REDUCTION IN LABOR REQUIREMENTS FOR BURLEY TOBACCO PRODUCTION, PART 2: POTENTIAL

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There have been numerous widely adopted mechanization developments and practices since the 1970s that reduced the manual labor requirements for producing burley tobacco by approximately half for efficient producers. A number of other labor-reducing developments that occurred during that time period were proven effective, but were not widely adopted, for various reasons. These developments, including a new 2-tier-height economy barn design, mechanical topping, the cable hoist housing system, no-till transplanting, and several different mechanized harvesting systems, were analyzed based on cited references for the amount that labor requirements were reduced and the costs and savings associated with the development. Developments such as the economy 2-tier barns, mechanical topping, and no-till transplanting resulted in not only labor savings but also in moderate cost benefits to the producer. Economy barns and no-till transplanting have been adopted to limited extent, but mechanical topping has not been adopted at all. Developments such as cable hoist housing and the various notching-type mechanical harvesting systems that resulted in some substantial labor savings were initially adopted by a number of growers, but their use has declined significantly for various reasons. These developments slightly reduced the cost of production if the savings of not having to build a new barn was taken into account, but increased the costs if it was not. A fully automated harvesting system reduced harvest labor requirements by about 80%, but resulted in greatly increased costs of production, nearly $0.70/pound/year. Even though the automated harvester greatly reduced labor requirements, overall burley tobacco labor requirements are still quite high, in large part because of high labor requirements for stripping. Mechanical stripping innovations continue to be pursued.

INTRODUCTION

The first article in this 2-part series, "Reduction in labor requirements for burley tobacco production. Part 1: Progress since the 1970s" (9), summarized past significant labor reductions for burley tobacco production based on mechanization and cultural developments that were, for the most part, widely adopted. The amount that labor requirements were reduced, and the costs and savings associated with labor-reducing methods, were analyzed based on data from cited references. A number of other mechanization developments that occurred during that time period have the potential to reduce labor requirements considerably more, but these developments were for the most part not widely adopted, for various reasons. Under the same analysis method as in the first article, this second article reviews the potential for further labor reductions considering mechanization and cultural developments that were proven, but not widely adopted. Major labor-reducing developments being considered include a new 2-tier-height economy barn design, mechanical topping, the cable hoist housing system, no-till transplanting, and several different mechanized harvesting systems (the burley spiker stick harvesting machine, the Powell and Kirpy notching harvesters used with wire-strung field structures, and the automated GCH harvester used with metal frames).

The results of this analysis of potential for further labor reductions in burley tobacco production are presented in a format similar to that used in the first article in the series, with a comprehensive table (Table 1) of labor requirements with columns for each of the major labor-reducing developments. Numbered paragraphs describing the developments correspond to superscript notations for the columns in the table, and individual tables show the costs or savings associated with the labor-reducing development. Note that the savings associated with the reduction in labor requirements are based on a reasonable estimation of the prevailing hourly wage rates at the time of the development, converted to a per-pound basis based on a standard yield of 2,500 lb/acre, and summed to give a net savings (or cost) per pound of tobacco. The "% Incremental Labor Reduction" is the percentage change of a labor-improvement method divided by its recent value. The "% Overall Labor Reduction" is the percentage change of a labor improvement divided by the baseline data carried over from the "2007 Big Bale" column from the summary table of the first article in the series (as explained below) (9). Calculations are shown in each table's entries.

In the table from the first article, the columns across the table representing the developments were in chronological order from left to right. This ordering followed the progression of changes in labor requirements for burley production activities, helping to show how labor requirements changed or stayed the same over time. Because this current analysis is concerned with developments that, although proven in effectiveness, were not very widely adopted, the order that the labor-reducing developments are represented in Table 1 is essentially random, with the exception that the mechanized harvest developments are grouped together for clarity. Note, however, that there is some significance to the order of

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Table 1. Summary of potential burley labor and cost reductions. Note: Labor and cost changes are not all additive due to repeated use of some equipment and methods. Standard data used: 2,500 lb/ac yield.

Item	Method - Worker-hour/Acre										
	Base Data[1a]	4–5 Tier Barn[2]	Economy 2-Tier Barn[3]	Mechanical Topper[4]	Cable Hoist[5]	No-Till Transplanting[6]	Burley Spiker[7]	Powell System 1[8]	Powell System 2[9]	Cut, Notch, Haul, Hang[10]	Automated Harvester[11]
Plant production	2	2	2	2	2	2	2	2	2	2	2
Field preparation	8	8	8	8	8	2.6[b]	8	8	8	8	8
Transplant	5	5	5	5	5	5	5	5	5	5	5
Growth	9.5	9.5	9.5	9.5	9.5	2.2	9.5	9.5	9.5	9.5	9.5
Topping + sucker control	12.5	12.5	12.5	2	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Dropping sticks and cutting	26	26	26	26	26	26	20	All[c]	All	All	All
Load and haul	8	8	8	8	11	8	8	Incl.	Incl.	Incl.	Incl.
House	26	26	20	26	3.5	26	26	31	31	40.7	7.5
Cure management	3	3	3	3	3	3	3	3	3	3	1
Takedown and bulk	10	10	10	10	10.3	10	10	10	10	10	6.6
Stripping	43	43	43	43	43	43	43	43	43	43	43
Load and market	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Sum wk-hr/ac	153	153	147	144	134	141	147	124	124	134	95
% incremental labor reduction[d]		0%	−23%	−84%	−44%	−73%	−23%	−48%	−48%	−32%	−80%
% overall labor reduction[e]		0%	−3.9%	−6.9%	−12.5%	−8.3%	−3.9%	−19%	−19%	−13%	−37%
Net cost/lb change		+$0.170	−$0.113	−$0.022	+$0.043	−$0.085	+$0.057	−$0.035	+$0.162	+$0.072	+$0.699

[a] Numbers for each column correspond to the labor-reducing developments listed and described in the text.
[b] Red numbers are for labor values changed because of labor-reducing development.
[c] Labor value for house is all inclusive of drop sticks and cut, load and haul, and house.
[d] Calculated from the labor reduction (shown in red) divided by the previous labor requirement. See individual tables corresponding to columns for calculations of percent incremental labor reductions.
[e] Calculated from the labor reduction (shown in red) divided by the baseline total labor requirement from 1972 (second column). See individual tables corresponding to columns for calculations of % overall incremental labor reductions.

Figure 1. Conventional 4–5 tier tobacco barn.

the columns in that the 2 leftmost columns serve as a baseline for calculating costs and savings associated with the labor-reducing developments. The first column is for the data carried over from the results of the analysis presented in the first article in the series, and the second gives a baseline of costs associated with the construction of a new traditional barn, important for cost comparisons because several of the developments included in the analysis involve new or innovative housing methods.

MAJOR LABOR-REDUCTION DEVELOPMENTS

1. Data Forward (Baseline Data). Labor data from the summary table of the first article in the series (9) for the rightmost "2007 Big Bale" column are continued forward in the first column of Table 1 of this article. Some more recent studies have provided supplemental data, but these data are carried forward for consistency in making further comparisons. One important data variation is that plant population in the 1980s was around 8,000–8,200 plants/acre, whereas populations were reduced down to around 7,000–7,500 plants/ac into the 1990s and onward for more efficient use of plant production and harvest handling without significant reduction in final leaf yield (18). The cutting and spearing process varies across the region, with different variations of workers cutting and spearing directly, leaving cut plants on the ground to wilt and then be speared later, or working in teams with 1 cutting and handing off to another for spearing. Considering the combination of several factors, the time requirements for dropping sticks and cutting are probably considerably less than the 26 wk-hr/ac used in the analysis. Actual housing labor requirements are likely somewhat lower as well, because the reported value is for taller, traditional barns, whereas current operations are likely to be using a combination of traditional barns with newer-version shorter barns and single-tier field structures known to have lower housing labor requirements (6). For consistency in the analysis the previous data of the rightmost column of summary table from the first article is used as the baseline for further comparisons in Table 1.

2. Build New 4–5 Tier Barn. The second column in Table 1 is for building a new conventional tobacco barn (see Figure 1). This is not a development that has any effect on the labor requirements for burley production, but it was included because it gives an important baseline for cost comparisons for many of the labor-reducing developments considered in the analysis that involve new or innovative housing methods. The cost projections are for building a new 4–5-tier conventional tobacco barn with 10-acre capacity, 40 ft wide, 3 driveways, wood siding with vent panels and driveway doors per University of Kentucky plans (Plan 735-27A available at www.bae.uky.edu/ext/Tobacco/Plans/735-27A.pdf). An estimated cost based on a computerized bill of materials cost computation and representative construction labor costs was calculated at approximately $65,400 by Duncan (6) (plan cost coded as 735-27A5). Table 12 shows the cost calculations for many tobacco and equipment and facility options considering standard amortization factors, expected life, and estimated annual capacity based on a plant population of 7,000 plants/ac and a yield of 2,500 lb/ac. According to Table 12, constructing a new conventional barn adds +$0.170/lb/yr over a 40-yr life and amortization. Labor for housing is taken as the previous 26 wk-hr/ac for taller conventional barns. The calculations are summarized in Table 2.

Table 2. Estimated cost of building new 4–5-tier barn.

Method	wk-hr/ac	$/lb/yr
Conventional 4–5 tier barn labor (16)	26	
Amortized cost/lb/yr (Table 12)		+$0.170
Net cost change		**+$0.170**

3. New Economy 2-Tier-plus-Slip-Rails Barn. For comparison, a new economy barn of 2-tier height, 2 driveways with temporary driveway rails, partially enclosed side walls, and no doors was estimated as $34,000 for 10 acres (6), or $0.0884/lb/yr (Table 12). An economy barn is shown in Figure 2. Taking housing labor as a median of 20 wk-hr/ac averaging the 26 wk-hr/ac for conventional tall barns and the 14 wk-hr/ac for 1-tier field curing structure, housing labor would be reduced −6 wk-hr/ac (26–20) with the economy barn compared to the conventional barn. Takedown and

Figure 2. Economy barn of 2-tier height, 2 driveways with slip rails (not shown), partially enclosed side walls, and no doors.

Table 3. Comparison of building economy 2-tier barn versus a traditional 4–5-tier barn.

Method	wk-hr/ac	Change	$Change/ac	$/lb/yr
Labor				
Conventional 4–5 tier barn labor (16)	26	–		
Economy barn labor	20	−6	−$60.00	−$0.024[a]
Amortization cost				
Conventional 4–5 tier barn cost (Table 12)				−$0.1770
Economy barn cost (Table 12)				+$0.0884
Net change				
Labor		−6		
Savings				−$0.1126

[a] $60.00/2,500 lb/ac (labor $10/hr).
Incremental −6/26 = −0.231 or −23%.
Overall −6/154 = −0.039 or −3.9%.

bulking should require less labor with this structure, but no data are currently available to substantiate the reduction, so the datum of the conventional barn is used. One disadvantage of the economy barn is that a longer structure would be required to house the same acreage of harvest. Building an economy 2-tier barn with slip-rail bottom tier saves −6 wk-hr/ac, −23% incremental labor savings compared to housing in a conventional barn, and −3.9% overall labor reduction (Table 3). At a labor rate of $10/hr and assuming a yield of 2,500 lb/ac, the labor savings results in a cost savings of −$0.024/lb/yr. The construction cost for the economy barn is $0.0884 over a 40-yr life and amortization (Table 12), a savings of −$0.0886 over construction of a new conventional barn ($0.1770 − $0.0884). Considering construction costs and taking into account the labor savings, the economy barn results in an overall savings of −$0.1126/lb/yr (Table 3).

4. Mechanical Topping. Mechanical toppers on high-clearance (hi-boy) sprayers have been used extensively in the flue-cured region from the 1980s forward. Figure 3 shows mechanical topping of burley tobacco. Studies by Swetnam et al. (21) reported labor for mechanically topping burley could be reduced to 1 wk-hr/ac. If an additional 1 wk-hr/ac is assumed for the application of sucker control (to be compatible with preceding data), labor savings using the mechanical topper was −10.5 wk-hr/ac (12.5 to 2), −75% incremental labor savings compared to conventional hand topping, and −3.9% overall labor reduction (Table 4). At a labor rate of $8/hr at that time and assuming a 2,500-lb/ac yield, the cost savings from reduced labor was −$0.0336/lb/ac. Typical topping equipment was priced at $4,000 for 2 rows (19), assuming machine hydraulics and mountings for the front-mounted toppers were adequate. Toppers and hi-boy equipment amortization is shown in Table 12, with $0.0084/lb/ac for the topper and $0.0210 for the hi-boy. Allocating 15% of the hi-boy cost to the mechanical topping task, the amortized cost for topping equipment is $0.0116 ($0.0084 + [$0.0210 * 0.15]). Considering labor savings and equipment costs results in an overall savings of −$0.0220/lb/yr (Table 4).

Figure 3. Mechanical topping of burley tobacco.

Adoption of mechanical topping was limited by producer resistance to the remains of severed top leaf fragments, uneven plant growth causing irregular topping effects, and limited hi-boys with hydraulics to power the mechanical toppers. The 1998 report (21) showed no significant effect on yield and market quality of the severed leaf tips. In past years, 3 topping units were known to have limited use on Kentucky farms.

5. Cable Hoist Housing System. Methods to reduce or eliminate the tedious task of lifting sticks of tobacco by multiple workers into the tall conventional barns have been pursued aggressively by farmer–innovators and researchers since the 1950s and 1960s. Numerous versions of fork-lift handled wooden and steel portable frames for filling in the field and curing under plastic or inside modified interior barns were tried. Results of significant University of Kentucky work were reported by Yoder and Smith (32), Yoder (30), and Yoder and Henson (31). Although reductions in labor requirements of up to 50% are possible for field-filling, transport, and barn placement with no workers climbing in the barn, only about a dozen on-farm systems using some form of portable frames were adopted by producers during the 1960s–1970s. There were limitations of converting conventional barns to get equivalent-capacity, off-season storage-space requirement of empty frames,

Table 4. Comparison of mechanical and manual topping.

Method	wk-hr/ac	Change	$Change/ac	$/lb/yr
Manual topping and application of sucker control	12.5			
Mechanical topping and application of sucker control	2	−10.5	−$84	−$0.0336[a]
Topper amortization (Table 12)				+$0.0084
High-clearance machine amortization (Table 12, at 15% of $0.0210/lb/yr)				+$0.0032
Net change				
Labor		−10.5		
Savings				−$0.0220

[a] $84.00/2,500 lb/ac (labor $8/hr).
Incremental −10.5/12.5 = −0.84 or −84%.
Overall −10.5/153 = −0.0686 or −6.9%.

and the marginal cost benefits of the method. New barn construction offered more favorable benefits with these systems, as clear span structures were more conducive to positioning and stacking the frames, but added considerably to the costs.

A promising method of reducing barn labor by lifting beams (5 × 6 in. × 12 ft. long) having 30–40 sticks of tobacco inserted into holes was divulged by Helbling (13) and dubbed the twin-rail system. An extensive network of 3/8-in.-diameter or larger cables and pulleys was required in a reinforced upper structure of a barn to facilitate lifting 4–5 beams of tobacco linked together vertically. A pair of cables, 4 pulleys, and a manual or hand-drill powered winch were required for each horizontal space of the beams. Only a couple of farmers adopted this system, but it inspired the development of a cable hoist system by Duncan et al. (10) during the late 1980s.

The cable hoist system, shown in Figure 4, featured bolted wooden members spaced 1 ¼ in. apart to support sticks of tobacco in a cantilever manner on each side of the beam. These beams holding 45–55 sticks of wilted tobacco were lifted 1 at a time into a modified or new barn by 1 worker using a hydraulic-powered pair of lifting hoists, and positioned onto the existing cross-members. The special bolted beams were the lowest-cost means at that time of supporting 50 or more sticks of tobacco for handling and curing effectively in a modified conventional barn. Plus, the off-season storage was a very compact stack of 6 × 8–in. cross-section by 12- or 14-ft-long wooden members. Over 50 known producers adopted the system and used modified conventional or newly constructed barns and commercially built hoist units.

Figure 4. Cable hoist housing of burley tobacco.

Labor data compiled from 17 farms showed hoisting of filled beams in the barn by 1 worker required 3.5 wk-hr/ac and the takedown and bulking by 2 or more workers was 10.3 wk-hr/ac for a total of 13.8 wk-hr/ac (10). Labor data for comparable conventional barn methods were 13.0 and 12.0 wk-hr/ac, respectively (10). Note that the conventional barn housing data is approximately half of previously cited data used for the baseline. Field filling and transport data were not reported in this study, but observations of the reduced capacity of 3–4 beam trailers hooked together estimated the increased field time to be about 20–30% more than conventional flat-bed wagon methods (8 wk-hr/ac), or approximately 11 wk-hr/ac. A cost comparison between cable hoist and conventional housing considering labor requirements and amortization costs is detailed in Table 5. The cable hoist method reduced housing and bulking labor by −8.2 wk-hr/ac based on timed data in respective barns. Considering this labor reduction and the barn modification and equipment costs (Table 12) results in a net increase in costs using cable hoist housing of +$0.079/lb/yr for the conditions given. Using Table 1 conventional loading and housing data of 44 wk-hr/ac for load, haul, house, and bulk, the labor was reduced considerably more at −19.2 wk-hr/ac, −44% incremental labor savings compared to conventional barn housing, and −12.5% overall labor reduction (Table 1). The net increase in costs when compared to the baseline conventional barn housing data is less, +$0.043/lb/ac. The calculations are summarized in Table 5. Additional calculations considering costs compared to building a new conventional barn show that the net annual costs were very competitive using the cable hoist system and offered a feasible labor-saving method to the producers. Most adopters in the era built new barns especially for the cable hoist system rather than modifying existing barns.

Table 5. Cable hoist housing comparisons.

	wk-hr/ac	$/ac/yr	Change	$Change	$/lb/yr
Conventional method (timed data)					
Load and haul	8		–		
Barn housing	13[a]		–		
Takedown, bulk	12[a]		–		
	33				
Cable hoist system (10)					
Load and haul	11		–		
Barn housing	3.5[b]		–		
Takedown, bulk	10.3[b]		–		
	24.8		−8.2	−$65.60	−$0.0262[b]
Barn modification and equipment costs (10)					
Materials and labor, hydraulic hoist, 10 ac/yr		$262			+$0.1048[c]
Net change using timed data					
Labor			−8.2		
Cost					+$0.079
With conventional-barn data for comparison					
Labor data from Table 1 for conventional barn					
Load, haul, house, and bulk	44				
Above cable hoist labor data	24.8				
Change			19.2	−$153.60	−$0.0614[b]
Materials and labor, hydraulic hoist, 10 ac/yr		$262			+$0.1048[c]
Net change using conventional-barn data					
Labor			−19.2		
Cost					+$0.043

[a] Timed data for comparable tasks in conventional barns (10).
[b] $65.60/2,500 lb/ac (labor $8/hr).
[c] $262/2,500 lb/ac.
Incremental −19.2/44 = −0.436 or −44%.
Overall −19.2/153 = −0.125 or −12.5%.

6. No-Till Transplanting. After several years of research and trials, no-till transplanting of tobacco plants into killed cover crop or soybean stubble began expanding in on-farm use in the early 2000s (see Figure 5). This practice eliminated plowing, disking, and cultivating, but had some additional use of chemical weed control and fertility management. No-till and conventional tillage tobacco transplanting are compared in Table 6. Appropriate equipment and labor data are taken from ID-81 (16). Conventional and no-till carousel transplanting equipment costs were assumed comparable other than for additional modifications needed for a transplanter to operate in the undisturbed soil. The mechanical additions to 2-row transplanters for no-till functions consisted of coulters and soil-penetrating shanks with component and installation costs estimated at $800 per machine (17) with per-acre cost listed in Table 12. No-till transplanting required added chemical weed control costs of approximately $18 or more per acre, depending on products needed (17). Any fertility differences are not included in this summary. No-till transplanting offers the potential for reducing labor of field preparation and cultivation by −12.7 wk-hr/ac, −73% incremental labor reduction compared to conventional tillage, −8.3% overall labor reduction, and a savings of −$0.085/lb/yr (Table 6). The main benefits advocated for no-till are soil conservation (reduced erosion) and cleaner field surface for harvest practices (17), but the above cost savings can be meaningful if yields are equivalent.

7. Burley Spiker Stalk Spearing Machine. A self-propelled machine that automatically impaled harvested plants onto wooden sticks with 2 workers operating it was developed in the mid-1990s. A supply of uniform wooden sticks was carried on the machine for spearing functions, thus eliminating traditional stick dropping

Figure 5. No-till burley tobacco.

Table 6. **Comparison of conventional tillage and no-till tobacco transplanting.**

	wk-hr/ac	$Change/ac	$/lb/yr
Conventional and no-till transplanting			
No-till practice (eliminates plow, disc, cultivate (16))		−$139.97	
Add spraying herbicide		+$7.89[a]	
Transplanter modification		+$4.64	
Additional chemicals		+$18.00	
		−$109.44	−$0.0438[b]
Conventional and no-till labor			
Conventional field preparation (16)	8		
Conventional cultivation (16)	9.5		
	17.5		
No-till practice	4.79		
No-till reduction	−12.71	−$101.68	−$0.0407[c]
Net change:			
Labor	−12.71		
Savings			− $0.085

[a] 15% of hi-boy annual cost of $52.60/ac.
[b] $109.44/2,500 lb/ac (labor $8/hr).
[c] $101.68/2,500 lb/ac (labor $8/hr).
Incremental −12.7/17.5 = −0.726 or −73%.
Overall −12.7/153 = −0.083 or −8.3%.

before harvest. One commercial machine was fabricated in the mid 1990s by Taylor Manufacturing, Inc. (22), and others in 2009 by Evans-MacTavish-Agricraft (11) after some renewed interest in stick-type mechanical harvesting (see Figure 6). Various data taken with different workers in varying tobacco conditions indicate a typical harvesting rate of around 120 sticks per hour, giving 20 wk-hr/ac (1,200 sticks/ac/120 sticks/hr * 2 workers = 20 wk-hr/ac) with variations up to 150 and down to 100 sticks/hr (7,9). The machine's sustained harvesting rate depended on the speed of 1 worker handling cut plants. Advantages of the machine were no spearing skill needed, thus enabling younger and older workers to operate the machine, and workers riding with it performed some different manual duties. A commercial machine cost of $13,000 was quoted in 1995 and $23,000 in 2009. Leaf loss was observed to be somewhat greater than with hand harvest depending on the tobacco conditions and handling care. Additional leaf-loss values have not been factored into these cost calculations. The amortized cost using the 2009 price and assuming a capacity of 15 ac/yr and 10-yr life is +$0.081/lb/yr (Table 12). Using the burley spiker resulted in a labor reduction of −6 wk-hr/ac compared to the baseline data for dropping sticks and cutting (26–20), a −23% incremental labor reduction, −8.3% overall labor reduction, and a savings of −$0.024/lb/yr. The net cost for use of the burley spiker was +$0.057 lb/yr (Table 7).

Figure 6. **Burley Spiker stalk spearing machine.**

8. Powell Harvester System. The Powell harvester system featured a towed machine enabling plant cutting, conveying, notching, and presenting the plants for workers to hang manually onto wire-strung wooden frames, as shown in Figure 7. It was introduced commercially in 1992 by Powell Manufacturing Co. based on a prototype developed and reported by Casada et al. (4), Bader et al. (1), and Walton et al. (23). A significant wire-strung wooden frame design was innovated by Mr. Steve Hunt of Butler County, KY (only 2 legs; each frame was supported at 1 side by an adjacent frame), and became the standard wire-strung wooden frame design (see Figure 8). Approximately 12 machines were built and sold in succeeding years. On-farm evaluation of a commercial machine system was reported by Swetnam et al. (20). They reported a harvest capacity of 0.65 and 0.78 ha/8 hr (a day) for 5 and 6 workers, respectively, based on 16,800 plants/ha (6,802 plants/ac). These data translate to 0.20 and 0.24 ac/hr harvesting capacity, or 5.0 and 4.12 hr/ac, for 5 and 6 workers, respectively. At the rate for the more prevalent 5-worker method, a value of 25.0 wk-hr/ac (5.0×5) is used to represent the harvester performance for this analysis.

Table 7. Comparisons for Burley Spiker field harvesting.

Method	wk-hr/ac	Change	$Change/ac	$/lb/yr
Conventional drop sticks and cut (16)	26			
Burley spiker	20	−6	$60.00	−$0.024[a]
Amortization cost, 2011, Table 12				+$0.081
Net change				
Labor		−6		
Cost				+$0.057

[a] $60.00/2,500 lb/ac (labor $10/hr).
Incremental −6/26 = −0.23 or −23%.
Overall −6/153 = −0.039 or −3.9%.

Covering the wooden frames aligned in the field with black plastic film was measured as 5 wk-hr/ac (23), giving a total of 30.0 wk-hr/ac. End-of-season movement of empty wooden frames to consolidate for storage was variable and could add 1 wk-hr/ac or more to give a sum of 31 wk-hr/ac. Leaf loss was determined to be 2.1% and 4.7% for 2 varieties. Additional leaf-loss values have not been factored into these cost calculations.

Cost comparisons for the Powell harvester system can be looked at 2 ways. The first way is using the mid-1990s machine price and comparing this to the cost of building a new conventional barn. For this comparison, the labor savings compared to the baseline data for dropping sticks and cutting, load and haul, and housing is 29 wk-hr/ac ([26 + 8 + 26] − 31), −48% incremental labor reduction, −19% overall labor reduction (Table 8), and a savings of −$0.0928/lb/yr assuming a wage rate of $8/hr at the time and a yield of 2,500/lb. Harvester cost was around $32,000 in the mid-1990s (19). Farm-built wire-strung wooden frames were estimated at $90 each (labor + materials) at 24 per acre with a useful life of 7 yr. Calculations from Table 12 show an amortized cost for harvester and frames of +$0.2278/lb/yr ($0.1857 + $0.0421). Taking into account the cost of building a new conventional barn ($0.1700) for comparison results in a net savings of −$0.0350 ($0.2278 − $0.1700 − $0.0421) with the use of the Powell harvester system (Table 8).

Figure 7. Powell harvester system for harvesting burley tobacco.

9. Powell Harvester System Updated. A second comparison considers just the addition of a Powell harvester–wooden frame system independent of the offsetting cost savings in comparison to building a new conventional barn. For this second comparison, the Powell harvester system is repeated with the updated cost data of the last public quote of $71,500 for a newly built machine (19). Farm-built wire-strung wooden frames were updated to $100 each (labor + materials) at 24/ acre with a useful life of 7 yr. Calculations from Table 12 show an amortized cost for harvester and frames of +$0.3007/lb/ac ($0.0940 + $0.2067). Considering the same reduction of 29 wk-hr/ac but updating to a wage rate of $12/hr results in a labor savings of −$0.139/lb/yr. The net cost for the Powell harvester system using updated prices for machine, wooden frames, and labor costs, without the offsetting savings compared to building a new barn, is +$0.162/lb/ac ($0.3007 − $0.139) (Table 9). The incremental and overall labor savings are the same as for the earlier system (Table 8).

10. Cutting-Notching Systems with Wire-Type Field Structures. A surge of excitement occurred in the summer of 2005 with the importation into the North Carolina burley region of several tractor-mounted cutting-notching machines from France referred to as the Kirpy tobacco harvester (2,3,5,14). This machine, shown in Figure 9, used a log-chain type plant conveyor having small plates with spikes welded onto the chain links to engage the butt-end of plants on 1 side; convey them, pressed against a back guide, past a notching saw; and deposit them horizontally onto a wagon towed

Figure 8. Wire-strung wooden frames used with Powell harvester system (later covered with plastic for curing).

Table 8. Comparisons for early Powell Harvester system with portable wire-strung wooden frames versus building new conventional barn.

Method	wk-hr/ac	Change	$Change/ac	$/lb/yr
Conventional methods (16)				
Drop sticks and cutting	26			
Load, haul	8			
Housing, conventional	26			
Total	60			
Powell harvest system (20)	31	−29	−$232	−$0.0928[a]
Conventional 4–5-tier barn amortization (Table 12)				−$0.1700
Powell harvester amortization 1997 (Table 12)				+$0.0421
Wooden frame amortization 1997 (Table 12)				+$0.1857
Net change (Powell No. 1)				
Labor		−29		
Savings				−$0.0350

[a] $232.00/2,500 lb/ac (labor $10/hr).
Incremental −29/60 = −.48 or −48%.
Overall −29/153 = −0.190 or −19%.

beside the harvester. Machine cost, importation, and delivery charges gave a U.S. price of around $23,000 in 2005. No information is available regarding current price or availability. A modification of the Powell harvester to just cut, notch, and convey plants with a commercial sticker chain onto a flat-bed wagon was soon thereafter introduced by MarCo in 2005 (2,5). This machine, shown in Figure 10, had a quoted price in 2007 of $27,758 plus delivery (15). Notched plants from these harvesters are manually hung on wire-strung field structures, pulling the individual plants from the wagons on which the plants are loaded (see Figure 11).

Timed data of these harvesters' performance showed a harvesting rate of 9 wk-hr/ac (weighted average) for 1 Marco and 3 Kirpy machines on 4 farms involving 35 wagonloads of harvested tobacco (8, 27). The weighted average timed hanging rate for these operations was 26.7 wk-hr/ac. Thus, the combined harvesting and hanging rate was 35.7 wk-hr/ac. Field layout, row length, turn time, wagon capacity, plant-handling methods, worker productivity, and other factors greatly affected these rates. Leaf loss (noticeably prevalent) values were not factored into these machine cost calculations.

Performance data from field studies reported by Velandia et al. (29) were 56.8 wk-hr/ac for harvest, hauling directly to a 1-tier hanging structure and hanging, after adjustment for mechanical downtime. Leaf loss was observed to be somewhat greater than with hand harvest depending on the tobacco conditions and handling care. Velandia et al. (29) reported leaf losses as 0.3–11.8% greater than the 5% conventional cutting and housing methods in a study of the Kirpy harvesting.

The harvester amortization costs computed in Table 12 are for a 50-ac/yr harvest with the Kirpy and MarCo machines. The wire structure costs were estimated at $1,800/ac for either system based on materials cost and completed construction labor from 1 grower (28) and taking into account the differences with field structure used for hanging stick-harvested tobacco. Additional annual covering labor is taken as 5.0 wk-hr/ac according to Walton et al. (23). These data are summarized in Table 10. They show a labor reduction of −19.3 wk-hr/

Table 9. Comparison for 2008 Powell harvester system and portable wire-strung wooden frames alone.

Method	wk-hr/ac	Change	$Change/ac	$/lb/yr
Conventional methods (16)				
Drop sticks + cut	26			
Load, haul	8			
Housing, conventional	26			
	60			
Powell harvest system (20)	31	−29	−$348	−$0.139[a]
Powell harvester amortization 2008 (Table 12)				+$0.094
Wooden frame amortization 2008 (Table 12)				+$0.207
Net change				
Labor		−29		
Cost				+$0.162

[a] $348.00/2,500 lb/ac (labor $12/hr).
Incremental −29/60 = −0.483 or −48%.
Overall −29/153 = −0.190 or −19%.

Figure 9. Kirpy notching-type harvester for burley tobacco.

Figure 11. Hanging notched plants on wire-strung field structure (later covered with plastic).

ac, −32% incremental, −13% overall, and additional cost of +$0.072/lb/yr for data from 4 farms using Marco and Kirpy cutting-notching harvesters and wooden wire-strung field curing structures.

11. Automated Harvester and Metal Frames. Development of a burley harvesting system to automate the harvesting, handling, and curing of plants more fully, at high capacity, was initiated in the early 1980s (24). Conceptualization, design, and fabrication of unique mechanisms for conveying, inverting, notching, and placing plants into receiver tubes of on-board portable metal frames resulted in a self-propelled prototype in the late 1980s. Developmental advances and early field-testing results were reported by Wells et al. (25), with a projected harvesting rate of up to 4 or 5 acres per 10-hr day with 2 workers to operate the harvester and a tractor front-end loader. Further refinements ensued through the 1990s with a second prototype machine and several dozen metal frames undergoing field tests. Each frame was a prefabricated 8 × 14–ft metal frame having slotted tubular plant receivers holding approximately 450 plants per frame (approximately 15 frames/ac) and fold-down legs for field curing. Prefabricated plastic covers were placed over the frames after a few days of field wilt for the remainder of the curing period. The labor hours for actual harvesting burley were greatly reduced by a stated 80–85% (25).

Figure 10. MarCo notching-type harvester for burley tobacco (initial model).

Commercial adoption was restrained by the projected high investment cost of the machine and metal frames. In 2005–2006 Philip Morris USA underwrote the fabrication of 3 automated harvesters and enough metal frames for nearly 100 acres. GCH International of Louisville, KY, became a licensee for the system and oversaw the fabrication, delivery, and support (12). Three cooperating farmers were loaned the machines and a supply of frames for large scale on-farm testing and evaluation on a year-to-year basis. The GCH automated harvester is shown in Figure 12. A field day on the Roberts' Farm in Henry County, KY, presented the system with a demonstration along with demonstrations of the Kirpy and MarCo notching harvester machines (5). Subsequent sales information indicated a quote of $379,000 for a harvester and $808 for each preformed but not assembled metal frame. Another automated harvester was built in 2011 for export. No price data have been made available on the 2011 cost of the harvester or frames (frames fabricated in another country).

While 1 worker operated the harvester, the second equipment operator was dedicated to keeping up to 5 empty frames ready to load onto the harvester as needed during field operation with the use of a long-reach tractor fork lift or commercial extended-reach boom. The filled frames were removed from the field to a sod area for curing by the front loader or a special trailer–carrier. The frames were covered later with preformed covers. After curing, the covers were removed and the tobacco was manually removed from the frame and bulked on transport vehicles for stripping. On-farm studies in 2007 by Wells et al. (26) showed a sustained

Table 10. Comparisons of Kirpy and MarCo notching harvesters and notched plant hanging.

Method	wk-hr/ac	Change	$Change/ac	$/lb/yr
Conventional methods (16)				
Drop sticks, cut	26			
Load, haul	8			
Housing, conventional	26			
Total:	60			
Notched harvester (27)				
Weighted-average data, harvest and hang	35.7			
Wooden-wire field structure (Table 12)				+$0.1641
Covering field structure (see paragraph 8)	5.0			
	40.7	−19.3	−$231.60	−$0.0926[a]
Net change				
Labor		−19.3		
Cost				+$0.0715

[a] $231.60/2,500 lb/ac (labor $12/hr).
Incremental −19.3/60 = −.32 or −32%.
Overall −19.3/153 = −0.126 or −13%.

average harvesting rate of 0.55 ac/hr and a total labor requirement for the above harvest and rack management tasks of just over 14 wk-hr/ac, as shown in Table 11.

Projections have been that a single harvester should be capable of 100 ac or more harvested per season allowing for weather interferences and other interruptions. Table 12 shows amortization costs for a 100-ac/yr system. The included data are summarized in Table 11. As can be seen by the cost data, the metal frames are a huge cost of the system: $0.675/lb/yr. Many efforts have been made to reduce this single-use-per-season investment cost or to get 2 uses per season for each frame (double harvest and cure), none of which have been successfully achieved yet beyond a fraction of the total crop. These data show a potential −80% reduction in harvest labor for the automated harvest system but a significant additional cost of +$0.699/lb/yr, primarily because of the amortization cost of the special once-per-season-use metal frames. Development of high-capacity stripping equipment could possibly enable double use of the metal frames each season and reduce the amortization cost.

Figure 12. GCH automated harvester for burley tobacco.

DISCUSSION OF RESULTS

There have been numerous widely adopted plant production, cultural, and marketing innovations since the 1970s that reduced the manual labor requirements for producing burley tobacco by approximately half for efficient producers (9). A number of other labor-reducing developments that occurred during that time period were proven in effectiveness but not widely adopted for various reasons. These developments, including a new 2-tier-height economy barn design, mechanical topping, the cable hoist housing system, no-till transplanting, and several different mechanized harvesting systems, were analyzed based on cited references for the amount that labor requirements were reduced and the costs and savings associated with the development.

The results of the analyses show that some of the labor-reducing developments, such as the economy 2-tier barns, mechanical topping, and no-till transplanting, resulted in not only labor savings but also in moderate cost benefits to the producer. Economy barns and no-till transplanting have in fact been adopted to a limited extent, whereas mechanical topping has not been adopted at all. The main reason that economy barns have not been more widely adopted is probably the aversion that producers have had to making long-term investments in new curing capacity. Achieving consistent success with no-till production of burley tobacco may be too site and weather dependent for the practice to be widely adopted. Grower unease with equipment and visual effects (on the plants) that seemed foreign to growers may account for the lack of adoption of mechanical topping.

The analyses showed that some of the developments resulted in slight to moderate labor savings and slight costs or savings to moderate increases in costs of production. Such developments included cable hoist housing, the burley spiker spearing machine, and the various notching harvesting machines (Powell harvester,

Table 11. Comparisons of automated harvester and metal frame system.

Method	wk- hr/ac	Change	$Change/ac	$/lb/yr
Conventional methods (16)				
Drop sticks, cut	26			
Load, haul	8			
Housing	26			
Takedown, bulk	10			
Total	70			
Automated harvest system (26)				
Field filling racks	3.64			
Moving racks	1.62			
Covering racks	2.27			
Emptying racks	6.60			
Total:	14.13	−55.9	−$670.80	−$0.2683[a]
Automatic harvester amortization, 100 ac/yr (Table 12)				+$0.1994
Extended-reach forklift, Telehandler (Table 12)				+$0.0084
Metal frames, 100 ac (Table 12)				+$0.6754
Preformed covers, 100 ac (Table 12)				+$0.0840
Net change				
Labor		−55.9		
Cost				+$0.6989

[a] $670.80/2,500 lb/ac (labor $12/hr).
Incremental −55.9/70 = −.80 or −80%.
Overall −55.9/153 = −0.365 or −37%.

MarCo, and Kirpy). The cable hoist housing system resulted in a reduction of approximately 8 wk-hr/ac in timed tests on farms, and 19 wk-hr/ac compared to the baseline data for conventional barn housing in Table 1, but a net increase in cost of approximately $0.08/lb/yr (based on timed tests on farms) or $0.043/lb/yr (using baseline data). Although the cable hoist housing system was actually adopted by a significant number of growers at the time, its use has been largely abandoned since the late 1990s, probably for cultural reasons, with the transition to a primarily migrant labor force and the consolidation of burley tobacco production since that time.

The burley spearing machine resulted in only a slight reduction in harvest labor requirements, and an increase in costs of production of $0.057/lb/yr. This machine has the advantage of making tobacco harvesting work much easier, but the low capacity likely reduces its acceptability for most growers in the current environment.

The various notching harvesters all provided some substantial reduction in harvesting and housing labor requirements, especially the Powell harvester system that included portable 2-legged wire-strung curing frames loaded directly by workers riding on the machine. The reported labor requirement of 31 wk-hr/ac for harvesting and housing inclusive is a reduction of nearly 50% from the combined stick dropping and cutting, load and haul, and housing labor requirements used for the baseline data. The reported labor requirement for the MarCo and Kirpy notching harvesters was a bit higher than the Powell harvester system at 41 wk-hr/ac. The added complexity of loading harvested plants on wagons pulled alongside the harvesters, in conjunction with the slowness of handling and hanging individual plants in transferring them from the wagons to wire-strung field structures, account for the higher labor requirements (27). From a cost consideration, these systems can actually reduce the costs of production slightly if the costs associated with building new curing capacity in the form of a traditional barn are factored in, as with the first analysis of the Powell harvester in Table 1 (system 1, column 8) with a cost savings of −$0.035/lb/yr. But the analysis of system 2 of the Powell harvester (column 9) shows the extent to which production costs are increased if new barn construction is not counted as a savings, +$0.162/lb/yr in this case. The increase in production costs is slightly less than half, with the less expensive MarCo and Kirpy notching harvesters at +$0.072/lb/yr.

The various notching harvesters were actually initially adopted by a number of growers in their time (the Powell harvester in the 1990s, the Kirpy and MarCo in the second half of the 2000s). Use of these harvesting systems has declined significantly for many reasons, however, including the added costs, concerns about leaf damage and loss, concerns about field and plant conditions related to getting harvesting machines into the field, and cultural consideration related to the labor force and scale of operations (as mentioned above relative to cable hoist housing). As producers have increased their reliance on migrant labor crews to harvest larger acreages of tobacco, it has become more important for them to let the harvesting crew operate with minimal oversight. Migrant laborers are more accustomed to traditional stick-harvesting methods (27).

Table 12. Equipment and facility cost analysis for tobacco labor comparisons (using straight-line depreciation for useful years (years not Internal Revenue Service compatible); 10% salvage value for equipment or as noted; interest = 7%/yr on average value of investment − repairs, maintenance, and insurance (RMI) = 0.5% and 1% on investment value of facilities and equipment, respectively, except per footnotes, ac/yr approximate annual capacity of equipment, 7,000 plants/ac, 2,500 lb/ac).

Item	Investment ($)	Salvage value ($)	Depreciation (yr)	Depreciation ($/yr)	Interest ($/yr)	RMI ($)	Subtotal ($)	ac/yr	$/ac/yr	$/lb/yr
Two-row carousel transplanter[a]	$6,500	$650	10	$585	$205	$65	$855	25	$34.19	0.0137
No-till modifications[a]	$800	$0	10	$80	$28	$8	$116	25	$4.64	0.0019
Conventional 4–5 tier barn[b]	$65,400	$0	40	$1,635	$2,289	$327	$4,251	10	$425.10	0.1700
Economy 2-tier barn and single-tier field structure[b]	$34,000	$0	40	$850	$1,190	$170	$2,210	10	$221.00	0.0884
Postrow field structure[b]	$13,000	$0	7	$1,857	$455	$65	$2,377	10	$237.71	0.0954
High-clearance machine (used)[d]	$10,000	$1,000	10	$900	$315	$100	$1,315	25	$52.60	0.0210
Mechanical toppers[d]	$4,000	$400	10	$360	$126	$40	$526	25	$21.04	0.0084
Powell harvester 1997[e]	$32,000	$3,200	10	$2,880	$1,008	$320	$4,208	40	$105.20	0.0421
Wood frames 1997[f]	$86,400	$0	7	$12,343	$3,024	$3,200	$18,567	40	$464.17	0.1857
Burley spiker 2009[e]	$23,000	$2,300	10	$2,070	$725	$230	$3,025	15	$201.63	0.0807
Powell harvester 2008[e]	$71,500	$7,150	10	$6,435	$2,252	$715	$9,402	40	$235.06	0.0940
Wooden frames 2008[e]	$96,000	$0	7	$13,714	$3,360	$3,600	$20,674	40	$516.86	0.2067
Kirpy harvester 2007[e]	$23,000	$2,300	10	$2,070	$725	$230	$3,025	50	$60.49	0.0242
MarCo harvester 2007[e]	$27,758	$2,776	10	$2,498	$874	$278	$3,650	50	$73.00	0.0292
Wire field structure 2007[g]	$90,000	$0	7	$12,857	$3,150	$4,500	$20,507	50	$410.14	0.1641
GCH harvester 2007[h]	$379,000	$37,900	10	$34,110	$11,939	$3,790	$49,839	100	$498.39	0.1994
Metal frames 2007[i]	$1,212,000	$60,600	10	$115,140	$40,299	$6,060	$161,499	100	$1614.99	0.646
Telehandler 13[j] (used)	$16,000	$1,600	10	$1,440	$504	$160	$2,104	100	$21.04	0.0084
Prefabricated covers 2007[k]	$150,000	$0	10	$15,000	$5,250	$750	$21,000	100	$210.00	0.0840

[a] Typical commercial price of 2-row carousel transplanter in 2006; coulter and shank modifications required (17).
[b] Curing structure construction estimates taken from Duncan (6), no salvage value.
[c] Approximate commercial price of equipment in 2007.
[d] Commercially quoted prices of respective equipment at the time noted.
[e] Portable wooden frames taken as $90 each in 1997 with $80/ac/yr plastic + labor repl., $100 each in 2007 with $90/ac/yr plastic + labor repl., 24/ac, no salvage value.
[f] Wire-type field structure taken as $1,800/ac construction cost from producer data (28), $90/ac/yr for plastic + labor replacement, no salvage value.
[g] Last known quoted price of GCH harvester; 0.5% RMI, 10% salvage value.
[h] Commercial metal frames stated as $808 each, at 15/ac, life is assumed and unconfirmed, 5% salvage value, 0.5% RMI.
[i] Used Telehandler price for handling frames taken from FASTLINE.COM as possible purchase price for some advertised models, 5/2013, 10% salvage value, 1% RMI.
[j] Prefabricated plastic covers stated as $100 each, at 15/ac, life is assumed and unconfirmed, no salvage value, 0.5% RMI.

The final case considered in this analysis, the fully automated harvester, shows how difficult it is to pay for mechanization through reductions in labor requirements. That system reduced total harvesting and housing labor requirements down to 7.5 wk-hr/ac, a huge savings in comparison to the 60 wk-hr/ac total of the baseline data. Even more labor savings was associated with taking the tobacco out of the frames (6.6 versus a baseline rate of 10 wk-hr/ac). Yet the high cost of the harvesting machine, and even more so of the metal curing frames, results in nearly $0.70/lb/yr being added to the cost of production despite the substantial reduction in harvesting and housing labor requirements. It should be noted that even with a reduction of about 80% in labor requirements for harvesting and housing, overall labor requirements for producing burley tobacco remain surprisingly high at 94 wk-hr/ac.

Of that remaining labor requirement for burley production with most of the harvesting and housing labor eliminated, close to half of it (43 wk-hr/ac) is for stripping, so that is a main area with potential for further reduction in labor requirements. During the period that was covered in the first article in this series, 1972–2007, stripping labor requirements were reduced significantly primarily by changes in packaging and marketing practices, first from hand-tied to small bales, and then from small to big bales (9). There have been trials with various stripping innovations and aids in the time since the use of big balers became predominant, but no citable studies thoroughly documenting labor reductions and costs of the stripping innovations or aids integrated with the use of big balers have been conducted to date.

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