Comparison of Platform versus Ladders for Harvest in Northern California Pear Orchard

R.B. Elkins
University of California
Cooperative Extension
Lakeport, California
USA

E.J. Mitcham and W.V. Biasi
Department of Plant Sciences
University of California
Davis, California
USA

J. Abreu
TriPortugal ACE
Cadaval
Portugal

J.M. Meyers, V. Duraj, J.A. Miles and D.J. Tejeda
Department of Biological and Agricultural Engineering
University of California
Davis, California
USA

L. Asín
Institut de Recerca i Tecnologia Agroalimentaries (IRTA)
Estacio Experimental de Lleida
Lleida
Spain

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Abstract

A self-propelled platform (Argiles AF-8) was tested in four mature 'Bartlett' pear orchards in Lake County, California in 2006 and 2007 to address productivity, post-harvest quality, ergonomics and worker satisfaction. Orchard characteristics included densities of 640-834 trees/ha, heights of 5.7-4.3 m, and trunk-to-canopy edge distances of 1.7-0.7 m. This contrasts with example orchards from Portugal and Spain with 1600 and 2300 trees/ha, 3 m and 2.5 m heights, and 0.9 and 0.5 m trunk-to-canopy edge distances, respectively. Results from a 12-day machine trial using a somewhat atypical hourly-paid crew (majority female, average age 43 years and 15 years orchard experience) were compared to the norm of a typical piece-rate crew harvesting from 5.3 m ladders (100% male, average age 27 years and 4 years orchard experience). Platform productivity, expressed in 500 kg bins/worker/day, averaged 1.8 for selective (partial tree) harvest and 3.4 for complete fruit removal ("stripping") compared to the ladder crew's 3.5 and 5.5, respectively. Productivity was highest where the canopy was narrowest (0.7 m). Platform-harvested fruit had 57% fewer stem punctures. 2007 platform modifications included night-time lights, overhead shading, increased vertical reach, and re-configured conveyors to target a productivity goal of 6 bins/worker/day. Productivity for the hourly-paid mixed-gender crew over 5 days and 2 nights was similar to 2006, but increased 75% (3.4 to 5.9) for a 100% male crew paid piece rate, comparable to an average ladder crew. Post-harvest quality was similar to 2006, despite faster picking rate. Worker ergonomics and satisfaction favored the platform both years. Hourly-paid platform crew productivity was comparable to that in Portugal and Spain but California's short harvest window and 35-70% higher per hectare yields necessitate higher machine productivity. Major barriers to widespread adoption of platforms for harvest in California pear orchards are 1) capital and maintenance costs, 2) orchard renovation expense, 3) fruit sorting challenges and 4) lack of imminent drastic labor shortage. Overhead costs might be mitigated with lower insurance rates, machine use in pruning, fire blight cutting, pheromone tying, night-time harvesting fruit thinning. Further harvest mechanization research is being initiated.

INTRODUCTION

Northern California pear orchards are very tall, ranging from 4 to over 6 m in height. Aluminum ladders from 4.7 to 5.3 m are used for harvest and pruning. Pears must be hand-harvested due to their fragility and thus far no suitable mechanical harvesting equipment, as is currently utilized for example in processing tomatoes and wine grapes, has been commercially available in the United States or elsewhere. The orchard labor force in California is mainly composed of Mexican, and to a lesser extent, Central American workers, who have historically migrated seasonally to harvest various fruit crops from southern California (citrus) up through the Central Valley (table grapes, cherries, apples, pears, winegrapes, olives) (Martin and Taylor, 2000). Many then travel north to Oregon and Washington States to harvest apples, cherries, and pears. The California tree fruit industry has relied on this consistent, inexpensive, and efficient labor force since the advent of the BL-78 Mexican Farm Labor Program ("bracero" program) in 1942 (Martin, 2003). There have been periodic efforts to introduce labor-assist machines for harvest in California but these have failed primarily due to the availability of the Mexican workers willing to harvest from ladders (Fridley et al., 1969). Recent political, social, and economic circumstances have led to renewed interest in reduced reliance on seasonal immigrant labor. Several factors have emerged: 1) increased labor costs and uncertainty due to competition from other economic sectors, i.e., construction and urban landscaping and 2) renewed anti-immigration activism and resultant border policing to discourage seasonal, and largely illegal, immigration. While year to year circumstances vary, the general trend is toward a tightening seasonal work force and yearly anxiety as the harvest season approaches, which has in turn fostered renewed interest in mechanization for labor-intensive fruit crops (McFerson, 2008; Rosenberg, 2004).

Within this context, the US tree fruit industry is again searching out, and testing, various complete mechanical and/or labor-assist machines to ultimately eliminate orchard ladders. The goal is to attract and retain orchard workers who are likely averse to the difficult and ergonomically strenuous work of carrying, ascending, and descending heavy, tall ladders while carrying heavy picking bags. There are now active research programs in California, Michigan, New York, Pennsylvania, and Washington in apples, cherries (table), olives, and peaches testing equipment manufactured in, or similar to that being used, in Europe (Baugher et al., 2009).

From 2005 to 2007, a team consisting of pear growers, researchers, and a manufacturing and sales company (Blueline Manufacturing, Moxee, Washington) tested a self-propelled autonomous platform (Argiles AF-8, Argiles, Lleida, Spain) in four mature pear orchards in Lake County, California to address productivity, post-harvest quality, ergonomics, and worker satisfaction. Orchard characteristics included densities of 640-834 trees/ha, heights of 4.3-5.7 m, and trunk-to-canopy edge distances of 1.7-0.7 m (Table 1). Because labor-assist machines are more commonly employed in Europe, it seemed logical to compare results from the California tests with the situation in Europe, specifically Spain, where the machine originated, and Portugal, where they are commonly utilized.

Based on results from initial brief testing (3 days) in 2005 and more extensive testing (17 days) in 2006, as well as industry assessment, structural and operational changes were made in order to increase productivity and comfort. Generator-powered lights were installed to allow for night harvest; an overhead shade structure and rubber matting added, side conveyors removed, and larger picking bags employed to increase through put. Both day and night harvest tests were run using an hourly-paid crew for most tests. A piece rate (per bin), all-male crew was employed for one harvest replicate at the tail end of the 2007 harvest in an attempt to attain a goal of six bins per person per 8-hour shift with a crew size of five (versus eight person crew) pickers and one driver/bin changer. This goal was a priority of growers concerned about machine productivity.

MATERIALS AND METHODS

A commercially-purchased Spanish Argiles AF-8 platform harvester was utilized

for a brief period during the 2005 pear harvest. It was then modified for 2006 based on 2005 observed limitations. Modifications included an upper platform lift (third level), replacing two front conveyor extensions with one wide conveyor to accommodate a higher volume of fruit, modifying the bin carrier transition for plastic bins, adding emergency stops and railing, and relocating the water container to the front of the platform.

In 2006, the platform was tested for 17 days during commercial pear harvest in four orchards ranging from 4.2 to 5.7 m between tree rows, 3 to 4.2 m between trees, and 4.3 to 5.7 m tall. Importantly, maximum depth of foliage from trunk to canopy edge ranged from 0.7 to 1.7 m (Table 1). A designated number of rows were chosen for each test. Data were recorded for partial fruit removal (either "size" picking or only harvesting the top half of the tree) versus complete fruit removal ("stripping"). Data included time to fill one bin and total number of bins harvested per test. Meters travelled per minute, km per hour, min per tree, bins per hour, and most importantly, average minutes to fill one bin and total number of bins per person, were calculated. Mechanical or other issues slowing or halting harvest progress were noted. The platform crew consisted of an atypical crew of five female and three male pickers and one male driver/bin changer paid hourly, in contrast to the typical 100% male ladder crew paid piece rate per bin. The purpose of the tests was to ascertain whether an alternative workforce could successfully harvest pears without the use of ladders in the event of labor shortages.

Post-harvest fruit quality was assessed by collecting fruit from each point of potential damage: directly from the tree, dumping locations on each of the conveyers (front and side), top of the main conveyor where fruit from all conveyors was amalgamated prior to descending into the bin filler, and from the rotating bin as it was being filled. Samples were also collected from bins filled by ladder crews working in the same orchard. Ladder and platform crew fruit was packed separately and packed boxes of small (148 g) and large (249 g) fruit from each treatment were collected immediately after being sealed. All samples were then transported immediately to UC Davis for quality evaluation. Samples of 10-30 fruit each were evaluated immediately following harvest, after 1 month and 3 months of CA storage at 0°C, immediately after removal from storage and then after ripening for 5 days at room temperature (20°C). Samples were scored for severity of scuffing, scratching, cuts, punctures and bruises using a scale of 0=no damage, 1=slight damage, 2=moderate damage, and 3=severe damage.

An ergonomic assessment was completed for both ladder and platform workers to determine relative acute (short-term) and chronic (long-term) risks, and a worker satisfaction survey was completed. The ergonomic assessment was conducted of the platform job compared with results for ladder harvest to show differences in risk factor exposure, including the amount of exertion over 50 lbs from lifting, carrying, and emptying a picking bag, contact stress, repetition, awkward postures, and vibration (machine only). Eighteen workers with extended experience on the machine were asked to respond to a series of standard adoptability questions. Interviews were conducted in Spanish by the same staff who conducted the ergonomics assessment, including pain and symptoms.

Based on 2006 results and industry input, further modifications included an overhead shade, rubber matting to reduce under-foot vibration, complete removal of side conveyors, use of standard-size picking bags, and generator-powered lights for night harvest. A goal of 6 bins per picker per day using a smaller crew was set. Seven hourly rate tests with six pickers (three female, four male) and one driver/bin changer and one daytime-only piece rate test with five pickers (all male) and one driver/bin changer were completed, as well as three night harvests. Post-harvest evaluation was similar to 2007 except post-ripening evaluations were eliminated as there were no apparent differences after removal from storage.

RESULTS

Productivity

Bin fill rate for partial tree harvesting averaged 32 min for an hourly paid crew of eight versus 17 min for a "typical" ladder crew of the same size paid piece rate and picking 5.5 bins per person per day. Fill rate was 29 min for both the six and seven person crew (versus 19 and 23 respectively for a ladder crew). The five person crew paid piece rate required 20 min, versus 27 for a "typical" five person ladder crew (Table 2). Fill rate decreased 50% "stripping". The hourly-paid eight person crew averaged 18 min per bin, versus 11 min for a typical ladder crew of equal size. The five person piece rate crew required 15 min versus 17 min for a ladder crew (Table 3).

Post-Harvest Quality

There were few differences between platform and ladder-picked fruit except machine fruit had 57% fewer stem punctures than ladder fruit (6 vs. 14%). Results were largely the same in 2007. Day and night fruit quality was equal. Damage increased during packing in both years (Fig. 1).

Ergonomics and Worker Satisfaction

Workers were largely satisfied with the platform. They did mention vibration and experienced ladder pickers were unanimously adverse to risking income loss potentially incurred from a slower picking pace. A key ergonomic problem noted was the use of safety railings as "ladder rungs", an indicator of the misalignment between orchard configuration and platform structure.

DISCUSSION

The Argiles AF-8 platform as originally configured was poorly suited to meet the demands of pear harvest in northern California. Growers have come to expect productivity of 5 to 9 (actual productivity averages 5-6, hence the designation of 5.5 for a "typical" ladder crew average) bins per worker per day from a (largely) seasonal workforce motivated by piece rate compensation. California typically employs young, nearly 100% male labor crews from Mexico, and to a lesser extent, Central America, whereas European fruit is harvested by a more diverse age and gender demographic less willing to climb tall ladders. Indeed, 70% of the fruit in Portugal and Spain is picked from the ground, nearly inverse of California (L. Asin and J. Abreu, pers. commun.). Despite having to climb 3 to 5.1 m ladders, pickers in California average 5.5 bins per day versus 2.9 in Portugal and 3.3 in Spain. Productivity is the most significant concern in California in deciding whether to adopt platforms as long as there is a supply of willing labor (Table 4).

Tree size and per hectare yields average 50 kg in California versus 33 in Portugal and 19 in Spain (L. Asin and J. Abreu, pers. commun.). Ladder picking enables growers to employ many workers to rapidly remove fruit during the three week harvest period and crew size can be adjusted rapidly to hasten rate of harvest (Table 5).

After modifications made in 2005 and 2006 some of the initial limitations experienced with newly purchased platforms were overcome. Per worker productivity increased appreciably, particularly in the orchard that more closely resembled those in Europe, i.e., row width and height less than 5 m, and most importantly, trunk to canopy edge distance of 1 m or less. Paying workers piece rate and allowing the platform crew to self-choose their team resulted in achieving a full rate of 15 min per bin, or 5.5 to 6 bins per person per 8 hour day. This was competitive with an average ladder crew of the same size, with very acceptable fruit quality.

Even if equal productivity can be shown, growers express concern about the capital cost of the machines. This apparently also limits their use in Europe to only 20-30% in some countries (L. Asin, pers. commun.). The Argiles AF-8 is currently priced at about US$ 61,000 and diesel and maintenance costs must be factored in. Machine costs,

however, can be amortized over time and costs spread over multiple operations such as 1) harvesting at night to double per day productivity, and 2) performing pruning (dormant and summer), fruit thinning, cutting fire blight, and hanging pheromone dispensers. Such operations account for 1000-1200 hours of operation in Portugal (J. Abreu, pers. commun.).

Finally, and becoming more important, worker satisfaction with platform is high once they have experienced it. Pear harvest is rated the riskiest among fruit crops in California due to the height of the ladders and trees (Fig. 2). The serious reduction of all hazards from eliminating the ladder and eliminating high forces and awkward postures needed to manage heavy picking bags are major injury prevention advantages (Miles et al., 2010). Interviews confirmed that workers were indeed able and willing to adopt platform harvesting provided certain changes are made (Table 6).

CONCLUSIONS

Interest in mechanization, and more specifically, using platforms for harvest in California (and the US) rises and wanes depending on the availability and cost of seasonal labor. As immigration laws become more strictly enforced and/or economic factors increase labor costs, growers may adopt platforms in greater numbers for one of the same reasons the Argiles AF-8 was purchased in 2005, to utilize year round crews of permanent residents who may be unable, or unwilling, to climb tall ladders, but are very able to harvest, prune, or thin fruit. Improvements that would facilitate more rapid adoption include ability to harvest large volumes of fruit in timely fashion, field sorting capability, durability, low maintenance costs, and flexibility to harvest various fruit shapes and sizes.

Tree canopy structure must be modified to accommodate platforms, as demonstrated by significantly increased productivity performance in the orchard with a "fruit wall" facing the row. These trees had less foliage depth and fruit was much more readily accessible to pickers than in orchards trees with a fully round shape. The relationship between picker-assist platforms and orchard canopy structure has long been known (Fridley et al., 1969).

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Tables

Table 1. Characteristics of four different orchards used to test the Argiles AF-8 autonomous self-steering platform from 2005 to 2007 in Lake County, California. The majority of testing was performed in Orchards 1 and 2.

Orchard characteristics	Orchard number			
	1	2	3	4
Distance between tree rows (m)	5.7	4.2	4.2	4.8
Distance between trees (m)	10	4.2	4.2	9
Maximum depth of foliage (m)	1.3 to 1.7	0.7 to 1	1 to 1.3	1.3 to 1.7
Maximum height of fruit (m)	4.3 to 4.7	4.7 to 5	5.3 to 5.7	4.7 to 5
Number of trees in a row (m)	122	68	90	132
Number of breaks within tree row	2	1	1	3
Total length of row (m)	411	283	375	402
Drip irrigation	yes	no	no	no
Sprinkler irrigation	yes	yes	yes	yes
Days worked in this orchard	7	7	2	1

Table 2. Comparison of the average number of minutes required to fill one 500-kg plastic bin between different sizes of hourly-paid crews and a typical piece rate-paid ladder crew harvesting only a partial number of fruit from each tree, Lake County, California, 2006-2007.

Harvest mode	No. days	Minutes/bin and number of pickers			
		5	6	7	8
Platform					
Orchard 1	10	-	29	29	46
Orchard 2	1	20	-	-	21
Orchard 3	2	-	-	-	29
Average 4 orchards[1]		20	29	29	32
Ladder (typical)		27	23	19	17

[1] Average provided for those orchards with from 2 and 10 test replicates.

Table 3. Comparison of the average number of minutes required to fill one 500-kg plastic bin between two types of platform harvest crews (5 person piece rate and 8 person hourly rate) and a typical piece rate-paid ladder crew removing all the fruit from each tree ("stripping"), Lake County, California, 2006-2007.

		Minutes/bin and crew size	
Harvest mode	No. days	5	8
Platform			
Orchard 1	4	-	20
Orchard 2 hourly	6	-	18
Piece	1	15	-
Orchard 4	1	-	15
Average[1]		15	18
Ladder (typical)		17	11

[1] Average provided for those orchards with from 4 and 6 test replicates.

Table 4. Comparison of worker productivity and harvest cost for a three-week harvest period between California, Portugal and Spain, 2010.

	Typical harvest cost (3-week harvest)			
	No. bins/hour	$/bin	Avg. bins/day	$/day[1]
California	.69	20	5.5	110.00
Portugal	.36	16	2.9	47.00
Spain	.40	24	3.2	77.00

Table 5. Comparison of orchard characteristic differences in California, Portugal, and Spain potentially affecting productivity and efficiency of using platforms for harvesting pears, 2010.

	Cultivar	Rootstock	Trees/ha	Height (m)	Distance to edge (m)	Training	Yield (kg/ha)
California	Williams	W. Nelis/OH×F/ *P. bet*	500-650	5	1.5	Vase	50
Portugal	Rocha	EMA/ BA-29/Sydo	1600	3	0.9	Axis	33
Spain	Conference	BA29C	2300	2.5	0.5	Axis	19

Table 6. Response of 18 workers with experience on the modified Argilie AF-8 platform to standardized questions related to worker adoptability, Kelseyville, Lake County, California, 2006.

	YES	NO
1. Do you think the machine is practical?	18	0
Advantages cited by these workers for the machine: feels more stable, don't get as tired, seems faster, don't have to carry ladder and bag.		
2. Is the machine better or are ladders better?	15	3
Workers citing preference for ladder system cited concern for speed combined with likely piece rate pay.		
3. Does the machine need changes?	14	5
Changes needed noted by workers: Needs a higher picking level, needs more vertical elevation on picking station, bin changing is cumbersome and slows progress, does not turn well slowing progress.		

Figures

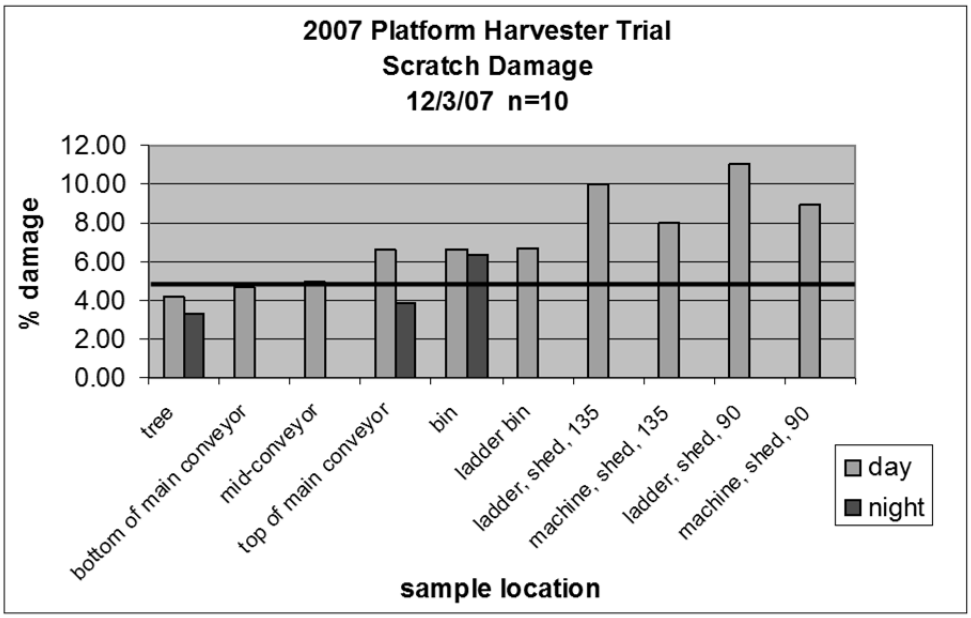

Fig. 1. Damage from scratching to fruit (n=10) incurred during pear harvest using an Argilies AF-8 platform versus ladders and after commercial packing. Acceptable damage is below 5% per cannery tolerance, Kelseyville, Lake County, California, 2007.

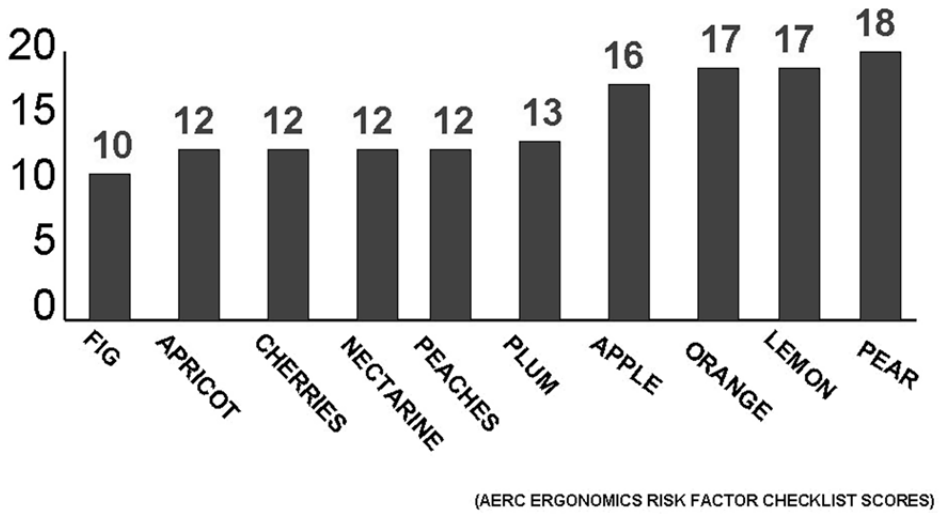

Fig. 2. Total ergonomics risk factor screening scores for ten tree fruit commodities based on documented hand-harvested job descriptions.