

Soil, Water,
Nutrient and Pesticide
Agricultural Management Practices
for
Field Nurseries
in the
Upper Cohansey River Watershed

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Table of Contents

Introduction	4
Nursery design	5
1. Site selection	
2. Site development and layout	6
Irrigation management	7
1. Water quantity and quality	
2. Water use certification	
3. Water system design	
a. Water treatment	8
b. Water system management	
i. When to irrigate	
ii. Cyclic irrigation	9
iii. Irrigation for heat or cold protection	
iv. Micro-irrigation	
Nutrient management	10
1. Soil fertility	
a. Soil amendments	11
b. Non-crop area management during production	
c. Soil conservation	12
i. Table 1: Ground Cover Crops	13
2. Fertilization	14
a. Fertigation procedures	
Pest management	15
1. Pest management planning	
2. Rules and regulations	16
a. Pesticide use certification program	
b. Employee requirements	
c. Reporting	
3. Monitoring pest populations	
4. Pesticide applications	17
5. Fumigation	18
6. Operation and maintenance for pesticide management equipment	
a. Storage	
b. Mixing and rinsing stations	
c. Pre-planting weed management planning	19
d. Pesticide considerations	
7. Guidelines for using pre-emergence herbicides	20
8. Guidelines for using post-emergence herbicides	
a. Post-emergence herbicide considerations	21
9. Guidelines for weed control without the use of herbicides	
Glossary	22
Useful References	24
Appendices	
1. Fertilizer Applications Record Sheet	25
2. Fertilizante Aplicación Tablero	26
3. Pesticide Application Record Sheet	27
4. Peste Aplicación Tablero	28

Introduction

Within New Jersey, the Cumberland/Salem/Gloucester area accounts for nearly half the nursery acreage in the state while the Monmouth/Burlington area adds over 25% more. The Southern region of Cumberland, Salem and Gloucester Counties has continued to expand while areas north have either remained stable or decreased in acreage.

New Jersey has many attributes that make it an ideal spot to produce nursery plants. The marketing potential is great since it is geographically located in the center of the BosWash megalopolis. The conglomeration of cities that makes up the megalopolis is around 500 miles long from the areas of Boston, Massachusetts to Washington, DC and has a population of approximately 44 million people. That represents about 16% of the total population of the United States.

Soils, water resources and environmental factors make Southern New Jersey optimal for nursery plant production. Soils are somewhat variable from very sandy to silt loams. This allows a wide range of plant material to be grown. Southern New Jersey sits atop the Cohansey aquifer. It is one of the largest aquifers on the East coast of the US. The environment is moderated by the Atlantic Ocean and the Delaware Bay. As a consequence, it has a similar hardiness zone to central North Carolina.

New Jersey is an expensive state in which to conduct business. The cost of land and higher than average operational costs force producers to find ways to maximize production while also protecting the environment. These factors provide significant challenges that require good managerial leadership. Profitability has a direct relationship to the time it takes to produce the crop and plant population density.

Interest in planting field-grown nursery stock has seen resurgence in recent years. This is the result of growers identifying a potentially profitable niche. It may be that the niche is there because there is a potential for increased sales of similar material, similar material of higher product quality, new or different material, or a myriad of other reasons. The marketing skills of an individual will largely determine the difference between success and failure. It has become very difficult for a business to survive for an extended period of time by just being nursery stock growers.

In a perfect world, nurseries would be designed for maximum efficiency with minimal environmental impact. In reality, few nurserymen have financial resources adequate to complete installation of an ideal facility when they are starting out in the business. However, many practices can be adopted which both increase profitability and minimize environmental impacts. If an established nursery moves to a new site, one should take advantage of the opportunity. The result of not designing from the ground up is the need for retrofitting existing nurseries that may end up costing more than a nursery built from the ground up. Planning is critically important for every nursery. No matter where one is financially, one should always plan for the future while building for the present.

When designing the nursery, pay special attention to water movement that minimizes environmental impact. Runoff water is typically higher in nutrient content than surface or groundwater. Because of the need to have minimal environmental impact, it is increasingly important to use turf between plant rows and in waterways to reduce erosion and capture nutrients. Depending on the site, a bio-filter may be important to install to enhance water quality before it leaves the nursery during significant rain events. A bio-filter uses vegetative plant material to remove pollutants from the water before it enters ground or surface waters. Wetlands plants have been shown to be quite effective at removing nutrients in biofilters while being resilient to varying water conditions.

Grouping plants by water or nutrient needs can help reduce water and nutrient use. Grouping by pesticide requirement is usually difficult but where possible may enhance pesticide use safety. Recommendations for pesticide use on nursery stock can be found in Rutgers Cooperative Extension Publication #E036: Pest Control Recommendations for Shade Trees and Commercial Nursery Crops (available online at the website listed in the References section of this document).

Nursery Design

Site Selection

The ultimate success of a field nursery is highly dependent on soil characteristics. While soils in field nurseries can be amended with organic matter, native soil characteristics such as texture, drainage, profile and slope need to be suitable for production of perennial crops. Most field-grown nursery crops are produced on 1 to 7 year cycles. Knowing the history of the field including previous crops grown, types of pesticides applied (especially herbicides) and types of organic soil amendments are important since each can affect plant growth.

Field-grown nursery stock production can range from multiplication of stock material and liners that are bare-rooted to digging large material that is balled and burlapped. When producing balled and burlapped material, field soils need to be cohesive enough to maintain an intact ball. Root balls that are excessively sandy may fall apart during handling. Ideally, soils should be relatively free of large rocks and deep enough to allow easy digging. The American Standards for Nursery Stock (ANSI Z60.1) includes standard dimensions for harvesting root balls according to the size of the plant (available online at the website listed in the References section of this document).

Balled and burlapped material may be hand dug or dug by machine. Machine digging is much faster than hand digging for intermediate-sized plant material and requires less-trained individuals. With trained personnel, hand digging is usually faster with small plant material and typically becomes the only option, as root balls get very large.

Soil drainage should be considered when selecting a site. Try to avoid soils that have poor internal drainage or that are subject to flooding. Nursery stock that has been flooded is often weakened and predisposed to increased disease and insect problems. Fields being considered for nursery stock production should have a minimum of 8 to 10 inches well-drained profile but this requirement varies based on which plants are to be grown. A soil probe can be used to investigate the soil profile, in order to determine the depth and texture of soil layers and see if there are layers that may restrict root growth or water drainage. Even sandy soils can have poor drainage if there is an impervious layer, as is common in many fields. At the other extreme, deep sandy soils have relatively little water holding capacity and generally require an irrigation system to ensure successful field production. A penetrometer can be used to determine the strength of soil layers. Soil layers that require a strong force for the insertion of a penetrometer may limit root growth or water infiltration. These hard layers can be the result of soil compaction or tillage practices, or may be natural hard pans in the soil.

While flat, non-flooding fields are optimal for mechanical production practices, some slope can offer enhanced air and water drainage. As the slope increases, one should consider contour planting and the use of turf plantings between rows to reduce erosion potential. A good place to start in determining soil potentials are the "Soil Surveys" for each county prepared by the Natural Resources Conservation Service. Paper copies of some county Soil Surveys were produced as recently as 2008 but the internet-based Web Soil Survey is now the official soil survey document. Websites for these resources are listed in the References section of this document.

It is critically important to have water available to irrigate crops. Nursery transplants are expensive and avoidable losses need to be minimized. Growers also need to maximize growth to be profitable. The use of irrigation can shorten the production cycle by 1 to 2 years over non-irrigated crops. It is important to choose field production land with good water resource access. When locating a field nursery near surface bodies of water, withdrawals for irrigation should not have a negative effect on nearby surface bodies of water. The nursery also bears a responsibility to protect the surface waters from field erosion sediment and nutrient contamination.

Site Development and Layout

Natural features of the land should be considered when developing a field nursery site. Consider all production operations when laying out the fields. Set them up for the best efficiency of plant maintenance, irrigation, harvesting and maneuvering sprayers, tractors and wagons. Consider contour plantings on sloped land and plan for turfgrass waterways and field edge buffer strips to reduce erosion. Grass strips can effectively slow runoff and trap sediment, thereby reducing soil losses by 30 to 50 percent compared to bare soil. A grass strip will slow runoff water, allowing silt to settle out. Buffer strips should be established between production areas and surface water bodies including streams and lakes. The first 3 to 4 feet of buffer strips do most of the filtering. As slope increases, the number of strips needed increases and the distance between them needs to decrease. Grasses for buffer strips and grass waterways should be able to withstand wet growing conditions and still produce an aggressive root system that will take abuse and maintain a good grass mat to slow runoff and catch sediment.

What's most important in choosing grass species for use as a buffer is to identify a species or mixture that will maintain a dense stand in the conditions of your site. Different species will thrive in different site conditions, including soil drainage, available moisture, and fertility. While some turfgrasses are more demanding in terms of water and fertilizer, tall fescue and creeping red fescue, for examples, are two rhizomatous species that may be more tolerant of drought, lower fertility and higher salts. If areas have poor drainage or will be wetted continually with runoff, other grasses or appropriate wetland plants should be chosen. A guide for choosing appropriate grass species can be found in the Rutgers fact sheet *Turfgrass Seed Selection for Home Lawns* (available online at the website listed in the References section of this document).

Mow grass strips to keep the grass from seeding and to encourage a thicker stand. Since these grasses accumulate nutrients from runoff, grass clippings should be removed and the organic matter used to amend field soils. To keep grass waterways and buffer strips vigorous, avoid frequent traffic over them and lift implements above the ground before crossing. Monitor growth to determine if supplemental fertilization is required.

Few fields are uniform in slope, drainage (air and water), and fertility. Determine optimal conditions for growth of plant material and plant accordingly. As examples, plants that will tolerate wetter soils include red maple, river birch, bald cypress, willows, sweet gum and black gum. Crape myrtle will thrive in moist locations but should be planted on well-drained sites because they tend to grow too long in the fall and may be damaged by frost when planted on moist sites. Dogwoods require very well-drained locations. Avoid frost pockets with crops such as flowering cherries and Colorado blue spruce, which begin growth early in the spring. A few degrees difference could damage early cherry and plum flowers or destroy the first flush of growth.

Irrigation Management

Water quantity and quality

It is important to secure good water resources when considering a new nursery site. Generally, nursery crops require between one and two inches of water per week. Natural rainfall will reduce the need for other water resources. If water quantity is limited, consider lower water use irrigation systems (drip or trickle irrigation, center pivots, travelers, etc.).

Micro-irrigation (drip or trickle irrigation) is a low volume, low-pressure system that applies water directly to the soil surface over extended periods of time. It results in less water lost to evaporation or run off. There are several benefits derived from the use of micro-irrigation.

1. Micro-irrigation applies water only to the root zone of the nursery crop so roots tend to concentrate within the zone wet by the micro-irrigation. That forces more roots into the ultimate root ball.
2. Fewer weeds tend to germinate since water is distributed over a smaller surface area than with overhead irrigation. Less weed competition can increase the effectiveness and reduce costs of pre-emergent herbicides and directed post-emergent herbicides management programs, which also reduces the need for frequent tilling.
3. Since only a small surface area is wetted when using micro-irrigation, field operations can continue with fewer interruptions.

Overhead irrigation is especially useful when using lower quality water and when it is necessary to make frequent cropping changes. Including infrastructure needs, the initial investment of an overhead irrigation system is typically lower than a trickle system but operational costs may be higher.

Micro-irrigation requires clean water, free of sediment and minerals. Well water generally requires little or no filtration. Surface water from rivers or ponds generally requires sand media filters so emitters don't plug. If fertilizer is applied with micro-irrigation, the amount of fertilizer applied to a crop can be reduced while increasing growth due to improved fertilizer use efficiency. Fertilizer use in field crops can be cut in half from traditional fertilization and overhead irrigation methods.

Water Use Certification

Without access to an adequate quantity and quality of water, the nursery industry and agriculture in general is not viable. In an effort to monitor and regulate water use in the state of New Jersey, the Department of Environmental Protection (DEP) has created a water use certification program. For crop needs in excess of 3,100,000 gallons per month, growers are required to have water diversions certified for use by the DEP. A second threshold is the composite farm pumping rate capability. When the combined total pumping capacity for wells exceeds 70 gallons per minute, certification is also required. The process requires a certification of need by the local Agricultural Agent, information on water sources, specific locations of diversions, crops grown, and public notification that allows area resident input. Annual reporting of actual use is required along with a five-year recertification cycle. Uses under the aforementioned levels should be registered with DEP in a similar process but lacking the public notice requirement.

The cost of doing business in New Jersey is high. Because of this, it is necessary to maximize growth and yields of nursery plants. A requirement for maximizing growth is that plants receive optimal amounts of water. History has proven that anticipated natural rainfall is never a sure thing. Avoid delays in irrigating crops. It is better to start irrigation as soon as crops need the water rather than delay watering in anticipation of a rain event. If one gets behind in supplying plants water, it may be nearly impossible to catch up without a significant rain event. Remember that although heavier soils dry out more slowly than sandy soils, when they dry down to a certain point they are difficult to re-wet.

Water system design

The irrigation system should be designed during the planning stage of the business and should be definitely considered prior to property purchase. Identify how much water, practically and legally, will be available to you and from what sources. Decide what types of irrigation systems will be placed in each field. If possible, design for flexibility in case there are changes in crop and/or irrigation system needs. The main irrigation trunk lines should be buried, usually along roads, with the valves located at convenient intervals. Irrigation lines are susceptible to

damage caused by winter freezing. When possible, plan for a gravity method of draining the lines so they don't have to be blown out.

Recognize water use differences and crop response to overhead versus micro-irrigation systems and the associated costs of installation and use. If considering overhead irrigation, understand that water cannons are not the only option. When conditions for installation are good, center pivots and travelers can provide a gentle rain-like effect while using less water than do water cannons. Center pivots and travelers also produce less soil compaction and consequent water runoff. There are many types of irrigation systems available, many of which are specifically tailored to certain types of production. Be sure to evaluate the options.

Water treatment

Treatment of water for irrigation purposes is generally unnecessary when using well water. When using surface water sources such as rivers and ponds, water should be evaluated to determine the need for water treatment. If there is the opportunity to use recycled water, the probability of needing to treat water to eliminate pathogens increases.

If using a source of water that has the potential for problems, carefully observe plant material for disease symptoms and dieback. Presently, most water treatment systems for pathogen control at nurseries are using chlorine. Realize that chlorine can be toxic to humans and some plants and that training and caution are needed when using chlorine. Other options include the use of ultraviolet radiation (UV), ozone, heat treatment, bromine, and copper. The combination of UV and ozone treatments may offer the most effective water treatment of any system. Costs of the systems vary widely.

Remember that each treatment option has strengths and weaknesses, and evaluate them accordingly. Copper is a known root inhibitor and bromine is in the same family as chlorine. When using these treatments, be vigilant in looking for negative effects on plants. UV radiation is the only treatment listed above that does not directly add potentially harmful chemicals to the treated water. One source of information to help evaluate treatments is found in the publication entitled "Management Practices to Protect Water Quality: A Manual for Greenhouses and Nurseries." It can be found at <http://ceventura.ucdavis.edu/files/32117.pdf>.

Water system management

When to irrigate

Avoid getting behind! Growers should rely on natural rainfall as the basis for nursery crops water needs but recognize that natural rainfall will either be inadequate in quantity or timing during the growing season. Many growers have a tendency to delay irrigation in anticipation of rain events. Unfortunately, rainfall is not entirely timely or reliable. When irrigation gets behind, virtually all plant material may be in need of water. If the need for water exceeds the nursery's water resources or the capacity of the water distribution system, choices will have to be made as to what will be watered and what will wait. There are economic costs no matter what the decision.

Be sure to understand how the physical properties of the soils in your nursery affect the water holding capacity of the soils and how quickly soils will dry out and require irrigation. Review NRCS soil survey information to help determine which types of soils you have in which location on the nursery. The available water capacity of a soil will depend on its texture and organic matter content. Sandy soils hold less plant-available water than do loamy and heavier soils. The desired frequency of irrigation will also depend on the rooting depth of the plants and the rate at which plants and soils are transpiring water. The evapotranspiration rate increases as solar radiation, temperature and wind increases and as humidity decreases. Plants will require more frequent irrigations in hot, dry, windy weather. It is also important to understand how dry of a soil your particular crop will tolerate without suffering water stress or decreased yield. Check with your local agricultural agent if you have questions. Remember, heavier soils dry more slowly but when dry are difficult to re-wet.

Cyclic irrigation

Cyclic irrigation uses shorter but more frequent irrigation cycles to conserve water. It is a system that wets and then re-wets soils but uses lower amounts of water so runoff is limited. Where micro-irrigation systems are not appropriate, it offers the opportunity for an effective method of irrigation water reduction using the same irrigation equipment. Field soils may exhibit a similar benefit, especially in cases where irrigation rates would exceed the infiltration capacity of the soil or not allow uniform wetting of the soil profile if cyclic irrigation were not used. Remember to consider field operations scheduling prior to using cyclic irrigation because the field will be irrigated more than once each irrigation cycle.

Irrigation for heat or cold protection

For crops that initiate growth early in the spring and those that grow late into the fall it is critically important to have overhead irrigation available to protect from late and early freezes respectively. To have water freeze, a great deal of energy is required to be released in what is called the "heat of fusion." Essentially, when temperatures drop below freezing, water will cool to approximately 32°F and will stay at that temperature for an extended time until it freezes solid. The ice temperature will then drop to near the ambient air temperature. All the time the water remains at the freezing point it offers protection to plant material on which it is located. As long as water keeps running, the temperature should never drop below freezing.

On a practical basis, irrigation systems should be started prior to when the air temperature drops below freezing and remain on until the temperature rises above freezing and ice formed on the plants disappears.

Micro-irrigation

Micro-irrigation (drip or trickle irrigation) is an irrigation system that applies water very slowly over a longer time period than with overhead irrigation. The result is a small wetted profile on the surface that expands outward and downward as it moves through the soil profile. A heavier soil will have a wider profile than a lighter soil.

Benefits of using this type system include lower water consumption, an effective irrigation of the root profile, reduced weed problems, reduced disease problems, good access to field operations with equipment since the area between rows is not wetted, and a lower cost of operation than with overhead irrigation. Drawbacks include an inability to protect from freezes, the need for higher quality water resources, the need to have set planting blocks and patterns in the field to allow for infrastructure and a higher cost of initial installation.

Nutrient Management

The concept of soil quality includes assessing a soil for its ability to grow plants, cycle nutrients, and percolate and hold water. In nursery production, a healthier soil will have a greater ability to maximize plant growth. The factors that help determine a soil's productivity include the cation exchange capacity, the water holding capacity, drainage characteristics and slope. Depending on the crops to be grown and production systems, different soils will be more or less desirable for nursery production. Soil survey information is available from the Natural Resources Conservation Service on line at: <http://soils.usda.gov/survey/>

Soil Fertility

Soil testing forms the basis for all fertility recommendations. Conduct soil tests prior to each crop cycle to determine nutrient status. Sampling needs to be representative of the field so the number of soil tests required per field will vary with the size and uniformity of the field. Unless there are specific areas of concern, submit composite samples of the field for testing. Take vertical cores of the soil profile that are 6 to 8 inches in depth. Separately sample areas that have differing field textures, colors and drainage characteristics.

The soil pH and nutrient content may vary considerably, thus requiring varied amendment practices. It is important to take soil tests well in advance of any cultivation, because of the time it takes to conduct the tests, evaluate the results, plan the most economical and effective program for crop production, apply treatments and allow time for the treatments to integrate into the soil. Lime and phosphorus applications should be completed well before planting. These materials should be thoroughly mixed with the top 6 to 8 inches of soil during normal soil preparation practices. Complete soil test results will also indicate if other soil nutrients are required as pre-plant adjustments.

Optimal management practices for fertilizer applications focus not only on maximizing growth of nursery stock but also the potential for excess fertilizer to be lost from fields through runoff, leaching, and soil erosion. These losses can negatively impact surface water bodies and groundwater. Nitrogen and potassium applications should take place close to the time of planting.

Nursery stock sold with a root ball includes soil necessary to stabilize roots and ensure transplanting success. Preventing further loss of soil and rebuilding soil in fields is very important. Each cropping cycle for field grown nursery crops generally requires one to seven years. Therefore, nursery professionals need to implement growing practices that maintain and improve soil quality characteristics during fallow periods, as well as during field preparation for planting and during the production cycle.

Organic matter, along with naturally occurring silt and clay, serves as a nutrient buffer for soils. Organic matter, silt and clay have high cation exchange capacities that allow a soil to hold some applied nutrients and make them slowly available to plants. While the amount of silt and clay in soils cannot be effectively modified, the organic matter content of a soil can be increased through management practices.

Most soils benefit from the addition of organic matter. Benefits include improving soil structure, water retention, drainage and aeration. The quality of nursery stock grown is typically improved and digging is usually easier in mineral soils that have been amended with organic matter. Some nursery species also develop a more fibrous root system as the amount of organic matter is increased.

Soil Amendments

The long-term health and productivity of soil is a major concern for field nurseries. The loss of soil and nutrients from fields due to environmental conditions such as wind and rain are responsible for major losses. Normal farming practices can result in losses under adverse environmental conditions. Tillage operations that are followed a short time later with significant wind or rain events results in loose soil that will blow and/or wash away. Tillage can also result in soil compaction that will reduce water penetration and moisture holding characteristics. Because of reduced water penetration into the soil, it can increase the formation of washes and gullies.

Costs may prohibit transporting significant quantities of bark, yard waste compost, mushroom soil or other organic amendments to any but the most intensively cultivated sites like seedbeds or transplant production beds. Light application of animal wastes can be applied to field soils but recognize there can be weed issues later. Apply only 1/4 to 1/2 inch and incorporate as soon as practical following application. If wastes are incorporated, 75 to 100 percent of the nitrogen in the waste may be available the first year. Rate of application should be based on nutrient analysis of animal wastes. Particular attention should be given to the metal content of animal wastes. Zinc and copper levels may be high enough to raise these elements to toxic levels if repeated applications are made over a number of years. Foliar tissue analysis of fully expanded leaves collected from crops early in the growing season can provide valuable information about the efficiency of the animal waste application and determine if any supplement is required.

Growers should check to see if composts from municipal yard wastes are affordable organic source for amending fields. Application rates of stabilized composted wastes range from 50 to 200 tons per acre and with nitrogen contents ranging from 0.2 to 0.5 percent, nutrient loss is of less concern. The 50 tons per acre application rate represents approximately 1/2-inch coverage over a 1-acre area, while the 200 tons per acre would be approximately a 2-inch depth.

An alternative to applying organic materials over the entire field is to incorporate the organic matter in planting rows only. If rows in the field are spaced 12 feet apart and the root zone area of plants is considered to be 2 feet on each side of the stem, a 4-foot strip would receive the organic matter, thus reducing the amount of organic matter applied in the field by two-thirds. Planting rows would need to remain in the same location each year for this to have long-term benefit.

Non-crop Area Management During Production

Semi-permanent turf-type grass cover established between rows in a field nursery is an important component of minimizing soil losses and maintain long-term soil productivity. Grass sod also makes it easier to move equipment through fields when they are wet or snow covered. Grassed contour strips slow down and direct flow of water across a slope and serve as a buffer and a biological filter to remove excess nutrients before water leaves the nursery. Turf-type fescues are probably the most effective grasses. They are vigorous, don't readily seed, are somewhat drought tolerant and provide some biomass when plowed down. Nursery planting rows should be kept clean or mostly weed free with pre-emergence or post-emergence herbicides while maintaining grass cover between rows.

Grass should be mowed regularly to avoid seed formation. An option to mowing is to use chemical mowing techniques. Sub-lethal rates of herbicides and/or growth regulators can be used to slow growth of grass but not kill it. For example, tall or fine fescues or a mix of the two grasses will be suppressed for eight to ten weeks by spraying in early spring when there are four to five new leaves or seven to ten days after mowing with 1 pint / acre of sethoxydim (Vantage), a selective grass herbicide. Another alternative is to use glyphosate (Roundup 4L) at the rate of 4 to 8 ounces per acre as a directed spray. The 4-ounce rate usually gives six weeks of suppression; the 8-ounce rate gives about 10 weeks of suppression. Glyphosate needs to be applied as a directed spray between the nursery stock rows. Use no more than 25 gallons of the final spray mix per broadcast acre. Chemical mowing will result in chlorotic (yellow) grass for up to 30 days.

Soil Conservation

Conservation efforts are needed to reduce soil and nutrient loss resulting from wind erosion and storm water movement. Soil stabilization and erosion control management practices include:

- Contoured layout of fields (planting across slopes)
- Use of cover crops between crops
- Fallowing land (letting it rest without a crop for a year or more)
- Use of vegetation in aisles, row ends, drive roads, field border strips & waterways
- Use of sediment dams in waterways
- Installation of swales to collect soil in runoff water
- Installation of wetlands areas to collect nutrients
- Use of irrigation practices that do not increase erosive washes
- Use of trickle irrigation to reduce the wetted surface area thereby reducing the need for tillage to help control weeds.

Most practices used to reduce soil loss involve planting and maintaining vegetation cover while growing nursery crops. The physical effect of cover crops protecting the surface of the ground has a direct beneficial effect on reducing soil loss. Growing cover crops may be one of the most important management tools to improve soil productivity.

As an example, integrating a cover-cropping plan that maintains or increases soil productivity into a three-year crop rotation plan requires four acres annually for every three acres of productive area. In a traditional crop cycle where a field of plants would be sold by April, following harvest, the field would immediately be prepared for planting. The field would be plowed, fertilized, and sown with a sorghum-Sudan hybrid. The cover crop would be mowed as many times as necessary to avoid seed-head formation and then the field would be plowed under in September. A small grain winter cover crop such as rye should then be planted for winter soil stabilization and as a source of additional organic matter. The rye or other winter cover crop should be plowed down in the spring prior to planting a nursery crop.

This use of sequential planting of grasses and small grains reduces sediment and nutrient losses and potentially increase the soil organic matter levels. Sudan hybrids can be grown all summer and are killed by freezing temperatures. Small grains make an excellent winter cover crop. Seeding rates and planting dates are shown in Table 1. To avoid a serious weed problem grasses should be mowed or killed with herbicides prior to seed formation. The residue should be plowed down.

Table 1: Ground Cover Crops

Species	Seeding Rate	Weight (pounds/bushel)	Planting Date
Barley	2.0 bu/A	48.0	Aug. - Oct.
Rye (annual)	1.5 bu/A	56.0	Aug. - Oct.
Ryegrass (annual)	2.0 bu/A	24.0	Aug. - Oct.
Oats	1.5 bu/A	32.0	Aug. - Oct.
Buckwheat	1.5 bu/A	45.0	Aug. - Oct.
Wheat	25.0 lb/A	60.0	Aug. - Oct.
Crimson Clover	20.0 lb/A	60.0	Aug. - Oct.
Sorghum-Sudan Hybrids	25.0 lb/A	50.0	April - May

The presumed increase of the organic matter in soils may not be the most significant benefit of cover crops. One of the most important physical property improvements is an increased size of soil aggregates in the 1-2 mm size range. An increase in the larger aggregates helps water infiltration and retention, provides a better biological habitat and provides a better rooting environment. Regular incorporation of organic residue is needed or improvements can be lost quickly under conditions of frequent tillage.

Vegetative filter strips between the production site and surface waters are recommended management practices to reduce movement of soil and nutrients off site. Cool season grasses used as filter strips are most effective during critical erosion periods in fall, winter and spring seasons when rain is frequent and during excessive storm run-off events. Filter strips collect sediment and nutrients by trapping and binding nutrients to the vegetative matter in the filter strip. To maximize the benefits of a filter strip, grass should be dense with at least 70% surface coverage. The width of the filter strip necessary will vary based on slope. A study conducted in Indiana indicated little additional benefit when the strip was wider than 8'. Another study completed in Iowa indicated benefits were maximized at a width of 30'.

During major rain events runoff can be expected no matter what system is employed to reduce impact. Storm water ponds and constructed wetlands used as natural filters can be designed to provide even greater retention of sediment and nutrients than can be accomplished with filter strips. Contact Rutgers Cooperative Extension or your local Soil Conservation District for more information on design.

All systems that capture nutrients and sediment require maintenance. Filter strips should be mowed and the residue removed. The residue will be nutrient-rich, so application on and incorporation into production fields will benefit not only the filter strip but also subsequent crops. Depending on surface cover, slope and environmental factors, sediment retention basins will require cleaning as often as every 2 years. The use of a sediment trap that can be easily cleaned and located upstream from the retention basin will prolong the time between cleanouts of the basin.

Fertilization

Perform soil testing regularly to identify fertilization needs and to develop a historical record of soil pH and nutritional status. If the field does not have a historical record, test for several years annually. When soil pH and phosphorus levels have stabilized, one can test less frequently.

When possible, plan to use split applications of fertilizers. Plants will use nitrogen and other nutrients more efficiently when applied in smaller doses, more frequently. Split applications will also reduce the potential for nutrient runoff. Remember that a number of other nutrients, as recommended by soil tests, should be incorporated into the soil before planting.

Side dressing plants rather than broadcast fertilization places fertilizers in proximity to the root zone. When plants are spaced out, nitrogen application should be based on an amount of nitrogen per plant rather than pounds of nitrogen per acre. When plants are closely spaced in rows, adjust the amount of fertilizer used to reflect the area actually fertilized. (If the row spacing is at 6 feet while the root zone is about 1 foot, use 1/6 the amount of fertilizer usually recommended.) Doing so maximizes growth with a minimum amount of fertilizer.

When using a two-way split application, the initial fertilization should take place before bud break. A second application should generally be applied by mid-June. When the total fertilizer requirement is split three ways, the final application should be administered no later than mid-August. With a two-way split application, the first application should use about 65% of the total for the year. For plants that normally have a single annual flush of growth, 65% of the total annual rate should be applied before bud break.

Slower-growing cultivars or species should be fertilized at the lower rates. Vigorous plants require higher rates of fertilizer to maximize growth. Excessive fertilization has been shown to reduce growth and can contribute to nutrient runoff, negatively affecting water quality. The use of controlled-release fertilizers is an optional method of applying nutrients. While initial costs are generally higher than using a granular fertilizer, there may be cost savings of time and equipment use since one application will last the entire growing season.

A combination (N, P, K) fertilizer may be the appropriate selection based on results of a soil test. Generally, applying combination or complete fertilizers has been less expensive than applying nutrient-specific fertilizers (e.g. urea (46-0-0), ammonium nitrate (33-0-0), potassium chloride (0-0-60), etc.). When a certain nutrient in the combination is not needed, however, negative environmental impacts may be greater. Phosphorus is usually the nutrient found to be most in excess for agricultural production. The pollution risk associated with phosphorus is generally related to soil particulate movement that occurs during significant rain events. When phosphorus-laden runoff water enters surface waters, the result can be algal blooms and fish kills.

Fertigation is the process of injecting fertilizers into irrigation water. It can be a good method of applying nursery crop fertilizers since it allows plant material to be "spoon fed" as the season progresses. It can also be effectively used to quickly address crop nutrient deficiencies. Care must be taken to avoid runoff during fertigation.

Fertigation Procedures:

1. Fully charge the irrigation system. When the system is fully charged, water should be coming out of the emitter farthest from the injection point. Record the amount of time required from when the irrigation is turned on until water is flowing from the farthest emitter, then add a couple of minutes safety margin. Using this figure during each fertigation event can save time walking to check the end of the system during each cycle.
2. Begin injection. The length of time required to inject the fertilizer should be at least as long as it took to fully charge the system.
3. After all fertilizer solution is injected, run the system for at least as long as it took to charge the irrigation system to be sure all fertilizer solution has been flushed from the system. This is a good time to walk the system to make sure emitters are not clogged.

Pest Management

Plants produced in the nursery require careful attention during production to maintain suitable plant quality. Plants may be grown under conditions that often favor development of pests that can adversely affect plant growth. These pests may include weeds, insects, and diseases. In the past, pest control utilized preventative pesticide (herbicides, fungicides, or insecticides) applications. Newer pesticides have been developed minimize environmental impact and to target specific pests or groups of pests. As newer pesticides have been developed, the cost of pest control applications have increased. To help contain costs associated with pest control, scouting nurseries for pests on a regular basis is necessary. Upon finding suspected pests, identification is necessary and then selection of appropriate control measures. Rotating chemical classes is important to reduce the probability of pest resistance.

Pest Management Planning

Certain pest problems can be anticipated by knowing the crop history of a field. If a field has been in sod, for instance, grubs might be expected. When sod is killed, root-feeding grubs remain and will feed on roots of liners planted into the field unless control measures are taken. In the case of certain nematode-sensitive crops like American boxwood, soil testing for presence of harmful nematodes is prudent. Contact your Extension Agricultural Agent for assistance in taking a nematode assay sample.

Pest management should be a primary consideration in designing the layout of a field nursery. Any practice that reduces stress on the plant will help promote healthy, vigorous growth and reduce pest problems. Ensure good air drainage by removing windbreaks or barriers to the downhill flow of cold air, plant on the contour to help maintain uniform soil moisture and maintain plants in optimal nutritional condition. Also, control weed growth and keep plants free of damaging insects and diseases.

Give careful consideration to crop rotation practices. Avoid plants with allelopathic relationships. Allelopathy is the inhibition of growth in one species of plants by chemicals produced by another species and can occur by just having leaf residues over the root areas of susceptible plants. The most familiar example of allelopathy is suppression of many plants within the root zone areas of black walnut trees. Growers have reported similar problems when planting deciduous shrubs after boxwoods, yews after yews, oaks after oaks, poplars after poplars, and many rosaceous crops such as cotoneaster, pears, mountain ash, hawthorn or quince in rotations.

Crops with complementary pest problems should not be grown in the same fields or fields close to each other. An awareness of these instances can help reduce pest problems such as cedar-apple rust in crabapple and cedars. Pesticides used on neighboring crops may negatively affect other crops. For instance, Burford holly is very sensitive to and can be defoliated by dimethoate (Cygon).

Rules and Regulations

- Pesticide Use Certification Program
 - All agricultural businesses that use pesticides must possess a pesticide applicator license. If the business applies pesticide only for their own business they should have a private license.
 - To receive a license, one must pass a test administered by the New Jersey Department of Environmental Protection (NJDEP).
 - Licenses are good for five years but need to be renewed annually. During the five-year license period one is expected to receive 8 credits of core and 16 credits of category recertification training.
- Employee requirements
 - Employees may apply pesticides as a “handler.” Annual training is required. A roster of trained handlers must be maintained.
 - Employees are required to receive EPA-approved Worker Protection Safety training every five years and have a current verification card in their possession.
- Agricultural Worker Protection
 - Employers are required to “assure that each worker has received a employee orientation at least once each year for each agricultural establishment on which the worker is employed, on the first day of their employment, or at least one day prior to any work in a field which has been treated within the past 30 days”
- Reporting
 - Businesses need to inventory stored pesticides annually and submit a copy to the local fire company by May 1.
 - It is required that an annual use report be submitted to the NJDEP Pesticide Control Program office.
- A complete set of rules and regulations can be found on the Internet at:
<http://www.nj.gov/dep/enforcement/pcp/pcp-regs.htm>.

Monitoring pest populations

Pest management strategies should be used to minimize the amount of pesticides applied. That entails the application of pesticides based on need and requires monitoring to make that determination. In addition, pesticides should be applied efficiently and at times when runoff losses are unlikely.

Scouting is a key element of pesticide management. Traditional pest management programs identify pest problems and then establish a threshold (a tolerable pest population) after which control measures are started. A significant difference for the nursery industry is that there is a zero threshold requirement for plant material stock that is shipped, as established by law. Essentially that means that all plant material shipped interstate must be pest-free. The following is a list of pest management strategies:

- Establish a scouting program to monitor pest problem outbreaks. Scouting can include direct observation or trapping with sticky cards or pheromone traps. Trained employees or professional pest control advisors should do scouting. Records of scouting results should be maintained and there should be a designated person for making pest management decisions.
- Apply insecticides, miticides and fungicides based on need. Only apply in anticipation of a pest problem when methods of predicting outbreaks have been documented. The major exception is that some disease pathogens require preventative sprays on susceptible crops.
- Apply weed control agents based on control characteristics of specific herbicides (pre-emergence or post-emergence).
- When possible, use pesticides that are effective but less environmentally persistent, toxic, or mobile.
- Maintain records on past pest problems, pesticide use, environmental and other information for treatment areas.

- Use control options that help maintain pest predators. Use narrow-spectrum pesticides that affect only target organisms and apply pesticides only to affected plants or areas.
- Evaluate the use of pheromones for monitoring populations, for mass trapping, for disrupting mating or other behaviors of pests and to attract predators or parasites.
- Destroy pest breeding, refuge and overwintering sites. Remove plant debris from plant growing areas or the nursery. Inspect and quarantine newly introduced plant material. When possible, choose plant species or cultivars that are known to be more resistant to common pests and diseases.
- Use spreader/stickers with fungicides and insecticidal sprays to increase efficiency and reduce losses due to rain or irrigation.

Pesticide Applications

When the application of pesticides is necessary, growers need to identify and evaluate pesticide options. Growers should develop a schedule that provides a rotation between pesticide classes to help reduce pest resistance to the controls. When a choice of registered materials exists, producers are encouraged to choose the most environmentally benign pesticide products. Consider persistence, toxicity runoff and leaching potential of products along with other factors.

Growers need to be licensed to use pesticides and meet the requirements of federal and state laws that regulate use of pesticides. Users must apply pesticides in accordance with the instructions on the label of each pesticide product and wear appropriate protective equipment. Farm-worker safety requirements should also be reviewed and met. A checklist of some pesticide safety needs follows:

- Calibrate pesticide spray equipment annually.
- Use backflow protection devices on hoses used for filling tank mixtures.
- Evaluate the soil and physical characteristics of the site. Locate mixing, loading and storage in areas that have a low potential leaching or runoff of pesticides. In situations where the potential for pesticide loss is high, emphasis should be given to practices and/or management practices that will minimize these potential losses. Recognize physical characteristics that may be impacted by pesticide movement and take steps to reduce the risk of an incident occurring.
 - Proximity to surface water
 - Runoff potential
 - Wind erosion and prevailing wind direction
 - Highly erodible soils
 - Highly permeable soils
 - Shallow aquifers
 - Wellhead protection areas
 - Proximity to dwellings
- When possible, use pesticides with a low solubility in water (5 ppm or less) or a low potential risk for leaching.
- Use pesticides with a short half-life to reduce the persistence of the pesticide in the soil and thus the opportunity for leaching.
- Time the pesticide application as far in advance as possible of irrigation and unfavorable weather conditions. The interval between pesticide application and irrigation or rain is closely related to the amount of pesticide runoff and leaching loss. It also relates to pesticide efficacy against the pest.
- Use efficient application methods, e.g., banding of pesticides or applying chemicals when containers are jammed (containers spaced pot-to-pot), or stagger applications.

Fumigation

Fumigation kills most insects, disease, nematodes and weeds, and may be the most practical solution for a valuable, pest-prone crop. Because fumigation kills by using toxic chemicals, it is important that care be given to each stage of the fumigation process to ensure the safety of the fumigator and the effectiveness of the treatment. *Fumigants are highly toxic chemicals. Purchase and application in many states requires certified applicator licensing.*

Maximum effectiveness may be achieved when the treated area is covered with plastic sheeting. The plastic helps ensure that certain fumigants remain in the soil long enough to be effective before escaping into the atmosphere. Cultivate the treated area seven days after application. Do not plant until 14 to 20 days after treatment. If the soil is cold and/or wet you will have to wait longer. ***Always refer to the product label for details and precautions.***

Regardless of the fumigant you use, soil preparation is the key to successful sterilization. Soil should be cultivated twice to a depth of 6 to 8 inches: once 7 to 10 days before fumigation and once immediately before fumigation. Tillers and rotavators are excellent for this purpose. At treatment time, the soil should be free of clods and fresh organic debris, moist enough for seed germination and have a temperature greater than 55°F at the 6-inch depth. Most fumigants are less effective when organic material (such as roots, stumps, leaves, and grass) have not decomposed. Either remove organic debris or allow it to decompose before fumigation.

Fall is an excellent time to fumigate because soils are warm and proper moisture levels are easier to attain. Investigate fumigant options prior to use for best effect. If you have never fumigated soil before, have an experienced pesticide applicator help the first time you fumigate. Fumigants are highly toxic chemicals that must be handled properly to be both safe and effective.

Operation and Maintenance of Pesticide Application Equipment

All pesticide application equipment should be maintained in good working condition. Make a checklist of known replacement, repair and wear items. Calibrate spray equipment with clear water prior to the start of the spray application season. All sprayer tanks should be labeled to identify what types of pesticides can be used with the specific equipment. Lock the tanks when not in use to avoid possible contamination of spray materials.

Storage

Chemical storage facilities must be designed or located such that weather conditions or accidental spills or leakage will not impact soil, water, air or plants. Chemical storage facilities should be posted with adequate safety warning signs and chemicals in storage must be reported to the local fire department annually. Store pesticides in their original containers in environmentally safe and secure locations. Storage should be secure and include proper ventilation and control for any potential chemical leakage that may contaminate water sources or be a detriment to living organisms. Designs for chemical storage and handling facilities can be obtained through Rutgers Cooperative Extension or through your local Natural Resources Conservation Service office.

Mixing and Rinsing Stations

Research has indicated that one of the greatest potentials for ground water contamination from pesticides comes from spills that may occur during the mixing and loading process. The location and design of proper mixing and rinsing equipment stations, relative to the potential contamination of ground or surface water sources should be considered.

To protect against ground water contamination, mixing, loading and cleaning operations should be done on an impervious surface covered with a roof and surrounded by impervious curbing. Wash water and waste products used in cleaning of pesticide application equipment should be disposed of in a safe manner. Rinse water from equipment and containers should be stored and used in the following batch mixture where possible. Where disposal is necessary and allowed by laws and regulations, it should be performed avoiding high runoff and leaching areas such as ponds, lakes, streams, and other water bodies. Disposal of empty pesticide containers should follow instructions provided on the container.

All operations should be performed at a safe distance (100 ft.) from any well. When wells are in close proximity, extreme care must be exercised when mixing or applying chemicals. Anti-siphoning devices should always be used to prevent backflow into the well.

Pre-Planting Weed Management Planning

The most important weed management tasks are done before planting. Good site preparation includes scouting for perennial weeds and controlling the difficult species such as multi flora rose, Canada thistle, mugwort and field bindweed before planting. Controlling perennial weeds requires killing the root system, since most perennial weeds will re-grow if only the top is destroyed. There are few effective options for controlling perennial weeds in crop areas. Fumigation is not an option and the control spectrum for systemic post-emergence herbicides is generally limited. Cultivation is a possible control technique and it can be effective against perennial weeds using multiple cultivations over a period of several months to control the root systems. Timing of the application is critical to ensure satisfactory perennial weed control. Fumigant information is indicated above.

Planting sequential cover crops and allowing the land to remain fallow can help to reduce some weed and insect problems. The intense shading, mowing and competition created in a cover crop program will greatly reduce, if not eliminate, certain weed problems.

Growing individual species of nursery crops in separate blocks allows for more options in weed control. Another management consideration is herbicide carryover from one season to another. When planning new fields, obtain the herbicide history because some herbicides remain in the soils and cause problems for new crops.

Pesticide Considerations

- **Follow label guidelines:**
 - Use recommended rates
 - Use recommended methods of container disposal
 - Follow all instructions as indicated on the pesticide label.
 - Re-entry interval
 - Worker protection standards, etc.
- **Mix only the amount of pesticide needed:**
 - Plan ahead and be sure to use all mixed pesticides.
 - Spray all material on labeled plants to avoid water quality problems.
- **Comply with Worker Protection Standards:**
 - Train workers on "Worker Protection Standards"
 - Train nursery workers and pesticide handlers to use correct procedures: applications, mixing, loading, handling, posting, record-keeping, re-entry of treated areas, use of personal protective equipment (PPE), and emergency assistance.
 - Document all training sessions.
 - Provide decontamination sites and post necessary information in a central location.
- **Stagger herbicide applications whenever possible:**
 - Most herbicide runoff occurs during irrigation or rain events shortly after application. Avoid making a pesticide application to the entire nursery to reduce peak loading of the runoff water.
- **Avoid injecting pesticides into the overhead irrigation system.**
- **Select pesticides with lower water solubility.**
- **Participate in pesticide recycling programs.**

Guidelines for using pre-emergence herbicides

Most pre-emergence herbicides can be used after the soil is settled around the transplants. They must be applied before weeds emerge. This prevents weed seeds from germinating from several weeks to months. As with any other tool, each herbicide has unique characteristics that should be considered when planning a weed management program. Always review labeled information prior to using pesticides. Consider the following during decision-making.

- Rate of application (The correct rate will vary with weed pressure, organic matter content of the soil and ornamental species.)
- Residual (length of time the herbicide will provide effective weed control)
- Activation (For maximum effectiveness, herbicides need to be watered with 1/2-inch of irrigation water or rain into the soil surface within a specified time.)
- Mechanism of action (how the herbicide kills weeds)
- Weed control spectrum (which weeds the herbicide will and will not control)
- Potential losses (leaching, runoff, and volatility)

Since pre-emergence herbicides will not control growing weeds, they should be applied before weeds germinate. In field production, pre-emergence herbicides should be applied on weed-free, stabilized soil after transplanting and then irrigated. Frequency of herbicide application will depend upon the herbicide's residual. Residual weed control will increase with increasing herbicide application rate; control decreases with increasing amounts of rainfall or irrigation, temperature, and organic matter. The proper herbicide for each situation will be dictated by the plant species, weed species, and future use of the field.

Guidelines for using post-emergence herbicides

Post-emergence herbicides can be classified as systemic or contact and selective or nonselective. Selective herbicides kill only specific plants while nonselective herbicides kill all plants. Systemic herbicides are absorbed and move through the plant. These are useful for controlling perennial weeds. For best control, the weeds must be actively growing so the herbicides can move throughout the plant. Contact herbicides kill only the portion of the plant on which the herbicide actually settles. Contact-type herbicides kill small annual weeds but only burn back perennial or large annual weeds. Good spray coverage is important. Check the label to determine the need to treat at a specific stage of weed growth.

All post-emergence herbicides need to dry on the plant to maximize effectiveness. Specific drying times range from 30 minutes to 8 hours and are specified on the label. This is the length of time that needs to pass after herbicide application before irrigation or rain to ensure that the herbicide has had adequate time to affect the plant. Although post-emergence herbicides labeled for field production remain in the soil for a short length of time after application, they have no residual and little or no soil activity; therefore, multiple applications are needed for perennial weeds. The majority of herbicides registered for post-emergence weed control in field production are used either for grass control or for nonselective weed control. Products that provide nonselective weed control should not be applied to the foliage of ornamental plants as severe injury or plant death may occur.

Post-emergence herbicide considerations:

- Apply at correct rate.
- Remember that multiple applications are usually required to control perennial weeds.
- Use the type and amount of surfactant specified on the label.
- Apply when the air temperature is above 50° F and the comfort index (temperature in °F plus humidity) is below 140.
- Treat weeds at proper growth stage.
- Avoid mowing three or four days before and after herbicide application.
- Allow adequate time for treated plants to die before disturbing the soil.
- When there is a potential for losses through leaching, runoff, and/or volatility, check the label and consider another option if necessary.

Guidelines for weed control without the use of herbicides

Herbicides cannot always be used, nor are they effective in controlling all weeds. In these situations, cultivation and hand pulling may be the only available options. Cultivation works well on small annual weeds. Perennials will often re-grow from the roots even if the top is removed. Also, remember cultivation can stimulate successive flushes of germinating weeds by bringing new weed seeds to the soil surface. Check for emerging weeds on a two- to three-week cycle if you are routinely cultivating. If pre-emergence herbicides have been applied and activated, they form a chemical barrier that must be left undisturbed to be effective. Cultivation disrupts this barrier and lessens the effectiveness of the herbicide. Therefore, avoid cultivating if using pre-emergence herbicides.

Cultivation is not without other drawbacks. Cultivated soil is very susceptible to erosion since there is little to no vegetation to hold the soil in place. In addition, implements such as in-row weeders, which cut off weeds 1 inch below the soil surface, can build up ridges. Ridged soil around the stem collar of newly set liners tends to suffocate them just as if they had been planted too deeply.

It is important to develop a weed management strategy that encompasses all 12 months of the year and uses all available options. This strategy should include preventative measures such as pre-emergence herbicides, as well as sanitary practices that prevent weed seeds and vegetative parts from spreading.

Glossary

- AMP** - the Agricultural Management Practices include schedules of activities, prohibitions, maintenance procedures and structural or other management practices found to be the most effective and practicable methods to prevent or reduce the discharge of pollutants to the air or waters of the United States. Best management practices also include operating procedures and practices to control site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.
- Cation Exchange Capacity (CEC)** – the total of exchangeable cations (positively charged ions) that a soil can adsorb. Mineral particles and organic matter in the soil are able to exchange cations adsorbed to their surfaces with other cations in the soil solution, acting as a store for nutrients and buffering against changes in pH. Some cations of interest are ammonium (NH_4^+), potassium (K^+), calcium (Ca^{2+}), and magnesium (Mg^{2+}), all of which serve as plant nutrients, and hydrogen ions (H^+), which cause soil acidity.
- Constructed wetland** - a shallow bed filled with selected vegetation, such as cattails, into which runoff water is diverted and which serve as a biological filter for removing chemicals from the water. Constructed wetlands are designed to slow moving water, allowing time for treatment, and can use a variety of substrates, from native soil to sand or gravel. They can be designed to have the water level above the substrate surface or so that the water is kept below the surface.
- Controlled-release fertilizer (CRF)** - a formulation of fertilizer where release time is controlled by the thickness of the coating (i.e. resin) or the amount of the release agent in the coating that dissolves in water to form pores in the coating (i.e. plastic). CRFs have the advantages of slowly but continually feeding crops and not exposing plants to a large dose of salt at one time (as using some granular fertilizers may).
- Cyclic irrigation** –an irrigation schedule in which a plant's daily water allotment is divided up and applied in a series of irrigation and rest intervals throughout the day.
- Emitter** - a device used to apply water in the form of spray or drops to the soil surface. It is a general term that can be applied to drip stakes, micro-sprinklers, misters, etc.
- Half-life** - the time required for a substance to degrade by one-half. Pesticides with a long half-life are considered *persistent*.
- Lime** - a material containing carbonates, oxides, and/or hydroxides, and used to neutralize substrate acidity. Dolomitic limestone contains calcium and magnesium.
- Nematode** - very small worms abundant in many soils and important because many attack and destroy plant roots.
- Pathogen** - a causal agent of disease. The term can refer to funguses, bacteria, viruses, or other disease-causing organisms.
- Permeability** - the capacity of porous rock, sediment or soil to transmit water.
- Pesticide** - any form of chemical or substance used to control pests. Pesticides include fungicides, herbicides, and insecticides.
- pH** - a measurement, ranging from 0 to 14, of the concentration of hydrogen ions (H^+) in a solution. A pH of 7 is neutral, a pH below 7 is acidic, and a pH above 7 is alkaline or basic.
- Pheromone** – a naturally occurring or synthetically produced substance that can result in specific reactions of organisms. Pheromones are notably used by insects for communication, and so can be used in pest management to scout for, trap, or disrupt mating in insect pests.
- Runoff** - the portion of precipitation or irrigation on an area that is discharged from the area. Runoff which is lost without entering the soil is called surface runoff and that which enters the soil is called ground water runoff or seepage flow. Managing runoff is critical in the nursery industry because it can carry sediment, fertilizers, pesticides and other pollutants to surface water bodies or groundwater.
- Soil** – a natural body composed of unconsolidated minerals, organic matter, air, water and organisms. Considering plant growth, soils serve to provide a plant with support, water, nutrients and air for its roots. Soils also provide important environmental functions including regulating water movement in a watershed, sequestering carbon from the atmosphere, and removing pollutants from water and air. In nursery production, care is necessary to conserve soil by preventing erosion and promoting soil health in order to preserve these functions and encourage healthy and vigorous plants.

Substrate - organic and inorganic materials, often bark, peat and sand, used as growing media in a container to support the plant and contain the root system.

Water holding capacity - the amount of water a soil can hold after being fully wetted and allowed to drain. In soils, the term *field capacity* is also used. Because some water will be held too tightly by the soil for plants to use, the term *available water capacity* is used to designate the amount water a soil can hold that can be used by plants. A soil's water holding capacity is affected by soil texture and organic matter content. An understanding of the water holding capacity of your soil is important because it determines how frequently you should irrigate and how much water should be applied.

Useful References

- Archived historical soil survey publications for New Jersey counties. http://soils.usda.gov/survey/online_surveys/new_jersey/
- Best Management Practices Guide 2.0. Order through the Southern Nursery Association, Inc. <http://www.sna.org/forms/SNAProductOrderForm.pdf>
- "Management Practices to Protect Water Quality: A Manual for Greenhouses and Nurseries". <http://ceventura.ucdavis.edu/files/32117.pdf>.
- New Jersey Department of Environmental Protection rules and regulations can be found on the Internet at: <http://www.nj.gov/dep/enforcement/pcp/pcp-regs.htm>
- Pest Control Recommendations for Shade Trees and Commercial Nursery Crops. By A. B. Gould, S. Hart and J. Lashomb. NJAES pub. #E036. <http://njaes.rutgers.edu/pubs/publication.asp?pid=e036>
- Pruning Field Grown Shade and Flowering Trees. By T. E. Bilderback, R.E. Bir and M.A. Powell. Horticultural Information Leaflet NO. 406. <http://www.ces.ncsu.edu/depts/hort/hil/hil-406.html>
- Soil quality information is available from the Natural Resources Conservation Service on line at <http://www.statlab.iastate.edu/survey/SQL/sqiinfo.shtml>
- The American Standards for Nursery Stock. ANSI 60.1. American Association of Nurserymen. 1250 I Street N.W. Suite 500, Washington D.C. 20005. <http://www.jerseygrown.nj.gov/jgstandards.pdf>
- "Water Quality Handbook for Nurseries". <http://osuxtra.okstate.edu/pdfs/e-951.pdf>
- Web Soil Survey website. <http://soils.usda.gov/survey/>

