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Economic Impacts of Mechanization or Automation on Horticulture Production Firms Sales, Employment, and Workers' Earnings, Safety, and Retention

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SUMMARY. Using a socioeconomic database collected by face-to-face interviews of nurseries and greenhouses, empirical models were estimated to measure the economic impacts of mechanization or automation on annual gross sales, annual employment, and workers' earnings, safety and retention. The survey was conducted among 215 randomly selected wholesale nurseries and greenhouses located in eight southern states from Dec. 2003 to Nov. 2009. The level of mechanization or automation (LOAM) observed among the participating wholesale nurseries and greenhouses averaged 20% of the major tasks performed by workers. Nurseries and greenhouses that reported greater annual gross sales demonstrated higher levels of mechanization, implying economies of scale associated with technology adoption by these wholesale horticulture production firms. The increase in total workers' earnings associated with improved mechanization indicated that nurseries and greenhouses were able to pay their workers higher wages and salaries. The increased levels of mechanization produced neutral effects on employment and raised the value of the marginal productivity (VMP) of labor, implying that technology adoption by wholesale nurseries and greenhouses did not displace any worker but instead improved total workers' earnings. Growers that reported higher levels of mechanization hired fewer new workers with basic horticultural skills, especially among horticultural firms which operated both nursery and greenhouse enterprises. The length of training period for basic horticultural skills was not influenced by the level of mechanization, but was significantly extended when nurseries or greenhouses hired more new workers without basic horticultural skills. The number of work-related injuries increased as a result of improvements in mechanization, which primarily consisted of back strains, cut fingers, shoulder and ankle strains, and eye injury. The workers' retention impact (WRI) of the level of mechanization turned out to be neutral or indeterminate since almost all of their workers were with them during the past 2 years before conducting the interviews. Overall, advances in mechanization or automation generated enhancing effects on the annual gross sales of horticultural production firms, enabled them to retain and pay better wages for their workers, hired fewer new skilled workers, and reported more work-related injuries.

a major concern facing agriculture and especially the horticultural industry in the United States (Bellenger et al., 2008).

Workers in this industry perform varied functions and are subjected to different working conditions (O*Net Online, 2012). Posadas et al. (2008) reported that at least 8 of the 15 major tasks were performed by workers with significant number of nurseries using mechanized or automated systems in media preparation, filling containers with substrates, moving containers from potting to transport, transporting containers to field, plant pruning, and fertilizer, pesticide, and irrigation application. Six of the 10 major tasks were performed by workers employed by a significant number of greenhouse operations with mechanized or automated systems in media preparation; filling containers with substrates; environmental control; and fertilizer, pesticide, and irrigation application. Very few nurseries or greenhouses were using mechanized or automated systems in cutting and seed collection and preparation; placing plant liners; sticking cuttings and planting seed; harvesting and grading production; spacing of plants and containers; removal, picking up, loading, and placing of plants; and jamming of plants for winter protection.

The nursery and greenhouse industry is often described as one of the fastest-growing sectors of U.S. agriculture and is inherently labor intensive (Regelbrugge, 2007) with greater than 40% of production costs consisting of labor costs (Mathers et al., 2010). Hodges et al. (2011) estimated the total economic impact of the U.S. green industry at \$175.26 billion representing $\approx 0.76\%$ of the national gross domestic product in 2007. The U.S. green industry generated a TEI of 1.95 million jobs, labor earnings impact of \$53.16 billion, and value-added impact of \$107.16 billion.

To sustain robust growth in the industry, continuous improvements in the skills of the workforce and their year-round availability are necessary. Many jobs in the industry require large amounts of stooping, lifting of heavy containers, and exposure to chemicals, dust, and plant materials (Bureau of Labor Statistics, 2012b). These tend to be relatively low-paying jobs, with median wages in 2010 amounting to \$8.98 per hour or

With the tightening in the regulations regarding migrant workers, the nursery

and greenhouse industry is facing a critical shortage of labor (Posadas et al., 2004). Migrant labor issues are

\$18,690 per year (O*Net Online, 2012), making it difficult for managers to compete for and retain workers in currently tight domestic labor markets. Many commercial operations have employed immigrant labor, which is mostly less skilled, to meet their rising labor requirements. The nursery migrant workforce are employed, on average 6 months, and most stayed for 10 months (Mathers et al., 2010). In the long run, there is a need to increase the skill level of these migrant workers to improve wage rates, recruitment, and retention of workers.

Mechanization of an operation can provide mechanical power, speed, repetition, safety, and a greater potential for consistency and quality control. Mechanization is normally defined as the replacement of a human task with a machine (Giacomelli, 2002). Automation includes these attributes, but with greater flexibility and, potentially, some automated decision making (Giacomelli, 2002). But true automation encompasses more than mechanization. Automation involves the entire process, including bringing material to and from the mechanized equipment. It normally involves integrating several operations and ensuring that the different pieces of equipment communicate with one another to ensure smooth operation. Many times, true automation requires reevaluating and changing current processes rather than simply mechanizing them (Porter, 2002). The possible benefits associated with automation were summarized by Ling (1994) as follows: reduce manual labor requirement, improve production quality, eliminate hazardous working conditions, reduce production costs, increase market value, and improve professional esteem. Simonton (1992) concluded that the benefits and incentives to automate are significant and include improving the safety of the work force and the environment, along with ensuring sufficient productivity to compete in today's global market.

Given the above-mentioned expected benefits and the tightening

labor markets faced by the nursery and greenhouse industry, this article evaluated the economic impacts associated with mechanization and automation by using socioeconomic databases collected in previous surveys. The specific objective of this article was to measure the economic impacts of mechanization or automation on the horticulture firms' total revenues (TR), annual employment, and workers' earnings, skills, training, safety, and retention rates.

This article is a spatially, temporally, and analytically expanded version of an earlier article which covered 87 growers located in the three northern Gulf of Mexico states (Posadas et al., 2008). With the data collected by face-to-face interviews of nurseries and greenhouses, multiple linear regression analysis was applied to estimate empirical models to measure the socioeconomic impact of automation or mechanization on annual gross sales; annual employment; and workers' earnings, safety, and retention. In this article, there are more southern states included in the study (eight vs. three states), covered a longer period (2003 to 2007 vs. 2003 to 2009), and included more producers (87 vs. 215 growers). Because of the longer period covered in the study, this article used deflated values of annual gross sales and total workers' earnings and hourly wage rates and also added the interview date as an explanatory variable. Additional variant models were estimated where the number of full-time equivalent (FTE) workers was segregated into permanent workers (PW) and part-time workers (PTW). The segregation allowed for the comparison of the VMP of the PW and PTW.

Empirical models

To evaluate the economic impacts of mechanization or automation, empirical models were estimated for the

horticulture production firms' TR, annual employment, workers' earnings, safety, skill levels, and retention rates. The general hypothesis of the empirical models is that if the estimated coefficient, slope, or first derivative of the estimated empirical equation with respect to the average level of mechanization is not statistically different from zero, then mechanization has a neutral effect on the designated economic variable. The economic impacts of the other variables included in each of the models were also measured by the same procedure.

The average LOAM (AVELOAM) of all the identified major tasks performed by workers in each nursery or greenhouse was used in the empirical models instead of the specific LOAM of each individual task identified in the survey. The use of the specific LOAM in each individual task performed by workers in each nursery or greenhouse resulted to errors in estimation because there was insufficient number of observations. The formula used in estimating the average level of mechanization of all the identified major tasks performed by workers in each nursery or greenhouse is as follows:

AVELOAM = (sum from n=1 to 19 of LOAM) / N

where LOAM = level of mechanization or automation in each specific task performed by workers in each nursery or greenhouse and N = number of tasks performed by workers in each nursery or greenhouse. The specific tasks performed by workers in nurseries and greenhouses that were included in the survey are listed in Table 1.

The TR of nurseries and greenhouses were derived from the mid-point of the annual gross sales category reported by each participating nursery or greenhouse operation. The TR were deflated by the consumer price index (CPI, 2009 = 100) to convert

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Units			
To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.01	%	g·g ⁻¹	100
10	%	g·kg ⁻¹	0.1
10	%	g·L ⁻¹	0.1
10	%	mg·g ⁻¹	0.1
10	%	mL·L ⁻¹	0.1
1	%	mL/100 mL	1
0.4047	acre(s)	ha	2.4711

Table 1. Proportion of the major tasks performed with some form of automation or mechanization by workers employed in nurseries and greenhouses by type of operation. The respondents were asked to describe, in percentage of terms, the level of automation or mechanization in each of the major tasks performed in their respective nursery or greenhouse operations.

Workers' tasks	Proportion of tasks in nurseries (%)	Proportion of tasks in greenhouses (%)
Media preparation	28.44	25.82
Filling containers with substrate	28.54	34.28
Cutting and seed collection	N/A ^z	0.28
Cutting and seed preparation	N/A	2.66
Placing plant liners, sticking cuttings and planting seed	8.76	12.66
Environmental control	N/A	47.16
Moving containers from potting to transport vehicle for movement within the nursery	14.92	N/A
Transporting containers to field in nurseries	31.91	N/A
Removing containers from transport vehicle and placing in the field	2.78	N/A
Spacing of plants and containers	4.02	N/A
Harvesting and grading production	N/A	0.00
Picking plants up and loading onto transport vehicle at time of sale	10.61	N/A
Removal of plants from transport vehicle and placing in holding area awaiting shipment	7.75	N/A
Picking up plants from holding area/transport trailers and loading onto delivery vehicles	11.23	N/A
Jamming plants for winter protection	0.00	N/A
Plant pruning	13.10	N/A
Fertilizer application	16.12	39.45
Pesticide application	24.70	30.63
Irrigation application and management	51.81	56.82
All workers' tasks included in the survey	17.51	25.48

The socioeconomic survey was conducted among randomly selected wholesale nurseries and greenhouses located in eight, selected southern U.S. states from Dec. 2003 to Nov. 2009.

^zNot applicable because this question was not asked to this group.

values to a recent base year. The CPI measures the changes in the prices paid for a representative basket of goods and services (Bureau of Labor Statistics, 2012a). The marginal revenue impact (MRI) of mechanization or automation was expected to be positive, indicating that horticulture production firms that experienced higher levels of production or sales would also demonstrate advanced LOAMs. To test the MRI hypothesis, the TR empirical model was estimated using the following formulation:

$$\begin{aligned}
 TR = & B_0 + B_1 AVELOAM + B_2 FTE \\
 & + B_3 ACRE + B_4 YEARS \\
 & + B_5 NURSERY \\
 & + B_6 GREENHOUSE \\
 & + B_7 PERCENT + B_8 DATE + E,
 \end{aligned}$$

where B_0 = constant term, B_i = regression coefficients, FTE = full-time

equivalent workers (number), ACRE = area in production (acres), YEARS = period since establishment (years), NURSERY = nursery-only operations, GREENHOUSE = greenhouse-only operations, PERCENT = area used in production (percent), DATE = date of interview, and E = error term. This empirical TR model is similar to Posadas et al. (2008) except for the use of deflated values, the addition of the interview date, and the estimation of an additional variant model where the number of FTE workers was segregated into PW and PTW. The segregation of FTE workers allowed for the comparison of the VMP of the PW and PTW. The regression results with the separation of FTE workers into PW and PTW in all the empirical models were not presented in table form but were cited in the text as part of the overall discussion.

The total earnings of workers (TWE) were derived from the total

annual man-hours employed (TMH) multiplied by the reported hourly wage rate. The TWE was deflated by the CPI with the year 2009 as base year. The marginal workers' earnings impact (MWEI) was expected to be positive, indicating that the VMP of labor was enhanced as a result of mechanization or automation. The MWEI hypothesis was tested using the following empirical model:

$$\begin{aligned}
 TWE = & B_0 + B_1 AVELOAM + B_2 FTE \\
 & + B_3 ACRE + B_4 YEARS \\
 & + B_5 NURSERY \\
 & + B_6 GREENHOUSE \\
 & + B_7 PERCENT + B_8 DATE + E.
 \end{aligned}$$

This empirical TWE model is similar to Posadas et al. (2008) except with the use of deflated values of workers' earnings, addition of the interview date as explanatory variable, and estimation of a variant model where the number of FTE workers was broken down into PW and PTW. The separation of the number of FTE workers allowed for the comparison of the marginal earnings of the PW and PTW.

Annual employment was measured in terms of the number of FTE workers, which was equal to the sum of the number of PW and one-half the number of PTW. The total man-hours employed were computed from the number of FTE workers multiplied by the number of working hours each month. The TEI was expected to be negative, indicating a labor-saving characteristic of automation or mechanization. The TEI hypothesis was evaluated using the following empirical model:

$$\begin{aligned}
 FTE, PW, PTW \text{ or TMH} \\
 = & B_0 + B_1 AVELOAM \\
 & + B_2 DEFWAGER + B_3 ACRE \\
 & + B_4 YEARS + B_5 NURSERY \\
 & + B_6 GREENHOUSE \\
 & + B_7 PERCENT + B_8 DATE + E,
 \end{aligned}$$

where DEFWAGER = deflated hourly wage rate (dollars). The empirical FTE workers, PW, PTW, or TMH model is comparable to Posadas et al. (2008) with the addition of the interview date as explanatory variable, a model variation where the dependent variable FTE workers was broken down into PW and PTW, and use of deflated wage rate. The division of FTE workers allowed

for the comparison of the impacts of mechanization on the employment of PW and PTW.

Workers' skills (WS) were measured in terms of the percentage of new workers hired having basic horticultural skills. The WS impact (WSI) was expected to be negative, indicating reduced requirements for manual workers arising from automation or mechanization. The WSI hypothesis was evaluated using the following empirical model:

$$\begin{aligned} \text{WS} = & B_0 + B_1\text{AVELOAM} + B_2\text{FTE} \\ & + B_3\text{ACRE} + B_4\text{YEARS} \\ & + B_5\text{NURSERY} \\ & + B_6\text{GREENHOUSE} \\ & + B_7\text{PERCENT} + B_8\text{DATE} \\ & + B_9\text{RETURN} + B_{10}\text{MEDIUM} \\ & + B_{11}\text{LARGE} + B_{12}\text{SUPER} + E, \end{aligned}$$

where RETURN = workers who were employed in the same nursery the previous year (percent), MEDIUM = operations with annual sales between \$250,000 and \$499,999, LARGE = operations with annual sales between \$500,000 and \$999,999, and SUPER = operations with annual sales of \$1,000,000 and above. The size of the nursery and greenhouse operations was measured by the reported annual gross sales. The dummy variables representing the various sizes of the nursery and greenhouse operations were based on the annual gross sales reported by the wholesale growers. These annual gross sales categories were based on the suggestions made by Hoppe et al. (2007) which included the following: less than \$250,000, \$250,000 to \$499,999, \$500,000 to \$999,999, and more than \$1,000,000. The empirical WS model is analogous to Posadas et al. (2008) with the addition of the interview date, the three farm sizes as explanatory variables, and a variation where the independent variable FTE workers was broken down into PW and PTW.

Training time (TT) was determined by the length of the basic training period for the newly hired workers. The workers' TT impact (TTI) was indeterminate depending on the need for increased training in the handling of specialized equipment and the lower requirement for manual workers as a result of automation or

mechanization. The TTI hypothesis was tested using the following empirical model:

$$\begin{aligned} \text{TT} = & B_0 + B_1\text{AVELOAM} + B_2\text{FTE} \\ & + B_3\text{ACRE} + B_4\text{YEARS} \\ & + B_5\text{NURSERY} \\ & + B_6\text{GREENHOUSE} \\ & + B_7\text{PERCENT} + B_8\text{DATE} \\ & + B_9\text{WS} + B_{10}\text{RETURN} \\ & + B_{11}\text{MEDIUM} + B_{12}\text{LARGE} \\ & + B_{13}\text{SUPER} + E. \end{aligned}$$

The empirical TT model is equivalent to Posadas et al. (2008) with the addition of the interview date, the three farm sizes as explanatory variables, and a variation where the independent variable FTE workers was separated into PW and PTW.

Workers' safety was measured in terms of the number of man-hours lost (MHL) due to work-related injuries and number of work-related injuries reported (WRIR) the year before the interviews were conducted. The workers' safety impact (WYI) was expected to be positive because automation or mechanization would eliminate hazardous working conditions. The WYI hypothesis was tested using the following empirical models:

$$\begin{aligned} \text{MHL or WRI} \\ = & B_0 + B_1\text{AVELOAM} \\ & + B_2\text{FTE} + B_3\text{ACRE} + B_4\text{YEARS} \\ & + B_5\text{NURSERY} \\ & + B_6\text{GREENHOUSE} \\ & + B_7\text{PERCENT} + B_8\text{DATE} \\ & + B_9\text{WS} + B_{10}\text{TRAIN1} \\ & + B_{11}\text{TRAIN2} \\ & + B_{12}\text{MEDIUM} + B_{13}\text{LARGE} \\ & + B_{14}\text{SUPER} + E, \end{aligned}$$

where TRAIN1 = workers trained on chemical and pesticide application (percent) and TRAIN2 = workers trained on basic horticultural skills (percent). The empirical MHL and WRIR models are comparable to Posadas et al. (2008) with the addition of the interview date and the three farm sizes as explanatory variables, and a model variation where the independent variable FTE workers was segmented into PW and PTW.

Workers' retention rates were expressed as a percentage of the workers who were employed in the same

nursery or greenhouse for the past 2 years before the interviews. Gabbard and Perloff (1997) reported that farmworkers are more likely to return to employers who offer benefits, pay by the hour, provide good working conditions, and hire directly. The WRI was expected to be positive because automation or mechanization would improve professional esteem and work satisfaction as a result of better and safer working conditions. The WRI hypothesis was tested using the following empirical model:

$$\begin{aligned} \text{RETURN} = & B_0 + B_1\text{AVELOAM} \\ & + B_2\text{FTE} + B_3\text{ACRE} \\ & + B_4\text{YEARS} \\ & + B_5\text{NURSERY} \\ & + B_6\text{GREENHOUSE} \\ & + B_7\text{PERCENT} + B_8\text{DATE} \\ & + B_9\text{REST} + B_{10}\text{HOUSING} \\ & + B_{11}\text{INSURANCE} \\ & + B_{12}\text{RETIREMENT} \\ & + B_{13}\text{MEDIUM} \\ & + B_{14}\text{LARGE} \\ & + B_{15}\text{SUPER} + E, \end{aligned}$$

where REST = workers with access to rest and lounging areas (percent), HOUSING = workers provided with housing benefits (percent), INSURANCE = workers provided with medical and dental insurance (percent), and RETIREMENT = workers provided with retirement benefits (percent). The empirical WRI model is analogous to Posadas et al. (2008) with the addition of the interview date and the three farm sizes as explanatory variables, and a model variation where the independent variable FTE workers was divided into PW and PTW.

The empirical models were estimated by using the multiple linear regression method. All the regression analyses were performed by using EViews 6 (Quantitative Micro Software, Irvine, CA). The descriptive statistics about mechanization, socioeconomic characteristics, and percentage distribution of nurseries and greenhouses by annual gross sales and types of operations were computed by using SPSS (version 19.0 for Windows; IBM Corporation, Armonk, NY).

Data collection and analysis

The face-to-face socioeconomic survey of wholesale nurseries and greenhouses in eight southern states—Mississippi, Alabama, Louisiana, Florida, Tennessee, South Carolina, North Carolina, and Georgia—was conducted between Dec. 2003 and Nov. 2009 (Fig. 1). This length of time was required due to the distance traveled to complete the surveys, and the availability of the growers to meet one-on-one with the survey administrator. Official lists of certified nurseries were retrieved from Mississippi Department of Agriculture and Commerce (2003), Alabama Department of Agriculture and Industries (2004), Louisiana Department of Agriculture and Forestry (2003), South Carolina Department of Agriculture (2006), Florida Department of Agriculture and Consumer Services (2005), North Carolina Department of Agriculture and Consumer Services (2008), Georgia Department of Agriculture (2007), and Tennessee Nursery and Landscape Association (2006).

Only wholesale growers operating throughout the seven states, and northern Florida, were included in the selection of survey participants. In northern Florida, nurseries were randomly selected from the listing

using only the nurseries in counties from Alachua County and north. The wholesale growers in each state included in the survey were identified and numbered from 1 to N . Using Excel (Office 2003; Microsoft Corporation, Redmond, WA), 50 random integers were individually generated from 1 to N , where N = the number of wholesale growers in each state.

Individual letters of introduction were sent to the 50 selected nurseries and greenhouses in each state in advance. Follow-up telephone calls were made to each of the nurseries and greenhouses selected to determine their willingness to participate and their availability for the interviews. All personal interviews were conducted by the research associate hired for this purpose by the Mississippi State University Coastal Research and Extension Center. The respondents to the survey were the owners or operators of the selected nurseries and greenhouses. These selected growers were contacted via mail and were asked to return a prepaid postcard indicating their willingness to participate in the survey. Those nurseries indicating a willingness to participate were then contacted by phone, and interviews scheduled. A total of 215 personal interviews were

completed with wholesale nurseries ($N = 88$), greenhouses ($N = 52$) and mixed nursery/greenhouse operations ($N = 75$) in Mississippi (32), Louisiana (29), Alabama (26), Florida (27), Tennessee (17), South Carolina (30), North Carolina (30), and Georgia (24).

The socioeconomic panel data consisted of variables dealing with labor, technical, and economic information about the nurseries and greenhouses in the eight southern states. The workers' demographic characteristics included among others race, age, gender, and formal education completed. The operational characteristics included but not limited to labor use, growing area, number of greenhouses, nursery operations, and annual gross sales. Previous reports using the above-mentioned databases covered the socioeconomic characteristics of workers and working conditions (Posadas et al., 2005b, 2010b), operational characteristics (Posadas et al., 2010a), socioeconomic determinants of technology adoption (Posadas et al., 2005a), and current mechanization systems (Coker et al., 2010). Additional reports will be forthcoming covering all the participating nurseries and greenhouses in the eight southern states included in the survey.

Fig. 1. Map showing all of the randomly selected wholesale nurseries and greenhouses in eight selected southern U.S. states that participated in the socioeconomic survey from Dec. 2003 to Nov. 2009 by type of operation.

The empirical models described above were estimated using the current socioeconomic datasets presented by type of operations in Tables 2–4. The types of horticultural operations included nursery-only, greenhouse-only, and mixed operations. Mixed operations are horticultural farms, which operate both nurseries and greenhouses. Dummy variables representing nursery-only and greenhouse-only operations were included in the models to differentiate them from mixed-type operations.

Mechanization of workers' tasks

The nursery mechanization or automation index (NMAI) could be defined as a measure of the level of automation or mechanization currently being practiced in each nursery or greenhouse included in the regional survey. The NMAI shows the extent to which nurseries have currently automated or mechanized the various tasks involved in the production of horticulture products (Posadas et al., 2008). The AVELOAM observed among the participating nurseries and greenhouses was 20.3% with significant differences observed among nursery-only (17.6%), greenhouse-only (24.9%), and mixed operations (20.3%, Table 2). The average NMAI reported by Posadas et al. (2008) was 20% for all operations, 13% for nursery-only, 28% for greenhouse-only, and 19% for mixed operations. There

were 15 major tasks included for workers in nursery operations and ten major tasks for workers in greenhouse operations (Table 1). The current mechanization systems observed among participating wholesale nurseries and mixed operations were described by Coker et al. (2010).

On average, $\approx 17.5\%$ of the major tasks in nursery operations were performed by workers with some form of mechanization or automation (Table 1). The top five major tasks performed by nursery workers with significant levels of mechanization included irrigation application and management (51.8%), transporting containers to field in nursery (31.9%), filling containers with substrate (28.5%), media preparation (28.4%) and pesticide application (24.7%). The second tier of five major tasks carried out by nursery workers with some level of mechanization were fertilizer application (16.1%), moving containers from potting to transport vehicle for movement within the nursery (14.9%), plant pruning (13.1%), picking up plants from holding area or transport trailers and loading onto delivery vehicles (11.2%), and picking plants up and loading onto transport vehicle at time of sale (10.6%). The lowest levels of mechanization were observed among the third cluster of five major tasks performed by nursery workers which included placing plant liners/sticking cuttings/planting seed (8.8%), removal of plants from transport vehicle and placing in holding area

awaiting shipment (7.8%), spacing of plants and containers (4.0%), removing containers from transport vehicle and placing in field (2.8%), and jamming plants for winter protection (0%).

Workers in greenhouse operations accomplished $\approx 25.4\%$ of their tasks with some form of mechanization or automation (Table 1). The top five major duties done by greenhouse workers with considerable levels of mechanization included irrigation application and management (56.8%), environmental control (47.2%), fertilizer application (39.4%), filling containers with substrate (34.3%) and pesticide application (30.6%). The lowest five major responsibilities undertaken by greenhouse workers with limited levels or no mechanization were media preparation (25.8%), placing plant liners/sticking cuttings/planting seed (12.7%), cutting and seed preparation (2.7%), cutting and seed collection (0.3%), and harvesting and grading production (0%).

Marginal revenue impact

There were wide variations in the annual gross sales of participating nurseries and greenhouses. Majority of the wholesale horticulture production firms (55.5%) reported annual gross sales below \$250,000. Less than one-fifth (19.4%) had annual gross sales between \$250,000 and \$499,999. About 10.4% of the participating nurseries and greenhouses

Table 2. Total number of operations, average level of mechanization, and percentage of distribution by annual gross sales of nurseries and greenhouses by type of operation.

Characteristic	All nursery and greenhouse operations	Nursery-only operations	Greenhouse-only operations	Mixed nursery and greenhouse operations
Total number of operations (number)	215	87	53	75
Average level of mechanization (%) ^{z,y}	20.34	17.58 a	24.94 b	20.29 ab
Total deflated gross annual sales (\$) ^{y,x,w}	605,334.33	518,166.26 a	293,633.37 a	931,253.13 b
Nurseries and greenhouses with annual sales below \$250,000 (%)	55.5	25.6	16.1	13.7
Operations with annual sales between \$250,000 and \$499,999 (%)	19.4	10.0	4.3	5.2
Operations with annual sales between \$500,000 and \$999,999 (%)	10.4	0.5	4.3	5.7
Operations with annual sales \$1 million and above (%)	14.7	5.2	0.0	9.5

These economic averages and percentages were computed from the results of the socioeconomic survey, that was conducted among randomly selected wholesale nurseries and greenhouses located in eight, selected southern U.S. states from Dec. 2003 to Nov. 2009.

^zSignificantly different by type of operation at $P \leq 0.05$ using analysis of variance (ANOVA).

^yValues in the same row with different letters are significantly different by type of operation at ≤ 0.05 using Duncan's multiple range test.

^xSignificantly different by type of operation at $P \leq 0.01$ using ANOVA.

^wAnnual gross sales were deflated by the consumer price index at 2009 prices.

generated annual gross sales between \$500,000 and \$999,999. About 14.7% of these horticulture firms achieved annual gross sales of \$1,000,000 and above, as shown in Table 2. The annual gross sales of the participating wholesale growers averaged \$563,981 per operation. Significantly different annual gross sales were reported by type of operation with the mixed operations averaging higher gross annual sales than the nursery-only and greenhouse-only operations.

The estimated TR model explained $\approx 89\%$ of the variations of the deflated TR of the participating nurseries and greenhouses, as shown in Table 5. The two explanatory variables which exerted significant impacts on deflated TR were the average level of mechanization (\$3824.63) and number of FTE workers (\$88,904.79). However, Posadas et al. (2008) reported three explanatory variables that had significant effects on annual gross sales: the average level of mechanization (\$4899.62), number of FTE workers (\$69,251.62), and acres in production (\$958.95). The average area in production in the eight southern states, which was 14.94 acres, was

not considerably different from the average 13.0 acres reported in the three northern Gulf of Mexico states (Posadas et al., 2010a). Attempts to estimate the TR model in quadratic form did not improve the predictive and explanatory properties of the regression results.

The MRI of the average level of mechanization, as expected, was positive, indicating that mechanization or automation had considerable enhancing effects on annual gross sales. However, the positive MRI did not specify the net effects on net revenues above total costs of production. The TR model results further suggested that an additional FTE worker was associated with an increase in annual gross sales by \$88,904.79. When the number of FTE workers was separated into its two components, the VMPs of the PW and PTW were estimated. The VMP of an additional PW employed in nurseries and greenhouse was about the same (\$87,910.77) as an additional FTE worker. When nurseries and greenhouses employed PTW in their operations, the VMP of an extra PTW averaged $\approx$ \$47,711.78.

Marginal workers' earnings impact

The TWE averaged \$175,272.57 per operation with significant variations by type of operations, as shown in Table 3. Workers in wholesale operations with annual sales \$1,000,000 and above received significantly higher total annual earnings. The total workers' earnings comprised on average, $\approx 29.1\%$ of the annual gross sales reported by nurseries and greenhouses. There were no significant variations in the ratios of the total annual workers' earnings to total annual gross sales by type of operation.

About 94% of the differences in the deflated total workers' earnings were explained by the variations in the independent variables included in the total workers' earnings model. Three independent variables explained significantly the differences in total workers' earnings, as Table 5 shows. The independent variables were the average level of mechanization (\$1830.64), number of FTE workers (\$21,980.17), and area in production (\$742.08). The same three variables were reported by Posadas et al. (2008) which exerted

Table 3. Selected economic and technical characteristics of nurseries and greenhouses by type of operation.

Characteristic	All nursery and greenhouse operations	Nursery-only operations	Greenhouse-only operations	Mixed nursery and greenhouse operations
Full-time equivalent (FTE) workers (number) ^{z,y}	6.52	5.15 a	3.83 a	10.01 b
Average FTE workers (workers/acre) ^x	1.21	1.32	1.45	0.91
Total annual man-hours employed (hours) ^{z,y}	16,830.25	13,571.20 a	9,589.90 a	25,415.48 b
Average annual man-hours employed (hours/acre) ^{y,x,w}	5,965.23	5,291.08 a	8,700.17 b	4,895.38 a
Wage rate (\$/hour) ^{y,w,v}	8.12	8.51 b	8.04 ab	7.74 a
Total deflated annual workers earnings (\$) ^{y,w,v}	175,272.57	150,640.48 ab	102,249.86 a	243,440.91 b
Ratio of total deflated annual workers earnings to deflated annual gross sales (%) ^v	29.06	28.62	32.96	27.21
Average deflated total annual workers earnings (\$/worker) ^v	19,736.57	20,162.67	19,361.88	19,736.57
Area in production (acres) ^{y,x,w}	14.94	18.93 b	1.97 a	18.72 b
Area used in production (%) ^{z,y}	60.68	67.36 b	45.30 a	62.87 b
Average area in production (acres/operation.) ^{y,x,w}	2.82	3.55 b	1.55 a	2.84 b
Period since establishment (years) ^{y,w}	24.42	23.84 ab	20.33 a	28.04 b

These economic and technical averages and percentages were computed from the results of the socioeconomic survey, that was conducted among randomly selected wholesale nurseries and greenhouses located in eight, selected southern U.S. states from Dec. 2003 to Nov. 2009.

^zSignificantly different by type of operation at $P \leq 0.01$ using analysis of variance (ANOVA).

^xValues in the same row with different letters are significantly different by type of operation at ≤ 0.05 using Duncan's multiple range test.

¹ 1 worker/acre = 2.4711 workers/ha, 1 h/acre = 2.4711 h·ha⁻¹, 1 acre = 0.4047 ha.

^wSignificantly different by type of operation at $P \leq 0.05$ using ANOVA.

^vEconomic values were deflated by the consumer price index at 2009 prices.

significant influences on the total workers' earnings, namely average level of mechanization (\$1608.88), number of FTE workers (\$18,650.94), and area in production (\$811.95).

The MWEI on the level of mechanization, as expected, was positive, indicating that mechanization or automation had enhancing effects on workers' earnings. The marginal earnings of an extra FTE worker were ≈\$21,980.17 as compared with the average earnings of an FTE worker which were \$19,736.57. There were no significant differences in the average workers' earnings per FTE worker by type of operation (Table 3). In addition, the cultivation of an additional acre to horticulture production raised workers' earnings by \$742.08.

When the number of FTE workers was separated into its two components, the regression results showed that, as expected, the marginal earning of an additional PW was about the same (\$20,791.65) as an additional FTE worker. The marginal earning of an extra PTW was ≈\$15,138.89. The VMP of additional PW and PTW were \$87,910.77 and \$47,711.78,

respectively. However, these regression results are not sufficient to draw any conclusions regarding hiring decisions involving PW and PTW.

Marginal employment impact

The number of FTE workers employed by participating nurseries and greenhouses averaged 6.52 workers per operation with significant variations by type of operation, 5.15 workers for nursery-only, 3.83 workers for greenhouse-only, and 10.01 workers for mixed-type operations, as shown in Table 3. On a per acre basis, the number of FTE workers averaged 1.21 for all types of operations without any significant variations by type of operation. The regression equation describing the decisions involving the number of FTE workers hired by the wholesale growing operations accounted for 41% of the decision-making process. Three of the independent variables included in the employment model exerted significant influences in the hiring decisions made by participating nurseries and greenhouses, as

shown in Table 5. The significant explanatory variables were area in production (0.12), nursery-only operation (−6.09), and greenhouse-only operation (−4.56). The estimated regression coefficient of the average level of mechanization turned out to be statistically insignificant. Comparable regression results were arrived at among the growers in the three northern Gulf of Mexico states (Posadas et al., 2008).

The total annual number of man-hours employed by each participating horticulture production firm averaged 16,830.25 h with significant variations by type of operation (Table 3). On a per acre basis, the total number of man-hours employed averaged 5,965.23 h/acre with the greenhouse-only operations using significantly more labor input per acre than the nursery-only and mixed-type operations. About 49% of the differences in the hiring decisions dealing with the number of man-hours were explained by the estimated regression equation (Table 5). Three of the explanatory variables played critical roles in the hiring decisions made by

Table 4. Workers training, safety, and benefits by type of operation.

Characteristic	All nursery and greenhouse operations	Nursery-only operations	Greenhouse-only operations	Mixed nursery and greenhouse operations
Workers who were employed in the same nursery or greenhouse the previous year (%)	88.90	91.63	86.67	87.32
New workers with basic horticultural skills (%) ^{z,y}	58.44	73.09 a	65.82 a	34.12 b
Length of annual training period (d) ^{z,y}	5.65	2.25 a	2.27 a	11.88 b
Workers trained on chemical and pesticide application (%)	26.48	24.69	25.10	29.60
Workers trained on basic horticultural skills (%) ^{z,y}	31.19	22.82 a	19.90 a	49.33 b
Total annual reported work-related injuries (number)	0.74	0.64	0.74	0.86
Total annual man-hours lost (hours)	15.52	12.87	5.98	25.08
Workers with access to rest and lounging areas (%) ^{y,x}	96.10	100.00 b	88.24 a	97.18 b
Workers provided with housing benefits (%) ^{z,y}	14.06	8.98 a	7.79 a	24.14 b
Workers provided with medical and dental insurance (%)	8.87	7.67	8.19	10.70
Workers provided with retirement benefits (%) ^{z,y}	7.59	3.07 a	3.19 a	15.77 b
Workers with access to sanitation facilities and drinking water (%)	97.03	100.00	96.08	94.29

These training, safety, and economic averages and percentages were computed from the results of the socioeconomic survey, that was conducted among randomly selected wholesale nurseries and greenhouses located in eight selected southern U.S. states from Dec. 2003 to Nov. 2009.

^zSignificantly different by type of operation at $P \leq 0.01$ using analysis of variance (ANOVA).

^yValues in the same row with different letters are significantly different by type of operation at ≤ 0.05 using Duncan's multiple range test.

^xSignificantly different by type of operation at $P \leq 0.05$ using ANOVA.

the participating nurseries and greenhouses, namely area in production (356.52), nursery-only operation (-15,574.71), and greenhouse-only operation (-11,517.46). The estimated regression coefficient of the average level of mechanization was not statistically significant (Table 5). Similar regression outcomes were generated among the growers in the three northern Gulf of Mexico states for this empirical model, as follows: acres in production (343.73), nursery-only operations (-16,682.48), and greenhouse-only operations (-11,663.73).

The employment impact of the level of mechanization was neutral, which is contrary to the expected labor-saving characteristic of automation or mechanization. Both the number of FTE workers and the number of man-hours employed were not significantly affected by the average level of mechanization. When the number of FTE workers was segregated into PW and PTW, the same results were observed. Both the numbers of PW and PTW were not significantly influenced by the average level of mechanization. The best possible explanation of these results is that the participating nurseries and greenhouses were able to use existing labor inputs more efficiently with any improvements in mechanization or automation. The International Labor Organization (2012) reported that the increase in mechanization and automation often speeds up the pace of work and at times can make work less interesting.

The number of acres placed in production exerted positive effects on man-hours employed and the number of FTE workers. Each added production acre required an additional 0.12 FTE worker or 356.52 h. The two dummy variables representing nursery-only and greenhouse-only operations applied negative impacts on number of FTE workers and number of man-hours employed. The mixed operations significantly employed more workers than the nursery-only or greenhouse-only operations.

Workers' skills impact

The percentage of new workers with basic horticultural skills who were hired by the participating nurseries and greenhouses averaged $\approx 58.4\%$ (Table 4). There were significant differences in the hiring decisions made by various types of operations. About

Table 5. Factors influencing the annual gross sales, workers total earnings, number of full-time equivalent (FTE) workers, and total man-hours employed in nurseries and greenhouses.

Independent variable	Deflated total revenues (2009 dollars)		Deflated total workers' earnings (2009 dollars)		FTE workers (no.)		Total man-hours employed (hours)	
	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
Constant term	33,685,256	28,187,941	-5,283,098	6,393,971	-707.67	737.15	2,279,864	1,835,665
Average level of mechanization (%)	3,824.63*	1,862.04	1,830.64**	374.71	-0.00	0.04	81.55	121.17
FTE workers (number)	88,904.79**	9,208.17	21,980.64**	666.04	N/A ^z	N/A	N/A	N/A
Deflated wage rate (\$/hour)	N/A	N/A	N/A	N/A	0.85	0.50	2,136.88	1,247.43
Area in production (acres) ^y	-26.35	930.42	742.08**	157.67	0.12**	0.01	356.52**	38.44
Period since establishment (years)	544.91	1,344.89	-313.39	364.37	0.04	0.04	98.90	104.64
Nursery-only operation	81,529.27	79,983.82	21,438.78	14,286.73	-6.09*	1.59	-15,574.71**	3,977.82
Greenhouse-only operation	-75,406.65	68,265.15	5,420.87	16,272.17	-4.56*	1.85	-11,517.46*	4,595.55
Area used in production (%)	-28.65	613.41	18.58	191.49	0.01	0.02	16.18	55.29
Interview date	-46.10	38.47	7.15	8.73	0.00	0.00	3.10	2.50
Included nurseries and greenhouses (number)	202	—	172	—	177	—	172	—
R-squared	0.89	—	0.94	—	0.41	—	0.49	—
Standard error of regression	337,802.10	—	70,569.10	—	8.26	—	20,322.67	—
F statistic	188.24**	—	294.49*	—	15.16**	—	19.63**	—
Durbin-Watson statistic	2.00	—	1.84	—	1.84	—	2.27	—

The multiple linear regressions used data collected from the socioeconomic survey of randomly selected wholesale nurseries and greenhouses located in eight selected southern U.S. states from Dec. 2003 to Nov. 2009.

^zNot applicable in this model.

^y1 acre = 0.4047 ha.

*, **Statistically significant at $P \leq 0.05$ or 0.01, respectively, using T value or F statistic.

32% of the decisions to hire new workers with basic horticultural skills were explained by the explanatory variables included in the model (Table 6). The estimated regression equation showed that four explanatory variables exerted significant influence on the decisions to hire new workers with horticultural skills. The significant determinants included the average level of mechanization (−0.49), nursery-only operations (27.84), greenhouse-only operations (24.48), and area used in production (−0.28). Only three significant variables were reported by

Posadas et al. (2008) among the growers in the three northern Gulf of Mexico states, namely average level of mechanization (−1.68), nursery-only (53.09), and greenhouse-only (74.80) operations.

Empirical results showed that nursery-only and greenhouse-only operations were more inclined to hire new workers with basic horticultural skills than mixed nursery and greenhouse operations. Operations which were using more of the existing acreage to horticulture production tended to employ lesser new workers with

basic horticultural skills. The WSI of the level of mechanization, as expected was negative, indicating reduced requirements for manual workers arising from automation or mechanization. The regression results suggested that a 10% increase in the level of mechanization reduced the hiring of new workers with horticultural skills by 4.9%. In addition, when the number of FTE workers was separated into its two components, there were no significant effects registered by the number of PW and PTW on the percentage of new workers with basic horticultural

Table 6. Factors affecting the hiring of new workers with basic horticultural skills, length of basic training period for new workers employed, man-hours lost (MHL) due to work-related injuries, and number of work-related injuries reported (WRIR) by the nurseries and greenhouses.

Independent variable	New workers hired with basic horticultural skills (%)		Length of basic training period for new workers (d)		MHL because of work-related injuries (hours)		WRIR (no.)	
	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
Constant term	−6,097.23	3,770.37	870.18	1,051.24	−1,088.92	3,438.08	−517.37*	168.27
Average level of mechanization (%)	−0.49*	0.22	−0.04	0.07	−0.31	0.24	0.03**	0.01
Full-time equivalent workers (number)	−0.17	0.30	−0.12	0.08	6.69**	0.46	0.09**	0.02
Area in production (acres) ^z	−0.12	0.07	0.06**	0.01	0.27*	0.08	−0.00	0.00
Period since establishment (years)	−0.33	0.30	0.00	0.05	−0.28	0.21	−0.01	0.01
Nursery-only operation	27.84*	9.25	−6.80*	2.83	5.04	8.62	−0.01	0.42
Greenhouse-only operation	24.48*	9.77	−8.54*	3.85	7.84	9.18	−0.04	0.44
Area used in production (%)	−0.28*	0.12	−0.16**	0.06	−0.00	0.10	0.00	0.00
Interview date	0.01	0.10	−0.00	0.00	0.00	0.00	0.00**	0.00
Workers who were employed in the same nursery or greenhouse the previous year (%)	0.03	0.29	0.07	0.05	−0.34	0.19	−0.01	0.00
New workers with basic horticultural skills (%)	N/A ^y	—	−0.13*	0.04	−0.06	0.07	0.00	0.00
Workers trained on chemical and pesticide application (%)	N/A	—	N/A	—	0.26*	0.09	−0.01*	0.00
Workers trained on basic horticultural skills	N/A	—	N/A	—	−0.11	0.09	0.01**	0.00
Operations with annual sales between \$250,000 and \$499,999	−0.60	9.19	−1.05	2.51	−15.05	9.06	0.17	0.44
Operations with annual sales between \$500,000 and \$999,999	−14.12	13.10	6.34	7.41	−35.64**	12.12	−0.16	0.59
Operations with annual sales \$1 million and above	9.54	13.89	−2.08	4.87	−83.21**	15.09	−0.10	0.73
Included nurseries and greenhouses (number)	170	—	161	—	169	—	169	—
R-squared	0.32	—	0.27	—	0.75	—	0.33	—
Standard error of regression	38.98	—	15.13	—	37.61	—	1.84	—
F statistic	6.17**	—	4.26**	—	31.34**	—	5.18**	—
Durbin-Watson statistic	1.85	—	1.85	—	2.00	—	2.03	—

The multiple linear regressions used data collected from the socioeconomic survey of randomly selected wholesale nurseries and greenhouses located in eight selected southern U.S. states from Dec. 2003 to Nov. 2009.

^z1 acre = 0.4047 ha.

^yNot applicable in this model.

*, **Statistically significant at $P \leq 0.05$ or 0.01, respectively, using T value or F test.

skills who were hired by the participating nurseries and greenhouses.

Workers' training time impact

The length of the basic training period for newly hired workers averaged 5.65 d with significant variations among various types of operations, as Table 4 shows. About 27% of the differences in the number of training days were explained by the estimated equation shown in Table 6. Five explanatory variables have significant effects on the decisions involving the length of the training period. The significant variables were area in production (0.06), nursery-only operations (-6.80), greenhouse-only operations (-8.54), area used in production (-0.16), and new workers with basic horticultural skills (-0.13). These results included more variables than the growers in the three northern Gulf of Mexico states which included only the new workers with basic horticultural skills (-0.27).

The workers' TTI of the level of mechanization was neutral, implying that its impacts depend on the need for increased training in the handling of specialized equipment and the lower requirement for manual workers as a result of automation or mechanization. The acres in production had positive impact on training period since additional acreage placed under production required more man-hours, as illustrated in the employment impact model. The nursery-only and greenhouse-only operations tended to spend fewer training days for newly hired workers since these operations were more inclined to hire new workers with basic horticultural skills than mixed nursery and greenhouse operations. Since those operations using more of the existing acreage to horticulture production tended to employ fewer new workers with basic horticultural skills, they devoted lesser number of days training them. In addition, when the number of FTE workers was separated into its two components, the number of PTWs registered a significant negative effect (-0.61) on workers' TT.

Workers' safety impact

Workers' safety was measured in terms of MHL due to work-related injuries and number of WRIR. The number of WRIR the year before they were interviewed averaged 0.74

injuries per operation with no significant differences observed among types of operations (Table 4). The number of MHL due to work-related injuries averaged 15.52 h per operation across the three types of operations. About 26.4% of the workers in all three types of operations were trained in chemical and pesticide application. About 31.2% of workers were trained on basic horticultural skills with more workers' training conducted by the mixed-type operations.

The regression results of the WYI models indicate that 75% and 33% of the variations in MHL and the number of injuries were explained by the independent variables included in the models, respectively (Table 6). The significant variables affecting the number of MHL due to work-related injuries were the number of FTE workers (6.69), area in production (0.27), workers trained on chemical and pesticide application (0.26), operations with annual sales between \$500,000 and \$999,999 (-35.64), and operations with annual sales between \$1,000,000 and above (-83.21). For the number of work-related injuries, the significant determinants were the average level of mechanization (0.03), the number of FTE workers (0.09), date of interview (0.00), workers trained on chemical and pesticide application (-0.01), and workers trained on basic horticultural skills (0.01). In comparison, only the number of FTE workers significantly affected the number of MHL (9.62) and number of injuries (0.32) reported by the growers in the three northern Gulf of Mexico states.

The WYI was expected to be positive because automation or mechanization would eliminate hazardous working conditions. However, the number of WRIR by participating growers increased as a result of the improvements in the average level of mechanization. The International Labor Organization (2012) reported that many workers suffer from injuries and diseases that result from manual work and the increased mechanization of work. One of the results of manual work, as well as the increase in mechanization, is that more and more workers are suffering from back aches; neck aches; sore wrists, arms and legs; and eyestrain. The most commonly reported injuries among the participating nurseries and greenhouses

were primarily back strains, cut fingers, shoulder and ankle strains, and eye injury.

Each FTE worker added to the labor force led to an additional 0.09 work-related injury and 6.69 h lost as a result of these injuries. The percentage of workers trained on chemical and pesticide application had direct effects on MHL. An increase in the area of production by an acre led to a rise in the MHL by 0.27 h due to injuries. Over the 6 years when the personal interviews were conducted with the nurseries and greenhouses, a gradual increasing trend in the number of work-related injuries was observed. The increase in the percentage of workers trained on basic horticultural skills caused the number of work-related injuries to gradually escalate. The increase in the percentage of workers trained on chemical and pesticide application drove the number of work-related injuries to fall but may have caused the MHL to rise. The wholesale operations with annual sales above \$500,000 reported lower number of MHL due to injuries. When the number of FTE workers was separated into its two components, the regression results showed that the work-related injuries were accounted for by the 0.09 injuries reported for every additional PW employed.

Workers' retention impact

Nursery and greenhouse growers can retain their current workers by maintaining good working conditions, providing workers' benefits, and improving productivity through the adoption of mechanized production systems. The lack of field sanitation on agricultural job sites increased the probability of workers reporting gastrointestinal disorders (Frisvold et al., 1987). The percentages of workers with access to sanitation facilities and drinking water and to rest and recreational areas averaged 97.0% and 96.1%, respectively (Table 4). On the other hand, low percentages of the workers were provided with housing benefits (14.0%), medical and dental insurance (8.9%), and retirement benefits (7.6%).

Exceedingly high workers' retention rates were observed among the participating wholesale operations averaging 88.9%, with no significant variations among various types of

operations, as shown in Table 4. However, the regression results of the retention model showed that only 12% of the variations in retention rates was explained by the independent variables and that the F test indicated that the estimated equation was not statistically significant (Table 7). The WRI of the level of mechanization was expected to be positive, but it turned out to be neutral. It seemed that no significant variations in retention rates were observed among the participating operations since almost all of their workers were with them during the past 2 years before conducting the interviews. The same neutral impacts were observed when the number of FTE workers was segmented into its two permanent and part-time components. In contrast, the retention of workers in the three northern Gulf of Mexico states (Posadas et al., 2008) was significantly affected by greenhouse-only operations (14.94), workers with access to

rest and lounging areas (0.78), workers provided with housing benefits (0.17), and workers provided with retirement benefits (−0.23).

Conclusions

About one-fifth of the major tasks performed by workers in nurseries and greenhouses in the eight southern states that participated in the face-to-face interviews were performed with some form of mechanization or automation. About 17.5% of the major tasks in nursery-only operations were performed by workers with some form of mechanization or automation. The top five major tasks performed by nursery workers with significant levels of mechanization included irrigation application and management (51.8%), transporting containers to field in nursery (31.9%), filling containers with substrate (28.5%), media preparation (28.4%), and pesticide application (24.7%). Workers in

greenhouse-only operations accomplished $\approx 25.4\%$ of their tasks with some form of mechanization or automation. The top five major duties done by greenhouse workers with considerable levels of mechanization included irrigation application and management (56.8%), environmental control (47.2%), fertilizer application (39.4%), filling containers with substrate (34.3%), and pesticide application (30.6%).

There was wide disparity in the annual gross sales reported by the horticulture firms in the eight southern states. Majority of the growers (55.5%) were operations, which generated annual gross sales below \$250,000. Less than one-fifth of the horticulture operations grossed between \$250,000 and \$499,999 per year. One out of 10 of the nurseries and greenhouses earned between \$500,000 and \$999,999. About 14.7% of the horticulture firms sold horticulture products and services valued at \$1,000,000 or more per year.

Nurseries and greenhouses in the eight southern states that reported higher levels of annual gross sales demonstrated higher levels of mechanization or automation, implying economies of scale associated with technology adoption by these wholesale horticulture production firms. The two explanatory variables that exerted significant impacts on deflated TR were the average level of mechanization (\$3824.63) and number of FTE workers (\$88,904.79). However, in the three northern Gulf of Mexico states, three explanatory variables were reported to have significant effects on annual gross sales, namely the average level of mechanization (\$4899.62), number of FTE workers (\$69,251.62), and acres in production (958.95).

The increase in total workers' earnings associated with improved mechanization indicated that nurseries and greenhouses were able to pay their workers higher wages and salaries. The overall ratio between the total annual workers' earnings and the total annual gross sales was $\approx 29\%$. When the number of FTE workers was separated into its two components, regression results showed that the marginal earning of an additional PW was \$20,791.65 and that of a PTW was \$15,138.89. It should be noted that the values of the annual marginal productivity of the PW and PTW were estimated to be

Table 7. Factors affecting the retention rate of workers who were employed in the same nursery or greenhouse the previous year.

Independent variable	Workers' retention rates (%)	
	Coefficient	SE
Constant term	117.73	1,418.15
Average level of mechanization (%)	0.14	0.11
Full-time equivalent workers (number)	0.20	0.12
Area in production (acres) ^z	−0.03	0.01
Period since establishment (years)	0.09	0.08
Nursery-only operation	2.05	3.15
Greenhouse-only operation	2.30	3.78
Area used in production (%)	−0.11	0.06
Workers with access to rest and lounging areas (%)	0.33	0.21
Workers provided with housing benefits (%)	0.07	0.03
Workers provided with medical and dental insurance (%)	0.23*	0.08
Workers provided with retirement benefits (%)	−0.17*	0.06
Workers with access to sanitation facilities and drinking water (%)	−0.48*	0.23
Interview date	−0.00	0.00
Operations with annual sales between \$250,000 and \$499,999	−3.50	4.36
Operations with annual sales between \$500,000 and \$999,999	−12.14	4.71
Operations with annual sales \$1 million and above	−13.38	4.97
Included nurseries and greenhouses (number)	194	—
R-squared	0.12	—
Standard error of regression	20.40	—
F statistic	1.55	—
Durbin-Watson statistic	1.81	—

The multiple linear regression used data collected from the socioeconomic survey of randomly selected wholesale nurseries and greenhouses located in eight selected southern U.S. states from Dec. 2003 to Nov. 2009.

^z1 acre = 0.4047 ha.

*Statistically significant at $P \leq 0.05$ using *T* value.

\$87,971 and \$47,712, respectively. Three independent variables explained significantly the differences in total workers' earnings including the average level of mechanization (\$1830.64), number of FTE workers (\$21,980.17), and area in production (\$742.08). The same three independent variables exerted significant influences on the total workers' earnings in the three northern Gulf of Mexico states, namely average level of mechanization (\$1608.88), number of FTE workers (\$18,650.94), and area in production (\$811.95).

The number of workers or man-hours hired by the horticultural firms in the eight southern states averaged 1.21 FTE workers per acre or 5965.23 h per acre with significant differences by type of operation. The increased levels of mechanization produced neutral effects on employment and raised the VMP of labor, implying that technology adoption by wholesale nurseries and greenhouses did not displace any worker but instead improved total workers' earnings. When the number of FTE workers was segregated into its components, both the numbers of PW and PTW were not significantly influenced by the average level of mechanization. The best possible explanation of these results is that the participating nurseries and greenhouses were able to use existing labor inputs more efficiently with any improvements in mechanization or automation. Three independent variables exerted significant influences in the hiring decisions made by participating nurseries and greenhouses, namely area in production (0.12), nursery-only operation (-6.09), and greenhouse-only operation (-4.56). Comparable regression results were arrived at among the growers in the three northern Gulf of Mexico states.

About 58.4% of the new workers hired by nurseries and greenhouses in the eight southern states had basic horticultural skills with the mixed-type operations hiring more less-skilled workers. Significant advances in mechanization have considerable implications on the skill levels of newly hired workers. Growers that reported higher levels of mechanization hired fewer new workers with basic horticultural skills, especially among mixed nurseries and greenhouses. Regression results showed that the average level of mechanization (-0.49), nursery-only operation

(27.84), greenhouse-only operation (24.48), and area used in production (-0.28) exerted significant influence over the hiring of workers with basic horticultural skills. On the other hand, only three significant variables were reported among the growers in the three northern Gulf of Mexico states, namely average level of mechanization (-1.68), nursery-only operations (53.09), and greenhouse-only operations (74.80).

Horticulture operations hiring fewer new workers with basic horticultural skills spent fewer training days providing them with basic horticultural skills. The length of training period for basic horticultural skills was not influenced by the level of mechanization, but was significantly extended when nurseries or greenhouses hired more new workers without basic horticultural skills. Five explanatory variables have significant effects on the decisions involving the length of the training period. The significant variables were area in production (0.06), nursery-only operation (-6.80), greenhouse-only operation (-8.54), area used in production (-0.16), and new workers with basic horticultural skills (-0.13). These results included more variables than the growers in the three northern Gulf of Mexico states which included only the new workers with basic horticultural skills (-0.27).

The WYI was expected to be positive because automation or mechanization would eliminate hazardous working conditions, as reported among the growers in the three northern Gulf of Mexico states. However, the number of WRIR by participating growers increased as a result of the improvements in the average level of mechanization. The significant variables affecting the number of MHL due to work-related injuries were the number of FTE workers (6.69), area in production (0.27), workers trained on chemical and pesticide application (0.26), operations with annual sales between \$500,000 and \$999,999 (-35.64), and operations with annual sales of \$1,000,000 and above (-83.21). For the number of work-related injuries, the significant determinants were the average level of mechanization (0.03), the number of FTE workers (0.09), date of interview (0.00), workers trained on chemical and pesticide application (-0.01), and workers trained on basic horticultural

skills (0.01). In comparison, only the number of FTE workers significantly affected the number of MHL (9.62) and number of injuries (0.32) reported by the growers in the three northern Gulf of Mexico states.

The WRI of mechanization or automation was neutral since most of the workers were with the participating nurseries and greenhouses during the past 2 years before conducting the interviews. This result was in contrast with the findings among the workers in the nurseries and greenhouses located in the three northern Gulf of Mexico states where workers' retention was significantly affected by greenhouse-only operations (14.94), workers with access to rest and lounging areas (0.78), workers provided with housing benefits (0.17), and workers provided with retirement benefits (-0.23).

Literature cited

- Alabama Department of Agriculture and Industries. 2004. Certified nurseries. Alabama Dept. Agr. Ind., Bur. Plant Ind., Montgomery, AL.
- Bellenger, M., D. Fields, K. Tilt, and D. Hite. 2008. Producer preferences for migrant labor and the wage, hours, and gross sales effects in Alabama's horticulture industry. *HortTechnology* 18:301-307.
- Bureau of Labor Statistics. 2012a. Consumer price index. 14 Feb. 2012. <<http://www.bls.gov/cpi/home.htm>>.
- Bureau of Labor Statistics. 2012b. Occupational outlook handbook, 2010-11 edition: Agricultural workers. 8 Feb. 2012. <<http://www.bls.gov/oco/ocos349.htm>>.
- Coker, R.Y., B.C. Posadas, S.A. Langlois, P.R. Knight, and C.H. Coker. 2010. Current mechanization systems among nurseries and mixed operations. *Mississippi Agr. For. Expt. Sta. Bul.* 1189.
- Florida Department of Agriculture and Consumer Services. 2005. Certified nursery and stock dealer list. Florida Dept. Agr. Consumer Serv., Bur. Plant Ind., Tallahassee, FL.
- Frisvold, G., R. Mines, and J.M. Perloff. 1987. The effects of job sites sanitation and living conditions on the health and welfare of agricultural workers. CUDARE Working Paper 431. Dept. Agr. Res. Econ., Univ. of California, Berkeley, CA.
- Gabbard, S.M. and J.M. Perloff. 1997. The effects of pay and work conditions on farmworker retention. *Ind. Relat.* 36: 474-488.

- Georgia Department of Agriculture. 2007. Live plant licenses. Georgia Dept. Agr., Bur. Plant Ind., Atlanta, GA.
- Giacomelli, G. 2002. Greenhouse structures. Paper no. E-125933-04-01. Dept. Agr. Biosystems Eng., Univ. of Arizona, Tucson, AZ.
- Hodges, A.W., C.R. Hall, and M.A. Palma. 2011. Economic contributions of the green industry in the United States, 2007. Southern Coop. Series Bul. No. 413. 10 Dec. 2011. <<http://www.fred.ifas.edu/economic-impact/pdf/US-green-industry-in-2007.pdf>>.
- Hoppe, R.A., P. Korb, E.J. O'Donoghue, and D.E. Banker. 2007. Structure and finances of U.S. farms: Family farm report, 2007 edition. EIB-24. U.S. Dept. Agr., Econ. Res. Serv., Washington, DC.
- International Labor Organization. 2012. Your health and safety at work. *Ergonomics* 8. <<http://actrav.itcilo.org/actrav-english/telearn/osh/ergo/ergoa.htm>>.
- Ling, P.P. 1994. From mechanization to the information highway. Greenhouse systems: Automation, culture and environment. Proc. Greenhouse Systems Intl. Conf. p. 5-7.
- Louisiana Department of Agriculture and Forestry. 2003. Nursery certificate listing. Louisiana Dept. Agr. For., Hort. Quarantine Programs, Baton Rouge, LA.
- Mathers, H.M., A.A. Acuna, D.R. Long, B.K. Behe, A.W. Hodges, J.J. Haydu, U.K. Schuch, S. Barton, J.H. Dennis, B.K. Maynard, C.H. Hall, R. McNeil, and T. Archer. 2010. Nursery worker turnover and language proficiency. *HortTechnology* 45:71-77.
- Mississippi Department of Agriculture and Commerce. 2003. Directory of Mississippi certified nurseries and nursery dealers. Mississippi Dept. Agr. Commerce, Bur. Plant Ind., Mississippi State, MS.
- North Carolina Department of Agriculture and Consumer Services. 2008. Directory of certified nurseries and plant collectors. North Carolina Dept. Agr. Consumer Serv., Plant Ind. Div., Raleigh, NC.
- O*Net Online. 2012. Summary report for: 45-2092.01: Nursery workers. 14 Feb. 2012. <<http://www.onetonline.org/link/summary/45-2092.01>>.
- Porter, M. 2002. Automation vs. mechanization. 5 May 2008. <[http://www.gpnmag.com/Automation vs. Mechanization-article3017](http://www.gpnmag.com/Automation%20vs.%20Mechanization-article3017)>.
- Posadas, B.C., G.B. Fain, C.H. Coker, P.R. Knight, C.D. Veal, and R.Y. Coker. 2004. Socioeconomic survey of nursery automation. Proc. Southern Nursery Assn. Res. Conf. 49:306-309.
- Posadas, B.C., P.R. Knight, C.H. Coker, R.Y. Coker, and S.A. Langlois. 2008. Socioeconomic impact of automation on horticulture production firms in the northern Gulf of Mexico. *HortTechnology* 18:697-704.
- Posadas, B.C., P.R. Knight, C.H. Coker, R.Y. Coker, and S.A. Langlois. 2010a. Operational characteristics of nurseries and greenhouses in the northern Gulf of Mexico states. Mississippi Agr. For. Expt. Sta. Bul. 1184.
- Posadas, B.C., P.R. Knight, C.H. Coker, R.Y. Coker, and S.A. Langlois. 2010b. Socioeconomic characteristics of workers and working conditions in nurseries and greenhouses in the northern Gulf of Mexico states. Mississippi Agr. For. Expt. Sta. Bul. 1182.
- Posadas, B.C., P.R. Knight, C.H. Coker, R.Y. Coker, S.A. Langlois, and C.D. Veal. 2005a. Levels of technology adoption among horticulture firms in the northern Gulf of Mexico. Proc. Southern Nursery Assn. Res. Conf. 50:365-368.
- Posadas, B.C., P.R. Knight, C.H. Coker, R.Y. Coker, S.A. Langlois, and C.D. Veal. 2005b. Socioeconomic characteristics of horticulture firms in the Gulf South. Proc. Southern Nursery Assn. Res. Conf. 50:348-350.
- Regelbrugge, C.J. 2007. American agriculture and immigration reform: An industry perspective. 5 May 2008. <<http://www.usda.gov/occe//forum/2007%20Speeches/PDF%20speeches/CRegelbrugge.pdf>>.
- Simonton, W. 1992. Automation in the greenhouse: Challenges, opportunities, and a robotics case study. *HortTechnology* 2:231-235.
- South Carolina Department of Agriculture. 2006. Nursery directory. South Carolina Dept. Agr., Columbia, SC.
- Tennessee Nursery and Landscape Association. 2006. Nursery buyers guide. Tennessee Nursery Landscape Assn., McMinnville, TN.