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Socioeconomic Impact of Automation on Horticulture Production Firms in the Northern Gulf of Mexico Region

Benedict C. Posadas[1,3], Patricia R. Knight[1], Randal Y. Coker[1], Christine H. Coker[1], Scott A. Langlois[1], and Glenn Fain[2]

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Summary. **Using results of a socioeconomic survey of nurseries and greenhouses, Tobit regression analysis was used 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. The survey was conducted among 87 randomly selected nurseries and greenhouses located in Mississippi, Louisiana, and Alabama, from Dec. 2003 to Mar. 2005. About 20% of all the identified major tasks were performed by workers in nurseries and greenhouses with some form of mechanization or automation. Regression results showed that nurseries and greenhouses that experienced higher levels of sales also demonstrated higher levels of automation or mechanization. The employment impact of automation or mechanization was neutral, indicating that any improvement in automation or mechanization did not necessarily lead to a reduction, but instead to a more efficient use of labor by nurseries and greenhouses. Improvements in automation or mechanization resulted in higher total workers' earnings reported by participating nurseries and greenhouses. Further Tobit regression results showed that automation or mechanization had neutral effects on the length of training period, workers' safety, and retention rates and enabled nurseries and greenhouses to hire less-skilled workers.**

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). To sustain robust growth in the industry, continuous improvements in the skills of the workforce and their year-round availability are necessary. These workers perform varied functions and are subjected to different working conditions. Many jobs in the industry require large amounts of stooping, lifting of heavy containers, and exposure to chemicals, dust, and plant materials. These tend to be relatively low-paying jobs, 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. 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.

A regional socioeconomic survey of nursery and greenhouse automation and mechanization was conducted in the northern Gulf of Mexico region as a part of a research program 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 10-page socioeconomic survey consisted of eight parts, namely, workers' demographic characteristics, nursery characteristics, nursery mechanization, greenhouse automation, labor and capital markets, pesticide and chemicals, working conditions, and respondents' characteristics. The overall goals of the regional socioeconomic survey were to develop a socioeconomic profile of horticulture workers and to evaluate the impact of automation on their employment, earnings, safety, skill levels, and retention rates (Posadas et al., 2004). However, the specific objectives of this paper were to develop an index of the level of automation or mechanization among nurseries and greenhouses in the northern Gulf of Mexico region, and to measure the socioeconomic impact of automation or mechanization on total revenues, annual employment, and workers' earnings, skills, training, safety, and retention rates.

Mechanization of an operation can provide mechanical power, speed, repetition, safety, and a greater potential for consistency and quality control. Automation includes these attributes but with greater flexibility, and potentially, some automated decision-making (Giacomelli, 2002). Mechanization is normally defined as the replacement of a human task with a machine. However, 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

[1]Mississippi State University, Coastal Research and Extension Center, 1815 Popps Ferry Road, Biloxi, MS 39532

[2]Department of Horticulture, 109 Funchess Hall, Auburn University, Auburn, AL 36849

[3]Corresponding author. E-mail: benp@ext.msstate.edu.

them (Porter, 2002). The possible benefits associated with automation were summarized by Ling (1994) as follows: reduce the manual labor requirement, improve production quality, eliminate hazardous working conditions, reduce production costs, increase market value, and improve professional esteem.

Materials and methods

The socioeconomic survey of nursery automation was conducted among wholesale nurseries and greenhouses located in the northern Gulf of Mexico region of Mississippi, Alabama, and Louisiana (Table 1). The nursery and greenhouse survey that was conducted between Dec. 2003 and Mar. 2005 lasted from 30 min to 1 h. Official lists of certified nurseries were requested from the Mississippi Department of Agriculture and Commerce (2003), the Alabama Department of Agriculture and Industries (2003), and the Louisiana Department of Agriculture and Forestry (2003). From these official lists of nursery growers, industry associations buyer's guides (Louisiana Nursery and Landscape Assn., 2005), online buyer's guides (Alabama Nursery and Landscape Assn., 2008), and extension service reference guides (Johnson and Wells, 2007), the wholesale growers in every state were identified and numbered from 1 to N. Using Excel (Office 2003; Microsoft Corp., 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 with 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 (Posadas et al., 2004). The respondents to the survey were the owners or operators of the selected nurseries and greenhouses. A total of 87 nursery automation survey forms (NASF) were completed from personal interviews with nurseries and greenhouses (Table 1).

The entire socioeconomic database consisted of variables dealing with labor, technical, and economic information about the nurseries and greenhouses in the region (Posadas et al., 2005a). The workers' demographic characteristics included race, age, gender, and formal education completed. Nursery characteristics included nursery area, number of greenhouses, nursery operations, and annual sales. The socioeconomic characteristics of workers and working conditions in nurseries and greenhouses, operational characteristics, and socioeconomic determinants of nursery and greenhouse technology adoption will be covered in forthcoming reports.

The nursery automation index 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 (Posadas et al., 2005b). It showed 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 system used in each nursery or greenhouse visited. Fifteen major tasks were included in determining the level automation or mechanization among nursery growers engaged in open-field production. Among greenhouse operators, 10 major greenhouse tasks were included in determining the current level of automation or mechanization. The level of automation or mechanization would range from 0% to 100%, where 0% = task was performed manually or 100% = task was fully automated or mechanized. The average level of automation or mechanization in every nursery or greenhouse operation was computed as the average percentage level of automation or mechanization in all the 15 nursery tasks or the 10 greenhouse tasks included in the survey (Table 2).

To evaluate the socioeconomic impact of mechanization or automation, empirical models were estimated for the horticulture production firm's total revenues, annual employment, workers' earnings, safety, skill levels, and retention rates. The general specifications of the socioeconomic empirical models were as follows:

Y_t = socioeconomic characteristics of nurseries and greenhouses at time t,

X_t = vector of technical, economic, geographic, and mechanization

Table 1. Annual gross sales and number of workers employed by nurseries and greenhouses that participated in the socioeconomic survey in the northern Gulf of Mexico region from Dec. 2003 to Mar. 2005.

Item	Operations (no.)	Nurseries and greenhouses by annual gross sales (%)					Full-time workers (no.)	Part-time workers[z, y] (no.)
		Less than $250,000	$250,000-$499,999	$500,000-$999,999	$1,000,000 and above	Total		
By state								
Alabama	26	60	28	4	8	100	4.0	1.2 a
Louisiana	29	61	21	14	4	100	4.5	1.3 a
Mississippi	32	52	10	16	23	100	5.0	4.2 b
Total	87	57	19	12	12	100	4.5	2.3
By type of operation								
Nurseries only	22	71	24	0	5	100	3.0	0.7 a
Greenhouses only	22	68	18	14	0	100	2.7	0.8 a
Mixed operations	43	44	17	17	22	100	6.2	3.9 b
Total	87	57	19	12	12	100	4.5	2.3

[z]Significantly different by state or type of operation at $P \leq 0.05$.
[y]Values in the same column with different letters are significantly different by state or type of operation at $P \leq 0.05$.

Table 2. Proportion of major tasks performed by workers and proportion of nurseries and greenhouses with some form of automation or mechanization during the socioeconomic survey in the northern Gulf of Mexico from Dec. 2003 to Mar. 2005.

Workers' tasks	Proportion of workers' tasks (%)		Proportion of operations (%)	
	Nurseries	Greenhouses	Nurseries	Greenhouses
Media preparation	28	27	31	36
Filling containers with substrate	30	34	41	45
Cutting and seed collection	N/A[z]	0	N/A	0
Cutting and seed preparation	N/A	2	N/A	6
Placing plant liners, sticking cuttings, and planting seed	6	12	14	15
Environmental control	N/A	47	N/A	72
Moving containers from potting to transport vehicle for movement within the nursery	13	N/A	21	N/A
Transporting containers to field in nurseries	28	N/A	52	N/A
Removing containers from transport vehicle and placing in the field	2	N/A	4	N/A
Spacing of plants and containers	1	N/A	4	N/A
Harvesting and grading production	N/A	0	N/A	0
Picking plants up and loading onto transport vehicle at time of sale	6	N/A	14	N/A
Removal of plants from transport vehicle and placing in holding area awaiting shipment	4	N/A	8	N/A
Picking up plants from holding area/transport trailers and loading onto delivery vehicles	5	N/A	10	N/A
Jamming plants for winter protection	0	N/A	0	N/A
Plant pruning	7	N/A	28	N/A
Fertilizer application	16	40	24	49
Pesticide application	24	29	48	64
Irrigation application and management	48	56	72	78

[z]Not applicable because this question was not asked to this group.

or automation variables enhancing or limiting the socioeconomic characteristics of nurseries and greenhouses at time t such that $Y_t = F(X_t)$.

These empirical models were used to measure the socioeconomic impact of automation or mechanization on total revenues, annual employment, workers' earnings, safety, skill levels, and retention rates. The average level of mechanization or automation was used in the empirical models instead of the individual mechanization or automation variables for nurseries (15 tasks) and greenhouses (10 tasks). The use of the individual tasks resulted to errors in estimation because there was insufficient number of observations. If the slope or first derivative of the estimated empirical equation with respect to the level of mechanization is not statistically different from zero, then mechanization has a neutral effect on the designated socioeconomic variable. The impacts of the other variables included in each of the models were also measured by the same procedure.

The total revenues of nurseries and greenhouses were derived from the midpoint of the annual gross sales group reported (Table 1). The marginal-revenue impact was expected to be positive, indicating that horticulture production firms that experienced higher levels of production or sales would also demonstrate higher levels of automation or mechanization.

The total earnings of workers were derived from the total annual man-hours employed multiplied by the reported hourly wage rate (Table 3). The marginal workers' earnings impact was expected to be positive, indicating that the value of the marginal productivity of labor was enhanced as a result of mechanization or automation.

Annual employment was measured in terms of the number of full-time equivalent (FTE) workers, which was equal to the sum of the number of permanent workers and one-half the number of part-time workers (Table 3). The total man-hours employed were computed from the number of FTE workers multiplied by the number of working hours each month. The employment impact was expected to be negative, indicating a labor-saving characteristic of automation or mechanization.

Workers' skills were measured in terms of the percentage of new workers hired that have basic horticultural skills (Table 4). The workers' skills impact was expected to be negative, indicating reduced requirements for manual workers arising from automation or mechanization.

Training time was determined by the length of the basic training period for the newly hired workers (Table 4). The workers' training time impact 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.

Workers' safety was measured in terms of man-hours lost due to work-related injuries, primarily back strains and cut fingers, and number of work-related injuries reported last

Table 3. Selected economic characteristics of nurseries and greenhouses that participated in the socioeconomic survey in the northern Gulf of Mexico region from Dec. 2003 to Mar. 2005.

Item	Operations (no.)	Avg level of mechanization[z, y] (%)	Total workers' earnings per nursery ($/yr)	Full-time equivalent workers per nursery (no.)	Employment per nursery (man-hours/yr)
By state					
Alabama	26	24 b	124,948	4.6	11,727
Louisiana	29	10 a	111,993	5.1	12,994
Mississippi	32	25 b	199,044	7.1	18,904
Total	87	20	144,994	5.7	14,725
By type of operation					
Nurseries only	22	13 a	123,481	3.5	10,460
Greenhouses only	22	28 b	69,518	3.1	7,151
Mixed operations	43	19 a	181,019	8.1	20,476
Total	87	20	144,994	5.7	14,725

[z]Significantly different by state or type of operation at $P \leq 0.05$.
[y]Values in the same column with different letters are significantly different by state or type of operation at $P \leq 0.05$.

Table 4. Workers' skills, training period, safety, and retention rates in nurseries and greenhouses that participated in the socioeconomic survey in the northern Gulf of Mexico region from Dec. 2003 to Mar. 2005.

Item	Operations (no.)	Workers' skills[z, y] (%)	Training time per nursery (d/yr)	Man-hours lost per nursery (man-hours/yr)	Injuries per nursery (no/yr)	Workers' retention rates[z, y] (%)
By state						
Alabama	26	75 b	2.5	10.7	0.2	98 b
Louisiana	29	26 a	12.4	21.0	0.2	78 a
Mississippi	32	46 a	5.7	2.9	0.7	86 ab
Total	87	52	6.7	11.1	0.4	88
By type of operation						
Nurseries only	22	68 a	4.3	14.7	0.3	94
Greenhouses only	22	70 b	2.8	0.4	0.2	84
Mixed operations	43	32 b	9.7	14.6	0.6	87
Total	87	52	6.7	11.1	0.4	88

[z]Significantly different by state or type of operation at $P \leq 0.05$.
[y]Values in the same column with different letters are significantly different by state or type of operation at $P \leq 0.05$.

year (Table 4). The workers' safety impact was expected to be positive because automation or mechanization would eliminate hazardous working conditions.

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 (Table 4). The workers' retention impact 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 socioeconomic empirical models were estimated by Tobit method due to the limited range of values of some of the variables used in estimation (Maddala, 1983). All the Tobit regression analyses were performed by using EViews 5 (Quantitative Micro Software, Irvine, CA). The descriptive statistics about automation and mechanization, socioeconomic characteristics, and percentage distribution of nurseries and greenhouses by annual gross sales and types of operations were computed by using SPSS (version 14.0 for Windows; SPSS, Chicago). The types of operations included nursery only, greenhouse only, and mixed nursery and greenhouse operations. The size of the nursery and greenhouse operations was measured by the reported annual gross sales, which included the following: <$250,000, $250,000 to $499,999, $500,000 to $999,999, and ≥$1,000,000 (Hoppe et al., 2007).

Results and discussion

The average level of mechanization of the 15 major tasks performed by nursery workers or the 10 major tasks performed by greenhouse workers was 20%, with a higher average level reported by greenhouse-only operations (28%) compared with nursery-only (13%) and mixed nursery and greenhouse (19%) operations (Table 3). About 31% of the participating nurseries reported mixing substrates, whereas the others were purchasing prefixed substrates or were using an in-ground production system (Table 2). Among those nurseries that mixed their own substrates, ≈28% of all the mixing activities were performed by workers with some form of mechanization. More than one-third (36%) of the greenhouses prepared propagation media, and the rest purchased the propagation media needed in their operations. For greenhouses that prepared their own media, 27% of the activities associated with it were performed with some form of mechanization.

The filling of containers with substrates was performed by workers in nurseries and greenhouses with significant levels of mechanization (Table 2). The collection and preparation of cuttings and seeds were generally performed manually by workers in greenhouses. The placing of plant liners in containers in

nurseries and the sticking of cuttings and planting of seeds in greenhouses were mostly done manually by workers. A majority of the greenhouses reported using mechanized or automated environmental control systems.

About one-fifth of the nurseries reported moving containers from potting to transport vehicles for movement within the nursery with some form of mechanization (Table 2). More than half of the nurseries reported transporting containers to the field in nurseries with some form of mechanization. Very few nurseries reported any form of mechanization in the spacing, picking up, transfer, and transport of plants and containers within the nursery. The jamming of plants for winter protection in nurseries and harvesting and grading of production in greenhouses were done by workers manually. More than one-fourth of the nurseries mechanized the plant pruning activities performed by their workers.

About 40% of nurseries and 49% of greenhouses used mechanized fertilizer application systems (Table 2). The application of pesticides was mechanized in 29% of nurseries and 64% of greenhouses. About 56% of nurseries and 78% of greenhouses reported that the application and management of irrigation systems were performed by workers using some form of mechanization.

MARGINAL REVENUE IMPACT. The majority (57%) of the participating nurseries and greenhouses reported annual gross sales below $250,000. About 19% of the participating nurseries and greenhouses were medium-size with annual gross sales between $250,000 and $500,000. The remaining 24% of the participating growers reported annual gross sales exceeding $500,000. The Tobit results measuring the marginal revenue impact indicated that three independent variables exerted positive and significant influences on the total revenues of nurseries and greenhouses in the northern Gulf of Mexico region (Table 5). Ninety-two percent (R^2 = 0.92) of the variations in total revenues were explained by the seven independent variables included in the total revenues empirical model.

Significant increases in total revenues were associated with the level of mechanization, the number of FTE workers, and the number of acres in production. These positive coefficients indicate that an increase in total revenues, on the average, by $4,900/year was associated with a one-unit increase in the level of mechanization. The hiring of an additional full-time worker, on the average, would raise total revenues by $69,252/year, whereas each additional acre placed under production would raise total revenues, on average, by $959/year. However, the positive marginal revenue impact of automation or mechanization did not specify the net effects on the net revenues above total production costs because the total costs and price impacts of the changes in automation or mechanization were not estimated.

MARGINAL WORKERS' EARNINGS IMPACT. Workers' earnings were directly impacted by the level of automation or mechanization, as shown by the increase in total workers' earnings by $1,601/year for the extra percentage improvement in the level of automation or mechanization (Table 5). The Tobit estimates of the marginal workers' earning impact empirical model showed a very high level of explanatory property of the included independent variables (R^2 = 0.94) on the variations of total workers' earnings. The employment of an extra full-time worker, on the average, raised total workers' earnings by $18,651/year, whereas each added acre placed under production raised total workers' earnings, on average, by $812/year.

The Tobit results of the empirical models for the marginal revenue and marginal workers' earnings

Table 5. Tobit results of total revenues, annual workers' earnings, number of full-time equivalent workers, and total man-hours employed in nurseries and greenhouses that participated in the socioeconomic survey in the northern Gulf of Mexico region from Dec. 2003 to Mar. 2005.

Independent variable	Total revenues		Total workers' earnings		Full-time equivalent workers		Total man-hours	
	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
Constant term	–65,455.84	49,879.16	–22,594.24	17,549.31	2.70	5.03	5,503.94	14,478.04
Level of mechanization	4,899.62*	2,281.04	1,600.88*	577.25	–0.01	0.06	42.33	156.87
Full-time equivalent worker	69,251.62*	3,818.96	18,650.94*	1,902.29	N/A	N/A	N/A	N/A
Wage rate	N/A[z]	N/A	N/A	N/A	0.35	0.62	956.75	1,824.09
Acres in production	958.95*	483.03	811.95*	146.19	0.12*	0.05	343.73*	122.63
Years since establishment	573.37	1,513.03	–652.23	452.03	0.02	0.05	33.51	107.94
Nursery only	–42,686.83	48,576.13	3,988.93	9,795.63	–6.88*	2.83	–16,682.48*	7,011.91
Greenhouse only	–94,576.24	71,463.68	–14,511.52	14,640.72	–4.27*	1.47	–11,663.73*	4,015.58
Percentage of acres used in production	95,868.01	70,641.71	4,387.35	17,971.50	2.68	3.09	5,336.26	7,999.92
Included observations	78.00		60.00		62.00		60.00	
R-squared	0.92		0.94		0.43		0.48	
SE of regression	217,145.30		59,195.87		7.94		20,136.57	

*Statistically significant at $P \leq 0.05$.
[z]Not applicable in the model.

impacts implied that an increase in total revenues by $4900/year and total labor costs or total workers' earnings by $1601/year was associated with a one-unit increase in the average level of mechanization. The growers would benefit from the improvement in automation or mechanization if changes in total revenues would equal to or exceed the associated changes in total production costs. This important issue involving the growers' decision to mechanize or automate will be addressed in a forthcoming paper.

EMPLOYMENT IMPACT. The employment impact as measured by the changes in the number of FTE workers and total man-hours employed as a result of any change in the level of automation or mechanization was neutral. The average number of FTE workers employed per nursery or greenhouse was 5.7 workers (Table 3). The Tobit results of the employment impact empirical model with $R^2 = 0.43$ showed three significant independent variables having a strong influence over employment, including acres and nursery type (Table 5).

The level of automation or mechanization did not have any significant effect on the number of FTE workers or total man-hours employed. One possible explanation is that nurseries and greenhouses tend to use existing labor inputs more efficiently with any improvement in automation or mechanization. The number of acres in production exerted positive effects on the number of workers and man-hours employed, indicating that for every additional acre placed under production, an average 0.12 workers/year or 344 year/year more will be needed by the growers.

WORKERS' SKILLS IMPACT. Workers' skills were measured in terms of the percentage of new workers hired that have basic horticultural skills. More than one-half (52%) of the new workers hired by participating nurseries and greenhouses had basic horticultural skills (Table 4). The Tobit results of the empirical model measuring the workers' skills impact indicate that 47% of the variations in workers' skills were explained by the independent variables included in the model (Table 6).

Higher levels of workers' skills were observed among nursery-only and greenhouse-only operations compared with mixed nursery and greenhouse operations. The average level of mechanization has a negative sign and statistically significant (–1.68), indicating that improvements in automation or mechanization enabled growers to hire more less-skilled workers.

WORKERS' TRAINING IMPACT. Training time was determined by the length of the basic training period for the newly hired workers. The participating nurseries and greenhouses provided training on basic horticultural skills to 38% of their workers. The length of the basic training period for the new workers averaged about 6.7 d per nursery or greenhouse. The Tobit results of the empirical model measuring the workers' training impact indicate that only 25% of the variations in training time were explained by the independent variables included in the model, indicating that there were other variables that exerted a major influence on training time (Table 6).

The estimated coefficient for the level of mechanization variable (0.05) is not statistically significant, indicating that automation or mechanization has a neutral effect on workers' training time. Nurseries and

Table 6. Tobit results of the percentage of new workers hired with basic horticultural skills, length of basic training period for new workers employed, total number of man-hours lost due to work-related injuries, and number of work-related injuries reported by nurseries and greenhouses that participated in the socioeconomic survey in the northern Gulf of Mexico region from Dec. 2003 to Mar. 2005.

	Workers' skills		Training days		Man-hours lost		Number of injuries	
Independent variable	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
Constant term	104.65*	39.00	31.26	23.99	–160.04	109.53	–17.05	9.95
Level of mechanization	–1.68*	0.63	0.05	0.26	–0.40	1.04	0.15	0.11
Full-time equivalent worker	2.44	1.40	0.17	0.27	9.62*	1.84	0.32*	0.16
Acres in production	–1.28	0.83	0.04	0.07	0.09	0.21	–0.03	0.02
Years since establishment	–0.28	0.67	0.11	0.08	–2.39	1.60	–0.03	0.06
Nursery only	53.09*	23.33	0.65	10.16	89.13	47.49	5.21	3.73
Greenhouse only	74.80*	21.56	2.44	8.27	59.75	49.25	–1.51	2.46
Percentage of acres used in production	–52.34	36.97	–34.91	20.28	1.85	77.29	1.87	5.07
Percentage of workers who were employed in the same nursery or greenhouse the previous year	–0.37	0.36	–0.05	0.17	N/A	N/A	N/A	N/A
Percentage of new workers with basic horticultural skills	N/A	N/A	–0.27*	0.13	–0.24	0.52	0.01	0.03
Percentage of workers trained on chemical and pesticide application	N/A	N/A	N/A	N/A	0.27	0.42	–0.01	0.03
Percentage of workers trained on basic horticultural skills	N/A	N/A	N/A	N/A	0.40	0.33	0.08	0.04
Included observations	58		52		57		57	
R-squared	0.47		0.25		0.91		0.49	
SE of regression	37.93		18.37		24.50		1.84	

*Statistically significant at $P \leq 0.05$.
N/A, not applicable in the model.

greenhouses that hired more new workers with basic horticultural skills spent lesser training time to equip their new workers with these skills.

Workers' safety impact. Workers' safety was measured in terms of years lost due to work-related injuries and the number of work-related injuries reported. The number of work-related injuries reported the year before they were interviewed averaged 0.4 injuries per nursery or greenhouse (Table 4). The number of years lost due to work-related injuries averaged 11.1 man-hours per nursery or greenhouse. The most common injuries reported by participating nurseries and greenhouses were back strains and cut fingers. The Tobit results of the empirical model measuring workers' safety impact indicate that 91% and 49% of the variations in man-hours lost and number of injuries were explained by the independent variables included in the model (Table 6).

The estimated coefficients for the level of automation variable were not statistically significant, indicating that automation or mechanization has a neutral effect on workers' safety as measured by the number of man-hours lost and the number of injuries reported by participating growers. Each FTE worker added to the labor force would most likely lead to an additional 0.3 work-related injury per year and 9.6 man-hours per year lost as a result of these injuries.

Workers' retention impact. Workers' retention rates, which were expressed as a percentage of the workers who were employed in the same nursery or greenhouse for the past 2 years, averaged 88% (Table 4). The Tobit results of the empirical model measuring workers' retention impact indicate that only 30% of the variations in retention rates were explained by the independent variables included in the model (Table 7). The estimated coefficient for the level of automation variable was not statistically significant, indicating that automation or mechanization had a neutral effect on workers' retention rates. Workers' retention rates tend to be higher among workers employed by greenhouse-only operations.

The improvements in working conditions and better workers' benefits generally led to higher retention rates. Nurseries and greenhouses that provided more access to rest and lounging areas, housing benefits, and medical and dental insurance retained more of their workers. About 94% of all workers had access to rest and lounging areas, 15% had housing benefits, 8% were provided dental and medical insurance, 10% received retirement benefits, and 96% had access to sanitation facilities and drinking water. However, lower retention rates were observed among workers who were employed by nurseries and greenhouses that provided more retirement benefits and access to sanitation facilities and drinking water to their workers.

Table 7. Tobit results of the percentage of workers who were employed in the same nursery or greenhouse the previous year that participated in the socioeconomic survey in the northern Gulf of Mexico region from Dec. 2003 to Mar. 2005.

Independent variable	Workers' retention rates	
	Coefficient	SE
Constant term*	113.52	9.26
Average level of automation	0.01	0.12
Full-time equivalent worker	–0.12	0.16
Acres in production	–0.03	0.03
Years since establishment	0.06	0.13
Nursery only	8.35	5.48
Greenhouse only*	14.94	4.83
Percentage of acres used in production	–14.44	10.15
Percentage of workers with access to rest and lounging areas*	0.78	0.29
Percentage of workers provided with housing benefits*	0.17	0.06
Percentage of workers provided with medical and dental insurance*	0.38	0.14
Percentage of workers provided with retirement benefits*	–0.23	0.09
Percentage of workers with access to sanitation facilities and drinking water*	–1.00	0.32
Included observations	72	
R-squared	0.30	
SE of regression	19.10	

*Statistically significant at $P \leq 0.05$.

Summary and implications

The results of the survey showed that the level of mechanization was limited to one-fifth of all the identified major tasks performed by workers employed by the participating nurseries and greenhouses in Louisiana, Mississippi, and Alabama. 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, if none at all, 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 average level, instead of the individual levels of mechanization or automation of the individual tasks performed by workers, was used in measuring its socioeconomic impacts on participating nurseries and greenhouses. Regression results showed that nurseries and greenhouses that reported higher levels of annual gross sales demonstrated higher levels of

automation or mechanization, implying economies of scale associated with technology adoption by these horticulture production firms.

The increased levels of mechanization or automation produced neutral effects on employment and raised the value of the marginal productivity of labor, implying that technology adoption by nurseries and greenhouses did not displace any worker but instead improved total workers' earnings. The increase in total workers' earnings associated with improved automation or mechanization indicated that nurseries and greenhouses were able to pay their workers higher wages and salaries. However, the regression results did not measure the effects of improved mechanization or automation on the profitability of the participating nurseries and greenhouses.

The improvements in automation or mechanization have significant implications on the skill levels of newly hired workers, but exerted neutral effects on workers' training, safety, and retention rates. Growers that reported higher levels of mechanization or automation were able to hire fewer new workers with basic horticultural skills, especially among mixed nurseries and greenhouses. The length of training period for basic horticultural skills was not influenced by the level of automation or mechanization, but was significantly extended when nurseries or greenhouses hired more new workers without basic horticultural skills. Workers' safety was observed to be influenced by the number of FTE workers and was not in any way affected by automation or mechanization, workers' skills, or workers' training. Workers' retention rates tend to be more influenced by the type of operation, working conditions, and workers' benefits rather than by the level of automation or mechanization. Nursery and greenhouse growers can retain their current workers by maintaining good working conditions, providing workers' benefits, and improving workers' productivity through the adoption of mechanized or automated production systems.

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