

HO-109

Sustainable Production Systems: Efficient Wholesale Nursery Layout

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Introduction

The nursery industry produces landscape plants for transplanting in residential, commercial, and natural landscapes. Typically, plants are either grown and marketed in containers or grown in field soils and sold as bare root or balled and burlapped (B&B) stock. Kentucky's nursery and greenhouse industry is an important contributor to the state's economy and has experienced rapid growth for several decades. However, the industry has faced some decline in the rate of growth coinciding with the recent economic downturn and reduced housing construction. A slower growth of the market has resulted in increased competition and decreased profit margins, which among other things, force nursery managers to increase production efficiency and marketing effectiveness. Controlling production costs is critical to the sustainability of individual enterprises. A sustainable enterprise is one that yields an acceptable return on investment for the owners as well as conserves natural resources and contributes in various ways to the community.

Sustainability can be approached through a multitude of efforts. One objective that produces meaningful results is the optimization of the nursery layout and operational design. A well-planned layout and design can greatly increase efficiency by reducing unproductive movement of people and materials. In most nurseries, labor is the single largest (about 25 percent to 35 percent) production cost, and movement of plants and materials utilizes a majority of that labor. In addition to increased efficiencies, nursery layout and design can also address the potential for minimizing the environmental impact of operations. For example, a container nursery could be designed to contain water runoff from

production beds, allowing for storage, reuse, and remediation as needed.

Many commercial nurseries begin as small operations with little thought given to initial or future layout design. Facilities, beds, and fields are added on an as-needed basis and their design is often directed by the availability of space rather than long-term layout considerations. Although optimization of layout and design is best achieved when planning a new nursery, modifications of an existing nursery can also be a good investment.

This publication provides the framework for planning and implementing efficient wholesale nursery layout. Concepts and ideas presented here are applicable to new construction or the modification of an existing nursery. A basic approach toward creating efficient systems will be discussed as well as common nursery activities that may require consideration during the planning stages. Functional areas will be defined, and a framework for understanding the relationships between these functional areas will be presented.

Planning for Labor Efficiency

Labor is an expensive but necessary component of any nursery operation. Employees complete numerous essential activities such as mixing media, transplanting, pruning plants, loading shipments, or helping customers. However, the time employees spend walking, searching for an item, or waiting on someone else to complete a task also contributes significantly to labor costs but does not increase product value. Activities or resources that add costs but do not add value to the product are considered "waste" and should be limited as much as possible through proper planning and continual improvement of operating processes. A hard look at the operating processes will reveal that many seemingly necessary activities do

not directly increase the customer's value of the product. With some ingenuity, even those once-necessary activities can sometimes be reduced or eliminated without compromising product quality.

Time and motion studies in manufacturing have been conducted since the late 1800s, and there are many books on the subject. The principles are simple but their application is more difficult. Published examples of time and motion studies in nursery crop production are rare. However, every nursery manager tackles the subject as he/she examines the operations in efforts to increase efficiency. It is easier to look at an existing system and determine the time it takes for individual activities, but is more difficult to predict time and motion requirements when designing a new nursery. Observing and examining other nurseries while planning a nursery can be very valuable. In the context of this publication, time and motion efficiencies will focus on the location of activities in relation to each other in order to reduce wasted motion.

Activities

A nursery operation encompasses many different production phases and activities. Proper timing of operations is essential, and efficient use of land and resources is important. Required activities vary with the type of nursery and specific production scheme employed. For example, a nursery may produce small plants or liners that only require greenhouse space. Other nurseries may purchase liners and not propagate plants themselves. Container-grown trees and shrubs typically require a smooth, well-formed bed and protective overwintering structure, whereas field-grown plants are planted directly in the ground and are exposed to the natural elements (Figure 1). Pot-in-Pot production systems share some of the characteristics of field and

container production but have unique elements as well.

The goal of any activity in the nursery is to add value to the product while minimizing cost. Before designing a nursery layout, it is essential to understand the details of each activity, how they relate to the system as a whole, and their impacts on production costs. The following list provides examples of activities that require some consideration when planning or improving the nursery layout and overall efficiency.

Business and marketing

- Attract and welcome targeted customers to the nursery.
- Present available products to customers in a comfortable environment.
- Maintain financial records.
- Receive customer orders.
- Schedule shipments.
- Maintain electronic marketing tools (website, e-newsletters, etc.).
- Organize mailings for marketing purposes.
- Order supplies.
- Maintain plant inventory.

Human resources

- Provide safe access to and within the nursery for employees and customers.
- Provide rest rooms, break rooms, and personal storage areas for employees.
- Provide employee support and maintain personnel records.

Plant-handling

- Prepare and plant cuttings or seeds.
- Transplant plants in containers or field.
- Prune, stake or train plants.
- Grow plants to desired size and quality.
- Harvest products and pull customer orders.
- Ship products.

Environmental manipulation and equipment management

- Prepare and maintain container beds.
- Receive and store ready-to-use media.
- Store media components and mix them for specific uses.
- Install and maintain irrigation and mist systems.
- Provide proper ventilation and temperature controlling growing structures.
- Prepare field for transplanting.

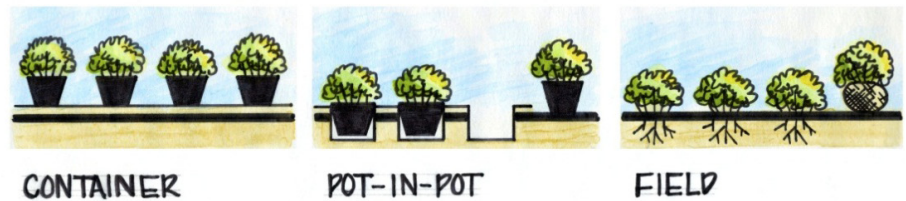


Figure 1. Three production systems: Plants are grown above-ground in containers on a container bed; plants are grown in containers placed in below-ground socket pots (pot-in-pot); or plants are grown directly in the field and harvested balled and burlapped or bare root.

- Mow turf areas.
- Store, maintain, and repair equipment.
- Store equipment and irrigation parts required for timely repairs.
- Use organic waste handling (discarded plants, pruned material).
- Use material recycling (collection, packing and shipping).

Chemical-handling

- Store pesticides and other chemicals.
- Mix pesticides.
- Apply pesticides.
- Clean spray equipment.
- Properly store and dispose of pesticide waste.
- Store and apply fertilizers.
- Maintain pesticide records.
- Use container recycling.

Functional Areas for Defined Activities

Certain activities are naturally grouped into distinct functional spaces such as an office, greenhouse, or shipping area. Grouping activities into functional areas is more intuitive for some activities than others, but efficiencies can be gained by reviewing the activities that will be conducted within each defined space. The first step in defining necessary functional spaces involves determining which of the listed activities use common equipment or resources. If these activities are done by the same person or group, then designing multi-functional space makes sense. Otherwise, consider the spaces needed for individual activities and determine how those activities relate to each other. Through studying the required activities during the design process, their functional relationships should become more obvious. Functional areas may include the entrance, nursery office, sales area, propagation

area, production area, media preparation and storage area, receiving area, shipping area, service area for equipment storage and maintenance, employee facilities, etc. Below are descriptions of some common functional areas.

Entrance

The organization and appearance of a nursery gives visitors and customers an impression of the operation, which directly influences sales, even for wholesale nurseries. The nursery entrance provides the first and most important opportunity to present a good image. The entrance(s) should provide easy access to the nursery office and shipping areas, with clear signage for each. Often the office, service and shipping areas are close to the main road for easy access and to reduce the installation cost of utilities. However, the lay of the land, adjacent property use patterns and the shape of the property may dictate locating the office and other service areas some distance from the main public road. Signage becomes even more critical in such situations. Drivers of incoming trucks should be able to find the loading areas without delay. Customer parking must be provided near the office, and the nursery entrance should be landscaped with an attractive, uncluttered arrangement of plants, including those sold by the nursery. The entrance planting could also contain any special plant materials that need to be introduced or emphasized for marketing purposes.

Office

Design of the office area should consider the activities that will be conducted in the building and the people involved. Workspaces should be arranged to streamline activities requiring continual interaction between employees or repeat-

ed use of certain equipment. Employees who interact regularly should have offices near one another. Similarly, an employee who must use the photocopier or fax machine regularly should have direct access to those items. Processes that involve the continual movement, photocopying, faxing, or filing of documents should be reflected in the arrangement of the people and equipment involved.

Some working spaces should be open, such as the desk of a receptionist who will greet customers or other visitors. Open working spaces can also be preferable when they require continual interaction between two or more individuals. Closed offices are useful for minimizing unwanted noise and other distractions, but they can impede workflow by creating unintentional barriers between coworkers. Closed offices are also more costly to construct and are less flexible when changes in the number and relationship of workspaces are desired.

When planning the size of the office building, consider the need for filing cabinets, desks, a photocopier, and other necessary large items. Company growth can lead to additional employees requiring offices, so this should be considered as well. Depending on the needs of the business, the office building may also include a waiting area for visitors or a conference room for meetings or employee training. Employee parking and customer/visitor parking should be located adjacent to the building if possible.

Sales Area

Locating a sales area close to the office with a display of representative salable plant materials enables customers to view plant material without traveling through the nursery. This saves time for customers and sales personnel and prevents exposure of customers to hazards.

Propagation Area

Unless all transplants are purchased from other sources, the propagation area is the heart of nursery operations and should be located in an area accessible to the production and potting areas. A propagation area located close to the office helps in communication between the office staff and the propagation managers who must make long-range decisions

regarding the number of specific plants to be produced. The size and design of the propagation area are determined by production type, number of plants and species produced, and markets.

The propagation area may contain greenhouse structures of various designs. Steel frame, gutter-connected, and ridge-and-furrow greenhouses are typically larger than greenhouses with conduit and PVC frames. Conduit and PVC greenhouses cost considerably less but have a shorter life than steel frame and ridge-and-furrow greenhouses. Smaller greenhouses may be used to segregate plant species that require different rooting environments. However, several small greenhouses require more land than one or two larger houses of equivalent square footage, and this should be considered if less than ample land is available for the propagation area and facilities.

Certain plant species, such as junipers, may be propagated outdoors in small containers or raised ground beds and do not require special propagation structures, except for possible overwintering requirements. Because of repeated mist cycles or frequent watering, outdoor propagation areas must be located on land not normally subjected to surface water drainage issues and with well-drained soil. Predominant wind direction and speed should be considered when locating outdoor mist systems so adequate wind breaks can be provided. Seeds may also be germinated in outdoor beds, although structures built to accommodate tiers or racks of seed-germinating flats use space more efficiently. Disadvantages of outdoor propagation include a lack of protection from heavy rainfall and animals such as deer and squirrels. Heavy rains may pack the rooting media, destroying aeration and contribute to soil-borne diseases.

The amount of land available for propagation may determine if plant stock blocks are maintained to supply cuttings. For some plants, it is recommended to have stock blocks from which to take cuttings. For other plants, taking cuttings from the production plants is acceptable and may coincide with pruning operations. Limited land availability may require taking cuttings from salable nursery plants. Cutting prepara-

tion areas may be included in the layout of the propagation area. A protective structure allows for cutting preparation during inclement weather and benefits the nursery producing large numbers of plant species propagated during the winter. A nursery producing primarily broadleaf evergreens, propagated during the summer, may choose to exclude a cutting preparation area from the layout and require that cuttings be prepared for sticking as they are harvested.

Media Preparation and Storage and Potting

Proper formulation and storage of growing media for specific production systems are critical for successful crop production. Media mixing and potting may be accomplished at one central location where potting media or media components are stored in bulk quantities. Potting media or components are stored either in loose piles or in open bins often constructed of concrete. Media components are usually mixed by commercially available soil mixers or by manure spreaders or front-end loaders that scoop and dump the media several times on a concrete slab. The scoop and dump process may not adequately mix media components. Some nurseries purchase one component of the mix that already contains more precisely incorporated amendments such as micro-nutrients. The selected approach to purchasing, mixing and storage of growing media largely determines the required size and arrangement of the media preparation and storage area.

Production systems requiring long-term storage of media or media components should plan for moisture management and minimization of wind-blown weed seed. Media must remain moist, either through the use of irrigation or exposure to natural precipitation. However, excess moisture can cause leaching of incorporated fertilizer. Walls and permeable coverings such as shade cloth help minimize wind-blown weed seed while allowing rain to reach the media. Special care in monitoring and managing storage of media with incorporated fertilizer is a must. A reinforced, raised concrete slab, 4 inches thick and 3 x 5 yards accommodates approximately 3 cubic yards of media. The raised con-

crete slab prevents incorporation of field soil into the media during mixing and eliminates contamination by pathogens and weed seed transported by surface water. Slabs should be sloped to allow adequate drainage.

Potting machines and motorized media mixing and transporting systems should be covered by a structure that houses a permanent potting area for the nursery. If commercial soil mixers and potting machines are not used, the potting area may or may not be sheltered. Nurseries that do not use a potting machine usually erect a permanent V-shaped hopper from which media falls onto a potting bench. Advantages and disadvantages of potting machines depend on the particular operation; however, most nursery operators agree that potting machines pace the workers for increased output.

In some cases, plants are only potted up once then moved to the growing area and later sold. In other scenarios, plants may be sequenced to increasingly larger containers before being sold. In situations that require additional transplanting, potting areas located in or near the growing areas are especially beneficial for reducing unnecessary movement of plant material during each transplanting process. This can be achieved by establishing two or more potting areas throughout the nursery or using a portable potting station. Even if plants are potted only once, nurseries may use multiple media preparation and potting areas to reduce the distance traveled when placing newly potted plants in the field.

Mobile transplanting systems still require motion to replenish media and containers at the transplanting site. In other words, either the potted plants or the media and containers must be transported. The most efficient approach depends on several factors, including the shape of the land, the possibility of remote potting and storage facilities, and ease of transporting potted plant material.

Production Areas

Production or plant-growing areas occupy the largest percentage of nursery land. The size and characteristics of these areas vary greatly between field and container production systems. Container-

grown plants can be produced above ground on beds or can be produced in socket pots buried below the soil surface (Pot-in-Pot) (Figure 1). The choice of production system should be driven primarily by the targeted market. Each system has its advantages and disadvantages and each has significantly different land and facility requirements. Some nurseries have two or more types of production systems but beginning nurseries usually focus on one system.

Roads and Waterways

Efficient movement of plants, equipment, and employees throughout the nursery requires a well-designed road system. Number and size of roads and walkways vary depending upon equipment used and type of production system. When farm tractors and wagons are used, the perimeter roads should be about 30 feet wide to allow turns from narrower roads between plant beds or rows. Roads should be crowned or sloped to one side and surfaced with gravel or other hard materials to support equipment during wet periods. Firm road surfaces also prevent splashing of mud and debris onto plants. Associating waterways with roads often results in optimal land use efficiency.

Drainage ditches, spillways, grassed waterway and water runoff containment areas must also be designed to handle heavy rainfall and any irrigation runoff. The amount of water and the rate of water movement expected from normal rainfall and irrigation determine the necessary specification of these features to minimize erosion and other impacts. Most container bed surfaces are minimally absorbent of surface water which increases the amount and speed of runoff. Fast moving surface water can result in significant erosion, to a point that limits access. Although not currently required by regulation in most states, surface water drainage systems in container production should contain all surface water on the nursery site in ponds, lakes and/or wetlands. At times this is not possible due to the rate and amount of rainfall, but at least normal rain events should be contained as well as any usual runoff from irrigation. Regulations in some states require that the first inch of rainfall be captured on nursery property.

The location of ditches, grassed waterways, and holding ponds must be established in relation to the topography of the site. With some hilly sites and depending upon the nature of the entire watershed, multiple containment facilities may be necessary. Contained water may be used for irrigation or released following treatment. Treatment could include such approaches as vegetated waterways, settlement ponds, constructed wetlands, etc. The design of surface water drainage and containment systems is critical and should be performed by a professional. More information on handling and treating runoff is available at the Clemson University website listed at the end of this publication.

Container Production

When plants are grown in containers, the production areas are most often adjacent to the potting area to facilitate the orderly movement of plants into the production area. This is not always possible due to topography, shape of the land and other physical limitations. Beds that are orderly arranged close to each other utilize the land space more efficiently and allow more efficient operations such as spraying, picking plants for shipment, etc.

Container beds should be shaped to eliminate standing water potential (Figure 2). Beds are most often crowned to allow water to move from the center to either side where the water can move through some type of waterway to a containment pond. However, the topography may favor a three or four percent slope from one side of the bed to another, directing all the water from that bed to a single waterway. This single waterway would have to carry twice the amount of water as those used for a crowned container bed. Use of a single waterway only on one side of the bed allows easier access to the bed from the other side. Some nursery beds are sloped downward from the edges toward the middle of the bed, directing runoff water down the center of the bed to a waterway. This design requires that a portion of the potential production space be allocated to water movement and is typically not the most efficient design option. In any case, beds must be designed with attention given to the potential of severe erosion of roads and waterways, especially on hilly sites.

The dimension of beds for container plant production can impact the efficiency of motion. The goal is to minimize the distance plants have to be carried. A few large nurseries use conveyer belts or other such equipment, but these are seldom employed in small to medium-sized nurseries. However, plant bed dimensions and the arrangement of containers on those beds can greatly impact the distance plants must be carried by employees. Narrow beds with roadways between each bed are the most efficient design in terms of movement of product. However, it is the least efficient in terms of land space utilization. The effective bed width can also be impacted by equipment. For

example, there is an optimum distance for air-blast sprayers and a feasible length of boom sprayers. Therefore, the optimal bed width is a compromise between effective land utilization, equipment specifications and efficiency of moving plants onto and from the bed.

The desired spacing of plants for optimum growth and quality varies with plant species and size of container. However, each square foot of bed has a cost, and the arrangement of plants in that space impacts spacing efficiency (Figure 3). Consider an example where the optimum spacing for a particular block of plants on a 26 x 100 feet bed is 2 feet on-center. If plants are arranged in a square fashion, a total of 325 plants fit on that bed. If plants are placed in a triangular pattern, two more rows of plants and a total of 375 plants will fit on that bed. There are many factors, such as plant size and shape and the need for equipment access, to consider in spacing and the pattern of placement, but growing fifteen percent more plants in a production space can impact the bottom line without impacting plant quality from inadequate spacing.

Production areas are commonly surfaced with gravel, porous polypropylene ground fabric, or black plastic. Gravel consisting of a particle mixture of 0.25 to 0.75 inches makes an excellent surface on which to place plants. However, 100 tons of gravel only covers about one-half acre, making it an expensive option for large areas. Smaller gravels wash away easily, and 1-gallon containers do not set level on larger gravel. If polypropylene or black plastic is used, it must be secured around the edges to prevent wind displacement and have a firm base under it. Equipment

driven on these materials may cause tears. Despite precautions, black plastic usually does not last more than two years in Kentucky. Landscape fabrics typically last longer and allow some infiltration of water, but having a well-drained, stable base for the fabric is critical to its longevity. Landscape fabrics provide better long-term weed control than gravel surfaces. Gravel covered with landscape fabric is an excellent, but expensive, bed surface.

The percentage shade required is highly plant species dependent but must be considered in planning the nursery. Quonset structures are most often used to support shade cloth of the required density and they can double as overwintering structures as well. Shade required for production of some plants can be provided by natural stands of trees. However, shade is most often provided by shade structures. Thinning of native woods to allow space for container production can often weaken trees, and the long-term impact of crop irrigation on the health of nearby trees should also be considered. Roads and drainage ditches for production areas where shade houses are constructed are usually similar to those of non-shaded areas. Ditches and roadway construction may not be possible in natural shade areas. Such areas cannot be graded because of possible damage to existing tree roots, so care must be taken to select areas with a one to two percent slope. Areas subject to flooding must be avoided. Accommodation of tall pieces of equipment and adequate turning space should be taken into account when shade structure dimensions are determined.

Irrigation systems are required for container production of nursery stock. Irrigation system design must consider

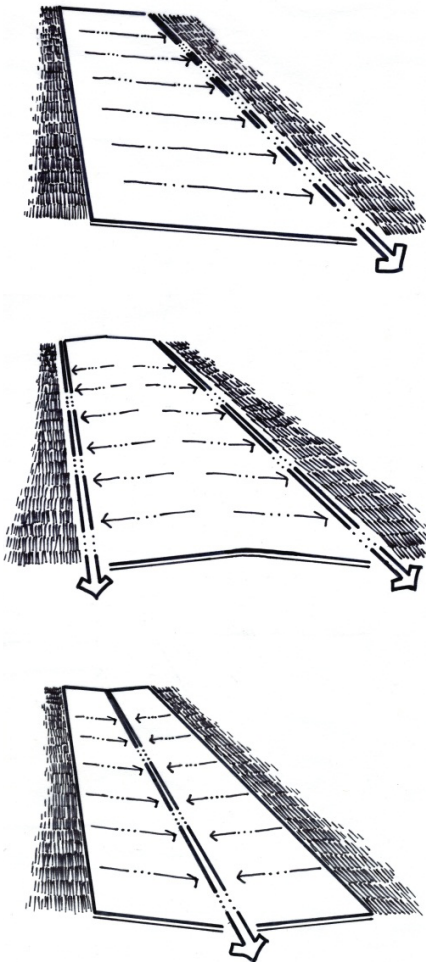


Figure 2. Container beds are sloped to eliminate standing water potential. Beds are sloped toward a single drainage pathway on one side (top); beds are crowned with drainage pathways on each side (middle); and beds are sloped toward a single drainage pathway in the center of the bed (bottom). Slopes are exaggerated for illustrative purposes.



Figure 3. Space is used more efficiently when containers are placed in a triangular pattern rather than a square pattern.

the layout and dimensions of the production beds as well as the potential surface water drainage and road system. The most efficient choice in irrigation systems is also influenced by container size and the length of the production cycle. Generally, smaller containers are irrigated by a stationary overhead system with nozzles raised on stand pipes. However, overhead irrigation is not very efficient because much of the water falls outside of the container. On the other hand, most low-volume systems, which use water more efficiently, require significant daily maintenance of emitters. Strong consideration for low-volume systems with emitters in individual containers should be given to containers as small as five-gallon, even smaller under certain situations. This decision is impacted partly by how long the plants will be in that location, if the block would be moved during the production cycle, the quality, quantity and cost of available water and labor availability.

Regardless of the type of irrigation system used, there must be buried pipe of the proper size to carry water throughout the container nursery. The system must be designed with efficient means of draining pipes between irrigation events in the winter to avoid the freezing and breaking of pipe and nozzles. Some supply lines may be buried below the freeze line and do not require draining for the winter. An irrigation system is among the most important elements of container production and is best designed by irrigation professionals with experience in nursery crops. The irrigation design of your nursery should be filed for future reference when irrigation system repairs are necessary.

Provisions for protection of overwintered crops must be considered when designing container production areas. Winter protection in Kentucky is best accomplished with poly-covered Quonset greenhouses or similar structures (Figure 4). The required size of overwintering houses is determined by the number and size, especially height, of plants to be housed. Overwintering houses in Kentucky are usually 18 to 28 feet wide, 64 to 96 feet in length and 7 to 10 feet tall in the center. These dimensions, as well as appropriately designed doors and side curtains that roll up, allow adequate ven-



Figure 4. Poly-covered Quonset-type greenhouses are used for winter protection of container-grown plants.

tilation during warm, sunny days in the winter and early spring normally characterized by fluctuating temperatures. The poly covering is usually only one layer thick and opaque in color to reduce heat buildup during bright winter days.

Overwintering houses can be closely spaced to conserve land area. This works well when plants are removed for sales directly from the tight plant-spacing typically used during overwintering. However, if plants are to be grown for an additional season, they must be repositioned for optimum spacing before the growing season. Some nurseries plan additional surface area between houses to which the plants from each house can be moved to an appropriate production spacing after the greenhouse covering is removed in the spring (Figure 5). Generally speaking, plants transitioned from overwintering to production spacing require almost twice the space. Therefore, planning for production space between houses equal to the width of the house is customary.

Pot-in-Pot (PNP) production systems have many of the same requirements as above-ground container systems, except winter protection is not necessary for production of hardy plants (Figure 1). The root-systems of PNP plants are maintained at temperatures similar to the surrounding soil. PNP production requires a semi-permanent modification of the land by installation of a drainage

tile system and socket containers. The characteristics of PNP systems are explained in detail in materials on the UK Horticulture website listed at the end of this publication.

Field Production

Optimal layout and operational design for field production is significantly different than for container production. Field production generally requires significantly more land per finished plant than container production. The exception to that general rule would be field nurseries that produce transplants. The land is much more limiting for field production. Planning for field production of trees and shrubs requires attention to soil characteristics. The soil must be well-drained and the land must not be subject to flooding. If plants are harvested as balled and burlapped (B&B), the soil texture must be suitable for balling and free of large rocks. The depth of topsoil is also important and some common soil classifications in Kentucky are not suitable to support field production. Generally speaking, soils in Kentucky that are free of large rocks also have suitable soil texture.

Row spacing and plant spacing within rows differ with plant species and the planned size of plants at harvest. For example, trees expected to be harvested as 2-inch caliper may be spaced 6 to 8 feet on-center in rows spaced 8 to 12 feet apart. Row spacing should allow access to

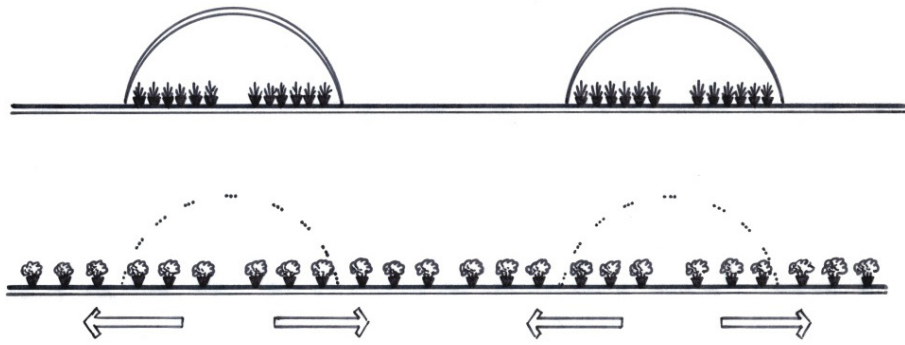


Figure 5. Above-ground container-grown plants are tightly spaced for overwintering (top). Plants generally require twice as much space during the growing season and can be moved into the spaces between houses after the greenhouse covering is removed in the spring (bottom). Production spaces between houses should equal the width of a house if used in this manner.

field equipment used for mowing, spraying pesticides and harvesting. Generally, longer rows, up to 600 to 800 feet, are more efficient for equipment use than a larger number of shorter rows. Rows oriented north-south have the best sunlight interception during the growing season.

Turfgrass is usually established around the production area and between rows to increase access during wet periods and for weed control. The in-row band is best maintained weed-free. Field roadways, composed of established turf, are often located every few planting rows (Figure 6). Traffic during wet conditions requires more substantial roadways throughout the nursery.

Irrigation in field production is considered optional by some. However, the ability to irrigate during first-year establishment and periods of drought is highly recommended. This is sometime termed “rescue” irrigation that is intended to keep plants alive and healthy but not necessarily to maintain high growth rates. Irrigation systems using moveable pipe can accomplish this as well as traveling irrigation guns. Many nurseries are beginning to use low-volume irrigation in field production as a cost-effective means of reducing loss and increasing growth.

Irrigation is usually required for transplant production. In some high-value crops grown in relatively high densities in the field, low-volume or drip irrigation is most economical. The water-holding capacity and drainage capacity of the soil strongly impact irrigation requirements, and soil type often varies from field to field.

Service Area

Equipment storage and repair facilities, along with pesticide, petroleum, and fertilizer storage facilities, comprise the nursery service area. The service area is often located close to the nursery office due to the cost efficiency of locating electrical and sewer services close together. This may create other issues such as having work areas adjacent to more public areas, etc. The service area also needs to be accessible to supply trucks servicing these facilities. The type of equipment and supplies needing shelter or storage determines the size and type of facilities. Enclosed metal buildings are excellent for repair and maintenance shops and may be used for storage of small pieces of equipment such as hand sprayers, chain saws and lawn mowers. Equipment repairs by commercial mechanical businesses

may be practical if timely and affordable service can be assured. Nurseries that use this approach reduce their requirements for equipment repair facilities. Storage facilities for large pieces of equipment, e.g., tractors, forklifts and sprayers, are often “pole barn” structures with an open side opposite the prevailing wind direction or modified tobacco barns.

Pesticide storage facilities should be separated from other activities and have secured access. Mixing is usually done adjacent to the pesticide storage area to minimize transporting concentrated pesticides. A water source which can deliver 20 to 50 gallons per minute to permit rapid filling of pesticide tanks is preferred. This capacity may not be available directly from a pressurized water source but can be achieved by a raised storage tank from which water flows through a 2- to 3-inch hose into the spray tank. A pesticide storage building must be properly designed and identified as containing poisons. Local, state, and federal requirements for pesticide storage and mixing facilities should be determined before proceeding as those regulations can change frequently.



Figure 6. Field plantings should allow sufficient space for equipment access. A combination of field roads (narrower, turf-covered) and perimeter roads (wider, often gravel-covered) should be incorporated in the field design.

Employee Facilities

Employee facilities are usually located adjacent to the office or service areas but should not be close to the pesticide storage and mixing area. Depending upon the season and amount and timing of customer traffic, employees with dirty boots, etc. in the office area could interfere with marketing activities. Restrooms, showers, personal lockers, refrigerators and dining tables are usually provided for employees. Employee parking between the service area and the employee facilities is a convenient arrangement. In large nurseries or for nurseries with non-contiguous production areas, employee facilities may best be provided in multiple locations. This would reduce travel time for employee breaks and increase employee comfort. Secured material and tool storage may also be part of more remote employee support facilities.

Shipping Area

The need for shipping areas, as well as their size and location, varies greatly from nursery to nursery and depends upon such things as the size and type of the operation, proximity to production areas, diversity of plant materials, size of trucks, type of customers, etc. The cost of a plant increases each time it is moved. However, it may be more cost effective to gather plants in a central location for shipment. Some nurseries load plants directly from production areas, but most operations have designated loading areas within the nursery where plants are placed prior to shipment. Relatively large nurseries shipping primarily in tractor-trailers generally require a shipping area. Production areas are usually not accessible by such trucks, and loads are often comprised of a wide array of plant materials for multiple customers. In such cases, plants can be collected and grouped according to shipments at a shipping area. Placing plants in this area before customer or freight truck arrival reduces loading time, but irrigation, and maybe even shade, must be provided. One or more loading docks may increase loading efficiency for smaller plants, and a covered loading dock may be desirable for loading trucks when inclement weather is anticipated.

Nurseries selling primarily to local landscapers who pick up plants with smaller trucks and trailers often have designated pick-up locations in production or holding areas. Possible conflicts between customer vehicles and production activities should be considered when establishing pickup locations.

In most cases, medium to large nurseries need a loading dock for receiving materials if for no other reason. Most loading docks are 4 feet high and constructed of concrete. Docks should be large enough to accommodate tractors, conveyors, plant racks and other equipment used in the loading/unloading process. Loading docks should be accessible from the public highway and adjacent to the office due to interactions between shipping and sales personnel. Shipping areas within the nursery require access roads 20 to 25 feet wide with firm surface material and turning space to accommodate trucks at least 30 feet long.

Space Required for Functional Areas

Once the functional areas have been defined, it is important to determine the space needed for each activity initially and as the nursery expands. Planning should be done using a scaled drawing to ensure that required areas or facilities are well planned and integrated so that nursery activities or operations progress efficiently. All important features of the site should be included on the drawing. Examples include existing buildings, highways, utility lines, wet areas, rock out-cropping, sink holes, soil types, water sources, potential frost pockets and areas with weed problems (Figure 7). GPS (global positioning systems) software and devices and even smart phones with appropriate apps can be used to determine the size, shape and location of site features. More sophisticated GPS units can also denote changes in elevation on the site. Kentucky's soil maps are extensive and should be used as a rough overlay on this scaled drawing. Appropriate judgment of distance and arrangement of areas can be achieved when every element is seen on the same scale. Scales of 1 inch equals 50 to 200 feet are common, but the dimension of the property and the available drawing supplies and

equipment may dictate other scales. The availability of simple and inexpensive computer-aided-drafting software has made this process easier. Such software usually requires a large printer to generate a drawing of a size that one can see the details, but local businesses usually offer these printing services.

The goal in defining space in the nursery is to maximize the amount of space dedicated to plant production while still providing adequate space for all other activities, which only exist to support production. The ratio between production area and other supportive areas varies greatly with the type and size of plant product to be sold, the production system used and the general size of the nursery. There is a critical size of support facilities even for a small nursery, and the size of the required space does not increase proportionally to increases in production space. One element that is easily overlooked in the planning process is the space required for a road system and other non-production space. Depending upon the characteristics of the site and the type of nursery, roads, borders, water ways, wetlands, etc. might occupy up to a third of land space in the nursery.

Locating Functional Areas

Drawing rough shapes of the functional areas, even in a bubble-diagram, is an effective way to start planning their optimal locations (Figure 8). Pieces of paper cut to represent the space requirements of each functional area can also be rearranged on the original scaled drawing of the nursery to determine the optimal nursery design. Discovering potential mistakes or lost efficiencies on paper is much less expensive than discovering them after building the nursery facilities. Discussed below are considerations that should be made regarding the relationships between functional areas.

Although time and motion considerations are important for individual processes, such as transplanting, pruning and harvesting, time and motion requirements for moving people and materials *between* functional areas are major considerations when designing a nursery. Understanding common movements between functional areas is necessary before arranging the areas in the overall

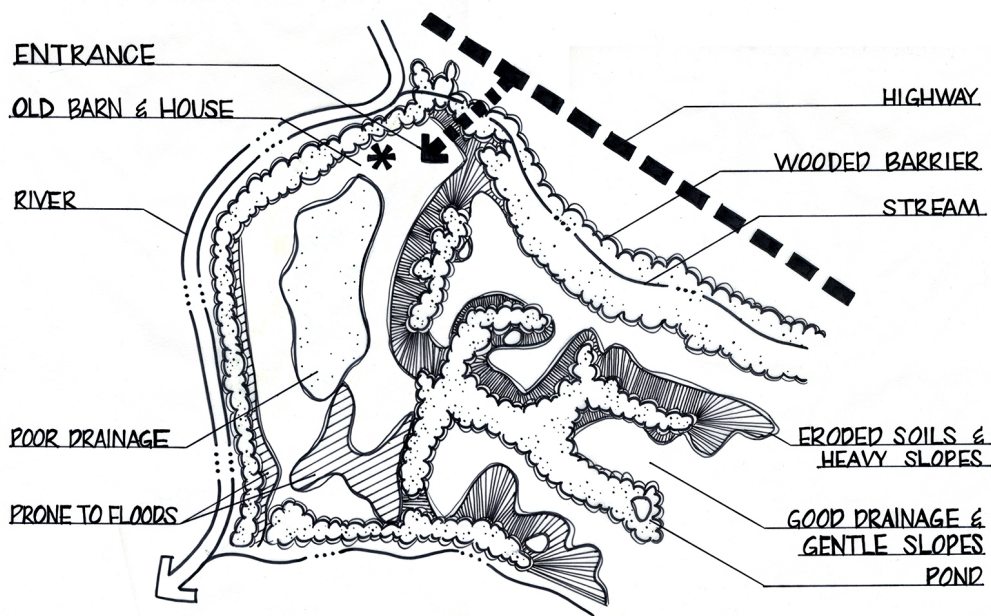


Figure 7. Before designing a nursery layout, the condition of the land should be identified in a scaled drawing. Examples of features to include are existing buildings, highways, utility lines, wet areas, rock out-cropping, sink holes, soil types, water sources, potential frost pockets, and areas with weed problems.

nursery design. For example, media, containers and transplants must be moved to potting areas and to production areas. People routinely move from the employee support area to service, office, production and shipping areas. Equipment moves between the storage and service areas to the production areas.

Activities that transverse functional areas must be identified in the design process so areas that support these activities can be efficiently located. For example, the entrance is best situated on the property bordering a county or state road. The sales office and product displays are usually located adjacent to the entrance area to make visits by customers most efficient. However, a longer driveway to a more centrally located office and service area may be justified on long, narrow properties to decrease the average distances for employees and materials movement.

Service and employee areas may best be centrally located among production areas, but the location of these areas may be limited by the shape and size of the property, availability and cost of electricity, water, sewer/septic system, etc. Plants and/or media and containers are transported from the potting and

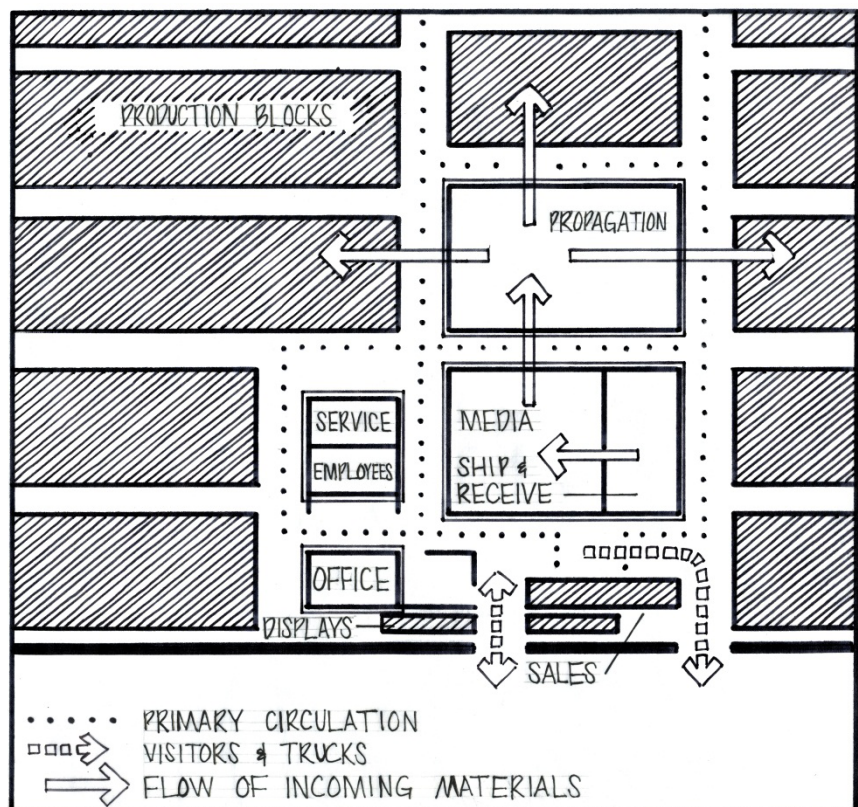


Figure 8. Drawing rough shapes of the functional areas is an effective way to start planning their optimal locations. Efficient movement of people and materials as well as the location of existing features such as buildings, water sources, and optimal soil must be considered during the initial planning stages.

storage areas to the production area once. Finished plants are transported from the production area to the shipping area once. However, employees move between the employee and service areas to the production areas multiple times per day. Employees need access to restrooms, water, shade/warmth, etc. during breaks. Locating the employee area adjacent to the service area might require fewer restrooms and break rooms. Locating equipment storage near areas where equipment can be routinely maintained or repaired may be efficient, but that might impact the travel distance to and from production areas.

Functional areas must be arranged within the constraints of land form, slope and natural barriers such as streams, rock outcroppings and areas that temporarily hold water during wet periods. These natural features can alter the shape of usable production spaces as well as hinder the movement of materials and people throughout the nursery. Existing private and public roads, utility easements and access to water must also be considered. Production areas should be located in relation to the water source to reduce pumping distance as well as to minimize “uphill” pumping. Ideally, the water source would be at a higher elevation than the production area but this is seldom possible. However, pumping water uphill requires more costly equipment to purchase and operate and properly sizing pumps and pipes is critical.

Nursery layouts for container, field or Pot-in-Pot production systems are adaptable to most land shapes, but very narrow tracts can result in unavoidable inefficiencies. These nurseries require more time to transport employees to work sites, and plants must be transported greater distances, either to and from potting areas or to shipping areas. In nurseries comprised of non-adjointing properties inefficiencies in routine movement of materials and people can be addressed by detailed planning of routes and with

up-front capital investments in split facilities (service, employee, shipping/receiving and storage areas). The short and long-term economic trade-offs of such decisions must be considered in relation to available capital.

The lay of the land should be considered when locating container production areas to ensure the capture of runoff water before it leaves the property. Adequate space must be established for containment ponds, constructed wetlands, vegetative buffers, etc. The required containment pond capacity must be estimated based on the topography, which largely dictates the potential volume of runoff water from the identified drainage/watershed areas. The containment capacity should also include water movement from adjacent property that would have to be contained, treated, etc. If the property is not located at or near the top of a larger watershed, off-site surface water drainage onto the nursery should be anticipated. Water containment capacity can include relatively deep reservoirs, when the topography allows, that would require a smaller footprint than shallow ones. The complexity of these factors dictates consulting a professional.

In the process of locating the functional areas on the property, start with functional areas with the most restrictions. In as much as possible, reserve the best land for production purposes. However, sometimes cost of running utilities, easements, zoning restrictions, etc. require the location of particular functional areas in specific locations. Understanding those factors before locating any functional area is highly advised.

Following the location of functional areas in the draft layout, the road system that connects them must be designed. Failure to allocate enough space for road construction with associated waterways is not uncommon. Roads requiring different carrying capacity require different space. Understanding these requirements at this stage will save time and money later.

Summary

Designing a new nursery focused on operational efficiency or modifying or expanding an existing nursery require advanced planning that considers the principles presented here. Efficient labor use achieved by minimizing movement of plants, materials and people can impact the economic sustainability of a nursery operation. This publication presents principles and examples to help nursery owners evaluate individual activities and functional areas and the ways they fit in the production system as a whole. Additionally, visiting nurseries with similar production systems is highly recommended. Discussions with other nursery managers about how they would change their production systems provide valuable insight.

Resources

- Best Management Practices: Guide for Producing Nursery Crops. Southern Nursery Association. <http://www.sna.org>.
- Pot-in-Pot Production: UK Horticulture Web site. <http://www.uky.edu/Ag/Horticulture/potinpote.pdf> and <http://video.ca.uky.edu/videos/video/426/>.
- U.S. Department of Agriculture. Natural Resource Conservation Service. Soil Survey of Kentucky. http://soils.usda.gov/survey/printed_surveys/state.asp?state=Kentucky&abbr=KY.
- White, Sarah. Runoff Management in the Nursery. Clemson University. http://www.clemson.edu/extension/horticulture/nursery/runoff_management.html.

All illustrations by S.J. Vanek