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. One series of strenuous tasks that workers perform repeatedly consists of lifting, carrying, and emptying containers of winegrapes weighing an average of forty-six pounds. To eliminate this particular risk, a reverse-traveling crawler-type tractor serving as a carrier was fitted with attachments and workstations to handle the containers left on the ground by the workers. Instead of reusing the same container, workers simply continued picking and depositing grapes into empty containers that were placed strategically ahead of the workers by a tub distribution team. With use of more than the minimum containers needed per row, workers were encouraged to use the next empty tub rather than continue handling a partially full heavier one. The machine included a long fork assembly to gather, elevate, and deliver the containers to a workstation queue where they were semi-automatically emptied for inspection. Leaves and damaged fruit were removed manually, and the remaining fruit was conveyed over the adjacent row into the regularly used trailer bulk bin.

Preliminary tests included independent operation of the system by a cooperating vineyard that conducts both hand harvesting and machine harvesting operations. The equipment operator and workstation attendants quickly became skilled. The system maintained speed with one harvesting crew and, with additional experience and specific improvements, is expected to handle the equivalent throughput of two or more crews of eight workers. Future work is needed to improve the system's capability on hilly terrain, to automate container dumping, adapt mechanical leaf sorting technology, and improve empty container handling.

INTRODUCTION:

The California winegrape industry, accounting for over 90% of the nation's winegrape production, employs over 31,000 workers many of whom perform labor intensive 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 is still performed by hand for reasons related to terrain and to winemaker preferences. This kind of work is thought to be very physically demanding and potentially injurious.

A University of California study of three cooperating vineyard companies in Napa and Sonoma Counties showed that back injuries predominate and that lifting during harvest is reported as a frequent cause (Meyers et al., 1998). One of the high risk tasks identified in this work was elevating the winegrape picking container - sometimes weighing over seventy pounds when full - and dumping it into trailer bulk bins. An outcome of the related series of studies was an intervention reducing the size of the picking container (Meyers et al., 2000). This change in tub size reduced the average full-container weight from 57 pounds to 46 pounds, accompanied by a statistically significant reduction in symptom scores determined from pre- and post-harvest, pre- and post-intervention surveys administered to workers of the three cooperating vineyard companies. Though this change improved the task ergonomics, the reduced weight still does not meet the weight limit suggested by Revised NIOSH Lifting Equation (Waters et al., 1993) for this lifting, carrying, and emptying task.

A current University of California study is exploring alternatives to manual handling of the picking containers. Machine handling of the filled picking containers was selected as a viable approach and pilot tested. The selection was made in consultation with the cooperating vineyard companies. A crawler tractor serving as a carrier was fitted with attachments and workstations to handle the containers left on the ground by the workers. Workers continued the picking task as before except they used empty tubs placed strategically ahead of them by a tub distribution team. In contrast to earlier work related to sorting and conveying winegrapes in the field (Duraj et al., 1999), machine handling of the picking containers presented the need for significant operational changes to the harvest work flow

BACKGROUND:

Existing Field Equipment

Manual harvest techniques are typically focused around tractor-towed trailer bulk bins (Figures1 and 2). Two systems are common: one utilizes multiple 4-foot by 3-1/2-foot by 29-inch tall plastic pallet-style containers on a roller-based trailer, and the other utilizes a 4-foot by 8-foot by 39-inch tall steel bin on a designed-to-fit trailer. Both of these systems operate on the principle of filling the bins in the vine row, delivering the full bin to a staging area, exchanging bins, and returning immediately to the harvesting crew with an empty bin. The off-loaded full bins are transported to the winery on a flatbed truck or trailer. Both systems involve work actions that clearly draw attention to ergonomics issues. Both systems lend themselves to the machine-handling concept tested.

Figure 1. Multiple plastic bin system. (For clarity, equipment is shown when out of the vine row.)

Figure 2. Single steel bin system.

Vineyard layouts and harvest operations have evolved to where little extra clearance remains between the equipment and the vines. Vine rows are spaced on centers that range from 8 to 12 feet, but some new vineyards can be found to have even smaller dimensions. When foliage and/or double trellis systems are taken into account, the remaining clearance width is often just enough to accommodate the tractor and trailer, leaving little if any room for a worker to pass between a bin trailer and a vine. Because specialized equipment or alternative work processes are required for the sub-eight foot rows, machine handling as addressed by this current development work was limited to eight foot and larger rows.

Ergonomics Considerations of Manual Harvesting

Whether utilizing the steel or the plastic bin systems, the harvesting crew spreads out across at least three rows and works to fill the bulk bin traveling in the middle row. This means a worker must somehow transport his/her tub of grapes into the middle row in order to dump the tub into the bin. Depending on trellis system, pruning style, and irrigation system, a worker may have to duck under a vine, step over an irrigation line but under the vine, or simply walk through some foliage in order to reach the middle row. Frequently the workers in the adjacent row dump their full tub by literally throwing themselves against the vine (supported by trellis wire) with their full tub above their head to project the grapes over vines and into the bin. Though discouraged strongly by supervisors, this method provides an attractive – to the worker - alternative to the awkward posture required to ducking through the trellis system. Another alternative employed by various crews is sliding full tubs under the vine in exchange for another crew member's partial or empty tub. This means some workers must lift a higher number of tubs than other workers.

Although both the plastic and steel style systems pose similar ergonomics problems, the following information focuses on the steel bin system. The steel bin is four feet wide, eight feet long, and when on the trailer the top edge is located approximately fifty inches above ground. This height requires a worker to lift the full harvesting tub over his/her head in order to empty the tub into the bin. Because a full tub weighs an average 57 pounds or 46 pounds as noted earlier, the dumping action requires strength and coordination. It involves using a thigh to help accelerate the tub upward, inverting the hand position for proper grip, and then combining arms, shoulders, back, and legs in a coordinated thrust, propelling the grapes into the bin.

Figure 3. Worker stands inside bin to remove leaves. Also, note how little clearance exists between the vines and the trailer's fenders.

Figure 4. Worker stands on trailer extension and bends over lip into bin to remove leaves.

In order to keep the number of leaves in the trailer bins to a minimum, one crew member (or sometimes two) works at the bin to remove many of the errant leaves (Figures 3 and 4). The worker stands on narrow extensions attached to the sides of the trailer near the bottom of the bin, bends over and into the bin, and reaches as far as possible to grab and remove the leaves. However, until the bin is one-third full, the worker may actually be inside the bin and standing in the grapes. Entry and exit involve ergonomically undesirable actions related to posture, hand grip, stability, and footing. Additionally, while inside of the bin, the worker remains in an extremely stooped posture for long periods of time. There are also product quality considerations in terms of sanitation and prematurely crushed fruit.

The leaves find their way into the bin primarily because they are collected in the tubs. Leaves remain attached to the grape clusters when the grapes are cut from the vines. Other leaves simply fall from the vine into the tub as the worker's cutting actions cause the vine to shake. Because workers are paid on a group production incentive basis, they focus foremost on tonnage, move as fast as possible, and pay as little attention to leaves as possible short of incurring reprimands from the supervisor.

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 free with a curved knife held in the dominant hand (Figure 5). As each cluster is cut, it is dropped towards a plastic tub lying on the ground 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 of his/her current location, the worker moves along the vine to reach new clusters. When moving, the worker must either stoop to lift and place the tub or push it with a foot to slide it along with a sideways leg movement. Prior to moving the tub, the worker stoops to gather up clusters that missed the tub and to remove visible leaves that fell into the tub (Figure 6).

When the tub is full the worker stoops to lift it and carries it to the bulk bin and dumps the grapes in over a 50-inch high container lip. Workers often carry tubs in overhead or shoulder height positions to dump them in the trailer. Alternatively, workers may lift the tubs to the trailer from knuckle height. As mentioned earlier, previous work by Meyers et al. introduced a smaller

picking tub, being gradually adopted by other vineyard companies, that reduced the average weight from 57 pounds to 46 pounds. It is this smaller container for which the current machine handling system was developed.

Figure 5. Worker cuts grape clusters.

Figure 6. Worker stoops to gather grapes, remove leaves, move tub, and/or lift and carry tub to bin.

MACHINE DESCRIPTION

The machine system for handling picking containers consists of material handling technologies mounted on a tractor (Figure 7). Designed as a set of attachments rather than a permanent installation, the assemblies are bolted or clamped to the tractor and make use of both on-board auxiliary hydraulic power supplies with little modification to the existing hydraulic plumbing.

Figure 7. Machine for handling picking containers, with only tractor driver and dump attendant pictured. Third person, designated for sorting would be standing to the right of the dump attendant pictured.

The base tractor unit is a tractor type that is being increasingly used in vineyards as a platform for pre-pruning equipment.

A fork assembly gathers and accumulates up to seven picking containers at a time left crosswise near the center of row or dragged from underneath each adjacent row by an attendant with a wheeled hook handle. Each fork lifts on one side of each tub's grip. The tractor's existing lifting arms elevate the containers, with lift and tilt controlled by the existing joystick control of the tractor. A four-bar link mechanism provides additional elevation needed to reach the declined gravity roller conveyor, with actuation controlled by a four-way, three-position, detent-return control valve installed inside the cab and plumbed into the available low-flow auxiliary hydraulic power circuit. The containers slide along Ultra High Molecular Weight strips when the fork/four-bar assembly is tilted backward. The containers accumulate on the gravity roller conveyor in a queue for the dump mechanism. The tractor operator can see through the cab roof whether the queue above is backed up.

At the workstation one attendant operates the dump mechanism by depressing and holding a button with the right hand and securing the container with the left hand when the container comes within reach. As soon as the container is removed from the dump mechanism, a micro-switch reverses the hydraulic circuit and when the mechanism is fully retracted the next container in the queue slides into place. When it is in place, a micro-switch enables the dump circuit control button for activation by the attendant when ready. Meanwhile, the attendant completes inverting the container and places it in an accumulation box supported from the back of the workstation. When this box contains about twenty-five containers, the box is rotated toward the ground by a cable winch operated by the attendant. The empty containers are deposited on the ground and left for the tub distribution team to gather and redistribute ahead of the harvest crew.

The dump mechanism empties the grapes of each container onto a twenty-inch wide sixty-inch long conveyor where the second attendant standing on the discharge end inspects the product flow. Leaves and damaged fruit are removed and the remaining fruit transfers onto a swing out discharge conveyor that conveys the fruit across the adjacent row into a traveling trailer bulk bin. The machine can use either the multiple plastic or single steel bin bulk transport systems.

Hydraulic power for the dump mechanism, the sort conveyor drive, the discharge conveyor drive, and the discharge conveyor positioning cylinder is provided by the high flow auxiliary hydraulic power circuit.

The sorting conveyor and discharge conveyor motor controls and discharge conveyor position control are located in front of the right-side attendant immediately below the sorting conveyor. A tractor emergency stop, connected directly to the fuel solenoid, is located at waist level in between the two attendants. Additionally, an earmuff intercom system is provided for the tractor driver and dump mechanism attendant to help coordinate work.

The base tractor unit was an All Season Vehicle Model 2810, now updated and a Caterpillar Company product. It is hydrostatically driven and powered by a 75hp engine. It was selected for its broad operator line of sight, growing use in vineyard operations as a base tractor for pre-pruning equipment, and perceived propensity for handling attachments. Its rubber track construction and medium size met the requirement of low ground forces, machine stability, and transportability over paved surfaces and upon a utility trailer.

FIELD TRIALS AND RESULTS

The machine was operated in conjunction with two cooperating vineyard companies in two locations near the end of the harvest season. Both trials demonstrated the potential viability of the system. In the first location the machine operators were the researchers and the vineyard company manager due primarily to safety, debugging, and operational concerns that might come to light when the machine was placed in a production environment. An additional concern was that this particular cooperating vineyard company harvests the overwhelming majority of their fields by hand and the workers are generally skeptical of machine assistance. Due also to the limited use of machines by the company, there was no one readily available who had the kind of skills necessary for operation of an experimental machine of this scope.

The machine fit into, through, and out of the rows. When required to turn around in a headland or a row break, lifting of the fork assembly provided the necessary clearance over the row for the long fork assembly as suggested in the Figure 8 below.

Figure 8. Forks in elevated and tilted position for turning clearance and container transfer.

Figure 9. Wheeled hook handle being used to align tubs

Figure 10. Container in queue at dump mechanism.

The tubs pictured in Figure 9 were very lightly filled. The wheeled hook handle was used to help align the containers near the middle of the row. Later, as experience showed, the containers needed not be so well aligned as the length of the forks and the pivot-type rotation of the tractor by the crawler tracks afforded a significant amount of maneuverability of the containers with the ends of the forks.

The joystick control required just a little bit practice before the simultaneous elevation and tilt was being accomplished expediently. The terminal tilt position required for inducing sliding of the containers off of the forks and onto the gravity roller conveyor became increasingly greater as grape juice got onto the sliding surface and made it sticky. When the containers did overcome the static coefficient of friction, they garnered a little more velocity than desirable but only occasionally became jammed, inverted, or otherwise problematic.

Figure 11. Dump mechanism elevates container.

The dump mechanism worked reliably (Figure 11). Its integrated curved container retainer bars held the queue of containers back while the dump mechanism cycled up and down. The speed at which it and the queue operated provided as much fruit for sorting as the sorting attendant could process.

Figure 12. Fruit flow across sorting station with discharge conveyor in the background.

There were many leaves removed at the sorting station, keeping the attendant fully occupied while fruit was passing by (Figure 12). Instructions had been given to the harvest crews to not pull any errant leaves from their containers, and instead to allow the sorting attendant to do this task at the workstation.

Figure 13. Transfer to discharge conveyor.

The discharge conveyor, sized to be able to be stowed within the width dimension of the tractor when retracted, was undersized. Though it could convey the required quantity of fruit, its narrowness was problematic for the transfer from the sorting to the discharge conveyor. The necessary diverting guides tended to jam the fruit on the sorting conveyor (Figure 13), requiring manual intervention by the sorting attendant. The discharge conveyor was positioned on its pivot to accommodate positioning over any row

centers between eight and twelve feet. Such variability of positioning required a rotation, measured from straight ahead, of about 45 degrees for eight-foot rows to 75 degrees for twelve-foot rows.

The tub distribution team used an all terrain vehicle "ATV" with a light duty four-foot by eight-foot trailer to gather and redistribute the empty containers. The effort and logistics of managing the empty containers proved significant, in some instances holding up harvesting activities in the pilot trial.

Though not quantified in these initial tests, it was clear that harvest workers no longer needing to carry and empty their containers into the trailer bulk bin nor spending time pulling leaves or damaged grapes from their container were able to harvest much more quickly.

A portable pressure washed in conjunction with a stainless steel water supply tank was used to rinse the containers clean at the end of the days' harvest activities.

The second location where the machine was used was at a vineyard where the mechanical harvesters are used for a significant portion of the harvest. For some of the fields, the choice can be a matter of weather, grape maturity, and/or winery needs. Though the tests were cut short because of a mechanical repair and later the need to quickly harvest the designated field by mechanical harvester in the waning days of the season, some tests did get conducted. Because one of the company's operators had earlier experience with a similar tractor fitted with a pre-pruner this operator quickly mastered the operation of the research machine.

DISCUSSION

The machine as tested was designed to simply pilot test the concept of relatively complete machine handling of picking containers as part of an alternatives selection process by the researchers and vineyard industry cooperators. Notwithstanding its learning curve and other shortcomings, such as reliable operation on extremely hilly terrain, its operation was satisfactory.

The concept of machine handling of picking containers includes elimination of known high ergonomic risks, affords significant potential productivity gains, and introduces new concerns as well. Eliminating the specific high risk is an improvement, notwithstanding what is discussed later. However, an indirect almost-administrative control to reduce the weight being handled by the workers is created by the introduction of excess containers in the field. Workers when given the opportunity to continue to drag or lift and reposition a container until completely full or to leave it right there and use the next empty one without any penalty likely will select the latter. The cumulative reduction in average weight handled may also save energy.

Eliminating the task of lifting, carrying, and emptying the picking containers affords the opportunity for increased peak harvest production by allowing the skilled workers to focus all their energy on the immediate task of selecting and cutting the winegrapes. This production opportunity can be of increasing importance when competition in the industry is requiring maximum harvest at maximum maturity to maximize profits. Efforts to increase productivity while maintaining the hand-harvested winemaking philosophy of particular value to the Napa and Sonoma regions could be sufficiently attractive in the right circumstances.

The ability of workers to be more productive and earn more money - they are paid as a crew by the ton of grapes picked - can be a motivator. However, the reality here may very well be that the capital investment required is financed partially by offset pay-per-ton rates.

A question that remains to be answered is what is the ergonomics effect on the workers who now remain in a poor posture for much longer periods of time. That is what happens when they do not receive what could be perceived to be a ergonomics benefit of a posture break when they stand erect and walk/run while carrying and emptying the full container and then walk/run back to the vine. This question may be answered through pre- and post-intervention health symptom surveys of trials of sufficient duration. Determining the lasting impact of these changes was not an objective of the pilot tests conducted.

The system tested in these pilot tests introduced a new approach to hand harvest of winegrapes. The additional hardware, the high number of picking containers, and the harvest management issues are not insignificant. They may also not be necessarily interesting when inexpensive, low overhead, manual labor is available. However, it should be noted a very small number existing winegrape products do in fact use dedicated picking containers, each one filled at the vine and emptied at the winery.

CONCLUSION

Pilot tests of a crawler-type tractor fitted with attachments and workstations to machine handle winegrape picking containers showed the viability of such hardware. Workers who normally lift, carry, and empty these containers weighing on average forty six pounds were able to leave the containers on the ground and continue picking into empty containers placed strategically ahead of them by a tub distribution team. The full or partially full containers of grapes were gathered, elevated, conveyed, and dumped by the machine and support attendants that included one driver and two workstation attendants. Two additional workers were the empty tub distribution team. The grapes were inspected for errant leaves and damaged fruit, and the remaining fruit was conveyed across the adjacent row into a traveling trailer bulk bin. Workers were observed to harvest a designated field much more quickly than normal, though this was not quantified. Workers were observed leaving partially full containers of grapes behind and continuing to pick into the empty tubs before them, reducing the average weight they needed to drag or lift along the vine. The capability of the machine to handle the containers filled by the equivalent of two or more existing crews is expected with additional experience and improvements to the machine. Future work is needed for powered container conveyors for operation on steeper terrain, to automate container dumping, adapt mechanical leaf sorting technology, and improve container handling.

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