The Glean Machine: A harvest-aid for field gleaning designed to reduce food loss and give volunteers improved field accessibility

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The *Glean Machine* was constructed by research specialists and students in the Biological & Agricultural Engineering Department (BAE) at North Carolina State University as part of a project funded by the USDA's Southern Sustainable Agriculture Research and Education Program*[1]. This document explains the design elements of the *Glean Machine*, and a description of its piloted use at two gleaning events in 2019.

For more information on materials required and build-out specifications, contact Justin Macialek, Research Project Coordinator, BAE Department, NC State University, jamacial@ncsu.edu.

The *Glean Machine* is housed at the Harnett County Extension Office and can be loaned to gleaning organizations. For more information, contact Jackie Helton, 4-H Agent, Jackie_helton@ncsu.edu.

Introduction

According to the Food and Agriculture Organization of the United Nations, about 20% of healthy, nutrient-dense vegetable crops are left either unharvested or sorted-out in packinghouses. The quality—size, color, etc.—may not be acceptable to retail and food service buyers, or there may simply be too much product on the market. Many horticultural crops are hand-harvested and produce the highest quality and most yield at the first, second, or third bearing cycle. According to recent research from North Carolina, economically important crops such as cucumber, bell pepper, and sweet potato can be left unharvested at rates of nearly 5,000 pounds per acre, on average (Johnson, et al., 2018a).

Farmers sometimes permit volunteers at gleaning organizations to do a last-over harvest to collect edible, unharvested produce, which is then typically distributed to food banks and pantries. Methods are needed to speed the collection of the often vast quantities that remain in the field on these host farms. Harvest- or labor-aids are simple pieces of equipment designed to

[11] Southern SARE project LS17-280, "A Supply Chain Approach to Finding Win-win Sustainable Solutions for Edible But Unharvested Project." For more info on this 2017-2020 project see: cefs.ncsu.edu/food-system-initiatives/whole-crop-harvest/

do one or a few physical tasks to improve the efficiency of harvest. One example is a tractor-mounted moving conveyor belt that carries watermelon from workers' hands to a bulk bin on a truck. These aids are used to assist a field crew by reducing the physical demands of harvest; they are not designed to entirely replace the crew as a fully mechanical harvester might. Many types of aids exist, but they are typically specific to a single crop or function.

The design of NC State University's *Glean Machine* reduces workers' harvest effort and is also flexible enough to be used on a variety of crops. Intended for use by gleaning organizations, piloted use of the *Glean Machine* was found to heighten volunteer morale and enable a broader participation of older and disabled individuals in gleaning events.

Design and construction

The primary requirements for the design of the harvest-aid were that it should eliminate stooping, walking, and carrying bins of harvested produce, thus enabling a crew to harvest a large area without intense fatigue. In addition, it should be adaptable to a wide variety of horticultural crops in the Southern U.S. These crops include: bell pepper, cucumber, summer and winter squash, cabbage, sweet potato, greens, tomato, eggplant, broccoli, cauliflower, lettuce, and cantaloupe. Some of these crops are grown on plastic that cannot be damaged; some are above ground or below ground; and some are on vines, on bushes, and/or staked.

The initial inspiration for the harvesting aid was similar to the "Johnson digger", a sweet potato harvest-aid. This design utilized a pickup head that would dig under the soil and lift sweet potatoes onto a sorting conveyor, then workers would manually sort through the vines to harvest the sweet potato. The original harvest-aid concept would utilize a header that would cut the plant and then transport the entire plant on the sorting conveyor to be picked through by hand crews. In order for the harvest-aid to work with all crops and at varying row widths, this would require the unit to have multiple header designs depending on the crop being harvested, substantially adding to the estimated cost of the unit. In addition, safety became a concern as this concept would include a variety of moving components such as blades and conveyors in close proximity to a volunteer crew of varying ages and skills.

Another consideration was powering and pulling the unit. The pull-type unit would require a tractor to power the unit and tow it through the field. Relying on the farm to provide a tractor during harvest time is not always feasible. If the gleaning crew has to purchase a tractor for the unit, which had a designed requirement of 50 to 60 horsepower, the cost of the operation increases dramatically. An additional expense was transporting the equipment from farm to farm. It was decided that in order to reduce demands on the host farm, the harvest-aid should be self-contained, self-propelled, and easily transported on a standard trailer.

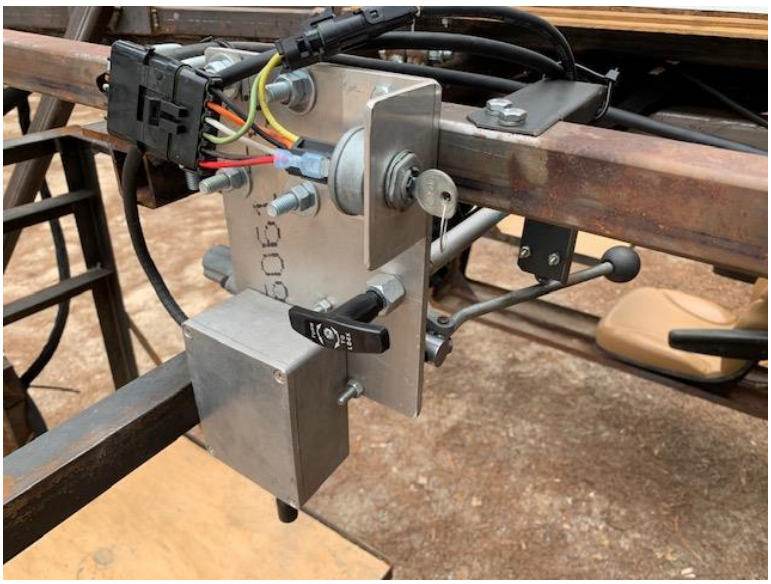
Therefore, a design was conceived that simply moves seated gleaners through fields for a last-over harvest. The seating and wheel spacing of the harvest-aid is adjustable to conform to a variety of row spacing and field management practices for a variety of vegetable crops. Additionally, seat height adjusts to position each crew member at the most ergonomic height for harvesting. Cushioned swivel seats with a full-length pan/ footrest add to rider comfort. Volunteer groups range in age and equipment skill-level, thus the design incorporates several

safety features and minimizes moving parts that could endanger volunteers. The main power train components for the Glean Machine are commercially available. The frame and component mounts were fabricated in the Biological and Agricultural Engineering Department of North Carolina State University.

The harvesting aid is powered by a 23 horsepower Briggs and Stratton gas engine. The engine is directly coupled to a hydraulic pump. The pump provides fluid power to the drive circuit and the steering circuit. Four hydraulic wheel motors provide full-time four-wheel drive to propel the unit through a variety of field conditions. Ag tires provide traction.

The primary operators of the harvesting aid are volunteers from gleaning groups. One design goal of the harvesting aid prototype was to simplify operation of the unit. Typically, a self-propelled harvester or harvesting aid would have a designated driver. To minimize the number of people needed to operate the harvesting aid the driver is also required to harvest. The slow ground speeds and simplified controls makes this possible without over-burdening the driver. The design of the harvesting aid utilizes controls that are simple for even inexperienced equipment operators.

The steering system is an electrically controlled hydraulic circuit. A 12 volt solenoid on a directional control valve is energized with a joystick that directs hydraulic fluid flow to extend or retract a cylinder to turn the front steer wheels left or right. Forward and reverse are controlled with a manual directional control valve. Push forward on the lever to go forward, pull back on the lever to go back. Forward speed is varied based on the distance the lever is pushed forward; reverse speed varies based on the distance the lever is pulled back. The ground speed can be limited within a range by adjusting a secondary manual flow control valve. Maximum ground speed is approximately 4 mph with the 26 inch diameter tires.



The cost estimate for materials and components was approximately $13,000. For more information on materials required and build-out specifications, contact Justin Macialek, Research Project Coordinator, BAE Department, NC State University, jamacial@ncsu.edu.

Figure 1. Steering and Drive Control.

Safety features built into the system include seat safety switches, neutral start switch, no moving parts except tires in close proximity to operators, all hydraulic hoses have hose covers for burst protection and abrasion damage, slow ground speed, and high heat generating components out of reach of operators.

Table 1. Harvesting Aid Specifications.

Dry Weight (lb)	2200
Maximum Seat Unit Carrying Capacity (lb)	300
Gross Vehicle Weight Rating (lb)	3400
Number of Pickers	1 to 4
Wheel Base (inch)	140
Overall Length (inch)	166
Wheel Spacing Minimum (inch)	68
Wheel Spacing Maximum (inch)	86
Minimum Outside Width (inch)	78
Maximum Outside Width (inch)	102
Minimum Inside Row Width Clearance (inch)	38
Maximum Inside Row Width Clearance (inch)	62
Crop Height Clearance (inch)	48
Seat Bottom Height Range from Ground (inch)	2 to 12
Overall Height (inch)	82
Table Dimensions L x W x H (inch)	26 x 20 x 20
Engine HP	23
Engine Speed (rpm)	3600
Hydraulic Pressure (psi)	3000
Hydraulic Fluid Flow (gpm)	8.84
Wheel motor torque (ft-lb)	763
Tire Diameter, 6-14 (inch)	26
Ground Speed Maximum (mph)	4
Fuel Capacity (gallon)	1.8
Operating Time per Tank (hour)	3
Hydraulic Reservoir Capacity (gallon)	5

Operation and testing

The Glean Machine can be towed on an equipment trailer with a capacity of approximately 3000 pounds, a flat deck clearance width of 82 inches and length of 16 feet. A design goal was to build a harvesting aid that would fit on a small equipment trailer that could be towed with a typical half-ton pickup truck. On or off loading the harvesting aid from the trailer is completed with just the driver riding. A seat switch by-pass control is mounted at each station. This allows the harvesting aid to be operated without all four riders being required to be in the seats at all times due to the seat safety switches preventing the operation of harvesting aid if a seat is empty. A safety bar is lowered to block access to the seat when in the by-pass mode. When the harvesting aid is off-loaded from the trailer, at a complete stop, and engine off, the by-pass control bar can be lifted and riders can mount the unit. All four stations have cushioned swivel seats with armrest.

Once offloaded, the wheel spacing is adjusted to fit the field row spacing. The harvesting aid is designed with tube-in-tube framing to allow adjustability for wheel spacing, overall machine height adjustment, seat height, and seat spacing. This requires unbolting, adjusting, and re-bolting square tubing with incremental hole locations that match typical row spacing and plant height. In some areas such as the seat adjustments, wire-lock clevis pins are used for speed of adjustment. The pins can be quickly removed and then the seats are raised or lowered to match the field parameters without the use of tools. The ground speed range is selected based on the desired picking speed anywhere from zero to 4 miles per hour.

Field tests of the machine with gleaners were successful. First-time drivers and users were able to operate the machine with under five minutes of verbal training. The harvesting aid was designed to track straight as it traveled along the rows. Once the ground speed was set and the harvesting aid was lined up on the row the driver could harvest until a steering or speed adjustment was needed.

The four gleaners can access three to four rows of produce, depending on the row spacing. Gleaners pick from either side, as the harvest-aid straddles the crop. The wheels and riders move down the row middles, and nothing contacts the plants in the rows, except the harvesters' hands. Gleaners pick and then fill totes sitting on tables mounted directly in front of them. Empty totes or boxes can be stored on top of the harvest-aid, and when filled, are either dropped to the ground for collection or handed off to other gleaners for aggregation in a vehicle or trailer.

The Glean Machine has been successfully used to harvest kale, beet, strawberry, bell pepper, broccoli, cabbage, and sweet potato. The ergonomic adjustments that can be made to the wheel spacing and seat height position the gleaners for the most comfortable harvest possible.

Use and Feedback

The *Glean Machine* was first demonstrated at the North Carolina State University Strawberry Field Day held on May 5th, 2019 at the Central Crops Research Station. A short presentation was given about the design of the harvesting aid. After the presentation audience members were allowed to ride the harvesting aid and pick strawberries. The *Glean Machine* was also discussed and demonstrated at the Sandhills Research Station for extension agent training. Extension agents were allowed to use the machine. On-farm tests were conducted in Sampson and Moore County. Feedback from all the events was used to make improvements to the system design.

Following the above tests and tweaks to the design, the Glean Machine had its first "real world" test at a fall 2019 gleaning event hosted by the Society of St. Andrew, the largest gleaning organization in the US. Their Harvest of Hope (https://endhunger.org/hoh/) event educated teens on hunger and food waste issues, then brought them to an eastern North Carolina farm to glean kale. Approximately 50 middle and high school students participated in the two-day event.

Figure 2. Society of St. Andrew gleaning event participants harvesting with the *Glean Machine,* eastern North Carolina, fall 2019.

Michael Binger, the Regional Director of the Society of St. Andrew in the Carolinas provided his feedback after the event. Based on field observations of teen volunteers using the *Glean Machine* compared to those who collected produce by hand, the *Glean Machine* did not appear to increase the rate of harvest. Rather, the most positive outcome is that it provides accessibility to the field for more volunteers. The most dedicated volunteers at typical gleaning events are recently retired, which means some may have limited mobility or stamina. The *Glean Machine* enables these gleaners to continue to participate. Secondly, the continuous movement of the harvest-aid encouraged continuous harvest, in contrast to a typical hand harvest which results in short bursts

of harvest, then rest. Additionally, there is an intangible “WOW” factor, especially in gleaning events involving youth.

Because of the transportation need and then setup and loading time, it would be most useful for large gleaning events. A covered area for storage is also desirable. A final consideration is the cleaning and washing that is required after each use to keep the equipment in good working order.

A second event utilizing the harvest aid was the 2019 Harnett County 4-H Sweet potato Gleaning Event. Approximately 80 kids and adults participated in the event, gleaning over 18,000 pounds of sweet potatoes. All participants that wanted to use the *Glean Machine* were able to ride and harvest. At both events there were participants that would not have been able to harvest produce if not for being able to ride on the harvesting aid.

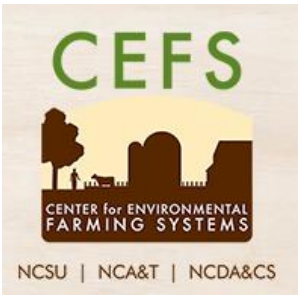
Figure 3: Harnett County Extension 4-H Gleaning Event.

Conclusion

The *Glean Machine* was conceptualized and brought to life at NC State University with the purpose of improving gleaning and reducing food loss in fields. Adapting a harvest-aid to capture the diversity of crops produced in North Carolina, while increasing gleaning participation, was a challenging goal. The most straightforward design simply moved workers through fields, putting them in close proximity to the crop and removing the burden of stooping, walking, and hauling heavy, filled totes. The prototype *Glean Machine* should spark many ideas for organizations looking to capture the last-over harvest.

This work was supported by the Southern Sustainable Agriculture Research and Education Program as part of this 2017-2020 project: A Supply Chain Approach to Finding Win-win Sustainable Solutions for Edible But Unharvested Project (AKA *Whole Crop Harvest; SARE LS-17-280*)

For more information, publications, and videos produced by the *Whole Crop Harvest* project, see: cefs.ncsu.edu/food-system-initiatives/whole-crop-harvest/



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