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ENGINEERING AND GINNING

Harvesting

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ABSTRACT

The spindle picker and brush-roll stripper are the two machines used to harvest cotton produced in the U.S. Adoption of each harvester type is dictated by regional differences in production environment, production practices, cultivar, and yield. The spindle picker is a selective-type harvester that harvests seed cotton only from well-opened bolls, collecting a minimal amount of undesirable foreign material with the seed cotton. The brush-roll stripper utilizes a nonselective harvesting mechanism to indiscriminately remove mature seed cotton, immature bolls, sticks, leaves, and any other vegetative material that is easily broken off the plant. Thus, fiber quality can be reduced for stripper-harvested cotton because of the increased presence of immature fibers relative to picker-harvested cotton. Spindle pickers are more mechanically complex than brush-roll strippers and require additional daily maintenance to ensure optimum performance. Considering conventional harvesters equipped with baskets, stripper-type harvesters cost less to own and operate than spindle pickers resulting in lower harvesting costs. Regardless of harvester type, careful attention to setup and maintenance is required to achieve maximum harvesting efficiency, field productivity, and fiber quality.

The two primary machines used to mechanically harvest the U.S. cotton crop are the spindle picker and the brush-roll stripper. The harvesting mechanisms used by each machine are fundamentally different and result in drastic differences in the amount of foreign material gathered with the seed cotton. Moreover, differences in the harvesting mechanisms between the spindle picker and brush-roll stripper can affect differences in the quality of the harvested fiber. The spindle picker utilizes a selective harvesting action whereby mature seed cotton in well-opened bolls is engaged by the spindle and removed from the plant with relatively small amounts of undesirable vegetative material. Brush-roll strippers indiscriminately harvest mature and immature seed cotton from the plant along with a great amount of undesirable plant material. All brush-roll strippers manufactured today include an onboard field cleaner, similar in design to a two-saw stick machine used in the ginning process, to remove some foreign material from the cotton just after the point of harvest. Spindle-picked cotton contains approximately 68 kg (150 lb) of foreign matter per bale and stripper-harvested field-cleaned cotton contains approximately 170 (375 lb) per bale (Table 1). Spindle pickers commonly remove approximately 85 to 90% of the seed cotton produced by the crop, whereas brush-roll strippers usually remove 97 to 99%. The difference in harvesting efficiency among harvester types is the main reason behind observed differences in fiber quality (Faulkner et al., 2011; Wanjura et al., 2013).

Adoption of each harvester type is different among U.S. growing regions due to environmental and cultivar factors. Evans (2000) and Supak and Snipes (2001) estimated that the brush-roll stripper was used to harvest in excess of 70% of the U.S. crop produced in the Southwest (Texas, Oklahoma, Kansas, and a portion of New Mexico). Supak and Snipes (2001) noted that the spindle picker was used almost exclusively to harvest cotton produced in the Far West, Midsouth, and Southeast regions of the U.S. The proportion of the U.S. crop that is picked and stripped changes with time due to annual variation in the amount of cotton produced in each region and changes in the adoption rate of each harvest system. The estimated proportion of the U.S. crop harvested by spindle pickers and brush-roll strippers since 1990 is shown in Fig. 1. The data presented in Fig. 1 was developed using harvest system adoption rate estimates published by Evans (2000) and Supak and Snipes (2001) along with annual upland cotton production data from USDA-ERS (2015). The dashed lines shown in Fig. 1 indicate a range in national adoption rate for pickers and strippers assuming a +/- 10% variation in the proportion of cotton that is stripper harvested in the Southwest region. In crop year 2015, it was estimated that approximately 65% of the U.S. cotton crop was spindle picked and 35% was stripper harvested.

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Table 1. Average foreign matter, seed, and lint weights observed for three harvest methods (adapted from Wanjura et al., 2012)

		Picker	Stripper with Field Cleaner	Stripper No Field Cleaner[Z]
Lint Turnout	%	34.7	29.7	25.8
Total Foreign Matter	%	11.1	23.2	35.8
Total Harvested Weight	kg/bale (lb/bale)[Y]	628 (1384)	733 (1616)	844 (1861)
Seed Weight	kg/bale (lb/bale)	344 (758)	354 (780)	324 (714)
Total Foreign Matter[X]	kg/bale (lb/bale)	70 (154)	173 (381)	302 (667)
Bur Weight	kg/bale (lb/bale)	21 (45)	83 (183)	149 (327)
Stick Weight	kg/bale (lb/bale)	7 (15)	32 (71)	50 (110)
Leaf/Fines/Motes	kg/bale (lb/bale)	42 (94)	58 (127)	104 (229)

[Z] Values listed for stripper no field cleaner are based on a limited number of field observations. Growers rarely bypass the field cleaners on cotton strippers today.

[Y] Weight per 218 kg (480 lb) lint bale.

[X] Total foreign matter is comprised of bur, stick, and leaf/fine/mote material. Weights listed for bur, stick, and leaf/fines/motes are from hand and pneumatic fractionation analysis of bur cotton samples pulled after harvest prior to ginning.

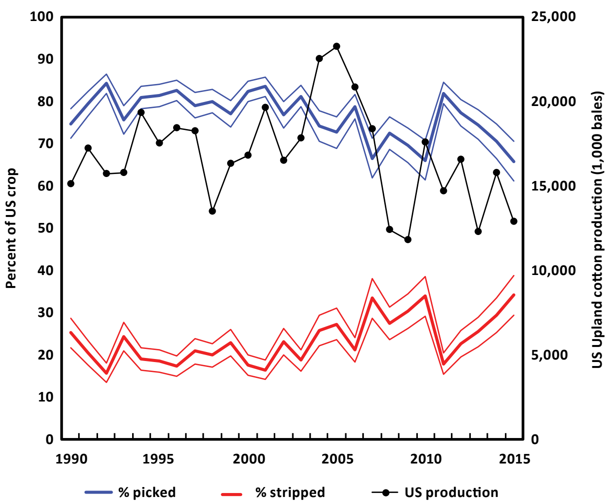

Figure 1. U.S. upland cotton production (1000s of 480-lb bales) since 1990 (USDA-ERS, 2015) shown with estimates for the percent of the U.S. crop that was picker and stripper harvested. Estimates for the percent of the U.S. crop harvested by each machine were obtained from data published by Evans (2000) and Supak and Snipes (2001). Dashed lines enclose estimate ranges around the mean percent picked and stripped and illustrate the effect of a 10% uncertainty in the proportion of stripper-harvested cotton in Texas and Oklahoma.

Spindle pickers are used in the Southeast and Midsouth areas of the U.S. where harvest-time humidity and rainfall can limit the daily available harvesting window. Spindle pickers are able to harvest seed cotton under field conditions where plant moisture content remains high enough that the stalk and branches remain pliable but the seed cotton is able to dry to a safe level for infield storage (less than 12% wet basis). Spindle pickers also are used in the irrigated western region of the U.S. to harvest the high quality and often high yielding upland and long staple cultivars produced. The brush-roll stripper is the primary harvester used in the southern high plains of the U.S. located in Texas, New Mexico, Oklahoma, and Kansas. It is also used in the rolling plains and blacklands of Texas and frequently along the gulf coast. The brush-roll stripper was developed as a cost-effective alternative to the spindle picker to harvest cotton from both irrigated and nonirrigated (dryland) production systems. Although irrigated crops typically have larger plants with yields often in excess of 4.9 to 7.4 bales per ha (2 to 3 bales per acre), dryland conditions usually produce small plants with harvested yields as low as 1.2 bales per ha (0.5 bales per acre). Unlike the spindle picker, the brush-roll stripper is capable of efficiently harvesting cotton with bolls exhibiting a high degree of storm tolerance (i.e., bolls that hold seed cotton tightly within the open bur, thus preventing loss from wind or harsh weather prior to harvest).

PRODUCTION PRACTICES

Production of a successful cotton crop requires careful attention to detail at each step in the process from before planting through harvest. Many of the decisions made by a grower regarding crop management influence the efficiency of harvest. Prior to planting the crop, fields should be configured to maximize row length and minimize the number of harvester turns to help maximize field efficiency during harvest. End rows or turn rows should be sufficiently wide to allow the harvester to turn around and re-enter the field without the need to stop or back up. Fields should be well drained to help lengthen the available harvest window, especially in areas prone to high rainfall during harvest.

Cultivar selection is likely the single most critical decision a grower makes to maximize yield, quality, and profitability for a particular field. Cultivar selection also influences harvest efficiency and productivity. Cultivars with poor seedling vigor can result in plant stands with excessively wide spaces between plants (skips), promoting rank plant conditions that reduces both harvesting efficiency and productivity. Reduced and uneven plant stands also can result from poor planter performance and poor germination rates caused by poor seed quality, low soil temperature, harsh weather conditions on seedlings, and insect/disease pressure during emergence. Cultivars that tend to produce excessive vegetative growth might require use of plant growth regulators to control plant height for mechanical harvest. Plant height should be limited to approximately 122 cm (48 in) for cotton that is to be spindle picked and approximately 91 cm (36 in) for stripper-harvested cotton. Cultivars with increased levels of storm resistance will have lower picking efficiency than cultivars that do not hold seed cotton as tightly inside open bolls. Additionally, cultivars that produce sympodial branches (fruiting branches) at higher node positions on the plant main stem tend to set bolls higher off the ground, which helps mechanical harvesters gather the crop into the harvesting units. Genetic tolerance or resistance to plant diseases and parasites (nematodes) will help promote the production of a uniform crop that can be harvested efficiently using either type of mechanical harvester.

Adequate weed control is also key to maximizing harvesting efficiency. Excessive weed infestations can slow harvest by causing row unit chokes that must be removed by hand. Weeds tend to hang up inside harvesting units and could become a fire hazard if left in a high friction zone between rotating components.

HARVEST AIDS

Harvest-aid chemicals have gained widespread use across the U.S. cotton belt because of their value in hastening the process of making a crop ready for harvest. Promoting early harvest benefits producers by minimizing weather-related yield and quality loss and allows for greater control in scheduling of harvest equipment. The goal of harvest-aid use for cotton to be spindle picked is to open all mature bolls and remove the leaves. Cotton that is to be brush-roll stripper harvested has the added requirement that the crop be adequately desiccated (either chemically or by a killing freeze) to aid in efficient stripping.

Growers apply harvest-aid chemicals in various combinations to effect boll dehiscence and opening, leaf abscission and defoliation, desiccation of remaining leaves and branches, and removal and inhibition of terminal and basal regrowth. Efficacy of harvest-aid chemicals is determined by environmental and crop conditions during and after application. Warm, dry, and open sky conditions help promote uptake and activity of harvest aids. Periods of cool, wet, or overcast conditions slow the uptake and activity of harvest aids. Soil conditions with high nitrogen and moisture levels at the time of application can reduce efficacy, promote regrowth, and cause low micronaire for stripper-harvested cotton (Wanjura et al., 2015). Crops that have begun the natural process of senescence generally have greater than 60% open bolls and have begun to drop some leaves, usually respond more readily to harvest-aid applications than less physiologically mature crops (Hake et al., 1996). Crops produced under moisture-stressed conditions are typically more difficult to prepare for harvest (Sanders et al., 2009).

Harvest-aid chemicals are generally grouped into three categories: boll openers, defoliants, and desiccants. Boll openers consist of formulations containing ethephon [(2-chloroethyl) phosphonic acid]. Ethephon is converted to ethylene inside the plant, which promotes the formation of abscission layers resulting in faster boll opening and leaf drop. Although ethephon-based products enhance the process of boll opening, they do nothing to increase the rate of boll or fiber maturation. Thus, application of ethephon products prior to adequate boll maturity could result in reduced lint yield and micronaire (Larson et al., 2002). Application of defoliant chemicals results in the formation of an abscission layer at the base of the leaf petiole and eventually leaf drop. Defoliants can be herbicidal or hormonal in nature (or a combination of both), but in either case, ethylene production is promoted to increase the formation of abscission layers. Desiccants are used to lower the moisture content of the plant by disrupting cell membranes causing the loss of cell contents and water (Brecke et al., 2001). The rapid loss of water from the plant leads to desiccation of plant stems and leaves, making the material brittle and easy to snap off the plant during stripper harvest.

Several methods for determining when a crop is ready for harvest-aid applications are available and it is recommended that a combination of the available methods be employed to determine the suitability of a crop for harvest-aid applications. Three of the most common methods are the percent open boll method, cut-boll or knife test method, and the nodes above cracked boll (NACB) method. The percent open boll method entails counting the total number of bolls on a plant and expressing the number of opened bolls as a percentage of the total. The cut-boll method determines the maturity of a specific boll by slicing through the boll and inspecting the seed cross sections. A boll is mature when 1) it is difficult to slice through with a sharp knife and 2) seed coats are dark and fully developed plant embryos can be seen inside the seed. Immature bolls give little resistance when sliced and contain a watery substance inside. NACB is a method of quantifying crop development that allows producers to judge if a crop is ready for harvest-aid applications and/or how long it will be until the crop is ready (Kerby et al., 1992). NACB refers to the number of main stem nodes between the uppermost first-position cracked boll and the uppermost first-position harvestable boll. The development of bolls occurs in a consistent manner up the main stem of the plant where the difference in age among first-position bolls between adjacent main stem nodes is approximately 30.5 to 33.3 DD15.6 (55 - 60 DD60) heat units. Thus, if a producer determines an NACB rating in excess of the recommended minimum, it is a trivial matter to estimate the number of days until the crop reaches adequate maturity for harvest-aid application. Defoliant (or boll opener)-type chemicals should not be applied until NACB is less than or equal to four and 50 to 60% of the bolls are open, with an adequate number of the remaining unopened bolls having reached maturity to attain the desired yield (Kelley et al., 2015). It is recommended that desiccant materials not be applied to a cotton crop until approximately 80% of the bolls are open and NACB is two or less.

BARK

Bark is a lint contaminant that originates from the outer layer of the stalk and branches of cotton plants. Bark contamination can result in considerable economic loss for growers. In 2015, level one and two bark discounts in the Texas, New Mexico, Oklahoma, and Kansas region reduced bale values (218 kg [480 lb] lint bale) by \$14 and \$24, respectively (USDA-CCC, 2015). In other regions of the country, level one and two bark discounts were more severe and decreased bale values by more than \$21 and \$34, respectively. Shurley and Collins (2013) estimated that bark discounts cost Georgia producers \$7.09 million in 2012. Wanjura and Baker (1979) showed that bark is generated on the stripper harvester from stick material broken up by the auger conveyors and also by seed cotton cleaning equipment used before the gin stand. Bark contamination can vary by cultivar and annual growing environment. Moreover, bark contamination potential is exacerbated by stripper harvesting of large plants with excessive vegetative growth, excessive field weathering of plants prior to harvest, sudden hard freezing conditions when the plants are in a condition with high moisture content, and seasons with extreme variation in climatic conditions. Although bark contamination usually is not a problem associated with spindle picking, environmental and harvesting conditions that increase seed cotton stick content and picking aggressiveness (e.g., nonsynchronized picking in second gear, excessive pressure plate settings, unnecessary use of scrapping plates) can exacerbate bark problems in some years.

SPINDLE-PICKER HARVESTERS

Spindle-type cotton pickers have increased in size and productivity over the years in response to increased farm size and efforts to minimize harvesting costs. The first commercially successful cotton pickers harvested one row per field pass, whereas the state-of-the art machines used today harvest six rows per pass. Although harvester ground speed and row unit component speeds have increased substantially over the years, the basic design and operation of spindle-picker harvesting units has changed little.

Spindle pickers use tapered spindles to remove seed cotton from opened bolls. Each spindle contains three rows of barbs machined along the tapered section that are oriented at approximately 30° with respect to the spindle axis. The barbs hook the fibers and wrap the locks of cotton around the outside of the spindle. Eighteen to 20 spindles are mounted with equal spacing (approximately 41.275 mm [1.625 in]) to a vertically oriented picker bar that contains an internal drive shaft and gears that turn the spindles at approximately 4200 rpm when the picker is moving at full ground speed. Twelve to 16 picker bars are mounted to drums that revolve such that the peripheral speed of the drums is equal to the ground speed of the harvester. One drum is positioned forward of the other in the row unit and, depending upon row unit type, the drums are oriented in an opposed (one on either side of the plant row being harvested, Fig. 2) or inline (both drums on one side of the plant row being harvested, Fig. 3) configuration. The synchronized condition between the drums and harvester speed results in no relative lateral movement between the spindles and the plants moving though the row unit picking zone, which helps to maximize picking efficiency and minimize inclusion of undesirable vegetative foreign matter. In the picking zone, all plant material taken in by the row unit is pressed into the spindles by the pressure plates (compressor sheets). The pressure plates limit the width of the picking zone, which helps to expose the seed cotton to the spindles. As the spindles move out of the picking zone they pass through the picker ribs, which help to remove foreign matter from the seed cotton. Foreign matter can be thrown out of the seed cotton by inertial force from the rotating spindle or by the agitating and stripping action of the spindle moving through the picker ribs.

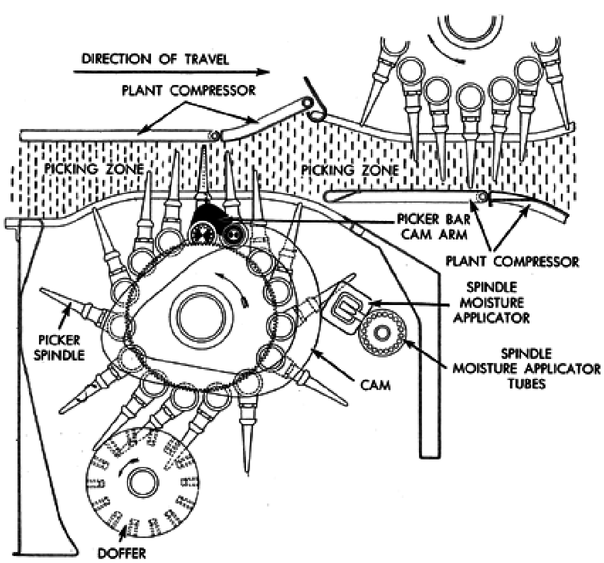

Figure 2. Schematic diagram of opposed-drum cotton-picker row unit showing internal components (Courtesy of Cotton Incorporated).

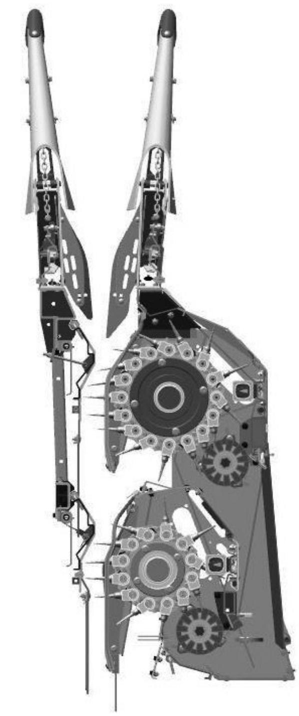

Figure 3. Schematic diagram of inline-drum cotton-picker row unit showing internal components (Courtesy of John Deere).

A cam track located above each picking unit drum controls the position of a cam arm affixed to each picker bar. The shape of the cam is designed to precisely govern the angular position of the spindles relative to the axis of the drum as the picker bars move into and out of the picking zone, under the doffing pads, and under the moistening pads. Lugged polyurethane doffer pads remove seed cotton from the spindles using an unwrapping and wiping motion that pushes the locks of cotton off the pointed end of the spindles. The doffer pads are fixed to a shaft with the same vertical spacing as the spindles and rotate at high speed such that the surface speed of the doffer is much faster than that of the spindles. Once past the doffer section of the row unit, the spindles pass under ribbed moistener pads that apply a liquid solution to the surface of each spindle. The solution helps wash away sap and residue from green plants and makes the spindles slightly tacky, making it easier for cotton to adhere to the spindle surface. After the spindles are exposed to the moistening pads, the picker bars are rotated toward the front of the row unit before positioning the spindles back into the picking zone.

Spindle pickers are mechanically complex machines and require significant attention to detail in regard to proper setup and maintenance.

Operator manuals provided by the manufacturer should be followed when performing all setup and maintenance procedures. Prior to the beginning of each harvest season, check and repair/replace worn components such as doffers, spindles, and moistener pads. Doffers should be ground to make the distance between each adjacent pad equal to the spindle spacing and to sharpen the edges of the doffer lugs to promote effective doffing. Doffer columns can be ground so long as the lugs remain long enough to prevent seed damage (approximately 9.5 mm [0.375 in] minimum). Doffer pads can become hard and inflexible due to age, weather, and sunlight; any hardened or broken pads should be replaced with new polyurethane pads. Cheaper black rubber pads should be avoided as the material can contaminate seed cotton if pieces break or slough off during use. Dead spindles (spindles that turn freely when spun between the thumb and forefinger) should be checked to determine the cause of the malfunction and repaired/replaced as necessary. Spindles with dull barbs should be replaced. Worn or broken moistener pads also should be replaced. Picker ribs should be checked for proper clearance with spindle nuts and any broken or bent ribs replaced.

The shimmed height of each picker bar should be checked and reset so that all spindles at a given vertical position on the picker bars run at the same height. Clearances between the doffer pads and spindles should be checked prior to the beginning of harvest and several times during the season. Spindle-to-doffer clearance should be set to operate at approximately 0.076 mm (0.003 in). Spindle-to-moistener pad clearance should be set so that the pads deflect slightly when the spindles pass underneath. Pressure-plate–to–spindle-tip clearance should be checked prior to and during the harvest season and set such that the spindles clear the plates by approximately 3.18 to 6.35 mm (0.125-0.25 in) at the narrowest location along the full height of the picker bars. Tension on the pressure plates should be set based on field conditions. Generally for high yield conditions, the plates on the front drums should be set fairly loose to allow the crop to feed into the harvesting unit and the plate tension increased for the rear drum to help pick the remaining crop left by the front drums. The operator's manual recommendations should be followed based on particular field conditions. Scrapping plates are sometimes added to the pressure plates to help increase the exposure of the spindles to tight locked or low yielding cotton.

Other basic setup considerations for spindle pickers include checking the row unit tilt on the header frame so that the rear drum operates approximately 2.54 cm (1 inch) higher than the front drum. Row unit tilt increases spindle coverage over the vertical range of the picking zone. Stalk lifters on the front of each row unit should be set to lift low hanging branches and lodged plants into the row unit without contacting the soil surface. Additionally, the pneumatic conveying ducts and supply lines to each harvesting unit should be checked for proper setup and ensure no air leaks are present. Separator screens at the discharge end of the conveying ducts should be checked to ensure they are in place and adjusted properly to direct cotton into the basket or accumulator of the harvester.

Daily cleaning and maintenance of spindle pickers is critical to maintaining high picking efficiency, field productivity, and cotton cleanliness and quality. Row units should be checked and cleaned several times during the day to remove foreign material buildup from inside row units, especially in the moistener pads and doffer column areas. Moistener pad columns should be checked to ensure all pads are applying solution evenly. High-pressure high-volume air is recommended for quickly and safely removing foreign material buildup from row units. Row units should be greased according to manufacturer recommendations (generally once per day) and excess grease should be removed prior to resuming harvest to prevent lint contamination. Other harvester specific hydraulic, engine, fan, and cooling systems should be checked daily to ensure proper operation.

COTTON-STRIPPER HARVESTERS

The stripping principal for harvesting cotton was used as early as the 1920s when cotton was sledded in the Southern High Plains region. Horse- or mule-drawn sleds consisted of a wooden box with a narrow slot through which the plants would pass. Material on the plants too large to pass through the narrow slot was pulled or stripped off and moved to the side of the box by a worker riding inside. The stripping principal has been used on several mechanized harvester designs including the finger stripper and the brush-roll stripper. Finger strippers utilize closely spaced, inverted angle iron "fingers" to strip cotton from narrow-row or broadcast planted crops characterized by short plants with small main-stem diameters and minimal vegetative branching (Kirk et al., 1964). A paddle reel is used to move material harvested by the finger-stripper header to an auger conveyor at the rear of the header. Finger-type stripper headers are not manufactured commercially in the U.S. today and are rarely used in the Southern High Plains.

The brush-roll stripper is the most common cotton harvester used in the Southern High Plains of the U.S. Plants pass through the open slot formed between two closely spaced parallel stripper rolls inside each row unit (Fig. 4). The stripper rolls are oriented at approximately 30° with the ground surface and rotate in opposite directions such that the upward movement of each roll is next to the plant row. Two-ply rubber strips (bats) and crimped-bristle strip brushes are installed in alternating sequence parallel to the axis of each stripper roll (Fig. 5). The brushes and bats engage the plants and break the bolls, some branches, and leaves off of the plants as they pass through. The harvested material is moved toward the rear of the row unit by small diameter augers located on both sides of the row unit. The row unit augers pass the harvested material out of the row unit and onto a larger cross auger that conveys the material from all row units toward the center of the header where it is picked up by the pneumatic conveying system. The pneumatic conveying system carries the harvested material to the top of the harvester where it is either deposited in the basket of the harvester or diverted into the onboard cleaner (field cleaner). Green bolls, rocks, and other large foreign material too heavy to remain entrained in the air stream are separated out of the cotton at the inlet and exit of the pneumatic conveying duct via gravitational settling. The onboard field cleaner (Fig. 6) is similar in design and operation to a two-saw stick machine used in the ginning process to extract sticks, burs, and other large foreign material. Cotton flows into the top of the cleaner and is exposed to a beater cylinder that helps to break up wads before the cotton is fed onto the top (primary cleaning) saw cylinder. Channel saws affixed to the surface of the saw cylinder engage the cotton and sling it across a series of grid bars. Foreign matter and some seed cotton are thrown off via centrifugal force and pass to the secondary (reclaiming) saw. The secondary saw engages the seed cotton thrown off by the primary saw and expels the foreign material through a set of grid bars located around the periphery of the saw. After extraction of the foreign material, cotton on both the primary and secondary saws is removed by the doffer brush and placed in an air stream for transport to the basket. Foreign material removed by the secondary saw is carried out of the machine by an auger conveyor and deposited back into the field.

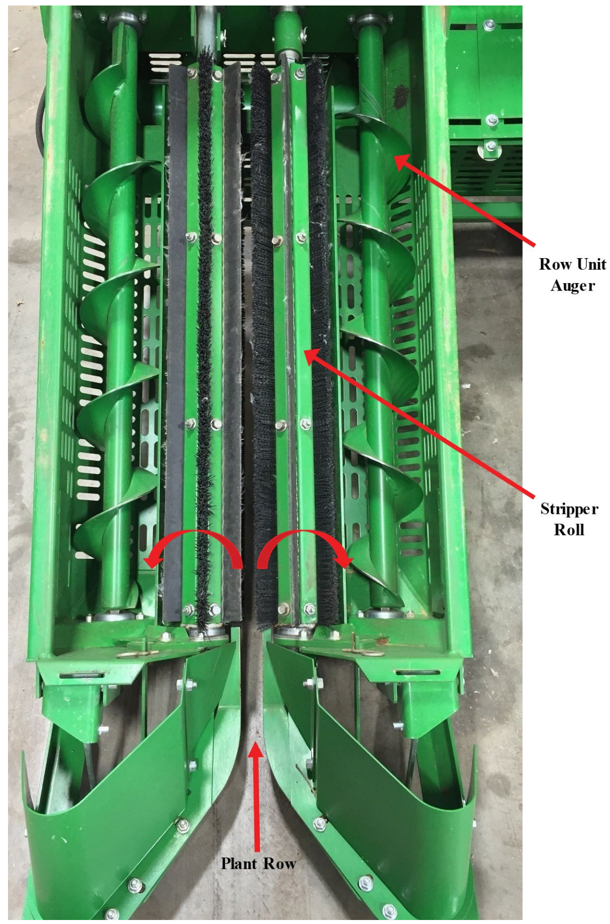

Figure 4. Internal image of brush-roll cotton-stripper row unit.

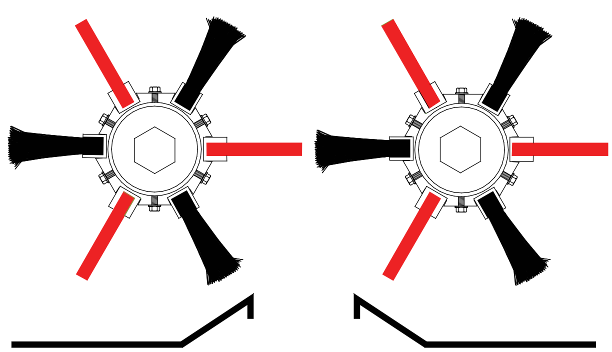

Figure 5. Stripper rolls configured with alternating brush and bat (red) pattern.

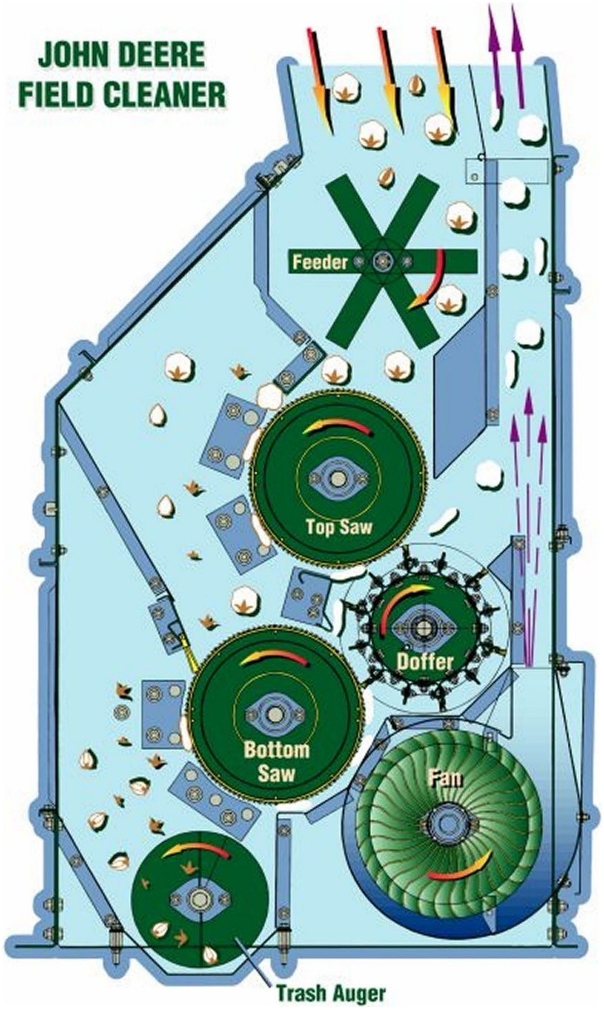

Figure 6. Schematic diagram of a field cleaner used onboard a cotton stripper showing internal cleaning components (Courtesy of John Deere).

Cotton strippers are not as mechanically complex as their spindle-picker counterparts but attention to detail in preseason setup and maintenance will ensure high harvesting efficiency, field productivity, and cotton quality. Row units should be checked frequently for worn components such as stripper roll and auger shaft bearings, brushes and bats, and drive components such as belts, pulleys, and gears. Any worn components should be replaced as soon as possible to prevent downtime and potential fires and safety hazards. Field cleaners should be checked for worn or broken channel saws, grid bars, and doffer brushes. Prior to the beginning of a harvest season, saw-to-grid-bar clearances should be checked and adjusted to manufacturer recommendations.

The gap between stripper rolls should be checked frequently and adjusted based on component wear and field conditions. Generally, the gap should be set according to the average stalk diameter in the field at the height where the row unit engages the plants. Brashears (1986) recommended a bottom roll spacing between 9.5 to 15.9 mm (0.375 and 0.625 in) to minimize harvest losses. Wider gap settings will reduce harvesting efficiency somewhat but will also reduce the aggressiveness of the harvesting action resulting in less foreign matter collected with the seed cotton. Tighter gap settings are more aggressive and will leave less cotton in the field, but will result in higher seed cotton foreign matter content, especially with regard to stick content. Higher stick content increases the likelihood of bark-contaminated lint. Laird and Baker (1975) observed minimal levels of bark contamination in lint from cotton that had less than 1.5% stick content at the extractor feeder apron just before the gin stand. The aggressiveness of stripper rolls also can be reduced by changing the alternating three-bat/three-brush factory configuration. Brashears (1992) found that decreasing the number of bats used in the stripper roll sequence or using half-width bats (2.54 cm [1 in] wide vs. standard 5.08 cm [2 in] wide bats) in the factory configuration reduced foreign matter content (especially stick content) with negligible decrease in harvest efficiency. Regardless of bat/brush combination, adjacent stripper rolls should be timed such that two bats never engage the plant row simultaneously.

INFIELD SEED COTTON HANDLING AND STORAGE

Conventional harvesting systems based on picker and/or stripper harvesters equipped with baskets utilize additional equipment to handle and process seed cotton for infield storage. Tractor-operated boll buggies commonly are used to collect cotton from harvester baskets in the field and carry the cotton back to a module builder located at the edge of the field. The use of boll buggies increases field efficiency during harvest by allowing harvesters to remain in the field working, rather than shuttling cotton to the module builder when full. Module builders form harvested seed cotton into rectangular modules that are 9.8 m (32 ft) long, with a trapezoidal cross section that is 2.3 m (7.5 ft) wide at the base and up to 3.4 m (11 ft) tall, with an inward side slope of approximately 8% (ASABE, 2010). Stripper-harvested modules contain eight to 13 bales (11 bales per module on average) and picker-harvested modules contain 10 to 16 bales (14 bales per module on average). Modules harvested early in the season generally weigh more and contain more lint bales than modules harvested later in the season. The transition from cotton trailers to module builders in the 1970s decoupled harvesting and ginning operations and substantially decreased the time required to harvest a crop (Wanjura et al., 2015).

The process of unloading cotton into a boll buggy requires the harvester to cease harvesting for a period of time ranging from several seconds to several minutes depending upon boll buggy availability. Boll buggies can be occupied by unloading operations at the module builder or when traveling back into the field after unloading. Harvester delays of any length result in decreased field productivity and field efficiency. Productivity and field efficiency of conventional harvesting systems also can be hampered when boll buggies, module builders, and tractors are not available due to breakdown or maintenance issues. Moreover, availability of reliable labor to operate ancillary equipment during harvest can be a critical problem.

Harvest productivity gains have been realized in recent years with the advent of harvesters with onboard module building (OMB) technology. These harvesters form seed cotton modules for infield storage on the harvester while the machine continues to harvest cotton in the field, eliminating the need for ancillary boll buggies and module builders. Although harvester ground speed has increased slightly for the new OMB machines compared to conventional basket-type harvesters, the main increase in field efficiency arises from the minimization of unloading time. The CaseIH 635 Module Express cotton picker forms seed cotton into modules that are 4.9 m (16 ft) long, 2.4 m (8 ft) wide, and up to 2.4 m (8 ft) tall. These modules weigh 3175 to 4535 kg (7000 to 10,000 lb), are about half the size of conventional modules (by volume) and contain five to seven lint bales. The CaseIH 635 continues to harvest until the module is completed at which time the harvester stops briefly in the field to unload the module. Once unloaded, each half-module is manually covered with a tarpaulin to protect the cotton from inclement weather. Similar to conventional modules, the half-modules are identified by a preprinted tag (usually obtained from the gin) attached by the grower after the module is unloaded and covered in the field. The John Deere CP690 (cotton picker) and CS690 (cotton stripper) form cotton into cylindrical modules that are about 2.4 m (8 ft) in diameter, 2.4 m (8 ft) long, and weigh about 2270 kg (5000 lb). Picker-harvested round modules usually contain 3.5 to four lint bales per module and stripper-harvested field cleaned round modules usually contain three to 3.5 lint bales per module. Each cylindrical or round module is wrapped in three layers of plastic, which helps to maintain the cotton in a cylindrical shape and protect it from wind and rain. The precut portions of plastic wrap contain radio frequency identification tags (RFID) with a preprogrammed module identification number that can be used by the producer and/or gin for inventory tracking and module logistics. The John Deere CP690 and CS690 can continue to harvest while the module-forming system finishes, wraps, and ejects a module onto the handler platform at the rear of the machine. Once on the handler platform, round modules can be dropped immediately in the field or carried to the end of the row so that the staging tractor does not have to travel so far to retrieve modules.

Regardless of harvester type or seed cotton storage system, proper management of seed cotton moisture content during harvest will help ensure optimum lint grades, seed quality, and ginning efficiency. Seed cotton moisture content should be limited to 12% (wet basis) for safe long-term infield storage. Sorenson and Wilkes (1973) observed a substantial decrease in safe storage duration from 30 to 10 d as seed cotton moisture content increased above 12%. Internal module heating and fiber color grade degradation were observed for cotton stored above the safe storage moisture content limit (Curley et al., 1987, 1990; Hamann, 2011). Seed quality degradation characterized by reduced germination and increased free fatty acid content occurs more readily over time for seed cotton stored at higher moisture content (Hamann, 2011; Wilkes, 1978). Searcy et al. (2010) observed significant decreases in ginning rate and turnout for cotton ginned from modules with high moisture content caused by moisture penetration during storage (i.e., poor module shape and poor tarp quality).

CONCLUSION

Successful production and harvesting of a cotton crop requires careful attention to detail at each step in the process. Growers should be vigilant to utilize cultivars and production practices that promote production of a uniform crop in regard to vegetative and reproductive growth. Moreover, use of appropriate crop termination techniques regarding irrigation termination, fertility management, and harvest-aid use will help ensure optimum yields and fiber quality at the end of the season. Fundamental differences between the harvesting mechanisms used by spindle pickers and brush-roll strippers result in differences in harvesting efficiency, foreign matter content, and fiber quality, which influence the economics of cotton production. Regardless of harvester type, careful attention to setup and maintenance is critical to achieving maximum harvesting efficiency and field productivity. Proper handling and infield storage of seed cotton after harvest will help minimize losses in terms of quantity and quality of cotton transported to the gin.

DISCLAIMER

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