Production & Marketing Reports

0.03). For the pecan industry as a whole, average price received for nut-meats is as closely associated with national supply of pecan nut-meats as that of almond and pistachio and is far better than that of walnut-pecan's primary competitor. The supply of pecan meats on-hand at the beginning of the season, plus supply from the current season's crop, plus the price of walnut meats accounts for 80% of price variation in average United States pecan meat price.

Pecan, a member of the Juglandaceae, is a relatively new and widely adaptable horticultural crop (Flack, 1970). It is the economically most important of the 20 known hickory species comprising the genus *Carya* and is a member of the Apocarya section (i.e., pecan hickories) of *Carya* (Wood, 1994). Its native range encompasses the woodlands along the river systems of the central United States and Mexico with the center of genetic diversity being in the northern portion of the native range (Ruter et al., 1999). As a long-lived perennial tree-crop, it has evolved from that of a relatively minor wild component of riparian ecosystems to a significant silvicultural and horticultural crop (Wood et al., 1990). While increasingly valuable in the wood products industry, its primary economic contribution is nut-meats used in baking (about 25%), confection (about 12%), ice cream (about 7%), gift-packs (about 10%), retailing (about 22%), wholesaling (about 14%), and vari-

Production Unit Trends and Price Characteristics within the United States Pecan Industry

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ADDITIONAL INDEX WORDS. industrialization, nut meats, yields, production, farms, acreage, locations, biennial bearing, price, trees

SUMMARY. The United States pecan [*Carya illinoensis* (Wangenh.) K. Koch] industry is based on about 10,107,170 trees (about 15% nonbearing) comprising about 492,137 acres (199,168 ha) of orchards (34% in Texas, 27% Georgia, and 17% Oklahoma) dispersed among about 19,900 farm operations (36% in Texas, 16% Georgia, and 7% Oklahoma) in 24 states. Fifty-six percent of this acreage is on farms with ≥ 100 acres (40.5 ha) of trees (i.e., 5% of total farms). An evaluation of production related changes over the last decade indicate fundamental changes occurring in the nature of the U. S. industry. These include a) movement toward agricultural industrialization as reflected by fewer small-farms and more large-farms; b) reduced percent-

age of young (i.e., nonbearing) trees in most major producing states; c) substantial decline in number of farms and acres in the southeastern region—historically the primary production area—yet substantial growth in the northern region of production; d) a national 3% increase in the number of pecan farms and 14% increase in acreage; and e) substantial demographic changes, such as the enhanced importance of the southwestern region including New Mexico with diminished importance of many southeastern states. States also drastically differ in degree of biennial bearing, as measured by the biennial bearing index (i.e., $K = 0.04 - 0.73$; where 0 = no production variation and 1 = maximum variation), average production efficiency of both orchards [$E_{oa} = 192 - 1,224$ lb/acre (215 - 1,374 kg·ha⁻¹)] and trees [$E_{pt} = 19 - 60$ lb/tree (8.6 kg/tree)], variation in grower prices (cv = 18 - 36%), and relationship between price and national supply of pecan ($r^2 = 0.94 -$

Fig. 1. Distribution of pecan orchards within the primary production regions of the United States. SW = southwestern region; SC = southcentral region; N = northern region, SE = southeastern region.

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ous food service outlets (about 4%) (Florkowski and Hubbard, 1994).

The general geographical location and acreage of the nation's primary pecan production zones is available (Fig. 1); however, up-to-date information on industry production and price characteristics and trends is unknown. Such information is of potential importance to efforts such as: strategic planning; marketing; government legislation; industry self-help programs; research; processing facilities; and risk assessment. This report provides new insight into; a) production characteristics and trends as related to size and number of farms, acreage, types of trees, production efficiency; b) price-supply relationships for state delineated production zones; and c) comparison of the relationship of average national pecan nut-meat price to supply factors for pecan and competing tree nuts.

Methodology

Pecan production data were extracted from the 1997, 1992 and 1987 agricultural censuses of the United States (U.S. Department of Agriculture, 1999a) and USDA agricultural statistics handbooks (U. S. Department of Agriculture, 1989–98). Pecan production data are for all management units (i.e., farms) in the United States with pecan sales receipts $\geq$ \$1,000 annually. Data on production characteristics was collected for all counties

for each U. S. state for number of bearing and nonbearing trees, acres of trees by farm size class [<1 , 1 to 4.9, 5 to 14.9, 15 to 24.9, 25 to 49.9, 50 to 99.9, >100 , and 500 acres (<0.4 , 0.4 to 2, 2.1 to 6, 6.1 to 10, 10.1 to 20, 20.1 to 40.4, >40.4 , and 202 ha) per farm (referred to in text as 1, 5, 15, 25, 50, 100, 100+, and 500+ categories)], and number of farms by farm size class. Data on annual production and price, by state and United States as a whole, was from the U.S. Department of Agriculture (USDA) Agricultural Statistics reports (USDA, 1989–98). Price, production, and supply data of competing tree-nut crops were from the USDA's Economic Research Service and National Agricultural Statistics Service (Wise, 1999). It should be noted that while the accuracy of USDA or census-derived production data is sometimes disputed due to uncontrollable factors potentially biasing the data, these data nevertheless remain the best available and are generally accepted as being reasonably accurate.

Production data were analyzed for biennial bearing intensity using the methods of Pearce and Dobersek-Urbanc (1967). Average production efficiency by pecan producing states was determined for unit area of orchard (E_{pa} = total state production divided by acres of orchards) and per tree (E_{pt} = total state production divided by number of bearing trees). Data were analyzed using standard

SAS descriptive statistics and step-wise regression procedures (SAS Institute, 1998). Regression analyses used data on nut crops from 1989 to 1998, whereas state production and price received by growers was based on data from 1993 to 1998 crop years (i.e., last three biennial bearing cycles).

Results and discussion

LOCATION AND VARIABILITY OF PECAN PRODUCTION. Pecan is a contributor to the agricultural economy in 24 of 50 U.S. states. These states, due to the acquisition of production data along political rather than environmental boundaries (i.e., agricultural statistical reports), are typically segregated into four production regions: southeastern (Georgia, Florida South Carolina, North Carolina, Virginia, Alabama, Mississippi, Louisiana, and Arkansas), southcentral (Texas and Oklahoma), northern (Tennessee, Kentucky, Indiana, Illinois, Iowa, Nebraska, Missouri, and Kansas), and southwestern (New Mexico, Arizona, California, Utah and Nevada) (Fig. 1). Although delineated by political boundaries the pecan growing environments within these production regions are generally similar.

Pecan nut production is classified as either improved (from cultivars), native (from wild trees), or seedling (from substantially inferior cultivars or feral offspring of cultivars). Because natives and seedlings are typically lumped together in crop production/

Table 1. Production characteristics of United States pecan industry by state and nut type (i.e., improved = commercial cultivars; others = native and seedlings).

State	Improved			Others		
	In-shell nuts		Bienniality ^y (K) ^w	In-shell nuts		Bienniality ^y (K)
	(1,000 lb) ^x	(cv)		(1,000 lb)	(cv)	
Alabama	7,000	64	0.45	11,583	144	0.64
Arizona	17,667	4	0.04			
Arkansas	733	42	0.30	883	86	0.54
California	2,250	35	0.34			
Florida	967	113	0.37	1,550	92	0.44
Georgia	71,167	43	0.27	15,500	49	0.34
Kansas	1,725	105	0.73			
Louisiana	2,167	24	0.16	11,333	17	0.12
Mississippi	1,883	50	0.29	1,300	53	0.30
New Mexico	33,667	30	0.29			
North Carolina	1,338	47	0.36	1,263	68	0.37
Oklahoma	1,633	58	0.49	7,695	104	0.47
South Carolina	2,383	68	0.39	1,300	93	0.56
Texas	37,000	22	0.19	22,166	77	0.60
United States	179,854	27	0.20	76,300	39	0.29

^xAverage in-shell production from 1993–98, covering three biennial bearing cycles.

^yBiennial bearing intensity where 0 is no change from year to year and 1 is no production in alternate years. The greater the number, the greater the intensity of bienniality.

^x1,000 lb = 405 kg.

^wK = bienniality index where 0 = no yield variation and 1 = maximum yield variation from year to year.

price data, they are referred to as other throughout the remainder of this report. In-shell (unshelled nuts) production by improved and other trees from 1993 to 1998 is presented in Table 1. Production over those 6 years, transcending three biennial bearing cycles, has resulted in the average national production of improved nuts being 237% of that of other pecan nuts [179,854,000 lb versus 76,000,000 lb (81,653,716 versus 34,504,000 kg)]. Variation in production for the United States as a whole, as measured by the coefficient of variation, was 27% for improved and 39% for other pecan nuts. Thus production of others is more variable than that of improved cultivars, presumably due to less intense orchard management because of the generally reduced value of others class nuts.

The alternate bearing characteristic of pecan at the tree, orchard, state, and national levels tends to be biennial. Biennial bearing causes major economic and marketing problems for growers and the industry as a whole (Wood, 1990). A measure of biennial bearing is intensity of bienniality (*K*;

where 0 = no variation in production and 1 = no production in subsequent years). For the United States as a whole over the last decade, the degree of bienniality was only slightly less for improved (0.20) than for other class nuts (0.29). Bienniality was less in Arizona, Louisiana, and Texas for improved nuts, and less in Louisiana for others nuts than the nation as a whole, thus production in these states for these types of nuts is much more stable than in competing states.

Georgia continues as the primary producer of pecan nuts, with 40% of improved cultivars and 34% of national production of all pecan nuts over the last decade (Table 1). Texas and New Mexico closely compete for second and third for production of improved cultivars (21% and 19% respectively) whereas Texas (29%), Georgia (20%), Alabama (15%) and Louisiana (15%) dominate in the production of others. Relative variation in production of improved nuts among states, as measured by the coefficient of variation, is greatest in Florida (113%), South Carolina (68%), and Alabama (64%) and least in Arizona

(4%), Texas (22%), and Louisiana (24%) (Table 1). Similarly, that for others is greatest in Alabama (144%), Kansas (105%) and Oklahoma (104%) and least in Louisiana (17%) and Georgia (49%). *K* for improved nuts is greatest in Oklahoma (0.49), Alabama (0.45), and South Carolina (0.39) and least in Arizona (0.04), Louisiana (0.16), and Texas (0.19). *K* for other nuts was most pronounced in Kansas (0.73), Alabama (0.64), and Texas (0.60) and least in Louisiana (0.12), and Mississippi (0.30). There was no national linkage ($P \leq 0.20$) between the bienniality indexes (*K*s) for improved and other class nuts when evaluated across states (data not included). Thus, for the nation in general, the degree of bienniality exhibited by improved orchards was generally unrelated to that being exhibited by other class orchards (data not included).

NUMBER OF PECAN FARMS. There are 19,900 farms in the United States that crop pecan (Table 2). Most of these (62%) manage <15 acres of trees. There are 905 (5.4%) farms managing ≥ 100 acres and 124 (0.7%) managing ≥ 500 acres of trees. Most of these

Table 2. Number and acreage of pecan farms by size and state.² Blanks denote that data are unavailable according to farm size class.

State	Farm size class (acres) ¹																	
	0.1-0.9 ³		1-4.9		5-14.9		15-24.5		25-49.9		50-99.9		100+		500+		Total ⁴	
	No.	Acres	No.	Acres	No.	Acres	No.	Acres	No.	Acres	No.	Acres	No.	Acres	No.	Acres	No.	Acres
Alabama	161	49	440	1,092	494	3,969	142	2,593	138	4,616	57	3,537	45	8,208	1	0	1,477	24,064
Arizona	32	11	111	274	46	351	9	176	7	255	7	492	14	12,943	8	11,176	226	14,502
Arkansas	48	13	71	158	58	496	30	550	26	840	23	1,392	19	5,613	0	0	275	9,062
California																	300	3,181
Florida	41	13	237	600	271	2,149	94	1,739	60	2,006	14	893	16	2,138	0		733	9,533
Georgia	107	39	867	2,290	1,039	8,340	382	6,972	300	9,944	166	11,106	232	93,181	59	56,409	3,093	131,872
Iowa																	5	2
Illinois																	36	176
Indiana																	21	86
Kansas																	145	5,189
Kentucky																	84	345
Louisiana																	579	15,091
Mississippi	71	27	267	689	209	1,619	56	1,036	68	2,365	26	1,815	17	3,976	1	0	714	11,525
Missouri	67	19	76	164	72	567	39	725	36	1,187	18	1,155	10	3,247	0	0	324	7,064
Nebraska																	17	66
Nevada																	5	19
New Mexico	96	47	578	1,295	224	1,755	57	1,021	57	1,878	31	2,136	62	21,491	11	11,431	1,105	29,623
N. Carolina																	330	1,373
Oklahoma	86	26	422	1,076	751	6,070	410	7,679	365	12,502	258	16,354	182	40,130	10	9,680	1,474	83,837
S. Carolina	86		214	485	146	1,139	32	538	23	791	3	193	3	0	0	0	507	3,206
Tennessee																	215	478
Texas	515	191	2,351	5,613	2,123	16,940	769	14,062	661	21,582	384	24,625	299	84,831	34	34,826	7,102	167,841
Utah																	28	172
Virginia																	105	223
U.S.	1,310	435	5,634	13,736	5,433	43,393	2,020	37,151	1,741	57,966	987	63,698	905	275,758	124	123,522	19,900	492,137

²Derived from the 1997 United States Agricultural Census (U.S. Department of Agriculture, 1999a); 1 acre = 0.4047 ha.

³Size of pecan acreage associated with the farm operation.

⁴Total number of acres within farm size class. For example, there were 161 farms in Alabama in 1997 with 0.1 - 0.9 acres (0.04 - 0.36 ha) of pecan trees and these farms totaled 49 acres (19.8 ha) of pecan trees.

Table 3. Ten-year (1987-1997) change in number and acreage of pecan farms according to farm size class by state. Blanks denote that data are unavailable (i.e., not listed in 1987 U.S. agricultural census). Numbers are expressed as a percentage of those existing in 1987.^z

State	Farm size class in acres (%) ^y																All farms ^y	
	0.1-0.9 ^x		1-4.9		5-14.9		15-24.5		25-49.9		50-99.9		100+		500+			
	No.	Acres	No.	Acres	No.	Acres	No.	Acres	No.	Acres	No.	Acres	No.	Acres	No.	Acres	No.	Acres
Alabama	61	55	69	70	77	78	81	81	99	99	73	69	83	75	50		74	78
Arizona	76	69	98	100	70	71	36	38	33	34	140	139	61	84	100		77	81
Arkansas	44	45	82	76	74	78	107	106	93	89	144	143	146	145	0		77	126
Florida	52	45	60	64	85	88	82	81	125	122	61	57	94	66	0		74	80
Georgia	56	56	82	85	91	91	109	110	107	108	97	101	102	112	120		90	109
Mississippi	50	56	77	88	67	65	74	75	110	111	90	94	89	62	33		72	76
Missouri	85	90	106	130	113	115	130	135	144	147	138	143	133	114	0		110	125
New Mexico	188	247	157	143	106	107	102	98	110	105	100	97	148	145	157		136	132
Oklahoma	57	47	81	87	127	124	126	127	198	200	266	252	198	202	143		126	187
S. Carolina	125		108	112	105	100	160	165	115	118	27	28	148		0		110	73
Texas	65	69	85	86	93	93	95	95	114	113	114	113	60	124	136		91	113
U.S.	67	65	86	87	93	93	101	101	121	121	122	121	89	120	123		103	114

^zFrom 1987 and 1997 United States Agricultural Censuses (U.S. Department of Agriculture, 1999a); 1 acre = 0.4047 ha.

^ySize of the pecan acreage associated with the farm operation. Data are expressed as a percentage of the 1987 level.

^xTotal number and acreage of farms within size class. In Alabama the number of pecan farms within the 0.1-0.9 acre (0.04 - 0.36 ha) class in 1997 was 61% of those within the same class in 1987; and the number of acres associated with this size class in 1997 was 55% of that in 1987.

^wSummation of farms of all size classes for number of farms and number of acres (there were 74% as many farms producing pecan in Alabama in 1997 as there were in 1987; and pecan acreage in 1997 was 78% of that in 1987).

≥500 acre holdings are in Georgia (48 %) and Texas (27%). State distribution of pecan farms according to farm size in the latest census was such that the greatest number of farms were in Texas (36%; 7,102), Georgia (16%; 3,093)

and Oklahoma (12%; 2,474) (Table 2). Most Texas farms cropped <5 acres of trees whereas those in Georgia and Oklahoma cropped 5 to 14.9 acres (2 to 6 ha).

The distribution of farms accord-

ing to size of pecan plantings is important in regards to efforts by industry to organize checkoff programs or marketing orders. For example, 74% of farms producing pecan nuts possess <15 acres of trees, and comprise only

Table 4. Number of bearing and nonbearing trees and percentage change in tree numbers within United States pecan producing states.^z Blanks denote that data are unavailable.

State	Trees within bearing class				Decade change (%) ^y		
	Nonbearing	Bearing	Total	Nonbearing			
	(no.)	(no.)	(no.)	(%)	Nonbearing	Bearing	Total
Alabama	56,269	287,705	343,974	16	-68	-7	-29
Arizona	61,413	423,164	484,577	39	-18	-43	-41
Arkansas	12,051	108,739	120,790	10	-62	+52	+17
California	18,809	108,813	127,622	15			
Florida	38,550	111,165	149,715	26	-45	-20	-28
Georgia	174,519	1,763,266	1,937,785	9	-45	-20	-28
Iowa	83						
Illinois	4,043	448	4,491	90			
Indiana	1,544	248	1,792	86			
Kansas	31,486	63,930	95,416	33			
Kentucky	3,937	2,207	6,144	64			
Louisiana	54,709	234,395	289,104	19	-12	-4	-13
Mississippi	91,726	120,550	212,276	43	-13	+1	-3
Missouri	35,222	115,627	150,849	23			
Nebraska	1,883	128	2,011	94			
Nevada		271					
New Mexico	173,121	1,058,781	1,231,902	14	+8	+24	+21
North Carolina	11,368	10,928	22,296	51			
Oklahoma	226,191	961,217	1,187,408	19	+22	+74	+61
South Carolina	14,733	32,959	47,692	31	-50	-11	-18
Tennessee	2,151	5,487	7,638	28			
Texas	465,776	3,213,831	3,679,607	13	-32	+24	+12
Virginia	1,829	1,898	3,727	49			
United States	1,481,413	8,625,757	10,107,170	15	-22	+19	+10

^zData from 1997 United States Agricultural Census, (U.S. Department of Agriculture, 1999a).

^yPercentage of trees in each bearing class in 1997 as compared to 1987 (i.e., Alabama = 68% means that there were 32% as many nonbearing trees in Alabama in 1997 as there were in 1987).

Table 5. Average production efficiency (E_p) of in-shell nuts of orchards and trees by state.

Location	Orchard (E_{pa}) ^z (lb/acre)	Tree (E_{pt}) ^y (lb/tree)
Alabama	519	36
Arizona	1,224	42
Arkansas	259	22
California	676	20
Florida	194	17
Georgia	720	54
Kansas	424	34
Louisiana	928	60
Mississippi	286	27
New Mexico	1,097	31
North Carolina ^x		
Oklahoma	221	19
South Carolina ^x		
Texas	387	20
United States	553	32

^zBased on average state production in 1996 and 1997 divided by number of acres of orchards in 1997. 1 lb/acre = 1.12 kg·ha⁻¹. E_{pa} = average in-shell nut production per acre of orchard for each U.S. state; E_{pt} = average in-shell nut production per tree for each U.S. state.

^yBased on average state in-shell production of improved plus other nuts in 1996 and 1997 divided by number of bearing trees in 1997; 1 lb = 0.452 kg.

^xReliable data are unavailable.

12% of the national acreage. Thus, attempts at implementing marketing orders and checkoff programs to enhance the competitiveness in the marketplace must be cognizant of the potential influence of small producers. These data therefore provide information useful in the establishment of exemption thresholds that influence the probability of success if industry imposed taxation efforts are opposed by small producers.

There was only a slight (3%) increase in the number of total farms producing pecan in the United States from 1987–97 (Table 3). Those in the 0.1 to 4.9, 1 to 4.9, 5 to 14.9 and ≥100 acre classes declined whereas those in the 15 to 24.5, 25 to 49.9, 50 to 99.9 and ≥500 acre classes increased over this period. Thus, there was a decline in farms with small acreages of pecan (≥15 acres) and an increase in those with larger acreages (≥25 acres)—with the greatest increase (23%) in farms ≥500 acres. The greatest percentage increase in number of farms among the 11 major producing states occurred in New Mexico (36%) and Oklahoma (26%) whereas the greatest decreases occurred in Mississippi (28%), Alabama and Florida (26%). The primary producing states of Georgia and Texas lost about 10% of their total farms producing pecan. Growth in the number of farms ≥100 acres of pecan were greatest in Oklahoma (98%), New

Mexico (48%), and South Carolina (48%) whereas the greatest loss in ≥100-acre units was in Texas (40%) and Arizona (39%). The change in number of pecan farms among the various states did not exhibit clear relationship to K , E_{pa} , E_{pt} or to the linkage (i.e., r^2) between supply and price within those states (data not included).

ACREAGE OF PECAN FARMS. There are about 492,137 acres (199,168 ha) of pecan cropped in the United States. Most of this is concentrated in three geographical locations: in southern Georgia (especially in southwestern portion of the state), in a broad arc extending from southeastern and southcentral Texas through eastern Oklahoma; and in the Mesilla Valley along the Rio Grande River of New Mexico (Fig. 1). The greatest acreage is in Texas [34% or 167,844 acres (67,926 ha)], Georgia [27% or 131,872 acres (53,369 ha)] and Oklahoma [17% or 83,837 acres (33,929 ha)] (Table 4). Production from the 24 pecan producing states crop <1,000 acres (405 ha), while 12 crop <5,000 acres (2,024 ha) of trees. Most (56%) of the national acreage is from farms with holdings ≥100 acres, with 25% of the total being from ≥500 acre (202 ha) units.

Pecan acreage in the United States increased by 14% from 1987–1997 (Tables 2 and 3) with considerable flux in many states. The greatest percent-

age increases were in Oklahoma (87%), New Mexico (32%) and Missouri (25%) whereas the greatest declines were in South Carolina (27%), Mississippi (34%), Alabama (22%) and Florida (20%). The greatest increases were in those cropping ≥25 acres of trees whereas those representing fewer acreages declined. This change in acreage within the states exhibited no clear association with K , E_{pa} or E_{pt} , but increased as the percent change in number of farms increased ($r = 0.64$, $P = 0.05$; data not included).

NUMBER OF BEARING VERSUS NONBEARING TREES. The pecan industry in the United States is based on about 10,107,170 trees (Table 4), of which 15% are nonbearing. The minor pecan states possess the greatest percentage of their total orchards as comprised of nonbearing trees. Most of these are in the northern region. For example, greater than 80% of trees in Iowa, Illinois, Indiana, and Nebraska are nonbearing, thus reflecting enhanced interest over the last decade. In the major producing states of Georgia, Texas, New Mexico and Oklahoma; and 9, 13, 14, and 19% of trees were nonbearing in 1997.

The southeastern region (Georgia, Alabama, South Carolina, Florida, Mississippi, Louisiana, Arkansas, Kansas, North Carolina and Virginia) about 15% of trees as nonbearing; the northern region (Tennessee, Kentucky, Indiana, Illinois, Iowa, Missouri, Nebraska, and Kansas) about 30% of trees as nonbearing; southcentral region (Texas, Oklahoma) about 14%; and the southwestern region (Arizona, California, New Mexico, Nevada, and Utah) about 14%. In terms of total trees (i.e., bearing plus nonbearing), the leading states are: Texas (36%), Georgia (19%), New Mexico (12%) and Oklahoma (12%).

Percentage nonbearing trees declined from 1987 to 1997 in all major pecan producing states except New Mexico (+8%) and Oklahoma (+22%) (Table 4). The greatest decline was in Alabama (–68%) and Arkansas (–62%). Georgia and Texas, the two primary pecan producing states, also exhibited a large drop in number of nonbearing trees over the last decade (–45% and –32%, respectively). The greatest increase in total trees occurred in Oklahoma (+61%) and New Mexico (+21%) whereas the greatest declines occurred in Arizona (–41%) and Ala-

bama (-29%). It is noteworthy that Georgia, the primary producer, experienced a 28% decline in total number of trees since 1987 whereas the second ranked producing area, Texas, increased tree numbers by 12%. On a national basis, the total number of trees in the major producing states increased by 10% over the last decade with there being a 19% increase in bearing trees and a decline of 22% in nonbearing trees.

PRODUCTION EFFICIENCY. E_{pa} and E_{pt} provide an estimate of the economic and agricultural impact of the average orchard or tree within the various pecan producing states and a relative comparison of these factors among states. A comparison of E_{pa} (based on the pounds of in-shell nuts produced per acre of trees) among states, revealed relative high average efficiency of farm operations in Arizona [1,224 lb/acre (1,372 kg·ha⁻¹)], New Mexico [1,097 lb/acre (1,230 kg·ha⁻¹)], and Louisiana [928 lb/acre (1,040 kg·ha⁻¹)] but low efficiency in Florida [194 lb/acre (217 kg·ha⁻¹)], Oklahoma [221 lb/acre (248 kg·ha⁻¹)], Arkansas [259 lb/acre (290 kg·ha⁻¹)], and Mississippi [286 lb/acre (321 kg·ha⁻¹)] (Table 5). This almost 6-fold E_{pa} difference is influenced by many factors, among which are state of management, tree age and size, irrigation management, disease and insect pests, and genotypes. E_{pa} is

generally greatest in the southwestern region [about 999 lb/acre (1,120 kg·ha⁻¹)], followed by the southeastern region [about 594 lb/acre (666 kg·ha⁻¹)], southcentral region [about 304 lb/acre (341 kg·ha⁻¹)], and the northern region [<300 lb/acre (336 kg·ha⁻¹)] according to personal observation].

Average E_{pt} among states was highest in Louisiana with 60 lb (27.2 kg) per tree, and lowest in Florida, with 17 lb (7.7 kg) per tree. This almost 3-fold difference is largely attributed to tree size and genotype differences and orchard management strategies. Average E_{pt} efficiency of trees in Georgia, the primary production state, is greater than that of Arizona [54 versus 42 lb (24.5 versus 19.1 kg) per tree], the state with highest E_{pa} [1,224 versus 720 lb/acre (1,372 versus 807 kg·ha⁻¹)]. This difference in E_{pt} is largely because Georgia trees are much older and larger, thus producing larger crop loads than the average Arizona tree. It is noteworthy that average E_{pa} and E_{pt} of both improved and other classes of nuts from producing states tended to decrease [respectively, $r = -0.59$ and -0.47 for E_{pa} and -0.48 and -0.50 for E_{pt} (all at $P \leq 0.12$)] as **K** increased (data not included).

PRICE. The price environment in the United States pecan industry is based on a competitive free-market

structure (i.e., guided by markets inasmuch neither state nor federal governments are directly or indirectly involved in controlling supply or price). The price of nuts received by growers is influenced by a diverse variety of factors. Salient among these are nut class, cultivar type, size, shell-out ratio between meat and total in-shell weight, meat color, kernel related defects, cost of shelling and transporting, proportion of pieces and halves upon shelling, time of year, and perceived market risks (Florkowski and Hubbard, 1994). These and other factors have resulted in substantial variation among locations within the United States in regards to the average price received for in-shell nuts.

Average farm-gate prices received for improved cultivars in general has varied as much as \$0.41/lb (\$0.90/kg), or from \$0.73/lb (\$1.61/kg) in Alabama to \$1.14/lb (\$3.11/kg) in California) among states over the last three biennial bearing cycles (Table 6). Farm-gate prices tended to increase westward across the pecan belt, even though the southeastern crop is marketed first and receives benefit of higher prices received by the first nuts on the market and are therefore deliverable during the highly favored Thanksgiving-Christmas season (i.e., the primary marketing season). This 18% higher price of southwestern pro-

Table 6. Price characteristics of United States pecan industry by state and nut class.

State	Improved				Others			
	Price ^z		Correlation (r^2)		Price ^z		Correlation (r^2)	
			Total	Type			Total	Type
	(\$/lb)	(CV) ^y	supply ^x	supply	(\$/lb)	(CV)	supply	supply
Alabama	0.73	26	0.40*	0.46*	0.58	24	0.37	0.20
Arizona	1.04	35	0.03	0.01				
Arkansas	1.06	22	0.28	0.85**	0.72	18	0.56*	0.37*
California	1.14	18	0.20	0.22				
Florida	0.87	29	0.49*	0.52*	0.64	21	0.36*	0.18
Georgia	0.92	29	0.56*	0.52*	0.67	35	0.53*	0.40*
Kansas	0.89	30	0.94**	0.88**				
Louisiana	0.98	36	0.83**	0.71**	0.51	26	0.45*	0.27
Mississippi	0.85	20	0.48*	0.42*	0.63	32	0.66**	0.45*
New Mexico	0.99	29	0.50*	0.58**				
North Carolina	0.88	29	0.56*	0.49*	0.63	26	0.53*	0.37*
Oklahoma	0.99	31	0.31	0.41*	0.61	25	0.58**	0.41*
South Carolina	0.87	13	0.34	0.26	0.66	18	0.23	0.21
Texas	1.07	31	0.67**	0.64**	0.65	35	0.76**	0.53*
United States	0.95	22			0.66	24		

^zAverage in-shell price from 1993-98, covering 3 biennial bearing cycles.

^yCoefficient of variation.

^xCorrelation of price per pound of in-shell nuts from 1989-1998 for Total supply in the U.S. (i.e., improved plus natives/seedlings) and Type supply [total United States supply of same type nuts (i.e., either improved or natives/seedlings)]. \$1.00/lb = \$2.20/kg.

***Significant at $P \leq 0.05$ or 0.01, respectively.

duced nuts over southeastern nuts is due to several factors. One is the relatively favorable average quality and shelling characteristics of cultivars grown in the western United States ('Wichita', 'Western Schley').

Average price for others range from \$0.51/lb (\$1.12/kg) in Louisiana to \$0.89 (\$1.96/kg) in Kansas. While the average price for other nuts is about 69% of improved, it is noteworthy that the average price received for others in Kansas (\$0.89/lb) is greater than the price of improved cultivars in several southeastern states. Price stability, as measured by coefficient of variation, from year to year is greatest in South Carolina (13%), California (18%), and Mississippi (20%) for improved varieties and least in Louisiana (36%), Arizona (35%), and Texas (31%). Because price is typically closely associated with supply, this suggests that price variation among the least biennial bearing states (i.e., low *K*) should be relatively low, however this was not true for either improved or other nuts over the last decade.

The inverse relationship over the last decade between average price received by growers in the several states where production originates and that of total national supply (i.e., on-hand supply at beginning of marketing season plus new marketable crop of both improved and others) of pecan nut-meats has generally been only fair at best (Table 6). In fact, on average, there is not a statistically significant ($P \leq 0.05$) association between price and total national supply of improved nuts in five of the 13 major producing states

whereas there is a relationship in all but two states in regards to others. Typically, less than about 60% of the variability in price for either improved cultivars or others has been directly related to total United States production over the last decade. The notable standout has been Louisiana and Kansas where the price linkage to supply accounted for 83% of price variation for improved nuts for Louisiana and 94% of other nuts for Kansas. It is also noteworthy that in the case of California and Arizona $\leq 12\%$ of price variation of improved cultivars is associated with total national supply; yet the farm-gate prices of pecan nuts from California and Arizona were generally among the highest in the nation. The relationship between farm-gate prices for improved nuts to total national supply of improved nuts is also relatively poor for most states. The same is true regarding the price for other nuts in relation to the total national supply of other nuts.

The poor correlation between average price received by growers within the specific states to that of national supply indicates that the average price received by growers is greatly affected by factors in addition to the national supply of the current season crop. The above discussed relationships suggests that producers of improved nuts in Louisiana and Texas and of others in Kansas, Arkansas, Mississippi, and Texas are, on the average, more likely to be satisfied with the existing pricing structure whereas those in several other states, including the key states of Georgia and New Mexico,

are more likely to be dissatisfied with prices received. Surprisingly, the average price received by growers within specific states has little or no relationship to *K* for the same class nuts within the same state (for improved, $r^2 = 0.01$; others, $r^2 = 0.14$). Additionally, the association between supply and price of either improved or other class nuts was unrelated (at $P \leq 0.20$) to *K* or efficiencies of trees or orchards (data not included).

In addition to the supply of nuts affecting price, there are many market related factors also influencing price. These include total expected seasonal production, nut-meats on-hand, and price of competing nuts [primarily walnut (*Juglans regia* L.)], weather, timing of supply, competition among shellers/processors, potential for imports, etc. Multiple regression analysis of the average price for pecan meats over the last decade indicate that 76% of the variation in the wholesale price received by growers is associated with both the supply of meats on hand at the beginning of the marketing season and on pounds of utilized production (Table 7). This variation compares with 38% for walnut, 77% for almond (*Prunus amygdalus* L.), and 74% for pistachio (*Pistacia vera* L.). Thus average price received by growers of pecan in the United States, in general, is at least as predictable as that of other tree-nut crops and that this overall pecan meat price is primarily influenced by factors affecting supply; although, a secondary factor, the price of walnuts, accounted for about 4% of price variation. Inclusion of the price of the primary

Table 7. Multiple regression models for price of shelled nut-meats for tree-nut crops grown in the United States.

Tree-nut crop	Prediction model ^a	Model <i>R</i> ²	<i>P</i> > <i>F</i>
Pecan	$Y = 6.175 - 0.025X_1 - 0.022X_2$	0.76	0.007
	$Y = 6.680 - 0.025X_1 - 0.020X_2 - 0.467X_3$	0.80	0.017
	$Y = 4.585 - 0.028X_1 - 0.023X_2 - 0.167X_3 + 0.001X_4$	0.85	0.029
Walnut	$Y = 3.716 - 0.017X_1 - 0.007X_2$	0.38	0.209
	$Y = 4.031 - 0.013X_1 - 0.008X_2 - 0.158X_3$	0.47	0.208
	$Y = 4.112 - 0.012X_1 - 0.007X_2 - 0.152X_3 - 0.001X_4$	0.48	0.434
Almond	$Y = 4.856 - 0.007X_1 - 0.004X_2$	0.77	0.006
	$Y = 4.967 - 0.006X_1 - 0.004X_2 - 0.066X_3$	0.77	0.024
	$Y = 3.787 - 0.007X_1 - 0.005X_2 - 0.021X_3 + 0.001X_4$	0.78	0.065
Pistachio	$Y = 4.304 - 0.024X_1 - 0.023X_2$	0.74	0.009
	$Y = 4.284 - 0.025X_1 - 0.023X_2 + 0.043X_3$	0.74	0.034
	$Y = 2.676 - 0.034X_1 - 0.028X_2 + 0.247X_3 + 0.001X_4$	0.77	0.076

^aY = Price in dollars per pound of shelled nut-meats. X_1 = Millions of pounds of nut-meats on hand at beginning of marketing season (e.g., 100 million lb meats = 100). This is 1 July for almond and pecan, 1 Aug. for walnut, and 1 Sept. for pistachio. X_2 = Millions of pounds of marketable nut-meats produced (e.g., 100 million lb = 100). Marketable production is utilized production minus inedibles minus noncommercial use. X_3 = Price per pound for shelled nut-meats of primary competing nut-meat in the marketplace (i.e., the primary competitor for pecan is walnut; walnut is pecan; almond is pistachio; and pistachio is almond). X_4 = Total United States supply of tree-nut meats (pecan, walnut, almond, pistachio, hazelnut (*Corylus avellana* L.) and macadamia (*Macadamia integrifolia* Maiden & Betche and *M. tetraphylla* L.A.S. Johnson) in millions of pounds. Model based on data for 1989–98 crops from USDA Agricultural Statistics Handbooks (U.S. Department of Agriculture, 1998).

competing nut-meats (i.e., walnut/pecan and almond/pistachio) and total national supply of all nuts in regression models improved price predictability for pecan so as to account for 85% of the price variation. Although, in the case of the other tree-nut crops, inclusion of these factors in the regression model did little to improve price predictability or to account for price variation. The relationship between average price received and total pecan nut-meat supply is as good for pecan as for almond and pistachio and is much better than for walnut. This indicates that on average the national relationship between price and supply for pecan is as good as for other primary tree-nut crops.

Conclusion

Since the proliferation of pecan cultivation beginning in the 1880-90s, pecan has evolved from wild tree status to over 10 million cultivated trees growing on about 0.5 million acres (202,350 ha). This 100+ year-old national trend of increasing popularity of pecan among farmers continues to slowly increase with 3% more farms and 14% more acreage since 1987. This increase has primarily been with farms in the category of ≥ 25 acres of trees, and especially with those ≥ 500 acres. Conversely, farm operations possessing < 25 acres of trees are declining. This trend toward concentration of production is consistent with fundamental structural changes occurring throughout the agricultural sector of the United States economy. The pecan industry is beginning to exhibit signs of industrialization, thus signaling a fundamental change in the evolution of pecan husbandry. Signs of industrialization typically include fewer producers and buyers, larger operations, increased degree of horizontal and vertical integration, diversification or specialization, market concentration, product differentiation, legal organization, contractual marketing arrangements, and barriers to entry (U. S. Department of Agriculture, 1999b). One factor likely driving this change is that while the real price (adjusted for inflation) for pecan nuts increased between the 1960 to 1976 era, average real price for the national crop has been declining since 1977 (Florkowski and Hubbard, 1994), thus contributing to a cost-price squeeze experienced by growers. This change

in the production sector of the industry has occurred while the shelling sector declined in total number of operations with fewer small operations and more large operations (Florkowski and Hubbard, 1994).

Greatest growth in the number of farm operations producing pecan, and the acreage of these operations, has been in New Mexico and Oklahoma; whereas a general decline in both has occurred in the southeastern region of production. Cropping of pecan is increasing in the northern region ($> 80\%$ of trees in these states are below bearing age) states, although there is relatively little acreage within the region. The number of pecan farms in the southeastern and southcentral regions have declined at a rate of about 2% annually over the last decade. A decline in number of nonbearing trees in most states, especially in the southeastern region, where it has only about one-half as many as it did a decade ago, indicates waning interest among farmers in general for planting in all but New Mexico and Oklahoma. The traditional importance of pecan operations within the southeastern region is waning for all states, except for Georgia, with about a 2% annual decline in acreage over the last decade. This decline is also reflected in relatively low efficiency of production (E_{pa} and E_{pt}) within most southeastern states.

While prices received by growers in certain states is closely linked to total national production, the simple price-production relationship (i.e., linkage of price to supply) is poor to moderate in most states; hence farmers within certain states are likely to exhibit strong dissatisfaction with the present pricing environment whereas others are likely to be more satisfied. This apparently poor linkage between price and supply within certain producing states is substantially affected in subtle ways by factors such as cultivar, size, shelling characteristics, local competition, transportation and handling costs, perceived market risk by local buyers, nut quality, time of ripening, marketing cooperatives, degree of vertical integration, etc. Thus, those planning to enter into pecan husbandry or to relocate operations should note the substantial disparity among states before investing.

The relationship between price and supply for the nation as a whole (the national average price received for

pecan nut-meats) is much more closely linked than that of the individual pecan producing states. About 76% of variation in the average national price of pecan meats is closely associated with on-hand supply (i.e., carry-over) plus current season's crop. Hence, about 24% of the variation in price the average lot of nuts brings to pecan producers is likely due to factors other than overall supply of pecan nuts due to carry-over and current season's crop. Additionally, the price walnut producers are paid for walnuts, the primary nut-meat competitor for pecan, accounts for about 4% of the variation in pecan prices. The influence of walnut prices on pecan price might have proven to be greater if data were available on prices of nuts sold by the processing industry.

These data on overall price and production characteristics indicate that the United States pecan industry is growing slowly and undergoing key demographic changes altering the fundamental nature of the industry in regards to number, size and location of pecan farms. Price-supply data indicates that these changes are likely due to problems associated with the pricing structure of pecan. Although there is a close association between average national price and total national supply of pecan nut-meats, the poor relationship exhibited within several states indicates that price discovery is either rather complex or that perhaps growers in certain states are receiving less than fair-market prices and therefore need to implement alternate marketing efforts. The lack of linkage in either improved or other class nuts for degree of bienniality (K) and the variation in price due to production within states, indicates that biennial bearing is not the primary factor directly influencing the pricing inconsistencies exhibited by certain states. The pricing of pecan nut-meats merits further investigation.

These data on production units, price, and production efficiencies indicate that the U.S. pecan industry is slowly evolving. Fundamental shifts are occurring in regards to location and size of pecan farms, how well trees are managed, and in number of farms. These shifts are consistent with certain early symptoms of industrialization—a common process for much of U.S. agriculture. While the supply to price relationship at the national level is as

good for pecan as for the other major tree-nut crops, there exists a relatively poor relationship in many of the states. Thus price is likely a key factor driving these evolutionary-like shifts. At the national level, there is no clear relationship between changes in acres of orchards, or total numbers of farms, and the supply-price linkage. These findings indicate that the U.S. pecan industry is undergoing subtle changes that will eventually produce a substantially different industry.

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