require decontamination before use in propagation and for highly susceptible crops.

If decontamination of source water or recycled water is warranted, there are a number of options. First, filtration may be used to eliminate plant pathogens. Modern sand filters remove most plant pathogens, except bacteria and viruses, to a practical level, but do not sterilize the water. This leaves many of the natural biological control organisms in place, which is an important advantage. Microfiltration to smaller pore sizes removes almost all plant pathogens, but it is only useful for low flow rates and low volumes such as those required in propagation areas. Several more stringent methods of decontamination can be used, provided water is filtered to a reasonably clean level before treatment. These decontamination methods have been adapted from purification methods for drinking water or swimming pool water and include the use of ultraviolet light, ozone, or chlorine. These are all effective in eliminating plant pathogens and other microorganisms, but they require careful management to achieve the desired effect.

Summary

The capture and recycle strategy used in conjunction with other pollution prevention practices is an effective way to protect the quality of water supplies. It also has many other advantages for nurseries, such as reduced water costs, an assured supply of good quality water, and more flexibility in crop production.

The major drawbacks of this strategy are the cost of building retention basins and storage ponds and the potential impact of using recycled water on disease management. It may not be the answer for every nursery; however, nurseries that are currently using the capture and recycle strategy are strong proponents of this technology as advancement for the nursery industry.

Shown here is a retention basin for capturing irrigation runoff and equipment for pumping captured water to a storage pond at a higher point in the nursery. In the storage pond, the water can be mixed with fresh water and held for later use.

8. Environmental Audit

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What Is an Environmental Audit?

An environmental audit is a tool to evaluate current management practices that may impact the environment, especially water quality. The following questionnaire is designed to increase awareness of management practices that may require improvements and help identify sound management practices that should continue.

The environmental audit is broken down into sections that focus on related management practices, such as irrigation management or pest management. Some sections or questions will not apply for all nurseries. Reading through these sections and attempting to answer the questions with management personnel provides a convenient and easy way of conducting a self-assessment. The other chapters of this manual provide background information associated with different types of management practices.

I. Climate, Topography, and Soils

A basic knowledge of your physical environment will help pinpoint potential environmental problems.

1. What is the average rainfall of the area?
____inches/year.

2. Is the bedrock limestone? ___Yes ___No
(Karst topography can increase risk of ground water contamination.)

3. Are soils generally:
___Sandy (most likely to allow leaching to ground water)
___Loams (medium leaching potential)
___Clays (least likely to allow leaching, but greater runoff potential)
___High organic matter (peat or muck)

4. If a soil survey of your area has been completed (by the Natural Resources Conservation Service, formerly the Soil Conservation Service), have you reviewed it and noted any special characteristics of your soil?
___Yes ___ No
(High erodibility, permeability, shallow depth to bedrock or ground water, etc.)

5. What are your sources of irrigation water?
___ Ground water/spring-fed wells
___ Captured rainfall/runoff
___ Stream/lake/reservoir
___ Artesian/deep wells
___ Municipal water supply

6. Are production areas located adjacent to any of the following?
___Streams or lakes
___Wetlands (areas which remain saturated for much of the year, contain plants tolerant of wet conditions)
___Known ground water recharge areas or sinkholes

II. Nursery Layout

Proper location and design of nursery facilities can minimize any potential negative environmental impact.

1. What is the total size of your site? _____acres

2. What percentage of your site is covered with impervious surfaces (paved roads and parking lots, roofs, etc.)? ____% or ____ acres.

3. Do you have retention ponds, settling basins, or manmade wetlands which capture nursery runoff to allow breakdown or settling of pollutants? ___Yes ___No

4. Are production areas contoured or graded to slow runoff and increase water infiltration? ___Yes ___No

5. Are plant holding areas surfaced with materials that slow runoff and increase water infiltration? ___Yes ___No

6. If field production, are grass filter strips established between rows or blocks to minimize runoff? ___Yes ___No

7. Is a buffer strip maintained and covered with grass, shrubs, or trees between production areas and streams, lakes, wetlands, or ground water recharge areas? ___Yes ___No

8. Are similar buffer or filter strips maintained adjacent to buildings, parking areas, or plant holding areas? ___Yes ___No

9. Are all drainage ditches and drain pipe outlets properly sloped and stabilized with grass, filter cloth, and/or rock to minimize erosion? ___Yes ___No

10. Are roads and parking areas located and constructed to avoid soil erosion? ___Yes ___No

11. Are wells properly constructed and sealed as required by local or state codes? ___Yes ___ No

12. Are aprons constructed around wellheads to prevent runoff from draining down casings and contaminating wells? ___Yes ___No

13. Is the nursery regularly evaluated for new runoff and potential contamination problems? ___Yes ___No

III. Storage and Handling of Potentially Hazardous Materials

Prevention of soil, surface, and ground water contamination through proper storage of chemicals, fuels, and other potentially hazardous materials should be a top priority.

A. Pesticides

1. Are all pesticides stored in a secured (locked) building, with impermeable floors (and no floor drain), and located an adequate distance from any water source (e.g., a well)? ___Yes ___No

2. Are pesticides stored in their original containers, kept closed, and their contents clearly labeled? ___Yes ___No

3. Is your operation equipped to clean up a pesticide spill in all storage, mixing, production, or sales areas of your operation? ___Yes ___No

4. Are leaks and spills promptly cleaned and properly disposed of? ___Yes ___No

5. Are regular inspections made for leaks or spills and all spills reported as required to the EPA or local officials?
___Yes ___No

6. Is mixing done an appropriate distance from wells and other water sources? ___Yes ___No

7. Have you provided for containment of a spill during mixing? ___Yes ___No

8. Are nurse tanks used to avoid filling sprayers from direct water sources? ___Yes ___No

9. Are water sources fitted with backflow prevention devices? ___Yes ___No
(Note: A backflow prevention device or an air gap is required by law when mixing pesticides.)

10. If yes, are the backflow prevention devices tested periodically and in conformance with any required standards? ___Yes ___No

11. Do you triple or pressure rinse all containers and pour rinsate into spray tank before properly disposing of containers?
___Yes ___No

12. Is application equipment always stored empty? ___Yes ___No

13. Is application equipment containing pesticide mixtures left unattended in unsecured areas? ___Yes ___No
(Leaving equipment containing chemicals unsecured could contribute to accidents, personal injury, and contamination.)

14. Is all excess pesticide mixture sprayed onto a labeled crop and not poured out? ___Yes ___No

15. Are any pesticides that have been banned or taken off the market stored on the premises? ___Yes ___No

B. Fertilizers

1. Are all fertilizers stored under a roof, out of rain? ___Yes ___No

2. Are spills monitored and cleaned up promptly and reported as may be required by EPA or Oklahoma Department of Agriculture officials? ___Yes ___No

C. Other Materials

1. Are fuel tanks and piping at risk of vehicle collisions? ___Yes ___No

2. Is used oil recycled, not sprayed, dumped, or spilled on nursery premises? ___Yes ___No

3. Are sewage sludge, compost, manure, bark, or similar organic materials which may produce hazardous or nutrient-rich leachate covered to reduce leaching risk? ___Yes ___No

4. Are septic systems located an appropriate distance from water sources (as required by state law)?
___Yes ___No

5. Are septic systems protected from damage, such as that caused by vehicle traffic or parking over a drain field? ___Yes ___No

6. Are septic tanks inspected periodically and pumped as necessary? ___Yes ___No

IV. Plant Production and Maintenance Practices

Following best management practices (BMPs) on and off site can reduce the quantity of water, fertilizer, and pesticides used and help prevent pollution.

A. *Pest Management*

1. Are the following integrated pest management (IPM) practices used?

Pest-resistant plant materials	_____Yes	_____No
Biological control	_____Yes	_____No
Pest and crop monitoring	_____Yes	_____No
Economic threshold levels	_____Yes	_____No
Spraying based on need, not the calendar	_____Yes	_____No
A good pest resource library	_____Yes	_____No
Use of least toxic pesticides	_____Yes	______No
Weed-free barriers	_____Yes	______No
Adjustment of pesticides to protect beneficials	_____Yes	______No
Use of a diagnostic clinic	_____Yes	______No
Inspection of incoming stock	_____Yes	______No

2. Do you investigate and consider new, cultural, mechanical, and biological controls? ___Yes ___No

3. Are pesticides applied at the lowest effective rate? ___Yes ___No

4. Do you read and consider special label precautions? ___Yes ___No
(Pesticides which are slow to break down or which leach readily may pose the greatest ground water risk.)

5. Are weather conditions monitored to avoid application when precipitation is expected within 24 hours?
___Yes ___No

6. Are pesticide applications scheduled to best avoid customer or employee contact with treated plants?
___Yes ___No

7. Are warning signs posted to alert customers or employees of recent chemical applications? ___Yes ___No

8. Is overhead irrigation postponed after chemical application? ___Yes ___No

9. Are "band treatments" of herbicides used where practical to reduce the amount of herbicide used and soil surface treated? ___Yes ___No

10. Is the pH of your water source known? ___Yes ___No
(pH can greatly affect the effectiveness of a pesticide.)

11. Is application equipment calibrated regularly, based on the equipment manufacturer's recommendations?
___Yes ___No

B. *Nutrient Management*

1. Are soils and growing media tested regularly to verify the need for nutrients? ___Yes ___No

2. Are slow- or controlled-release nitrogen sources used when appropriate? ___Yes ___No
(Slow-release nitrogen sources can reduce nitrate loss through leaching or runoff.)

3. Is superphosphate incorporated in organic potting media? ___Yes ___No
(Phosphate readily leaches within a few irrigations from organic media and can promote algae growth in collection basins, ponds, and surface waters.)

4. Are total fertilizer amounts applied in split applications? ___Yes ___No

5. Are nutrient "credits" given for sludge, compost amendments? ___Yes ___No

6. Is fertilizer injected into irrigation water? ___Yes ___No

If yes, have you looked at alternatives or other practices which may reduce nutrient leaching and runoff, e.g., capture and reuse of irrigation water? ___Yes ___No
(Some studies have demonstrated large reductions in total fertilizer used through "drip" fertigation in field production. In greenhouse or container production, fertigation may increase risk of nutrient leaching and/or runoff.)

C. Irrigation

1. Is application rate and timing of irrigation controlled to minimize movement of fertilizers and pesticides? ___Yes ___No
(Example: Applying water in several shorter intervals rather than one long period has been demonstrated to reduce runoff and nutrient leaching.)

2. Have techniques for conserving water been investigated? ___Yes ___No
(Moisture sensing meters, wetting agents, indicator plants, water absorbent polymers, etc.)

3. Are irrigation heads/emitters, pipes, and joints regularly checked for damage? ___Yes ___No

4. Is irrigation water captured, recycled, and reused? ___Yes ___No

5. Have media been altered to increase water-holding capacity to conserve water and reduce pesticide and nutrient leaching? ___Yes ___No

D. Waste Reduction

1. Is winter cover poly used more than one season? ___Yes ___No

2. Are degradable pots used or are plastic pots reused or recycled? ___Yes ___No

3. Is a compost program used for organic wastes? ___Yes ___No
(A composting program, possibly including landscape waste from nearby communities, can provide a valuable source of organic soil amendment and can serve as an excellent public relations tool.)

V. Safety, Employee Training, Documentation, Emergency Plan

Good employee training will reduce the risk of accidents, employee injury, and environmental contamination.

A. Employee Safety, Training

DO YOU:

1. Train all employees in proper handling of pesticides and fertilizers, including how to clean up accidental spills? ___Yes ___No
2. Provide protective clothing, eye protection, and safety equipment and train employees in their proper use? ___Yes ___No
3. Verify all employees handling such products use protective clothing and equipment properly? ___Yes ___No
4. Hold regularly scheduled safety meetings and training sessions? ___Yes ___No
5. Maintain accessible eye washes, showers, and respirators? ___Yes ___No
6. Have material safety data sheets (MSDS's) on file and readily available to employees for all hazardous materials, including pesticides, ammonia, and gasoline used in your operation? ___Yes ___No
7. Prominently display all appropriate warning signs? ___Yes ___No
8. Keep all containers and storage tanks properly labeled by content? ___Yes ___No

B. Documentation

1. Do you document and maintain records of safety training, safety meeting subjects, and attendance? ___Yes ___No
2. Do your employees sign forms indicating they have attended a training sessions? ___Yes ___No
3. Do you have a written hazard communication plan? ___Yes ___No
4. Are all necessary permits filed, easily located, and periodically reviewed? ___Yes ___No
5. Are all staff and supervisor's pesticide applicator licenses current? ___Yes ___No
6. Do you have a schedule for reregistering or renewing permits, licenses, and other documents on time? ___Yes ___No

C. Emergency Plan

1. Do you have a plan to be followed in the event of a fire or other catastrophic event? ___Yes ___No
2. Are employees familiar with the emergency action plan? ___Yes ___No
3. Are exits and emergency equipment clearly labeled? ___Yes ___No
4. Are emergency telephone numbers clearly posted? ___Yes ___No

5. Are local emergency officials familiar with the materials (pesticides, fertilizers) stored on site?
___Yes ___No

6. Is an updated inventory of stored products, their MSDS's, and locations maintained at your site?
___Yes ___No

7. Do you know where runoff will go from your pesticide and fertilizer storage areas? ___Yes ___No

8. Could runoff from these areas be capture or diverted? ___Yes ___No

VI. Site Contamination

Practices considered acceptable in the past may have contaminated soil or ground water, creating a potential liability problem for your operation.

Have any waste materials ever been buried?	___Yes	___No	
Have any waste materials been dumped on the ground?	___Yes	___No	
Has any waste otherwise been disposed on site?	___Yes	___No	
Have any active or previously used burn areas been used for pesticide containers?	___Yes	___No	
Has application equipment been routinely washed or rinsed on site in an area not equipped with a rinse pad?	___Yes	___No	
Are barren areas present?	___Yes	___No	
Has soil analysis shown detectable levels of pesticides or other contaminants?	___Yes	___No	___Unknown
Has analysis of ground water samples shown detectable levels of pesticides or other contaminants?	___Yes	___No	___Unknown

VII. Public Relations/Education

Once your firm has conducted an environmental audit and developed water or environmental management plans, consider education and communication of your proactive stance. Landscape and retail firms can benefit from customer contact during the design, sales, and installation phases. This contact can provide additional opportunities to educate their clients and to follow proper practices on the job site.

A. Public Relations

1. Are employees able to act as spokespersons for your operation? ___Yes ___No

2. Have employees received training in working with media? ___Yes ___No

B. Landscape Considerations

1. Are site characteristics carefully considered when selecting plants? ___Yes ___No

2. Are designers and installation crews trained in the preservation of existing landscape trees? ___Yes ___No
   (Grading, adding soil, or storing materials over root systems of existing trees can lead to their decline and death.)

3. Are erosion and sediment controls installed, such as silt fences or mulch to minimize soil erosion if soil is left bare on a job site for more than one or two weeks after grading (or as may be required by local erosion and sediment control ordinances)? ___Yes ___No

4. Are clients instructed on proper watering, mulching, and other maintenance of new plants? ___Yes ___No

5. Are clients taught about the proper timing of irrigation to conserve water and avoid damage to trees and shrubs? ___Yes ___No

6. Are lawn irrigation areas separated from shrub areas? ___Yes ___No

7. Is returned debris separated and appropriate material chipped or composted? ___Yes ___No

C. Customer Education

1. Which of the following methods are used to educate customers on proper and safe use of pesticides and fertilizers:

   ___Knowledgeable salespeople provide advice
   ___Free publications
   ___Newsletters
   ___Seminars featuring guest or staff instructors
   ___In-store videos
   ___Refer to Cooperative Extension Service or other sources
   ___Other

2. Is your staff trained to accurately identify pest problems before making a control recommendation? ___Yes ___No

3. Is your staff trained in principles of integrated pest management? ___Yes ___No

4. Are "least toxic" controls recommended, such as mechanical or biological controls or least toxic pesticides? ___Yes ___ No

5. Are employees educated on water conservation techniques? ___Yes ___No

Water Quality Handbook for Nurseries is a guide to utilizing best management practices (BMPs) in the nursery to produce quality plants while protecting water quality. This handbook was designed to help find a balance between protecting water quality and maintaining a profitable business. The authors' suggestions are applicable to the beginner as well as the seasoned nursery professional.

This handbook covers topics which include nutrient and irrigation practices, recycling water, pest management, and environmental audits. *Water Quality Handbook for Nurseries* is for nursery personnel, environmental consultants, students, and anyone interested in water quality practices and how they relate to growing nursery stock.