Continued Work on Machine Handling of Winegrape Picking Containers

V Duraj, JA Miles, JM Meyers
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ABSTRACT:

Manual harvest of winegrapes exposes workers to high risk factors for lower back and other musculoskeletal disorders. Workers repeatedly lift, carry, and empty forty-six pound winegrape-filled containers. A rubber-tracked tractor was fitted with improved attachments and workstation to mechanically elevate and empty these containers that had been placed ahead of the workers by machine device and had been left in the row after filling by the workers. The machine's primary improvement was a side-shifting indexing elevator system that delivered the containers to a sorting conveyor from which the grapes were inspected and conveyed across the vine row to a collection gondola. The machine was operated in several commercial vineyard operations for several days at a time. The machine functioned well on essentially flat terrain, for which the improvements were designed. The peak, localized throughput was fifteen containers or about 700 pounds per minute. Workers preferred using the machine system, but circumstances precluded the effective use of health symptom surveys to gage potential health benefits.

INTRODUCTION:

The California winegrape industry, accounting for over 90% of the nation's winegrape production, employs over 31,000 workers. Many of these workers perform labor intense tasks. In northern California's Napa and Sonoma Counties, which together account for nearly half of all winegrape acreage in the state, much of the harvest (generally a 6 – 8 week long period) is performed by hand due to hilly terrain and winemaker preferences. Winegrape hand harvest work has been shown to be physically demanding and to take a physical toll (Meyers et al., 2001).

A University of California vineyard ergonomics study found that back injuries predominate reported injuries and that lifting during harvest is reported as a frequent cause (Meyers et al., 1998). The introduction of a smaller picking container (46 pounds full versus 57 pounds full, averaged over a season and varieties) showed a statistically significant reduction in health symptom survey scores (Meyers et al., 2000). The reduction in weight and pain symptoms, which are thought to be precursors to cumulative trauma disorders, was an improvement in the task's ergonomics. However, the reduced weight still did not meet the weight limit suggested by Revised NIOSH Lifting Equation (Waters et al., 1993).

A current University of California study, supported by a grant from the National Institute for Occupational Safety and Health, is exploring alternatives to manual handling of picking containers. The machine handling concept was pilot tested with a forklift-style attachment and a workstation with conveyors all mounted onto a rubber-tracked reverse-traveling crawler tractor (Duraj et al., 2000). Promising indications and continued industry cooperator support justified the continued development that is described in this paper.

EXISTING MANUAL HARVEST PRACTICES:

A typical harvest crew size is either around eight or between twelve and fourteen. One of these workers is usually assigned on a rotational or work capability basis to pull leaves from the tractor-drawn collection gondola. Another person, the crew foreman, is usually an hourly employee of the company, supervises the picking, and may drive the tractor as well. The workers spread out across multiple rows, with usually no more than two workers in proximity to each other on one vine to avoid excessive interference and knife cut risks from vine movement.

Each worker has a single container that is filled at the vine and emptied into a gondola. The gondola, or comparable bin system, is kept forward of the crew and moved as necessary. The cycle time for container filling and emptying is in the range of two to three minutes. The cycle includes cutting grapes, repositioning the container, retrieving grape clusters that missed the container, removing leaves from the container, lifting, carrying, and emptying the container into a gondola, and returning to the vine to repeat the cycle.

Figure 1: Worker cuts grape clusters.

To cut grape clusters from the vine, a worker stands facing the vine, reaches in with the non-dominant hand, grasps a grape cluster, and cuts it with a curved knife held in the dominant hand (Figure 1). As each cluster is cut, it is dropped towards the plastic container lying at the worker's feet. The worker must frequently alter his/her body position to see, reach, cut, and dispose of the grape clusters.

After harvesting the immediate area, the worker moves along the vine to reach new clusters. The worker either stoops to lift and place the container or pushes it with a foot with a sideways leg movement to slide it along. Often, the worker passes by a coworker who is harvesting the same vine row, requiring the worker to lift and carry the container perhaps ten or more feet. In either case, prior to moving the container, the worker usually stoops to gather up clusters that missed the container and occasionally to remove visible leaves that fell into the container (Figure 2).

Figure 2: Workers stoops to remove leaves.

When the container is full the worker stoops to lift it and carries it to the gondola and empties the container into the gondola over its 50-inch high side (or a 40-inch high side if the smaller multiple bin system is used), as shown in Figures 3 and 4. Workers often carry tubs at overhead or shoulder height positions, in part because they will usually propel the grapes to less filled areas of the gondola.

Figure 4: Steel gondola on a trailer.

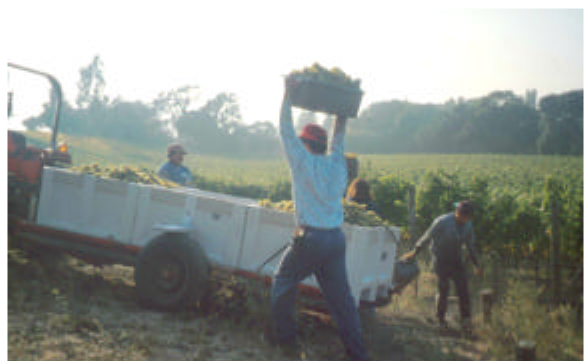

Figure 3: Multiple plastic bins on a trailer.

Because the workers spread out over several vine rows, usually one half or more of the workers are not in the same land row as the gondola. Depending on crop cultural practices, workers may have to duck under a vine cane or trellis wire, step over a low hung irrigation line, or even push through canopy foliage in order to reach the gondola. One frequently used alternative is to literally throw their self against the vine (supported by trellis wire) with their full container above their head to propel the grapes over the vine and into the gondola. Another alternative is to slide and exchange containers under the vine row, which results in some workers lifting a higher number of containers during the day.

In order to keep the number of leaves in the trailer bins to a minimum, at least one worker works at the gondola removing leaves and poor fruit (Figures 5 and 6). The worker stands on narrow platforms attached to the sides of the trailer near the bottom of the bin, bends over and into the

Figure 5: Worker stands on narrow trailer step to bend over into gondola and remove leaves.

Figure 6: Worker stands inside gondola to remove leaves until it is about one third full.

bin, and reaches as far as possible to grab and remove the leaves. However, until the bin is about one-third full, the worker may actually be standing inside the bin in a stooped posture in the grapes. Entry and exit also involve undesirable movements and postures.

Previous work by Meyers et al. resulted in the introduction of a smaller picking container that reduced the average weight of a filled container from 57 pounds to 46 pounds. The container's acceptance by the industry is growing significantly, as evidenced by current cooperator use and feedback from the manufacturer. It is for this smaller container, the lift-carry-empty task, and the leaf-pulling job that the machine handling system was developed.

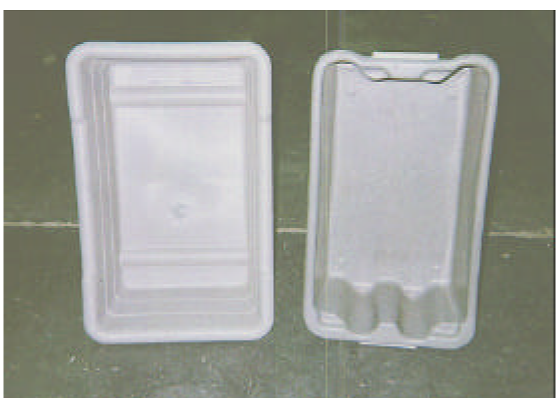

Figure 7: Pre- (l) and post-intervention (r) containers.

Figure 8: 57 pounds gross (l) and 46 pounds gross (r).

EARLIER WORK ON MACHINE HANDLING

The machine handling concept was pilot tested with a forklift-style attachment and a workstation with conveyors all mounted onto a rubber-tracked reverse-traveling crawler tractor (Duraj et al., 2000).

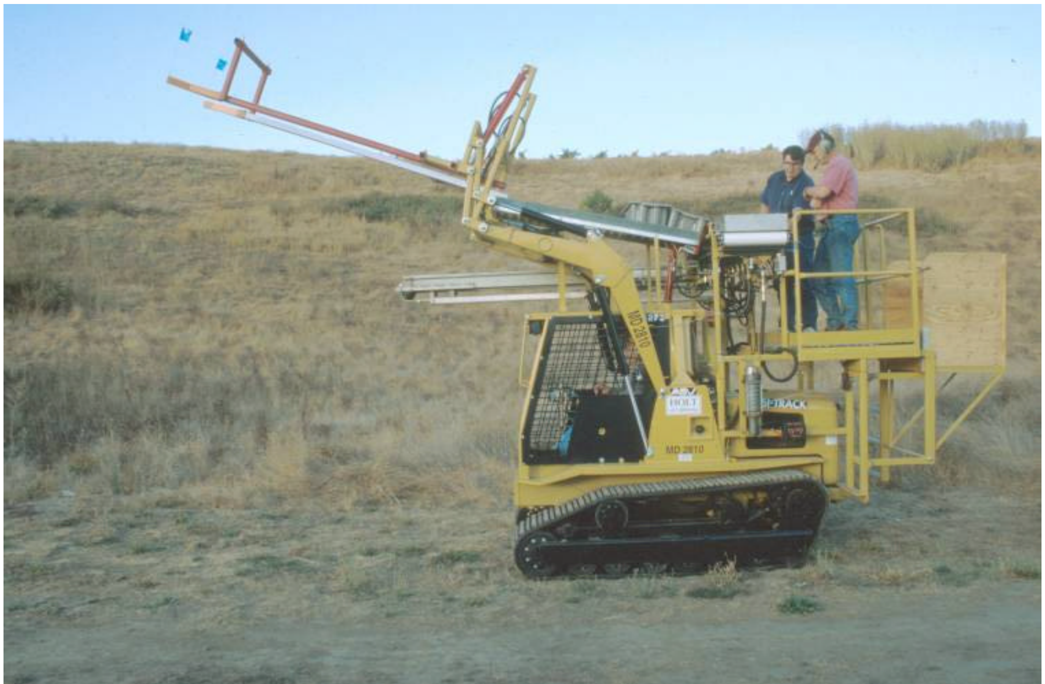

Figure 9: Machine for handling picking containers. Staffing requirements included tractor driver, container handler, and leaf remover.

Designed as a set of attachments rather than an installation, the assemblies bolted or clamped to the tractor and utilized both of the on-board auxiliary hydraulic pumps with little modification to the existing plumbing.

The base tractor unit was an All Seasons Vehicles Model 2810. This tractor and the larger 4810 are a popular platform for vineyard pre-pruning equipment, but they play little or no role during harvest operations. The potential to make greater use of underutilized assets helped make the ASV an attractive selection for the study.

The trials' promising indications and ongoing industry cooperator support justified continued development. Future work was identified to include considering replacing the batch processing with continuous elevation, replacing gravity slides/rollers with powered conveyors, automating further the container dump mechanism, and improving empty container distribution and cleaning.

CURRENT WORK ON MACHINE HANDLING

For the 2001 harvest season trials, significant changes were made to the container handling system. The primary change was the continuous pick-up device with side-shifting capability. This included hydraulically powered roller chain and v-belt conveyors with microswitch/relay logic controls. Additional changes included greater automation of the container dumper, a raised and forward-moved workstation, a wider discharge conveyor, and equipment for empty container handling that included a container collection trailer, an empty-container distributor, and a wash rack (Figures 10, 11, 12).

Figure 10: Modified machine for 2001 harvest trials.

Figure 11: Container distributor without tow/storage vehicle.

Figure 12: Portable trailer-based container wash rack.

The modifications provided the following functionality, beginning with aligning the container into the pick-up device and lifting the container from the ground (Figure 13). This front-end device consists of #2040 conveyor roller chain with small angle iron tabs that contact the container on both sides behind the grips. The chains are powered from the tail shaft of the register infeed conveyor, which uses twist-lock type v-belt in UHMW guides (Figure 14). When a container reaches the

Figure 13: Container pick-up with centering guides.

Figure 14: Register infeed conveyor; tranfer to elevator.

alignment stops it also triggers the microswitches at the back. When these series-wired microswitches are triggered the infeed drive stops and the C2050-chain elevator starts. The elevator attachments (Figure 15) engage the container, and the elevator indexes up thirty-six inches. When it stops, the infeed/pick-up drive restarts to repeat this cycle. The operator in the tractor cab may depress a momentary switch to simulate a container in the register, for purposes of clearing the system of containers.

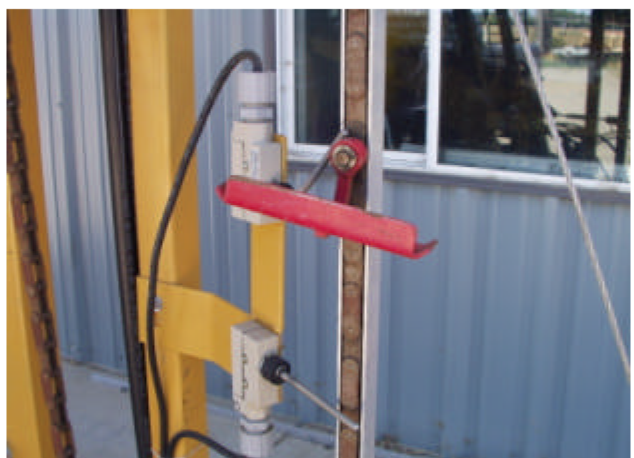

Figure 15: Container "grabber" attachment.

As a container travels over the top of the elevator it transfers onto a v-belt conveyor (Figure 16) that delivers the container to the dumper. This conveyor includes microswitches at both ends for queue control. The dumper-end of the top conveyor pivots, as does the elevator-end, to accommodate the side-shifting capability of the entire front-end pick-up/infeed/elevator attachment. The pivot at the elevator-end (Figure 17) also allows the front-end to be raised for clearance during trailer loading and for machine maneuvers in narrow headlands.

Figure 16: Top-side transfer conveyor.

The front-end side-shift is capable of twenty-four inches total side-to-side travel, actuated by a hydraulic cylinder that is controlled by the existing tractor's joy-stick control for an available bucket loader attachment. The tractor's lift-arm function is plumbed through a double-selector valve to operate the lift arms for front-end lifting as described earlier or to elevate and lower the pick-up/infeed elevator device.

Figure 17: Elevator pivot.

Figure 18: Container dumper device.

Figure 19: Container at end of dumper travel.

The container(s), lifted by the front-end and top-side attachments, reach the dumper where it triggers a microswitch. Depending on the full-off-semi setting of a selector switch, the dumper will automatically actuate, not actuate, or actuate with the attendant's depression of a momentary button. The actuated dumper inverts the container over the sorting conveyor and the attendant grasps the emptying container and places onto the chute leading to the collection trailer. The dumper returns to accept another container as soon as the current container separates from the dumper.

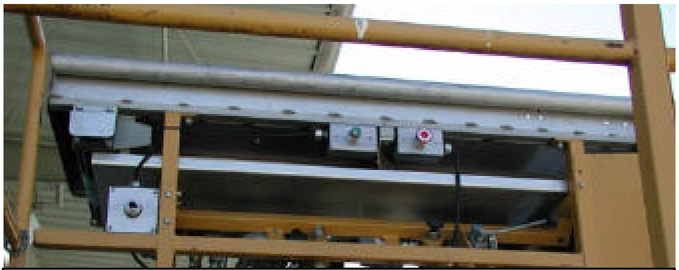

Figure 20: Workstation controls: selector switch (l), momentary pushbutton for semi-automatic function (m), machine emergency stop (r). Difficult to see, but present, are the manual valves for belt conveyor run/stop and the directional valve for the discharge conveyor's swing-out positioning cylinder.

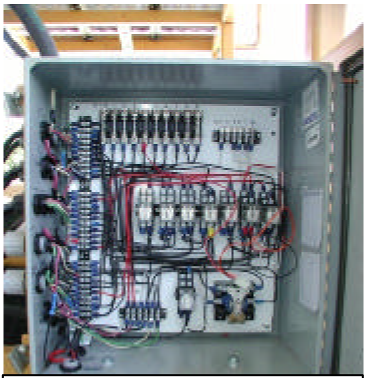

Figure 21: Electrical relay panel.

Another worker atop the machine removes leaves and poor fruit before the fruit transfers onto the discharge conveyor. The discharge conveyor, which swings out via hydraulic control to adjust for different vineyard row spacing, delivers the fruit into the tractor-drawn gondola in the adjacent row.

RESULTS & DISCUSSION

The machine was operated generally successfully for several days in several different vineyards. Because the 2001 harvest proceeded at an uneven and unpredictable pace due to weather, field trials were more limited than planned. The limited duration of the trials precluded effective use of health symptom surveys. However, there was ample time to operate the machine system for day-long periods in peak harvest operation conditions.

Beginning with the pick-up device at ground level, the various mechanical and electrical systems operated well with only minor problems. The pick-up device hooked the containers as they came past the alignment guides and elevated them up onto the infeed conveyor even if the container was not perfectly aligned. Occasionally, the container would come off of the chain conveyor when one of the container's add-on grips broke free of its glued position. The container style being used is actually not ideal for machine handling but is being used because the cooperators are using this particular smaller container that was successfully introduced in an earlier weight-reduction study. The drive power taken from the tail shaft of the downstream v-belt conveyor was reliable. In fact, the v-belt conveyor served as an effective "shear device" during the occasional container jam by slipping and avoiding potential mechanical damage to the conveyor components.

The infeed conveyor, between the pick-up conveyor at the front and the elevator behind, effectively fed the lifted containers into the elevator register. Though the v-belting was not a positive transfer conveyor – the containers could slip atop the v-belt – its functionality was reliable on slight down slopes of about four percent grade through incline slopes of about ten percent. In the instances of excessive decline slopes, the machine operator would elevate the pick-up/infeed conveyor assembly with the hydraulically powered cable lift feature.

The register, the place where the container stops horizontal travel and was engaged into vertical travel, functioned reliably. The precise alignment of the elevator attachment sprocket guides held during the entire season and functioned reliably at varying machine angles relative to horizontal and pick-up device angles relative to the machine. The series-wired triggering microswitches also functioned reliably, except occasionally when an empty container just did not have enough tractive force atop the v-belt to maintain the microswitch(es) long enough to latch the logic relay.

The elevator worked reliably, except when a container came through with an incorrectly positioned add-on grip (due to glue failure). In such cases, the container had as much chance to process successfully as it did to slip off one of the attachments and create a jam and grape mess below. This again was an issue with the add-on grips that in normal hand harvest practices did not need to be glued. The retrofit effort utilized hot-melt glue to join PVC pipe to the polyethylene-based plastic containers. The elevator chain attachments otherwise worked very well even under highly agitated motion of the elevator during combination side-shifting, forward-backward terrain induced machine motion, and vertical start-stop travel.

The transfer between the top sprockets and the topside transfer conveyor was also quite reliable. The occasional jam that occurred at the transfer point was usually caused by a misaligned container due to add-on grip issues, but had not fallen off during its elevation. This transfer junction operated reliably through the entire two-foot side-shifting range of the elevator.

The top-side queue conveyor operated well, except when a container transferred from a side-shifted elevator and then bumped up against the side guide rail to such an extent that the container began a twist. The v-belts could not provide the necessary traction force to prevent the onset of such rotation, which was exacerbated under slope conditions. The microswitch-based relay logic controls effectively controlled the flow of containers from the elevator, through the top side transfer conveyor and into the dumper mechanism.

The dumper mechanism operated reliably in full automatic and semi-automatic modes. In full automatic mode, as soon as a container entered the dumper far enough to trigger a calibrated microswitch then the dumper cycle would latch and maintain until the container separated from the dumper. In semi-automatic mode, for when additional sorting time was required for each container of grapes, the dumper would actuate and latch only when a momentary pushbutton was pressed after a container was situated in the dumper.

The wider discharge conveyor eliminated throughput constriction that existed in the previous year's machine during high volume operation.

The empty container handling system comprised of the trailer, distributor, and wash rack improved the efficiency of the related tasks compared to the previous year's trials. However, effective use of the distributor was compromised by the stickiness of the juice-covered containers and the need for precise prediction of the number of containers required depending on vine yield.

A broader issue that manifested itself pertained to field and crew logistics. In one instance, the vines were being harvested late and the yield was a very high eleven tons per acre, necessitating a much denser distribution of tubs and the use of a larger crew. The vine rows in this particular field were very long, and the machine crew was providing some cushion distance for the picking crew to avoid undue pressure or other potential psychological factors. Moreover, to accommodate the larger crew and preclude the workers from having to carry the filled containers to a central machine row – carrying being the aspect of the harvest that was being eliminated – the containers were left in two separate land rows. So, the machine was required to back out of the long row and return down the other row, and back and forth. Altogether, the result was delays in empty container distribution and delivery of grapes to the winery. The issue of logistics management was expected but nevertheless was striking when observed in practice; it was difficult to try to integrate a relatively complex machine system into an existing manual practice under unpredictable field conditions.

Generally, the mechanical handling was successful. The hydraulic power supplied by the existing auxiliary pumps was adequate. The electrical relay and logic functioned without failure, except for one occasion when water shorted out the dumper selector switch. The machine's throughput performance was compromised primarily by limited leaf sorting capability: often the controls would be placed into semi-automatic, compromising the continuous-container-conveying capability, in order to have additional time to remove all of the leaves. Expected installation of provisional mechanical leaf removal equipment did not occur prior to testing, though structural design modifications provided for such equipment in the future. When the leafing task was ignored, there was no such bottleneck.

The machine system generally maintained production with crews of twelve to fourteen workers, which nearly numbers the size of two smaller crews. Workers liked to use the machine, because it meant they did not have to carry their containers as they have to otherwise. There was indication of reduced fatigue and higher production by the workers. This characterization does not take into account the efforts of the researchers staffing the machine system. These observations also do not take into account the ultimate need to factor in machine capital value and staffing into an overall productivity analysis that would also somehow factor in somewhat intangible health benefits.

One cooperator in particular committed to extended trials for the coming harvest season. These trials are expected to include further improvements to the mechanical systems including positive traction conveyors, the use of a sturdier container better suited for mechanical handling, attendant free dumper system, mechanical leaf removal system, and higher capacity empty tub distribution and washing. These trials are expected to provide an opportunity for effective utilization of health symptom surveys to gage the potential ergonomics and health benefit of a machine system for handling winegrape picking containers.

CONCLUSION

Improved attachments for machine handling of winegrape picking containers were fitted onto a reverse-traveling crawler tractor and tested in several vineyards. The tests demonstrated the continued potential viability of a mechanical intervention integrated into an existing hand harvest practice, though some logistical and efficiency matters remain to be addressed. The mechanical and electrical aspects of the systems worked reasonably reliably under peak harvest conditions. Vineyard managers' and harvest workers' positive and interested participation in the tests have encouraged further work on the system. Future work is expected to include positive transport conveyors, fully automated dumping of containers, mechanical leaf removal system, and improved empty-container distribution and washing.

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