A Manual for Field Production of Nursery Stock

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Introduction

Interest in planting field-grown nursery stock has increased in recent years as agricultural producers have considered new ways of diversifying. Although many growers are familiar with field production of certain other agricultural crops, they may have less experience with nursery stock. Some aspects of growing shade trees in the field are similar to producing row crops, but many characteristics—such as procuring line-out stock, spacing, weed management, and managing a crop for more than one year—are quite different. Initially, new growers must plan a marketing strategy to identify clientele and make it possible to determine what plant species or cultivars to grow. Depending on the final plant size at sale, growers can determine the field layout, spacing, and equipment required to meet the strategic plan. Generally, if nursery stock is sold within a local area, marketing may be limited to retail garden centers, which prefer small and very well-formed trees and shrubs. Landscapers, on the other hand, need larger plant material and in some cases may prefer specific leader, canopy height, and branch structures when they select shade trees at the nursery. Shipping nursery stock to other geographic locations requires special handling during harvest and transportation. The more specific the marketing strategy, the easier it will be to determine which plants to grow and how to design the planting plan.

Deciding How to Structure Your Business

When entrepreneurs, whether they are farmers, retailers, service providers, high-tech inventors, or others, determine to start or reorganize a business, they should investigate common options for structuring a business and choose one as the way to organize their enterprise. In general, they should pick the simplest form of organization possible, but one that meets their needs.

Choosing a form of business organization will depend on the goals and objectives of the owners. Many factors must be evaluated, including tax consequences, costs of formation, complexity, limitations on liability, needs of outside investors, estate planning and transition issues, and other goals of the owners.

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Here is an overview of the most commonly used business-organization models—sole proprietorship, partnership, limited liability company, and corporation. Some other business models, such as trusts and estates, are not described here. Statutory limitations on the time that an estate may remain open prevent the use of an estate as a realistic choice for long-term operation of a business. Trusts, except for living trusts, usually function as passive owners in the business models described here. Revocable living trusts, when used to operate businesses directly, usually do not operate much differently than a sole proprietorship.

Sole Proprietorship

A sole proprietorship is the simplest form of business organization: One person owns all of the assets and is responsible for all of the debts. The business income is reported on the owner's federal tax return, Form 1040, Schedule C, C-EZ, or F. Many farms and independent businesses, such as restaurants, are operated as sole proprietorships.

Partnership

A partnership is an association of two or more persons established to conduct a business for profit. The relationship is consensual and usually bound by a legal contract that defines the partnership agreement. A partnership is treated as an entity for litigation and bankruptcy proceedings and may hold title to property. North Carolina has adopted the Uniform Partnership Act (UPA). Under the UPA, partners have equal management authority and share equally in profits and losses. The partners also have an equal obligation to contribute time, energy, and skill to the partnership business without compensation. Each partner has unlimited personal liability to the partnership's creditors, and all partners are liable for wrongful acts and breaches of trust by any partner. The UPA provides these default provisions in the absence of a partnership agreement to the contrary. Most provisions of the UPA can be modified in a written partnership agreement that specifies the details of capital contributions, management, sharing of profits and losses, rights and obligations, terms of property ownership, termination and dissolution, and buy/sell agreements.

A partnership files a federal information tax return (Form 1065) annually. Each partner receives a Schedule K-1, which provides information about his or her share of partnership income, credits, deductions, and other information. All income flows through and is taxed to the individual partners. A partnership interest is personal to the partner. The partnership is dissolved by the death of a partner or by the sale of a partnership share. While the spouse of a deceased partner is usually entitled to payment for the deceased partner's equity in the enterprise, the spouse is not entitled to participate in the partnership. Law firms and accounting practices were once operated almost exclusively as partnerships, although other models have become more prevalent in the past few decades.

A limited partnership has the characteristics of both a partnership and a corporation. It is used when some partners want neither management responsibilities nor unlimited liability for the business venture. Limited partnerships are sometimes used for investments sold to the public.

North Carolina has adopted the Revised Uniform Limited Partnership Act (RULPA). Under this statute, a limited partnership is formed by at least one general partner and one or more limited partners. The general partner manages the partnership and has full personal liability for any debts incurred by the partnership. Limited partners contribute cash or other property, and their liability for partnership debts is limited to the amount of their investment in the venture. Limited partners do not participate in the management of the partnership. A limited partnership also files an information tax return, but income is taxed to all the individual partners according to the distribution of profits specified in the partnership agreement.

Also governed by RULPA are family limited partnerships. These partnerships are generally restricted, by written agreement, to a defined range of family members. Family limited partnerships may be used to keep business assets in the family; protect the business from the consequences of divorce, death, and disability; provide for better organization and management of the business; and reduce estate taxes through valuation discounts and other means.

Limited Liability Company

A limited liability company (LLC) is a distinct entity that is a hybrid of a partnership and a corporation. North Carolina law authorized this type of business entity effective October 1, 1993. It may be treated as a partnership for tax purposes. The IRS allows an LLC to choose ("check the box") whether to be taxed as a corporation or as a partnership.

As with a corporation, the members have limited liability for debts of the LLC.

This business entity offers more flexibility because of its hybrid nature. The LLC is not allowed to have an unlimited life, as a corporation is, but it may have orderly transfer provisions. Membership interests are not freely transferable without the consent of all other members, but a member may assign his or her economic rights, but not voting rights. The statute has been amended to allow for a one-member LLC.

This business entity is often used in estate planning because it can be an efficient way to transfer assets over time to the next generation. It may also generate valuation discounts that can reduce the value of the business in the gross estate and therefore reduce estate taxes. Valuation discounts typically result from restrictions on sales placed upon owners of interests in the business and the minority owner status of some or all owners.

The LLC has the same limitations on liability as a corporation. The owners, like shareholders of a corporation, are not liable for the debts, torts, or other civil liabilities of the LLC. However, the limitations on liability, for owners in family-owned LLCs and shareholders in closely held corporations, are largely illusory. Because the business owners are also generally its operators, they are likely to incur personal liability in tort because it will be argued that their personal actions as a business operator or manager gave rise to the liability. Few lenders are willing to lend to LLCs and closely held corporations without the personal guarantees of their owners or shareholders.

Corporation

Corporations are formed under state statutes. A corporation is a separate legal entity that has rights and liabilities separate from its shareholders. Shareholders of a corporation are liable for the debts of the corporation only to the extent of their investments in the corporation. Shareholders elect a board of directors, which sets policy and appoints officers to manage the company on a daily basis. Shareholders do not participate directly in management decisions (unless they are also directors or officers). A corporation has a potentially unlimited life, and it is not dissolved by the death of a shareholder, director, or officer. As noted in the discussion of LLCs, the limitations on liability from civil actions and debts for closely held family corporations, however taxed, are largely illusory.

A corporation formed under Subchapter C of the federal Internal Revenue Code is the type of corporation whose shares may be publicly traded, if exchange and SEC requirements are met, and it is an ordinary corporation subject to double taxation: Profits are taxed as they are earned by the corporation; then, when those profits are distributed to the shareholders as dividends, they are taxed again to the individual. The Internal Revenue Code places some limitations upon the ability of the corporation to avoid double taxation by not paying dividends and accumulating earnings within the corporation.

A corporation formed under Subchapter S is a "close corporation" that has elected to be taxed like a partnership. Shares of such a corporation are not publicly traded. Instead of being taxed at the corporate level, the income flows through to the shareholders and is taxed only once, at the individual level (whether the profits are distributed or not). The shareholders are responsible for payment of all taxes. As with a partnership and an LLC, the failure to distribute sufficient funds to the shareholders to allow them to pay taxes on their prorated share of profits may place hardships on those shareholders who lack other funds with which to pay the taxes. Such shareholders may have to borrow money to pay their taxes.

Generally, shares of stock in a corporation are freely transferable by any stockholder. However, North Carolina law permits restrictions on stock transfers by the articles of incorporation, bylaws, an agreement among shareholders, or an agreement between shareholders and the corporation. The restriction must be authorized by statute and must not be excessively one-sided (unconscionable) under the circumstances.

There must be a conspicuous printed notice of the restriction on the stock certificate or in the stock information statement required by the statute. One type of restriction would be a buy-sell agreement between a stockholder and the corporation or other stockholders in which the selling stockholder must first offer his or her stock to the other party to the agreement. The agreement would set a price to be paid for the shares. The restriction is useful where the shares are not publicly traded and a share price would otherwise be difficult to establish.

Shares in a corporation are defined as either common or preferred (Subchapter C only), based on the rights and privileges that belong to the owner. Common stock represents a fractional proprietary interest in a corporation’s property and assets. Therefore, the common shareholder participates on a pro rata basis in the distribution of corporate assets upon dissolution and participates in corporate profits (dividends) and management of corporate activities (right to vote). Traditionally, preferred stockholders are not creditors of the corporation and do not share in corporate assets upon dissolution. Instead, they have a right to a fixed dividend, due and payable before any dividends to common shareholders. However, the articles of incorporation may grant preferred shareholders the right to receive preference over common shareholders with regard to dividend distributions and corporate dissolution proceeds.

The shareholders are the actual owners of the corporation, and ultimately they choose the people who will manage the company. Under North Carolina law, the shareholders must elect a board of directors to whom they delegate the power of management. The board is responsible for all of the corporation’s business affairs, such as issuing shares of stock and defining the rights that those shares accord, selling corporate assets, mortgaging corporate assets, declaring dividends, and managing the election of corporate officers. The senior management of the company, represented by the chief executive officer (CEO) and the senior management team, are responsible for the day-to-day operations of the corporation. Their authority and duties are prescribed by the bylaws and the directors. Officers and directors owe a fiduciary duty to the corporation and the shareholders and must not engage in self-dealing. An officer or director must not engage in a competing business without full disclosure and permission from the corporation.

A corporation’s articles of incorporation must be filed with the North Carolina Secretary of State, and they must contain the following information: (1) a corporate name, (2) the number of shares that may be issued, (3) the street address and mailing address, including county, of the initial registered office and the name of the initial registered agent, and (4) the name and address of each incorporator. This document may also provide (1) the names and addresses of the initial board of directors, (2) provisions regarding the business purpose and par value of shares, and (3) limitations on the personal liability of directors.

At the organizational meeting of the corporation, bylaws should be adopted and formalized in a document. This document may contain any provisions for managing the company and regulating the affairs of the company that are legal and consistent with the articles of incorporation. The bylaws are the continuing set of governing rules under which the corporation, its officers, directors, and shareholders exercise management powers, transfer shares, hold meetings, and carry on all other activities related to the corporate objective.

A corporation may be dissolved and terminated in one of two ways—voluntary dissolution or involuntary dissolution. The directors and shareholders may voluntarily dissolve a corporation by passing a resolution of dissolution and filing articles of dissolution with the Secretary of State. In addition, a corporation may be dissolved without its consent by court action or administrative action of the Secretary of State. If the directors are believed to be not acting in the best interest of the company, any shareholder may obtain judicial dissolution. If the corporation fails to file annual reports or pay franchise tax, for example, the Secretary of State may dissolve the corporation administratively.

Formalities are very important if the corporate model is to be used effectively. These formalities include holding regular shareholder and director meetings; keeping accurate records, including minutes of shareholder and director meetings; and maintaining separation between the property and accounts of the corporation and its shareholders. Failure to observe these formalities may result in a court’s setting aside the corporate structure. This will defeat any effort to use the corporate form to limit liability or protect the business from disruptions caused by the death or divorce of a shareholder. It may also result in dire and unforeseen tax consequences.

Choosing a Form of Business Organization

The goals and objectives of the owners are key elements in choosing the structure a business will take. Selecting a business model to defeat existing creditors, to disinherit a spouse, or to defeat a spouse’s interests in an impending divorce are generally not valid reasons for selecting a particular business structure. However, selecting a model to protect a business from disruptions associated with the death or divorce of an owner are valid reasons for selection, so long as the choice is made well before either a death or divorce is imminent. It may also be necessary to employ other tools, such as life insurance to provide an estate for a surviving spouse or a premarital agreement to limit each spouse’s rights in the other’s property. In the end, those planning to establish a business need more than a business plan; they need a form—or model—for their business.

Site Selection

No single factor influences the success of a field nursery more than soil. Unlike container nurseries, field nurseries depend on native soil characteristics such as soil texture, drainage, profile, and slope to be suitable for production of nursery stock crops.

Field grown nursery stock is grown normally in a 3-5 year production cycle. Therefore, the history of the field and the cultural practices employed previously are critical to success. If you have not talked with a county extension agent by now, this is the best time to contact one. County agents can access previous crop records to determine the type of herbicides and pesticides applied, as well as the application of animal or municipal wastes. Knowledge of the previous crops, for example, soybeans may let you know the potential for soybean cyst nematodes. County agents are an invaluable resource; utilize them if you want to be successful.

Since some soil will be sold with field-grown nursery stock, consideration should be given to whether a field soil will produce a root ball with enough soil cohesion to remain around the roots. Generally, root balls with sandy soil fall apart during handling. Soils should be relatively free of rocks to facilitate digging when planting and harvesting, as well as deep enough to allow digging a root ball at harvest. The American Standards for Nursery Stock (Ansi Z 60.1-2004) establishes standard diameters for harvesting root balls according to the size of the plant (Table 1). The American Standards also require standard depths based on the diameter of the root ball, which are generally 60 to 75% of the root ball diameter depending on the stem caliper of the plant (Table 1). For example, a 1-inch caliper dogwood requires a root ball diameter of 18 in and a depth of 13.5 in (Table 1).

Field-grown nursery stock is harvested by extracting the root system either by hand or with a machine. Historically root balls were extracted by hand digging a “ball” of soil containing a portion of the root system. This method was labor intensive and the quality could vary with digging crews. Machine digging with a tree spade has become the standard harvesting technique. Tree spades are equipped with three or four hydraulic blades that extract a cone of soil and roots. Whether or not root-balls are dug by hand or machine, they are wrapped in burlap, pinned with nails and finally tied with twine to pull the burlap tight around the soil and roots. Machine dug plants are first placed in a burlap-lined wire basket before securing the root-balls. Mechanical diggers and wire baskets have made harvesting nursery stock in sandy soils more successful, but it is still important for soil to be retained around the roots (Figure 1).

Soil drainage is another factor you must consider when selecting a site. 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 disease and insect problems. Fields being considered for nursery stock production should have at a minimum an 8 to 10 in. well-drained profile. A soil probe can be used to determine the soil profile. Given the importance of drainage, perhaps it would be beneficial to conduct a simple percolation test. A shovel, a handful of clean gravel, a ruler, and a bucket of water can provide some good information. Dig a few holes at least 6” wide by 24” deep scattered over the area where plants will be grown. If post hole diggers are used, rough up the interior walls of the hole to aid seepage. Put the gravel in the bottom of the hole (about 2”deep). Fill the hole with water and keep it at a minimum depth of 12” for an hour. (You may have to refill the hole repeatedly during this hour.) The following day, fill the hole with water to a depth of 6”, then measure the amount of water lost after an hour. Next fill the hole with water to a level of 20” and measure drainage after an hour. Repeat 2 more times. Calculate each percolation rate using the last three readings. For each measurement time, divide the number of minutes (in this case 60), by the number of inches of water lost. For example, 60 minutes/2 inches = 30MPI (minutes per inch). A reading of 60MPI or lower is good for field nurseries.

Mottled yellow, grey, blue or sour-smelling soil indicates poor drainage and a standing water table at some time during the year. Soils with mottled characteristics are often saturated during winter months. These soils are not suitable for most nursery stock production. Field crops with a

1 year rotation are affected less by high winter water tables than field grown nursery stock with longer rotation times. If the high water table is only seasonal, the effect can be alleviated by preparing ridged planting rows. Even sandy soils can have poor drainage if underlain by an impervious B-Horizon found 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.

Slope is another important consideration. Many major field nurseries are located in flat, nonflooding river bottoms. These bottom lands are generally close to irrigation water, relatively rock free and flat enough to allow easy equipment operation. However, properly located upland soils with these same characteristics can make excellent nursery sites, as long as the slope is not too great, topsoil too thin, or erosion too severe. Locating a field nursery near rivers and streams also bears a responsibility to protect the watershed from field erosion sediment and nutrient contamination.

Few fields are absolutely uniform in slope, drainage (air and water), and fertility. For optimum growth, crops that will tolerate wet soils such as red maple, river birch, bald cypress, willows, sweet gum, and black gum might be placed on wetter sites. Although crape-myrtle will thrive in moist locations, they should be planted on well-drained sites because they tend to grow too long in the fall and are damaged by frost. Dogwoods require very well-drained locations.

Poor air drainage occurs in bottom areas surrounded on all sides by hills. These areas can remain colder longer in winter and even create frost pockets while adjacent areas are not affected. Crops that begin growth early in the spring, for example Colorado blue spruce, or crops that flower before the leaves appear, for example flowering cherries, should not be planted in frost pockets. A few degrees difference could damage early cherry and plum flowers or destroy the first flush of growth.

Some field nurseries are not irrigated, but in choosing land for field production, the potential to irrigate crops should be a major consideration. Nursery liners are expensive and many are named cultivars.. ‘Franksred’ Red Sunset maple liners, for example, frequently cost as much as $15.00 for a 6 ft lightly branched plant. Mortality during the first year after planting can be considerably higher in non irrigated compared to irrigated nursery fields. In subsequent years, irrigated crops out grow non-irrigated crops, have less dieback, require less pruning and can shorten the production cycle by 1 to 2 years. Liner mortality also costs in terms of less trees per acre and subsequent lost of production space. Therefore, most growers conclude that irrigation equipment pays for itself quickly.

Nursery Site Development and Layout

When arranging a field nursery site, nurserymen should consider the natural features of the land, as well as length, width, and turning radius required for sprayers, tractors, and wagons. Take care to ensure that rows follow the contour.

Plan for grass waterways and field edge buffer strips to reduce erosion and sedimentation. Grass strips can effectively slow runoff and trap sediment, thereby reducing soil losses by 30 to 50 %

compared to bare soil. A grass barrier will slow runoff water in front of it, allowing soil to settle out in the crop area before it reaches the grass strip. Buffer strips should be established next to surface water or in fields parallel to rows of planted trees. Strips should be 12 ft wide to meet conservation standards; however, the first 3 to 4 feet does most of the filtering. As slope increases, the number of strips needed increases and the distance between them decreases to sufficiently slow runoff water velocity. Best grasses for buffer strips and grass waterways tend to be sod-forming types, such as fescue or spreading rhizome grasses like bermudagrass because they produce a dense mat to slow runoff and catch sediment. Before planting, prepare these areas as you would other planting areas and incorporate nutrients recommended by soil tests. Mow grass strips at least during the first year to keep the grass from seeding and to encourage a thicker stand. To keep grass waterways and buffer strips vigorous, avoid frequent traffic over them, lift implements above the ground before crossing, and mow and fertilize regularly.

The most effective BMP for protecting water quality in all watersheds has been identified as maintenance or development of 50 ft riparian buffers along all natural conveyances including streams, rivers and estuaries. Existing buffers between fields and public surface water should be preserved as field nurseries are planned and planted. (To learn more about riparian buffers see http://www.nrcs.usda.gov/search).

Fact sheets on field border strips, waterways, grading, contours, terraces and riparian buffers are available on at USDA Natural Resources Conservation Service (formerly Soil Conservation Service) National Handbook of Conservation Practices.

Soil Fertility

Conduct soil tests to determine soil fertility. The number of soil tests required per field will vary with the size and uniformity of the field. Take at least one soil test for each change in soil texture, color, 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 it takes time to conduct the tests, evaluate the results, and plan the most economical and effective nutritional program for crop production. Certain practices such as adding lime and superphosphate should be completed before planting so that these materials can be thoroughly mixed with the top 6 to 8 inches of soil during normal soil preparation practices. Soil test results will indicate if other soil nutrients are required as pre-plant adjustments. In clay loam soils of the upper piedmont and mountains, where phosphorus (P) and potash (potassium, K) tend to remain high once adequate levels are established, nitrogen (N) may be the only required yearly addition. Historically, ammonium nitrate (33-0-0) and urea (46-0-0) have been used widely. Due to home security issues, ammonium nitrate is more difficult to obtain; and 25% of the nitrogen in Urea may volatilize unless it is incorporated or watered in soon after application. Urea is still a perfectly effective source of N. Particularly if pre-plant incorporated, sufficient overhead irrigation is available, or if chances of natural precipitation are good. If those conditions do not occur, ammonium sulfate (21-0-0 with 24%S) can be applied as a surface side dress in field nurseries. In some regions, yearly applications of P are also warranted. In those instances, di-ammonium phosphate (DAP 18-46-0) is often used as an N and P source.

New land for field production of nursery stock could contain copper and zinc at high levels if animal or municipal waste was applied previously. High levels of zinc or copper compete with the absorption of iron, thus creating iron deficiencies even if iron levels appear normal on soil tests. Additions of lime at the highest recommended rates may reduce the availability of copper and zinc, but unfortunately reduces the availability of iron. One alternative is to apply a foliar application of chelated iron to relieve the iron deficiency problems; however, one to two applications per year may be required. If possible, growers should avoid planting nursery crops in fields with high zinc and copper levels. Planting in these fields should be considered experimental and nurserymen should consider growing several species of nursery crops to determine if there are tolerance levels for these crops. Meanwhile, growers should develop management strategies to improve the productivity of the field.

Best management practices for fertilizer application focus on minimizing nutrient runoff and impacts to water quality, while maintaining maximum growth. To minimize surface run-off in new field preparation, incorporate N at 50 lbs. per acre and incorporate all other nutrients according to soil tests to a depth of 6-8 inches (this is a perfect example where Urea would be an acceptable source of N). In subsequent years, base nitrogen applications on the amount of N per plant rather than pounds of N per acre. Place fertilizer within the root zone as a side dress at the rate of 0.25 to 0.5 oz. N per plant rather than previous recommendations of 100 to 200 lbs. N per acre. Doing so maximizes growth with a minimum amount of fertilizer. If supplemental fertilizer is required the first year for fall-transplanted plants, each plant should receive 0.25 to 0.5 oz. N before bud break. The second year each plant should receive 0.5 to 1.0 oz. distributed in split applications: the first two-thirds of the total amount should be applied before bud break, and the second application should be applied by mid-June. The third and following years each plant should receive 1.0 to 2.0 oz. in split applications as described for the second year. Slower-growing cultivars or species should be fertilized at the lower application rates, whereas vigorous plants will have increased growth if the higher application rate is used. Rates greater than those recommended are not warranted and, in fact, have reduced growth and can contribute to nutrient runoff and impact water quality. Recently, slow-release fertilizers developed specifically for field use have been introduced. Although they are more expensive, one application will last the entire growing season.

Soil Amendments and Cover Crops

Nursery professionals need to implement best management practices which maintain and improve soil quality characteristics during fallow periods, field preparation for planting, the production cycle, and at harvest and sale. The term “soil quality” is the fitness of a soil to function within its surroundings, support plant and animal productivity, maintain or enhance water and air quality and support human health and habitation. Soil quality information is available from the USDA Natural Resources Conservation Service and on line at http://www.nrcs.usda.gov/search.

Soil amendments and cover crops are the most effective best management practices for field nursery growers to reduce soil and nutrient losses from production areas. Reduction of tillage practices is one way to decrease the incidence of soil-loss by erosion. High winds and heavy rains are responsible for major losses of soil and leaching of nutrients during periods of high volume run-off. Frequent tilling increases that loss by changing soil structure, contributing to soil compaction, and reducing water infiltration. Washes and gullies are more likely to occur also. Moreover, frequent tilling reduces the activity of soil organisms, which would otherwise break down nutrients. Therefore, reducing tillage decreases run-off while providing an environment for natural organisms to complete the nitrogen cycle.

Three important management practices for field growers to adopt are amending the soil with organic matter, planting cover crops throughout the production cycle, and the establishment of filter strips to maintain water quality. Amending soils with organic matter improves soil quality and structure, aeration, water retention, drainage, and the quality of nursery stock grown. Additionally, some nursery species develop a more fibrous root system as the amount of organic matter is increased. Planting cover crops reduces soil erosion while increasing the nutrient content of the soil, and filter strips bind and trap nutrients and soil during heavy rains (Figure 2).

Organic matter amendments, for example, bark, yard waste and compost can be cost prohibitive to transport and apply in significant quantities, thus growers may use these amendments in the most intensively cultivated sites like seed beds or transplant production beds. Growers should check to see if composts from municipal yard wastes are affordable organic sources for amending fields. Application rates of stabilized composted wastes can be 50 to 200 tons per acre because composted yard wastes may provide only 0.2 to 0.5 percent nitrogen. The 50 tons per acre application rate represents approximately 1/2 in. coverage over a 1-acre area, while the 200 tons per acre would be approximately a 2 in. depth.

Animal wastes such as cattle manure or poultry litter can be applied to fields, but only in light applications of 1/4 to 1/2 inch over surface areas, or better yet, incorporated into the soil after application. If wastes are incorporated, 75 to 100 percent of the nitrogen in the waste may be available the first year. Rates of application for either organic matter or animal waste should be based on nutrient analyses. Particular attention should be given to the metal content of animal wastes. Zinc and copper levels may become toxic if repeated applications are made annually. Foliar tissue analysis of recent, fully expanded leaves collected early in the growing season can provide valuable information about the efficiency of soil amendment applications and determine if any supplement is required.

An alternative to applying organic materials over the entire field is to incorporate the organic matter in planting rows only. If rows are spaced 12 feet apart and the root zone area of plants is considered to be 2 feet on each side of the stem, additions of organic matter to this 4-foot wide strip would reduce the amount of organic matter applied in the field by two-thirds.

Use of cover crops can significantly reduce soil loss. Cover crop rotation should also be considered. Planting hybrid sudan grass in large fallow areas during summer months followed by dwarf barley as a winter cover crop can reduce sediment and nutrient loss. Grasses and small grains can also be used in a double cropping system. For example, small grains can be sown in the fall, then killed with herbicide or plowed in before seeds are produced in spring (Table 2). Sorghum-sudan grass hybrids and even corn are commonly used as summer cover crops. Because of abundant and rapid growth, large amounts of biomass are produced. Sudan grass is mowed at least twice to prevent seed formation, then plowed or disked under in fall. This practice increases the amount of organic matter in soils.

Increases in organic matter occur when cover crops are used in production, however, the most important physical property improvement is increased size of soil aggregate fractions in the 1-2 mm size range. An increase in the larger aggregates facilitates water infiltration and retention and provides a better biological habitat and a better rooting environment. Direct links can be demonstrated between the number of resident fungivores and macropredators with cover cropping practices. Fungivores regulate the rate of nutrient mobilization while macropredator density has been correlated with pest control. Arthropods and earthworms also appear to be stimulated by cover cropping. Deposition of green manure cover crops on soil surfaces has been shown to support high populations of beneficial mites which are bio-control agents.

Use of filter strips reduces erosion by first slowing the movement of surface water, then increasing its infiltration, and lastly by trapping and/or binding the sediments and nutrients carried by the surface water. To be an effective best management practice for field production, filter strips should have no less than 70% surface cover and be at least 12 feet wide. Cool season grasses used as filter strips are most effective during critical erosion periods in fall, winter and spring when rainfall is frequent and storm run-off events excessive.

The use of storm water ponds and wetlands as natural filters can be used to provide even greater retention of sediment and nutrients than can be accomplished with filter strips. Field nurseries often are located on land with gentle slopes where sediment loss potential is high, particularly if vegetation is sparse. Depending on surface cover, slope and environmental factors, sediment retention basins may require cleaning as often as every 2 years. These materials may be recycled and spread back on the fields.

Conservation efforts are needed to reduce soil and nutrient loss from wind erosion and stormwater movement off site. Soil stabilization and erosion control best management practices include: planting across slopes and contoured layout of fields, use of cover crops for fallowing land, use of vegetation in aisles, row ends, drive roads, field border strips, grassed waterways, sediment dams in waterways, bio-swale collectors, wetlands and irrigation practices that do not increase erosive washes or the need for tillage due to weed germination stimulation.

Field Preparation

Whether or not you decide to use a green manure program, it will be necessary to incorporate previous crop stubble, fertilizer, lime, and soil amendments. Tall weeds should be mowed before seed dispersal then disced or plowed under. This will permit more effective soil mixing during plowing and minimize the problem of long, coarse stems becoming entwined in equipment.

A chisel plow will mix materials efficiently in the soil profile, ensuring an even distribution of materials and rapid root development during the growing season. Rotovating can also prove effective but generally does not mix the soil as deeply as a chisel plow. Avoid the use of a mold board plow because this implement overturns the top layer of soil and deposits it just beneath the soil surface rather than distributing it evenly throughout the soil. For best results, chisel plow twice. If erosion is not a problem, plow first across the field in one direction then plow at right angles to the first path. Terraces and contours should not be destroyed during chisel plowing.

Fumigation

When weeds, soil-borne insects, nematodes or pathogens cannot be controlled adequately after the crop is planted, or if noxious pest inspection standards cannot be met by any other means, then fumigation may be the most practical pest control strategy, particularly in valuable, pest-prone crops. Fumigants are highly toxic chemicals and kill most insects, pathogens, nematodes, and weeds. Furthermore, fumigation is expensive and is only used when other management options will not provide economically viable control.

Two commonly used fumigants are metham-sodium and dazomet. The most effective soil fumigant, methyl bromide, is no longer available except for certain exempted uses such as forest nursery seedbeds. Metham-sodium and dazomet are somewhat less effective on some pests and require longer to dissipate from the soil before planting, but are easier to handle and somewhat less toxic than methyl bromide. Because each fumigant is toxic and expensive, it is important that care be given to each stage of the fumigation process to ensure both the safety of the fumigator and the effectiveness of the treatment. Furthermore, purchase and application of these products requires certified applicator licensing.

Although metham-sodium is a liquid and dazomet is in granular form, the active ingredient in both is methyl isothiocyanate (commonly referred to as MIT), which is released as a gas after the materials are applied to the soil. Metham-sodium is a liquid, and may be easiest to use on small areas as a liquid drench. Larger areas may be treated with tractor-mounted soil injectors specifically designed for the purpose. For best results, cultivate the soil thoroughly, and irrigate to uniformly moisten the soil. Then apply metham-sodium at a rate of 1 pint per 50 square feet of surface area. After application, irrigate the soil with enough water to saturate the surface. As with all common fumigants, you will achieve maximum effectiveness if you cover the treated area with plastic sheeting. The plastic helps ensure that the fumigant remains in the soil long enough to be effective before escaping into the atmosphere. Remove the plastic and cultivate the treated area seven days after application to a depth of 2 inches. Do not plant until 14 to 21 days after treatment. If the soil is cold and wet you will have to wait longer. Always refer to the product label for details and precautions.

Dazomet is a granular material, and is easily applied with any spreader. Rototill to a depth of 6 inches immediately after application, then irrigate. Although not mandatory, you will achieve the best results if you cover the treated area with plastic sheeting. If you choose not to use plastic sheeting, roll the surface to seal it, and keep the soil surface moist for several days to slow the loss of methyl isothiocyanate from the soil. Again, 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 rotovators 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 50 degrees F at a depth of 6 inches. Since most fumigants are inactivated by high levels of un-decomposed organic material (i.e. roots, stumps, leaves, and grass), remove organic debris or allow it to decompose before fumigation.
If the soil is not properly prepared or free of fresh organic matter, there may be insects, diseases, nematodes, or weeds present that the fumigant will not kill. Although the soil should be moist, wet soils are not sufficiently aerated to allow free movement of the fumigant within the soil and will result in poor pest control.

Fall is an excellent time to fumigate because soils are warm and proper moisture levels are easier to attain. Rooting beds and seedbeds are used frequently during the cold winter months. If they have not been fumigated in the fall it is very difficult to achieve the required temperature and moisture conditions needed to fumigate in the winter or early spring

Your county Cooperative Extension Agent is a good source of advice on which fumigation technique would be best for you. 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.

Pest Management Planning

What Growers Need to Know About Integrated Pest Management (IPM)

One management tool or approach, which growers can integrate into their production systems to assist in producing quality plants that are healthy and marketable, is **Integrated Pest Management** or **IPM**. Simply defined, "**IPM** is a ***sustainable*** approach to ***managing*** pests by combining ***biological***, ***cultura*l** and ***chemical*** tools in a way that minimizes economic, health and environmental risks".

The key to IPM is *managing* pests. Each grower must realize that potentially harmful pests will continue to exist in the nursery. The goal of an IPM program is not complete eradication of all pests from the nursery, as no nursery can be kept totally free of aphids, mites or caterpillars for extended periods of time. Instead the aim is to reduce pest populations below a critical threshold where plant damage is minimal.

Combining different control practices is also key to IPM and to sustainability. Reliable pest control that will stand up to test of time rarely depends on a single control strategy, such as pesticide use. In an IPM program the cost of chemicals and sprays to eliminate all pests cannot be justified. This is why control measures should be integrated.

With IPM, growers attempt to maximize natural control agents. *Biological* pest control is often viewed as releasing insect predators such as ladybugs or praying mantises -- something few growers do because acceptable pest control is not achieved. A number of different beneficial organisms may inhabit any nursery field. A key component of IPM is to conserve the existing predators that are already present and providing free pest control. Each grower should strive to create a healthy environment for these beneficials so that they can reduce problems with a number of insect pests.

Cultural practices include all things that go into growing an ornamental: proper site selection, plant spacing, fertility, and ground covers. In general, a healthy, vigorously growing plant is much less likely to have problems with pests. Often chemical controls don't work when cultural practices aren't adjusted to reduce the potential for the development of pest problems.

Chemical tools are pesticides. These should be applied only when needed based on scouting results. In IPM, growers treat only blocks of plants, individual plants or a portion of the plant requiring treatment. This reduces the amount of unnecessary pesticide use in the field. The choice of pesticide is very important in IPM. Select pesticides that are least disruptive to beneficial insects in the nursery (e.g., soaps and oils). Many commonly used pesticides are broad-spectrum materials, which kill beneficial predators as well as pests. As a result, pest populations (like mites) recover quickly in the absence of predators.

With IPM, each nursery site or field must be managed as a separate unit and viewed as a separate ecosystem. Temperature, rainfall, irrigation, soil structure, nutrients, plants, animals, insects, mites, weeds and disease are often specific for any given site in the nursery. Growers must realize that any management practice carried out over the entire nursery may produce unexpected and undesirable effects within any localized nursery site or field.

Growers adopting and implementing IPM must also understand that a reasonable management objective is to maintain pest populations below acceptable threshold levels. Low levels of pests in the nursery may provide food for beneficial organisms in the managed system. These beneficial organisms may help to control pests in the nursery at a later time if needed.

An Effective IPM Program

In order for an IPM program to be effective, the grower should have or develop a strong knowledge of the key pests, key plants and key locations in the managed system.
The grower should also be able to recognize beneficial predators and have an understanding of how the weather affects both pest and plant growth. Key *pests* are those that occur in damaging numbers or levels year after year, and usually consists of a small number of insects, diseases, weeds and nematodes. The grower should become familiar with the identification, biology and control of these pests. Key *plants* are those most likely to incur damage and require some level of treatment year after year. By knowing the plant species and cultivars most susceptible to pests, growers can reduce losses by growing resistant plants or focusing monitoring and management activities on pest-prone plants. Key *locations* are those fields or areas within the nursery prone to pest problems year after year. For example, lace bugs tend to appear first on susceptible plants planted on sites exposed to full sun.

A grower implementing IPM should monitor or scout by regularly inspecting plants for the presence of insects, weeds, mites, diseases, nematodes or adverse environmental conditions. Information gained through monitoring can be used to pinpoint the location of pests and to apply control methods in the most effective and timely manner. Monitoring also provides information on the presence and activity of beneficial organisms that may eliminate the need for other controls. Regular monitoring provides the grower information on how effective previous controls have been. Monitoring includes visual inspections, using trapping devices, and recording weather data such as temperature, rainfall and humidity.

Once the decision is made to apply control methods, an integrated management plan or strategy consisting of cultural controls, biological controls, resistant plant materials, and chemical controls should be implemented. The grower will need to evaluate the success of the IPM program on a regular basis. Evaluating success should include the effectiveness of the control methods used, the cost effectiveness of monitoring and scouting, and the overall value of the IPM program to the nursery and the environment.

STEP ONE: Decide IPM Is Important

Make IPM and reducing pesticide use an objective for your nursery. Write down this objective where you can see it often. Having a written goal is the best way to change.

Some nurseries have in place a system that is used for tracking plant species and cultivars, plant age and plant height. Others may need to develop a plant inventory map of each field or growing site. By mapping the nursery into manageable, measurable blocks, a grower will be able to identify and track areas within the nursery which are problem areas or hot spots for scouting and monitoring in the overall IPM program.

Set achievable goals for the next 6 to 12 months. Don't try to change everything at once. By experimenting in a small way, you can learn what works at your nursery and with your resources. The idea is to reduce the risk of failure so you don't become discouraged. This will give you the confidence and experience needed to eventually expand the IPM approach to the whole nursery.

Start by choosing a block of plants with a history of hosting a common pest (i.e. aphids) and start using IPM techniques only in that block. To be more comfortable about changing past pesticide practices, choose plants that are more than a year from sale. Review and record current pest control practices in that block. Start scouting to monitor if your current practices are effective in controlling the pest population. As you continue regular scouting and adjust your management plans and chemical use, you will begin to see the benefits of IPM. As you gain confidence in the scouting techniques that control decision making, what you have learned in one block can be used throughout your nursery.

STEP TWO: Learning How To Scout

Scouting involves regular, repeated inspections of plants in the field throughout the year. The objective is to catch pest problems as they begin to develop so that an effective treatment can be applied. Scouting also involves keeping records so that trends in pest populations can be followed through the growing season and from year to year.

Beginning in January, growers should schedule plant monitoring and scouting visits for the coming year. This should be written on a calendar; otherwise it may never happen during the busy times of the year. A grower should plan to scout his fields, sites or blocks of plants once a month during January, February, October, November and December. From March through September, a grower should plant to scout his fields at least twice a month. During key pest periods, some blocks of key plant species and cultivars may need to be scouted once a week.

There are four goals to accomplish during scouting. *First*, assess what pests are present and their stage of growth. The presence of predators should also be noted. *Second*, determine if pest numbers have reached the economic threshold and need to be treated. *Third*, determine if it is the proper time to control a particular pest. *And lastly*, determine if pesticide treatments have worked well.

A scouting block is an area, which can include as few as 100 plants or over an acre of plants. Each species and even each cultivar should be scouted separately. There are differences between cultivars of the same species for susceptibility to many pests, such as Japanese beetles and foliar fungal diseases. Blocks of plants of the same species should be scouted throughout their production cycle because different pests attack the same plant at different ages. Very large fields of a single species may also be broken into blocks by farm roads to make scouting easier.

The decision to take some action against a pest is based on an understanding of the level of damage a plant can tolerate without an unacceptable economic loss. Ornamentals can withstand little pest damage because of the aesthetic qualities they must possess, as well as their need to pass plant inspections when shipping out-of-state. For some plants to pass inspections, a single beetle or caterpillar may be enough to justify the application of a pesticide. However, for most pests such as aphids, spider mites, scales, and caterpillars, many individuals must be present to justify the cost of a pesticide application.

The economic threshold is the level at which a pesticide application or some other treatment action is taken. Economic thresholds are usually expressed as the number of pests found per set number of plants, or as a percentage of plants infested with pests. It is determined through research and observations over several growing seasons. It takes into account that pests will probably multiply, so that pesticides are not applied too late. Through scouting, a grower can determine if a particular pest has reached the economic threshold in time to make an effective pesticide application.

Growers scouting for plant pests should give more attention to highly susceptible species and cultivars, and less attention to plants that appear healthy with fewer known problems. The rule to follow is to scout for the most serious pests (key pests) of the most susceptible plants (key plants) first. A good IPM scout should also understand the life histories of the pests, which develop on the plants being grown in the nursery. The pests you will be scouting for will depend on the time of year. Most pests are only a problem for several weeks out of each year.

Many pests scouted for are small or only found on a few plants out of thousands. How a scout walks through a block to assess pest problems can determine whether the pest is found or not. There are three different strategies used to walk a field to find different pests. The first method is *rigid block* scouting (Figure 3A), which requires a scout to walk the entire length of a set number of rows. The second method is *random walk* scouting (Figure 3B), where the scout takes a different path each time the field is scouted. The third method is *hot spot* scouting (Figure 3C), where a scout makes frequent visits to a previously identified "hot spot" in order to monitor any changes in populations of specific pests such as mites, insects, diseases or weeds.

The rigid block scouting method is the most time consuming and thorough of the scouting methods. It is based on searching for spider mites, which requires the most intensive scouting. Comparisons of the numbers of spider mites found from one visit to the next will show whether a population is increasing or decreasing. To scout a block using the rigid block scouting method, enter the block two to four rows from one corner. Record the row you start with on the scouting form so that on your next visit you will be able to start your survey one or two rows above or below this row. Walk the full length of the row, scanning from side to side up to five rows in each direction, depending on the size of the plants. To detect mite problems, it is necessary to see the top half of every plant, and a full side of most plants. When you see a problem plant, go to it for a closer look, but return to your original row to continue through the field. When you reach the end of the row, step over six to ten rows as previously determined from tree size. Continue this pattern until you have covered the entire block. Record scouting results.

The random walk scouting method is less time consuming, but it does not give you the confidence you need to scout for certain pests like spider mites. It is appropriate to determine disease and weed problems, bagworms, aphids, and many other pests. To scout using the random walk scouting method, enter the block from one side, and circle through the block, trying to see into all areas of the field. Each time you scout the block, enter from a different side and take a different path. Walk toward any problem trees that can be seen from a distance. Record scouting results, and draw your path through the block on a field map so that a different path will be taken the next time trees are scouted.

Hot spot scouting can be used to keep track of developing problems. The hot spot becomes a representation of what is going on in the rest of the block. Hot spot scouting can be used to monitor a slowly spreading disease problem such as *Rhizoctonia* Web Blight. These hot spots may only need to be visited once or twice a year. Hot spot scouting can also be used to determine the size and stage of weeds to time herbicide treatments, the presence of dogwood borer moths in a pheromone trap, or to monitor the effects of the weather on spider mites or powdery mildew on individual plants that are prone to damage. In these cases, frequent trips for several weeks may be necessary. Identify the hot spot through other scouting methods and mark it with flagging and on a field map. If the pests in the hot spot are becoming more active, use another scouting method to determine if the entire block requires a pesticide application.

Nursery scouts in an IPM program often use a number of monitoring techniques and devices. Pheromone traps can be used to time for sprays for clearwing moth borers (banded ash borer, lilac/ash borer, oak borer, dogwood borer, rhododendron borer, peach tree borer), conifer tip moths, Japanese and Oriental beetles, and bagworms. Sticky traps can be used to sample for aphids, adelgids, thrips, leafhoppers and other pests that fly among host plants. To detect for mites and other minute sucking pests, leaves or portions of branches are often beat on to a white surface or beater tray. The scout must make visual inspections of plant leaves and bark for the presence of pests where other monitoring techniques are not available.

One of the major differences between an IPM program and traditional pest control program is that an IPM program develops good record keeping practices among growers. It is very important to keep records of scouting results, soil sample results, and pesticide and fertilizer applications. Items to record for each scouting visit include date and weather, location of site, time in and out of site, major problems observed and location on nursery maps, control decisions made, control techniques used, and evaluation of previous control activities. A record of name and volume of pesticides used, where they where used, when they where used, and why they were sprayed should also be recorded. Information should be kept on each block of plants from the time they are first planted until harvest. Records can help keep a grower from repeating past mistakes.

STEP THREE: Determine The Best Control Strategy

The flowers or flower buds of ornamental plants are the most susceptible to pest attack when compared to leaves, stems and roots. When flower quality is essential for sale of ornamental plants, control decisions must be made rapidly. Leaves are the next most susceptible plant part with respect to pest injury. It is important to know whether the leaves affected will be the final leaves for the season or if the plant will put out new leaves to mask low levels of early season damage from either an insect or leaf disease. Stems, twigs and branches rarely suffer from low levels of pests, such as scale insects. However, borers that girdle the stem or trunk as they feed can seriously damage woody parts of the plant. Whether the damage is on the flowers, leaves, stems or roots, pesticide application may not always be the answer for pest control.

An IPM approach to control pests integrates several control strategies. There are several cultural practices that can reduce problems with insects, mites, diseases and weeds. These include proper plant spacing, proper watering and fertility, ground cover management, use of resistant varieties and sanitation. When pesticide treatment is needed it is important to choose the least-toxic material possible, especially if beneficial insects are present. The primary concern is toxicity to insect and mite predators. Secondly, the material should be least toxic to wildlife and aquatic life in particular. If these materials are used, care should be taken not to allow them to drift or spill into streams or ponds.

Irrigation

Design your irrigation system while planning your field layout and planting strategy. The main irrigation trunk lines will need to be buried in the field, usually along roads, with the valves located at convenient intervals. Remember to plan for a method of draining irrigation lines to avoid damage caused by winter freezing. Also, leave space for a traveling gun to move across a field if you think you will be using this type of irrigation system. If you may expand your nursery in the future, plan the layout accordingly.

Quantity of the water source is dictated by the total area and crops being irrigated while the water quality can influence the type of irrigation system used. Agricultural crops can be watered using hose reel irrigation equipment fed from surface water. Nursery crops can also be watered with this equipment and this water source, however two things are important. Nursery crops continue growing after agricultural crops are harvested, so nursery crops must continue to be watered. If not, loss of growth may occur, which results in loss of sales at harvest. Secondly, hose reel and gun types of irrigation are extremely inefficient to use when watering nursery crops because of large plant spacings. An acre of nursery stock may need an inch of irrigation (acre-inch) applied 1-2 times per week. An acre-inch of water is 27,000 gallons. If this amount of water is applied at each irrigation to large acreages, then a large water supply is required. Otherwise a highly efficient, low volume application method is required. Drip irrigation alleviates both of these critical issues in one system. Less water is used per irrigation and water is delivered only to the root zone.

Drip irrigation is a low volume, low pressure system with many benefits compared to irrigation with large irrigation guns. In fields irrigated with overhead systems, water is lost when applied between rows and run-off may occur. With drip irrigation, water is applied within rows, directly to the soil surface, gradually over extended periods of time (e.g., 1.0, 2.0 or 5.0 gallons per hour), which results in less water lost to evaporation or run off. Because drip irrigation applies water only to the root zone of the nursery crop, roots tend to concentrate within this wet zone. Digging root balls is easier and survivability after sale may be better. An additional benefit is that weed seeds are not irrigated by water distributed over large areas, thus weed pressure is decreased within the nursery. Less weed competition increases the effectiveness and reduces the costs of preemergence and directed postemergence herbicide management programs. One disadvantage of drip irrigation is the inability to protect flowers buds and flowers from frosts or freezes by irrigating lightly overhead. Another disadvantage is the inability to “water-in” preemergence herbicide applications. When drip irrigation is employed, preemergence herbicides need to be applied well before weed germination is expected, or in advance of a natural rain event. Finally, rodents can be a nuisance as they can chew holes in drip lines and spaghetti tube.

Drip irrigation does require clean water free of sediment and minerals that can clog emitters. Well water generally requires only minimal filtration for drip irrigation. County water supplies, if available, may prove to be affordable and are also a clean water source requiring only minimal filtration. Surface water from rivers or ponds generally requires costly sand media filters ($5000) to prevent plugged or reduced water flow through drip emitters, therefore surface water may be more effective for overhead irrigation.

If fertilizer is applied to crops through drip irrigation (fertigation), the amount of fertilizer can be reduced because applications can be proportioned during the growing period and each application is directed at the root zone. When fertigating, the amount of fertilizer used is one-half that of granular top-dress. Less fertilizer can produce more growth because nutrients are more likely to reach the plant when fertigating and less fertilizer will be leached from the soil.

For example: If you have 1200 plants per acre, each plant would normally receive 0.5 oz. granular nitrogen (N) per plant. Instead, with drip irrigation each plant would receive 0.25 oz. N per plant or half of 0.5 N. Further calculations are as follows:

1. The number of plants per acre multiplied by the amount of fertilizer needed equals the amount of fertilizer needed per acre.

1200 plants per acre X 0.5 oz. N per plant = 600 oz. N per acre

2. One-half of 600 oz. N is 300 oz. N (600/2 = 300). If the source of nitrogen is ammonium nitrate (34-0-0), approximately 900 oz. of ammonium nitrate per acre is required (300 oz. N divided by 0.34 N in ammonium nitrate equals 882 oz total product). Because 16 oz. are a pound, approximately 56 pounds of ammonium nitrate (900/16 = 56) are required to fertigate 1200 plants.

3. Fifty-six pounds of ammonium nitrate is to be applied over a period of eight weeks during the growing season. Therefore, 1/8 is applied each week. To determine how much to apply each week, divide the total amount by the number of weeks fertilizer is applied (56/8 = 7). Dissolve seven pounds of ammonium nitrate in water then inject this nitrogen stock solution through the irrigation system.

Fertigation Procedures:

1. Determine the length of time to fertigate nursery crops. 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. Add a couple of minutes for safety margin.

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 so you are 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.

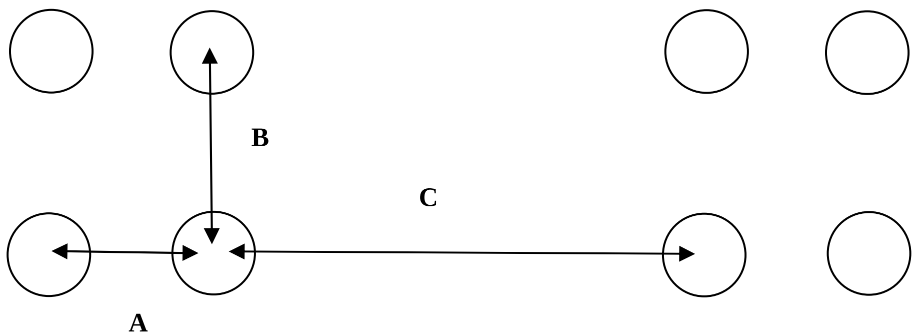
4. Herbigation is the application of herbicides through the irrigation system. In nursery crops, herbicides should not be applied through the irrigation system, whether drip or overhead.

Planting Density

Spacing is always a concern in new fields, especially if you are uncertain about the size of plants you will need or about the market for your crops. If you anticipate that you will sell trees to professional landscapers or that they will be used as municipal street trees, space them wider to allow for more growth and better access during harvest. Wider spacing is also encouraged if the market strategy is uncertain, because it allows more opportunity for finding a market before the trees become overgrown. A spacing method that allows the most flexibility is planting two rows 8 ft. apart and a drive row of 10 to 14 ft. on each side of the two rows. Repeat this pattern across the field. This spacing allows greater room for digging activities and results in less injury to trees during harvest. Smaller flowering trees such as dogwoods and shrubbery can be spaced 6 ft. apart in rows, while larger tree species should be spaced up to 10 ft. apart in the row. In choosing planting dimensions, it is important to account for space required by fertilizing, cultivating, mowing, and spraying equipment. When calculating the number of trees per acre, assume that each tree is considered to “own” half the space between it and the next tree or row. In reality, however, the canopies and roots may exceed half the distance by harvest time.

Various examples are given below to determine the number of trees per acre utilizing a spacing pattern of two rows and then a drive row:

Planting Density examples 1 through 4.



A. Spacing between rows.
B. Spacing within rows.
C. Spacing of drive row.

1. Two rows 6 ft. apart (A), trees 4 ft. apart within row (B), 10 ft. drive rows (C).

   4 ft. (2 ft. either side of tree within row) x 8 ft. (3 ft. between rows + 5 ft. of drive row) / tree = 32 ft^2 / tree

   43,560 ft^2 per acre / 32 ft^2 = 1,361 trees / acre.

2. Two rows 6 ft. apart, trees 6 ft. within row, 10 ft. drive rows.

   6 ft. x 8 ft. / tree = 48 ft^2 / tree = 43,560 ft^2 per acre / 48 ft^2= 907 trees / acre.

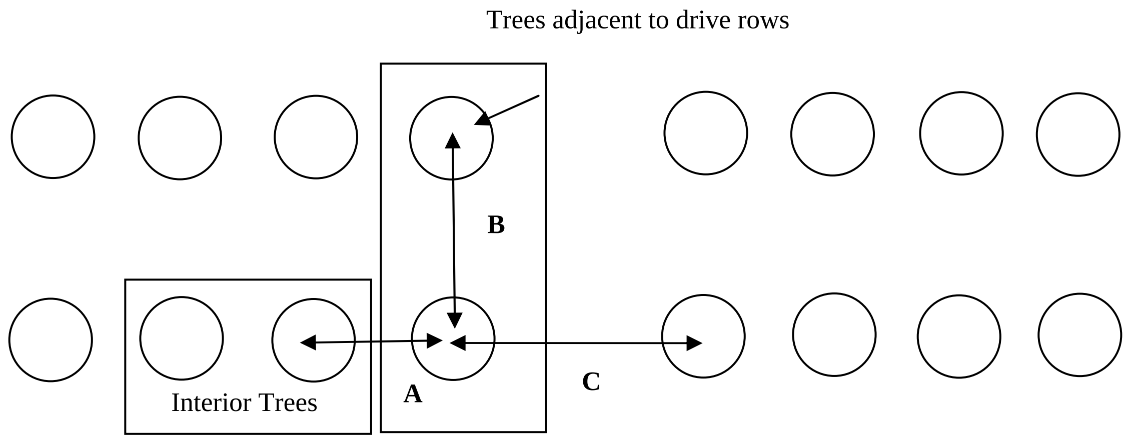
3. Two rows 8 ft. apart, trees 8 ft. within row, 12 ft. drive rows.

   8 ft. x 10 ft. / tree = 80 ft^2 / tree = 43,560 ft^2 per acre / 80 ft^2= 544 trees / acre.

4. Two rows 10 feet apart, trees 8 feet within row, 14 foot drive rows.

   8 ft. x 12 ft. / tree = 96 ft^2 / tree = 43,560 ft^2 per acre / 96 ft^2= 454 trees / acre.

Here is example 5 using 4 planting rows and then a drive row.



A. Spacing between rows.
B. Spacing within rows.
C. Spacing of drive row.

In this example, not every tree has the same amount of growing space. For example, trees planted adjacent to the drive row benefit from the extra square feet of open space in the drive. Trees located on the interior of the 4 tree row are surrounded by other trees and not the drive row, therefore they have less square footage than other trees.

5. Four rows 6 ft. apart (A), trees 6 ft. apart within row (B), and 10 ft. drive rows (C). For this example, we need to calculate an average square footage for each tree based on both the trees adjacent to the drive rows and the trees on the interior rows.

Trees adjacent to drive rows
6 ft. (3 ft. either side of tree within row) x 8 ft. (3 ft. between rows + 5 ft. of drive row) / tree = 48 ft^2 / tree.

Trees on the interior
6 ft. (3 ft. either side of tree within row) x 6 ft. (3 ft. between rows)/tree = 36 ft^2/tree.

($48ft^2$ + $36ft^2$)/2 = 42 ft^2/tree. 43560 ft^2/42 ft^2 = 1037 trees per acre. This allows a grower to utilize more land for growing trees while providing more square footage for canopy formation, and using less land for transportation.

Examples 6 and 7 on the following page illustrate planting on a triangular or off-set spacing between adjacent rows. In example 6, a row is planted with trees approximately 6' part within the row . The adjacent row is 6' away and trees are also planted 6' apart within the row . There is one exception, however, the second row of trees is off-set 3' from the first row before planting (see below). This shift in planting uses a little more growing area in the field but yields a similar amount of canopy growing space, while providing other benefits as well. Plants are shifted down 3' in the planting row, so more land is required than just planting trees in straight, even rows. Plants occupy about 51 ft^2 of growing area rather than $48ft^2$ described above in example 2 for trees on 6' x 6' spacing. This is due to the off-set spacing because not every tree is exactly 6' away from every other tree. Trees that are diagonal to one another, for example trees 1 and 3 in example 6 below, are actually 6.7' apart rather than a the spacing of 6'of Trees 1 and 2 (see D in example 6). This change allows for more canopy space to be shared among trees and allows more light to penetrate between row plantings. Moreover, the off-set planting allows more room for digging equipment and crews to maneuver around trees, thus potentially causing less harm and maintaining quality. Therefore 854 trees are planted per acre instead of 907.

In example 7, triangular spacing allows the opportunity to utilize the extra spacing between diagonal trees to plant trees closer together. If tree 3 is planted so it is actually 6' apart from both tree 1 and tree 2, then the tree will actually be spaced 5.2' from the center of the adjacent row (see D in rows to the right). This method yields 46 ft^2 per tree, which is 946 trees per acre. This method offers slightly less canopy space than in example 2 above, but more trees are planted per acre in the same layout design.

In summary, you can't have it both ways: More canopy space equals less trees per acre, or more trees per acre equals less canopy space.

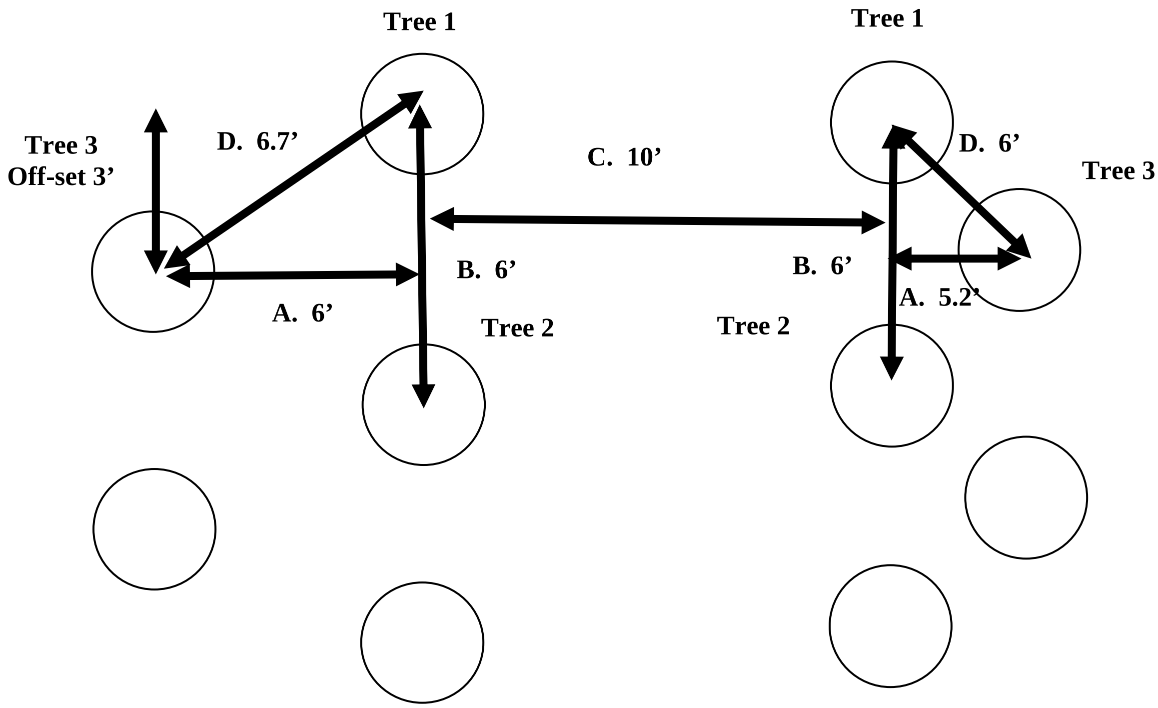
Larger nurseries use main or fire break roads for field loading. Most smaller nurseries will need to load onto tractor-pulled wagons or small trucks to transport plants to the loading area. You need to plan for enough space for transport vehicles and other maintenance equipment. A rule of thumb for determining the minimum distance needed between rows is to add the width of the tractor plus the maximum width required by American Standards for Nursery Stock for that crop. For example, a tractor might be 48 in. wide. In growing a crop of five- to six-ft. trees, another 48 in. are required for the plants to make grade; therefore rows must be at least 96 in. or 8 ft. apart.

One method of increasing planting density is to plant some species, such as dogwoods, 3 ft. apart within rows and after two years, dig and sell every other plant down the row. The following season, the remaining trees would have additional space to develop caliper and full, well-branched canopies. In theory, this method seems like a good idea. The critical issue with this plan is that you must have a sales mechanism in place for the trees that are dug after two years. If all the alternating trees are dug and sold, or possibly containerized to be sold during the current season, this plan may be feasible. However, in many cases, if the grower has no immediate market for the smaller trees or place to hold them, then the entire crop becomes over-grown and diminishes in value.

A. Spacing between rows.
B. Spacing within rows.
C. Spacing of drive row.
D. Spacing of the diagonals

Example 6

Example 7 - Rows are planted closer due to adjusted spacing of triangular planting



Planting

While field layout should be determined well in advance of planting, the actual distribution of plants in the field is determined at planting. Grading of transplants is very important. Plants of the same size and grade can be expected to grow at approximately the same rate and should be planted together, thereby creating uniformity in production stands. Similarly sized plants are more likely to respond similarly to cultural practices and harvesting similarly sized trees is more cost effective. Invest in the largest and best grade of liners that you can afford at planting. About half of the liners from a seed bed may not be large enough or have adequately branched root systems when planted. Small differences in cost between liners graded differently at planting will be much larger at harvest and sales. Quality liners make quality plants.

To ensure that rows will be planted straight, mark the first row with rope, strings, wire, or some similar guide attached to stakes. Set plants at the determined spacing along this line, then make sure that the second row is planted parallel to the first. These first two rows are then used as a guide for planting the rest of the field. A steady hand is important when planting mechanically, because the tracks of the tractor tire are often used as the guide to ensure a uniformly spaced field. Mechanical transplanters are well suited for planting a large number of similarly sized plants (Figure 4). To facilitate mechanical transplanting it is helpful to grade transplants carefully and be sure the field is relatively level and uniform. If you can not meet these conditions, you should plant by hand (Figure 5).

Although field-ready transplants should be sufficiently hardened to withstand the rigors of field production, they should be kept moist and shaded as much as possible before being planted. Particular care should be given to keeping roots from drying out. Soak roots for 1-2 hours within 24 hours of planting to help increase the moisture in plants and improve their chance of survival. Various starch-based hydrogel dips may also be useful in keeping roots from drying out.

Transplants should be set into moist soil in late winter and early spring in the piedmont and mountains. Freeze-thaw cycles during winters have made late fall and winter plantings less successful in these areas. Transplants set in spring will have the opportunity to establish a root system prior to flushing foliage. A well established root system aids the uptake of water lost from tender foliage. Additionally, transplants are often not available from field-grown liner producers until late January or February. Planting late fall and winter in the lower piedmont and coastal plain, however, can be successful when liners are available.

Even where liners are set into moist soil or water is applied to the planting hole by a mechanical transplanter, it is a good idea to water recently set transplants within 24 hours after planting. Water, whether from a sprinkler truck, irrigation system, or rain, will help firm soil around roots, thereby eliminating air pockets that might dry-out plants.

For most species, liners should be set at the same level as they were growing in the transplant bed. If soil is particularly soft at planting, liners may be set slightly higher to allow for settling. There are no good horticultural reasons to set liners deeper than they were previously growing. In fact, setting liners too deep frequently results in stunted growth and death of many species.

Pruning

Many landscape problems can be avoided if plants are pruned correctly while in the nursery. Incorrect pruning practices or lack of pruning diminish the quality of landscape plants. Learn when and what to prune in order to grow premium field grown nursery stock.

The most important aspect of growing nursery stock during the first year is root establishment and development. Top form and shape are less important for small liners than root growth, and allowing the top to grow provides the energy to develop roots. Small nonirrigated liners often experience loss of leaders and secondary branch dieback, which requires pruning later.

Pruning during the first year should be limited to (1) unbranched nursery line-out stock if it is too tall and weak to stand erect and if staking is impractical; (2) dead terminals that need to be pruned on single-stemmed trees to establish a new leader. If the leader is pruned or is dead, branching will occur during the first year on whips, and these may also require some heading back to keep vigorous shoots from growing too long; and (3) any vigorous lateral branches of newly transplanted liners may need to be pruned by mid-summer. On trees that are sold as straight, single-stemmed specimens, for example maples, ash, oaks, and flowering pears, prune any vigorous lateral branches that out grow and suppress the main leader.

Select a lateral bud or shoot as a new terminal if the terminal of a leader is dead or if it is cut back while the tree is still dormant. On pears, cherries, and crabapple, it is advisable to remove three to four buds below the selected terminal bud to prevent multiple leaders from forming. A bud clip placed next to the bud or masking tape wrapped around the bud can direct the growth upward without a crook forming (Figure 6). If the tree is opposite budded, the bud on the opposite side of the bud selected as the terminal must be removed. If a terminal is observed to be dead after shoot growth has occurred, a lateral shoot can be bent upward and attached to the portion of the dead terminal for support; remove other competing shoots or head them back at a node approximately one-half the length of the shoot. The dead leader can be removed after the new terminal is firm enough to stand or removed during dormant-season pruning.

For misshaped seedling trees, often the best choice is to cut them off at the ground just before bud break the second season. This practice can result in high mortality in dogwoods, Japanese birches, and other plants with low vigor, so use this method selectively. After new shoots develop, the healthiest and straightest one should be selected and the others removed.

Any other pruning the first year should be confined to broken branches and large lateral branches which are out-of-scale with the main leader. Large lateral branches that are low on the main stem should be removed, and smaller low branches may be pruned back to two to three buds to help caliper development of the main stem. Remove these short branches during dormant winter pruning. If branched trees are planted, similar procedures may be required to reduce competition of lateral branches with the leader. By mid-summer, competing lateral branches may need to be pruned to approximately one-half their length by cutting to an outward facing bud.

For clump or multi-stemmed trees such as river birch and crapemyrtle, no pruning is necessary during the first year; however, all but three to five main stems should be cut at ground level before the second growing season.

The species' growth habits generally dictate pruning requirements during the second and third growing seasons. It is easiest to work with the natural growth habit of a species than to change the natural form. Medium to large shade trees such as oaks, callery pear, or maples are usually pruned to maintain a single leader and well-spaced, wide-angled branches. Other trees such as many crabapple cultivars, flowering plums and cherries, and other small ornamental trees may be pruned to form three to five modified leaders with low, wide scaffold branches. These modified leaders should be spaced 4 to 6 in. apart on the main stem. The height at which the modified leaders are established is determined by the intended market.

Summer Pruning

Summer pruning in deciduous trees the second and third seasons includes 1) removing watersprouts and suckers (small upright shoots) along the trunk and base; 2) maintaining a single straight leader. Ideally, most deciduous trees should be pruned when dormant, but corrective shaping is essential and should be done at the first opportunity. Broken, damaged, and dead branches are best removed when observed.

Broadleaved, upright plants such as ‘Nellie R. Stevens’ and ‘Fosters #2’ hollies need attention throughout the summer months. The terminals should be tip-pruned to increase branching density. A strong vertical terminal should be 8 to 10 inches long before being pruned. Multiple leaders will develop from this shoot; therefore, later in the season another single terminal should be selected. Evergreen trees are often sheared by removing the terminals of all lateral shoots, but a single leader is maintained.

Trees susceptible to fire blight, such as crabapple, pear, and other rosaceous species, may require extra spring and summer pruning. Tips of branches turn black as the disease moves down the branch. To control the disease, prune at buds or branches well below the discolored area. (This may be 12 to 15 inches on infected branches.) This disease is easily spread by infected pruning shears, so disinfect pruning equipment by wetting all cutting surfaces with isopropyl alcohol or another disinfectant.

Winter Pruning

Pruning of most deciduous nursery stock is often completed in the winter before plants break dormancy. Reasons to prune plants while they are dormant are that (1) the branch structure can be seen more easily; and (2) pruning during dormancy stimulates growth on remaining branches. Pruning should be limited to removal of no more than a third of the total bud and leaf-bud-bearing branches. Otherwise extensive water sprouting may result. Prune out crossing, inward growing, parallel, and competing branches. Branches growing in the center of multi-laddered trees such as river birch and crapemyrtle should be removed so that attention is focused on exfoliating bark. Scaffold branches are permanent branches which make up the frame of the tree. When trees are small, tiers of branches may be 3 to 6 in. apart such as in pear cultivars. During the next two years in the field, prune to develop spacing between whorls to a foot or more, particularly, for large maturing trees. Branches should also be well spaced around the trunk. Acutely angled limbs are weaker than more horizontally angles branches and should be eliminated. Parallel branches growing in the same plane, one above the other, should also be eliminated by removing one of them. Branches growing back toward the trunk or across other branches should be removed.

Possible exceptions to dormant pruning are trees species such as maples, beech, and birch, which are called “bleeding trees” because they lose considerable water and sap after pruning in the spring. Pruning shortly after leaf drop in the fall or pruning during summer months when leaves are present will control bleeding. However, reference books indicate that mostly water is lost, which causes little damage to plant health. Another reason to avoid dormant pruning on trees such as crabapple is excessive water sprouting. If they are pruned later in the year when leaves are present, less sprouting occurs.

Depending on the intended use, customer demand, and market, deciduous shade trees are usually limbed to 36 or 48 in. Smaller trees used for residential landscapes usually branch lower than larger trees and may be as low as 24 in. Boulevard and parking island trees need higher clearance than specimen or residential trees, so prune these trees as high as 60 or 72 in. Lower branches should be removed each year so that the canopy is raised up gradually as the tree grows in height. Ideally, lower branches are removed before they reach 1/2 to 3/4 in. in diameter to close pruning cuts rapidly (Figure 7).

Root Pruning

Historically, experts have recommended root pruning after nursery stock is dormant, a practice that develops a more concentrated root system and thereby enhances transplant survival. However, in many areas of the Southeastern U.S. with rocky and heavy clay soils, root pruning is difficult or nearly impossible without very specialized equipment. Current research suggests that drip irrigation encourages roots to grow to the standard root ball size and allows harvesting of a larger portion of the root system when digging.

A factor frequently forgotten in nursery stock production is the weight of the root ball. Transporting plants that weigh more than 50 pounds without mechanical assistance is time consuming, expensive, bad for employee morale, and may result in worker's compensation claims. Examples of the size of rootballs required for coniferous evergreens, and the resulting soil weights are shown in Table 4.

Ground Cover Management During Production

Ground cover within a field nursery is essential to minimize soil losses due to water and wind erosion, to maintain long-term soil productivity, and to prevent the encroachment and spread of weeds. In addition, a well-established sod makes it easier to drive through fields when they are muddy or covered in snow or ice. A well-established sod is frequently the only economical way to support equipment such as tractors, sprayers, or mechanical harvesters when the soil is wet. Furthermore, research has demonstrated the need for a vegetative barrier around the edges of a field nursery. As previously discussed, grassed contour strips slow down and direct flow of water across a slope and serve as a buffer and final biological filter to remove any excess nutrients before runoff leaves the nursery. Tall fescue, fine-leafed fescues, and bermudagrass are effective in providing workable sod because they are vigorous and provide a great deal of biomass.

If improperly managed, however, ground covers can compete with nursery crops for fertilizer, light, and water, thereby reducing crop growth. A common way to minimize competition while enjoying the advantages of a ground cover is to keep the rows clean or mostly weed free with preemergence and / or postemergence herbicides, while maintaining a ground cover between the rows.

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 trumpet creeper, multiflora rose, mugwort, Florida betony, kudzu, and hedge bindweed before planting. Manual or mechanical control of perennial weeds can be difficult and costly once the field is planted. Controlling perennial weeds requires killing the root system, because most perennial weeds will regrow if only the top is destroyed. There are three options for controlling perennial weeds: cultivation, fumigation, or systemic postemergence herbicide (glyphosate). While cultivation can be effective against certain perennial weeds, multiple cultivations over a period of several months are often required to control the root systems. Furthermore, some perennial weeds such as mugwort are spread by cultivation. Fumigation, as discussed in an earlier section, is an option of last resort to eradicate infestations of weeds that cannot be controlled after planting. Systemic postemergence herbicides such as glyphosate (Roundup-Pro and many other trade names) will control many perennial weeds, but timing of the application is critical to ensure satisfactory perennial weed control. Suggested rates and timing of glyphosate application to control selected perennial weeds are shown in Table 3.

Planting cover crops, plowing in fall, 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 green manure or cover crop program will greatly reduce, if not eliminate, certain weed problems. Fall plowing exposes roots and tubers to the freeze-thaw cycles of a Southeastern U.S. winter but will also expose the soil to erosion and is therefore <u>not</u> encouraged.

Weed Scouting

The first step in any pest management program is to identify the pest(s). Scouting the fields for weeds will enable the grower to determine which weeds are present and to plan appropriate management strategies. Field nurseries should be scouted at least twice a year – in late summer or early fall, and again in early summer. In late summer most summer annual, perennial, and biennial weeds are easily identified. In early summer, winter annuals, perennials, and summer annuals that escaped control procedures can be identified. Weed scouting involves assembling an inventory of the weeds in each block. This is done by simply walking each field and recording the species encountered. Then, highlight the most important species – those that are most prevalent, perennial, new to the field, on noxious weed lists, or should have been controlled by the weed management program in place. With this information, the grower can better plan a weed management program that matches the needs of each crop and field.

In-Row Vegetation Management.

The two basic strategies for in-row vegetation management are (1) *residual,* relying primarily on preemergence herbicides, and (2) *non-residual*, relying almost exclusively on non-selective postemergence herbicides. Each strategy has advantages and disadvantages. The residual approach will utilize more expensive herbicides but will require fewer trips through the fields. The non-residual approach is simple and inexpensive but will require many trips across the fields each season to control emerged weeds.

In the *residual strategy* preemergence herbicides are applied in late winter to control summer annual weeds, and late summer to control winter annual weeds. Depending upon the local conditions, weeds present, and the particular herbicides used, an additional treatment in late spring or early summer may be required. Perennial weeds are spot treated with appropriate postemergence herbicides.

The *non-residual strategy* involves frequent applications of non-selective, postemergence herbicides, on an as-needed basis. Treat weeds when they are 6 to 8 in. in height; this will enable the applicator to contact weeds and avoid the crop. It is common during the growing season to treat fields every 4 to 6 weeks but the interval between applications will vary with weed spectrum present, the mode of action of the herbicide used, and the prevailing weather conditions. Frequent field scouting should be conducted to identify the appropriate times for re-treatment. Herbicides commonly used in the non-residual management strategy include glyphosate (Roundup-Pro and many other trade names), glufosinate (Finale) and paraquat (Gramoxone). Each has its advantages and disadvantages. To decide upon the most appropriate one, follow the guidelines for using postemergence herbicides (below), and consult with your county Cooperative Extension Service and an appropriate reference. However, complete reliance on any one herbicide will lead to population shifts and herbicide resistance. This is particularly important for glyphosate-reliant vegetation management programs. Widespread adoption of the glyphosate-resistant crops technology has lead to relatively rapid development and spread of glyphosate-resistant weeds. Fields should be scouted for “escaped” weeds. When resistance is suspected, remedial action should be taken immediately to prevent the reproduction and spread of resistant weed populations.

Between-Row vegetation management.

Vegetation between rows is managed to prevent encroachment of the vegetation into the crop rows, eliminate habitat for vertebrate pests (such as deer), to provide improved access to the field, and to prevent the spread of weeds into the crop row. The vegetation between crop rows is managed by mowing, cultivation or sub-lethal rates of herbicides (referred to as chemical mowing), and/or growth regulators can be used to slow growth of grass but not kill it. The most common vegetation management practices are cultivation and mowing. Cultivation is discouraged because it leads to erosion and may actually spread perennial weeds. Mowing is generally conducted three to four times each year. The interval between mowing events can be extended by careful selection and use of plant growth regulators. For example, spraying tall fescue or orchardgrass in early spring, when there are four to five new leaves or seven to ten days after mowing, with 1 pint / acre of sethoxydim (sethoxydim), a selective grass herbicide, will suppress the grass for 8 to 10 weeks. Sethoxydim may also be used for chemical mowing. Another alternative is glyphosate (Roundup-Pro, others) at the rate of 4 to 8 oz. per acre as a directed spray. The 4-oz. rate usually provides 6 weeks of vegetation suppression; the 8 oz. rate suppresses vegetation for about 10 weeks at a cost of a few dollars per acre, much less than regular mowing. 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 and will result in a gradual transition of the vegetation from grass to broadleaf cover. Such a transition may not be desirable as broadleaf cover generally provides less traction for vehicle tires and poorer wear tolerance compared to perennial grasses.

Guidelines for using preemergence herbicides

Preemergence herbicides will not control emerged weeds, so they should be applied before weeds germinate. In field production, preemergence herbicides should be applied after transplanting to weed-free soil and then irrigated for effectiveness. Most preemergence herbicides can be applied after the soil is settled around the transplants, but before weeds emerge. This prevents weed seeds from germinating for several weeks to months. Frequency of herbicide application will depend upon the residual activity of the herbicide. Residual weed control will increase with increasing herbicide application rate; control decreases with increasing amounts of rainfall or irrigation, higher temperatures and organic matter. The proper herbicide for each situation will be dictated by the crop species, weed species, and future use of the field. Common preemergent herbicides labeled for field production are listed in Table 5. As with any other tool, each herbicide has unique characteristics that should be considered when planning a weed management program:

- Crop Safety – First and foremost, the herbicides must be safe on your crops.
- Weed control spectrum -- Which weeds the herbicide will and will not control.
- Rate of application -- The correct rate will vary with weed pressure, organic matter content of the soil, and ornamental species.
- Residual -- The length of time the herbicide will provide effective weed control.
- Activation -- For maximum effectiveness, each herbicide needs to be watered (about 1/2-inch irrigation or rain) into the soil surface within a specified number of days.
- Mechanism or mode of action -- Prevent herbicide resistance by using different modes of action in combinations or rotation.
- Potential losses – Avoid leaching, runoff, spray drift and volatility through proper product selection and use.

The most common practice in field nursery weed control is to combine a "grass" herbicide with a "broadleaf" herbicide in order to control a broad spectrum of weeds. Products commonly used in field nursery crop production are listed below.

Common "broadleaf" herbicides	Common "grass" herbicides
flumioxazin	napropamide
isoxaben	metolachlor
oxyfluorfen	oryzalin
simazine	pendimethalin
	prodiamine

Each herbicide differs in the weeds controlled, longevity of residual control, ornamental crop safety and cost. For example: simazine is the least expensive broadleaf herbicide but can injure newly planted deciduous crops. Consequently, isoxaben is often used on those newly planted crops even though it is more expensive and does not control some broadleaf weeds as well as simazine. Where morningglory is common in fields, flumioxazin is commonly used. Additionally, among the "grass" herbicides, only metolachlor controls yellow nutsedge (*Cyperus esculentus*), yet it has a shorter residual life in the soil and is weaker on many common broadleaf weeds than the other herbicides listed above.

A typical residual weed control program will likely use some variation of the following scenarios:

<u>Newly planted broadleaf trees and shrubs:</u>

After planting: band-apply isoxaben combined with pendimethalin, prodiamine or oryzalin. ten to twelve weeks later repeat the application.

In late summer, species that are tolerant of simazine may be treated with a combination of simazine plus pendimethalin, prodiamine or oryzalin. Species that are intolerant of simazine will receive flumioxazin or isoxaben instead of simazine.

<u>Newly planted conifers:</u>

Simazine, oxyfluorfen or flumioxazin, plus pendimethalin, prodiamine, or napropamide

<u>Established plantings:</u>

In late winter apply simazine or flumioxazin for broadleaf weed control combined with oryzalin, pendimethalin or prodiamine for grass control.

If morningglory is common in the field, an application of flumioxazin in early summer may be required.

In late summer re-apply simazine or flumioxazin combined with oryzalin, pendimethalin or prodiamine.

Escaped weeds may be controlled with spot applications of non-selective postemergence herbicides.

Young, seedling broadleaf weeds are controlled with either oxyfluorfen or flumioxazin, so if weeds have already emerged at the time of application, it is possible to control many seedling weeds without the addition of a non-selective postemergence herbicide.

Before deciding which herbicides are right for each crop, consider these guidelines and consult with your county Cooperative Extension Agent and an appropriate reference.

Guidelines for using postemergence herbicides

Postemergence herbicides are applied to weeds after they have emerged. Characteristics of postemergence herbicides that should be considered before selection and use are:

- Crop Safety – Even non-selective herbicides differ in their levels of phytotoxicity to crops.
- Weed control spectrum -- which weeds the herbicide will and will not control the target weed(s).
- Selective versus nonselective – Selective herbicides will provide greater crop safety but limited spectrum of weed control.
- Systemic versus contact – Contact herbicides are less effective on perennial weeds but are potentially less injurious to actively growing crop plants.
- Application timing (or season) for optimum control – Seedling weeds are easier to control, and season of application will influence the efficacy of glyphosate on many perennial weeds.
- Drying time – Foliar applications must get into the plant before rain or irrigation wash the herbicide off.

- Mechanism or mode of action -- Prevent herbicide resistance by using different modes of action in combinations or rotation.
- Persistence – A few postemergence herbicides have soil residual that can affect subsequent crops.
- Potential losses -- Avoid leaching, runoff, spray drift and volatility through proper product selection and use.

Postemergence herbicides can be classified as systemic or contact, and as selective or nonselective. 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 that is actually contacted by the herbicide. Nonselective herbicides have the potential to kill or injure any plant they contact; whereas, selective herbicides kill some types of plants and not others.

The majority of postemergence herbicides used in field nursery crops are non-selective. Diquat dibromide (Reward), paraquat (Gramoxone Extra) and pelargonic acid (Scythe) are nonselective, contact herbicides. They control small annual weeds but only burn-back perennial or large annual weeds. Good spray coverage is especially important when applying contact herbicides. Re-application is necessary to control larger weeds. Glyphosate (Roundup-Pro and many other trade names) and glufosinate (Finale) are systemic, nonselective herbicides, and are more effective than contact herbicides on perennial weeds or larger annual weeds. Glyphosate is better translocated in plants, and is consequently more effective at controlling perennial weeds and grasses compared to glufosinate. Glufosinate is considered to be a contact herbicide by many practitioners, but limited translocation does occur within treated leaves or branches.

Grasses can be selectively controlled in many nursery crops. Clethodim (Envoy), fluazifop-P-butyl (Fusilade II), and sethoxydim (Sethoxydim) are selective, systemic, postemergence herbicides which only kill grasses while leaving broadleaf weeds and crops unharmed. Conversely, very limited options are available for selective postemergence broadleaf weed control in nursery crops. Consequently, broadleaf weeds are generally controlled preemergence or with non-selective herbicides.

All postemergence herbicides have a specified drying time for maximum effectiveness ranging from 30 minutes to 6 hours. 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 postemergence herbicides labeled for field production remain in the soil for a short length of time after application, they generally have little or no soil activity; therefore, multiple applications are needed for perennial weeds. The majority of herbicides used for postemergence 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 or green stems of ornamental plants as severe injury or plant death may occur.

Postemergence herbicides may be applied in many different manners. Where weed populations are sparse, spot spraying with hand held spray nozzles is common. If weed populations are consistent, tractor-mounted (or ATV mounted) sprayers may be used. Tractor mounted sprayers should me adjusted and calibrated to spray a band on either side of the crop row. Do not attempt to spray the entire band width from one side of the row! This will result in too much spray contact with the crop stem and bark damage. Controlled droplet applicators have also been used successfully to apply postemergence herbicides. However, bark damage to the crop has resulted when the applicators are operated in such a manner that crop stems are contacted by the concentrated spray. Regardless of the application method utilized, do not treat with systemic herbicides when suckers, water sprouts, or fresh pruning scars are present, else crop injury will likely result. Remove suckers at least 48 hours before spraying with systemic herbicides such as glyphosate. Spray shields or curtains can be added to the spray rig to reduce crop exposure, but such systems do not eliminate the potential for crop exposure through spray drift or rubbing from wetted spray shields or curtains.

When using postemergence herbicides:

- Apply at correct rate
- Select the most appropriate herbicide for the task
- Rember 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^{o} F and the comfort index (temperature in ^{o}F plus humidity) is below 140.
- Treat weeds at proper growth stage.
- Allow plenty of drying time.

Alternatives to 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 regrow 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. You will need to check for emerging weeds on a two- to three-week cycle if you are routinely cultivating. If preemergence herbicides have been applied and activated, they form a herbicide barrier that must be left undisturbed to be effective. Cultivation disrupts this barrier and lessens the effectiveness of the herbicide. Therefore, cultivate sparingly if you use preemergence herbicide.

Cultivation is not without other drawbacks. Cultivated soil is very susceptible to erosion since there is little or no vegetation to hold the soil in place. In addition, implements such as in-row weeders, which cut off weeds below the soil surface, can build up ridges, which are detrimental to growth of nursery crops. Ridged soil around the stem collar of newly set liners tends to suffocate them just as if they had been planted too deeply. Cultivating nursery stock in subsequent years causes considerable root pruning and delays growth, and can lead to a soil buildup around the collar of nursery stock. Many landscape contractors have had problems with trees grown with soil thrown over the surface of the roots. The surface of the root ball may have several inches of soil with few roots above what was the original soil line. Landscapers think they are planting at the correct height (Figure 8). In reality, they are planting several inches too deep. Thus, cultivation has received considerable attention in landscape magazines and has been identified as a poor practice for growing nursery stock.

It is important to develop a weed management strategy that encompasses all 12 months of the year and uses all available options. These include preventative measures, such as preemergence herbicides and sanitary practices that prevent the introduction and spread of weed seeds and vegetative parts, and remedial measures such as postemergence herbicides, cultivation and supplemental hand weeding. A comprehensive weed management program will incorporate the most appropriate options for each cropping situation.

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Table 1. Appropriate height, caliper and root ball diameters for field grown dogwood trees (Cornus sp.) based on the American Standards for Nursery Stock ANSI 60.1.

Height used until tree reaches 6’.	Caliper^{z} (inches) when trees is over 6’ tall.	^{y}Minimum diameter root ball (inches).
2’		10”
3’		12”
4’		14”
5’		16”
	¾”	16”
	1”	18”
	1 ½”	20”
	1 ¾”	22”
	2”	24”
	2 ½”	28”
	3”	32”
	3 ½”	38”
	4”	42”
	4 ½”	48”
	5”	54”

z Caliper is the diameter of the trunk measured six inches from the soil line.
Ball Depth Ratio
y Diameter less than 20”, depth of root ball must not be less than 75% or ¾ of width.
Diameter between 20”- 30”, depth of root ball must not be less than 66% or 2/3 of width.
Diameter between 31”- 48”, depth of root ball must not be less than 60% or 3/5 of width. Root balls with a diameter of 30” or more should be drum-laced (See Fig. 1).

Table 2. Seeding rates and planting dates of cover crops used in field production of ornamental plants.

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

Example Cover Crop Plan

Suppose you sell one acre of hemlock per year, on a four year rotation. You would require four acres over four years to grow the crops plus one acre for a green manure crop (five acres total). In a typical cycle, an acre would be sold by April. Those fields should be plowed or rotovated, leveled, fertilized, and sown with a sorghum-sudan hybrid as soon as possible after you harvest the hemlock. This cover crop should be mowed at least once, and perhaps twice, then plowed under in September. Ideally, you could then plant a small grain, such as rye, as a winter cover. For the rye between the rows, suppress it by either mowing or spraying with a grass herbicide. One variation to this method would be to sow oats instead of rye in the fall. In Spring, plant directly into the oats. In this case, the oats would be left within planting rows to provide some shade and wind protection while the transplants became established in late spring and early summer. A grass herbicide would then be used to suppress the oats when they reached 6 to12 in. tall. Oats can also provide protection the first winter for crops that do not develop an extensive root system after planting. The oat roots help to prevent the soil from “frost-heaving", which can push young, shallow-rooted plants out of the ground due to normal freeze-thaw cycles. Moreover, oat foliage provides some protection from wind burn and windblown soil.

Table 3. Application rates and timing of glyphosate to obtain 90% or better control of selected perennial weeds one season later.

Weeds	Rate (%)*	Optimum Application Time
Aster, goldenrod, dogfennel	1	First flowering
Bermudagrass	2	First flowering
Blackberry	2	Fall to early winter
Greenbrier	3	Three to five fully expanded new leaves (early spring)
Honeysuckle	1 to 1.5	Full bloom (early summer)
Kudzu	1.5 to 2	Full bloom (late summer)
Lespedeza	1	Full bloom (mid to late summer)
Perennial grasses (Johnson grass, fescue, others)	1	First flowering to two weeks either side of full bloom
Trumpet creeper	1.5	Later summer to mid-fall
Manufacturer does not claim effectiveness on the product label for the following species; however, research has shown the following to provide effective control.		
Clematis vine	1	After bloom until fall
English Ivy	2 to 3	Three to five fully expanded new leaves (early spring)
Greenbrier	3	Five fully expanded new leaves (early spring)
Japanese knotweed	2	Late summer to early fall before frost
Mugwort	2	Spring and again at Full flower (Spring and late summer to fall)
Passion flower	2	Bloom to first fruit
Sericea lespedeza	2	Bloom to first fruit
Virginia creeper	2	Late summer to early fall
Wisteria		Six to eight weeks after bloom (late spring and early summer)

*1% = 1.25 fluid ounces of the 41% ai per gallon formulations of glyphosate in a gallon of water. There are several different formulations of glyphosate on the market. This dilution may have to be adjusted depending upon the amount of active ingredient in the formulation.

Table 4. Nursery standards for coniferous evergreens.

Height	**Spread**	**Root Ball Standards**		
	(Cone - Type 4)	Minimum Diameter (in.)	Minimum Depth (in.)	Weight* (lbs.)
18 to 24 in.	12 to 18 in.	10	7.5	30
2 to 3 ft.	15 to 24 in.	12	9.0	45
3 to 4 ft.	21 to 30 in.	14	10.5	70
4 to 5 ft.	2 ½ to 3 ft.	16	12.0	100
5 to 6 ft.	3 to 4 ft.	20	15.0	200

*Weight will vary depending on soil type and moisture content. Soil typically weighs about 110 lbs. ft^{-3}.

Table 5. Common preemergence herbicides labeled for field production.

Chemical Name	Trade Name
diclobenil	Casoron, Barrier
isoxaben	Gallery
flumioxazin	Sureguard
(s-)metolachlor	Pennant-Magnum
napropamide	Devrinol
oryzalin	Surflan, Oryzalin
oxadiazon	Ronstar
oxyfluorfen	Goal
pendimethalin	Pendulum, others
prodiamine	Barricade
pronamide	Kerb
simazine	Princep, others
trifluralin	Treflan

Note: This table represents herbicides that were labeled for use in field nursery crops at the time of publication. Herbicide trade names do change. Furthermore, new herbicides become labeled and some herbicides may be removed from the market. Consequently, the reader is advised to obtain up-to-date information about herbicides from the manufacturers and local Cooperative Extension personnel before making any product choices, purchases, or applications.

Figure 1. Mechanically dug root ball placed in a wire basket lined with burlap.

Figure 2. Fescue cover crop in the (A) row middles combined with (B) drip irrigation within rows are two important best management practices to reduce soil erosion. Using other cover crops may also add essential nutrients and improve soil structure (see cover crop section).

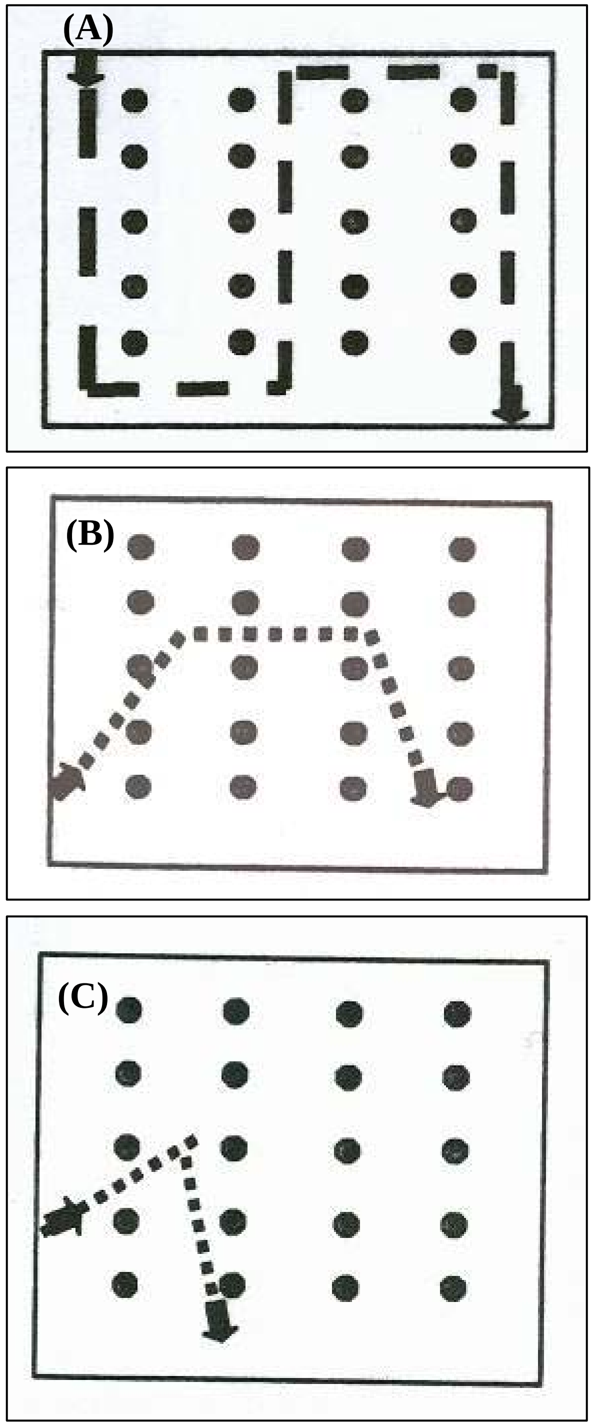
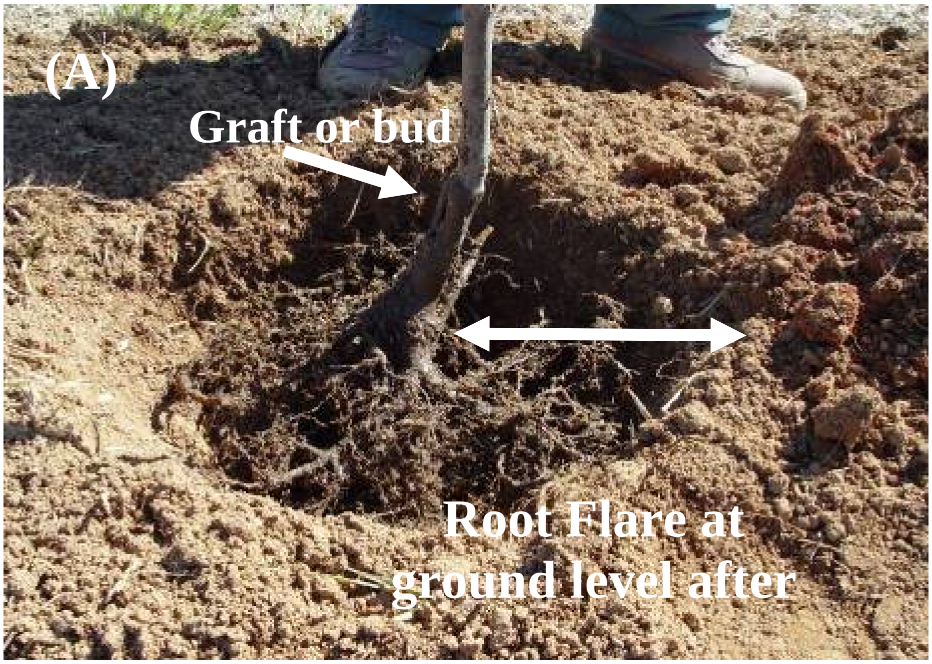


Figure 3. The (A) rigid block, (B) random walk, and (C) hot spot scouting diagrams used for integrated pest management programs.

Figure 4. Planting containerized liners using a tractor-driven transplanter. (A and B) Notice that the nurserymen is still taking care to plant the root flare at the soil level. (C and D) The soil level in the container remains even with the new field soil ground level. Prior to planting, plants were removed from containers, soil was removed from the top portion of the container to expose the root flare, and circling roots were cut or removed.


(A)
Graft or bud
Root Flare at
ground level after


(B)
Root collar or root flare

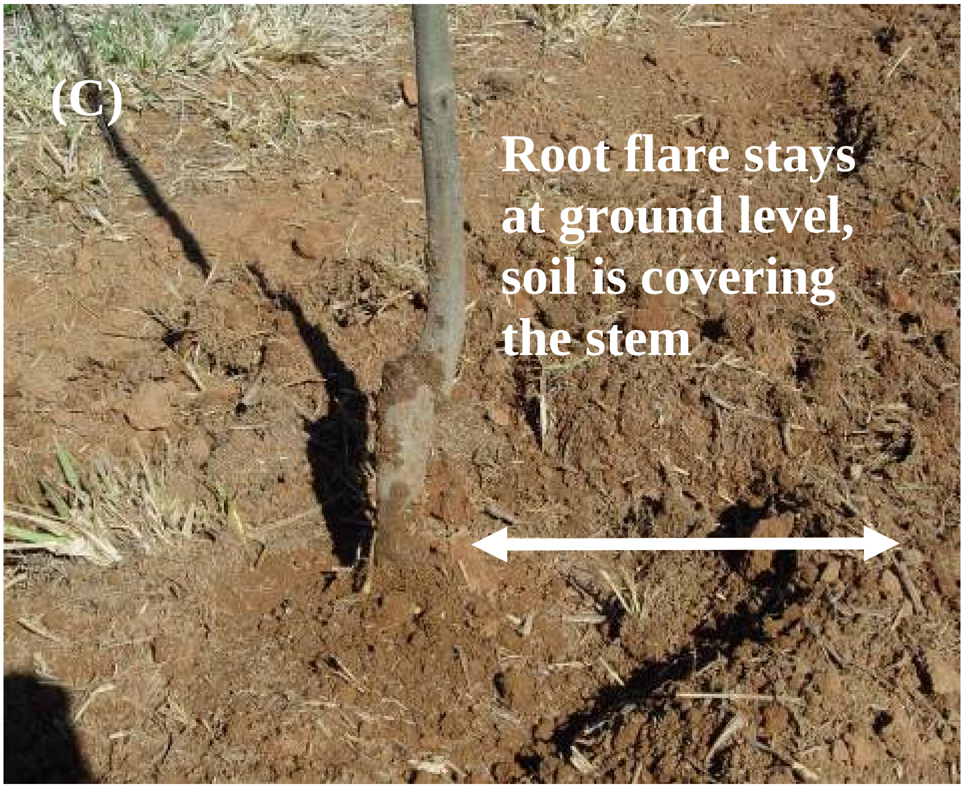


Figure 5. Hand planting bare-root deciduous tree liners. (A) Root systems of bare-root liners are held so that the root flare/collar (portion of the stem where the trunk meets the roots) is even with the existing soil level. Notice that the graft or bud union is about 3-4 inches above the soil line and the root collar is just above the soil surface. On some liners, graft unions may be absent, but the root collar should still be planted just above the soil surface. This method will require staking in the field. (B) Field soil is placed around the existing roots to a depth of 1" covering the root system. (C) After planting is completed correctly, soil should cover the uppermost primary roots, but not cover the root collar.

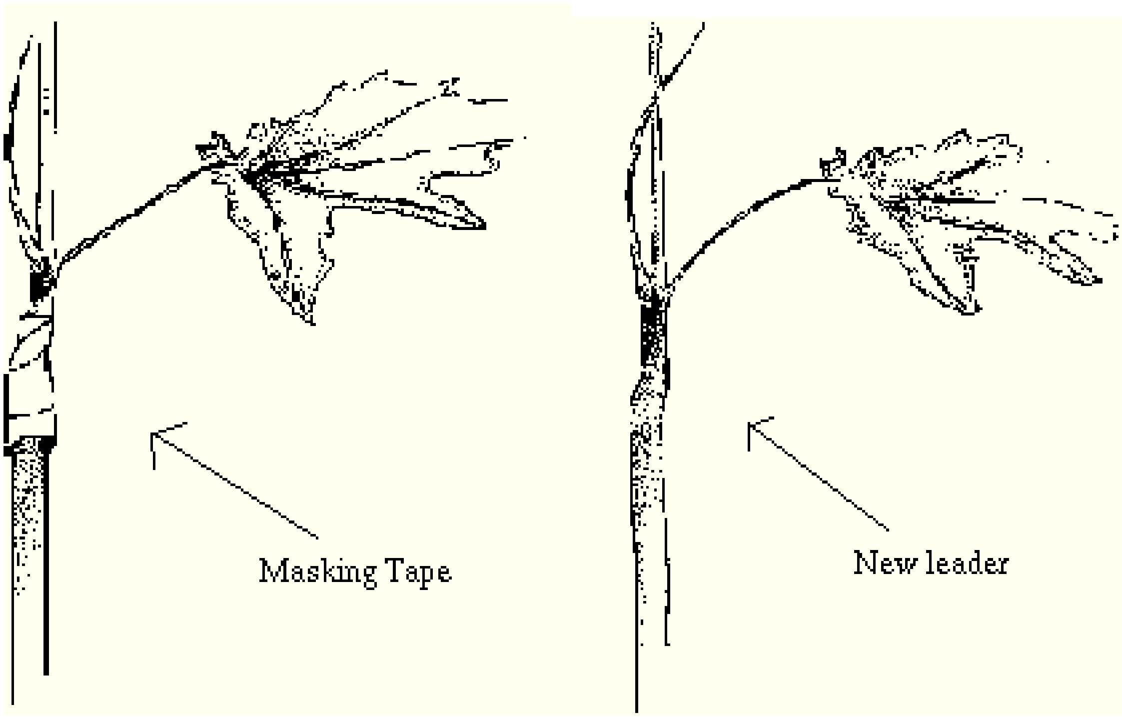


Figure 6. Straight leader developed by wrapping masking tape around expanding bud and existing stem.

Figure 7. Selective removal of upright-growing branches, tight-angled limbs, and parallel branches to create space between scaffold branches.

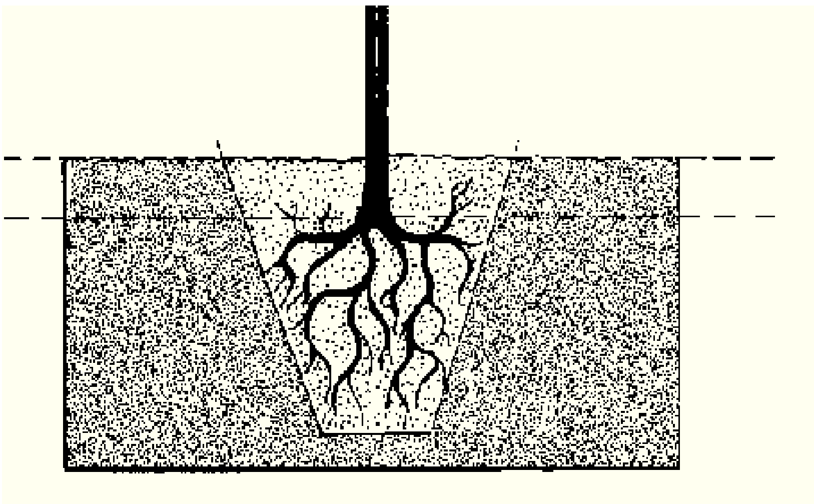


Figure 8. Cultivating can cause soil buildup high around the collar of nursery stock, creating a false soil line, as illustrated above. Planting at that false line is harmful to the health of the tree.