The *Journal of Cotton Science 27:90–101 (2023)*
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ENGINEERING AND GINNING

Evaluation of Practices to Unwrap Round Cotton Modules

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ABSTRACT

Adoption of John Deere harvesters with on-board module building capacity that produce round modules covered with a patented engineered polyethylene film has been rapid and has forced gins to adapt their module feeding systems with techniques and machinery to feed round modules into the gin. The system used by a gin is dependent on the number of round modules handled by the gin, cost of implementing the system, and preferences of gin management. Irrespective of the system used, all require well-trained staff to prevent plastic wrap from entering the gin and contaminating lint bales. Modules are fed in different orientations, and the plastic is removed with either manual or semi-automated systems. This work evaluates the well-known unwrapping systems used to handle modules in the U.S. and Australia, which include manual and semi-automated methods. No single system can be recommended, as the needs, layout, and priorities of each gin vary. However, the details of the systems are presented in terms of manpower, time and motion, safety, and potential to prevent module wrap from entering the gin. The data presented here were gathered from numerous on-site visits to gins across the U.S. and Australia.

Since the 1970s, practically all seed cotton in the U.S. and Australia has been harvested by conventional basket-type spindle and stripper harvesters, which either dump the harvested seed cotton directly into a module builder or into boll buggies (tractor-drawn bin) that transport the seed cotton from the harvester to the module builder, allowing the harvester to continue operating. Typically, harvesters with basket systems require up to four pieces of support equipment (tractor-drawn boll buggies as well as module builders) along with workers to operate the equipment. Two (4-row) harvesters in operation with this other equipment generally will require a crew of eight to 10 workers, incurring both financial cost and safety risk.

The release of different models of harvesters by Case IH (Module Express 625 and 635; CNH, Racine, WI) and John Deere (Models 7760, CP690, and CS690; Deere & Company, Moline, IL) with on-board module building capability has offered significant opportunities to reduce the amount of equipment and the number of operators required for cotton harvesting. The Case IH harvesters produce a smaller version of a conventionally shaped rectangular module. The John Deere harvesters have been described as a hybrid of a cotton harvester and an oversized round hay baler and produce round modules, which are covered with a patented engineered polyethylene film (TamaWrap; Tama Group, Kibbutz Mishmar HaEmek, Israel) that both protects the seed cotton and provides compressive force to maintain the module density. Adoption of harvesters with module building capacity has been rapid; more than 50% of the cotton harvested in the U.S. and more than 90% in Australia (van der Sluijs, 2020b) use John Deere models.

A full-size round module with diameter of 2.44 m and width of 2.39 m can weigh 2,000 to 2,600 kg, depending on moisture content. A full-size round module produces approximately three and four cotton lint bales for stripper- and spindle-harvested cotton, respectively. Round modules are covered in either yellow or pink (TamaWrap Premium) or blue (TamaWrap Blue Value) wrap. Each TamaWrap portion is 21 m long, consists of 4.5 kg of plastic, and covers a full-size module in a minimum of three layers (Fig. 1). Every TamaWrap portion contains four radio-frequency

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identification (RFID) tags to communicate with the wrapping system, enhancing traceability and assisting in the removal of the plastic wrap prior to ginning (ASABE, 2018).

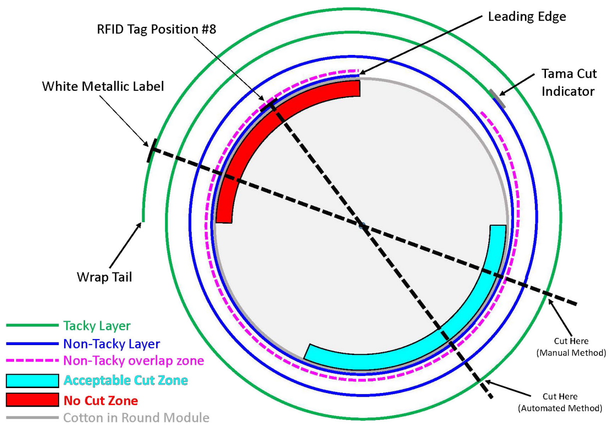

Figure 1. Schematic of TamaWrap Premium for round cotton modules with diameter of 2.29–2.44 m. Proper cut locations for manual and automated cutting systems are shown 180° from the white metallic separation label and RFID tag position #8, respectively. Cutting the wrap in the recommended cut zone maximizes the size of the non-tacky segment (pink dashed line) that is not adhered to the next layer out so that it can be easily seen and removed.

Compared to their basket-type predecessors, round module harvesters have a greater initial capital cost and consume single-use plastic wrap. Nevertheless, the cotton industry in Australia, Brazil, U.S., and other countries have embraced these harvesters because they can harvest cotton continuously without having to stop and empty a basket into a boll buggy, when conditions permit, which makes them efficient, and dispenses with the requirement of sourcing reliable seasonal workers for the more labor intensive module building (Martin and Valco, 2008; van der Sluijs et al., 2015; Wanjura et al., 2017; Willcutt et al., 2009). Because of the adoption of the new harvesting technology, no basket-type cotton harvesters are manufactured currently in the U.S. The adoption of these harvesters has forced gins to adapt their module feeding systems with techniques and machinery to feed these round modules. The modules are fed in different orientations at the cotton gin: parallel (aligned flat end to flat end and often referred to as sausage style, Fig. 2a), perpendicular (rotated 90° from parallel orientation and often referred to as wagon wheel style, Fig. 2b), and vertical (standing upright on one flat end sometimes referred to as can style, Fig. 2c) with the plastic being removed by either a manual or semi-automated system. The system used by the gin is dependent on the number of round modules handled by the gin, cost of implementing the system, and preferences of gin management. Irrespective of the system used, all require well-trained staff to prevent the plastic wrap from entering the gin and contaminating lint bales (van der Sluijs and Holt, 2017). Because of variable layering and use of adhesive to affix the module wrap, the plastic should be cut only in the cut zone recommended by the manufacturer to minimize the chance of a loose piece of wrap remaining with the module and contaminating lint bales. The RFID tags embedded in the plastic wrap can assist in locating the recommended cutting zone and, since 2018, Tama has added a "cut indicator" to identify the correct cutting location (Fig. 1) (Funk and Wanjura, 2017). To further prevent plastic wrap from entering the ginning process, gins have also installed automatic detection and removal systems at various stages of the ginning process (Clark and Hardin, 2020; Rutherford and Sweers, 2020; van der Sluijs and Krajewski, 2015).

(a) Parallel (sausage style) (b) Perpendicular (wagon wheel style) (c) Vertical (can style)

Figure 2. Options for orienting round modules.

MODULE HANDLING

An important consideration of harvesting is the handling and transport of modules. Modules must be moved from the field to the staging and pickup location, loaded for transport from the field to the gin, off loaded at the gin into the module yard, and finally transported from the module yard to the module feeder. These operations must be carried out carefully to prevent damage to the plastic wrap and preserve the integrity of the module (Mitchell and Ward, 2020).

Ideally, modules should be dropped from the harvester at the ends of the field away from harvested stalks and other potentially damaging debris to reduce costs and prevent wrap damage. Due to the size and yield of the field, this is not always possible, and modules sometimes must be dropped in the field. One solution is to attach a cotton module trailer (Fig. 3) to the harvester, which can carry up to three modules to the end of the field. If this is not possible, the modules must be picked up from where they were dropped in the field and staged together for transportation to the gin. In Australia, the most common system for in-field transport is a mast-type tractor-mounted implement that holds the module with the axis parallel to the tractor rear axle (Fig. 4). In the U.S., in-field movement of modules is typically done with the module axis oriented parallel to the direction of travel using a multi-spike or smooth-fork implement attached to the three-point hitch of a tractor (Fig. 5). Because round modules can weigh up to 2,600 kg, a large tractor is required for staging. When moving modules through harvested rows, it is important that the module is carried high enough to minimize contact with stalks to prevent tearing the underside of the wrap (van der Sluijs, 2020a; Wanjura et al., 2020). Where possible, round modules should be staged for transport in a manner optimized for the transport method. The two typical staging types are sausage and wagon wheel, with wagon wheel more common for transportation by flatbed trucks and sausage staging better suited for self-loading chain-bed trailers and module trucks. The final diameter of modules to be hauled by module trucks must be monitored to prevent damage to the wrap, which can occur when a module is too wide and rubs against the internal sides of the truck. Significant wrap tears must be repaired in the field before module pickup to prevent further wrap damage and minimize problems at the gin. Loose outer tails must be secured with a high-strength spray adhesive (3M 90; 3M, St. Paul, MN) or lint bale repair tape (Cantech 277-05 or 277-10; Intertape Polymer Group, Montreal, Canada) (van der Sluijs, 2020a; Wanjura et al., 2020).

Figure 3. McCormack Industries cotton trailer for cotton harvester.

Figure 4. Mast-type tractor mounted implement that holds the module with the axis parallel to the tractor rear axle.

Figure 5. Transporting a module via multi-spike or smooth-fork implement attached to the three-point hitch of a tractor.

Round modules are transported from the field to the gin in different ways. In the U.S., conventional module trucks with self-loading chain beds are used more often to transport modules than flatbed trucks and trailers. Specialty trailers that can transport up to 10 round modules (e.g., KBH Round Module Transport Trailer and Stover Cotton Train & 6 Bale Trailer) also are used. In Australia, flatbed trucks and trailers, which can carry four to six round modules, are the most popular means of transporting round modules, with specialty trailers that can transport up to 18 round modules over long distances becoming increasingly popular (Fig. 6). Module trucks and trailers equipped with self-loading chain beds previously used to transport conventional modules should be modified with puncture-resistant lugs to prevent wrap puncture and tearing. Module trucks can haul four round modules in the sausage orientation. Care must be taken to leave 100 to 200 mm (4-8 in) between each module to allow the top of the module to tilt as it is loaded into the module truck; however, too much space between modules will result in the inability to fit four modules in the truck. Flatbed trailers can be used with the addition of side railings to aid in securing the round modules. Modules are usually loaded onto flatbed trucks and trailers with a front-end loader equipped with a module handling attachment (e.g., with spikes to pierce the flat open end of the module or with an adjustable smooth-fork attachment that lifts the module from the bottom) (Fig. 7). Modules on flatbed trailers are transported mainly in wagon wheel orientation. Unloading at the gin into the module yard normally is carried out with properly equipped front-end loaders. Modules are generally stored as they are received in either wagon wheel or sausage orientation. In some instances, round modules are stacked on top of each other in a wagon wheel orientation due to lack of module yard space.

In Australia, the modules are usually loaded (fed) into the gin by a front-end loader equipped with spikes (Fig. 7) or by moon buggy (Figs. 8 and 9). In the U.S., modules are placed onto the module feeder bed by a front-end loader with module handling attachment or by a chain-bed-type module truck dedicated to gin yard use.

Figure 6. CM Cotton Cartage trailer with 18-module capacity.

Figure 7. Front-end loader equipped with spikes for handling modules.

Figure 8. Typical Australian moon buggy transporting modules on the gin yard in sausage orientation.

(a) (b)

Figure 9. Moon buggy transporting and assisting in unwrapping modules in wagon wheel orientation.

Modules can be unwrapped and presented to the module feeder in any orientation. There are numerous methods used to unwrap round modules, ranging from manual methods, where the plastic is cut by hand with a sharp knife, to nearly completely automated methods. At this stage in the process there are no fully automated systems as all systems need at least one operator to remove and recycle the wrap. This report evaluates the various methods to unwrap round modules and feed a steady supply of cotton into the gin. This evaluation was conducted on the common unwrapping methods in the U.S. and Australia, which includes manual and automated methods: Stover Unwrapper GIS, Spider 1V Dual Tube Round Cotton Module Handler, Cherokee Round-Up Module Unwrapper (and variations thereof), MODZILLA RMO-20 Standard Style, Side Winder Round Module Unwrapping System, Green Machine Cotton Module Unwrapper, and BUS Round Module Unwrapper. The systems are evaluated in terms of manpower, processing time, safety, and potential to prevent module wrap from entering the gin. No judgment was made as to a best system because needs, layout, and priorities of each gin vary. The data presented here were gathered via numerous on-site visits by the authors to gins across the U.S. and Australia.

UNWRAPPING OPTIONS

Gins require a consistent supply of material to maintain steady operating conditions, and the unwrapping option chosen must be able to provide seed cotton at a sufficient rate. Currently manual systems are used most often followed by semi-automated systems.

In the U.S., the most common semi-automated systems unwrap modules in the sausage orientation, whereas the most common manual methods use vertical orientation. In Australia, the most common semi-automated systems use vertical modules, whereas the most common manual systems use wagon wheel orientation. Wagon wheel is the most common orientation in Australia. There is considerable orientation variation from gin to gin in the U.S.

Most unwrapping systems require cutting the wrap; however, companies in both the U.S. and Australia have designed systems that remove the module wrap without cutting. The orientation of the module during unwrapping will influence how the seed cotton spreads upon release, and side walls need to be installed on roller beds to contain the seed cotton. Roller beds can generally accept modules in any orientation, whereas walking floors (e.g., Keith Walking Floor DrivOn Cotton Module Feeding System) or moving head-type module feeders generally use wagon wheel orientation and are equipped with variable speed control to ensure consistent material supply.

Manual Unwrapping Methods. Manual systems introduce modules to the module feeder in either sausage, wagon wheel, or vertical orientation. Regardless of the orientation used, an operator slices the plastic wrap with a sharp knife prior to the module being presented to the module feeder and dispersing cylinders. The wrap should always be cut 180° from the large white tag affixed to the outside of the wrap. The large white tag, also known as the metallic separation tag, contains module identification information. Cutting the module wrap outside the recommended cutting zone increases the possibility of loose portions of the wrap not being removed and fed into the gin with the seed cotton.

Vertical Orientation. Many manual unwrapping approaches require a module to be in a vertical orientation. Thus, modules transported from the gin yard to the module feeder in either wagon wheel or sausage orientation must be reoriented. Wagon wheel transported modules will often be unloaded on a section of roller bed that is perpendicular to the main module feeder bed so that the module is transitioned from wagon wheel to sausage style on the way to the feeder (Fig. 10). Once in sausage style, modules can be positioned into vertical orientation in several ways. A higher roller bed can be used for unloading, providing a vertical drop to a lower bed, thereby using gravity to flip the module into vertical orientation. This technique also can be used to unload a module truck from sausage to vertical orientation. Where there is no opportunity for the module to drop from a higher surface to a lower a surface, a system such as the Round Module Flipper (Lipsey Gin Tech Inc., Sunflower, MS) can be used to assist in changing the orientation from sausage to vertical orientation. Similar to sausage style feeding, this orientation requires feeder side walls to contain unwrapped modules and prevent spillage. If this orientation is used, the exposed edges of the module wrap need to be cut and pulled back to prevent the wrap from being trapped underneath the bottom flat end of the module. Some ginners have reported that higher moisture content modules are best fed vertically to minimize production issues such as quality downgrades and blockages due to inconsistent moisture content of the seed cotton.

Manual unwrapping of vertically oriented modules is performed by positioning an operator on each side of the module to begin cutting the wrap off. There are numerous variations in the manual cutting of the wrap. The operators can completely cut the plastic wrap and pull the pieces away from the seed cotton. Alternatively, the operators can partially cut the sides of the wrap and use poles to raise the wrap to the top of the module where it is gathered as a single intact piece of wrap.

Wagon Wheel Orientation. Manual unwrapping of modules in the wagon wheel orientation is most common in Australia. In this technique, up to six round modules are loaded on a moon buggy in the wagon wheel orientation in the module yard and driven into the module feeder bay. The moon buggy requires the addition of a horizontal cross bar across the front of the modules both to prevent the modules from rolling off the chain bed and to assist in removal of the wrap (Fig. 9a). Once the operator positions the moon buggy in front of the module unwrapping area, an employee on the ground approaches, initiates a lock-out button to prevent the moon buggy from being able to drive forward, and then approaches the first module on the chain bed. The ground operator uses a sharp knife to cut horizontally across the module wrap (Fig. 9b). The

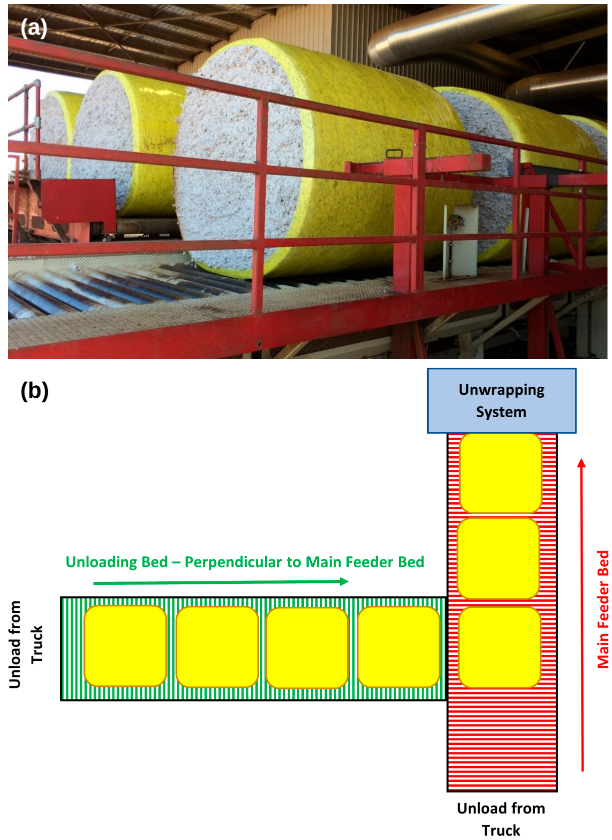

Figure 10. (a) A roller bed at Southern Cotton (Whitton, NSW, AU) configured to accept modules in wagon wheel or sausage orientation and transition all modules to sausage orientation on their way to unwrapping. (b) Schematic of perpendicular unloading bed (green) used to transition round modules from wagon wheel to sausage orientation on main feeder bed (red). Arrows indicate module movement direction. Modules can be loaded directly onto the main bed in sausage orientation or onto the perpendicular unloading bed in wagon wheel orientation.

upper section of the cut module wrap is attached to the horizontal cross bar via a spike or clamp. The operator steps out of the way and signals the driver to raise the cross bar, which pulls away the upper section of wrap while the lower section falls away and the freed seed cotton rolls forward and off the moon buggy onto the module feeder floor. The cross bar is lowered, and the ground operator steps forward and collects the wrap, including any “tail” that could have been cut free due to cutting outside the recommended zone. Once the wrap is removed, the moon buggy driver operates the chain bed to move the remaining modules forward. Depending on the arrangement, either a walking floor or a traveling module feeder, the driver can use the moon buggy to push all the unwrapped modules closer together and forward towards the feeder.

Semi-Automated Systems. The systems closest to being considered automated are introduced first followed by the semi-automated systems.

Spider 1V Dual Tube Round Cotton Module Handler (Vandergriff Inc., Clovis, CA). The Spider 1V Dual Tube Round Cotton Module Handler system (Fig. 11) loads modules in a sausage orientation. The Spider lifts the module on rollers that rotate the module to the proper cutting position as indicated by the RFID reader mounted on the top of the system. Although the system is designed to rotate the module into position for proper wrap cutting, some gins do not use the auto-positioning feature and cut the modules in the position in which they were loaded onto the feeder. A serrated knife cuts the wrap by perforating the bottom of the module and the rollers spread apart to allow the perforations to tear. The knife sometimes causes smaller modules to lift rather than perforate the wrap, requiring repeated strikes by the knife or an operator to cut the wrap using a blade on a long pole. Similar results can occur as the knife becomes dull or covered in lint or mud. The system can be bypassed to process conventional modules.

Figure 11. Spider 1V Dual Tube Round Cotton Module Handler.

Although the Spider has a set of cylinders to rotate the module and assist in the initial removing of the cut wrap, an operator is required to manually assist in removing the plastic once it has been cut by the serrated knife. A second operator, on the opposite side of the Spider from the first operator, removes any tails due to cutting the wrap outside the recommended zone. The module is fed forward while the wrap remains in the unwrapping system. The operators gather the removed plastic before the next module is fed forward. Ginners have suggested that the frame and rollers of the system need to be made more rigid and robust to deal with heavier modules. Gins that do not use the auto-positioning feature to cut in the recommended zone are at higher risk for introducing plastic contamination from the wrap.

Stover Unwrapper GIS (Gin Improvement System) (Stover Equipment Co. Inc., (Corpus Christi, TX). The Stover system (Fig. 12) requires modules to be oriented in a sausage orientation. The Stover system lifts the module on a set of closely spaced rollers and uses an RFID reader to sense the position of the module allowing the wrap to be cut in the proper location. As with the Spider system, some of the gins that use this system cut the wrap in the position it was received and do not use the RFID reader for positioning the module. The wrap is cut by a rotating knife that travels across the top of the module, or manually by an operator. An operator uses a hook on a pole to pull the cut wrap off the top of the module towards themselves and gathers the plastic as the module is rotated by the rollers. Undersized modules cannot be processed with this system and the wrap needs to be cut manually, whereas oversized modules (larger diameter or those with an oval shape due to extended periods of storage or transported by specialty trailers) do not fit into this system and require operator intervention and special handling. Ginners report that the system also has difficulty in lifting heavier modules resulting in damage to components, with various components, such as the frame, needing reinforcement.

Figure 12. Stover GIS Unwrapper.

MODZILLA RMO-20 Standard Style (Cotton Machine Works, LLC, Cordele, GA). The MODZILLA RMO-20 is similar in concept to the Stover and Spider unwrappers with modules in the sausage orientation. The module is rotated by conveyors on either side of the module and can be equipped with an RFID reader to position the module correctly for cutting the wrap. The operator uses a knife to cut the wrap on the side of the module through a slot in the side wall. The operator pulls the cut edge through the slot in the side wall and the module is rotated by conveyors to remove the plastic wrap. The MODZILLA can also be bypassed for processing conventional modules.

Round-Up and Round-Up2 Unwrapper (Cherokee Fabrication, Salem, AL). In this system, round modules are unloaded in a sausage orientation. The system has two arms with pins protruding from their surfaces. The arms grab and raise the module (Fig. 13a) while rotating the module into a vertical orientation (Fig. 13b). The seed cotton slides out of the open bottom end of the module wrap (Fig. 13c), thereby leaving the wrap intact. The system slowly pulls the wrap up in stages while foldable side walls raise up to contain the seed cotton on the feeder bed. The walls fold back when the module advances out of the unwrapping area and the operator removes the empty wrap from the paddles by means of a hook on a pole. The system can be bypassed for processing conventional modules.

Several gins in Australia developed an in-house system inspired by the Cherokee Round-Up Unwrapper. This system is locally referred to as “the crab” or “the claw” (Fig. 14). Unlike the Cherokee system, this system requires that the modules be introduced vertically. The claw system lowers around the module using a series of paddles with pins that push into the plastic wrap. After the system grabs the module, the module is lifted and the cotton slides out of the bottom end of the module wrap. The Australian system does not use the folding walls of the Cherokee system. Undersized and oversized modules can be handled by the system, and the system can be bypassed for processing conventional modules. Extremely undersized modules must be handled manually. An operator is required to gather the plastic wrap from the paddles after the module has been unwrapped; this is often aided by a hook on a pole. High moisture modules can present difficulties with this system as the cotton does not readily slide free of the plastic. Shaking the module by raising and lowering the paddles quickly can cause the cotton to begin sliding out of the wrap. The operator might need to cut a portion of the plastic at the bottom of the module to start the process. This manual cutting requires the operator to use a knife on a pole or enter the feeder area, which can be a safety issue.

(a) Empty “claw” (b) “Claw” unwrapping a module

Figure 14. Australian Claw unwrapping system.

(a) Lifting the sausage style module (b) Module rotated to vertical (c) Seed Cotton sliding out of wrap

Figure 13. Cherokee Round-Up Module Unwrapper.

Side Winder Round Module Unwrapping System (LSB Machinery, Lubbock, TX). The Side Winder is unique in that four modules are handled simultaneously. The modules are loaded in sausage orientation onto a short module feeder bed adjacent to the main feeder bed and are unwrapped simultaneously. The short bed tilts up and the modules are restrained from rolling by a retaining wall that moves into position. The operator attaches a pulling assembly to the wrap at the top of each module and then the operator walks between the modules and the main feeder bed to manually cut the wrap on each module. The module wraps are pulled off simultaneously as the short bed tilts up and the retaining wall is quickly lowered allowing the modules to roll onto the main feeder bed. The wraps are pulled up and over the modules as they roll onto the main feeder bed. This method does not rotate the modules to align the area to be cut with the recommended cutting zone.

Green Machine Cotton Round Module Unwrapper (James Green, Joiner, AR). The Green Machine Cotton Round Module Unwrapper presents modules to the module feeder dispersing cylinders on a roller bed in sausage orientation. A blade perforates the bottom of the plastic and two lifting bars raise the module slightly above the feeder bed so the cut plastic edges can be wrapped onto the lifting bars by operators positioned on each side of the feeder bed. Then the modules are lowered and transported forward, leaving the attached wrap behind. Operators gather the wrap before the next module is moved into position. This method does not rotate modules to align the area to be cut with the recommended cutting zone.

The Brown Unwrapping System (BUS) Round Module Unwrapper (Joe Brown, Tunica, MS). Modules are presented to the module feeder dispersing cylinders in a sausage orientation. In this system several rollers in the feeder bed are replaced with a modified section of rollers that contains a cutting blade that is raised and lowered by an operator turning a handle. The bottom of the wrap is cut as the module is moved over the fixed blade. The next section of feeder bed has side walls that have been modified to include angled hydraulic arms to roll the module from side to side. The arms roll the module to one side allowing an operator to remove the cut wrap with the assistance of a hook on a pole, and then the module is rolled in the opposite direction and the wrap removal repeated. The freed wrap can then be removed. This system requires an operator on each side of the feeder bed and uses a mirror mounted above the work area so that the operator of the hydraulic arms can ensure the other operator is clear of the module. In this system, round modules are not rotated to ensure use of the recommend cutting zone. The cutting blade can be lowered for the processing of conventional modules.

TIMING

Time and motion studies were conducted on the Spider, Stover, Claw, Round-Up, and moon buggy unwrapping systems. These are in common use across the U.S. and Australia. Fully manual unwrapping of round modules is highly variable from gin to gin based on manpower, gin layout, and ginning rate. The time and motion studies were carried out during multiple gin visits to study each system. Each gin used in the study was experienced in handling round modules with the respective system. A stopwatch was used to measure the time needed to remove the plastic wrap from a module and to position the module to be ready for processing by the module feeder.

The study found that the moon buggy system (manually cutting round module wrap off the loader) was the fastest method for both unwrapping and completely loading the module feeder bed. The approximate time to cut and unload the module from the moon buggy onto the feeder was 30 sec. The system requires a moon buggy driver and a ground operator. The ground operator is the limiting factor in this system as the operator must move in and out of the unloading zone to cut and remove the wrap before signaling the driver to send the next module. At the end of a full load of six modules, the moon buggy operator can elect to use the machine to push the unloaded modules together thereby compressing the modules on the feeder floor to ensure consistent feeding. A load of six modules can be unwrapped and staged in under four minutes, including compressing the rounds on the feeder floor.

The Claw system takes approximately 80 sec to position, engage the module, and remove the wrap. Once the module is in place and the arms have engaged the wrap, the lifting and removal of the wrap takes approximately 35 sec. This time does not include instances when the operator needs to shake the module to remove the cotton due to high moisture or when the operator needs to take special steps due to small or heavily damaged rounds.

The Spider system requires approximately 35 sec to move the module into the system, and then approximately 40 sec to lift and rotate the module to the correct position for cutting the wrap. The serrated knife takes approximately four seconds to swing in and out of position and two swings commonly are needed to fully separate the wrap for a total of eight seconds for cutting. After cutting it takes approximately 94 sec to lower the module and clear the system for the next module. As the module is lowered, the operator must secure the cut end of the wrap to allow it to be stripped off the module as the roller bed moves the module forward, and any loose wrap must be retrieved from the rollers, which would result in increased time between modules. In total, the Spider takes just under three minutes to position and unwrap a module and reset for the next module. The speed of the Spider limits ginning rates to approximately 70 bales per hour. Due to the length of time taken, some gins using this system do not rotate the modules. The need to trigger the serrated knife repeatedly for undersized or muddy modules also adds to the processing time. At least one operator is needed for the Spider, but it is common practice to have an operator on the opposite side to assist in securing the cut wrap. The second operator is used to secure potential loose tails of wrap at gins that do not rotate the modules.

The Stover system takes approximately 25 sec to position a new module into the system as the previous module is being removed. Once in position, it takes approximately 15 sec to engage and lift the module and another 30 sec to cut the wrap. After the wrap is cut, another 20 sec is needed to rotate and remove the plastic, followed by approximately 15 sec to return the module to the feeder bed and begin to move it towards the feeder. In general, the Stover was observed to take just under two minutes (1 min 50 sec) to process a module. The rotation of the module to the proper cutting position was not observed at any of the gins using the Stover system. Rotating the modules would add time to the process. At least one operator is needed to operate the system and gather the wrap. It is common practice to have a second operator on the opposite side of the module to assist in gathering loose tails.

The Cherokee Round-Up system was observed to take just under two minutes (1 min 50 sec) in total to process a module. The system took approximately 15 sec to move a module into position and begin to lift it, and then another 10 sec to rotate the module from horizontal to vertical. The removal of the seed cotton from wrap takes approximately 45 sec. Once the cotton is removed from the wrap it takes approximately 40 sec for the seed cotton to move forward while the walls fold down and the arm assembly returns to the starting position. Once in the starting position, an operator removes the empty module wrap and initiates the next module to move forward.

SAFETY CONSIDERATIONS

Safety is a paramount concern for the various transportation and unwrapping systems. Free, open access to the module feeder bed rollers is an extreme hazard. Module feeder sideboards provide some separation between the operator and bed rollers, but not all module feeders offer sideboards. Those without sideboards are especially troublesome. Operators should never walk on the bed rollers without first disconnecting the power and following lock-out/tag-out procedures.

The Stover, Spider, and Claw systems are all intended to keep the operator away from the modules; however, this is not always the case. When the Spider system fails to cut the wrap, or the wrap is not cut completely, the operator must enter the feeder bay to complete the cut. Often the Stover and Spider systems require operators to reach into the feeder bay to grab either the loose end of the wrap or the tail of the wrap when the plastic is cut in the wrong position.

The Claw system also can require the operator to enter the feeder bay to assist in cutting the wrap or removing the wrap of badly misshapen or damaged modules. Entering the feeder bay has many potential hazards, starting with walking on the roller bed, which can cause the operator to slip and fall. As the modules are cut, cotton can fall and spread rapidly, which can be dangerous to the operator; this hazard is magnified for the Claw system because the module is in a vertical position.

The manual system using a moon buggy also has safety concerns. Although a horizontal arm is used to hold the module back, the system requires the operator to work in front of the moon buggy out of the line of sight of the operator. The use of an e-stop on the machine mitigates this hazard.

The most common fully manual wrap cutting system involves cutting the module in the vertical orientation. This system, at minimum, involves two operators standing on either side of the module cutting the sides of the module. There is the potential for the module to spread rapidly upon release from the wrap and the operators can be trapped between seed cotton and the walls of the feeder. This system also can require operators to walk on the roller bed, a serious concern. Several gins were observed in which an operator stood on top of the module and pulled the cut wrap to the top of the module. This method is unsafe due to the potential for the module to collapse as it is released from the wrap.

CONTAMINATION PREVENTION

Plastic contamination from module wrap in lint bales is a major concern for the global cotton industry. In theory, unwrapping systems that do not cut the wrap should minimize the risk of plastic entering the seed cotton supplied to the gin. However, improper operation of the wrapping system on the harvester or damage to the wrap prior to arrival at the unwrapping system can allow plastic to enter the material supply. Gins should consider alternative handling options for heavily damaged round modules, regardless of the system used in unwrapping the modules. Moreover, modules with excessively small diameters that cannot be unwrapped by one of the semi-automated systems or that must be unwrapped manually can increase contamination risk. Small-diameter modules are often too heavy and awkward to reorient by hand when plastic is trapped between the bottom of the module and the feeder bed or floor. At a minimum, the presence of additional workers to look for plastic is a best practice when handling heavily damaged or small-diameter rounds.

When cutting is used as part of the unwrapping process, it is important to follow the instructions from the wrap manufacturer on the proper cutting location, such as shown in Fig. 1. Systems such as the Stover and Spider have the capability to locate the cut and this option should be used. All the manual methods for unwrapping modules reported here employed cutting methods that place the wrap cut irrespective of module orientation. This practice increases the chances of cutting the wrap outside the recommended cutting zone and increases the risk of contamination by leaving a short piece of the unadhered inner tail material in the cotton. Manual methods, where the wrap is cut on two sides, guarantees that at least one of the cuts will be outside the recommended cut zone. In this method, it is extremely important that the operators be on the lookout for stray tails and other portions of wrap to prevent it from entering the material supplied to the gin.

SUMMARY

A wide array of systems for handling, transporting, and unwrapping round cotton modules are available for use. Procedures and equipment for handling and transportation of modules must prioritize the preservation of wrap integrity until the module is unwrapped at the module feeder. The selection of a system and process used to unwrap round modules is dependent upon the needs of each individual gin, and is based on the seed cotton unloading system equipment and layout, processing rate of the gin, integration costs, and preferences of the gin management. Therefore, no system was identified as an ideal solution for implementation at all cotton gins. A summary of the time and motion studies are provided in Table 1. Some of the semi-automated systems reviewed in this report offered the capability to unwrap modules without cutting the wrap, which can lead to reduced risk of plastic contamination. Although the semi-automated systems exhibited higher cycle times than the manual systems observed, none of the manual systems offered the ability to orient the module for proper wrap cut placement. Cutting the wrap outside the recommended cut zone increases the potential for small pieces of the unadhered inner wrap material to remain in the cotton as it is fed into the gin. No fully automated solution that completely replaces the human from the unwrapping process is available. Thus, all systems reported herein have some associated worker safety concerns.

Table 1. Summary of time and motion study

System	Approximate Cycle Time (s)	# of operators	Safety Concerns	Contamination Risk
Moon buggy	30	2	Ground operator works out of sight of driver	Medium – loose tails may be inaccessible
Claw	80	1	Requires manual handling of small modules	Low – wrap is not cut
Spider	169	2	Operator enters cutting area if wrap is not fully cut	Low – if module is properly positioned in cutting zone
Stover GIS	110[z]	1	Requires manual handling of small modules	Low – if module is properly positioned in cutting zone
Round-Up	110	1	Requires manual handling of small modules	Low – wrap is not cut

[z] Stover GIS time was for installations that did not rotate the module to correct cutting zone, time would be increased to properly position module

ACKNOWLEDGMENTS

The authors acknowledge the financial support from Cotton Incorporated and the Australian Cotton Research and Development Corporation.

DISCLAIMER

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REFERENCES

American Society of Agricultural and Biological Engineers [ASABE]. 2018. S647. Seed cotton module identification system (S647). ASABE Stand., St. Joseph, MI.

Clark, K., and R.G. Hardin. 2020. Plastic removal at the module feeder. p. 783–787 *In* Proc. Beltwide Cotton Conf., Austin, TX. 8-10 Jan. 2020. Natl. Cotton Counc. Am., Memphis, TN.

Funk, P.A., and J.D. Wanjura. 2017. Seed cotton unloading systems. J. Cotton Sci. 21(1):51–59. https://doi.org/10.56454/ZJJG4144

Martin, S.W., and T.D. Valco. 2008. Economic comparisons of on-board module builder harvest methods. p. 802–804 *In* Proc. Beltwide Cotton Conf., Nashville, TN. 8-11 Jan. 2008. Natl. Cotton Counc. Am., Memphis, TN.

Mitchell, L.C., and J.K. Ward. 2020. A time and quality study of round cotton modules from field to ginning. 2020 ASABE Annual International Virtual Meeting. https://doi.org/10.13031/aim.202001281

Rutherford, R.D., and G.J. Sweers. 2020. Field evaluation of the VIPR™ system. p. 575–579 *In* Proc. Beltwide Cotton Conf., Austin, TX. 8-10 Jan. 2020. Natl. Cotton Counc. Am., Memphis, TN.

van der Sluijs, M.H.J. 2020a. Harvesting & delivering uncontaminated cotton. p. 125–130 *In* Australian Cotton Production Manual. Cotton Research and Development Corp. and Cotton Info., Narrabri, NSW, Australia. Available at https://www.cottoninfo.com.au/sites/default/files/documents/ACPM%202020.pdf (verified 16 Feb. 2023).

van der Sluijs, M.H.J. 2020b. The influence of row unit settings and ground speed of modern spindle-type harvesters on cotton fibre and seed quality. J. Textile Institute. 112(12):1904–1912. https://doi.org/10.1080/00405000.2020.1848116

van der Sluijs, M.H.J., and G. Holt. 2017. Survey results of the research needs and requirements of the ginning industries in Australia and the United States. J. Cotton Sci. 21(1):40–50. https://doi.org/10.56454/ZUXI9566

van der Sluijs, M.H.J., and A. Krajewski. 2015. Contamination detection using module hood feeder sensors. p. 990–998 *In* Proc. Beltwide Cotton Conf., San Antonio, TX. 5-7 Jan. 2015. Natl. Cotton Counc. Am., Memphis, TN.

van der Sluijs, M.H.J., R.L. Long, and M.P. Bange. 2015. Comparing cotton fiber quality from conventional and round module harvesting methods. Textile Research J. 85(9):987–997. https://doi.org/10.1177/0040517514540770

Wanjura, J., M. Pelletier, J.K. Ward, R.G. Hardin, and E. Barnes. 2020. Prevention of plastic contamination when handling cotton modules. Cotton Inc. Available at https://cottoncultivated.cottoninc.com/prevention-of-plastic-contamination-when-handling-round-modules/ (verified 16 Feb. 2023).

Wanjura, J.D., K. Baker, and E.M. Barnes. 2017. Harvesting. J. Cotton Sci. 21(1):70–80. https://doi.org/10.56454/AXFA4722

Willcutt, M.H., M.J. Buschermohle, E.M. Barnes, F. To, J. Field, and P. Allen. 2009. In field time in motion comparisons of conventional, John Deere 7760 and Case 625 Module Express cotton pickers. p. 462–476 *In* Proc. Beltwide Cotton Conf., San Antonio, TX. 5-8 Jan. 2009. Natl. Cotton Counc. Am., Memphis, TN.