Engineering, Structures and Innovations

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Section Editor and Moderator

In-Field Subsurface-Drip Evaluation

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Index Words: subsurface drip irrigation (SDI), application uniformity, pressure compensation

Significance to the Industry: The purpose of this study was to develop and validate an *in-situ* testing methodology for evaluating application uniformity of pressure-compensated subsurface drip irrigation (SDI) product in Alabama. Given an appropriate methodology, operating-pressure tests could be performed to evaluate whether emitter clogging or terrain slope impacts application uniformity. While producers are aware of the benefits of implementing SDI, those that manage such irrigation must ensure proper operation to garner SDI benefits; primarily maximized crop yield. Results may contribute to the development of an industry-recognized testing standard for SDI evaluation which minimizes in-field soil disturbance to ensure SDI systems are operating at peak performance.

Nature of Work: Subsurface drip irrigation (SDI) is an irrigation technology that delivers precise amounts of water to agronomic crops within root zone via underground tape or tubing ("drip tape"). Drip tape offers water-use savings through reduced water application volume and reduced evaporative losses since water is applied within the root zone subsurface. These products discharge irrigation water in a controlled manner through built-in emitters along the tape. The emitters are manufactured to have little or no flow variability between one another leading to efficient water distribution. For pressure compensated tape, emitter output is supposed to be uniform regardless of the water pressure within the tape. This uniform performance is desired for agronomic applications since fields are typically not level allowing gravity to impact tape pressure along its length.

While much research has focused on improved agronomic growth, relatively few studies have investigated the longevity of the drip tape systems. Ayars *et al*. (2) operated several SDI experimentation plots throughout California over a fifteen-year period with crops such as cantaloupe, corn, cotton, and tomato. They reported that some of their plots performed comparably to the initial installation for nine years as long as proper maintenance of the systems were followed.

A commonly-referenced standard pertaining to SDI performance is ANSI/ASABE S553 (1). This testing standard outlines methods for certifying performance and quality characteristics of drip tape products. The methods were developed such that quality tests could take place under laboratory conditions---specifically, the tape product should be above ground in a controlled environment as opposed to field conditions. When Lesikar *et al.* (3) followed this standard to evaluate drip-tape flow rates used for wastewater effluent for up to five years, they had to excavate the soil so that small catch pans could be placed underneath each emitter in order to perform in-field application uniformity tests. However, in an effort to protect neighboring plants, Steele *et al.* (4) employed a less-intrusive method of exposing only a few emitters to perform in-field uniformity testing. Catch pans were also placed under the exposed emitters with collected volumes averaged and then extrapolated to an equivalent flow rate based on manufacturer's stated product specifications.

Recently, manufacturers have developed SDI products that are "pressure compensated," meaning that regardless of pressure variations within the tape caused by system surges or rolling terrain, emitter discharge rates are uniform. There is a lack of research literature available regarding pressure-compensated SDI performance. The primary reason could be that pressure-compensated SDI products are still relatively new, and manufacturers continue to refine their designs of new products.
At the Tennessee Valley Research and Extension Center (TVREC, Belle Mina, Alabama), precision-agriculture practices involve the utilization of pressure-compensated SDI to grow cotton and other crops. Supplemental research indicated that moisture variability existed in one experiment plot in ways that suggest either clogged emitters or flow rate differences between emitters with pressure compensated technology. The study site has a 0% to 5% percent slope that can influence water distribution via the SDI if the pressure compensation feature does not function correctly. This product has been in operation since 2004 but has not been evaluated for specific in-field performance; however, as a long-term experiment is being conducted on this test plot, major excavation of the planting zone is not an ideal option. No standard engineering procedures have been developed to evaluate the *in-situ* performance of SDI tape. Thereby, a method is needed evaluate *in-situ* water delivery uniformity of SDI products. Such a testing practice could then be used to determine whether emitter clogging or terrain slope is impacting application uniformity.

The test plot at TVREC is irrigated using a commercially-available pressure-compensated SDI product. For this product, each emitter was rated by the manufacturer to provide 0.26 gallon per hour (2.5 percent coefficient of variation) at 2.0-ft spacing (Netafim USA, 2002). One of the preliminary goals for this study was to collect topographic data over the test site for development of a digital elevation model (DEM) to establish slope across the plot. Data sampling locations would be categorized based on slope with randomization of locations within each category. The experimental design is a 4x3 randomized complete block. Five contiguous drip-tape sections, consisting of twenty emitters per section, have been randomly selected within three field-slope categories: 0 – 2%, 2 – 4%, and >4%. Each drip-tape section would be subjected to four operating pressures: 7, 11, 17, and 20 pounds per square inch (psi). One of several possible evaluation variables to be calculated is a discharge ratio which is the cumulative discharge rate compared to the nominal discharge. A ratio of 1.0 indicates ideal application uniformity, those less than 1.0 indicating less than the desired flow (emitter clogging, crimped tape, etc.), and values greater than 1.0 signifying high flow. This value may serve to quantify application efficiency in a field setting, but that part of the study will be conducted at a later date.

Results and Discussion: Topography data were collected utilizing a survey-grade GPS receiver, capable of accurately collecting elevation data. The slope model derived from this data is presented in Figure 1. The slope model implies far more testing locations are available within the 0 – 2% category with few available within the >4% treatment. However, five locations within each category were selected.
Another objective for this study was to determine whether a discharge value could be derived without collecting per-emitter discharge. Preliminary laboratory tests involved conducting pressure-response tests as per clause 8.3 of ASABE S553 (1) for 20 contiguous emitters on an unused drip tape as used in the in-field study. In addition, the tape section was elevated on one end to create a 6% slope uphill of the water supply. Information from these tests indicated that the mean discharge rate was 0.01 – 0.02 gph higher than the nominal discharge rate of 0.26 gph (Table 1). The coefficient of variation (CV) values nearly doubled from that reported by the manufacturer, suggesting that 20 emitters might not be enough for the in-field testing. Further, despite the 6% slope, emitter discharge did not vary between emitters (data not presented). This result was expected since the drip-tape samples were new. Finally, discharge ratio values were above the nominal value of 1.0; however, as these ratio values represent new drip-tape product, observed values suggest that a nominal rating ranging from 0.9 to 1.1 may be more practical for field-evaluation purposes.

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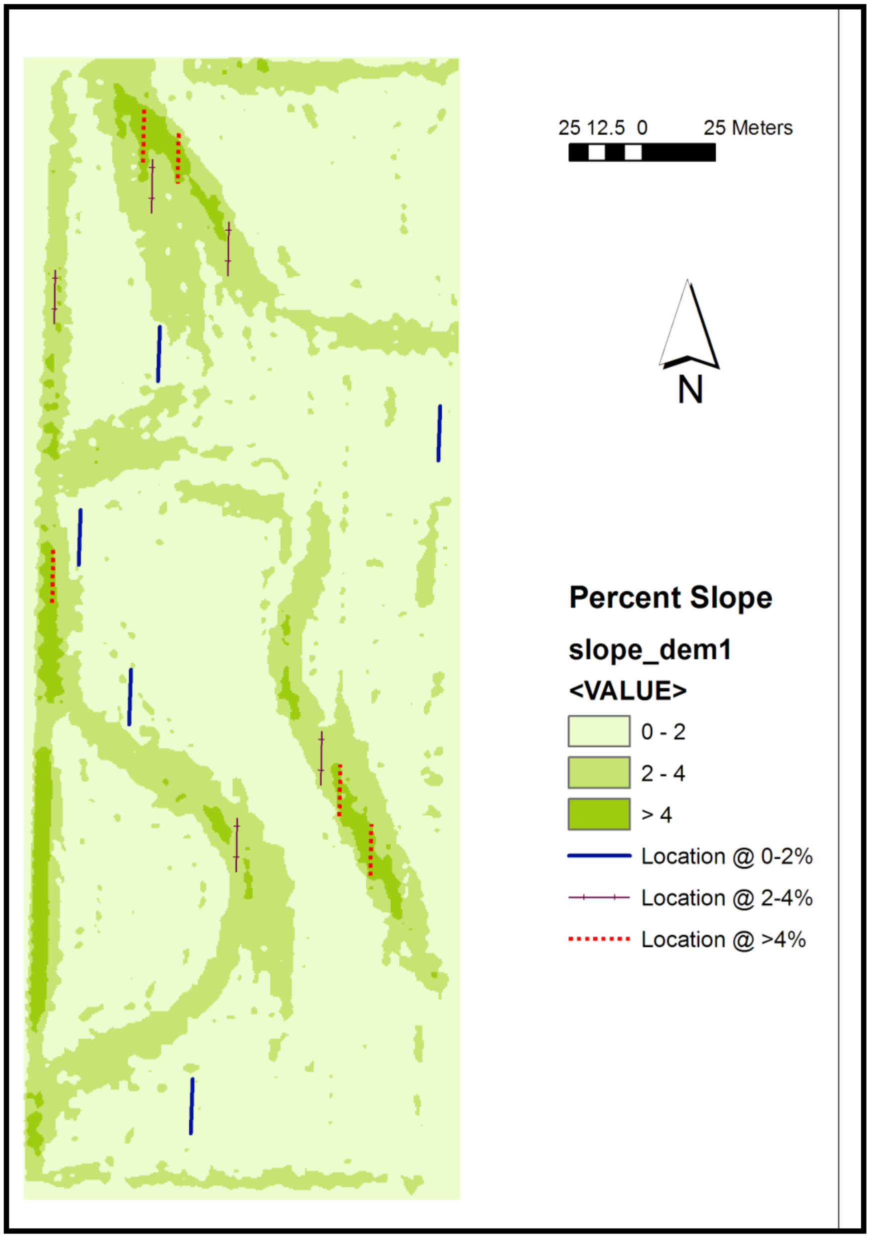

Figure 1. Illustration of slope across the test site represented as percent rise, including sampling locations according to slope category.

Table 1. Preliminary discharge emitter rates (gallons per hour) over a range of operating pressures on 20 contiguous emitters.

Operating Pressure, psi [z]	Rep 1, gph	Rep 2, gph	Rep 3, gph	Avg. Flow Rate, gph	Cumulative Discharge, gph [y]	Discharge Ratio [x]	Avg. Coefficient of Variation, %[w]
7	0.28	0.28	0.28	0.28	5.56	1.07	4.3
11	0.27	0.27	0.28	0.27	5.49	1.06	4.3
17	0.28	0.28	0.27	0.28	5.50	1.06	4.3
20	0.28	0.27	0.27	0.27	5.51	1.06	4.0

[z] Emitters were conditioned at desired operating pressure for 5 min. before collecting discharge.

[y] Discharge rate stated by the manufacturer (Netafim USA).

[x] Ratio of observed discharge to nominal discharge of 5.2 gph (0.26 gph per emitter x 20 emitters).

[w] Coefficient of variation = standard deviation of emitter discharge rates of the sample / average discharge rate of sample.

Integration of Intensive Aquaculture and Greenhouse Crop Production

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Index Words: aquaponics, horticulture, hydroponics, integrated aquaculture-agriculture

Significance to Industry: Tank effluent from intensive cultured tilapia (*Oreochromis niloticus*) was evaluated as a source of irrigation and fertilization for greenhouse crop production. Results indicate plants grown using effluent-laden water from intensive aquaculture performed similarly to plants grown with municipal and a medium-rate fertilizer application. As production costs continue to rise and environmental policies grow more stringent, effluent from intensive fish culture might provide an economical and environmentally sustainable alternative to current water use and fertilizer practices in plant production and intensive aquaculture.

Nature of Work: Integration among agricultural industries can be valuable, and in some cases improve ecosystem health, human health, increase sustainability, and produce two or more products from over-lapping resources. Beneficial aspects of integrating horticulture and aquaculture include a reduced amount of nutrients introduced into water sheds, nutrients of one system serving to meet needs for another, product diversification, re-use of water, and possibly providing food in locations suffering from a lack of food resources (5).

Currently in Alabama, 25,000 water acres are utilized in aquaculture, contributing more than $125 million in farm-gate sales (4). However, Alabama is capable of ten times the current usage, able to support 250,000 water acres for aquaculture (4). The Green Industry, in Alabama, accounts for a two billion dollar economic influx annually (6), including $250 million in farm-gate sales from approximately 850 nursery and greenhouse producers statewide (7). However, a number of concerns impact the Green Industry. For example, the entire industry is high-input/high intensity using up to 20,000 gallons of water/acre/day, with run off potentially impacting surface and ground water resources (1, 2, 8).

Previous work shows integrated intensive aquaculture and horticulture systems, production rates for aquaculture rise significantly from 6,000 – 15,000 lbs fish/acre/year to 300,000 – 800,000lbs fish/acre/year (9, 10, 11). Intensive aquaculture produces, minimally, an increase of twenty times the production rate of traditional aquacultural practices. Lastly, aquaculture and horticulture integration provides an opportunity for double-cropping, resulting in fish and horticulture crop production from some of the same resources.

On September 3, 2008, a greenhouse bedding plant production study was initiated using Nemesia Aromatica™ Blue Deep Improved *Nemesia fruticans* and Calibrachoa Cabaret™ Red *Calibrachoa* hybrid (Donated by Ball Horticulture Company). Seventy two plugs of each species were transplanted into 6 inch azalea pots (6.0 AZ traditional TW, Dillen Products/Myers Industries, Middlefield, OH), filled with a common greenhouse substrate (70% peat, 15% perlite, and 15% vermiculite) into mix depending upon treatment. Dependent variables included water source (municipal water (MW), fish effluent (FE), or a 50:50 blend) and incorporated fertilizer (1.5 lbs N/cubic yard using 12-6-6 Gro and Sho Nursery Special, The State Plant Food, Inc Dothan, AL). Treatments included 100% MW, no fertilizer; 100% FE, no fertilizer; 50:50 MW:FE, no fertilizer; 100% MW, fertilizer; 100% FE, fertilizer; and 50:50 MW:FE, fertilizer. Containers were arranged in a Randomized Complete Block Design, with 6 treatments and 12 blocks for both species. Containers were placed in a polyurethane greenhouse at the North Auburn Upper Fisheries Research Station in Auburn, Alabama. Plants were watered uniformly across treatments by hand daily as needed. Leachate measurements were taken four times throughout the study, the first 20 days after planting (DAP), each consecutive leachate test followed in one week increments.

Nile Tilapia is in production at the North Auburn Upper Fisheries Research Station. Nile tilapia is a tropical fish species tolerating water temperatures from 11-12^{oC} to 42^{oC} (52^{oF}-108^{oF}). An integrated intensive aquaculture system is in use, consisting of two 136 m^3 (4800 ft^3) volume, above ground-tanks in a 30' x 100' polyurethane greenhouse. Monitored daily are dissolved oxygen levels, temperature and amount of feed (grams). Due the fish stocking density within the tanks, water must be exchanged for maintaining optimal water quality levels. The effluent water removed is subsequently used as a source of irrigation and fertilization for greenhouse crop production. The water contains sufficient amounts of key nutrients required for plant production (Table 1), indicating that integration of horticulture crop production and intensive aquaculture is a viable proposition.

Leachates samples were collected using the Virginia Tech pour-through method measuring pH and electrical conductivity at 20, 27, 34, and 41 DAP (12). Leaf chlorophyll content was measured 17 DAP using a SPAD-502 Chlorophyll Meter (Minolta Camera Co., Ramsey NJ). Growth indices were measured 33 DAP, fresh weights and dry weights (48 hours at 155^{oF}) were recorded, foliar and substrate nutrient analysis content was recorded, and a visual root rating based on root density (1= lowest density, 5 = highest density) was taken. All data was analyzed using proc GLM, Duncan's Multiple Range Test and means comparison tests using SAS (Version 9.1; SAS Institute, Cary, NC).

Results and Discussion:

Nemesia fruticans. Leaf chlorophyll content showed differences between treatments means (Table 2). Growth indices indicated differences as well, with a block effect. 100% FE, no fertilizer (25.03b) and 100% MW, fertilizer (25.11b) showed no differences among GI, indicating that supplementing conventional fertilizer with fish effluent applications is a viable alternative. Dry weights showed differences among means, yet between 100% FE, no fertilizer and 100% MW, fertilizer, the mean for 100% FE was higher than 100% MW treatment (Table 2). Root density rating showed differences; 100% FE, no fertilizer had the highest mean value, which was different from 100% MW, fertilizer (Table 2). No block effect was detected.

***Calibrachoa* Hybrid.** Results for *Calibrachoa* hybrid were similar to *N. fruticans*. Leaf chlorophyll content was not different among means (Table 3). Growth indices indicated a wide range of mean values, with no block effect, and differences among all treatments means (Table 3). Between 100% FE, no fertilizer and 100% MW, fertilizer, means were different, MW treatment having a larger mean value. Dry weight measurements were different between treatments, with no block effect (Table 2). 100% MW, fertilizer and 100% FE, no fertilizer had similar mean values (4.41c and 4.85bc, respectively). No difference being observed indicates FE is an effective replacement for synthetic fertilizer inputs. Root ratings proved different among treatment means (Table 2).

Results of all tests show FE contains suitable nutrient composition to serve as potential replacement to synthetic fertilizers. Results are beneficial for horticultural crop growers using fish effluent would decrease cost exponentially if adopted in place of fertilizer inputs. Distinct attention has been paid to comparing 100% FE, no fertilizer and 100% MW, fertilizer. Both treatments are similar to each other, in some cases with fish effluent treatment out performing the municipal water treatment. Results show aquaculture wastewater can be used as a successful replacement to conventional fertilizer usage for the crops evaluated.

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Table 1: Fish effluent water analysis report.

Nutrient	Recorded Levels		BPM Recommended[Z] Levels
	May 20th	May 21st	
pH	5.64	7.01	4.5-6.5
EC[Y]	0.4092	0.3968	05 to 1.0
NO3-N	31.08997	27.60033	15-25
P	13.2816	13.5175	5 to 10
K	27.7474	26.6268	10 to 20
Ca	24.2997	23.1787	20 to 40
Mg	11.8191	11.3668	15 to 20
Mn	0.30556	0.26645	0.3
Cu	0.11581	0.18806	0.02
NH4-N	9.317372	8.750902	na

[Z] Best Management Practices (Yeager et al, 2007).

[Y] Electrical conductivity measured in µs/cm.

Table 2. Effects of municipal water versus fish effluent irrigaton on growth of *Nemesia fruticans*

Treatment[Z]	Leaf Chlorophyll Content[Y] 17 DAP[X]	Growth Indices[W] 33 DAP	Shoot Dry Weight (g) 50 DAP	Root Rating[U]
100% MW, No Fertilizer	34.57b[V]	13.74d	1.28d	1.16c
100% FE, No Fertilizer	36.75ab	25.03b	9.23b	4.00a
50% MW:50% FE, No Fertilize	31.52b	21.19c	4.82c	3.50ab
100% MW, Fertilizer	30.92b	25.11b	5.76c	3.16b
100% FE, Fertilizer	41.45a	29.74a	11.68a	3.75ab
50% MW:50% FW, Fertilizer	36.27ab	27.49ab	8.83b	3.92a

[Z]Treatment: MW = Municipal Water, FE = Fish Effluent, Fertilization rate is 1/2 lb N per cubic yard.

[Y]Leaf chlorophyll content quantified using a SPAD-502 Chlorophyll Meter (Minolta Camera Co., Ramsey NJ)

[X]DAP = days after planting.

[W]Growth indices [(height + width1 + width2)/3].

[V]Means followed by the same letter are not significantly different based on Duncan's Multiple Range Test.

[U]Root ratings were rated by visual assessment of density of roots systems(1 = Lowest Density, 5 = Highest Density).

Table 3. Effects of municipal water versus fish effluent irrigaton on growth of *Calibrachoa* Hybrid.

Treatment[Z]	Leaf Chlorophyll Content[Y] 17 DAP[X]	Growth Indices (cm) 33 DAP	Shoot Dry Weight (g) 50 DAP	Root Rating[U]
100% MW, No Fertilizer	37.23a	14.88f[V]	1.35e	2.83ab
100% FE, No Fertilizer	44.83a	24.19d	4.85bc	2.25b
50% MW:50% FE, No Fertilizer	40.94a	21.61e	3.34d	2.07b
100% MW, Fertilizer	38.97a	26.24c	4.41c	3.33a
100% FE, Fertilizer	45.33a	31.04a	8.07a	3.33a
50% MW:50% FW, Fertilizer	41.63a	28.45b	5.71b	2.42ab

[Z]Treatment: MW = Municipal Water, FE = Fish Effluent, Fertilization rate is 1/2 lb N per cubic yard.

[Y]Leaf chlorophyll content quantified using a SPAD-502 Chlorophyll Meter (Minolta Camera Co., Rasmey NJ).

[X]DAP = days after planting

[W]Growth indices [(height + width1 + width2)/3].

[V]Means followed by the same letter are not significantly different based on Duncan's Multiple Range Test (α= 0.05).

[U]Root ratings were rated by visual assessment of density of roots systems (1= Lowest Density, 5= Highest Density).

Designing a Growth Chamber to Monitor Transpiration

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Index Words: vapor pressure deficit, modeling, water use, stomatal response

Significance to Industry: Water is a valuable resource in the horticulture. By understanding how different species use water and respond to water deficit, growers are able to manage crops more efficiently and minimize the effect of drought. Crop models can be used to schedule irrigation and maximize water use efficiency. These models require accurate measurements of the relationship between container substrate moisture and plant water use. The developed growth chamber will permit continual measurements of plant transpiration under varying container moisture levels while controlling temperature, light and air vapor pressure.

Nature of Work: Transpiration is the loss of water vapor through the stomata. Stomata are small pores in leaves through which gas exchange occurs. Gas exchange, specifically, the movement of water vapor, oxygen, and carbon dioxide, is crucial for photosynthesis and transpiration. Photosynthesis allows plants to convert light energy into chemical energy and uses CO_2 and releases water vapor and oxygen. Transpiration is the driving force that moves water and minerals from the roots and cools the plant. Much research has been done on plant leaf and root mechanics that control the rate at which a plant transpires (Aroca, 2006). By understanding plant water use, researchers and producers can refine irrigation regimes.

In order for a plant to photosynthesize, the stomata must be open to allow gas exchange; carbon dioxide enters the leaf and oxygen exits the leaf. Along with the oxygen that escapes from the leaf, water vapor also escapes whenever there is a vapor pressure deficit (VPD). The vapor pressure deficit is defined as the difference between the vapor pressure of the surrounding air and the vapor pressure of fully saturated air, in this case air inside the leaf. Greater VPD leads to a greater the transpirational water loss. By controlling the VPD, transpiration can be controlled (Taiz and Zeiger, 2002). If the stomata are closed, the plant is able to conserve water by not transpiring, but it is also not able to photosynthesize. Furthermore if the stomata are closed the plant cannot release water vapor, a means of releasing heat input from light (Taiz and Zeiger, 2002). Transpiration chambers with supplemental lighting have been used previously to manipulate the transpiration of cuttings (Wilkerson, 2005). The objective of this research was to build a transpiration chamber in which light intensity, temperature, and

VPD are controlled and substrate moisture (gravimetrically), and stomatal response (through leaf temperature change) of seedlings are measured.

The transpiration chamber was constructed from insulated plywood with a temperature and a humidity control unit used to impose specified VPD treatments (Parameter Generation and Control, Inc., Black Mountain, NC). An adjustable light rack housed incandescent and fluorescent lights on separate circuits to allow adjustable light intensity . Twelve stations were established in the controlled environment system with each station consisting of an infrared temperature sensor, (Everest Interscience, Inc. Tuscon, AZ) to monitor leaf temperature and an electronic balance (ScoutPro OHAUS, NJ) to monitor container weight (water) loss. Two separate data acquisition systems were used to monitor leaf temperature and container weight. Container weight used was PC-based system and temperature was monitored using a Campbell's Instrument data logger.

The methods used to test the transpiration chamber included three tests. To test the gravimetric system, containers were filled with substrate (but no plants) watered, placed on scales and weight loss was recorded over a 72 hour period. To test the leaf temperature system, the temperature of black filter paper was monitored. An initial measurement of the dry filter paper was taken, then filter paper was then wetted and allowed to dry inside the chamber with the temperature sensors focused on the surface. In both tests the humidity control unit was used to control the temperature and the VPD. The third test verified that the light intensity through out the chamber was even, and that by changing the distance between the rack and the plants light intensity can be manipulated.

Research and Discussion: The system was found to effectively monitor and record the changes in substrate moisture and simulated leaf temperature. Because the chamber did not have to be opened and closed, the environmental conditions, including light intensity, temperature and VPD, were able to be set and maintained relatively constant. The system was tested with filter paper and plant-less pots of soil. As water evaporated from the filter paper, the datalogger recorded a temperature that increased and then remained steady as the filter paper dried (Figure 1). The temperature sensors and associated data acquisition system should allow detection of stomatal closure, by showing how the leaf temperature changed over time. When the stomata closed, the plant is no longer transpiring and cooling itself. The leaf temperature will increase because of the energy that is still being absorbed by the leaves from the light source. As water evaporated from the plant-less pots, the data acquisition system recorded a continuous weight loss (Figure 2). The gravimetric water content of the substrate thus determined should be useful in determining steady state transpiration over a range of temperature, light and VPD as well as transpiration related to container moisture. For example, when weight change becomes minimal, the stomata are assumed to be closed and stomatal closure can be related to percent of container capacity. A calibration curve was established to determine light intensity at various heights of the rack light (Figure 3).

In conclusion the system developed allows for studies to be done on plants in a controlled environment in which the substrate moisture content and the stomatal response can be monitored. The humidity control unit that controls the environment allows the temperature and VPD to be set and maintained at a constant condition. The system allows the experimenter to impose a wide range of conditions on the plants and have continual observation of their status as they dry.

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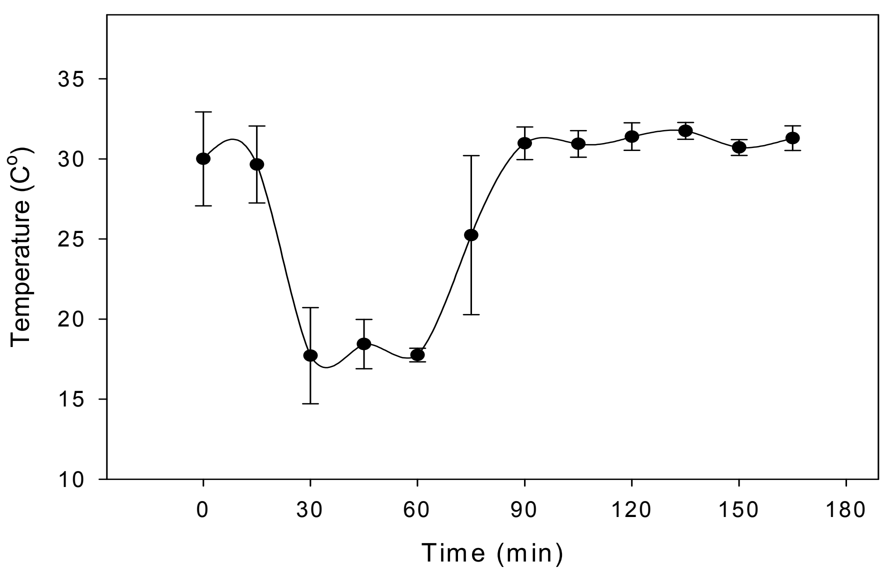

Figure 1. Increase in filter paper temperature as drying occurs.

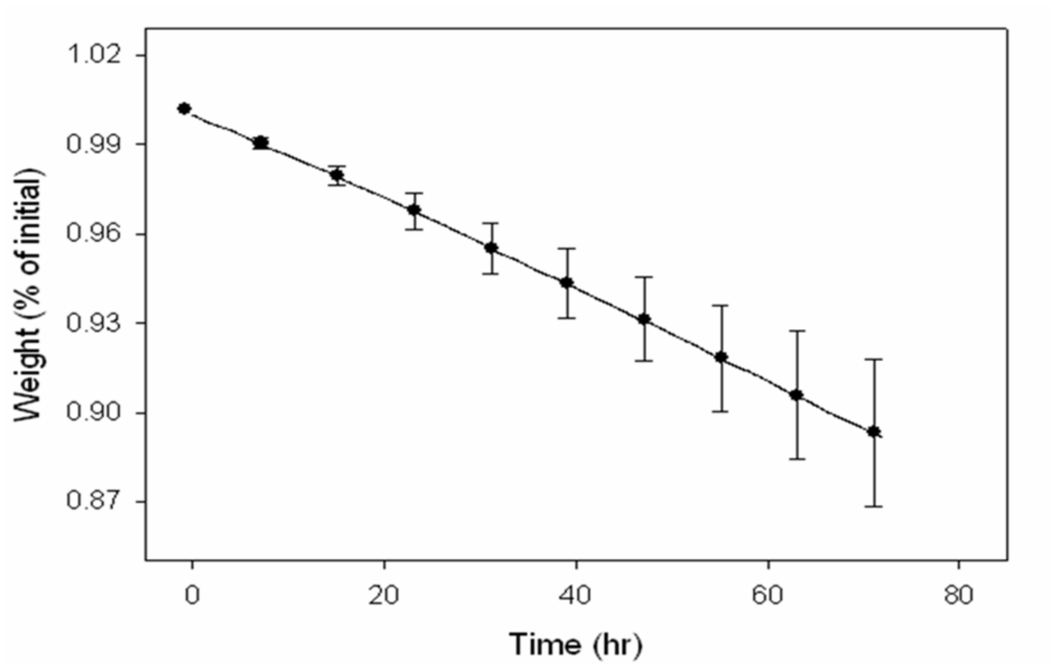

Figure 2. Percent of weight change of plant-less pots as they dry.

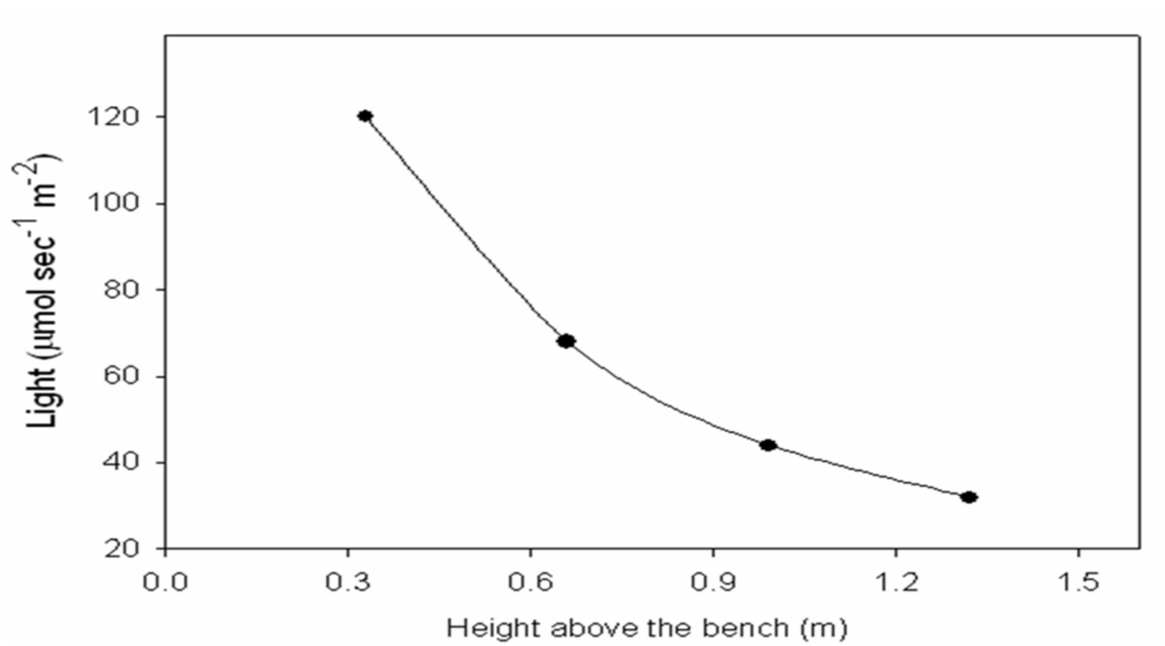

Figure 3. Light intensity over a range of rack heights.

Alternative Renewable Energy Sources for the Green Industry

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Index Words: energy, renewable, sustainability, finance, wind, solar, hydroelectric

Background: For years, the greenhouse and nursery segments of the green industry have been concerned with the volatility of energy prices, and the seemingly continuous spiral upward in petroleum-based fuels, such as natural gas, propane, heating oil, and gasoline or diesel. Energy costs have affected not only the growers of plant materials but also the marketers, including retail garden centers that have greenhouse structures for display and over-wintering of plant materials. When winter heating fuels spiked several years ago, many green industry businesses converted to electricity, and they now find these costs to be also rising dramatically. Are there any alternative energy sources that give the grower and marketer any control as a meter-beater, yet are viewed as sustainable and/or renewable energy sources?

Methodology: For those entrepreneurs with confinement growing operations, especially those with greenhouses or other enclosed structures, the task of selecting an alternative renewable energy source to the electricity or other fuels being used required a few check-list type responses. These questions included such items as why do you want to change energy sources (cost savings, profitability, desire to be sustainable, poor customer service with current energy or fuel provider, etc.)?; what are your current resources that would be included in the changeover (capital, labor, structural design of facilities, management expertise, etc.)?; what is the desired outcome from adopting an alternative renewable energy source (a specific dollar cost or savings, a specific financial return, a particular cash flow, a particular carbon footprint, peer/industry recognition for going green, etc.)?

Once these, and other questions, were sufficiently answered, the problem could be identified and through a thorough information search, appropriate alternative renewable energy sources were delineated. Facts and figures alone could not make the decision, as intangible factors were also considered – zoning restrictions, access to or availability of the technology and support, image desired, timeframe or commitment to the project, etc. Unfortunately, the ultimate decision as to which alternative energy source would be most appropriate was not a simple yes or no, nor even an engineering solution. The task became one of learning what experiences other individuals or businesses had had with the choices. Using numerous innovators and early adopters of renewable energy as models, data was collected from each business as to their experiences economically and financially. Although several had very few years of data, a trend was at least shown from which extrapolation of future costs and savings could be developed.

Results and Conclusions: In the determination of plausible and probable alternative energy sources to utilize, one common concern arose among the green industry entrepreneurs, be they growers or marketers – will the financial returns justify the turn key and operational costs of the technology? With that in mind, five renewable energy sources that could be utilized by the businesses were identified – small wind machines, photovoltaic solar panels, biomass (wood chip, corn, grass, etc.) burners, mini- or micro-hydroelectric, and anaerobic digesters. Using the anticipated economic savings from having made a change in energy source, five financial determinants were considered – payback period, simple or accounting rate of return, net present value, benefit/cost ratio, and internal rate of return.

The financial results for the five energy sources and five financial evaluation criteria were:

Renewable	Financial Determinant				
Energy Source	PBP	SRR	NPV	BCR	IRR
	Years	%	average $ @ 10%	:1	%
Small Wind	6 – 11	17 – 9	43,785	1.6	9 – 17
Photovoltaic	7 – 9	14 – 11	52,126	1.8	10 – 16
Biomass Burner	5 – 9	20 – 11	16,024	1.1	5 – 9
Mini-Hydroelectric	5 – 7	20 – 14	18,790	1.2	8 – 14
Anaerobic Digester	4 – 8	25 – 13	17,538	1.2	6 – 11

These results do not factor into the analysis such considerations as net metering for credits or selling electricity back to the utility provider, tax incentives, tax credits, rebates, technology advancements, or any other government or regulatory encouragements. Any of these factors raise the financial returns/values/ratios or shorten the payback period. The desired parameters of the entrepreneur ultimately determine if an alternative renewable energy source would be best-suited for him/her – maximum payback period, minimum rate of return (simple or internal), minimum net present value, or minimum benefit/cost ratio. The net present value, benefit/cost ratio, and internal rate of return procedures all utilize the time value of money concepts over the expected life of the technology or asset.

Significance to the Industry: One of the three key elements of the sustainability concept is profitability. Any time savings can be gained by making a change in operations, especially in the long run, is a wise decision. For the green industry businesses, selecting an alternative renewable energy source that fits within the operation and provides economic savings should, at the least, be further investigated. The five renewable energy sources show positive returns at or above most investments that a company can make in today's economic climate and recessionary environment. If environmental horticulture is truly the first green industry, then it makes wise public relations to lead by example by selecting sustainable and renewable alternative energy sources.

Current Mechanization Systems among Nurseries and Greenhouses

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Index Words: nursery, greenhouse mechanization

Significance to Industry: The nursery and greenhouse industry in the northern Gulf of Mexico creates a significant economic impact to the economy within the region. Hall *et al*. (1) estimated that the annual economic impact of the industry in the region amounted to $5.2 billion with Alabama, Mississippi, Louisiana, Florida, Tennessee, South Carolina and Georgia contributing $411 million, $55.6 million, $149.3 million, $3 billion, $548 million, $445.2 million, and $566.8 million, respectively. In addition, these states generated 59,903 jobs and an estimated $148 million of indirect business taxes throughout the region. As horticulture production in the region increases in value, it is expected that nursery and greenhouse growers will desire to increase production capability and efficiency through adoption of mechanized/automated technologies, improved working conditions and workers' safety, and enhance the markets for horticulture products.

Nature of Work: A survey of nurseries and greenhouses was conducted in the southern states as part of a research project undertaken by the Mississippi Agricultural and Forestry Experiment Station and the U. S. Department of Labor entitled Enhancing Labor Performance of the Green Industry in the Gulf South (2). The data collection procedures and earlier results from the survey for Mississippi, Alabama and Florida were presented in publications dealing with the socioeconomic characteristics of workers and working conditions (3, 4), socioeconomic impact of automation and mechanization (5), and operational characteristics of nurseries and greenhouses (6). The objective of this paper is to present an overview of the types and levels of automation and mechanization employed by nursery and greenhouses operations. The socioeconomic survey of wholesale nurseries and greenhouses in seven southern states: Mississippi, Alabama, Louisiana, northern Florida, Tennessee, South Carolina and Georgia, was conducted between Dec. 2003 and Sep. 2008. Official lists of certified nurseries were acquired from state regulatory agencies and green industry buyers' guides. Only wholesale growers were used for selection of survey participants. A random sample of 50 growers was generated in every state. These growers were contacted and survey interviews scheduled. A total of 185 nursery automation survey forms were completed through personal interviews with nurseries (N=66), greenhouses (N=48) and mixed nursery and greenhouse operations (N=71) in Mississippi (32), Louisiana (29), Alabama (26), north Florida (27), Tennessee (17), South Carolina (30) and Georgia (24). Only the nurseries and the mixed nursery and greenhouse operations were used for the purposes of this paper, for a total of 137 growers. SPSS version 16.0

(7) was used to analyze the survey data to determine the frequency distribution of each type of automation and mechanization within each task of container nursery production as described in the survey instrument. Merriam-Webster defined mechanization as “to equip with machinery, especially to replace human or animal labor”, and automation as “automatically controlled operation of an apparatus, process, or system by mechanical or electronic devices that take the place of human labor” (8).

Results and Discussion: Frequency distributions were calculated for the 15 tasks performed by workers in nursery and mixed operations who participated in the socioeconomic survey.

Substrate mixing: Of the growers surveyed, 56% purchased the substrate used in production, 13% use in-ground production, 9% manually mix their own substrate, and 13% use some form of mechanization to mix substrate such as machinery are mixers, pot fillers, and front end loaders. The rest of the operations (9%) were listed as unspecified or were not indicated.

Container filling: About 47% of growers manually fill their pots. Pot fillers were used by 23% of growers. Twelve percent of producers use another form of machinery for pot filling including flat fillers, front end loaders, shovels, mixers and silage wagons.

Placing plants in containers: To place plants in containers, 69% of the growers do it manually. Other forms of mechanization were used by 11% of the growers such gas powered drills, planters, plug poppers and pot fillers.

Moving containers from potting to transport vehicle for movement through nursery: 61% of growers move containers to transport vehicles manually. A conveyor is used by 8% of the producers. Four percent of growers employ a rail system. Other forms of mechanization were used by 4% of growers, including 4-wheeler and trailer, mobile pot filler, tractor and trailer and wheel barrow.

Transporting containers to field: A variety of transportation methods are used throughout the industry. Thirty-six percent of growers transport containers manually, 10% use carts, 7% use tractors with trailers, and 6% use tractors with carts. Nineteen percent of growers use other forms of transportation, such as: ATVs, 4-wheelers, golf carts and carts, planters, mobile pot fillers, truck and trailer and rail systems.

Placing plants in field: 75% of growers place the containers in the field manually. Only 4% use some form of mechanization including conveyors, planters, tobacco setters and tractors.

Spacing containers: Containers are spaced manually by 80% of growers surveyed. Four percent use a planter to place plants in the ground, and 2% employ a tractor/planter combination.

Picking plants and loading on transport vehicle at time of sale: Seventy-two percent of the growers manually handled plants, while 4% use a bobcat and tree spade. A front end loader and a boom are used by 3% of growers. A bobcat alone is used by 3% of growers, and bobcat and shovels are used by 2% of growers. Five percent of the growers use some other form of mechanization, including carts, conveyors, rail systems, and tree spades.

Removing plants from transport vehicles in holding area: Plants are manually removed by 71% of growers. A bobcat is used by 4% of growers, while 3% use a front end loader and boom. Conveyors are used by 2% of growers, and 2% use other forms of equipment, such as carts and bobcat with tree spade.

Loading plants onto delivery vehicles: Plants are manually loaded on delivery vehicles by 67% of growers, while 6% load the vehicles with bobcats, and 6% use some other form of loading equipment (forklift, carts, conveyors, hook systems, tractor and boom, and tractor with carts).

Jamming plants in winter: No automation or mechanization was indicated for jamming plants for winter. Forty-seven percent of growers jam plants manually, while 53% were unspecified or did not jam plants.

Plant pruning: Plants were pruned manually by 44% of growers surveyed. Eight percent employ gas trimmers, 6% use hand pruners, 6% prune with power shears, and 4% use pruners. Also, 4% of growers use shears, and 6% use some combination of the methods listed above (shears and pruners, scissors and pruners), or specially adapted equipment like lift trailers and pruners. The remaining 26% of respondents were unspecified or do not prune plants.

Fertilizer application: Sixty-nine percent of growers indicated that fertilizer application is done manually on their nurseries. Six percent use an injector system, and 5% use a bucket and spoon to apply fertilizer. Three percent employ belly grinders and spreaders, while 3% incorporate fertilizer at potting. A tractor and spreader is used by 3% of growers. Other equipment constitutes 5% of growers' fertilizer application, including batch-feed CLF, drip tape, and select-a-feed.

Pesticide application: Pesticide application is done manually by 40% of growers. Fifteen percent use backpack sprayers and 10% use hand sprayers, 5% of growers use sprayers, 2% apply pesticide with air blowers, and 2% use air blast sprayers. Three percent use injectors and misters, while 3% employ tractor and sprayer. Some combination of the equipment listed above (hand sprayers and backpack, tractor and boom sprayer, tractor and air blast) is used by 14% of growers.

Irrigation application: Twenty-two percent of the growers interviewed indicated that irrigation is done manually at their nurseries. Two percent of growers use 24V controllers and 2% use electric valves with golf course controllers with computers. A

combination of drip with timers and controllers and valves is employed by 18% of growers. Seventeen percent of respondents use some configuration of overhead irrigation, while 6% use some combination of hose and sprinkler. Twenty-one percent of the respondents use some combination of all of the equipment listed above.
The results of this survey indicate that, while there is automation and mechanization available to growers, a majority of the growers surveyed are still relying on manual labor for many tasks. While irrigation management, pesticide and fertilizer application, and plant pruning are somewhat automated or mechanized, growers still have some room to apply available technological innovations suitable to their operations. Activities involving the transport of plants throughout the nurseries and placing plants in the field would yield the most room for new or existing technology to be applied. Mixing substrate, container filling, and planting are also areas where automation and mechanization technology might be implemented or modified to help increase production.

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Evaluation of Bark-Based Poultry Litter as a Substrate Component in Nursery Crop Production

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Index of words: Bedding, broiler, CAFO, amendment

Significance to Industry: Broiler production facilities throughout the United States are facing intensifying pressure to dispose of broiler waste with little environmental impact. A decrease in availability of pine shavings has led broiler producers to search for alternative bedding materials. Through broiler bedding trials, pine bark was identified as a suitable bedding alternative to pine shavings. The results from this study suggest that pine bark-based poultry litter could be used in container plant production to increase water holding capacity and provide an alternative to peat if properly managed.

Introduction: Environmental policies such as CAFO (confined animal feeding operations) have for many years been tightly regulating disposal of animal waste, but recently these polices have intensified and land disposal of animal wastes is being further constricted. Many CAFO operations have used the horticulture industry as a means to dispose of manure waste while also generating some amount of cost recovery. Retail bagged goods and nursery substrates are two primary means by which animal wastes are dispersed through horticulture sales. Instead of concentrating manure in one area through repeated land applications, the horticulture industry is able to disperse waste in the form of bagged manure for soil amending and using manure in small quantities as a substrate amendment in container plant production (1). Consumers purchase of these products diffuses the waste impact on the environment by spreading it over a greater area than in a few local hay fields. One of the largest CAFO waste problems arises from broiler production where broilers defecate on pine shavings. In the southeast, interest has been shown in alternative bedding materials as availability of pine shavings is becoming more limited due demand for shavings as a biofuel. A recent trial by the Auburn University Horticulture and Poultry Science Departments reviewed several bedding materials in an attempt to find alternatives to pine shavings. These materials included; pine bark, ground pallets, chipped pine, chopped straw, door filler, cotton gin trash, and mortar sand. The bedding materials were all compared to the physical properties of pine shavings in bulk density, moisture retention, and bacterial decomposition (Table 1). Bedding materials also were evaluated as bedding for broilers where impact on growth performance (weight gain, feed consumption, mortality, and foot pad dermatitis) and caking (compressed clumping of bedding) were determined. No differences were found in mortality due to bedding type. At the end of the trail all materials were considered to be adequate for bedding materials for several grow-outs. Pine bark was a less expensive alternative to pine shavings while also providing comparable or better results. Pine bark was then evaluated on a commercial scale at three commercial broiler production farms. Pine bark was applied as bedding at a depth of 4 to 6" and was used for one full flock for up to 1 year of grow-out. Growers observed that the pine bark bedding had higher moisture retention, caked less, and produced less dust than traditional pine shavings. Growers were pleased with the overall results of pine bark and have considered switching solely to pine bark bedding. The suggested use of pine bark as a bedding material for broilers led to a second trial to determine if pine bark bedding could be used as an amendment for a peat replacement in nursery substrates.

Materials and Methods: Four ratios of amendments were used to compare pine bark bedding to peat moss in a standard pine bark based nursery mix. These amendment treatments included a 4:1 (v:v) 3:1, 2:1, 1:1 pine bark:amendment for both pine bark bedding and peat moss. A 6:1 pine bark:sand was also evaluated. Three species donated by Van der Giessen Nursery, Inc, Semmes, AL (*Rhododendron* 'Red Formosa' (azalea), *Buxus koreana* 'Wintergreen' (boxwood), and *Lorapetulum chinense* 'Plum Delight' (lorapetulum)) were potted with each substrate into a trade gallon nursery pot (6 in high and 6.5 in diameter). All substrate treatments were amended with 3 lbs of nitrogen (17-5-11 Polyon), 1.5 lbs of MicroMax, and 5 lbs of dolometic lime. Containers were arranged in a randomized complete block design at the Paterson Greenhouse Complex (Auburn, AL) where they received 0.5 " of overhead irrigation daily. Electrical conductivity and pH were periodically monitored throughout the study and growth index was recorded at initiation and closure of the study.

Results and Discussion: Growth difference was calculated for plants 22 weeks after potting and analyzed using Duncan's Multiple Range Test ($\alpha = 0.05$). There was an inverse effect as the amendment rate of bark bedding increased, growth decreased across species. The opposite effect was seen with peat moss, as the rate of peat moss increased so did growth increase. Electrical conductivity (EC) was initially high for all bark poultry bedding treatment and increased as the rate of bedding increased. One month after planting EC decreased for all bedding treatments to levels that fell in acceptable ranges (2). Peat amended treatments were consistently within range throughout the experiment. Our results indicate that bark based poultry litter could be used successfully to increase water holding capacity as a peat substitution in pine bark based substrates if managed properly. All treatments in this study were watered uniformly. Results are likely to have differed if water was applied as needed instead of a blanket application. Most substrates containing bark-based poultry bedding absorbed excessive water and kept containers too wet throughout the study. At the close of the study root systems of bark-based poultry bedding treatments were concentrated at the surface of the containers indicating wet conditions as substrate depth increased. The high levels of EC that were detected early in the experiment could be better controlled with flushing or leaching containers after potting or by composting the bedding prior to use.

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Table 1. Physical characteristics of bedding materials tested

Bedding Sources	Bulk Density (g/cm^3)	Moisture Retention (%)		Water Activity (a_w)	Initial Moisture (%)	Bacterial composition (log10cfu/g)		
		24 h	48 h			Aerobic	Anaerobic	Enteric
Pine Shavings	0.110 d	71.2 c	71.8 c	0.67 ab	11.3 bc	7.86	7.17 ab	2.85
Pine Bark	0.198 b	68.6 d	73.8 c	0.519 c	11.4 bc	8.44	6.65 ab	3.13
Ground Pallets	0.130 c	78.0 h	80.2 h	0.674 a	13.2 ab	7.63	2.50 ab	3.09
Mortar Sand	1.230 c	25.8 e	22.0 d	0.524 c	9.9 c	7.98	2.00 b	3.1
Chopped Straw	0.040 f	80.5 h	80.8 h	0.564 bc	14.5 a	7.79	6.39 ab	3.7
Door Filler	0.158 c	87.4 a	88.0 a	0.638 a	12.0 bc	7.47	7.26 a	3.59
Cotton Gin Trash	0.096de	87.6 a	88.4 a	0.605 ab	11.2 bc	7.79	2.33 ab	3.15
Chipped Pine	0.064ef	73.0 c	74.4 c	0.674 a	12.2 abc	7.51	6.39 ab	3.45
P<F	***	***	***	***	**	NS	*	NS