Engineering, Structures & Innovations

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Attributes Considered When Purchasing a Greenhouse Environmental Control System

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Index Words: Environmental controls, Energy, Labor, Economics, Innovation

Significance to Industry: The first few years of the 21st century have experienced new greenhouse construction in Georgia, and presumably throughout the Southeast, either among new entrants into floriculture production or expansion by small- or medium-sized growers. For many of these growers investing in greenhouse construction, the motive is to capitalize upon market share opportunities, but in many cases, the need is for “customized” construction for environmental purposes so as to produce specialty crops.

Nature of Work: A series of closed-end questions were posed to growers who either had shown intent to construct greenhouse capacity or who had recently made a commitment to a greenhouse construction firm for building new greenhouse capacity. Likert scale (a statement with which the respondent shows the amount of agreement/disagreement), importance scale (a scale that rates the importance of some attribute), rating scale (a scale that rates some attribute from “poor” to “excellent”), and intention-to-buy scale (a scale that describes the respondent’s intention to buy) questions were included in the grower/greenhouse purchaser survey.

A separate survey of open-ended questions was distributed to the leading greenhouse construction and installation firms doing business in Georgia. Completely unstructured questions (that respondents can answer in an almost unlimited number of ways) as well as sentence completion (an incomplete sentence is presented and respondents complete the sentence) and story completion (an incomplete story is presented, and respondents are asked to complete it) questions were included in the greenhouse operations’ survey.

Results and Discussion: As to the greenhouse construction survey, when asked “Who, in your opinion, are the primary purchasers of environmental control systems?,” the respondents indicated that the larger growers (those with typically over 100,000 sq. ft. of production space) were those investing in environmental controls (78% of construction) – in some situations, these were greenhouses being retrofitted to meet current or anticipated needs instead of totally new construction. Most of the recent greenhouse construction was occurring in climatic zones 6, 7a, and 7b, with concerns about cooling, heating, and humidity control. The types of control systems currently used (at least observed by installers) include thermostat controls (60%), advanced computer controls (18%), integrated or STEP controllers (10%), and manual or no controls (12%).

An example of the sentence completion questions posed is “When choosing an environmental control, the most important consideration in the grower’s selection or choice is ___________________.” The leading responses were energy cost savings (18%), product reliability and features (17%), improved plant quality (15%), and ease of use and responsiveness (14%). Additional responses included labor cost savings, system price (including installation), brand recognition, and service reputation, in descending order of response frequency.

A Likert scale question posed was: “Advanced computer or integrated environmental controllers are a necessity for producing high quality, salable plant material,” with the five-point scale ranging from strongly disagree (1) to strongly agree (5). [The scored result was 3.84.] An importance scale question posed to the grower was “Energy cost savings, as a consideration for purchase of an environmental control, is: extremely important (1) to not-at-all important (5).” [The scored result was 1.98.] An example of a rating scale question posed was: “Based upon personal experience, customer or technical support of environmental control systems for greenhouses is: excellent (1), very good (2), good (3), fair (4), poor (5).” [The scored result was 2.38.] The intention-to-buy question was: “If an environmental control technology could be purchased and installed in my greenhouse for less than $5,000, I would: definitely buy (1), probably buy (2), not sure (3), probably not buy (4), definitely not buy (5).” [The scored result was 2.05.]

Additional questions were posed, but due to lack of space, any additional results or the complete analysis can be obtained by contacting the author.

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Pelleted Poultry Litter Provides Viable Fuel Source for Greenhouse Heat

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Index Words: Biofuel, Renewable resources, Agricultural wastes, Alternative heating

Significance to Industry: Our initial trial demonstrated that pellet furnaces can be used to heat greenhouses during winter months in Alabama. Because of a need for periodic removal of ash/slag residue from the firepot and occasional clogging/jamming of the feeding system with greenhouse size pellet stoves, a fossil fuel fired furnace as backup may be necessary. In our first year's results (without factoring in the equipment cost), heating with a pellet furnace gave $5 to $8 per day savings in energy and heating cost for a standard 24ftx96ft greenhouse. Pelleted biofuels provided obvious environmental benefits – e.g. use of wastes from agroprocessing, less dependence on limited fossil fuels, lowered emissions of noxious and greenhouse gases (such as CO_2, NO_X, SO_2), etc. Additionally, there are numerous economic advantages in the short (decreased heating costs) and long run (less dependence on imports, potential on-site generation of fuel, etc). Furthermore, in most cases, the ash obtained from biofuel combustion has potential value as a substrate component (2).

Nature of Work: Bioenergy is energy in the form of liquid fuels (e.g. ethanol and biodiesel), heat and electricity produced from biomass such as wood, energy and agricultural crops, crop and forest residues, processing by-products and animal manure. On the other hand, fossil energy is produced from fossil fuels such as oil, coal, and natural gas. While Alabama, and much of the Southeast enjoys a good supply of natural gas, almost all of our gasoline and related products, along with about 60% of our coal are is imported. In Alabama, about 70% of our electricity is generated from burning coal, the balance coming primarily from hydro and nuclear sources (1). Ten years ago, all the coal needed to generate electricity in Alabama was mined in the state, but now we import over 18 million tons (about 65% of total consumption) of coal each year, mainly from Wyoming, where the coal is lower in sulfur than that mined in Alabama. As such, over $500 million in financial resources are leaving the state every year.

In contrast to fossil fuels, bioenergy is renewable. Alabama has 22 million acres of forest land and 6 million acres of grassland and cropland (www.forestry.state.al.us/Forest_Statistics.html). In the production of over 1 billion broilers and 2 billion eggs a year in the state of Alabama, more than 2 million tons of poultry litter are generated annually (3, 4). Considering just one major agronomic crop, more than 0.5 million tons of peanut hulls are produced within 100 miles of Dothan, AL annually. Based strictly on the agricultural and forestry sectors, Alabama has enough raw biofuel to provide the electricity for all the residences in the state. Additionally, municipal landfills daily receive millions of tons of wastes with fuel value.

The objectives of the work presented in this paper were to demonstrate that a pellet furnace can be used to heat a greenhouse during winter conditions in Alabama, and to evaluate the fuel potential for pellets from various raw materials on an energy efficiency basis.

The trials were conducted at the Paterson Horticulture Complex at Auburn University in a 24ft by 96ft quonset greenhouse equipped with a Modine natural gas fired furnace with an operation range from 125,000 BTU/hr to 150,000 BTU/hr. For this study a pellet furnace was installed with a capacity of 130,000 BTU/hr. Temperature dataloggers were placed every 30ft.

Pellet samples were manufactured at Auburn in the Corley Biosystems Engineering Building from switchgrass grown at an Alabama Agricultural Experiment Station (AAES), poultry litter from AAES, and composted household garbage from WastAway Sciences, McMinnville, TN while pelleted peanut hulls were obtained from Ag Fiber Inc., Dothan, AL. The energy and labor required to produce the pellets were determined prior to use in the greenhouse.

Results and Discussion: Our trials indicated that a number of raw materials can be used to produce fuel pellets for greenhouse heating (Table 1). When compared directly to 'natural gas only' each material evaluated led to cost savings (excluding equipment costs and raw material cost) on a per day basis ($4.91 for poultry litter pellets, $7.64 for peanut hull pellets, and $8.16 for switchgrass pellets). As would be the case throughout most of the Southeast, we used a standard size (24x96ft) greenhouse for our study. As such, a small pellet stove was used so as not to overheat the house. In a larger greenhouse range a larger pellet furnace could be employed, thereby reducing some of the clogging in the pellet auto-feed. We had occasional CO_2 buildup (data not shown) but this did not pose a problem to the crops (an assortment of 30 bedding plant species) grown in the house.

We also evaluated additional pellet material sources, one of which was composted household garbage. This material was not ready in time for the 2004/2005 winter, but appears to have a comparable Btu/lb value (each just under 6000 Btu/lb on dry weight basis) and a similar ash residual.

The pelleting process reduced the bulkiness of handling lightweight materials. For example, pelleting reduced three cubic feet of poultry manure to one cubic foot. Pelleting also reduced the dustiness of most materials as well as making most materials more flowable for automated delivery.

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Table 1. Energy savings and efficiency data from pelleted materials for greenhouse heating[1].

	Switchgrass	Peanut Hulls	Poultry Litter	Processed Garbage[6]
No. of days	3	7.5	6	-
Amount burned, kg (lb)	280 (617)	700 (1543)	580 (1280)	-
Energy for pelleting, kWh	107.52	310.8[5]	70.77	-
Cost of pelleting ($)	8.60	24.90	5.66	-
Natural gas use cost ($)[2]	4.98	12.98	41.07	-
Total heating cost ($)[3]	13.58	37.88	46.73	-
Heating cost without bioenergy ($)	38.06	95.18	76.14	-
Savings ($)	24.48	57.33	29.41	-
Savings/day ($)	8.16	7.64	4.91	-
Percent saving (without biofuel cost)	64.3	60.20	38.6	-
Percent saving (with biofuel cost)[4]	34.89	30.78	8.16	-
Btu/lb dry basis	8256	8570	5639	5982

[1]Estimates

[2]Cost of natural gas is $6.1 per million BTU.

[3]Cost of electricity is 8.1 cents per kWh.

[4]Cost of purchasing biofuel pellets is assumed to be $40/ton.

[5]Value obtained from pelleting of some peanut hulls at Auburn University.

[6]Not used in 2004/2005 study. Will be used in 2005/2006.

Levels of Technology Adoption Among Horticulture Firms in the Northern Gulf of Mexico

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Index Words: Greenhouse and nursery, Mechanization, Automation, Socio-economics

Nature of Work: This socioeconomic (SEC) project is a part of a research program currently being 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.” The overall goal of this SEC project is to develop a socioeconomic profile of horticulture workers and evaluate the impact of automation technologies on their employment, earnings, safety, skill-levels, recruitment and retention rates (1). This paper presents the level of technology adoption among nurseries located in the Northern Gulf of Mexico region which participated in the survey conducted from December 2003 to March 2005. A total of 87 Nursery Automation Survey Forms (NASF) were completed from personal interviews with horticulture firms randomly selected in Mississippi, Louisiana and Alabama. Participating nurseries were randomly selected from lists of wholesale nursery growers from each of the three states included in the 2003-2005 survey.

Results and Discussion: The 87 nurseries included in the survey reported a total of 1,804 acres or an average of 21 acres per nursery. Total open field production area was 926 acres while total greenhouse production area was 2.86 million sq. ft. Most participating nurseries were either single proprietorships (52%), corporations (30%), or partnerships (8%). Majority of the nurseries included in the survey reported annual gross sales of less than $250,000 (57%), 19% sold between $250,000 and $499,999, 12% grossed between $500,000 and $999,999, and the remaining 12% reported more than $1 million annual gross sales.

The Nursery Automation Index is a measure of the level of automation or mechanization currently being practiced in each nursery included in the regional survey (1). It shows the extent to which nurseries have currently automated or mechanized the various tasks involved in the production of horticulture products. A series of questions was asked to solicit the respondent’s perceptions of the level, costs and labor requirements of every automation or mechanization used in every nursery visited.

1. How would you describe the level of automation in <nursery task> in your nursery?

0%	10%	20%	30%	40%	50%	70%	70%	80%	90%	100%

where 100% = fully automated or mechanized and 0% = fully manually done.

2. If automated or mechanized, what type of automated system is used?
3. What was the cost of purchasing and installing the automation system?
4. How many workers are required to operate the equipment?

The level of automation or mechanization of 15 different tasks performed by nurseries engaged in container production in the Gulf of Mexico region ranged from 0 to 50% (Table 1). About two-thirds of the container nurseries purchased premixed substrates. Current automation or mechanization among container nurseries was limited to the following tasks: mixing container substrate - 35%, filling containers with substrate - 32%, transporting containers to field - 28%, fertilizer application - 19%, pesticide application - 26%, and irrigation application and management - 50%.

The level of automation or mechanization of 10 different tasks performed by nurseries engaged in greenhouse plant production in the Gulf of Mexico region ranged from 0 to 57% (Table 2). About two-thirds of the greenhouse nurseries purchased premixed propagation media. The tasks that these nurseries performed with significant levels of automation or mechanization included: media preparation - 28%, pot and/or tray filling - 32%, environmental control - 45%, fertilizer application - 36%, pesticide application - 29%, and irrigation application and management - 57%.

Significance to the Industry: Sustaining the growth of the nursery and greenhouse industry requires a steady supply of reliable workforce capable of performing several horticultural tasks including planting, cultivating, harvesting, and transplanting plants. In order to achieve higher labor productivity and a satisfactory work environment, nurseries can strive to automate or mechanize their operations fully or partially, depending on their own individual circumstances. The results of the survey will be further used to evaluate the socioeconomic impact of automation currently used in container nursery production and greenhouse plant propagation on work force, nursery and greenhouse characteristics, and use of labor, capital, pesticides, chemicals and computers. The results of the survey will also show the differences in production levels and sales attributable to the differences in the levels of automation in the major tasks performed in nursery and greenhouse operations in the region. It is expected that with this information, growers can make informed decisions regarding nursery and greenhouse automation that would be beneficial to the nursery business and to its workforce.

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Table 1. Levels of automation or mechanization in container nursery production in the Northern Gulf of Mexico.

Nursery Tasks		Number	Container Production Only	Both Container and Greenhouse	Total
1	Mixing container substrate	16	0%	37%	35%
2	Filling containers with substrate	47	15%	38%	32%
3	Placing plant liners in containers	49	0%	9%	7%
4	Moving containers from potting to transport vehicle for movement within the nursery	46	3%	19%	15%
5	Transporting containers to field	45	28%	28%	28%
6	Removing containers from transport vehicle and placing in the field	46	8%	0%	2%
7	Spacing of plants and containers	51	4%	0%	1%
8	Picking plants up and loading onto transport vehicle at time of sale	51	13%	3%	6%
9	Removal of plants from transport vehicle and placing in holding area awaiting shipment	44	8%	3%	5%
10	Picking up plants from holding area or from transport trailers and loading onto delivery vehicles	46	5%	6%	7%
11	Jamming plants for winter protection	25	0%	0%	0%
12	Plant pruning	41	14%	5%	8%
13	Fertilizer application	55	14%	21%	19%
14	Pesticide application	55	15%	30%	25%
15	Irrigation application and management	53	44%	53%	50%

Table 2. Levels of automation or mechanization in greenhouse plant propagation in the Northern Gulf of Mexico

Nursery Tasks		Number	Container Production Only	Both Container and Greenhouse	Total
1	Media preparation	20	48%	21%	28%
2	Pot and/or tray filling	57	30%	33%	32%
3	Cutting and seed collection	51	0%	0%	0%
4	Cutting and seed preparation	51	0%	3%	2%
5	Sticking cuttings and planting seed	53	16%	5%	8%
6	Environmental control	55	50%	42%	45%
7	Harvesting and grading production	55	0%	0%	0%
8	Greenhouse fertilizer application	57	30%	39%	36%
9	Greenhouse pesticide application	55	30%	29%	29%
10	Irrigation application and management	55	55%	59%	57%

RFID Technology for Plant Inventory Management

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Index Words: Radio frequency identification

Significance to Industry: The nursery industry in general suffers from poor inventory control. Problems associated with inventory include the labor intensive, physical counting of the thousands of plants in a nursery, tracking stage of plant growth, tracking plant losses from mechanical damage, cultural problems and disease, and tracking shipped orders during the busiest time of year for the nursery. Spring planting season is also the primary shipping season for most nurseries. This makes it difficult to dedicate labor to the process of inventory management. An inventory system which can track plant information from potting to shipping would enable nurseries to conduct cost analysis accounting for the number of plants potted, number lost during production, production practices used, and number sold. In addition, it would allow a closer tracking of the plants on the nursery grounds.

Nature of Work: Radio Frequency Identification (RFID) transponders (tags) are small, battery-less devices which can be coded with either a unique number similar to a bar code or more information depending on the memory size of the tag (2). RFID systems are widely available from companies like Texas Instruments, Honeywell, RF SAW, Inc., RFID Technology, and others. RFID tags are energized and activated upon receiving a radio frequency from the remote tag reader. Tags range from those which require actual contact to be read to those that can be read from several feet away. The reader can be a small, handheld device which ultimately will download the data to a computer, laptop, pocket PC, or PDA. Tagging of individual plants has been shown to be effective in a greenhouse setting where implementation of RFID technology greatly improves efficiency of tracking plants (1).

In May 2004 160 6’ bareroot crabapple trees (Malus ‘Donald Wyman’) (Bailey Nurseries, St. Paul, MN) were potted into 7 gal. nursery containers in a 9:1 composted pine bark:sand mixture with 10 lbs/yd^3 Dolomitic Lime and 10 lbs/yd^3 Osmocote 15-9-12 (8-9 month release) added. After potting, the trees were tagged with RFID tags. Four types of low frequency tags were used: 23mm glass ampule, 32mm glass ampule, 12mm plastic wedge, 30mm plastic disk (Texas Instruments, Inc., Plano, TX). The tags were either glued to the container, buried in the growing substrate 2.5cm deep and ~2.5cm from the edge of the container, glued to a plastic plant label and hung on the lowest branch of the tree, or a hole was drilled into the trunk of the tree 15cm above the graft union and the tag inserted (except the 30mm disk which was attached with a screw to the tree trunk).

One year after placing the tags in the treatments, the tags were read using a TI S2000 reader (Texas Instruments, Inc., Plano, TX). Tags were monitored for ability to be read after one season in the nursery plots. Data were analyzed using SAS statistical software (SAS, Inc., Cary, N.C.).

Results and Discussion: Observations show that the tree growth, height and caliper, was not adversely affected by any of the tag placements (data not shown). The 12mm wedge tags were all rendered inoperable after one year on the plants exposed to the weather (Table 1). Tags placed on hang tags and those buried in the substrate were most likely to be lost regardless of tag type. Flooding in late June and early July indicated that soil placement of the tags is not feasible due to loss from soil disturbance. Tags on hang tags were missing as a result of trees blowing over in the wind, the tags blowing around, or the tag falling off the hang tag. The trees where the tag was inserted into the trunk have in most cases healed over at the insertion point. The transponder is totally encased within the tree trunk in many cases. The long term effects of the tag being in the tree are being followed. Tags glued to the inside rim of the potting container retained their effectiveness more consistently than any other position of tag placement.

The optimum tag placement would be attached to the inside rim of the container. The next best location would be imbedded in the plant or on a hang tag. The tags retaining the overall greatest percent read rate were the glass ampule tags.

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Table 1. Low frequency Texas Instruments Radio Frequency Identification transponder tag's condition after one year in the field. The tags either read correctly, had a read error, were visible but returned no signal, or were lost due to treatment effects.

Tag	Placement	% Readable	% Read Error	% No Signal	% No Tag
30mm disk	In plant	0	0	90	10
30mm disk	Hang tag	70	0	0	30
30mm disk	Pot rim	90	0	10	0
30mm disk	In substrate	70	0	0	30
12mm wedge	In plant	0	100	0	0
12mm wedge	Hang tag	0	40	0	60
12mm wedge	Pot rim	0	100	0	0
12mm wedge	In substrate	0	90	0	10
23mm glass ampule	In plant	100	0	0	0
23mm glass ampule	Hang tag	60	0	0	40
23mm glass ampule	Pot rim	100	0	0	0
23mm glass ampule	In substrate	90	10	0	0
32mm glass ampule	In plant	90	0	10	0
32mm glass ampule	Hang tag	70	0	0	30
32mm glass ampule	Pot rim	100	0	0	0
32mm glass ampule	In substrate	100	0	0	0