EVALUATION OF DAIRY MANURE COMPOST AS A PEAT SUBSTITUTE IN POTTING MEDIA FOR CONTAINER GROWN PLANTS

By

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To my Mother and Father

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This study was conducted to determine if excess manure from dairy farms could be used in potting media for plant nurseries. The number of dairy farms in Florida has decreased, but the number of animals per dairy farm has increased. This usually leads to a larger amount of manure in a smaller land area. Composting organic wastes is an effective way to process manure. It transforms raw manure into a stable material that can be suitable for use as a growth media in the nursery industry. The compost, either as a stand-alone medium or as a component in potting mixes, was evaluated in a series of experiments during the study.

The first objective was to determine the physical, chemical and biological properties of screened dairy manure solids that had been composted. Biological properties showed no phytotoxicity or damage in germination tests compared with the control. Total porosity, container capacity, air space, moisture content and bulk density showed good values when compared with ideal ranges. Chemical properties tests showed

that compost did not contain excess soluble salts levels nor excess nutrient levels, which are both a primary concern for growers when dealing with compost.

The second objective was to evaluate how much peat could be substituted for compost in a potting mix without causing any significant differences in plant growth. Results showed that the mixes, which produced higher plant dry weights, were mixes from the 0% compost to the 40% compost substitutions. The 60% compost mix produced the same plant dry weight as the mix used as a control (60% peat). There were no significant differences in the mixes for total porosity and air space. Bulk density increased with the amount of compost in the mix. Container capacity and moisture content decreased with increasing compost in the mix. Analysis of chemical properties showed that compost provided micronutrients in the sufficiency range. Diagnostic leaf tissue analysis did not revealed any deficiencies or toxicities to plants with the addition of compost.

The third objective was to compare common nursery mixes that contained peat with mixes that had compost instead of peat. Physical properties tests revealed that all mixes were within the recommended range values, but compost provided more air space and bulk density but less container capacity and moisture content. Total porosity remained the same. Chemical properties tests showed that compost provided sufficient chemical elements compared with the peat mixes. The pH in peat-based mixes was too low for plant growth. Plant growth parameters showed dry weights were higher in compost mixes, and plant size was similar to those in peat mixes.

CHAPTER 1
INTRODUCTION

Background and Justification

Florida dairy farms have decreased in number but have increased in size. According to the Florida Agricultural Statistics Service (FASS, 2001b), as of January 2001, cow numbers in the state of Florida were at 155,000 milk cows plus 40,000 replacement cows on 225 dairy farms. This represents an average fresh manure production of 11,700 tons per day and 4.3 million tons per year (ASAE, 1995). The average herd size in the state is one of the nation's largest, about 688 milk cows per dairy farm (UF/IFAS, 2001). This can create an environmental problem, since there are a larger number of animals maintained on a smaller acreage of land. The concentration of waste and nutrients tends to be much higher compared with having more dairy farms with a smaller number of animals per farm. Nutrient losses from these large herds can be an environmental threat to groundwater and surface runoff. High water table and sandy soils in Florida are very susceptible to environmental problems. Therefore, to comply with nutrient budget requirements being set by environmental agencies, dairy farms are trying to create unique and sophisticated waste treatment systems. Such a nutrient removal and drum composting system was installed at a commercial dairy farm near Zephyrhills, Florida. The system's main purpose was to remove nutrients from a land-limited dairy farm located in an area of increasing urbanization within the Hillsborough River watershed. The system removed coarse manure solids by mechanical screening and then digested them in a horizontal drum composter. The end product from the drum composter was a compost material suitable for use as a potting media material in the plant nursery industry. The term “dairy manure compost” in this thesis refers to compost produced in conditions similar to those in the nutrient removal and drum composting system installed at Gore’s Dairy, Zephyrhills, Florida. Similar systems with similar conditions can produce similar dairy manure compost, but they may have to be evaluated as well. Differences between compost products depend heavily on parent material.

Composting is a very effective way to turn fresh manure solids into a product that has a high potential for use as a growth medium in the nursery industry. The main purpose is to replace peat, which is the predominant organic matter component in growing media and possesses properties similar to those of dairy manure compost. There is a potential market for this product in Florida’s wholesale nursery industry. The nursery industry in Florida according to FASS (2001a) leads the nation in gross wholesale sales of potted foliage for indoor use and foliage hanging baskets with sales of $393.9 million during the year 2000. Potted foliage sales accounted for $366.9 million of the same year’s total, while the sales of foliage hanging baskets totaled almost $26.9 million. Every time a foliage plant is sold, the medium is sold with it. This means that for every new plant grown, you need to replace the medium.

If dairy manure compost can be proven effective for use in container grown media, then dairy farmers can sell this product. This will provide them with an incentive to deal with their environmental nutrient removal problems. Before this can happen, it must be demonstrated that the drum composter can produce compost suitable for use in nursery container mixes or as a stand-alone medium. The compost should meet the physical, chemical and biological properties standards that the nursery industry demands. According to Goh (1979), two major factors determine the successful production of container grown plants in commercial nurseries: the choice of the medium, particularly its physical properties, and the supply of plant nutrients. Although ornamental crops have different requirements for their growing conditions, most growers want a growing substrate that is consistent, reproducible, readily available, easy to work with, cost effective, and with appropriate physical and chemical properties (Poole et al., 1981). There would be two major benefits from replacing peat with composted cow manure: environmental benefits from reduction of peat mining, and export of nutrients from dairy farms to reduce problems of excess nutrients in ground and surface waters.

Problem

The main problem to deal with is the strict nutrient budget requirements that dairy farms have to face. The high nutrient concentrations from diary farms, especially when a large number of animals are involved, can cause an environmental impact upon the area around it. The dairy industry cannot stop production, but pollution also has to be controlled to maintain a safe environment. If dairy farms are not required to control their manure then they will cause odors and contamination of groundwater and natural waterways through seepage and surface runoff, respectively. High nitrate levels in groundwater that is used for drinking water can cause blue baby disease or methemaglobinemia. Also, high levels of P lead to eutrophication, which is the high proliferation of algae that consumes dissolved oxygen from the water, killing flora and fauna of rivers and lakes. So removing solids from the effluent and composting them will help reduce all these environmental problems. Removing solids from the effluent will reduce the anaerobic activity in the storage lagoon and reduce odors. Odors associated with aerobic composting from the manure are minimal, not only because it is an aerobic process but also because it takes place inside the drum composter. Also, by separating solids from the liquid manure, agitation of the manure is not usually necessary for emptying of the storage pond or structure. This minimizes the odor at the farmstead at the time of field application. Composting the solids can be very effective in a nutrient removal and composting system like the one installed near Zephyrhills, Florida.

It must be proven that the composted solids have a high potential for use in potting media for the nursery industry. Composted materials have been used successfully to grow a wide spectrum of nursery crops, from flowering annuals (Wootton et al., 1981) to container grown tropical trees (Fitzpatrick, 1985). Compost maturity has to be evaluated to rule out any potential damage that plants may suffer due to any toxic compounds. According to FDACS (1994), compost maturity can be regarded as the degree to which the material is free of phytotoxic substances that can cause delayed or reduced seed germination, plant injury or death. The material has to have ideal growing properties for it to be used as a growing media and not just rely on the fact that it is not phytotoxic. Nelson (1991) stated that media components in plant production are not as important as the medium properties like total porosity, water holding capacity, cation exchange capacity, pH and soluble salt concentrations. Also, Klock (1999a) states that, before recommending the use of any compost amended substrate for the growth of bedding plants, identifying substrate physical and chemical properties associated with superior bedding plant growth is important. Therefore, actual plant experiment trials should also be performed to ensure the effectiveness of composts in ornamental crop production.

Objectives

The goal of this study was to verify that dairy manure compost could be used as a growth medium in container grown plants. There were three objectives to follow during the study:

1. Evaluate dairy manure compost properties to assess its suitability for the growth of plants in container media.
2. Determine the percentage of compost that can be substituted for peat in a typical nursery container mix.
3. Evaluate its effectiveness as a component and by itself as a growing substrate for nursery plants.

CHAPTER 2
LITERATURE REVIEW

Compost

There are many definitions of compost. For the purpose of this research thesis the U.S. Composting Council (2000) gives a very appropriate definition of compost, which is "Compost is the product resulting from the controlled biological decomposition of organic matter that has been sanitized through the generation of heat and stabilized to the point that it is beneficial to plant growth. It bears little physical resemblance to the raw material from which it has originated. It is an organic matter resource that has the unique ability to improve the chemical, physical, and biological characteristics of soils or growing media, and it contains plant nutrients but is typically not characterized as a fertilizer".

The Composting Process

The composting process is a waste management method used primarily to stabilize organic wastes. The stabilized end product can be used as a rich amendment for soil applications, such as in agricultural fields, landscape industry or nursery industry in potting mixes (EPA, 1998). Compost can improve the physical, chemical and biological properties of a soil or of a growing medium. Physical properties of soil improve mainly due to the high organic matter content of composts. It enhances soil structure, thereby increasing porosity, water holding capacity, and infiltration. Composts improve chemical properties by providing cation exchange capacity, and they are also a source of micronutrients. They improve biological properties by creating a diverse microbiological environment that can suppress plant diseases and nematodes. To achieve all of these benefits there are several factors that have to be taken into account. Factors, which affect the composting process, include aeration, parent material, temperature, particle size, pH and moisture (Rynk et. al 1992). All of these factors play a role in the natural decomposition and degradation of the raw organic materials. If these factors are optimal, the composting process is greatly accelerated. In this study, the solids used for composting were solids separated from the effluent of a dairy manure nutrient removal system installed at a commercial dairy. The solids were placed in a horizontal drum composter for the composting process to take place (Nordstedt & Sowerby, 2000).

A good composting process should have three basic phases. The first is an increase in temperature phase in which mesophilic microorganisms carry out the initial decomposition, breaking down the soluble and readily degradable compounds. During the second phase, mesophilic microorganisms tend to fade away due to higher decomposition temperatures (55 ºC or higher), so thermophilic microorganisms take over the decomposition process. This high temperature stage accelerates the breakdown of proteins, fats, and complex carbohydrates like cellulose and hemicellulose from plant cells. Most of the plant pathogens, weed seeds and nematodes are destroyed during the high temperature stage. After most of the degradation has taken place the temperature starts decreasing. Mesophilic microorganisms reemerge in the process and take over the last stage, which is the maturing or curing stage of compost. With all these microorganisms proliferating in different stages of the composting process, the resulting end stable product called “compost” is a material high in microorganism diversity.

The solids that come out as a stable product “compost” should have several characteristics for it to be a material worthy of use as a growing media. It should have a dark brown to black color, earthy odor, and pH close to neutral (pH 6-8), should not be phytotoxic (mature), and should have a soluble salts concentration of less than 2.5 mmhos/cm.

Marketing Compost

Compost quality and uniformity are the two most important characteristics that should be taken into consideration when producing compost. The compost quality should be evaluated for the consumer or target market. Compost quality includes a number of parameters like organic matter content, water holding capacity, bulk density, particle size, nutrient content, level of contaminants, C: N ratio, phytotoxicity, weed seeds, soluble salts, pH, color and odor (EPA, 1993). Although there isn’t a universally accepted standard procedure on testing composts, there are many tests that can be performed to determine the efficacy of compost. One way to have a good impact on the compost market is to inform the consumer of the exact use that the compost is intended to provide, either as a potting mix, field application or mulch. Growers will then be able to look for compost products that will meet physical, chemical and biological parameters for the crop that they are growing, either on a field or in a greenhouse. For the consumer to acknowledge the use of compost and purchase it, it is important that the benefits are equal or better than a product already on the market. In other words, for compost to be cost effective for the consumer, it should be equally effective to the control media, and it should also be readily available and competitively priced (Klock & Fitzpatrick, 1999). Given enough information on the product and its benefits, customers can know what they are dealing with and use it appropriately. In the nursery industry growers are always trying to find different alternatives for their potting mixes. This is where compost can be an alternative either as a component or as a stand-alone substitute in potting mixes.

Compost vs. Peat

Both compost and peat will have the same function in a container-grown media, and that will be to provide organic matter to that media. Compost can be used as a less expensive substitute for peat and other organic components in potting mixes. Peat has a lot of benefits that composts can also provide to a plant, like absorbing and retaining water, and be free of weed seeds, diseases and pests. For a compost to be free of weed seeds, diseases, and pests and also be a stable material comparable to peat, the composting process has to be carried out properly to provide good quality compost.

There are several types of peat sold in the U.S. market: 1) sphagnum peat moss 2) hypnaceous peat moss, 3) reed and sedge peat, and 4) humus peat or muck. Sphagnum peat moss is the most suitable for use in the nursery industry, because it improves drainage, aeration, water holding capacity, and cation exchange capacity. It has two disadvantages: 1) it has a low pH and usually requires lime when used in potting media, and 2) it is difficult to wet so warm water or a wetting agent must be used to get it wet and ready for crop production. Hypnaceous peat moss decomposes more quickly but can still be used in potting media. The decomposition can reduce air space. Reed and sedge peat and humus or muck peat are not recommended for container media because they decompose too quickly, interfering with the physical properties of the media. The largest source of sphagnum peat moss used in the U.S. comes from Canada. Canadian sphagnum peat moss is derived from the slow decomposition of sphagnum moss, which accumulates in Canada's bogs or peat lands. To harvest peat, harvesters clear bogs of vegetation and then dig shallow ditches to lower the water table, when the peat dries, the equipment necessary to harvest the peat can operate on the field. Once a bog is ditched, harvesting begins with harrows coming into the field to loosen the top peat moss, which then dries in the sun for two to three hours before being vacuumed into large harvesters. It is then transported from the field to the plant where it is screened, graded and baled for storage or shipment (Canadian Sphagnum Peat Moss Association, 2001). This process obviously takes a lot of heavy machinery and labor, which in turn means higher prices for the material. Also, when harvesting all of these bogs, this land cannot be used for water collection and filtration, and natural habitats for flora and fauna diversity are being eliminated or restricted. Another problem is that peat bogs are a large source of oxygen production for the atmosphere. Peat harvesting in most European countries has been banned due to the impact it has on the ecosystems. Peat bogs take centuries to regenerate once they have been harvested. On the other hand, compost production has increased tremendously in recent years, and it is now being viewed as an excellent alternative for dealing with raw wastes. In the United States, more farms are composting than municipalities, commercial/institutional establishments and other private sector groups combined (Kashmanian & Rynk, 1995).

Compost as a potting media component has some advantages over peat. Compost has a higher pH (neutral), while peat moss is very acidic. Potting mixes using peat will usually have to be limed to raise the pH to the proper level for most plants. Peat moss is very low in plant nutrients, while compost provides the plant with micronutrients and microorganism diversity in the growing media. Compost can also provide natural protection against diseases of the seedlings and roots of plants due to beneficial organisms that live in well-made compost (Greer, 1998). Compost is less expensive than peat. If a large potting media company has access to a source of good quality compost, they can reduce their costs with the correct use of compost in their mixes. Additionally, peat has been traditionally used as the organic component in horticultural substrates. The demand for and use of peat is much greater than its natural production rate. Therefore, peat is not going to be a quickly renewable source in the short term because it is accumulated over long periods of time (Klock & Fitzpatrick, 1999). From an environmental standpoint the use of compost in potting mixes instead of peat is not only reducing peat harvesting, which in some places are natural habitats for animals and plants, but also contributing to the elimination of some organic wastes such as dairy manure.

Compost Maturity and Stability

Compost maturity and stability are two very important parameters that can be measured to assure the quality of compost, thereby preventing not only plant damage but also storage and marketing problems. Maturity and stability are two terms that are sometimes used interchangeably when referring to composts. Stability refers to the stage of decomposition of the organic matter in the compost, and maturity means the level of completeness of composting (California Compost Quality Council, 2001). Plant growth problems can be caused by incorrect usage or by immaturity of composts. Many factors in immature composts can affect plant growth. That is why plant studies can help determine if the composts are suitable for plant growth. Immature composts may have high C:N ratios, high soluble salt concentrations, high concentrations of organic acids and other phytotoxic compounds, high microbial activity, and/or high respiration rates (Jimenez & Garcia, 1989).

Compost can be used in several ways: 1) as a container-growing medium, 2) as a component of a growth media, 3) as mulch or top dress, or 4) as a field soil amendment. The use of compost in a container-growing medium is one that requires the best quality compost. Maturity and stability should be determined to avoid plant growth problems or mortality. A key trait of immature compost is that it consumes oxygen, so it will be more likely to have a negative effect on the oxygen supply to the roots (Brinton, 2000). Maturity should be assessed by measurement of two or more biological or chemical properties of the composted product. Germination index is a good indication of phytotoxins in the compost. Zucconi et al. (1981a) demonstrated reduced cress (*Lepidium sativum* L.) seed germination index in the presence of phytotoxins produced during early stages of the composting process. According to Zucconi et al. (1981b) phytotoxicity during the composting process appeared to be strictly associated with the initial stage of decomposition. It was a transient condition that was possibly connected to the presence of readily metabolizable material. Production of phytotoxins ceases and phytotoxins themselves are inactivated in the succeeding decomposition stages. Phytotoxins can sometimes be identified as volatile organic acids like benzoic acid, phenylacetic acid, 3-phenyl propionic acid and 4-phenyl-butyric acid (Toussoun and Patrick, 1963). In properly controlled composting systems, the stage characterized by a strong toxicity is completed well before the end of the thermophilic phase. The horizontal drum composter, which produced the compost for this study, was a controlled-composting environment during the entire composting process. Poorly aerated compost can have a long lasting toxicity due to the unstabilized end product. The drum composter provided a continuously turning environment, giving the material a high temperature and continuous aeration. This provided a great advantage over other composting methods. The temperature inside the drum composter measured an average of 55ºC. According to Shiralipour & McConnell (1991), a period of time longer than 48 h at 55ºC and longer than 24 h at 65 ºC was required to inhibit the germination of beggarweed seeds without the presence of compost extract. In the presence of the compost extract, beggarweed germination was inhibited within 48 h at 55ºC and 18 h at 65ºC. Beggarweed is a heat-resistant seed. At all temperatures tested, the addition of compost extract significantly reduced seed germination. During the composting period both high temperatures and phytotoxins will produce an inhibitory effect on weed tree seeds. Rigid control of compost maturity will lead to a wider use of compost in the nursery industry. Commercial compost companies must monitor and manage their product to consistently produce a product that can be successfully used by container growers (Klock & Fitzpatrick, 1999).

Growth Media for Container Grown Plants

A very important part of nursery crop production is understanding the ideal characteristics that a growth medium should have to have successful crop production. Ideal characteristics of a growth medium are that it be free of weed seeds and diseases, be stable during a long period of time, be heavy enough to support itself but at the same time not weigh too much to facilitate handling, be available at a low cost, and have good physical, chemical and biological properties. Nursery crops can be grown in almost any potting medium that provides physical support, adequate water, oxygen, essential mineral elements, and is nontoxic to plants. If the growth medium possesses the ideal characteristics for plant growth, the management required by the nurseryman will be minimized and plant production will be of high quality. Another advantage is that the use of less fertilizer and water usage will reduce the potential for groundwater contamination and for nutrient runoff from the greenhouse.

Growth Media Physical Properties

Physical properties are the most important parameters related to plant performance in potting media (Chen et al., 1988). A growth media is composed of solid, liquid and gaseous components. The solid components usually constitute between 33-50% of the media volume. The second portion is liquid, which consists of water and dissolved nutrients and organic materials. The third portion is the gaseous material that includes oxygen and carbon dioxide, which constitutes 60 – 80% of the container medium volume. Oxygen is very important for root growth in the media. An oxygen concentration of at least 12% should be maintained for roots not to suffer any damage or reduce growth (Bilderback, 1982).

Potting mixes must be formulated to provide a balance between solid particles and pore space. In growing media, porosity is the amount of pore space in container media which influences water, nutrient absorption and gas exchange by the root system. Container capacity or water holding capacity is measured when a medium has been irrigated up to a saturation point that will fill the total pore space with water, then it is allowed to drain only due to gravitational pull. The small pores will retain water while large pores empty and fill with air. When all of the water has drained from the large pores, the amount of water left in the small pores is referred to as container capacity or water holding capacity (Fonteno, 1996).

Pore space in the medium will be dependent on the shape, size and distribution of its media particles. Large pores will be filled with air, while small pores will be filled with water. If a potting mix contains a higher amount of large pores, it won't hold as much water as if it contains a greater amount of small pores (Greer, 1998). If a potting mix has a greater amount of small pore spaces filled with water the air space decreases and the chance for the plant to suffer damage due to over watering increases. According to Ingram and Henley (1991), roots growing in poorly aerated media are weaker, less succulent and more susceptible to micronutrient deficiencies and root rot pathogens such as *Pythium* and *Phytophtora* than roots growing in well-aerated media. For adequate gas exchange, aeration porosity should ideally constitute 20-35% and water-retaining micro pores should comprise 20-30% of the total media volume (Kasica, 1997). Another aspect that can affect media aeration and porosity is that the volume of the medium may decrease due to compaction, shrinkage, erosion and root penetration. All of these will cause a reduction in drainable air space and readily available water. To reduce compaction during pot filling, no pressure should be applied to the potting mix while filling the container. Shrinkage also occurs over time due to particle degradation.

Another important physical property of a growth medium is the bulk density. Bulk density is the mass per unit volume, usually expressed in grams per cubic centimeter (g/cc). This parameter will indicate the volume of solids and pore space occupied by the growing media. A loose, porous mix will have a lower bulk density than a heavy, compact growing media. The ideal bulk density will depend on the plant’s handling or location at the nursery. A higher bulk density will be needed for plants grown outdoors to prevent wind from forcing them down on the floor, and a lower bulk density will be needed for plants with more handling. To reduce bulk density according to plant needs, organic material like peat or compost is usually added. In general as bulk density increases, the total pore space decreases (Holcomb, 2000).

Growth Media Chemical Properties

Chemical properties of a media are also very important and deal mostly with the plant's nutrition and the factors around it. First of all, a very important factor to control in growth media is the pH. Media pH is the measure of alkalinity of a substrate, with a pH of 7 indicating neutral pH. A pH higher than 7 signifies that it is alkaline, and a pH below seven denotes acidic conditions. It is measured on a logarithmic scale from 0 to 14 that reflects the concentration of hydrogen ions in the media. Media components, fertilizers and irrigation water can affect media pH. The main reason for pH control is to regulate nutrient availability. A plant does not usually suffer due to pH increasing or decreasing. It is the deficiency of some nutrients that actually affects the plant. Micronutrient availability is optimal at pH 5.0-6.5. Outside this pH range, the availability of nutrients becomes difficult for the plant due to changes in the nutrient chemical properties (Ingram & Henley, 1991). The plant can start showing some deficiency symptoms, and the quality of the plant is eventually lowered.

Another important aspect of the media's chemical properties is the cation exchange capacity (CEC). The CEC is a measure of media's nutrient holding capacity. It is defined as the sum of exchangeable cations, or positively charged ions, that the media can adsorb per unit weight or volume. The unit of measure is milliequivalents per 100 cubic centimeters (me/100cc) or grams (me/100g). A high CEC means that a media will hold nutrients even after irrigation. The use of organic matter in potting mixes will provide an increase in cation exchange capacity or the media's availability to hold nutrients. Potting mixes made mostly of sand won't have the ability to hold as much nutrients compared with one containing organic components such as peat or compost, which will have a greater ability to hold nutrients. However, if a potting mix holds too many nutrients, salts may accumulate. Some low surface area component like sand might help control salt buildup (Ingram and Henley, 1991). Important macronutrient cations that the media will hold on its exchange sites are calcium (Ca^{+2}), magnesium (Mg^{+2}), potassium (K^{+}), ammonium (NH^{+4}) and sodium (Na^{+2}), and micronutrients such as iron (Fe^{+2} and Fe^{+3}), manganese (Mn^{+2}), zinc (Zn^{+2}), and copper (Cu^{+2}). The concentrations of all these ions in the media are restricted to a limited container volume. To prevent the accumulation of these minerals, commonly measured as soluble salts concentration in the media solution, they should be monitored. The buildup of salts can make it difficult for the plant roots to absorb water, due to a higher or positive concentration gradient in the media. The gradient should be higher in the plant system for it to absorb water. If the gradient in the media is higher, the plant will probably suffer from lack of water and wilt. Also, a continuous monitoring of soluble salts will help estimate the amount of nutrients in the media solution, since most soluble salts are mineral elements that are essential for plant growth. At the beginning of the crop cycle, the initial soluble salts readings should be low so that sensitive plants and seedlings will not suffer any damage.

Compost as a Component in Potting Media

Most ornamental plants are grown in containers. When the ornamental plants are sold, the media in the container goes along with it. Every time a new crop cycle of plants is grown in the greenhouse, it needs new container media (Klock & Fitzpatrick, 1999). Compost can be used as an alternative to peat to meet this increasing demand for an organic component in growing media for the nursery industry. It can either be used as a component or as the growth media itself.

Although most ornamental plant crops may require different characteristics in their container media conditions, most growers want a container media that is consistent, reproducible, readily available, easy to work with, cost effective, and with appropriate physical and chemical properties (Poole et al., 1981). A summary of general recommendations for physical and chemical properties of container growth media is shown in (Table 2-1).

Table 2-1. General recommendations for physical and chemical properties of container grown media for bedding plants, foliage plants, and woody ornamentals. (Fonteno, 1996; Warncke and Krauskopf, 1983; Poole et al., 1981; Dickey et al., 1978)

Media Characteristic	Bedding Plants[1]	Foliage Plants[2]	Woody Ornamentals[3]
Total pore space	75-85 %	NA	NA
Water holding capacity	NA	20-60%	35-50%
Air filled porosity	5-10%	5-30%	NA
pH	5.8-6.2	5.5-6.5	5.8-6.2
Soluble salts	0.75-3.49 mS/cm	0.57-1.43 mS/cm	0.5-1.00 mS/cm
Nitrate	80-160 mg/kg	50-90 mg/kg	NA
Phosphate	6-10 mg/kg	[4]NA	NA
Potassium	150-225 mg/kg	NA	NA

[1] Soluble salt and all nutrient values determined using SME (saturated media extract method).
[2] Soluble salt determined using 1:2 method and nitrate determined using SME.
[3] Soluble salt determined using 1:2 method.
[4] NA = not available.

Container mixes have a combination of organic materials and inorganic materials in them. Peat has traditionally been used as the organic component for most nursery media. The organic component in a mix will vary from 20 - 100% by volume of the mix, depending on the crop and the growing conditions (Whitcomb, 1988). There have been many plant experiments with compost as part of the potting mix where the results have been either the same as the control or even better. Most experiments have been done with biosolids and other waste composts and not many with dairy manure compost. Biosolids and municipal solid waste composts have a high variability in properties after the composting process. This variability is due mainly because the parent material influences compost quality. Therefore, these composts are not as uniform as dairy manure compost. Composts made from biosolids tend to have relatively high nitrogen levels (Rynk et al., 1992). Some biosolids composts tend to have a higher salt concentration as determined by (Shiralipour et al., 1992). Thus, as the percentage of municipal solid waste compost in the substrate increases above 50%, growth of some plant species can be depressed due to high soluble salt concentrations, poor aeration, and or heavy metal toxicities. Dairy manure compost has very similar physical characteristics (water holding capacity, air space, total porosity and bulk density) as peat. Chemical characteristics of compost show that they provide some micronutrients. Because of extreme heterogeneity among compost products, it is important to identify the physical and chemical properties of compost as well as compost blending rates associated with superior bedding plant growth (Klock, 1997).

There have been many successful experiments conducted using various kinds of composts in container media. For example, Wootton et al. (1981) reported that ‘Golden

Jubilee' marigold, 'Fire Cracker' zinnia, and 'Sugar Plum' petunia growth in a sludge compost and/ or sludge compost-vermiculite medium was similar to or better than growth in a sand-peat medium. According to Klock and Fitzpatrick (1997), their work demonstrates the feasibility of using a compost product as a stand alone medium for growing 'Accent Red' impatients if it meets the following criteria: APS (percent of air filled porosity) of 5 to 30 percent, a WHC (water holding capacity) of 20 to 60 percent, a bulk density of 0.30 to 0.75 g/cm^3, initial pH of 6.5 to 7.0, initial soluble salts concentration of 0.50 to 0.65 dS/m, and a C:N ratio of 15 to 20.

CHAPTER 3
EVALUATION OF DAIRY MANURE COMPOST PROPERTIES FOR USE AS POTTING MEDIA

This chapter discusses how the compost used in this study was produced and the biological, physical and chemical properties that made it a potential material in potting media. The compost came from the nutrient removal and drum composting system installed at Gore's Dairy, Zephyrhills, Florida.

Compost Production

The system was designed to treat wastewater from two free stall barns that held about 800 cows and used a flushing system for manure removal and cleaning. It consisted of a gravity sedimentation basin, a wastewater holding tank, Agpro Extractor (Agpro Inc, Paris, Texas) mechanical screen, a tangential flow separator, a plate clarifier and thickener, and a horizontal drum composter (Figure 3-1). The purpose of the gravity sedimentation basin was to trap most of the sand coming from the cow's bedding. The wastewater holding tank served as a temporary storage before the wastewater entered the Agpro Extractor mechanical screen. The Agpro Extractor screens solids out of the wastewater and stores them in a temporary storage area where additional water drains out of the solids. The solids were loaded into one end of the drum composter with a conveyor belt. The drum composter was a 3 m diameter by 12.2 m long cylinder. It was continuously turned at about 11 revolutions/hour, and it had about a 5-degree angle to facilitate movement of solids from the inlet to the outlet. There were two interior baffles with four 1.2 m diameter holes, and it had an air blower which forced air through four horizontal ducts on the inside of the drum. Temperature inside the drum composter sometimes exceeded 65 ° C. The volume of manure in the drum was approximately 67 cubic meters with a solids retention time of at least three days (Nordstedt & Sowerby, 2000).

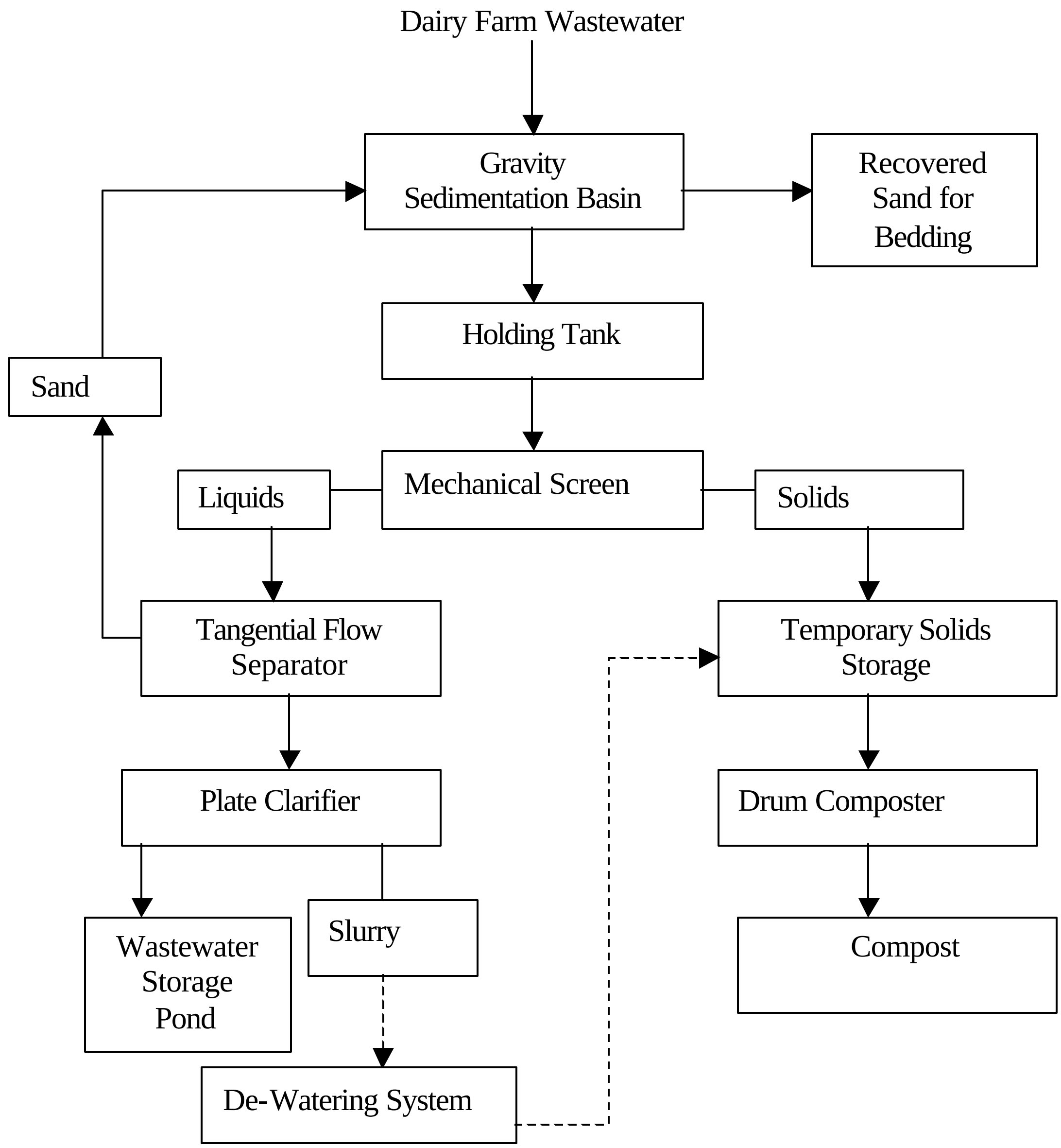


Figure 3-1. Flow diagram of the nutrient removal and composting system at Gore's Dairy, Zephyrhills, Florida. (Nordstedt & Sowerby, 2000)

Biological Properties

Introduction

Germination tests with compost extract and direct compost seed tests were performed to evaluate any phytotoxicity that the compost could cause. Biological properties of compost can be measured in many ways, and each one addresses a different characteristic that makes compost either safe or unsafe for plants. Two compost extract germination tests were performed. The first test was performed to calculate germination index, and the second test was performed to compare germination results over time between the compost extract and deionized water. The first test for calculating the germination index was a compost extract modified biological maturity test by Zucconi et al. (1981a). The methodology for this procedure is based on seed inhibition caused by toxic environmental conditions usually associated with immature compost. It yields percent germination, which is an average of the seeds germinated in the sample divided by the average of the seeds germinated in the control. It also gives percent root length in the same way. When these two numbers are multiplied together, it gives the "Germination Index". The idea of this germination index is to obtain a parameter that can account for both low toxicity, which affects root growth, and heavy toxicity, which affects germination (Zucconi et al., 1981a).

$$\% \text{ Germination} = \frac{\text{Average number of seeds germinated in the sample}}{\text{Average number of seeds germinated in the control}}$$

$$\% \text{ Root Length} = \frac{\text{Average of root length in the sample}}{\text{Average of root length in the control}}$$

$$\text{Germination Index} = (\% \text{ Germination} * \% \text{ Root Length})/100$$

For the second test the same procedure was used, except root length was not measured only percentage of germination was recorded at 24, 48 and 72 hours from two different packets of watercress seeds.

In addition to the compost extract procedures a "bioassay test" was also performed to provide more evidence of compost maturity using peat as a control. Warman (1999) concluded that between three different types of germination tests performed on composts the commonly used compost extract germination test was not sensitive enough to detect differences between mature and immature composts. Direct seed tests were the most sensitive. With this in mind, both germination tests with compost extract and direct seed germination in compost procedures were performed on the media.

Materials and Methods

A sample of compost was collected in April 2001 from the nutrient removal and composting system at Gore's Dairy. The sample was taken from a pile that had recently been taken out of the digester. Three germination tests were performed on the compost:

1. **Compost extract germination test (A)** was performed using a modified procedure performed by Zucconi et al. (1981a), which used a 4:1 mix (water: media) by weight (Figure 3-2). Mixes were placed in Nalgene 50 ml centrifuge tubes and allowed to stand for 15 minutes so that water could soak the compost. They were then centrifuged for 30 min at 5000 rpm. The extract was filtered through a Whatman # 113 wet strengthened filter paper. Ten ml of the filtered extract was used to wet the germination paper, which had been placed in a 9.5 x 1.5 cm petri dish. Twenty-five watercress seeds (*Lepidium sativum*) were placed per dish and replicated six times. Each replication had a control that contained

deionized water. Dishes were placed in an incubator at 27 ºC for four days (Figure 3-3). The lids of the petri dishes were left on to prevent evaporation of the extract. Percent germination and percent root length were measured after four days and the germination index was calculated. A statistical analysis was also performed on the germination results using SAS, assigning a number "one" to each germinated seed. The means were separated using Duncan's multiple range test with a p=0.05 (SAS, 1999).

2. **Compost extract germination test (B)** this test followed the same procedure as the previous test except that ten watercress (*Lepidium sativum*) seeds were placed per petri dish and replicated six times. Germination results were recorded at 24, 48 and 72 hours using two different seed packets I and II.
3. **The bioassay procedure** was performed by filling 9.5 x 1.5 cm petri dishes with compost and Canadian Peat Moss (Figure 3-4). There were six replications for compost and peat with twenty-five radish (*Raphanus sativus*) seeds per dish. All of them were moistened to saturation with deionized water. Lids were used to prevent moisture from evaporating. All petri dishes were placed in an incubator at 27 ºC. Germination was recorded and analyzed statistically using SAS, and means were separated using Duncan's multiple range test with a p=0.05 (SAS, 1999).

Figure 3-2. Germination of watercress seeds comparing compost extract and deionized water.

Figure 3-3. Incubator used for germination tests.

Figure 3-4. Bioassay or direct seed germination method comparing peat and compost.

Results and Discussion

In the compost extract test (A) the germination index was calculated at 103 % (Appendix A). A germination index of 40% or less would denote phytotoxic potential (Lemus, 1998). The germination index was high due to a higher root length for the compost than in the control germination test. The compost extract germination tests (A) versus deionized water mean separation analysis showed that the means from seeds germinated in deionized water and the means from seeds germinated in compost extract were not significantly different. Germination percentages from the compost extract test

(B) compared to the control are both shown below in Figures 3-5 and 3-6 (Appendix A). Mean comparison of direct seed germination test results between compost and peat used as the control showed no significant differences (Appendix A). Biological tests of the compost in these tests did not show that the compost would cause any potential damage to plants. The compost seemed to be completely mature after being digested at an average temperature of 55 ºC for 3 days. That is when the samples were taken for the tests.

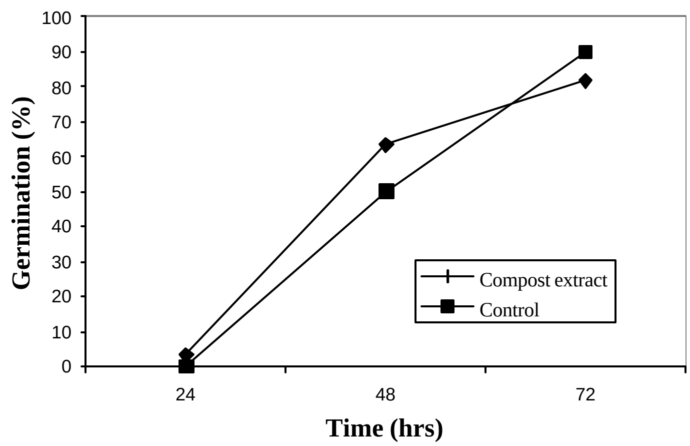


Figure 3-5. Percent germination versus time in compost extract germination test (B) for watercress seed packet I.

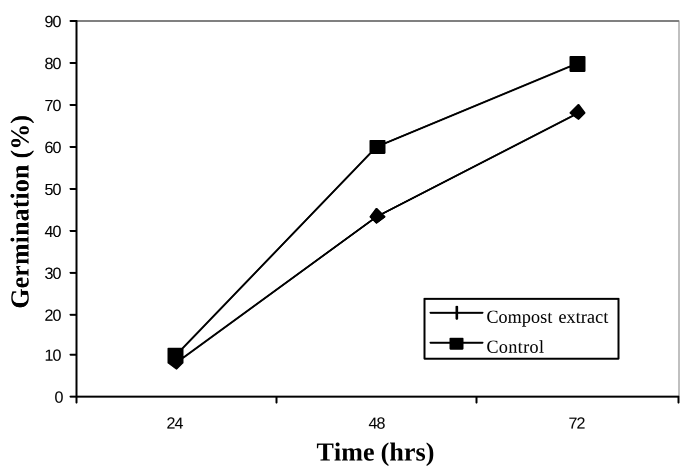


Figure 3-6. Percent germination versus time in compost extract germination test (B) for watercress seed packet II.

Physical and Chemical Properties

Introduction

Physical properties were determined using a procedure by Beeson (1995) called “Substrate Aeration Test” to measure total porosity, container capacity, air space, and bulk density. Chemical properties of the compost were determined by A & L Southern Agricultural Laboratories, Pompano Beach, Florida. They conducted a “State Manure Test M-2” and a soil container media “S-7 Test Method” using a modified Morgan extractant with sodium acetate and DTPA (Wolf, 1982). These results were used in evaluating the properties of the compost for use in potting mixes for the experimental plant trials.

Materials and Methods

A sample of compost was collected in April 2001 from the nutrient removal and composting system at Gore's dairy. The sample was taken out of the piles that had recently been taken out of the digester. The compost was screened with a 1.3 cm screen to remove larger particles and to have a uniform product. All samples and material used in subsequent experiments was also screened. For measuring physical properties the "Substrate Aeration Test" procedure by Beeson (1995) was used. A & L Southern Agricultural Laboratories determined the chemical properties of the compost, first with a “State Manure Test” that included moisture, solids, total N, P, P_2O_5, K, K_2O, S, Mg, Ca, Na, Al, B, Cu, Fe, Mn, and Zn. Compost was then analyzed as a container media using an “S-7 test” that used a Morgan extractant with sodium acetate and DTPA (Wolf, 1982) for container media that included soil pH, soluble salts, N, P, K, Ca, Mg, Fe, Mn, Zn, Cu, B and S.

Substrate Aeration Test

The procedure by Beeson (1995) required building a device out of a 15.2 cm long x 7.5 cm diameter polyvinylchloride (PVC) pipe with a cap on the bottom and a coupler on top. Four 5 mm holes were drilled in the cap. The total volume of the pipe was determined, and it was filled with moist substrate and packed three times by dropping it from ten centimeters. The pipe was then placed in an 18.9-liter container filled with water to the top of the coupler. After three hours the pipe was removed and allowed to drain for 5 minutes, the coupler was removed, and a cloth was tied to the top. It was then submerged for 10 more minutes, and then it was lifted out of the water. The holes were covered, and it was placed on a pan elevated at the bottom with a piece of pipe. It was allowed to drain for 10 minutes. The drained volume was carefully measured with a graduated cylinder. The pipe was then emptied on a paper bag to weigh the sample and obtain the wet weight. The sample was placed in an oven at 105 ºC for 48 hours and weighed to obtain dry weight.

Media volume in this case was 680 ml, which was determined by measuring the volume of the capped pipe without the coupler. It was then possible to calculate total porosity, container capacity, moisture content, air space and bulk density according to the equations by Fonteno (1996).

Results

The physical properties results (Table 3-1) on average were within the range values recommended by Yeager (1995) for evaluating container mixes except for moisture content. This means that the compost by itself could meet the physical properties ranges specified for the growth of container media nursery stock. The chemical properties results (Table 3-2) were compared with range values that were standards used by Woods End Research Laboratory (2001) to evaluate compost for use in container mixes. The nitrogen range value (Table 3-1) was not available, because they measure N as TKN and not as total N. Most of the values were within the ranges, except for K, Mg and Ca, which were higher than the range, and Zn was below the normal range.

Table 3-1. Results from evaluating physical parameters of dairy manure compost.

Sample Number	Total Porosity (%)	Container Capacity (%)	Air Space (%)	Bulk Density (gr/cc)	Moisture Content (%)
1	82.0	44.4	37.6	0.22	66.9
2	79.3	53.6	25.7	0.37	59.4
3	77.0	54.2	22.8	0.39	58.4
4	77.4	53.9	23.5	0.37	59.3
Average	78.9	51.5	27.4	0.34	61.0
Range Values[1]	50-85	45-65	10-30	0.19-0.70	70-80

[1]Range values are recommended physical characteristic values from Yeager (1995).

Although K, Mg and Ca were higher than the recommended range, they did not seem to affect the tissue analysis results. In the chemical test "S-7" performed on the compost (Table 3-3) the soluble salts were within the normal range. While a high salts content from K, Mg and Ca seemed to appear in the complete digestion test, it was not as apparent in the extractant or container media test. Macronutrient analysis showed a slightly lower N value and a slightly higher P value, but K was higher than the range in this test as well as in the previous total digestion test. K concentrations were probably higher due to the compost's parent material.

Table 3-2. Complete digestion macronutrient chemical analysis for dairy manure compost.

Replication	Moisture (%)	Solids (%)	N (%)	P (%)	K (%)	Mg (%)	Ca (%)
1	42.4	57.6	[2]0.92	0.19	0.25	0.14	0.64
2	31.4	68.6	0.85	0.20	0.27	0.15	0.69
3	42.8	57.1	0.85	0.18	0.23	0.13	0.65
4	43.8	56.2	0.89	0.18	0.25	0.13	0.62
Average	40.1	59.9	0.88	0.19	0.25	0.14	0.65
Range Values[1]	NA	NA	NA	0.04-0.25	0.04-0.1	0.005-0.05	0.025-0.5

[1]Range values established by Woods End Research Laboratory (2001).
[2]Wet basis results.

Table 3-2 continued.

Replication	Na (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
1	0.07	50.0	1430.0	41.0	55.0
2	0.08	52.0	1754.0	47.0	58.0
3	0.07	49.0	1349.0	39.0	51.0
4	0.07	46.0	1661.0	40.00	51.0
Average	0.07	49.2	1548.5	41.8	53.8
Range Values[1]	< 1/2 K	< 350	< 12,000	< 1,000	100-2,800

[1]Range Values from Woods End Research Laboratory (2001).

The micronutrient analysis (Table 3-4) showed that only Cu had a lower value compared with the range. Although copper is an important micronutrient, it can also be toxic if present at higher levels in the plant. Compost can provide container media with micronutrients.

Table 3-3. Macronutrients chemical analysis performed on the compost using extractant for evaluation as a container media.

Sample Number	Media pH	Soluble Salts (mmhos/cm)	N (ppm)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	S (ppm)
1	7.8	0.89	28	80	907	1720	531	22
2	7.7	0.84	18	80	515	560	188	20
Avg.	7.8	0.87	23	80	711	1140	359.5	21
Range Values[1]	5.5-6.5	0.2-1.0	25-150	12-60	50-250	500-5000	50-500	15-200

[1]Values were provided by A&L Southern Agricultural Laboratories as typical good values.

Table 3-4. Micronutrients chemical analysis performed on the compost using extractant for evaluation as a container media.

Sample Number	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	B (ppm)
1	2.5	6.2	6.2	0.4	1.7
2	5.7	3.3	3.9	0.8	1.1
Avg.	4.1	4.8	5.1	0.6	1.4
Range Values[1]	2.5-25	2.5-25	2.5-25	1.2-5	0.5-2.0

[1]Range values provided by Southern Agricultural Laboratories as typical good values.

Discussion

The analyses indicated that the compost did not contain toxic levels of nutrients that would affect plant growth. It possessed physical properties that common commercial potting nursery mixes offer for the growth of container grown plants. Chemical analyses also showed that the compost would not replace nutrients supplied by a common fertilizer. An ideal container media should provide the plant with some nutrients, especially some micronutrients, which normal soilless media do not provide. At the same time it would not provide the plant with an excess or deficiency that could cause phytotoxicity or damage to the plant. K was the only element present that was higher than normal, and K is not an element that can pose a high risk to the environment. Its high concentration may have been due to the fact that the solids composted were undigested forages, and most forages contain high concentrations of K. According to Grant (1996) alfalfa routinely tested over 3% K on a dry basis, and NRC (1989) reported that Bermuda grass hay sun cured 15-28 days had a 2.2% K level. K is a major cation nutrient, and it is needed by plants in greater quantities than any other nutrient, except perhaps N. Analyses of screened manure solids from a dairy research showed that K content ranged from 0.16 to 0.22% of dry matter (Van Horn et al., 1998). Excess K can promote cation deficiencies in the plants due to competition with elements like Ca and Mg, but Ca and Mg are also present in the compost and can be used as nutrients for plants. Plant trials accompanied by diagnostic leaf tissue analyses would help determine if the compost would be a good substitution as container growth medium.

CHAPTER 4
DETERMINING THE AMOUNT OF DAIRY MANURE COMPOST THAT CAN BE USED AS A PEAT SUBSTITUTE IN CONTAINER GROWTH MEDIA

Introduction

After determining that the dairy manure compost had a high potential for use in the nursery industry, the next step was a plant trial experiment. A common lightweight potting mix that contained peat, vermiculite and perlite was used, and compost was substituted for peat. The substitution was made in increasing percentages from 0 to 60% by volume to determine whether an organic mix of peat and compost would be a good container mix. The addition of compost was not to supply a nutrient amendment in the growth media. Rather, the compost was intended to be used in the same manner as peat in a mix. To provide an accurate evaluation of the plants and media reactions to the different treatments, there were several parameters measured on the plants and on the media. Physical and chemical properties of the media were determined, diagnostic leaf tissue analyses were performed, and plant yield and characteristics were measured and compared between treatments.

Materials and Methods

A sample of compost was obtained in April 2001 from the nutrient removal and drum composting system at Gore’s Dairy. The sample was taken from a pile that had recently been taken out of the digester. The compost was screened with a 1.3 cm screen to remove larger particles and to have a uniform product. Canadian sphagnum peat moss was used for the treatments. The following treatments were mixed by volume:

1) 60 % peat: 0%compost: 10% perlite: 30% vermiculite.
2) 50%peat: 10%compost: 10% perlite: 30%vermiculite.
3) 40% peat: 20% compost: 10% perlite: 30% vermiculite.
4) 30% peat: 30% compost: 10% perlite: 30% vermiculite.
5) 20% peat: 40% compost: 10% perlite: 30% vermiculite.
6) 10% peat: 50% compost: 10% perlite: 30% vermiculite.
7) 0% peat: 60% compost: 10% perlite: 30% vermiculite.

To get a homogeneous mix the treatments were mixed with a small concrete mixer. All components used in the treatments were based on a common mix called Fafard® Lightweight mix (Fafard, 2001). The first treatment contained no compost; it was used as a control mix for comparison with the other six treatments. The seventh treatment had no peat and the highest amount of compost (60%). Perlite and Vermiculite were both used as an inorganic amendment to the mix. They both provide air space, and vermiculite also provides some cation exchange capacity to the mix.

At the beginning of the experiment samples from each of the treatment mixes were sent to A & L Southern Agricultural Laboratories where they performed an “S-7” container media test with a Morgan extractant, sodium acetate and DTPA. This was the same procedure as the container media analysis performed on the compost in chapter 3 (Wolf, 1982). The container media test provided pH, soluble salts, available N, P, K, Mg, Ca, S, Z, Mn, Fe, Cu and B. A physical properties test was also performed on the media used in the seven treatments. It was done in the same way as the procedure in Chapter 3

(Beeson, 1995). The substrate aeration test was used to determine total porosity, container capacity, moisture content, air space and bulk density. Salvia 'Indigo Spires' (*Salvia farinacea*) plugs were transplanted in ten-centimeter pots containing the potting mixes described above. The pots were placed in a completely randomized design with 7 treatments, 5 plants per treatment, and 4 replications for a total of 140 plants. The variables measured at the end of the experiment were: 1) Plant Size (average of height and diameter) 2) Flowering (number of flower spikes) 3) Shoot dry weight, and 4) pH and soluble salts (SS) of the media. SS and pH were measured using the PourThru method three times during the duration of the experiment (procedure explanation below). Plant Size was calculated as the average of height and width. Height was measured from the surface of the media to the highest tip of the plant. Width was measured as an average from two measurements, east-west and north-south. If the plant was tilted to one side at the time of measurement, it was straightened and both measurements were taken with the plant in the same position.

The experiment was conducted in a greenhouse on the University of Florida campus using drip irrigation, beginning in May 2001. After the first week all pots were irrigated three times a day at 8:00 a.m., 12:00 p.m. and 3:00 p.m. for 1 min, which was slightly less than 100 ml per irrigation. Irrigation water came from the Gainesville municipal water supply. Pots were fertilized three days after planting by top dressing with 5 grams of a slow release fertilizer 14N-6.2P-11.6K Osmocote (14N-14P_2O_5-14K_2O) (The Scotts Company Marysville, Ohio). A plant tissue analysis was performed 31 days after planting (procedure explanation below). Plants were grown for 38 days after transplanting until they were at their approximate market size. Shoots were cut at the surface of the media, dried at 70 ºC for 48 hrs, and then weighed to obtain shoot or plant dry weight.

Pour Thru Method

The PourThru method was done according to Cavins et al. (2000). Samples of potting media leachates were taken the second, fourth and final week after transplanting. Samples of 5 pots from each one of the seven treatments were taken randomly for a total of 35 pots. All plants were irrigated at least one hour before samples were taken so that all of them contained the same amount of moisture. A plastic saucer or plate was placed under the pots for leachate collection. About 80 ml of deionized water was then poured on the surface of the pot to get a leachate sample. The leachates were placed in Fisher brand 20 ml scintillation vials and taken to the laboratory where they were tested for pH and soluble salts (SS). The SS measurement was performed as quickly as possible before any reactions occurred that could affect the readings. Results were analyzed statistically with SAS, and means were separated with Duncan's multiple range test with a $p = 0.05$ (SAS, 1999).

Plant Tissue Analysis

A plant tissue analysis was also performed 31 days after planting according to Mills and Jones (1996). Fifty mature leaves from new growth were sampled per treatment. Leaves were dried at 70 ºC for 48 hrs and were weighed to obtain dry weight. Tissue was then ground with a Wiley Mill (Thomas Scientific, Swedesboro New Jersey) and stored in plastic sealed bags. There were 3 (50 leaves) samples taken from each one of the 7 treatments for a total of 21 samples. A sample of 150 mature leaves (50 leaves per/sample) was needed per treatment. Since there were 20 plants (4 reps x 5 plants) per treatment 8 mature leaves were taken from each plant. With 8 leaves per plant there were 160 leaves sampled per treatment (20 plts/treatment x 8 leaves/plant). Since it was only necessary to get 150, the samples were divided into three parts. One part had 53 mature leaves and the other two had 54 mature leaves, instead of the 50 required by Mills and Jones (1996). All samples were sent to the Analytical Research Laboratory, Soil and Water Science Department at the University of Florida. The samples were subjected to chemical analysis for TKN, P, K, Ca, Mg, Zn, Mn, Cu, and Fe. All results were analyzed statistically with SAS, and means were separated with Duncan's multiple range test with a $p = 0.05$ (SAS, 1999).

Results

The comparison between physical properties results from the seven treatments (Table 4-1) showed that there were no significant differences in total porosity between them. Total porosity is the percentage of the container media volume, which is not occupied by solid media particles. Also, air space did not show any significant differences between treatments. Air space is the percent volume of media or media component that is filled with air after the media has achieved container capacity or its maximum water holding capacity. The air space required for adequate gas exchange should constitute at least 15%, but ideally it should be 20-35% of the media volume depending on the plants (Kasica, 1997). All of the treatments had an air space higher than 25%. In terms of air space and total porosity, there were no differences between compost and peat in the media.

Container capacity, moisture content and bulk density, did prove to have highly significant differences between them. Container capacity, also called water-holding capacity, decreased with increased addition of compost to the treatments. This may have been due to the fact that peat has the ability to absorb a greater amount of moisture than the compost substitute (Figure 4-1). Container capacity is the percent volume of the media that is filled with water after an irrigated media has drained. Water retained by the media is likely to be in smaller pores or absorbed by the material itself, so not all of the actual water held by soilless media, as in the case of peat, will be available to the plant. According to Fonteno (1996), peat has about a 25% volume of water that is unavailable water or water that the plant cannot use at a matric tension of 1.5 Mpa. The usual matric tension or negative pressure measured in dry media is going to be between 10 to 30 kpa.

Table 4-1. Initial physical properties from the seven media treatments.

Treatment Number	Compost (%)	Total Porosity (%)	Container Capacity (%)	Air Space (%)	Moisture Content (%)	Bulk Density (g/cc)
1	0	[2]78.6	47.5ab[1]	31.1	81.5ab	0.106c
2	10	79.8	51.3a	28.5	82.7a	0.106c
3	20	78.7	46.9a	31.8	77.3bc	0.140b
4	30	76.7	48.1ab	28.6	77.5bc	0.140b
5	40	80.6	46.9ab	33.6	75.7c	0.153ab
6	50	75.8	46.2b	29.6	74.5cd	0.156ab
7	60	78.9	41.2c	37.7	70.4d	0.170a
Range Values[3]		50-85	45-65	10-30	70-80	0.19-0.70
Significance		[4]ns	0.0072	ns	0.0028	0.003

[1] Duncan's mean separation alpha p = 0.05
[2] All values are means from three replicates.
[3] Range values are recommended physical characteristics (Yeager, 1995)
[4] ns = not significant $p > 0.05$

Moisture content decreased with the addition of compost to the media (Figure 4-2). The decrease is probably due to the same reason that peat absorbs a lot more moisture than compost.

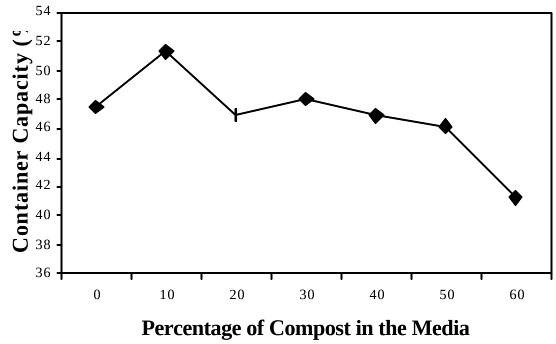


Figure 4-1. Container capacity differences between the seven media treatments.

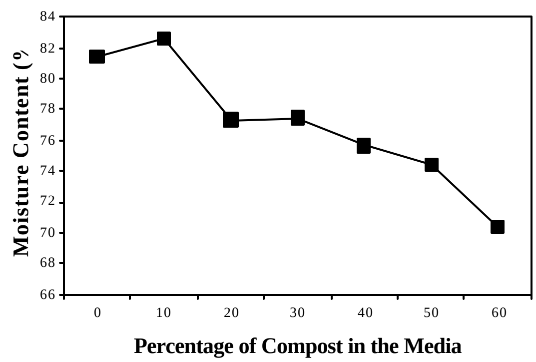


Figure 4-2. Moisture content differences between the seven media treatments.

Bulk density increased with increasing amount of compost in the media. The reason was probably because the compost contained a small amount of sand left over from the cows' bedding, thus providing increased weight to the media (Figure 4-3). Media bulk density is the weight per unit volume that includes solid particles and pore spaces. Although peat moss has a relatively low dry bulk density, once saturated, the bulk density may increase considerably. Bulk density in the nursery industry is very important and depends on how much the pots will be handled. If plants will require a lot of handling, then the bulk density should be low. On the other hand a high bulk density may be required to keep nursery crops upright in windy conditions when grown outdoors. Bulk density values for all treatments in this case were very low, because the mix used was a common lightweight mix used in the nursery industry.

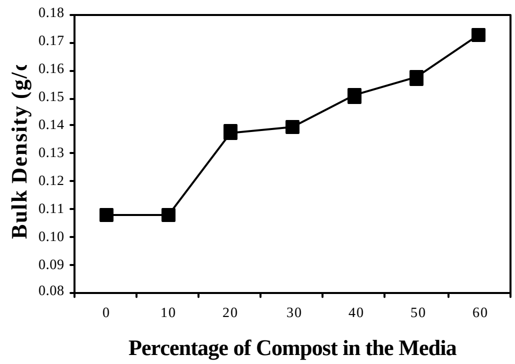


Figure 4-3. Bulk density differences between the seven media treatments.

The pH measurements from the leachate samples showed significant differences between treatments (Table 4-2). The pH increased with the addition of compost to the media. The pH for all treatments decreased with time. This was more pronounced on the higher peat mixes (Figure 4-4). Compost base mixes will have a higher pH at the initial stages of growth due to the fact that dairy manure compost and most composts have a near neutral pH. Nurserymen that have problems with low pH from the use of acidic fertilizers could have an advantage using compost instead of peat. Conversely, growers that use compost in their container mix and irrigate with water containing high pH levels will have to be aware that the media they are using has a near neutral pH. If they add more carbonates (main cause of water alkalinity) with irrigation water, then the media pH will increase. This may cause some micronutrient deficiencies in the plants. The desirable pH range for the production of most container-grown ornamental plants is 5.5-6.5 (Ingram and Henley, 1991). The main reason for this range is that the pH should be slightly acid for micronutrient availability, but not so low as to limit macronutrient availability to the plant.

Table 4-2. Soluble salts (SS) and pH monitoring using the Pour Thru procedure on the media treatments.

Treatment (#)	Compost (%)	Second week		Third week		Fourth week	
		pH	SS[4]	pH	SS	pH	SS
1	0	[2]6.7b[1]	0.446	6.3b	0.438	5.7bc	0.674
2	10	6.7b	0.434	6.3b	0.488	5.4c	0.744
3	20	6.2b	0.438	6.6ab	0.428	5.8abc	0.510
4	30	6.9ab	0.452	6.6ab	0.442	5.9abc	0.474b
5	40	7.1a	0.422	6.7a	0.432	6.1ab	0.526
6	50	7.1a	0.38	6.7a	0.406	5.9abc	0.590
7	60	7.2a	0.428	6.8a	0.400	6.3a	0.430
Range Values[3]		5.5-6.5	1.0-2.6	5.5-6.5	1.0-2.6	5.5-6.5	1.0-2.6
Significance		0.0051	[5]ns	0.062	ns	0.041	ns

[1] Duncan's Mean Separation p= 0.05
[2] All values are means from five replicates
[3] Range values from Cavins et al. (2000) Pour Thru Method.
[4] Soluble salts values in dS/m.
[5] ns = not significant $p > 0.05$

Soluble salts readings did not show any significant differences between the treatment media (Table 4-2). There is a perception among growers that composts contain high soluble salts levels. In this case the soluble salts levels were not high and they were even lower than the values established by Cavins et al. (2000). A slow release fertilizer was used in the experiment. These fertilizers are resin-coated fertilizers that provide a constant release rate of nutrients over time, a normally recommended electrical conductivity and nutrient level measured might be lower compared with a liquid fertilization program.

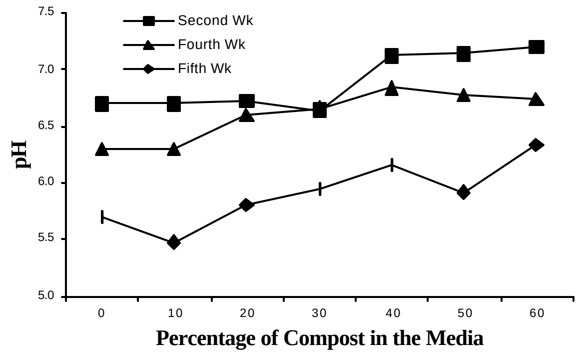


Figure 4-4. pH behavior for each of the media treatments compared with percentages of compost in the media.

Initial chemical analyses performed on the media treatments (Table 4-3) showed that pH increased with increasing percentage of compost, and peat predominant mixes had a very low pH when compared with the recommended range. High compost treatments had a pH close to neutral. Macronutrient analyses showed that N concentration was lower than the normal range on all seven treatments (Table 4-3). P values tended to increase with the addition of compost in the media. However it was only about 20 ppm higher than the normal range on the 60 % compost treatment. K concentration increased with increasing percentage of dairy manure compost in the media. The K concentration in the compost was probably higher than normal because of high K content from the compost's parent material, which is mostly forage material. Ca and Mg concentrations seemed to increase with increasing percentage of compost in the media. But while Mg did remained inside the recommended range values, Ca was lower than the recommended range on all treatments. S concentration for all treatments was in the normal recommended range and did not seem to change with increasing compost in the media (Table 4-3).

Micronutrient analysis of the media showed that the addition of compost to the media provided them with sufficient range levels except for Cu. It was clear that the control and predominant peat mixes had low concentrations of micronutrients compared with the treatments with higher percentages of compost (Table 4-4).

Table 4-3. Initial pH, SS and macronutrient chemical analysis of the seven media treatments.

Treatment (#)	Percent Compost in the Media	Media pH	Soluble Salts (mmhos/cm)	N (ppm)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	S (ppm)
1	0	4.7	0.02	15	5	62	90	122	18
2	10	4.8	0.11	14	15	161	190	158	24
3	20	5.2	0.23	16	23	223	260	182	26
4	30	5.8	0.34	14	41	354	360	194	24
5	40	6.4	0.35	15	48	292	250	127	31
6	50	6.9	0.53	14	52	461	480	211	20
7	60	7.7	0.64	16	80	314	290	143	21
Range Values[1]		5.5-6.5	0.2-1.0	25-150	12-60	50-250	500-5000	50-500	15-200

[1] Values were provided by A&L Southern Agricultural Laboratories as typical good values.

Table 4-4. Initial micronutrient analysis from the seven media treatments.

Treatment (#)	Percent Compost in the Media	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	B (ppm)
1	0	3.3	1.2	0.4	0.1	0.1
2	10	3.7	1.6	1.3	0.4	0.1
3	20	3.7	1.9	2.0	0.6	0.3
4	30	4.5	2.6	2.9	0.9	0.3
5	40	5.1	2.2	2.7	0.8	3.5
6	50	4.7	2.7	3.0	0.8	0.6
7	60	5.3	2.2	2.7	0.8	0.6
Range Values[1]		2.5-25	2.5-25	2.5-25	1.2-5	0.5-2.0

[1] Values are provided by A&L Southern Agricultural Laboratories as typical good values.

Diagnostic leaf tissue analysis was performed to evaluate if the compost would provide deficiencies or toxicities that could have prevented the plant from achieving normal growth. Except for Ca and Mn all of the elements in the plant's tissue did not show any significant differences between treatments that contained a higher percentage of compost and treatments that contained less compost (Table 4-5). Mg concentrations on all treatments were above the high sufficiency range. Mn concentration showed differences between treatments, but they were not due to the increasing percentage of compost in the mix (Figure 4-5). The 20 and 30% compost treatments had the highest concentrations of Mn, while both the control and 60% compost content mixes had lower Mn concentrations. Ca concentration showed significant differences between treatments. It increased with increasing percentage of compost in the media (Figure 4-6).

Table 4-5. Diagnostic leaf tissue chemical analysis.

Treatment Number	Percent compost	TKN (%)	P (%)	K (%)	Ca (%)	Mg (%)
1	0	[1]1.40	0.31	4.54	1.39b[3]	0.97
2	10	1.26	0.31	4.42	1.44ab	1.01
3	20	1.27	0.31	4.44	1.50ab	1.06
4	30	1.33	0.34	4.48	1.57a	1.05
5	40	1.30	0.32	4.27	1.55a	0.99
6	50	1.31	0.33	4.16	1.55a	1.03
7	60	1.265	0.31	4.12	1.56a	0.99
Sufficiency range[2]		NA	0.30-1.24	2.90-5.86	1.00-2.50	0.25-0.86
Significance		[4]ns	ns	ns	0.0575	ns

[1] All values are means from three replicates.
[2] Sufficiency ranges from Mills and Jones (1996).
[3] Duncan's Mean Separation p = 0.05.
[4] ns = not significant p>0.05

Table 4-5 continued.

Treatment Number	Percent compost	Fe (mg/L)	Mn (mg/L)	Cu (mg/L)	Zn (mg/L)
1	0	[1]202.73	83.83c[3]	4.34	38.62
2	10	149.73	131.7b	3.94	44.16
3	20	281.67	177.27a	4.2	55.88
4	30	235.43	180.53a	4.58	58.97
5	40	203.41	141.50b	4.20	51.69
6	50	188.93	134.10b	3.80	53.27
7	60	123.9	110.53bc	3.77	43.03
Sufficiency range[2]		60-300	30-284	7-35	25-115
Significance		[4]ns	0.0016	ns	ns

[1] All values are means from three replicates.
[2] Sufficiency ranges from Mills and Jones (1996).
[3] Duncan's Mean Separation p = 0.05.
[4] ns = not significant p> 0.05

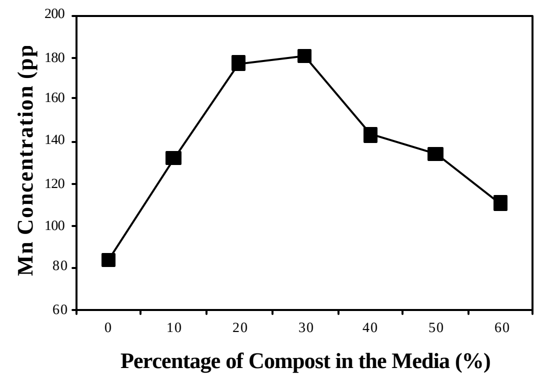


Figure 4-5. Mn concentration from diagnostic leaf tissue analysis

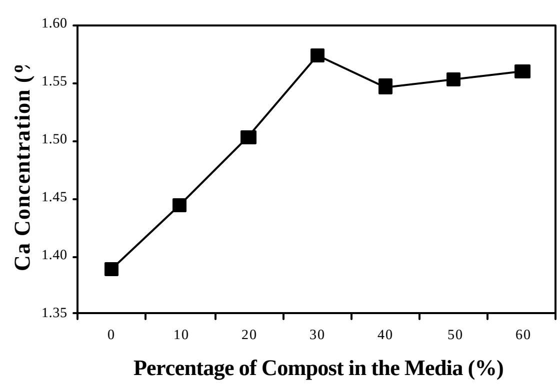


Figure 4-6. Ca concentration from diagnostic leaf tissue analysis

The plant yield parameters did not show significant differences except for dry weights measured and plant size (Table 4-6). Dry weights mean separation showed that the 10, 20, 30 and 40% compost containing mixes were all the same and had the highest yields (Figure 4-7). However, there were no differences between the control and the mix that had the highest amount of compost. According to the statistical analysis the mean dry weights between the 0% compost treatment and the 60% compost treatment will not be statistically different 95% of the time. Plant Size between the 60% compost and 0% compost treatments was significantly different.

Table 4-6. Final salvia yield parameters measured for comparison between the seven media treatments.

Treatment (#)	Percent Compost	Fresh weight (g)	Dry weight (g)	Percent Dry Matter (%)	Plant Height (cm)	Plant Width (cm)	Plant Size (cm)	Flower Spikes (#)
1	0	[2]21.6ab[1]	5.2abc	24.0	50.0	21.9	36.0ab	1.5
2	10	23.9ab	5.9a	24.4	49.4	22.9	36.1ab	1.0
3	20	24.7a	6.1a	24.6	53.5	23.1	38.3a	1.2
4	30	24.2ab	6.0a	24.6	49.8	22.7	36.3ab	1.3
5	40	21.4ab	5.4ab	25.1	47.2	22.4	34.8abc	1.2
6	50	20.6b	4.9bc	23.9	46.0	21.4	33.7bc	1.4
7	60	17.2c	4.4c	25.9	43.5	20.2	31.8c	1.6
Significance		0.0002	0.001	[3]ns	ns	ns	0.076	ns

[1] Duncan's mean separation alpha $p = 0.05$
[2] All values are means from 20 replicates.
[3] ns = not significant $p > 0.10$

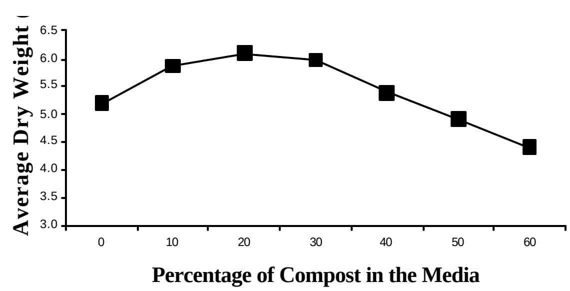


Figure 4-7. Average shoot dry weight compared with percentage of compost in the growth media for salvia plants.

Discussion

The purpose of using this compost in the nursery industry would be to provide an organic amendment or a stand-alone potting media. It would not be intended to provide nutrients to plants. The intention would be to substitute the compost for peat in most growing mixes. Organic amendments in most mixes are included to provide a growing media with improvement in physical properties, such as increased water-holding capacity, aeration, and decreased wet weight. A good media should drain rapidly after irrigation, and it should ideally contain at least 15% or more air space after draining, ideally, 20-35% (Kasica, 1997). Oxygen stress conditions are likely to develop at values lower than 10% (Cabrera, 2001). At the same time, a good media should contain at least 30% available water. All of these characteristics were achieved in this experiment.

Chemical analyses of the experimental media showed that the presence of compost did not provide toxic levels of nutrients. Rather the compost provided sufficient quantities of some micronutrients. In fact the compost amended potting media resulted in higher Ca concentration in leaf tissue for the growth of salvia plants. The Ca concentration increased until the 30% compost mix and then remained stable at approximately 1.5% Ca (Figure 4-6).

The dairy manure compost provided what was needed in a container media. Characteristics like good water-holding or container capacity, good aeration and drainage, total porosity, air space, lightweight (low bulk density), and good fertility. Best growth index of salvia occurred with the 40% peat: 20% compost: 30% vermiculite: 10% perlite (Table 4-6). However it was not significantly different from all of the other treatments except for the 60% compost mix. This mix had superior plant height, width, and plant size. It also provided ideal leaf tissue chemical analysis and physical properties.

Although a mix with a higher amount of peat yielded a better plant size, the control was not significantly different from the mix containing the most compost. They both showed that they were not statistically different for most physical properties except for container capacity. Lower container capacity provided by compost mixes can be suitable for an outdoor production with small containers. In the case of chemical properties compost did provide an increase in micronutrient concentration. Using a mix with both peat and compost seemed to have produced the best results. Combining both peat properties and compost properties in a mix will probably yield a superior container growth media for use in nursery stock, but using compost alone should not be any different than using peat in terms of plant dry weight.

CHAPTER 5
DAIRY MANURE COMPOST AS A COMPONENT IN CONTAINER GROWN MEDIA

Introduction

The previous experiment verified that dairy manure compost could be used as a growth media in container nursery mixes without causing any potential damage to plants.

The next step was to evaluate the compost with several other types of container growth media and also as a completely stand-alone media. This was accomplished by comparing common commercial peat based nursery mixes with mixes containing compost in place of peat. According to Fonteno (1996), most soilless media used in the United States are derivatives of two groups established by university research. One group was from the University of California (UC), which used various combinations of peat, sand, and peat alone. The other group is from Cornell University, which uses various combinations of peat, perlite and vermiculite.

Seven mixes were used for compost evaluations (Fonteno, 1996). Mirror treatments were setup. The first and second mixes were from a Peat-lite Mix A that contains 50% peat and 50% vermiculite compared with 50% compost and 50% vermiculite. The third and fourth mixes were based on one from the University of California Mix E that contained 100% peat moss, and it was compared with 100% compost. The fifth and sixth mixes were based in a common mix that woody ornamental nurseries use around the Tampa, Florida, area that contained 70% peat, 20% bark and 10% sand. It was compared with 70% compost, 20% bark and 10% sand. The seventh mix was also from the Cornell group, but it was the one that yielded the best results in the previous experiment. It contained 40% peat moss, 20% compost, 30% vermiculite and 10% perlite. The evaluation procedure was the same as in the previous experiment.

Materials and Methods

A sample of compost was obtained in July 2001 from the nutrient removal and drum composting system at Gore's Dairy. The sample was taken from a pile that had recently taken out of the digester. The compost was screened with a 1.3 cm screen to remove larger particles and to produce a uniform product. Canadian sphagnum peat moss was used for the treatments. The following treatments were mixed by volume:

1. 50 % peat: 50% vermiculite (PV).
2. 50% compost: 50%vermiculite (CV).
3. 100% peat (P).
4. 100% compost (C).
5. 70% peat: 20% bark: 10% sand (PBS).
6. 70% compost: 20% bark: 10% sand (CBS).
7. 40% peat: 20% compost: 10% perlite: 30% vermiculite (PCVPr).

To get a homogeneous mix the treatments were mixed with a small concrete mixer. Samples from each of the treatment mixes were sent to A & L Southern Agricultural Laboratories where they performed an “S-7” container media test with a Morgan extractant with sodium acetate and DTPA. The same chemical analyses were performed on the compost as in chapters 3 and 4 (Wolf, 1982). The chemical analyses provided pH, soluble salts (SS), available N, P, K, Mg, Ca, S, Z, Mn, Fe, Cu and B. A physical properties test was also performed on the seven treatment media. It was performed in the same way as the procedures in chapters 3 and 4 according to Beeson (1995). Total porosity, container capacity, moisture content, air space and bulk density were determined.

Salvia (*Salvia farinacea*) plugs were transplanted into 10 cm pots containing the potting mix treatments described above. The pots were placed in a completely randomized design with 7 treatments, 5 plants per treatment, and 4 replications for a total of 140 plants. The variables measured at the end of the experiment were 1) Plant size (average of height and diameter), 2) Flowering (number of flower spikes) 3) Shoot dry weight and 4) pH and soluble salts (SS) of the media using the PourThru method. SS and pH measurements were made three times during the duration of the experiment according to Cavins et al. (2000). Plant size was calculated as the average of height and width. Height was measured from the bottom surface of the media to the highest tip of the plant. Width was an average of two measurements east-west and north-south.

The experiment was conducted in a greenhouse on the University of Florida campus using drip irrigation, beginning in July 2001. After the first week all pots were irrigated three times a day at 8:00 a.m., 12:00 p.m. and 3:00 p.m. for 1 min, which was slightly less than 100 ml per irrigation. Irrigation water came from the Gainesville municipal water supply. Pots were fertilized three days after planting by top dressing with 5 grams of a slow release fertilizer 14N-6.2P-11.6K Osmocote (14N-14P_2O_5-14K_2O) (The Scotts Company Marysville, Ohio). Plants were grown for 35 days after transplanting until they were at their approximate market size. Shoots were cut at the surface of the media and dried at 70 ºC for 48 hrs, then weighed to obtain shoot or plant dry weight.

Results

Physical properties evaluation of the media showed significant differences between treatments. Treatment comparisons (Table 5-1) were made between mirror treatments, since all treatments were different in physical properties.

Table 5-1. Initial physical properties from the seven media treatments.

Media[4]	Total Porosity (%)	Container Capacity (%)	Air Space (%)	Moisture Content (%)	Bulk Density (g/cc)
PV (50:50)	[3]75.0bc[2]	53.0b	22.0abc	82.5b	0.11f
CV (50:50)	73.2c	47.2c	26.0a	65.7d	0.25d
P (100)	78.8a	58.9a	19.9bc	85.7a	0.10f
C (100)	77.9ab	53.9b	24.0ab	59.0e	0.37b
PBS (70:20:10)	68.3d	49.4c	18.9c	60.3e	0.33c
CBS (70:20:10)	67.6d	43.6d	24.0ab	45.3f	0.53a
PCVPr (40:20:30:10)	73.6c	54.5b	19.1bc	76.6c	0.17e
Range Values[1]	50-85	45-65	10-30	70-80	0.19-0.70
Significance	0.0002	0.0001	0.0215	0.0001	0.0001

[1] Range values are recommended physical characteristics (Yeager, 1995).
[2] Duncan's mean separation alpha p = 0.05
[3] All values are means from three replicates
[4] P=peat;V=vermiculite;C=compost;B=bark;S=Sand;Pr=perlite

There were no significant differences between the total porosity of mirror treatments, which means that there were no differences between compost or peat based media (Figure 5-1a). Container capacity did show significant differences between mirror treatments. It was less when using compost instead of peat in the mixes (Figure 5-1b). Air space comparison between treatments showed that there was an increase of air space in the mixes that contained compost (Figure 5-1c).

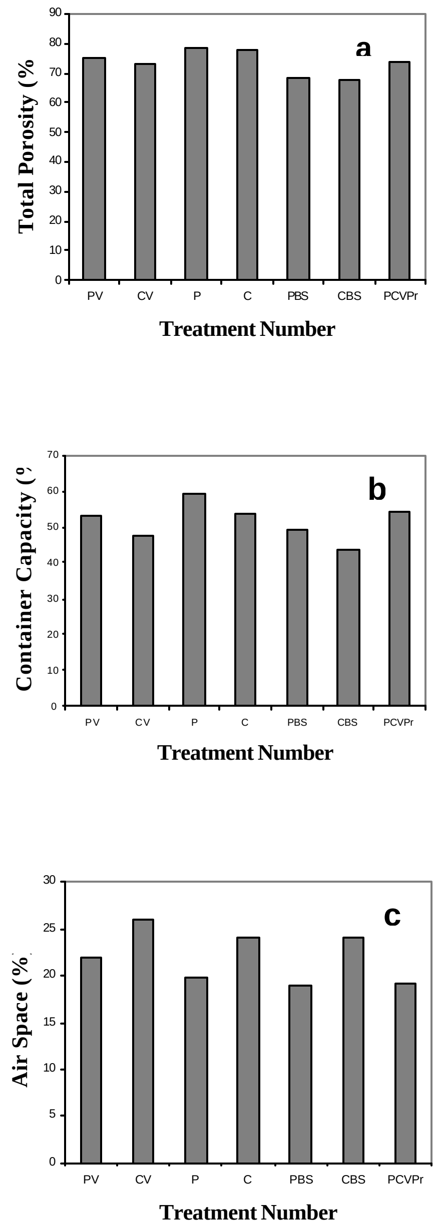


Figure 5-1. Initial physical properties from the seven media treatments. a) total porosity, b) container capacity, c) air space

Moisture content showed significant differences between mirror treatments. It was lower in the compost mixes by about 18-20% (Figure 5-2a). Compost did not seem to absorb as much moisture as peat. Bulk density was also different between mirror treatments. It was higher in compost mixes compared with peat mixes, which tend to have a very low bulk density (Figure 5-2b). When comparing bulk densities the peat based mixes had values lower than the normal ideal range. Ideal bulk density of a potting mix will depend on anticipated handling of plants in the nursery.

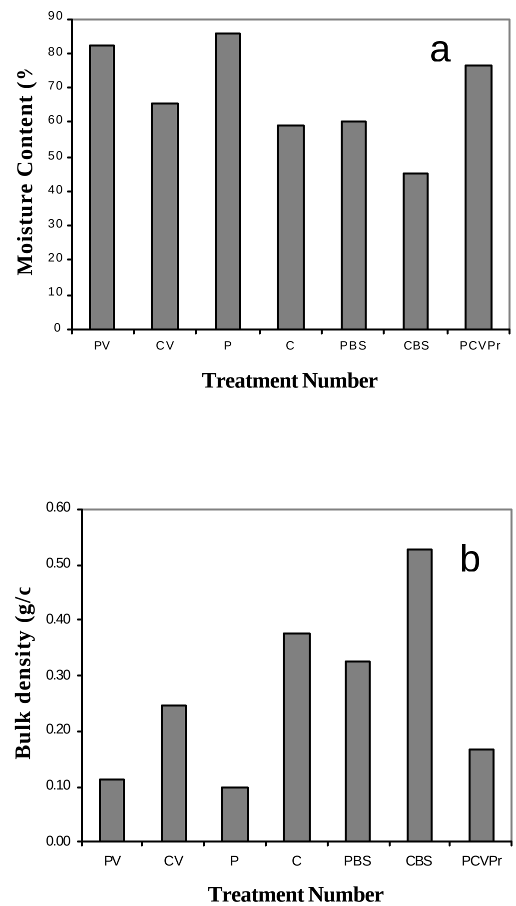


Figure 5-2. Initial physical properties from the seven media treatments. a) moisture content, b) bulk density.

Soluble Salts monitoring during the experiment showed no significant differences between the compost mixes and the peat mixes (Table 5-2). The first soluble salts reading was the only reading in which values were in the normal range. The reason was that most slow release fertilizers take a while to start releasing nutrients. For the plants to not suffer from lack of nutrients, especially at the beginning stages of growth, each pot was injected with 10 ml of a 500-ppm solution of 15-30-15 as a starter fertilizer with a higher P content for root development.

Table 5-2. Soluble Salts (SS) and pH monitoring using the PourThru method on the media treatments.

Media[4]	Second week		Third week		Fourth week	
	pH	SS	pH	SS	pH	SS
PV(50:50)	[3]4.7c[2]	1.12	4.5c	0.38	4.3c	0.63a
CV(50:50)	7.0a	1.41	6.3a	0.41	6.3a	0.45a
P(100)	3.3d	1.73	3.3d	0.57	3.4d	0.61a
C(100)	6.9a	1.67	6.6a	0.52	6.2a	0.78a
PBS(70:20:10)	3.5d	1.45	3.4d	0.50	3.4d	0.65a
CBS(70:20:10)	6.6a	1.39	6.5a	0.43	6.1a	0.53a
PCVPr(40:20:30:10)	6.1b	1.22	5.3b	0.53	5.1b	0.74a
Range Values[1]	5.5-6.5	1.0-2.6	5.5-6.5	1.0-2.6	5.5-6.5	1.0-2.6
Significance	0.0001	[5]ns	0.0001	ns	0.0001	0.557

[1] Range values from Cavins et al. (2000) PourThru method

[2] Duncan's Mean Separation = 0.05

[3] All values are means from five replicates

[4] P=peat;V=vermiculite;C=compost;B=bark;S=Sand;Pr=perlite

[5] ns = not significant $p > 0.05$

However, pH monitoring did show significant differences between the mirror treatments. Overall the pH values from compost mixes were better than pH values from the peat mixes. During the first weeks, the pH in compost mixes was near a neutral value. Later, the pH from compost mixes fell into the normal range, while the peat mixes provided a very acid or low pH. In the compost-alone and peat-alone mixes the differences in pH were obvious (Figure 5-3). Compost started at a neutral pH and tended to go to the recommended values from the beginning, while peat produced a very acid pH in the media from the beginning. That is why most peat mixes have to be limed to prevent any nutrient deficiencies that can cause plant damage.

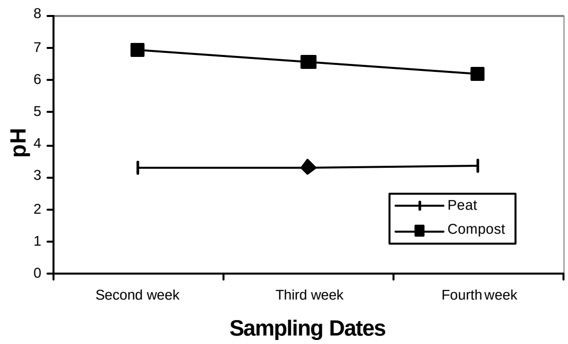


Figure 5-3. Differences in pH between mixes containing 100% compost vs. 100% peat.

Initial macronutrient chemical analyses performed on the media showed the same results as previous analyses, i.e., compost provided the mixes with an increase in K, Ca and Mg content. Due to the presence of these nutrients in the compost, the soluble salts levels were higher, but they were not out of the recommended range. Additionally, P was increased by 20 ppm more than the high value range on all treatments that contained compost (Table 5-3). Obviously, the addition of compost to the media did provide the mix with macronutrients that a normal peat based mix would not provide.

Micronutrient analysis showed that Mn, Zn and B concentrations reached their recommended range value only in the mixes containing compost. Fe and Cu concentrations seemed to stay the same when using either peat or compost in the mixes (Table 5-4). In both micronutrient and macronutrient analyses, compost seemed to have provided the media with nutrients for plant growth.

Table 5-3. Initial pH, Soluble Salts (SS) and macronutrient chemical analysis from the seven media treatments.

Media[2]	Soil pH	Soluble Salts (mmhos/cm)	N (ppm)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	S (ppm)
PV(50:50)	5.1	0.01	28	5	128	140	191	20
CV(50:50)	7.6	0.43	200	80	429	910	393	26
P(100)	4.5	0.01	29	8	14	120	67	24
C(100)	7.8	0.89	28	80	907	1720	531	22
PBS(70:20:10)	4.5	0.01	27	8	19	120	31	29
CBS(70:20:10)	7.3	0.74	25	80	509	960	284	31
PCVPr(40:20:30:10)	5.5	0.19	27	78	288	570	289	23
Range Values[1]	5.5-6.5	0.2-1.0	25-150	12-60	50-250	500-5000	50-500	15-200

[1] Range values were provided by A&L Southern Agricultural Laboratories as typical good values.

[2]P=peat;V=vermiculite;C=compost;B=bark;S=Sand;Pr=perlite

Table 5-4. Initial micronutrient analysis from the seven media treatments.

Media[2]	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	B (ppm)
PV(50:50)	2.4	0.9	0.5	0.2	0.1
CV(50:50)	2.9	3.5	4.9	0.5	0.8
P(100)	2.9	0.7	0.5	0.1	0.1
C(100)	2.5	6.2	6.2	0.4	1.7
PBS(70:20:10)	2.4	0.6	0.4	0.2	0.2
CBS(70:20:10)	3	3.9	5.6	0.6	1.3
PCVPr(40:20:30:10)	2.4	2.5	2.7	0.5	0.3
Range Values[1]	2.5-25	2.5-25	2.5-25	1.2-5	0.5-2.0

[1] Range values were provided by A&L Southern Agricultural Laboratories as typical good values.

[2] P=peat;V=vermiculite;C=compost;B=bark;S=Sand;Pr=perlite

Plant yield parameters measured on salvia showed significant differences between treatments (Table 5-5). Dry weight results showed that the treatment that yielded the best result in the previous experiment was also the best in this one (PCVPr), followed by the three compost mixes (CV, C and CBS). The lowest dry weight value was the 100% peat mix (Figure 5-4). Comparing dry weights between mirror treatments, the mix that contained compost had a higher dry weight than the mixes containing peat.

Table 5-5. Final salvia yield parameters measured for comparison between the seven media treatments.

Media[3]	Fresh weight (g)	Dry weight (g)	Percent Dry Matter (%)	Plant Height (cm)	Plant Width (cm)	Plant Size (cm)	Flower Spikes (Number)
PV(50:50)	[2]40.86bc[1]	8.65bc	21.26c	89.2a	32.6a	60.9a	3.9ab
CV(50:50)	41.93b	9.75b	23.28ab	77.9b	33.1a	55.5bc	4.9a
P(100)	29.82d	7.49d	25.14ab	75.9b	29.7b	52.8c	3.5b
C(100)	40.55bc	9.51b	23.44ab	80.5b	34.5a	57.5ab	4.7ab
PBS(70:20:10)	32.24d	7.75cd	24.13ab	77.9b	30.5b	54.2bc	4.5ab
CBS(70:20:10)	37.21c	8.91b	24.06ab	78.0b	32.7a	55.3bc	3.6b
PCVPr(40:20:30:10)	47.89a	11.01a	22.96bc	89.7a	33.0a	61.3a	5.1a
Significance	0.0001	0.0001	0.0128	0.016	0.0042	0.0017	0.048

[1] Duncan's mean separation alpha p = 0.05

[2] All values are means from 20 replicates.

[3] P=peat;V=vermiculite;C=compost;B=bark;S=Sand;Pr=perlite

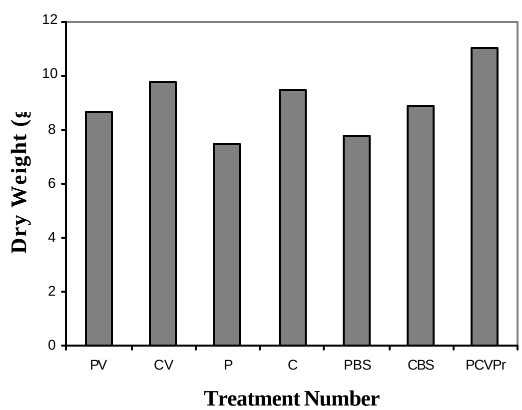
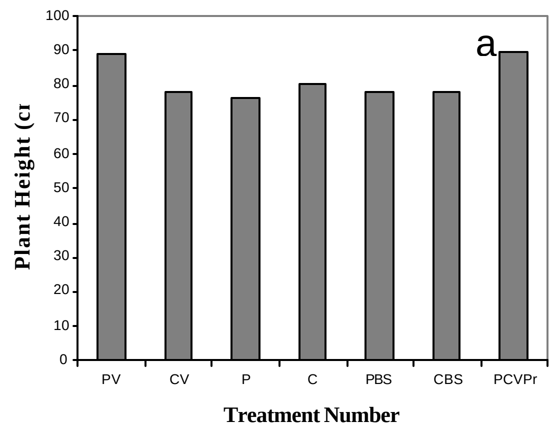
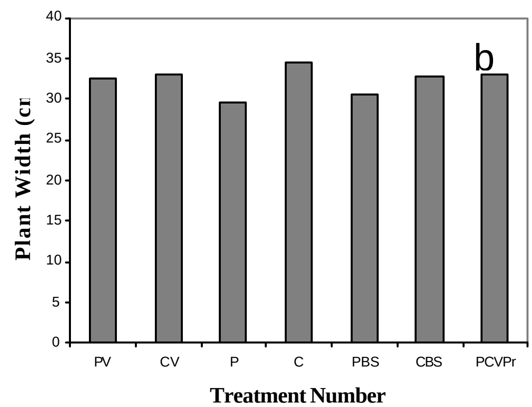


Figure 5-4. Final plant dry weight measured from salvia.





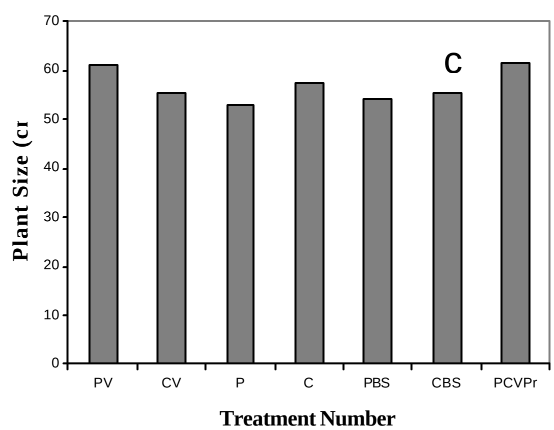


Figure 5-5. Final plant yield parameters measured from salvia. a) plant height, b) plant width, c) plant size.

There were two treatments that had the tallest plants, and those were the peat: vermiculite (PV) and the treatment that had peat: compost: vermiculite: perlite (PCVPr). The latter was the treatment with best results from the previous experiment. Except for these two mixes, all others had the same height (Figure 5-5a). Plant width showed that compost mixes provided a wider plant compared with the mirror treatment, except on the PV and CV treatments, which were the same. The treatment with the 100% compost had the widest plant (Figure 5-5b). Peat based mixes yielded taller plants while compost based mixes yielded wider plants. Plant size showed no significant differences between the treatment with 100% compost (C), peat: vermiculite (PV) and the peat: compost: vermiculite: perlite (PCVPr) (Figure 5-5c). An important finding was that the mean separation of plant size from the compost stand-alone mix was not different from the highest dry weight yielding mix, the PCVPr. Although flower spike differences were significant between treatments, the mean separation differences between mirror treatments showed that the means were the same. This means that neither compost nor peat affected the number of flower spikes on the plants.

Discussion

According to the physical properties tests, the total porosity was not affected when using compost instead of peat. On the other hand container capacity did show differences when using compost instead of peat. It decreased in the mixes that contained compost. When creating potting mixes with compost instead of peat, the container capacity or water holding capacity of the media will be reduced by about 10% compared with what a normal peat mix provides. Air space determinations showed that the compost provided the potting mixes with an increased air space. Greater air space means that the mix will provide better root development and drainage. Peat based mixes had greater moisture content values than compost mixes. Peat has a greater ability to absorb moisture. Bulk density values on compost mixes were higher than on peat mixes.

The pH differences between peat mixes and compost mixes were very significant. Peat mixes have to be limed to correct the acid pH. Compost mixes had a neutral pH on the first sampling date. However, by the second time the sampling was done, the pH had decreased and reached the recommended range. Soluble salts analyses did not reveal any significant differences between compost and peat. Based on the container media chemical analyses, compost based mixes provided the media with added K, Ca and Mg. As shown in chapter 4, compost provided the plant with an increased amount of Ca in leaf tissue analysis. As explained in Chapter 3, K levels were high in the compost due to its parent material. Micronutrient concentrations reached their ideal range values when compost was present in the mixes, except for Cu. Neither compost nor peat mixes provided sufficient range values for Cu.

Plant growth parameters showed again that the mix with highest plant dry weight was the same mix as from the previous experiment in Chapter 4 (PCVPr). It can be inferred that compost and peat produced comparable plant growth results. However, a potting mix with both compost and peat produced highest plant dry weight. Plant height was greater with mixes containing peat, but plant width was greater with mixes containing compost. However, plant size for the 100% compost (C), peat: vermiculite (PV) and the peat: compost: vermiculite: perlite (PCVPr) mixes were not significantly different. The 100% compost mix proved to be a good growing mix. The dry weight and plant size were not significantly different from the highest yielding mix.

CHAPTER 6
SUMMARY AND CONCLUSIONS

Summary

A series of tests were performed on dairy manure compost produced at a nutrient removal and drum composting system to evaluate its use as a growth medium in the nursery industry. The first objective was to evaluate the compost's physical, chemical and biological properties and prove that it had potential for use as growth medium in the nursery industry. Biological properties evaluated on the compost showed that it did not have substances that would cause plant damage. In the compost extract test the germination index was calculated at 103 %. Germination tests were significant, and mean separation did not show any significant differences between germination with compost extract versus deionized water and compost versus peat as a direct seed germination media. The compost seemed to be very mature after being digested at an average temperature of 55 ºC for 3 days.

Results of physical properties tests on the compost were compared with common range values recommended for container mixes. Results showed that averaged physical properties values were made within the recommended ranges and that compost had physical properties, which made it suitable for use in common nursery mixes.

The chemical properties of compost revealed that the compost did not contain any toxic levels of heavy metals or nutrients that would cause plant damage. Complete digestion analysis showed that most of the values were within the recommended ranges, except for K, Mg and Ca. They were higher than the recommended ranges, and Zn was below the normal range. Chemical tests with a Morgan extract demonstrated a K concentration higher than the range, but soluble salts were within the normal range. The micronutrient analysis showed that compost would provide the plant with micronutrients, except Cu, which had a lower value compared with the normal range.

The second objective of the study was to evaluate the compost as a substitute for peat, a common organic material used in container mixes. An experiment was performed to compare plant growth and behavior between using peat or an increasing amount of compost substituted for peat in the mix. Several plant growth parameters were measured, along with a diagnostic leaf tissue analysis and physical and chemical tests performed on the potting mixes to determine if compost had any effect on plant growth. Compost and peat mixes had similar total porosity and air space, but they differed in container capacity, moisture content and bulk density. Peat seemed to have higher container capacity and moisture content but a lower bulk density than compost. Container capacity decreased with the increased addition of compost to the potting mix. Moisture content also decreased with the addition of compost to the medium. The compost did not absorb as much water as peat. Bulk density increased with increasing amount of compost in the medium. Chemical properties evaluation showed that pH increased with the addition of compost to the medium. Compost provided the medium with a higher buffer capacity than what peat provided to potting mixes. Soluble salts readings did not show any significant differences between the treatment mediums. The macronutrient analysis revealed a higher K concentration in mixes with compost. Micronutrient analysis showed that mixes containing compost provided micronutrient levels in the sufficiency range, except for Cu. Diagnostic leaf tissue analysis was performed to evaluate if the compost would cause deficiencies or toxicities to the plant. Only Ca and Mn showed significant differences in the tissue analyses. Mn differences were not due to addition of compost. Ca concentration increased with increasing addition of compost to the mix. Plant yield parameters did not show significant differences except for dry weights. Dry weights mean separation for the 10, 20, 30 and 40% compost containing mixes showed that they were all the same and had the highest yields. The mean dry weights between the 0% compost treatment (control) and the 60% compost treatment were not significantly different.

The final objective was to evaluate compost in different container mixes, which were commonly used used in the nursery industry. Plant yield parameters, and also physical and chemical parameters, were evaluated on the mixes for comparison. Physical properties tests indicated that total porosity was not affected when using compost instead of peat, container capacity was reduced by about 10%, air space in compost containing mixes increased by about 5%, moisture content was higher in peat mixes and bulk density was higher in compost mixes. Chemical properties tests revealed that pH was low in peat mixes and almost neutral in compost mixes, soluble salts were not significantly different between compost and peat, and compost based mixes provided the medium with added K, Ca and Mg. Micronutrient concentrations reached their ideal range values when compost was present in the mixes, except for Cu. Plant parameters which were measured indicated that the mix with highest plant dry weight was the same high yield mix from the previous experiment. The 100% compost mix had the same plant size as the highest yielding mix, which was the mix with 40% peat, 20% compost, 30% vermiculite and

10% perlite. The dairy manure compost proved to be a good substitute for peat in most mixes, and it was a good stand-alone medium. The 100% compost parameters measured in the experiment were 78% porosity, 54% container capacity, 24% air space, 59% moisture content, 0.37 g/cc, pH range of 6.9 - 6.2.

Conclusions

After various experiments conducted on the compost, dairy manure compost was found to be mature, and it did not contain high amounts of nutrients that could cause toxicity to plants. Compost physical properties values were within the ranges recommended for container media. Plant experiments revealed that compost could be substituted for peat, and it could also be used as a stand-alone medium in the nursery industry. Use of compost resulted in higher pH (neutral), about a 6% decrease in container capacity, and about an 11% decrease in moisture content when compost was added to container media. Compost had adequate total porosity and provided increased air space compared with peat. Plant dry weight results were not significantly different between the highest compost mix and the highest peat mix. Tissue analyses revealed no toxicities or deficiencies with the addition of compost to the mix. Compost as a stand-alone medium performed well in plant yields and for physical and chemical properties. Plant growth parameters showed that a mix with peat and compost provided a higher dry weight plant. Compost alone resulted in the same plant size as the mix with compost and peat. Compost showed a good comparison to peat, and it would be a good medium or amendment to use for nursery stock production.

APPENDIX A
GERMINATION TEST CALCULATIONS

Compost Extract Germination Test (A)				
Replication	Germination		Root Length (cm)	
	Compost Extract	Deionized water	Compost Extract	Deionized water
1	4	3	4.9	3.2
2	3	4	2	3.5
3	1	5	0.1	1.4
4	1	2	1	1.1
5	3	2	2	1.2
6	4	3	4.4	1.4
Average	2.7	3.2	2.4	2.0
% germination and % shoot length	84.2		122.0	
Germination Index	102.77			

Compost Extract Germination Test (B)						
	Packet 1			Packet 2		
Replication	Germination recorded			Germination recorded		
	24 hrs	48 hrs	72 hrs	24 hrs	48 hrs	72 hrs
1	0	7	8	0	7	8
2	1	7	9	1	7	9
3	0	4	9	0	4	9
4	1	8	8	1	8	8
5	0	6	7	0	6	7
6	0	6	8	0	6	8
Average	0.3	6.3	8.2	0.3	6.3	8.2
Control	0	5	9	0	5	9

Bioassay Test (peat versus compost)		
Replication	Germination	
	Direct Compost	Direct Peat
1	18	16
2	2	7
3	18	8
4	19	13
5	3	10
6	17	15
Average	12.8	11.5

Peat vs. Compost Germination

Compost		
REP	#	Germ
1	1	1
1	2	1
1	3	1
1	4	1
1	5	1
1	6	1
1	7	1
1	8	1
1	9	1
1	10	1
1	11	1
1	12	1
1	13	1
1	14	1
1	15	1
1	16	1
1	17	1
1	18	1
1	19	0
1	20	0
1	21	0
1	22	0
1	23	0
1	24	0
1	25	0
2	1	1
2	2	1
2	3	0
2	4	0
2	5	0
2	6	0
2	7	0
2	8	0
2	9	0
2	10	0
2	11	0
2	12	0
2	13	0
2	14	0
2	15	0
2	16	0
2	17	0
2	18	0
2	19	0
2	20	0
2	21	0
2	22	0
2	23	0
2	24	0
2	25	0
3	1	1
3	2	1
3	3	1
3	4	1

Peat		
REP	#	Germ
1	1	1
1	2	1
1	3	1
1	4	1
1	5	1
1	6	1
1	7	1
1	8	1
1	9	1
1	10	1
1	11	1
1	12	1
1	13	1
1	14	1
1	15	1
1	16	1
1	17	0
1	18	0
1	19	0
1	20	0
1	21	0
1	22	0
1	23	0
1	24	0
1	25	0
2	1	1
2	2	1
2	3	1
2	4	1
2	5	1
2	6	1
2	7	1
2	8	0
2	9	0
2	10	0
2	11	0
2	12	0
2	13	0
2	14	0
2	15	0
2	16	0
2	17	0
2	18	0
2	19	0
2	20	0
2	21	0
2	22	0
2	23	0
2	24	0
2	25	0
3	1	1
3	2	1
3	3	1
3	4	1

Compost		
REP	#	Germ
3	5	1
3	6	1
3	7	1
3	8	1
3	9	1
3	10	1
3	11	1
3	12	1
3	13	1
3	14	1
3	15	1
3	16	1
3	17	1
3	18	1
3	19	0
3	20	0
3	21	0
3	22	0
3	23	0
3	24	0
3	25	0
4	1	1
4	2	1
4	3	1
4	4	1
4	5	1
4	6	1
4	7	1
4	8	1
4	9	1
4	10	1
4	11	1
4	12	1
4	13	1
4	14	1
4	15	1
4	16	1
4	17	1
4	18	1
4	19	1
4	20	0
4	21	0
4	22	0
4	23	0
4	24	0
4	25	0
5	1	1
5	2	1
5	3	1
5	4	0
5	5	0
5	6	0
5	7	0
5	8	0

Peat		
REP	#	Germ
3	5	1
3	6	1
3	7	1
3	8	1
3	9	0
3	10	0
3	11	0
3	12	0
3	13	0
3	14	0
3	15	0
3	16	0
3	17	0
3	18	0
3	19	0
3	20	0
3	21	0
3	22	0
3	23	0
3	24	0
3	25	0
4	1	1
4	2	1
4	3	1
4	4	1
4	5	1
4	6	1
4	7	1
4	8	1
4	9	1
4	10	1
4	11	1
4	12	1
4	13	1
4	14	0
4	15	0
4	16	0
4	17	0
4	18	0
4	19	0
4	20	0
4	21	0
4	22	0
4	23	0
4	24	0
4	25	0
5	1	1
5	2	1
5	3	1
5	4	1
5	5	1
5	6	1
5	7	1
5	8	1

Compost		
REP	#	Germ
5	9	0
5	10	0
5	11	0
5	12	0
5	13	0
5	14	0
5	15	0
5	16	0
5	17	0
5	18	0
5	19	0
5	20	0
5	21	0
5	22	0
5	23	0
5	24	0
5	25	0
6	1	1
6	2	1
6	3	1
6	4	1
6	5	1
6	6	1
6	7	1
6	8	1
6	9	1
6	10	1
6	11	1
6	12	1
6	13	1
6	14	1
6	15	1
6	16	1
6	17	1
6	18	0
6	19	0
6	20	0
6	21	0
6	22	0
6	23	0
6	24	0
6	25	0

Peat		
REP	#	Germ
5	9	1
5	10	1
5	11	0
5	12	0
5	13	0
5	14	0
5	15	0
5	16	0
5	17	0
5	18	0
5	19	0
5	20	0
5	21	0
5	22	0
5	23	0
5	24	0
5	25	0
6	1	1
6	2	1
6	3	1
6	4	1
6	5	1
6	6	1
6	7	1
6	8	1
6	9	1
6	10	1
6	11	1
6	12	1
6	13	1
6	14	1
6	15	1
6	16	0
6	17	0
6	18	0
6	19	0
6	20	0
6	21	0
6	22	0
6	23	0
6	24	0
6	25	0

APPENDIX B
PLANT TRIAL EXPERIMENT #1 DATA

Experimental Design for Experiment #1

		Treatments 1	2	3	4	5	6	7
REP#1	1	111	121	131	141	151	161	171
	2	112	122	132	142	152	162	172
	3	113	123	133	143	153	163	173
	4	114	124	134	144	154	164	174
	5	115	125	135	145	155	165	175
REP#2	1	211	221	231	241	251	261	271
	2	212	222	232	242	252	262	272
	3	213	223	233	243	253	263	273
	4	214	224	234	244	254	264	274
	5	215	225	235	245	255	265	275
REP#3	1	311	321	331	341	351	361	371
	2	312	322	332	342	352	362	372
	3	313	323	333	343	353	363	373
	4	314	324	334	344	354	364	374
	5	315	325	335	345	355	365	375
REP#4	1	411	421	431	441	451	461	471
	2	412	422	432	442	452	462	472
	3	413	423	433	443	453	463	473
	4	414	424	434	444	454	464	474
	5	415	425	435	445	455	465	475

7 Treatments (%):

	Peat	**C.M.**	**Perlite**	**Verm.**
1	60	0	10	30
2	50	10	10	30
3	40	20	10	30
4	30	30	10	30
5	20	40	10	30
6	10	50	10	30
7	0	60	10	30

CRD Model:

<u>Degrees of freedom</u>

			MS	**F**
Treatments	(t-1)	6	SS_T/df	MS_T/MS_E
Error	(n.-t)	133	SS_E/df	
Total	(n.-1)	139		

$F > F_{0.05}$, t-1 n.-t
F > 2.10 with 95% confidence

Experiment #1 Physical Properties Test

First Rep

Treatment #:	Drained Volume (ml)	Bag Weight (g)	Wet Weight (g)	Dry Weight (g)	Total Porosity (%)	Container Capacity (%)	Moisture Content (%)	Air Space (%)	Bulk Density (g/cc)
1	190.5	12.4	397.3	75.7	75.3	47.3	80.9	28.0	0.11
2	190.5	12.4	417.5	54.3	81.4	53.4	87.0	28.0	0.08
3	180.3	12.4	419.0	92.5	74.5	48.0	77.9	26.5	0.14
4	190.0	12.4	410.6	101.7	73.4	45.4	75.2	27.9	0.15
5	220.4	12.4	419.3	106.1	78.5	46.1	74.7	32.4	0.16
6	200.3	12.3	403.1	115.2	71.8	42.3	71.4	29.5	0.17
7	280.0	12.3	373.0	115.8	79.0	37.8	69.0	41.2	0.17

Second Rep

1	206.0	12.5	422.7	73.3	81.7	51.4	82.7	30.3	0.11
2	195.0	12.6	432.7	81.9	80.3	51.6	81.1	28.7	0.12
3	267.0	12.5	412.3	100.2	85.2	45.9	75.7	39.3	0.15
4	184.0	12.4	441.4	92.0	78.4	51.4	79.2	27.1	0.14
5	204.0	12.5	435.2	101.6	79.1	49.1	76.7	30.0	0.15
6	170.0	12.4	437.6	88.6	76.3	51.3	79.7	25.0	0.13
7	234.0	12.6	428.7	118.4	80.0	45.6	72.4	34.4	0.17
8	255.5	12.6	451.0	149.1	82.0	44.4	66.9	37.6	0.22

Third Rep

1	238.0	12.6	368.0	70.8	78.7	43.7	80.8	35.0	0.10
2	196.0	12.5	416.5	83.9	77.7	48.9	79.9	28.8	0.12
3	202.0	12.6	407.1	88.0	76.6	46.9	78.4	29.7	0.13
4	210.0	12.6	413.8	91.1	78.3	47.5	78.0	30.9	0.13
5	262.0	12.6	409.9	100.0	84.1	45.6	75.6	38.5	0.15
6	234.0	12.7	422.1	117.1	79.3	44.9	72.3	34.4	0.17
7	255.0	12.5	391.4	117.6	77.8	40.3	69.9	37.5	0.17

Experiment #1 pH and SS measurements

Treatment #	May 21, 2001		June 1, 2001		June 14, 2001	
	pH	SS	pH	SS	pH	SS
423	6.2	0.40	6.7	0.44	4.5	0.71
233	6.6	0.40	6.8	0.44	5.4	0.68
245	7.0	0.43	6.6	0.41	6.2	0.48
211	6.5	0.49	6.4	0.5	5.4	0.59
235	6.8	0.44	6.4	0.44	5.5	0.41
154	7.0	0.42	6.9	0.42	6.3	0.63
431	6.8	0.42	6.6	0.47	5.6	0.56
454	6.9	0.41	6.6	0.52	6.2	0.36
124	6.9	0.38	6.3	0.42	6.1	0.78
175	7.2	0.42	6.9	0.38	6.6	0.48
213	6.2	0.56	5.6	0.42	5.6	0.82
361	6.8	0.51	6.9	0.28	5.9	0.56
445	6.8	0.52	6.8	0.42	6	0.44
331	6.4	0.56	6.2	0.49	6	0.46
342	6.9	0.38	6.7	0.39	5.6	0.51
464	7.2	0.28	6.8	0.44	5.3	0.8
122	6.2	0.66	5.8	0.62	5.2	0.74
462	7.0	0.38	6.6	0.42	5.7	0.64
113	7.0	0.38	6.6	0.43	5.8	0.58
354	7.2	0.37	6.9	0.4	6.1	0.58
274	7.3	0.42	6.7	0.4	6.2	0.48
411	6.8	0.46	6.8	0.33	6.2	0.42
333	7.0	0.37	7	0.3	6.5	0.44
443	7.1	0.44	6.3	0.56	5.9	0.43
173	7.1	0.52	6.6	0.58	6.2	0.27
473	7.1	0.45	6.7	0.36	6.2	0.6
221	7.1	0.35	6	0.58	5.5	1
271	7.3	0.33	6.8	0.28	6.5	0.32
111	7.0	0.34	6.1	0.51	5.5	0.96
255	7.2	0.45	7.2	0.42	6.1	0.73
441	7.0	0.49	6.9	0.43	6	0.51
453	7.3	0.46	6.6	0.4	6.1	0.33
265	7.4	0.34	6.7	0.4	6.5	0.43
223	7.1	0.38	6.7	0.38	6.1	0.49
463	7.3	0.39	6.9	0.49	6.2	0.52

Leaf Tissue Samples

Number #	Bag Weight (g)	Leaf Tissue Fresh Weight w/bag (g)	8 Leaves Fresh Weight (g)	Leaf Tissue Dry Weight w/bag (g)	Leaf Tissue Dry Weight (g)	Percent Dry Matter (%)	Number #	Bag Weight (g)	Leaf Tissue Fresh Weight w/bag (g)	8 Leaves Fresh Weight (g)	Leaf Tissue Dry Weight w/bag (g)	Leaf Tissue Dry Weight (g)	Percent Dry Matter (%)
1 1 1	3.16	6.95	3.79	4.22	1.06	27.97	3 1 1	3.18	4.63	1.45	3.57	0.39	26.90
1 1 2	3.15	4.82	1.67	3.70	0.55	32.93	3 1 2	3.18	4.76	1.58	3.67	0.49	31.01
1 1 3	3.18	4.83	1.65	3.80	0.62	37.58	3 1 3	3.13	4.50	1.37	3.63	0.50	36.50
1 1 4	3.19	4.15	0.96	3.57	0.38	39.58	3 1 4	3.16	5.15	1.99	3.78	0.62	31.16
1 1 5	3.19	5.43	2.24	4.00	0.81	36.16	3 1 5	3.18	4.61	1.43	3.50	0.32	22.38
1 2 1	3.18	4.60	1.42	3.67	0.49	34.51	3 2 1	3.19	5.36	2.17	3.75	0.56	25.81
1 2 2	3.18	5.35	2.17	3.91	0.73	33.64	3 2 2	3.21	4.98	1.77	3.73	0.52	29.38
1 2 3	3.20	5.40	2.20	3.88	0.68	30.91	3 2 3	3.21	4.04	0.83	3.54	0.33	39.76
1 2 4	3.20	5.30	2.10	3.90	0.70	33.33	3 2 4	3.23	5.15	1.92	3.82	0.59	30.73
1 2 5	3.18	4.24	1.06	3.45	0.27	25.47	3 2 5	3.24	4.42	1.18	3.57	0.33	27.97
1 3 1	3.21	4.51	1.30	3.66	0.45	34.62	3 3 1	3.19	4.64	1.45	3.70	0.51	35.17
1 3 2	3.19	5.19	2.00	3.73	0.54	27.00	3 3 2	3.20	6.53	3.33	4.15	0.95	28.53
1 3 3	3.18	5.56	2.38	3.84	0.66	27.73	3 3 3	3.16	4.33	1.17	3.49	0.33	28.21
1 3 4	3.20	4.44	1.24	3.50	0.30	24.19	3 3 4	3.17	5.06	1.89	3.81	0.64	33.86
1 3 5	3.16	5.03	1.87	3.66	0.50	26.74	3 3 5	3.18	5.38	2.20	3.74	0.56	25.45
1 4 1	3.19	4.63	1.44	3.74	0.55	38.19	3 4 1	3.18	4.94	1.76	3.74	0.56	31.82
1 4 2	3.18	4.93	1.75	3.68	0.50	28.57	3 4 2	3.18	4.87	1.69	3.66	0.48	28.40
1 4 3	3.21	5.30	2.09	3.81	0.60	28.71	3 4 3	3.16	4.25	1.09	3.37	0.21	19.27
1 4 4	3.20	5.20	2.00	3.93	0.73	36.50	3 4 4	3.17	4.75	1.58	3.78	0.61	38.61
1 4 5	3.21	5.94	2.73	4.04	0.83	30.40	3 4 5	3.19	4.58	1.39	3.66	0.47	33.81
1 5 1	3.16	4.34	1.18	3.60	0.44	37.29	3 5 1	3.20	4.21	1.01	3.48	0.28	27.72
1 5 2	3.17	5.81	2.64	4.04	0.87	32.95	3 5 2	3.20	4.16	0.96	3.58	0.38	39.58
1 5 3	3.19	4.55	1.36	3.67	0.48	35.29	3 5 3	3.18	4.44	1.26	3.56	0.38	30.16
1 5 4	3.18	4.46	1.28	3.57	0.39	30.47	3 5 4	3.18	4.86	1.68	3.80	0.62	36.90
1 5 5	3.20	4.95	1.75	3.71	0.51	29.14	3 5 5	3.16	4.97	1.81	3.73	0.57	31.49
1 6 1	3.20	5.70	2.50	3.84	0.64	25.60	3 6 1	3.18	5.23	2.05	3.78	0.60	29.27
1 6 2	3.20	4.88	1.68	3.73	0.53	31.55	3 6 2	3.18	4.41	1.23	3.53	0.35	28.46
1 6 3	3.19	4.58	1.39	3.65	0.46	33.09	3 6 3	3.15	4.96	1.81	3.76	0.61	33.70
1 6 4	3.18	4.17	0.99	3.48	0.30	30.30	3 6 4	3.17	4.55	1.38	3.52	0.35	25.36
1 6 5	3.18	4.19	1.01	3.51	0.33	32.67	3 6 5	3.16	3.97	0.81	3.46	0.30	37.04
1 7 1	3.18	4.91	1.73	3.63	0.45	26.01	3 7 1	3.19	4.41	1.22	3.51	0.32	26.23
1 7 2	3.17	4.70	1.53	3.70	0.53	34.64	3 7 2	3.18	4.32	1.14	3.57	0.39	34.21
1 7 3	3.17	4.45	1.28	3.59	0.42	32.81	3 7 3	3.19	4.17	0.98	3.58	0.39	39.80
1 7 4	3.17	4.18	1.01	3.50	0.33	32.67	3 7 4	3.19	4.29	1.10	3.57	0.38	34.55
1 7 5	3.19	4.91	1.72	3.73	0.54	31.40	3 7 5	3.17	4.40	1.23	3.52	0.35	28.46
2 1 1	3.19	4.85	1.66	3.69	0.50	30.12	4 1 1	3.17	4.22	1.05	3.53	0.36	34.29
2 1 2	3.18	4.70	1.52	3.62	0.44	28.95	4 1 2	3.19	6.12	2.93	4.05	0.86	29.35
2 1 3	3.19	5.76	2.57	3.97	0.78	30.35	4 1 3	3.19	4.68	1.49	3.79	0.60	40.27
2 1 4	3.20	4.77	1.57	3.66	0.46	29.30	4 1 4	3.22	4.67	1.45	3.63	0.41	28.28
2 1 5	3.19	4.72	1.53	3.68	0.49	32.03	4 1 5	3.20	4.60	1.40	3.58	0.38	27.14
2 2 1	3.17	5.14	1.97	3.73	0.56	28.43	4 2 1	3.20	4.98	1.78	3.77	0.57	32.02
2 2 2	3.15	4.58	1.43	3.51	0.36	25.17	4 2 2	3.17	4.28	1.11	3.50	0.33	29.73
2 2 3	3.16	5.08	1.92	3.71	0.55	28.65	4 2 3	3.14	5.32	2.18	4.05	0.91	41.74
2 2 4	3.16	5.21	2.05	3.75	0.59	28.78	4 2 4	3.17	4.99	1.82	3.74	0.57	31.32
2 2 5	3.19	4.68	1.49	3.67	0.48	32.21	4 2 5	3.19	4.19	1.00	3.50	0.31	31.00
2 3 1	3.16	4.88	1.72	3.70	0.54	31.40	4 3 1	3.18	5.18	2.00	3.88	0.70	35.00
2 3 2	3.17	4.31	1.14	3.66	0.49	42.98	4 3 2	3.20	4.76	1.56	3.68	0.48	30.77
2 3 3	3.14	5.54	2.40	3.90	0.76	31.67	4 3 3	3.18	4.29	1.11	3.60	0.42	37.84
2 3 4	3.13	4.58	1.45	3.55	0.42	28.97	4 3 4	3.19	4.49	1.30	3.54	0.35	26.92
2 3 5	3.15	4.99	1.84	3.64	0.49	26.63	4 3 5	3.20	4.75	1.55	3.61	0.41	26.45
2 4 1	3.17	3.86	0.69	3.33	0.16	23.19	4 4 1	3.21	4.63	1.42	3.58	0.37	26.06
2 4 2	3.15	4.21	1.06	3.45	0.30	28.30	4 4 2	3.23	5.61	2.38	3.98	0.75	31.51
2 4 3	3.16	4.58	1.42	3.67	0.51	35.92	4 4 3	3.20	4.31	1.11	3.60	0.40	36.04
2 4 4	3.17	5.64	2.47	3.93	0.76	30.77	4 4 4	3.24	4.27	1.03	3.65	0.41	39.81
2 4 5	3.19	4.02	0.83	3.63	0.44	53.01	4 4 5	3.20	4.62	1.42	3.69	0.49	34.51
2 5 1	3.18	4.47	1.29	3.55	0.37	28.68	4 5 1	3.21	5.44	2.23	3.96	0.75	33.63
2 5 2	3.17	4.25	1.08	3.64	0.47	43.52	4 5 2	3.23	5.26	2.03	3.90	0.67	33.00
2 5 3	3.14	4.71	1.57	3.67	0.53	33.76	4 5 3	3.24	3.93	0.69	3.44	0.20	28.99
2 5 4	3.16	4.70	1.54	3.55	0.39	25.32	4 5 4	3.22	4.10	0.88	3.53	0.31	35.23
2 5 5	3.16	4.07	0.91	3.52	0.36	39.56	4 5 5	3.20	5.31	2.11	3.94	0.74	35.07
2 6 1	3.17	4.79	1.62	3.69	0.52	32.10	4 6 1	3.18	4.73	1.55	3.65	0.47	30.32
2 6 2	3.19	4.71	1.52	3.67	0.48	31.58	4 6 2	3.21	4.41	1.20	3.55	0.34	28.33
2 6 3	3.15	4.90	1.75	3.70	0.55	31.43	4 6 3	3.21	5.13	1.92	3.76	0.55	28.65
2 6 4	3.17	4.32	1.15	3.54	0.37	32.17	4 6 4	3.24	4.38	1.14	3.57	0.33	28.95
2 6 5	3.16	4.60	1.44	3.56	0.40	27.78	4 6 5	3.24	5.69	2.45	3.96	0.72	29.39
2 7 1	3.21	4.82	1.61	3.76	0.55	34.16	4 7 1	3.20	5.78	2.58	3.95	0.75	29.07
2 7 2	3.21	4.08	0.87	3.42	0.21	24.14	4 7 2	3.22	4.20	0.98	3.55	0.33	33.67
2 7 3	3.19	4.58	1.39	3.67	0.48	34.53	4 7 3	3.22	4.42	1.20	3.61	0.39	32.50
2 7 4	3.19	4.34	1.15	3.58	0.39	33.91	4 7 4	3.22	5.94	2.72	4.15	0.93	34.19
2 7 5	3.19	4.40	1.21	3.58	0.39	32.23	4 7 5	3.22	4.25	1.03	3.50	0.28	27.18

Experiment #1 Plant Yields

Number #			Bag Weight (g)	Whole Plant Fresh Weight w/bag (g)	Whole Plant Fresh Weight w/out Leaf Tissue(g)	8 Leaves Fresh Weight (g)	Whole Plant Fresh Weight (g)	Whole Plant Dry Weight w/bag (g)	Whole Plant Dry Weight w/out Leaf Tissue (g)	Leaf Tissue Dry Weight (g)	Whole Plant Dry Weight (g)	Percent Dry Matter (%)
1	1	1	7.30	32.22	24.92	3.79	28.71	13.45	6.15	1.06	7.21	25.11
1	1	2	7.28	30.32	23.04	1.67	24.71	11.83	4.55	0.55	5.10	20.64
1	1	3	7.30	22.78	15.48	1.65	17.13	10.98	3.68	0.62	4.30	25.10
1	1	4	7.28	22.79	15.51	0.96	16.47	10.95	3.67	0.38	4.05	24.59
1	1	5	7.31	36.00	28.69	2.24	30.93	13.85	6.54	0.81	7.35	23.76
1	2	1	7.34	29.42	22.08	1.42	23.50	13.00	5.66	0.49	6.15	26.17
1	2	2	7.29	40.60	33.31	2.17	35.48	14.70	7.41	0.73	8.14	22.94
1	2	3	7.38	19.59	12.21	2.20	14.41	9.59	2.21	0.68	2.89	20.06
1	2	4	7.34	31.46	24.12	2.10	26.22	13.36	6.02	0.70	6.72	25.63
1	2	5	7.26	24.40	17.14	1.06	18.20	11.28	4.02	0.27	4.29	23.57
1	3	1	7.35	38.40	31.05	1.30	32.35	14.93	7.58	0.45	8.03	24.82
1	3	2	7.34	24.28	16.94	2.00	18.94	12.48	5.14	0.54	5.68	29.99
1	3	3	7.43	43.46	36.03	2.38	38.41	15.63	8.20	0.66	8.86	23.07
1	3	4	7.40	29.93	22.53	1.24	23.77	13.20	5.80	0.30	6.10	25.66
1	3	5	7.36	27.52	20.16	1.87	22.03	11.43	4.07	0.50	4.57	20.74
1	4	1	7.35	28.32	20.97	1.44	22.41	12.18	4.83	0.55	5.38	24.01
1	4	2	7.42	36.40	28.98	1.75	30.73	14.69	7.27	0.50	7.77	25.28
1	4	3	7.37	31.20	23.83	2.09	25.92	13.40	6.03	0.60	6.63	25.58
1	4	4	7.37	32.49	25.12	2.00	27.12	13.21	5.84	0.73	6.57	24.23
1	4	5	7.38	25.30	17.92	2.73	20.65	11.05	3.67	0.83	4.50	21.79
1	5	1	7.38	27.93	20.55	1.18	21.73	12.50	5.12	0.44	5.56	25.59
1	5	2	7.38	24.53	17.15	2.64	19.79	11.19	3.81	0.87	4.68	23.65
1	5	3	7.43	30.19	22.76	1.36	24.12	13.38	5.95	0.48	6.43	26.66
1	5	4	7.38	30.40	23.02	1.28	24.30	12.30	4.92	0.39	5.31	21.85
1	5	5	7.40	25.01	17.61	1.75	19.36	11.37	3.97	0.51	4.48	23.14
1	6	1	7.40	27.36	19.96	2.50	22.46	11.70	4.30	0.64	4.94	21.99
1	6	2	7.39	30.88	23.49	1.68	25.17	12.50	5.11	0.53	5.64	22.41
1	6	3	7.42	24.88	17.46	1.39	18.85	11.49	4.07	0.46	4.53	24.03
1	6	4	7.40	22.95	15.55	0.99	16.54	12.09	4.69	0.30	4.99	30.17
1	6	5	7.40	26.06	18.66	1.01	19.67	12.08	4.68	0.33	5.01	25.47
1	7	1	7.43	24.94	17.51	1.73	19.24	11.44	4.01	0.45	4.46	23.18
1	7	2	7.40	22.02	14.62	1.53	16.15	10.87	3.47	0.53	4.00	24.77
1	7	3	7.40	22.45	15.05	1.28	16.33	11.35	3.95	0.42	4.37	26.76
1	7	4	7.40	17.72	10.32	1.01	11.33	10.14	2.74	0.33	3.07	27.10
1	7	5	7.42	24.30	16.88	1.72	18.60	11.10	3.68	0.54	4.22	22.69
2	1	1	7.47	32.08	24.61	1.66	26.27	12.94	5.47	0.50	5.97	22.73
2	1	2	7.37	19.89	12.52	1.52	14.04	9.91	2.54	0.44	2.98	21.23
2	1	3	7.47	32.13	24.66	2.57	27.23	13.00	5.53	0.78	6.31	23.17
2	1	4	7.43	19.15	11.72	1.57	13.29	9.78	2.35	0.46	2.81	21.14
2	1	5	7.45	23.34	15.89	1.53	17.42	11.02	3.57	0.49	4.06	23.31
2	2	1	7.37	33.40	26.03	1.97	28.00	13.66	6.29	0.56	6.85	24.46
2	2	2	7.32	34.68	27.36	1.43	28.79	13.12	5.80	0.36	6.16	21.40
2	2	3	7.30	25.30	18.00	1.92	19.92	11.44	4.14	0.55	4.69	23.54
2	2	4	7.33	29.43	22.10	2.05	24.15	13.10	5.77	0.59	6.36	26.34
2	2	5	7.30	34.54	27.24	1.49	28.73	14.68	7.38	0.48	7.86	27.36
2	3	1	7.32	26.20	18.88	1.72	20.60	11.80	4.48	0.54	5.02	24.37
2	3	2	7.34	19.55	12.21	1.14	13.35	10.02	2.68	0.49	3.17	23.75
2	3	3	7.42	34.54	27.12	2.40	29.52	13.86	6.44	0.76	7.20	24.39
2	3	4	7.35	27.33	19.98	1.45	21.43	12.61	5.26	0.42	5.68	26.50
2	3	5	7.34	30.42	23.08	1.84	24.92	12.80	5.46	0.49	5.95	23.88
2	4	1	7.40	21.70	14.30	0.69	14.99	10.45	3.05	0.16	3.21	21.41
2	4	2	7.33	30.79	23.46	1.06	24.52	13.15	5.82	0.30	6.12	24.96
2	4	3	7.27	18.88	11.61	1.42	13.03	9.47	2.20	0.51	2.71	20.80
2	4	4	7.30	35.35	28.05	2.47	30.52	13.90	6.60	0.76	7.36	24.12
2	4	5	7.32	30.74	23.42	0.83	24.25	12.77	5.45	0.44	5.89	24.29
2	5	1	7.32	30.39	23.07	1.29	24.36	12.88	5.56	0.37	5.93	24.34
2	5	2	7.36	28.95	21.59	1.08	22.67	13.08	5.72	0.47	6.19	27.30
2	5	3	7.34	23.15	15.81	1.57	17.38	11.66	4.32	0.53	4.85	27.91
2	5	4	7.36	24.25	16.89	1.54	18.43	11.10	3.74	0.39	4.13	22.41
2	5	5	7.42	25.80	18.38	0.91	19.29	11.55	4.13	0.36	4.49	23.28
2	6	1	7.36	26.43	19.07	1.62	20.69	11.85	4.49	0.52	5.01	24.21
2	6	2	7.37	27.39	20.02	1.52	21.54	12.32	4.95	0.48	5.43	25.21
2	6	3	7.39	23.73	16.34	1.75	18.09	11.33	3.94	0.55	4.49	24.82
2	6	4	7.40	24.07	16.67	1.15	17.82	10.77	3.37	0.37	3.74	20.99
2	6	5	7.40	23.83	16.43	1.44	17.87	11.79	4.39	0.40	4.79	26.80
2	7	1	7.40	23.65	16.25	1.61	17.86	11.24	3.84	0.55	4.39	24.58
2	7	2	7.42	25.15	17.73	0.87	18.60	11.04	3.62	0.21	3.83	20.59
2	7	3	7.40	27.65	20.25	1.39	21.64	12.04	4.64	0.48	5.12	23.66
2	7	4	7.35	24.81	17.46	1.15	18.61	12.34	4.99	0.39	5.38	28.91
2	7	5	7.42	22.60	15.18	1.21	16.39	11.30	3.88	0.39	4.27	26.05
3	1	1	7.45	28.64	21.19	1.45	22.64	12.23	4.78	0.39	5.17	22.84
3	1	2	7.38	27.50	20.12	1.58	21.70	12.77	5.39	0.49	5.88	27.10
3	1	3	7.38	30.69	23.31	1.37	24.68	12.43	5.05	0.50	5.55	22.49

3	1	4	7.38	32.47	25.09	1.99	27.08	13.73	6.35	0.62	6.97	25.74
3	1	5	7.36	24.33	16.97	1.43	18.40	11.90	4.54	0.32	4.86	26.41
3	2	1	7.37	30.90	23.53	2.17	25.70	12.72	5.35	0.56	5.91	23.00
3	2	2	7.36	27.31	19.95	1.77	21.72	12.05	4.69	0.52	5.21	23.99
3	2	3	7.38	19.05	11.67	0.83	12.50	10.03	2.65	0.33	2.98	23.84
3	2	4	7.38	27.82	20.44	1.92	22.36	13.02	5.64	0.59	6.23	27.86
3	2	5	7.36	30.16	22.80	1.18	23.98	12.74	5.38	0.33	5.71	23.81
3	3	1	7.35	28.03	20.68	1.45	22.13	12.60	5.25	0.51	5.76	26.03
3	3	2	7.34	27.76	20.42	3.33	23.75	11.53	4.19	0.95	5.14	21.64
3	3	3	7.30	19.42	12.12	1.17	13.29	9.90	2.60	0.33	2.93	22.05
3	3	4	7.34	26.31	18.97	1.89	20.86	11.54	4.20	0.64	4.84	23.20
3	3	5	7.40	33.23	25.83	2.20	28.03	13.38	5.98	0.56	6.54	23.33
3	4	1	7.34	39.78	32.44	1.76	34.20	14.63	7.29	0.56	7.85	22.95
3	4	2	7.32	31.50	24.18	1.69	25.87	14.03	6.71	0.48	7.19	27.79
3	4	3	7.37	24.41	17.04	1.09	18.13	11.04	3.67	0.21	3.88	21.40
3	4	4	7.34	25.80	18.46	1.58	20.04	12.57	5.23	0.61	5.84	29.14
3	4	5	7.37	30.70	23.33	1.39	24.72	13.49	6.12	0.47	6.59	26.66
3	5	1	7.40	21.93	14.53	1.01	15.54	10.74	3.34	0.28	3.62	23.29
3	5	2	7.30	33.53	26.23	0.96	27.19	13.90	6.60	0.38	6.98	25.67
3	5	3	7.34	25.21	17.87	1.26	19.13	11.90	4.56	0.38	4.94	25.82
3	5	4	7.34	26.25	18.91	1.68	20.59	12.15	4.81	0.62	5.43	26.37
3	5	5	7.24	18.55	11.31	1.81	13.12	9.81	2.57	0.57	3.14	23.93
3	6	1	7.35	30.62	23.27	2.05	25.32	12.15	4.80	0.60	5.40	21.33
3	6	2	7.32	21.89	14.57	1.23	15.80	10.73	3.41	0.35	3.76	23.80
3	6	3	7.34	28.47	21.13	1.81	22.94	11.95	4.61	0.61	5.22	22.76
3	6	4	7.34	22.87	15.53	1.38	16.91	10.05	2.71	0.35	3.06	18.10
3	6	5	7.31	25.32	18.01	0.81	18.82	11.82	4.51	0.30	4.81	25.56
3	7	1	7.34	18.18	10.84	1.22	12.06	10.37	3.03	0.32	3.35	27.78
3	7	2	7.10	30.60	23.50	1.14	24.64	13.12	6.02	0.39	6.41	26.01
3	7	3	7.12	18.22	11.10	0.98	12.08	10.56	3.44	0.39	3.83	31.71
3	7	4	7.10	20.63	13.53	1.10	14.63	10.51	3.41	0.38	3.79	25.91
3	7	5	7.12	23.10	15.98	1.23	17.21	11.19	4.07	0.35	4.42	25.68
4	1	1	7.10	18.98	11.88	1.05	12.93	9.81	2.71	0.36	3.07	23.74
4	1	2	7.10	27.67	20.57	2.93	23.50	12.04	4.94	0.86	5.80	24.68
4	1	3	7.10	30.32	23.22	1.49	24.71	12.90	5.80	0.60	6.40	25.90
4	1	4	7.10	31.18	24.08	1.45	25.53	12.67	5.57	0.41	5.98	23.42
4	1	5	7.10	20.92	13.82	1.40	15.22	10.93	3.83	0.38	4.21	27.66
4	2	1	7.10	41.24	34.14	1.78	35.92	15.60	8.50	0.57	9.07	25.25
4	2	2	7.10	18.20	11.10	1.11	12.21	9.80	2.70	0.33	3.03	24.82
4	2	3	7.14	34.90	27.76	2.18	29.94	14.05	6.91	0.91	7.82	26.12
4	2	4	7.20	29.02	21.82	1.82	23.64	12.68	5.48	0.57	6.05	25.59
4	2	5	7.20	29.48	22.28	1.00	23.28	12.05	4.85	0.31	5.16	22.16
4	3	1	7.10	41.37	34.27	2.00	36.27	16.55	9.45	0.70	10.15	27.98
4	3	2	7.20	36.41	29.21	1.56	30.77	13.91	6.71	0.48	7.19	23.37
4	3	3	7.20	36.07	28.87	1.11	29.98	14.82	7.62	0.42	8.04	26.82
4	3	4	7.20	32.63	25.43	1.30	26.73	13.75	6.55	0.35	6.90	25.81
4	3	5	7.20	22.60	15.40	1.55	16.95	11.10	3.90	0.41	4.31	25.43
4	4	1	7.30	28.96	21.66	1.42	23.08	12.50	5.20	0.37	5.57	24.13
4	4	2	7.10	30.20	23.10	2.38	25.48	13.07	5.97	0.75	6.72	26.37
4	4	3	7.17	29.57	22.40	1.11	23.51	12.95	5.78	0.40	6.18	26.29
4	4	4	7.20	31.03	23.83	1.03	24.86	13.40	6.20	0.41	6.61	26.59
4	4	5	7.10	35.04	27.94	1.42	29.36	13.74	6.64	0.49	7.13	24.28
4	5	1	7.12	27.93	20.81	2.23	23.04	12.20	5.08	0.75	5.83	25.30
4	5	2	7.10	33.15	26.05	2.03	28.08	13.37	6.27	0.67	6.94	24.72
4	5	3	7.10	31.28	24.18	0.69	24.87	13.28	6.18	0.20	6.38	25.65
4	5	4	7.10	22.16	15.06	0.88	15.94	10.95	3.85	0.31	4.16	26.10
4	5	5	7.10	34.17	27.07	2.11	29.18	14.55	7.45	0.74	8.19	28.07
4	6	1	7.10	32.23	25.13	1.55	26.68	12.44	5.34	0.47	5.81	21.78
4	6	2	7.00	31.27	24.27	1.20	25.47	13.38	6.38	0.34	6.72	26.38
4	6	3	7.10	27.50	20.40	1.92	22.32	11.81	4.71	0.55	5.26	23.57
4	6	4	7.10	26.60	19.50	1.14	20.64	11.90	4.80	0.33	5.13	24.85
4	6	5	7.10	23.92	16.82	2.45	19.27	11.00	3.90	0.72	4.62	23.98
4	7	1	7.10	24.47	17.37	2.58	19.95	11.50	4.40	0.75	5.15	25.81
4	7	2	7.10	20.86	13.76	0.98	14.74	11.16	4.06	0.33	4.39	29.78
4	7	3	7.00	22.72	15.72	1.20	16.92	10.96	3.96	0.39	4.35	25.71
4	7	4	7.10	21.24	14.14	2.72	16.86	9.78	2.68	0.93	3.61	21.41
4	7	5	7.10	26.18	19.08	1.03	20.11	12.75	5.65	0.28	5.93	29.49

Experiment #1 Diagnostic Leaf Tissue Analysis

Trt	Rep	TKN (mg/L)	P (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Zn (mg/L)	Mn (mg/L)	Cu (mg/L)	Fe (mg/L)
1	1	14150	3151	43860	13560	9640	45.21	83.4	6.32	277.4
1	2	13400	2906	44100	14060	9660	32.71	77.3	3.26	166.1
1	3	14400	3344	48120	14050	9650	37.93	90.8	3.44	164.7
2	1	11850	2928	44820	13930	9240	38.3	124.4	3.75	86
2	2	13200	3227	46100	13760	9880	41.37	117.2	4.19	125.4
2	3	12650	3024	41800	15630	11130	52.8	153.5	3.89	237.8
3	1	12550	3178	42130	15150	11020	65.6	201.3	4.35	396
3	2	12700	3191	45500	15070	10300	53	165.8	4.6	208.8
3	3	12900	3047	45640	14880	10530	49.05	164.7	3.87	240.2
4	1	13200	3385	43560	14470	9300	46.01	149	4.61	126.4
4	2	13800	3755	46570	16330	11310	71.4	208.6	4.94	341.7
4	3	12750	3150	44270	16420	10890	59.5	184	4.19	238.2
5	1	12650	3371	41720	15510	9880	47.78	138.7	3.77	112.3
5	2	12700	3093	44530	16000	10170	56.5	149.6	3.64	197.1
5	3	13700	3262	41910	14890	9550	50.8	136.2	4.12	133.1
6	1	13400	3210	42720	14090	9370	39.89	109.5	3.28	117.4
6	2	12600	3113	41440	15790	10190	48.23	126.5	3.54	143.1
6	3	13300	3503	40700	16710	11290	71.7	166.3	4.57	306.3
7	1	11850	3036	39350	15600	9820	40.34	110.6	3.12	121.7
7	2	12750	3190	43080	15300	9650	44.04	107.5	3.42	104.9
7	3	13350	3134	41140	15890	10180	44.71	113.5	4.78	145.1

Plant Measurements

Number (#)	Plant Height (cm)	Plant Width (cm)	Plant Size (cm)	Plant Height (in)	Plant Width (in)	Plant Size (in)	Number of Flowers
1 1 1	48.3	22.9	35.6	19	9	14.0	2
1 1 2	45.7	24.1	34.9	18	9.5	13.8	3
1 1 3	40.6	21.6	31.1	16	8.5	12.3	0
1 1 4	55.9	21.6	38.7	22	8.5	15.3	3
1 1 5	48.3	21.6	34.9	19	8.5	13.8	0
1 2 1	55.9	24.1	40.0	22	9.5	15.8	0
1 2 2	45.7	22.9	34.3	18	9	13.5	1
1 2 3	30.5	17.8	24.1	12	7	9.5	1
1 2 4	63.5	25.4	44.5	25	10	17.5	3
1 2 5	63.5	21.6	42.5	25	8.5	16.8	0
1 3 1	57.2	24.1	40.6	22.5	9.5	16.0	2
1 3 2	66.0	25.4	45.7	26	10	18.0	2
1 3 3	53.3	30.5	41.9	21	12	16.5	0
1 3 4	66.0	26.7	46.4	26	10.5	18.3	2
1 3 5	35.6	19.1	27.3	14	7.5	10.8	0
1 4 1	40.6	20.3	30.5	16	8	12.0	2
1 4 2	58.4	30.5	44.5	23	12	17.5	4
1 4 3	50.8	24.1	37.5	20	9.5	14.8	2
1 4 4	54.6	21.6	38.1	21.5	8.5	15.0	0
1 4 5	50.8	20.3	35.6	20	8	14.0	1
1 5 1	61.0	21.6	41.3	24	8.5	16.3	2
1 5 2	48.3	16.5	32.4	19	6.5	12.8	2
1 5 3	55.9	25.4	40.6	22	10	16.0	1
1 5 4	45.7	21.6	33.7	18	8.5	13.3	2
1 5 5	40.6	21.6	31.1	16	8.5	12.3	1
1 6 1	43.2	22.9	33.0	17	9	13.0	0
1 6 2	41.9	22.9	32.4	16.5	9	12.8	1

1 6 3	38.1	20.3	29.2	15	8	11.5	0
1 6 4	50.8	22.9	36.8	20	9	14.5	3
1 6 5	30.5	22.9	26.7	12	9	10.5	1
1 7 1	58.4	19.1	38.7	23	7.5	15.3	1
1 7 2	35.6	17.8	26.7	14	7	10.5	1
1 7 3	45.7	21.6	33.7	18	8.5	13.3	0
1 7 4	53.3	15.2	34.3	21	6	13.5	2
1 7 5	43.2	21.6	32.4	17	8.5	12.8	2
2 1 1	45.7	22.9	34.3	18	9	13.5	3
2 1 2	27.9	21.6	24.8	11	8.5	9.8	2
2 1 3	58.4	22.9	40.6	23	9	16.0	0
2 1 4	43.2	17.8	30.5	17	7	12.0	2
2 1 5	38.1	22.9	30.5	15	9	12.0	2
2 2 1	59.7	24.1	41.9	23.5	9.5	16.5	1
2 2 2	63.5	21.6	42.5	25	8.5	16.8	2
2 2 3	30.5	24.1	27.3	12	9.5	10.8	2
2 2 4	40.6	21.6	31.1	16	8.5	12.3	2
2 2 5	45.7	26.7	36.2	18	10.5	14.3	0
2 3 1	45.7	22.9	34.3	18	9	13.5	0
2 3 2	49.5	20.3	34.9	19.5	8	13.8	1
2 3 3	48.3	21.6	34.9	19	8.5	13.8	0
2 3 4	62.2	22.9	42.5	24.5	9	16.8	0
2 3 5	55.9	24.1	40.0	22	9.5	15.8	3
2 4 1	43.2	17.8	30.5	17	7	12.0	1
2 4 2	53.3	26.7	40.0	21	10.5	15.8	0
2 4 3	30.5	16.5	23.5	12	6.5	9.3	1
2 4 4	55.9	26.7	41.3	22	10.5	16.3	0
2 4 5	45.7	21.6	33.7	18	8.5	13.3	3
2 5 1	33.0	24.1	28.6	13	9.5	11.3	2
2 5 2	61.0	21.6	41.3	24	8.5	16.3	0
2 5 3	50.8	25.4	38.1	20	10	15.0	2
2 5 4	35.6	20.3	27.9	14	8	11.0	3
2 5 5	58.4	22.9	40.6	23	9	16.0	0
2 6 1	53.3	22.9	38.1	21	9	15.0	5
2 6 2	53.3	21.0	37.1	21	8.25	14.6	2
2 6 3	35.6	20.3	27.9	14	8	11.0	0
2 6 4	48.3	19.1	33.7	19	7.5	13.3	4
2 6 5	54.6	21.6	38.1	21.5	8.5	15.0	1
2 7 1	33.0	16.5	24.8	13	6.5	9.8	3
2 7 2	30.5	20.3	25.4	12	8	10.0	0
2 7 3	49.5	19.1	34.3	19.5	7.5	13.5	0
2 7 4	40.6	20.3	30.5	16	8	12.0	2
2 7 5	45.7	20.3	33.0	18	8	13.0	0
3 1 1	58.4	21.6	40.0	23	8.5	15.8	1
3 1 2	64.8	21.6	43.2	25.5	8.5	17.0	1
3 1 3	48.3	24.1	36.2	19	9.5	14.3	0
3 1 4	58.4	21.6	40.0	23	8.5	15.8	1
3 1 5	61.0	20.3	40.6	24	8	16.0	0
3 2 1	38.1	22.9	30.5	15	9	12.0	1
3 2 2	48.3	22.2	35.2	19	8.75	13.9	0
3 2 3	53.3	16.5	34.9	21	6.5	13.8	0
3 2 4	57.2	22.9	40.0	22.5	9	15.8	1
3 2 5	61.0	25.4	43.2	24	10	17.0	0
3 3 1	61.0	21.6	41.3	24	8.5	16.3	3
3 3 2	53.3	20.3	36.8	21	8	14.5	2
3 3 3	43.2	19.1	31.1	17	7.5	12.3	1
3 3 4	50.8	20.3	35.6	20	8	14.0	0
3 3 5	61.0	26.7	43.8	24	10.5	17.3	0
3 4 1	63.5	21.6	42.5	25	8.5	16.8	1
3 4 2	66.0	22.9	44.5	26	9	17.5	2
3 4 3	27.9	25.4	26.7	11	10	10.5	1
3 4 4	45.7	19.1	32.4	18	7.5	12.8	2
3 4 5	55.9	27.9	41.9	22	11	16.5	0
3 5 1	33.0	19.1	26.0	13	7.5	10.3	0
3 5 2	43.2	22.9	33.0	17	9	13.0	1
3 5 3	40.6	21.6	31.1	16	8.5	12.3	1
3 5 4	45.7	22.9	34.3	18	9	13.5	0
3 5 5	35.6	17.8	26.7	14	7	10.5	2
3 6 1	44.5	25.4	34.9	17.5	10	13.8	0
3 6 2	55.9	20.3	38.1	22	8	15.0	2
3 6 3	40.6	17.8	29.2	16	7	11.5	0
3 6 4	27.9	25.4	26.7	11	10	10.5	2
3 6 5	63.5	22.9	43.2	25	9	17.0	1
3 7 1	33.0	20.3	26.7	13	8	10.5	3
3 7 2	45.7	21.6	33.7	18	8.5	13.3	1

3	7	3	55.9	26.7	41.3	22	10.5	16.3	2
3	7	4	53.3	19.1	36.2	21	7.5	14.3	2
3	7	5	27.9	24.1	26.0	11	9.5	10.3	2
4	1	1	50.8	21.6	36.2	20	8.5	14.3	0
4	1	2	61.0	22.9	41.9	24	9	16.5	5
4	1	3	43.8	22.9	33.3	17.25	9	13.1	2
4	1	4	48.3	22.9	35.6	19	9	14.0	0
4	1	5	53.3	19.1	36.2	21	7.5	14.3	3
4	2	1	52.1	27.9	40.0	20.5	11	15.8	0
4	2	2	33.0	19.1	26.0	13	7.5	10.3	4
4	2	3	61.0	22.9	41.9	24	9	16.5	0
4	2	4	50.8	25.4	38.1	20	10	15.0	2
4	2	5	33.0	22.9	27.9	13	9	11.0	0
4	3	1	58.4	29.2	43.8	23	11.5	17.3	0
4	3	2	48.3	22.9	35.6	19	9	14.0	2
4	3	3	61.0	25.4	43.2	24	10	17.0	2
4	3	4	61.0	21.6	41.3	24	8.5	16.3	2
4	3	5	33.0	16.5	24.8	13	6.5	9.8	3
4	4	1	33.0	22.9	27.9	13	9	11.0	0
4	4	2	62.2	19.1	40.6	24.5	7.5	16.0	3
4	4	3	58.4	21.6	40.0	23	8.5	15.8	3
4	4	4	45.7	25.4	35.6	18	10	14.0	0
4	4	5	53.3	22.9	38.1	21	9	15.0	0
4	5	1	45.7	22.9	34.3	18	9	13.5	0
4	5	2	58.4	22.9	40.6	23	9	16.0	2
4	5	3	53.3	25.4	39.4	21	10	15.5	2
4	5	4	45.7	25.4	35.6	18	10	14.0	2
4	5	5	53.3	26.7	40.0	21	10.5	15.8	0
4	6	1	58.4	20.3	39.4	23	8	15.5	1
4	6	2	33.0	22.9	27.9	13	9	11.0	2
4	6	3	35.6	16.5	26.0	14	6.5	10.3	2
4	6	4	52.1	19.1	35.6	20.5	7.5	14.0	0
4	6	5	58.4	21.6	40.0	23	8.5	15.8	1
4	7	1	45.1	17.8	31.4	17.75	7	12.4	2
4	7	2	33.0	20.3	26.7	13	8	10.5	1
4	7	3	35.6	21.6	28.6	14	8.5	11.3	0
4	7	4	48.3	19.7	34.0	19	7.75	13.4	7
4	7	5	55.9	20.3	38.1	22	8	15.0	2

APPENDIX C
PLANT TRIAL EXPERIMENT #2 DATA

Physical Properties Test Experiment #2

First Rep

Treatment #:	Drained Volume (ml)	Bag Weight (g)	Wet Weight (g)	Dry Weight (g)	Total Porosity (%)	Container Capacity (%)	Moisture Content (%)	Air Space (%)	Bulk Density (g/cc)
1	135.0	7.1	466.6	82.1	76.4	56.5	82.4	19.9	0.12
2	170.0	7.2	487.9	168.3	72.0	47.0	65.5	25.0	0.25
3	135.0	7.2	468.4	65.8	79.1	59.2	86.0	19.9	0.10
4	175.0	7.1	613.5	249.3	79.3	53.6	59.4	25.7	0.37
5	140.0	7.0	573.6	235.9	70.3	49.7	58.9	20.6	0.35
6	175.0	7.2	628.9	338.5	68.4	42.7	46.2	25.7	0.50
7	135.0	7.1	488.7	107.9	75.9	56.0	77.9	19.9	0.16

Second Rep

1	175.0	7.1	405.5	73.6	74.5	48.8	81.9	25.7	0.11
2	220.0	7.1	459.0	149.0	77.9	45.6	67.5	32.4	0.22
3	140.0	7.1	472.0	68.7	79.9	59.3	85.4	20.6	0.10
4	155.0	7.1	631.2	262.4	77.0	54.2	58.4	22.8	0.39
5	140.0	7.1	541.7	212.8	69.0	48.4	60.7	20.6	0.31
6	155.0	7.1	680.8	387.8	65.9	43.1	43.0	22.8	0.57
7	140.0	7.1	476.9	114.7	73.9	53.3	76.0	20.6	0.17

Third Rep

1	138.0	7.2	438.4	73.7	73.9	53.6	83.2	20.3	0.11
2	140.0	7.2	521.7	187.5	69.7	49.1	64.1	20.6	0.28
3	130.0	7.1	462.5	66.6	77.3	58.2	85.6	19.1	0.10
4	160.0	7.1	618.4	251.8	77.4	53.9	59.3	23.5	0.37
5	105.0	7.2	558.1	216.7	65.6	50.2	61.2	15.4	0.32
6	160.0	7.2	652.9	346.7	68.6	45.0	46.9	23.5	0.51
7	115.0	7.2	486.0	117.1	71.2	54.3	75.9	16.9	0.17

pH and SS Monitoring Experiment #2

Treatment #	A		B		C	
	pH	SS	pH	SS	pH	SS
111	5.0	0.95	5.12	0.24	4.7	0.82
113	4.4	1.44	4.55	0.37	4.1	0.5
122	7.1	1.15	6.36	0.4	6.2	0.3
124	7.0	1.50	6.38	0.36	6.3	0.57
154	3.4	1.20	3.35	0.55	3.5	0.82
173	5.1	1.10	5.26	0.68	4.8	0.98
175	5.8	1.41	5.22	0.38	5	0.78
211	5.1	1.15	4.7	0.58	4.4	0.64
213	5.1	0.99	4.19	0.32	4.2	0.5
221	6.9	1.90	6.3	0.48	6.2	0.41
223	7.1	1.00	6.4	0.42	6.5	0.64
233	3.5	1.30	3.3	0.64	3.4	0.6
235	3.4	1.46	3.6	0.61	3.4	0.52
245	6.9	1.39	6.7	0.46	6.3	0.41
255	3.5	1.23	3.4	0.46	3.4	0.6
265	6.5	1.45	6.6	0.26	6.1	0.72
271	6.2	1.15	5.1	0.67	4.8	0.88
274	6.6	1.30	5.5	0.62	5.2	0.62
331	3.1	1.45	3.3	0.52	3.4	0.6
333	3.2	3.00	3.2	0.6	3.2	0.7
342	6.9	1.65	6.8	0.52	6.1	0.68
354	3.7	1.95	3.4	0.39	3.3	0.59
361	6.7	1.25	6.4	0.36	5.9	0.35
411	4.1	1.05	3.9	0.4	4	0.7
423	6.9	1.50	6.2	0.39	6.1	0.35
431	3.3	1.45	3.2	0.5	3.4	0.65
441	7.0	1.91	6.4	0.4	6.4	0.57
443	6.8	2.05	6.5	0.56	6.2	0.64
445	7.1	1.35	6.5	0.66	6	1.6
453	3.3	1.35	3.5	0.44	3.4	0.62
454	3.4	1.54	3.2	0.68	3.4	0.61
462	6.8	1.31	6.5	0.44	6.3	0.56
463	6.6	1.30	6.4	0.59	6	0.46
464	6.5	1.65	6.4	0.48	6.3	0.56
473	6.6	1.16	5.5	0.32	5.8	0.46
	JULY 25		2-Aug		10-Aug	

Plant Yield Results Experiment #2

Number #			Bag Weight (g)	Whole Plant Fresh Weight w/bag (g)	Whole Plant Fresh Weight (g)	Whole Plant Dry Weight w/bag (g)	Whole Plant Dry Weight (g)	Percent Dry Matter (%)
1	1	1	7.30	49.10	41.80	14.20	7.47	17.87
1	1	2	7.30	40.90	33.60	15.60	8.87	26.40
1	1	3	7.30	52.00	44.70	7.10	0.37	0.83
1	1	4	7.30	42.50	35.20	13.50	6.77	19.23
1	1	5	7.30	55.50	48.20	17.50	10.77	22.34
1	2	1	7.30	58.30	51.00	19.10	12.37	24.25
1	2	2	7.30	43.90	36.60	14.90	8.17	22.32
1	2	3	7.30	61.00	53.70	18.30	11.57	21.55
1	2	4	7.30	58.00	50.70	19.00	12.27	24.20
1	2	5	7.30	54.50	47.20	17.40	10.67	22.61
1	3	1	7.30	40.60	33.30	15.00	8.27	24.83
1	3	2	7.30	37.30	30.00	13.10	6.37	21.23
1	3	3	7.30	41.70	34.40	15.80	9.07	26.37
1	3	4	7.30	43.50	36.20	15.10	8.37	23.12
1	3	5	7.30	33.40	26.10	12.10	5.37	20.57
1	4	1	7.30	53.90	46.60	18.00	11.27	24.18
1	4	2	7.30	46.30	39.00	15.60	8.87	22.74
1	4	3	7.30	45.00	37.70	15.70	8.97	23.79
1	4	4	7.30	45.20	37.90	16.00	9.27	24.46
1	4	5	7.30	39.70	32.40	13.40	6.67	20.59
1	5	1	7.30	50.10	42.80	15.50	8.77	20.49
1	5	2	7.30	36.20	28.90	13.40	6.67	23.08
1	5	3	7.30	48.60	41.30	16.80	10.07	24.38
1	5	4	7.30	42.00	34.70	15.20	8.47	24.41
1	5	5	7.30	26.90	19.60	11.70	4.97	25.36
1	6	1	7.30	40.10	32.80	15.00	8.27	25.21
1	6	2	7.30	34.50	27.20	15.80	9.07	33.35
1	6	3	7.30	42.20	34.90	14.20	7.47	21.40
1	6	4	7.30	40.60	33.30	15.00	8.27	24.83
1	6	5	7.30	49.00	41.70	17.30	10.57	25.35
1	7	1	7.30	46.40	39.10	15.50	8.77	22.43
1	7	2	7.30	58.20	50.90	17.70	10.97	21.55
1	7	3	7.30	45.30	38.00	15.10	8.37	22.03
1	7	4	7.30	47.10	39.80	16.80	10.07	25.30
1	7	5	7.30	57.90	50.60	17.80	11.07	21.88
2	1	1	7.30	48.70	41.40	16.00	9.27	22.39
2	1	2	7.30	51.50	44.20	16.40	9.67	21.88
2	1	3	7.30	53.10	45.80	17.00	10.27	22.42
2	1	4	7.30	44.10	36.80	15.80	9.07	24.65
2	1	5	7.30	47.50	40.20	14.60	7.87	19.58
2	2	1	7.30	44.90	37.60	15.00	8.27	21.99
2	2	2	7.30	53.10	45.80	17.70	10.97	23.95
2	2	3	7.30	47.00	39.70	16.60	9.87	24.86
2	2	4	7.30	43.70	36.40	15.70	8.97	24.64
2	2	5	7.30	45.70	38.40	16.10	9.37	24.40
2	3	1	7.30	45.60	38.30	16.40	9.67	25.25
2	3	2	7.30	26.40	19.10	11.70	4.97	26.02
2	3	3	7.30	33.40	26.10	13.00	6.27	24.02
2	3	4	7.30	38.00	30.70	15.50	8.77	28.57
2	3	5	7.30	35.30	28.00	14.00	7.27	25.96
2	4	1	7.30	46.70	39.40	16.10	9.37	23.78
2	4	2	7.30	41.90	34.60	14.70	7.97	23.03
2	4	3	7.30	60.00	52.70	19.60	12.87	24.42
2	4	4	7.30	51.30	44.00	17.20	10.47	23.80
2	4	5	7.30	44.30	37.00	15.80	9.07	24.51
2	5	1	7.30	44.80	37.50	16.30	9.57	25.52
2	5	2	7.30	45.80	38.50	16.00	9.27	24.08
2	5	3	7.30	37.90	30.60	14.00	7.27	23.76
2	5	4	7.30	39.10	31.80	14.70	7.97	25.06
2	5	5	7.30	43.20	35.90	16.20	9.47	26.38
2	6	1	7.30	49.40	42.10	15.70	8.97	21.31
2	6	2	7.30	42.70	35.40	15.00	8.27	23.36
2	6	3	7.30	39.10	31.80	15.00	8.27	26.01
2	6	4	7.30	57.90	50.60	19.20	12.47	24.64
2	6	5	7.30	32.00	24.70	12.60	5.87	23.77
2	7	1	7.30	55.05	47.75	16.80	10.07	21.09
2	7	2	7.30	58.90	51.60	19.10	12.37	23.97
2	7	3	7.30	54.62	47.32	18.60	11.87	25.08
2	7	4	7.30	53.70	46.40	17.80	11.07	23.86
2	7	5	7.30	58.30	51.00	17.70	10.97	21.51

3	1	1	7.30	44.20	36.90	14.90	8.17	22.14
3	1	2	7.30	44.70	37.40	15.40	8.67	23.18
3	1	3	7.30	42.50	35.20	14.40	7.67	21.79
3	1	4	7.30	46.70	39.40	15.50	8.77	22.26
3	1	5	7.30	59.40	52.10	19.40	12.67	24.32
3	2	1	7.30	49.00	41.70	16.10	9.37	22.47
3	2	2	7.30	45.10	37.80	16.10	9.37	24.79
3	2	3	7.30	51.00	43.70	17.10	10.37	23.73
3	2	4	7.30	52.20	44.90	15.80	9.07	20.20
3	2	5	7.30	43.10	35.80	14.60	7.87	21.98
3	3	1	7.30	37.10	29.80	14.20	7.47	25.07
3	3	2	7.30	38.10	30.80	14.60	7.87	25.55
3	3	3	7.30	30.40	23.10	12.40	5.67	24.55
3	3	4	7.30	35.60	28.30	13.70	6.97	24.63
3	3	5	7.30	41.20	33.90	15.30	8.57	25.28
3	4	1	7.30	41.00	33.70	16.30	9.57	28.40
3	4	2	7.30	47.80	40.50	16.30	9.57	23.63
3	4	3	7.30	44.00	36.70	15.90	9.17	24.99
3	4	4	7.30	50.00	42.70	16.30	9.57	22.41
3	4	5	7.30	43.10	35.80	14.40	7.67	21.42
3	5	1	7.30	39.20	31.90	14.90	8.17	25.61
3	5	2	7.30	29.27	21.97	12.90	6.17	28.08
3	5	3	7.30	34.10	26.80	13.30	6.57	24.51
3	5	4	7.30	39.90	32.60	15.20	8.47	25.98
3	5	5	7.30	36.50	29.20	13.80	7.07	24.21
3	6	1	7.30	46.20	38.90	17.10	10.37	26.66
3	6	2	7.30	48.20	40.90	16.70	9.97	24.38
3	6	3	7.30	49.80	42.50	15.90	9.17	21.58
3	6	4	7.30	48.10	40.80	15.40	8.67	21.25
3	6	5	7.30	43.20	35.90	14.30	7.57	21.09
3	7	1	7.00	52.8	45.80	17.80	11.07	24.17
3	7	2	7.00	50	43.00	17.10	10.37	24.12
3	7	3	7.00	56.2	49.20	17.30	10.57	21.48
3	7	4	7.00	51.4	44.40	17.20	10.47	23.58
3	7	5	7.00	56.10	49.10	17.10	10.37	21.12
4	1	1	7.00	44.40	37.40	15.50	8.77	23.45
4	1	2	7.00	47.80	40.80	14.70	7.97	19.53
4	1	3	7.00	49.00	42.00	18.00	11.27	26.83
4	1	4	7.00	47.00	40.00	15.60	8.87	22.18
4	1	5	7.00	51.00	44.00	16.40	9.67	21.98
4	2	1	7.00	53.70	46.70	18.10	11.37	24.35
4	2	2	7.00	45.60	38.60	15.60	8.87	22.98
4	2	3	7.00	40.30	33.30	15.70	8.97	26.94
4	2	4	7.00	46.10	39.10	15.70	8.97	22.94
4	2	5	7.00	46.90	39.90	14.90	8.17	20.48
4	3	1	7.00	32.00	25.00	15.00	8.27	33.08
4	3	2	7.00	40.00	33.00	13.40	6.67	20.21
4	3	3	7.00	38.30	31.30	13.80	7.07	22.59
4	3	4	7.00	40.80	33.80	17.70	10.97	32.46
4	3	5	7.00	32.10	25.10	12.60	5.87	23.39
4	4	1	7.00	52.20	45.20	15.80	9.07	20.07
4	4	2	7.00	42.60	35.60	14.50	7.77	21.83
4	4	3	7.00	56.30	49.30	18.20	11.47	23.27
4	4	4	7.00	54.10	47.10	18.30	11.57	24.56
4	4	5	7.00	50.00	43.00	16.60	9.87	22.95
4	5	1	7.00	38.10	31.10	13.00	6.27	20.16
4	5	2	7.00	38.20	31.20	14.10	7.37	23.62
4	5	3	7.00	36.50	29.50	13.70	6.97	23.63
4	5	4	7.00	38.60	31.60	13.40	6.67	21.11
4	5	5	7.00	44.30	37.30	15.40	8.67	23.24
4	6	1	7.00	44.30	37.30	15.30	8.57	22.98
4	6	2	7.00	42.00	35.00	15.10	8.37	23.91
4	6	3	7.00	39.20	32.20	13.80	7.07	21.96
4	6	4	7.00	57.10	50.10	19.30	12.57	25.09
4	6	5	7.00	43.10	36.10	15.10	8.37	23.19
4	7	1	7.00	65.00	58.00	21.10	14.37	24.78
4	7	2	7.00	50.00	43.00	15.80	9.07	21.09
4	7	3	7.00	53.80	46.80	16.60	9.87	21.09
4	7	4	7.00	63.42	56.42	21.00	14.27	25.29
4	7	5	7.00	66.60	59.60	20.90	14.17	23.78

Plant Measurements Experiment #2

Number (#)	Plant Height (cm)	Plant Width (cm)	Plant Size (cm)	Plant Height (in)	Plant Width (in)	Plant size (in)	Flower Spikes (#)
1 1 1	94.0	34.3	64.14	37	13.5	25.3	3
1 1 2	73.7	38.1	55.88	29	15	22.0	4
1 1 3	106.7	33.0	69.85	42	13	27.5	4
1 1 4	104.1	31.8	67.95	41	12.5	26.8	1
1 1 5	110.5	31.8	71.12	43.5	12.5	28.0	5
1 2 1	76.2	34.3	55.25	30	13.5	21.8	7
1 2 2	91.4	34.3	62.87	36	13.5	24.8	3
1 2 3	95.3	34.3	64.77	37.5	13.5	25.5	7
1 2 4	78.7	34.3	56.52	31	13.5	22.3	9
1 2 5	94.0	31.8	62.87	37	12.5	24.8	6
1 3 1	83.8	27.9	55.88	33	11	22.0	4
1 3 2	88.9	29.2	59.06	35	11.5	23.3	3
1 3 3	88.9	31.8	60.33	35	12.5	23.8	2
1 3 4	76.2	33.0	54.61	30	13	21.5	3
1 3 5	73.7	29.2	51.44	29	11.5	20.3	2
1 4 1	74.9	36.8	55.88	29.5	14.5	22.0	9
1 4 2	68.6	38.1	53.34	27	15	21.0	4
1 4 3	61.0	31.8	46.36	24	12.5	18.3	3
1 4 4	78.7	31.8	55.25	31	12.5	21.8	5
1 4 5	58.4	35.6	46.99	23	14	18.5	5
1 5 1	86.4	30.5	58.42	34	12	23.0	5
1 5 2	73.7	26.7	50.17	29	10.5	19.8	5
1 5 3	76.2	30.5	53.34	30	12	21.0	13
1 5 4	68.6	33.0	50.80	27	13	20.0	4
1 5 5	63.5	26.7	45.09	25	10.5	17.8	1
1 6 1	96.5	30.5	63.50	38	12	25.0	3
1 6 2	76.2	31.8	53.98	30	12.5	21.3	4
1 6 3	71.1	34.3	52.71	28	13.5	20.8	7
1 6 4	99.1	31.8	65.41	39	12.5	25.8	1
1 6 5	81.3	36.8	59.06	32	14.5	23.3	6
1 7 1	82.6	30.5	56.52	32.5	12	22.3	5
1 7 2	91.4	33.0	62.23	36	13	24.5	7
1 7 3	95.3	31.8	63.50	37.5	12.5	25.0	2
1 7 4	99.1	31.8	65.41	39	12.5	25.8	5
1 7 5	86.4	34.3	60.33	34	13.5	23.8	3
2 1 1	69.9	35.6	52.71	27.5	14	20.8	4
2 1 2	68.6	31.8	50.17	27	12.5	19.8	5
2 1 3	101.6	34.3	67.95	40	13.5	26.8	4
2 1 4	99.1	26.7	62.87	39	10.5	24.8	4
2 1 5	96.5	35.6	66.04	38	14	26.0	3
2 2 1	74.9	29.2	52.07	29.5	11.5	20.5	4
2 2 2	69.9	36.8	53.34	27.5	14.5	21.0	9
2 2 3	96.5	33.0	64.77	38	13	25.5	3
2 2 4	66.0	31.8	48.90	26	12.5	19.3	2
2 2 5	76.2	33.0	54.61	30	13	21.5	4
2 3 1	91.4	30.5	60.96	36	12	24.0	5
2 3 2	68.6	24.1	46.36	27	9.5	18.3	2
2 3 3	71.1	30.5	50.80	28	12	20.0	4
2 3 4	71.1	30.5	50.80	28	12	20.0	5
2 3 5	58.4	30.5	44.45	23	12	17.5	3
2 4 1	96.5	34.3	65.41	38	13.5	25.8	3
2 4 2	109.2	34.3	71.76	43	13.5	28.3	3
2 4 3	81.3	35.6	58.42	32	14	23.0	6
2 4 4	90.2	36.8	63.50	35.5	14.5	25.0	7
2 4 5	91.4	31.8	61.60	36	12.5	24.3	4
2 5 1	83.8	34.3	59.06	33	13.5	23.3	6
2 5 2	83.8	31.8	57.79	33	12.5	22.8	5
2 5 3	87.6	31.8	59.69	34.5	12.5	23.5	3
2 5 4	71.1	30.5	50.80	28	12	20.0	5
2 5 5	83.8	30.5	57.15	33	12	22.5	3
2 6 1	80.0	31.8	55.88	31.5	12.5	22.0	3
2 6 2	66.0	35.6	50.80	26	14	20.0	2
2 6 3	68.6	26.7	47.63	27	10.5	18.8	2
2 6 4	63.5	40.6	52.07	25	16	20.5	5
2 6 5	43.2	35.6	39.37	17	14	15.5	0
2 7 1	91.4	33.0	62.23	36	13	24.5	3
2 7 2	101.6	31.8	66.68	40	12.5	26.3	5
2 7 3	78.7	31.8	55.25	31	12.5	21.8	7
2 7 4	71.1	38.1	54.61	28	15	21.5	7
2 7 5	73.7	38.1	55.88	29	15	22.0	6

3 1 1	81.3	22.9	52.07	32	9	20.5	4
3 1 2	83.8	35.6	59.69	33	14	23.5	4
3 1 3	91.4	31.8	61.60	36	12.5	24.3	2
3 1 4	83.8	31.8	57.79	33	12.5	22.8	3
3 1 5	111.8	31.8	71.76	44	12.5	28.3	3
3 2 1	88.9	31.8	60.33	35	12.5	23.8	4
3 2 2	78.7	36.8	57.79	31	14.5	22.8	6
3 2 3	71.1	26.7	48.90	28	10.5	19.3	4
3 2 4	81.3	34.3	57.79	32	13.5	22.8	5
3 2 5	86.4	29.2	57.79	34	11.5	22.8	3
3 3 1	99.1	29.2	64.14	39	11.5	25.3	2
3 3 2	91.4	34.3	62.87	36	13.5	24.8	3
3 3 3	43.2	27.9	35.56	17	11	14.0	1
3 3 4	78.7	29.2	53.98	31	11.5	21.3	3
3 3 5	63.5	33.0	48.26	25	13	19.0	6
3 4 1	100.3	35.6	67.95	39.5	14	26.8	4
3 4 2	88.9	33.0	60.96	35	13	24.0	3
3 4 3	94.0	30.5	62.23	37	12	24.5	4
3 4 4	63.5	35.6	49.53	25	14	19.5	7
3 4 5	71.1	34.3	52.71	28	13.5	20.8	5
3 5 1	68.6	36.8	52.71	27	14.5	20.8	4
3 5 2	71.1	31.8	51.44	28	12.5	20.3	4
3 5 3	71.1	33.0	52.07	28	13	20.5	3
3 5 4	99.1	33.0	66.04	39	13	26.0	3
3 5 5	85.1	26.7	55.88	33.5	10.5	22.0	3
3 6 1	63.5	33.0	48.26	25	13	19.0	4
3 6 2	111.8	35.6	73.66	44	14	29.0	2
3 6 3	83.8	33.0	58.42	33	13	23.0	4
3 6 4	61.0	34.3	47.63	24	13.5	18.8	6
3 6 5	66.0	30.5	48.26	26	12	19.0	4
3 7 1	88.9	30.5	59.69	35	12	23.5	7
3 7 2	101.6	33.0	67.31	40	13	26.5	4
3 7 3	96.5	35.6	66.04	38	14	26.0	3
3 7 4	91.4	30.5	60.96	36	12	24.0	6
3 7 5	106.7	30.5	68.58	42	12	27.0	4
4 1 1	91.4	30.5	60.96	36	12	24.0	4
4 1 2	66.0	34.3	50.17	26	13.5	19.8	7
4 1 3	72.4	35.6	53.98	28.5	14	21.3	6
4 1 4	81.3	31.8	56.52	32	12.5	22.3	4
4 1 5	96.5	34.3	65.41	38	13.5	25.8	4
4 2 1	63.5	35.6	49.53	25	14	19.5	7
4 2 2	73.7	30.5	52.07	29	12	20.5	4
4 2 3	50.8	38.1	44.45	20	15	17.5	3
4 2 4	66.0	31.8	48.90	26	12.5	19.3	5
4 2 5	78.7	34.3	56.52	31	13.5	22.3	4
4 3 1	55.9	31.8	43.82	22	12.5	17.3	9
4 3 2	94.0	17.8	55.88	37	7	22.0	2
4 3 3	63.5	30.5	46.99	25	12	18.5	3
4 3 4	71.1	34.3	52.71	28	13.5	20.8	5
4 3 5	86.4	29.2	57.79	34	11.5	22.8	3
4 4 1	76.2	36.8	56.52	30	14.5	22.3	4
4 4 2	66.0	31.8	48.90	26	12.5	19.3	4
4 4 3	81.3	38.1	59.69	32	15	23.5	3
4 4 4	69.9	31.8	50.80	27.5	12.5	20.0	7
4 4 5	88.9	35.6	62.23	35	14	24.5	3
4 5 1	81.3	29.2	55.25	32	11.5	21.8	4
4 5 2	71.1	31.8	51.44	28	12.5	20.3	2
4 5 3	91.4	20.3	55.88	36	8	22.0	4
4 5 4	68.6	29.2	48.90	27	11.5	19.3	5
4 5 5	71.1	33.0	52.07	28	13	20.5	7
4 6 1	91.4	29.2	60.33	36	11.5	23.8	3
4 6 2	71.1	30.5	50.80	28	12	20.0	4
4 6 3	92.7	33.0	62.87	36.5	13	24.8	2
4 6 4	81.3	31.8	56.52	32	12.5	22.3	7
4 6 5	91.4	27.9	59.69	36	11	23.5	3
4 7 1	86.4	34.3	60.33	34	13.5	23.8	4
4 7 2	86.4	34.3	60.33	34	13.5	23.8	3
4 7 3	101.6	35.6	68.58	40	14	27.0	7
4 7 4	76.2	36.8	56.52	30	14.5	22.3	10
4 7 5	86.4	24.1	55.25	34	9.5	21.8	4

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BIOGRAPHICAL SKETCH

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