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The ICAC Recorder

International Cotton Advisory Committee

Nano-cellulose pilot plant CIRCOT, Mumbai, India. Photo courtesy: Dr. PG Patil.

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The ICAC Recorder

Editorial

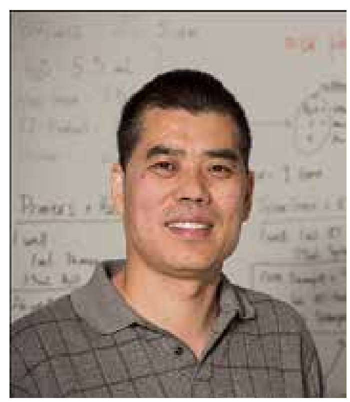
This *ICAC RECORDER* is a special issue based on the theme 'Sustainable, better practices in the processing of cotton fibres and byproducts'. Technologies are changing for the better. They are getting better and better with time, because at least in the cotton sector, these are getting oriented towards social, economic and environmental sustainability. Ginning practices across the globe have undergone a tremendous change in the past two decades. Market yards across the globe are cleaner now. Ginning factories are being upgraded to ensure cleanliness, automation, higher efficiency and bale tagging. There is enhanced awareness on by-product utilization for value addition. Researchers are constantly striving to invent new applications for cotton fibres and also to replace the chemical processes with eco-friendly biological alternatives. Nano-cellulose applications are gaining ground at a faster pace. All these developments point out towards exciting times ahead.

This issue attempts to capture these exciting changes using a wide-angle lens to provide a panoramic view of the technological advances in ginning, utilisation of cotton by-products and eco-friendly fibre processing. Dr. Greg Holt and Dr. Michael K. Dowd describe the economic importance of cottonseed and cotton plant biomass, while Dr. P. G. Patil and his team enumerate sustainable practices in small-scale cotton production, hand picking, fibre processing and by-product utilisation and highlight case studies in India. In his chapter on ''Best ginning practices', Dr. M. K. Sharma provides critical and scientific insights into key aspects of the ginning sector and recommends the way forward to enhance processing efficiency, preserve fibre quality and increase cotton fibre output. The chapter is pictorial, descriptive and brilliant because it provides an insider's account in an impartial and unbiased manner.

I earnestly hope that you will enjoy reading this special issue of *THE ICAC RECORDER*.

Dr. Baohong Zhang - ICAC Researcher of the Year 2018

Dr. Zhang grew up in a small village in China. Since childhood, he helped his parents in the cotton fields, which motivated him to work on cotton genetics and breeding. He graduated from China Agricultural University with a degree in plant genetics and breeding. He joined the Institute of Cotton Research at the Chinese Academy of Agricultural Science (ICR-CAAS) in 1991, where he pioneered the development of transgenic Bt cotton. In 2003, he attended Texas Tech University and received his PhD from the school in 2006, after which he joined the faculty at East Carolina University (ECU). His major focus areas have been to develop genetic tools, resources and studies on cotton small RNAs.



Dr. Zhang developed an advanced CRISPR/Cas9 genome-editing tool and its application on cotton genetics and breeding. He is the first scientist who succeeded in employing CRISPR/cas-9 genomeediting technology to knock out an individual functional gene in cotton, including the fibre-related MYB25-like and miRNA genes. Additionally, Dr. Zhang developed highly efficient approaches for cotton somatic embryogenesis, plant regeneration and highly efficient *Agrobacterium*-mediated genetic transformation systems in cotton. These powerful tools and resources open new avenues and provide directions for cotton researchers and breeders to perform cotton gene functional studies and molecular breeding. Dr. Zhang conducted innovative research on small regulatory RNAs and is a pioneer for cotton microRNA studies. In the past 10 years, Dr. Zhang has been employing different technologies such as deep sequencing, transgenics, genome editing and bioinformatics to identify and conduct functional analyses of microRNAs in cotton fibre development to assess cotton responses to 10 different biotic and abiotic stress factors. He identified several microRNAs for genetic and breeding purposes. His results provide new targets for cotton improvement, including fibre yield and quality, as well as tolerance to environmental biotic and abiotic stresses. Dr. Zhang is one of the major contributors to breeding transgenic Bt-cotton in China. He developed 5 cotton cultivars that are being used in China and several other Asian countries. The cultivars continue to generate huge economic benefits for cotton farmers. Additionally, Dr. Zhang also created many elite cotton germplasm lines using transgenic, somatic variant screening and genome editing.

Dr. Zhang has a highly impressive citation index of 10,460; h-index 46 and i10 index 104. He has been serving as co-editor-in-chief, associate editor and guest editor for 10 international journals, including *Scientific Reports*, *Plant Biotechnology Journal* and *The Crop Journal*. Dr. Zhang frequently reviews manuscripts for more than 100 international journals, including *Nature*. Dr. Zhang won ECU's Five-Year Achievement Award for Excellence in Research/Creative Activity, the highest award available to ECU faculty members. He was also awarded early tenure and early promotion to associate professor in 2012, and then to full professor in 2017.

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Cottonseed and Cotton Plant Biomass

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The cotton plant generates several marketable products as a result of the ginning process. The product that garners the most attention in regard to value and research efforts is lint, with cottonseed being secondary. In addition to lint and cottonseed, the plant material itself has a value that has often been underappreciated — and more often than not, ignored completely. The cotton plant material separated from the lint and cottonseed in the ginning process is historically referred to as either "gin trash" or "gin waste" primarily because it was discarded and did not have a market like the lint and seed. This paper will focus on cottonseed and the cotton plant material hereafter referred to as cotton plant biomass (CPB), and discuss what the materials are, how much is produced annually, and current and potential uses.

Cottonseed

After ginning, there remains a considerable mass of seed that can contribute value to the cotton crop. For each pound of fibre produced, 1.4 to 1.5 pounds of seed is generated (Dowd, *et al*., 2017). In the United States, approximately 2.8 million metric tons of fibers were produced in 2015 (ICAC, 2016), generating about 4 million metric tons of seed. This seed contains significant amounts of protein and oil, and accounts for 20% or more of the total value of the cotton crop.

Cottonseeds are generally oblong, with a dimension of 10 mm and 12 mm and an average weight of around 100 mg (i.e., a seed index of around 10.0 g). However, within a given sample, a range of shapes and weights are possible. Typically, the seed contains an outer hull that protects the embryonic tissue or the kernel. In addition, seeds from *Gosspium hirsutum* varieties (commonly known as upland cotton) have short residual fibres, or linters, that are retained after ginning. These seeds are often referred to as white or fuzzy cottonseeds. For typical *G. hirsutum* seed, the percentage of kernel, hull and linters is 54%, 36%, and 10%, respectively (Dowd, 2017). In contrast, cottonseed from *G. barbadense* cotton varieties tends to have far fewer linters after ginning, and the ratio of kernel, hull, and linters may be closer to 60%, 37% and 3%, respectively. Whole fuzzy cottonseed contains 18% to 20% oil and 20% to 22% protein (Tharp, 1948).

Residual linters are often removed from seed to produce what is commonly called black or naked seed. This occurs by either an acid treatment, which often is used to prepare planting seed, or by a mechanical process similar to saw ginning (discussed further below).

Cottonseed is used in two important ways. First, it is used as an ingredient of proteinaceous feed for ruminant animals. While sheep, goats, and cattle are often fed with diets containing cottonseed, the biggest use of cottonseed today is for feeding dairy cows. The dairy industry favours whole cottonseed in dairy rations because it tends to increase the butterfat content in the milk (Smith, *et al*., 1981), which has direct value to the dairy farmer. In the United States, approximately 60% of the cottonseed produced by ginners is used as animal feed. However, in Africa, Uzbekistan, China and other regions without large dairy industries, a smaller percentage of cottonseed is fed to dairy cattle.

The remainder of the seed is processed to recover several products. The processing of cottonseed has developed over the years into an involved multi-step process, with the principle goal being to recover almost all of the oil. Several steps are conducted to prepare the kernel tissue for oil extraction. Typically, the bulk of the linters are removed by a mechanical process similar to saw ginning. After de-linting, the seed is dehulled with a cutting-type mill that shears the seed into a few pieces. A series of aspirators (a type of pump) and shaking sieves are then used to separate the hulls. The remaining kernel tissue is then rolled to produce thin flakes and cooked to start disrupting the cellular tissue so that the oil can be more easily released. The cooked flakes are then passed through an extruder (called a cooking expander), which applies considerable shear and additional heat to the kernel tissue, further macerating the kernel cells and allowing the microscopic oil droplets to start to coalesce. Considerable pressure is built up in the expander, which is released by forcing the kernel tissue to exit a dye plate resulting in a stream of porous cylindrical kernel tissue called "collets", which have most of the oil deposited along their outer surfaces. These porous collets are easily and quickly extracted with hexane to recover the oil. The defatted collets are then dried to recover the solvent and ground to form a meal product, typically with around 41% protein.

Four products result from this process: linters, hulls, vegetable oil and a protein meal. The oil is the most valuable of the products, and most of the above processing steps are designed to maximize oil recovery. Today, most of the oil is used in food preparation. Much of the oil is sold to processors of prepared and packaged foods and large-scale restaurant chains. The oil has been used for margarine production, in salad dressings, as cooking oil, and for deep fat frying, although some of these uses are less important today. Linters have a variety of uses, either as small fibres (such as fillers in mats) or they are chemically converted into different cellulose pulps and used as coatings, bulking agents, etc. Because linters are the purest natural form of cellulose, they are frequently used in applications where the impurities in wood-based cellulose pulps are problematic. Hulls are used principally as a roughage in animal feeds but are occasionally used as a garden or planting mulch, or as a component in the substrates used for growing mushrooms. Finally, the meal is also used as a proteinaceous ingredient in ruminant animal feeds.

Cotton Plant Biomass (Gin Trash/ Gin Waste)

Each year, approximately 2 million to 3 million metric tons of cotton plant biomass (CPB) are generated across the U.S. from the ginning process, depending on the size of the crop. These materials are primarily comprised of lint, leaf, carpel (burs), sticks (branches or stalk material from the plant broken off during mechanical harvesting), and soil particles. The amount of material generated from a bale of seed cotton varies depending on the type of harvester used. The two types of mechanical harvesters used are known as pickers and strippers. Cotton that is harvested with a picker (also referred to as spindle harvester) produces 45 kg to 68 kg of CPB per bale of lint (approximately 220 kg), whereas cotton harvested with a stripper results in 127 kg to 363 kg of CPB per bale of lint (Baker *et al*., 1994; Wanjura *et al*., 2010, 2012). The wide range of CPB associated with stripper-harvested cotton is due to whether or not the harvester has a field cleaner. A field cleaner reduces the amount of CPB collected and brought to the cotton gin. Table 1 shows the composition of CPB in the seed cotton harvested by pickers and strippers, with and without field cleaners.

The CPB removed from the seed cotton during the ginning process is usually stored either on the ground behind the cotton gin or in a large hopper known as a "bur house". Since CPB materials do not have a ready market, occupy considerable space in the gin yard, and cost money to dispose of, they have been deemed as "trash" or "waste". Over the years, various means of disposal have been employed, including on-site incineration, application to growers' land, bedding for dairy cattle, and as a roughage ingredient for livestock feeds. Incineration was largely abandoned in the 1960s. Due to pesticide residues remaining on the material, concerns about the use of CPB as a feedstock have also been expressed, although Holt *et al*. (2000) have shown that most of the residue of chemicals used in producing the crop are below the minimum detection limits.

Because there is not a single widespread means of utilizing CPB, cotton gins currently employ a variety of disposal methods, depending on the location and local practices. In an effort to utilize the entire cotton crop and improve sustainability, there has been a resolute effort to enhance the value of CPB and use the material more effectively. Over the last 10 years, a number of processes have been developed and evaluated that add value to the discharge from a cotton gin (cotton gin trash/waste) by converting it to partial or main ingredients in diets for ruminants (Holt *et al*., 2003); erosion-control products, such as hydro-mulch (Holt *et al*., 2005; Scholl *et al*., 2012, 2013); fuel pellets for pellet stoves and hot water boilers (Holt *et al*., 2004, 2006); filler fibres in thermoplastic composites (Bajwa *et al*., 2011, 2014; Holt *et al*., 2014); and natural fibre substrates in eco-friendly composites, such as moulded packaging material (Holt *et al*., 2012) and acoustic-absorbing panels (Pelletier *et al.,* 2013, Pelletier *et al*., 2017). An important aspect of improved utilization

Table 1. Typical composition of cotton plant biomass in seed cotton harvested by mechanical harvesters (Wanjura *et al*., 2012).

	Composition of cotton plant material (%)		
Harvesting method	**Burs**	**Sticks**	**OPM†**
Machine picked	3.3	1.1	6.8
Machine stripped without field cleaner	22.8	7.7	11.8
Machine stripped with field cleaner	11.3	4.4	7.9

† OPM = other plant material, which includes leaf, soil particles, and lint.

is separation of the constituent components (lint, burs and sticks, leaf and soil particles), since each has properties and characteristics that promote or inhibit their use in different applications (Holt *et al*., 2000).

In light of increasing production and processing costs and a growing global emphasis by industrial manufacturers to utilize renewable resources such as agricultural substrates and by-products, CPB from the cotton gin — along with the biomass residuals remaining in the field (Wanjura *et al*., 2014) — are excellent sources of natural-fiber substrates that should find useful applications.

Summary

The two cotton by-products generated as a result of the ginning process, cottonseed and CPB, have experienced different success rates in the marketplace. Cottonseed is a well-established commodity product of the cotton plant with multiple uses that generates significant revenue. CPB has a variety of components that potentially can be used in a wide range of applications, but to date has not yet found a use that allows it to add to crop revenue for ginners and farmers.

References

Bajwa, S., D. Bajwa, G.A. Holt, F. Nakayama and T.A. Coffelt. 2011. Properties of thermoplastic composites with cotton and guayule biomass residues as fiber fillers. Ind. Crop. Prod. 33(3):747-755.

Bajwa, S.G., D.S. Bajwa, G.A. Holt, and T.C. Wedegaertner. 2014. Commercial scale evaluation of two agricultural waste products, cotton burr/stem and module wraps in thermoplastic composites and comparison with laboratory-scale results. J. Thermoplast. Compos. Mat. 27(6): 741-757.

Baker, R. V., W. S. Anthony, and R. M. Sutton. 1994a. Seed cotton cleaning and extracting. Cotton Ginners Handbook. Agricultural Handbook No. 503. U. S. Department of Agriculture, Washington D.C. p. 69-90.

Dowd, M.K., S.M. Pelitire, and C.D. Delhom. 2017. Estimation of current cottonseed-fiber ratios, seed indices, and seed tissues and compositional properties. Proceedings of the Beltwide Cotton Conferences, National Cotton council, Memphis TN. 8 pp. (in press.)

Holt, G.A., G.L. Barker, R.V. Baker, and A.D. Brashears. 2000. Characterization of cotton gin byproducts produced by various machinery groups used in the ginning operation. Trans. ASAE 43(6):1393-1400.

Holt, G.A., C.R. Richardson, G.A. Nunnery, K.F. Wilson, T.C. Bramble, L.D. Rea and T.C. Wedegaertner. 2003. Performance of growing heifers fed diets containing cotton gin by-products extruded by the COBY process. Prof. Animal Sci. 19(6):404-409.

Holt, G.A., J.L. Simonton, M.G. Beruvides, and A.M. Canto. 2004. Utilization of cotton gin by-products for the manufacturing of fuel pellets: An economic perspective. App. Eng. Agric. 20(4):423-430.

Holt, G.A., M. Buser, D. Harmel, and K. Potter. 2005. Comparison of cotton-based hydro-mulches and conventional wood and paper hydro-mulches--Study II. J. Cotton Sci. 9:128-134.

Holt, G.A., T.L. Blodgett and F.S. Nakayama. 2006. Physical and combustion characteristics of pellet fuel from cotton gin by-products produced by selecting processing treatments. Ind. Crops Prod. 24(3):204-213.

Holt, G.A., G. McIntyre, D. Flagg, E. Bayer, J.D. Wanjura and M.G. Pelletier. 2012. Fungal mycelium and cotton plant materials in the manufacture of biodegradable molded packaging material: Evaluation study of select blends of cotton byproducts. J. Biobased Mater. and Bio. Energy, 6(4):431-439.

Holt, G.A., P.Chow, J.D. Wanjura, M.G. Pelletier and T.C. Wedegaertner. 2014. Evaluation of thermal treatments to improve physical and mechanical properties of bio-composites made from cotton byproducts and other agricultural fibers. Ind. Crop. Prod. 52: 627-632.

ICAC. 2016. Cotton: Review of the World Situation. Secretariat of the International Cotton Advisory Committee, Washington, DC. Vol. 70(2) Nov.-Dec. 2016.

Pelletier, M.G., G.A. Holt, J.D. Wanjura, E. Bayer, and G. McIntyre. 2013. An evaluation study of mycelium based acoustic absorbers grown on agricultural by-product substrates. Ind. Crop. Prod. 51: 480-485.

Pelletier, M.G., Holt, G.A., Wanjura, J.D., Lara, A.J., Tapia-Carillo, A., Bayer, E., McIntyre, G. 2017. An Evaluation study of pressure-compressed acoustic absorbers grown on agricultural by-products. Ind. Crops Prods. 95: 342-347.

Scholl, B.N., G.A. Holt and C.I. Thornton. 2012. Screening study of select cotton-based hydromulch blends produced using the cross-linked biofiber process. J. Cotton Sci. 16:249-254.

Scholl, B.N., G.A. Holt and C.I. Thornton. 2013. Hydromulch blends using agricultural byproducts: performance implications of cotton quantity. J. Cotton Sci. 17:302-308.

Smith, N.E., L.S. Collar, D.L. Bath, W.L. Dunkley, and A.A. Franke. 1981. Digestibility and effects of whole cottonseed fed to lactating cows. J. Dairy Sci. 64:2209-2215.

Tharp, W.H. 1948. Cottonseed composition--relation to variety, maturity and environment of the plant, in Cottonseed and Cottonseed Products, ed by. Bailey, A.E. Interscience, New York, 117-156.

Wanjura, J. D., W. B. Faulkner, E. M. Barnes, G. A. Holt, and M. G. Pelletier. 2012. Crop residue inventory estimates for Texas High Plains cotton. Beltwide Cotton Conferences, Orlando, Florida. pp. 543-552.

Wanjura, J. D., W. B. Faulkner, and G. A. Holt. 2010. Ginning picker and stripper harvested high plains cotton. Beltwide Cotton Conferences, New Orleans, LA. pp. 628-638.

Wanjura, J. D., E. M. Barnes, M.S. Kelley, G. A. Holt, and M. G. Pelletier. 2014. Quantification and characterization of cotton crop biomass residue. Ind. Crop. Prod. 56: 94-104.

Sustainable Practices in Small-Scale Cotton Production, Hand-Picking, Fibre Processing, and By-product Utilization: Case Studies from India

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Cotton is a commercial crop with great economic importance across the world, including India, where there are 8 million to 10 million cotton farms. This article deals with case studies from India that demonstrate profitable implementation of sustainable practices in small-scale cotton farms and good practices for hand-picking, ginning, spinning, dyeing, weaving and by-product utilization.

India has an array of production practices that range from completely organic to chemical-intensive. All Indian cotton is hand-picked and is generally clean, with less than 5% trash and very little contamination. However, some contaminants — including human hair, pebbles, dust, jute, or plastic threads from the transport material — could make their way into the hand-picked cotton depending on the practices followed during picking and transportation. Seed cotton enters into the value chain through the process of ginning, in which lint is obtained and used to produce yarn, which is then used to make fabric and garments. Over the past few years, environmental awareness has prompted the adoption of many sustainable crop-production practices. Some of these production systems, both on-farm and off-farm, are more sustainable than others. The first and crucial unit of operation involved in the off-farm value chain is ginning — the conversion of seed cotton into lint. This is still considered to be one of the weakest links in many developing countries because it is characterised by excessive use of energy, low productivity, the absence of facilities for proper lint cleaning, and lint-quality assessment. Although the spinning industry in India is considered to be modern, with standards that are comparable to the rest of the progressive countries, the same probably cannot be said about the weaving/knitting sector. Further, a few factors that need immediate attention are related to downstream processing, including preparatory chemical treatments like scouring and bleaching of yarn or fabrics, eco-friendliness, energy efficiency, and the generation and treatment of effluent. Cotton by-products such as seedcake, short fibres, comber noil, and cotton stalks are either wasted or underutilized. We highlight case studies in which extra-long-staple (ELS) cotton was produced on small farms using environmentally compatible and sustainable practices, and then tracked the fibre throughout the value chain — from ginning, spinning, weaving and dyeing — using eco-friendly technologies. Short fibres were used for absorbent cotton or for the production of nanocellulose. Cotton stalks were used for the production of mushrooms, particle-boards, briquettes, pellets, compost and power generation.

A project was undertaken in ICAR-CIRCOT, India, funded by the World Bank under the National Agricultural Innovation Project (NAIP). Entitled, "A Value Chain for Cotton Fibres, Seed and Stalk: An Innovation for Higher Economic Returns to Farmers and Allied Stake Holders".

The main objectives were:

- to cultivate cotton in adopted villages using sustainable, integrated production-technology practices;
- to reduce the level of contaminants in cotton by adopting appropriate on-farm and off-farm management practices,
- to tag and label cotton bales with fibre attributes after appropriate ginning, and
- to prepare yarn, fabrics and garments in a modern mill to manufacture eco-friendly textiles in the handloom sector by deploying the Institute's proprietary technology for bio-scouring and colouring with natural dyes.

Cotton was harvested from the project farmers' fields using hand-picking practices to obtain clean cotton. Seed cotton was ginned in modern ginneries, pressed into bales, tagged with fibre parameters, and spun into yarn based on segregation of bales, and then woven into fabric. The project demonstrated that the cost of producing shirts from cotton fibres grown in a sustainable environment was much less than that the shirts of comparable quality in the marketplace. Technologies developed at CIRCOT were used to add value to by-products such as short-fibres, cotton-seedcake and cotton stalks.

Case Study #1: Sustainable Production of Fibre to Fabric

(i) Production of quality cotton using sustainable cotton production practices

A new, low-cost drip system with 150-micron poly-tubes was used, instead of the standard Linear Low Density Polyethylene (LLDPE). The poly-tube drip systems were 57.8% cheaper than the drip system commonly used today. Poly-tube drip systems were used in selected villages. It provided water savings of as much as 36% and a yield increase of 25.4%. The results showed that by adopting integrated cotton production technologies (ICPT), farmers could achieve higher yields and profits. This led to an expansion in the project area, from 6 acres to 352 acres, of ELS cotton cultivation over a four-year period in the village cluster near Coimbatore in South India. Adopting ICPT led to a mean productivity increase of 42% in seed-cotton yield with project farmers. In addition to higher yields, higher market prices for seed cotton during the experimental period cumulatively led to a higher net return of US$502/ hectare, and an improved 3.50 benefit-to-cost ratio for the project farmers. The corresponding economics of baseline per hectare was US$281 as net return, with a benefit-to-cost ratio of 1.67.

(ii) Clean-cotton picking practices

Cotton in India is harvested by hand picking. Awareness workshops on clean cotton picking were conducted in the project areas in northern, central and southern India. Women constitute between 80% and 90% of the labour force employed in cotton picking in India. They were provided with headgear to cover their hair, which is one of the major contaminants in seed cotton. Farmers were trained to segregate insect-damaged seed cotton from good, fully opened seed cotton. They were given cotton aprons with pouch that could hold as much as 3 to 4 kg of seed cotton at a time. Farmers were also provided with 20-foot by 20-foot tarpaulin sheets to place on the harvested seed cotton, thus minimising contamination by stones, dust, and other materials. Cotton bags that could hold as much as 90 kg of seed cotton were also provided. Using these improved methods of picking and storage, there was almost no contamination, and even the trash levels in ginned cotton dropped from 5% to about 2% for farmers in the project.

Figure 2. Training on 'clean-cotton picking practices'

The growers were encouraged to keep ELS separate and not mix it with any other kind of cotton. This helped farmers to get a better price for their production. Moisture content in seed cotton was determined using a probe to confirm that it was within the permissible limits of 7.5% to 8.5%.

(iii) Transporting seed-cotton in cloth bags and ginning

Seed cotton was packed in cloth bags and transported to ginning factories. Ginning was done using best management practices to obtain good-quality lint. The use of cotton bags for transporting the cotton helped to almost completely eliminate contamination.

Figure 1. Tarpaulin sheets to place hand-picked cotton

Figure 3. Transporting seed-cotton in cloth bags

(iv) Baling and 'bale-tagging'

The lint was pressed into individually tagged 170-kg bales; samples were drawn at the time of bale pressing and identified with the corresponding bale number. Each of these lint samples was tested on HVI – fibre testing

Figure 4. Baling and bale-tagging

machines for measurement of fibre attributes, namely, 2.5% staple length, % uniformity ratio, micronaire for fineness and bundle strength at 3.2 mm gauge length. The label on each bale was then updated with the corresponding fibre attributes as determined by the HVI machines.

(v) Spinning after segregation of bales based on fibre properties

Pressed bales with tagged fibre attributes were transported to selected spinning mills in each region. Bales were segregated based on their fibre properties, with major emphasis on fibre fineness. Lots of 8 to 10 bales each were then spun into yarn of suitable count depending on the fibre properties. Bales of ELS cotton were converted into 80s-count yarn.

Figure 5. Spinning

(vi) Weaving and fabric properties

Samples were drawn from the yarns of different groups and used for testing. The remaining bulk was converted into fabrics and garments. Researchers studied fabrics belonging to particular groups of yarns, spun from

Figure 6. Natural dyes for cotton

segregated groups of bales based on fibre properties, with an emphasis on dyeing properties.

(vii) Bio-scouring of yarn and fabric

Cotton fibres in the raw state have wax on their surface thus making them water repellant. Though cellulose of which cotton fibres are made (more than 95%) is highly hygroscopic, cotton fibres do not get wet in water. A chemical process called scouring is used to remove the surface wax and make the fibres hydrophilic (water absorbent), which is necessary for dyeing, printing and finishing. The chemical process of scouring uses alkali sodium hydroxide at high temperatures and pressures, which consumers a lot of energy. These methods also pollute the environment. CIRCOT developed a biological scouring process that uses a microbial consortium.

Figure 7. Eco-friendly bio-scouring

(viii) Dyeing bio-scoured yarn and fabric with natural dyes

In the first part of the study, about 80 kg of bio-scoured yarn in hank form was dyed with natural dye in three different colours at the Khadi and Village Industries Commission (KVIC), Coimbatore Unit. The dyed yarn was then converted on a handloom into fabric that was 350 meters long and 60 inches wide. The 80s-count yarn from ELS cotton was converted into fabric of about 55 GSM. A small part of it was processed and dyed.

Case Study #2: Treating Cotton Seedcake to Reduce Gossypol

Cotton Seedcake is mostly used to feed ruminant animals such as cattle, sheep and goats. The seed cake is not suitable as food for humans and non-ruminant animals such as fish and poultry due to the presence of gossypol at 0.6% to 1.15% (0.05 – 0.7% free gossypol). It is essential to remove gossypol from the cotton seedcake or reduce its content below harmful levels before it is fed to non-ruminant animals. CIRCOT has developed a technology to reduce free gossypol by 80%, bound gossypol by 60%, and crude fibre by 30%. The technology improves protein content by 40% and lysine content by 25%. Cotton seedcake processed by the CIRCOT technology meets the standards defined by the United Nations Protein Advisory Group (UPA), making it suitable as a human protein supplement and to feed poultry and fish.

Pilot scale treatment plant (one tonne/day capacity) to reduce gossypol

A. Capital investment:

- Land and structures (2,000 m^2 for land; 50 m^2 for a building to house the equipment; 500 m^2 for material storage; 40 m^2 for an office building). Cost: US$7,962
- Plant and equipment: US$13,846
- Auxiliary and service equipment (electricals and handling tools): US$1,538
- Total investment: US$23,077

B. Operational expenses:

- Raw material cost for 4 months (1 tonne/day for 120 days @ US$330 per tonne): US$36,923
- Operational costs including repair, maintenance and other charges (US$46/tonne) for 4 months: US$5,538

C. Gross annual income: (US$385/tonne): US$93,308

D. Net annual income: (US$33/tonne): US$7,385

- Payback period: 38 months
- Return on investment: 26.3%

Case Study #3: Utilization of Short-Staple Cotton and Short Fibres

(i) Production of nanocellulose

Nanocellulose with a size of less than 100nm is characterized with high mechanical strength (1 to 10 GPa), high young modulus (100-130 GPa), high surface area (50 to 200 m^2/g) and novel optical properties. Nanocellulose is biodegradable. It can be used in virus infiltration, emulsion/dispersion stabilizer, liquid crystal displays, non-caloric food thickeners, targeted drug delivery, fillers in cement and film, paper coating, and furnish additives. CIRCOT has the distinction of setting up the world's 5th nanocellulose pilot plant. The plant has a capacity of 10 kg nano-cellulose per day.

Figure 8. Nano-cellulose pilot plant & Nano-cellulose products

(ii) Absorbent cotton

Generally coarse (micronaire > 6.0) and short-staple cotton is ideally suited for the manufacture of surgical-grade absorbent cotton. Short fibres that are obtained as mill waste are commonly called "comber noil". These are used as raw material to manufacture technical textiles, surgical-grade absorbent cotton, medicated cotton, ear buds, waddings, security paper, currency notes, blends for coarse yarn, and open-end spinning for denim production.

Absorbent cotton maufacturing plant

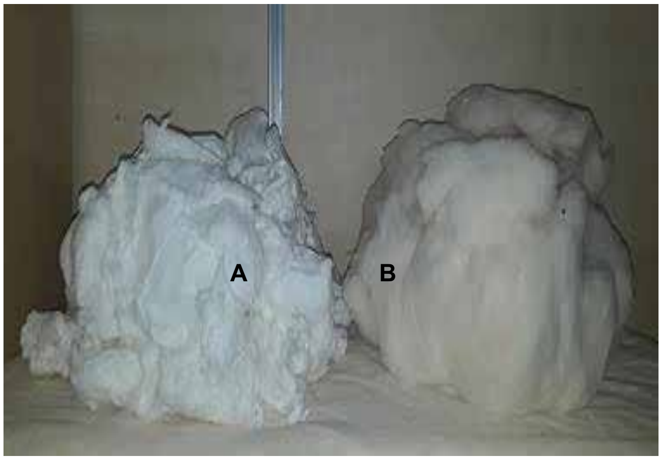
A. Capital investment: (1.5 tonnes/day capacity)

- Land and building: (land area: 1,000 m^2; building for machinery: 600 m^2; material storage area: 200 m^2; office building: 300 m^2) US$7,692
- Plant and equipment: US$61,538
- Auxiliary and service equipment (electricals and handling tools): US$7,692
- Total investment: US$76,923

B. Operational expenses

- Raw material cost for 3 months (1.5 tonne per day for

Figure 9. (A) Absorbent cotton and (B) Raw cotton



90 days @ US$1,385 per tonne): US$186,923

- Operational costs including repair, maintenance and other charges (US$615/tonne) for 3 months: US$83,076

C. Gross annual income: (US$2,925/tonne) US$1,315,384

D. Net annual income:(US$770/tonne): US$34,615

- Payback period: 27 months
- Return on investment: 37%

Case Study #4: Commercial Utilization of Cotton Stalks

In many developing countries, cotton stalks are either burned or used as firewood. However, studies have shown that cotton stalks can be utilized for commercial purposes to generate power and to produce particle-boards, briquettes, pellets, mushrooms etc.

(i) Briquetting & pelleting plants

About 110 briquetting plants with a capacity of 20 tonnes/day and 50 pelleting plants with a capacity of 60 to 80 tonnes/day have been installed near Nagpur, India. Generally, briquettes of 90 mm diameter and pellets of 6 to 10 mm diameter are produced. Briquettes are used as a substitute for coal as fuel in industrial boilers, brick kilns, etc. Briquettes cost 80% less than coal and are considered as a renewable resource. Pellets are used in industrial boilers and for stoves in restaurants. Pellets are 50% cheaper than LPG gas cylinders. Cotton stalks from one hectare are worth US$45 to US$50 and can provide additional source of revenue for farmers.

Briquetting plant

A. Capital investment: (20 tonnes/day capacity)

- Land and building (Land area: 2 acres; building for machinery: 150 m^2; material storage area: 1000 m^2; office building: 50 m^2): US$23,077

Figure 10. Briquetting & pelleting plant

- Plant and equipment: US$38,462
- Auxiliary and service equipment (chipper (3) and handling tools): US$7,692
- Total investment: US$69,231

B. Operational expenses

- Raw material costs for 3 months (20 tonnes/day for 90 days @ US$43 per tonne): US$77,538
- Operational costs including repair, maintenance and other charges (US$10/tonne) for 3 months: US$16,615

C. Gross annual income: (US$70/tonne): US$369,231

D. Net annual income: (US$7/tonne): US$36,923

- Payback period: 23 months
- Return on investment: 43.5%

Pelleting plant

A. Capital investment: (3 tonnes/day capacity)

- Land and building: (land area: 0.5 acre; building for machinery: 100 m^2; material storage area: 500 m^2; office building: 50 m^2): US$7,692
- Plant and equipment: US$15,385
- Auxiliary and service equipment (chipper (1) and handling tools): US$3,077
- Total investment: US$26,154

B. Operational expenses

- Raw material for 3 months (3 tonnes per day for 90 days @ US$43 per tonne): US$11,630
- Operational costs including repair, maintenance and other charges (US$45/tonne) for 3 months: US$12,253

C. Gross annual income: (US$115/tonne): US$103,846

D. Net annual income: (US$15/tonne): US$8,308

- Payback period: 33 months
- Return on investment: 30.3%

Figure 11. Pelleting plant at the Ginning Training Centre (GTC), Nagpur, India

Figure 12. Particle board plant at GTC, Nagpur, particle boards and furniture made from particle boards

(ii) Power generation

A total of 225 power plants with a capacity of 4831 MW have been installed in India. About 50 tonnes of cotton stalks can produce 1 MW power generation. The stalks are a renewable source for power generation. Power plants accept cotton stalks with high moisture content of 50 - 60 % wt. basis.

Power generation plant

A. Capital investment: (30 MW capacity)

- Land and building (land area: 5 acres; building for machinery: 50 m^2; material storage area: 5000 m^2; office building: 50 m^2): US$1.53 million
- Plant and equipment: US$12.37 million
- Auxiliary and service equipment (crushers, gridding, chimney, etc.): US$1.53 million
- Total investment: US$15.43 Million

B. Operational expenses

- Raw material cost for 3 months (1,500 tonnes/day for 90 days @ US$43 per tonne): US$5.80 million
- Operational costs including repair, maintenance and other charges (US$461/MWh) for 3 months: US$29.90 million

C. Gross annual income: (US$877/MWh): US$227.29 million

D. Net annual income: (US$0.25/MWh): US$3.84 million

- Payback period: 48 months
- Return on investment: 25%

(iii) Particle boards

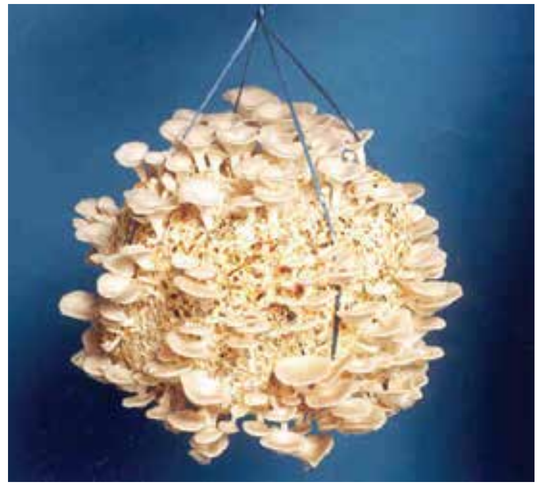
Particle boards are used in furniture making, partitioning, paneling, drop-ceilings, etc. One ton of cotton stalks can be used to produce 600 kg of particle boards. Particle- board factories accept cotton stalks as a substitute for bagasse. In India, particle boards from cotton stalks conform to IS standard 3087-1985. Pilot plants were set up to demonstrate the utilization of cotton stalks to manufacture particle boards, pulp and paper, hard boards, etc.

(iv) Compost

CIRCOT has developed an accelerated process for compost preparation. Compost is enriched with nutrients and plant-growth-promoting microorganisms. It is stable for about one year. Compost from cotton stalks contains nitrogen, phosphorus and potash (N:P:K (%) 1.43: 0.78: 0.82) at higher levels than the NPK content of farm yard manure:

Figure 13. Composting, cotton stalks and compost

Figure 14. Mushrooms



(N:P:K (%) 0.5: 0.2: 0.5). Moreover, it takes only 60 days to produce compost from cotton stalks, whereas it takes 120 days to produce a comparable amount of farm yard manure (FYM).

About 800 kg of compost can be produced from one tonne of cotton stalks. The procedure involves the chipping of stalks, and mixing with:

- 0.2% sodium hydroxide,
- 10% cattle dung,
- 1.2% urea,
- 2% diammonium phosphate,
- 1% microbial consortia, and
- 50% water.

The mixture is then covered under polythene sheets and stirred once a week for two months.

(v) Mushroom production

Edible oyster mushrooms can be grown on cotton stalks, with yields up to 500g of mushrooms per kg of cotton stalks. Small-scale mushroom production units were found to be viable in small villages.

Summary

Cotton is a commercial crop of great economic importance. A well-established value chain exists in which seed cotton is converted into lint, spun into yarn and woven into fabric and finally converted into garments that cater to the demands of both internal consumption and export. Sustainability is emerging as a concern for major commercial brands in recent times. There is enhanced awareness to deploy sustainable farming practices in cotton production and use sustainable processes for the conversion of fibres into high quality fabrics and cotton byproducts into high value commercial products. Value addition to cottonseed and stalks not only enhances livelihood options but also reduces vulnerability of small scale farms to the market risks and uncertainties. The globalization of supply chains coupled with the ever increasing consumer and stakeholder preferences for sustainable and ethically sourced products, are gradually leading towards sustainability becoming recognized as a core procurement requirement.

References

Key Note, Green and Ethical Market Assessment 2012 http://www.keynote.co.uk/marketintelligence/view/product/10537/green-and-ethicalconsumer?highlight=green+and+ethical+consumer&utm_source=kn.reports.search

Forbes, Understanding the Spend Shift 2010 http://www.forbes.com/2010/11/29/recession-consumersvalues-spend-shift-sentiment-shopping-sales-leadership.html

http://awsassets.wwfindia.org/downloads/cotton_market_and_sustainability_in_india.pdf

Sustainable Cotton Project, 2015

http://www.sustainablecotton.org/pages/show/cleaner-cotton-marketing-cmpaign

UN Global Compact Global Corporate Sustainability Report 2013

https://www.unglobalcompact.org/AboutTheGC/global_corporate_sustainability_report.html

http://www.wwf.se/source.php/1544267/RSPO%20SCCS%20factsheet.pdf

Best Ginning Practices

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Abstract

The market share of cotton fibre is decreasing progressively as compared to man-made fibres mainly due to a surge in the production of the cheaper synthetic alternatives. Reducing the cost of cotton production and processing can be an effective way to compete with man-made fibres. Scientific ginning practices can help to minimise costs, preserve cotton-fibre parameters, and reduce both energy consumption and manpower in the processing of cotton. Ginning can be made more efficient by adopting up-to-date handling and cleaning systems and allied machineries and also by selecting the most appropriate processing technologies in ginning and pressing factories for different varieties and types of cottons. Development of improved universal standards for trash content in the baled cotton and harmonization of a universal bale size of common weight would optimise global machineries, thereby greatly reducing costs across the globe. This paper discusses the best ginning practices to enhance efficiency, preserve quality and increase cotton fibre output so that the value realization of the cotton can be improved to achieve competitiveness.

Introduction

Cotton is the purest form of cellulose, which is what makes it a great product. Its softness and breathability make it the world's most comfortable fibre to wear. However, in the present era, cotton is facing unrelenting competition from man-made fibres. Despite the fact that cotton consumption has increased from 18.5 to 25.5 million tons over the last 25 years, the market share of cotton in textile fibre consumption has decreased from 45% to 27% during the same period. In contrast, man-made fibre consumption has continued to expand at a higher rate than cotton consumption. According to the latest data available, man-made fibre consumption rose from 19 million tons in 1993 to 67 million tons in 2017. As a result, the market share of man-made fibres has increased by more than 23 percentage points, from 48.4% to 72%, during the same period. This is mainly due to the rapid surge in the production and use of cheaper chemical fibres compared to the ever-increasing costs of cotton production and processing. The best textile mills in the world lose 3% to 8% of a cotton bale due to short fibres and other defects, whereas every single fibre in a bale of man-made fibre is used with zero (or negligible) waste. Further, man-made fibres provide retailers and brands with higher profit margins.

The competitiveness of cotton can be enhanced if higher fibre yields can be obtained with lower costs for production and processing. While efforts are being made across the globe to reduce the cost of production and increase yields, ginning and pressing technologies need to be improved to reduce costs, enhance fibre recovery, and preserve quality. Finding new applications for cotton fibre also would strengthen its competitiveness.

The discussions presented in this paper are restricted to the best practices recommended for ginning factories. The main objectives of best practices are to:

- reduce the cost of processing per unit,
- enhance efficiency,
- preserve quality, and
- increase fibre output from the extant varieties of cotton in different parts of the world, so as to ensure sustainable and profitable growth for the cotton-processing sector.

Nature of Ginning Gactories that Influences Costs and Fibre Quality Parameters

The majority of the ginning factories worldwide can be categorized into three primary groups:

1) **Ginning factories in private/co-operative sector operating on a 'job-work' basis:** These ginners seek a higher volume of ginning per hour so they can charge more money for conversion of seed cotton into bales. When cotton is ginned on a job-work basis, the client owns the seed cotton and the ginner is seldom concerned about conserving the fibre quality parameters or preventing fibre waste.

2) **Ginning factories in the government sector:** The governments of many countries have adopted monopolistic cotton-purchase schemes and have set up ginning factories with government funds or term loans from international financial institutions. These

ginning factories have the advantage of purchasing seed-cotton from farmers in large quantities, generally at lower price that might be fixed by government officials. Government employees or political appointees often run these types of ginning factories. The employees, in most cases, aren't particularly concerned about fibre quality or ginning efficiency. Further, it is quite likely that ginning machinery is not really suited for the varieties grown in that region, which could be either due to lack of scientific knowledge or because they simply don't want to pay more to procure the proper machinery.

3) **Owner/trader ginners in the private sector:** In this case, the ginner purchases seed cotton from farmers or middlemen, gins it and sells the lint to traders or spinners. Normally this type of ginner tends to select proper ginning technologies that are suitable for the cotton fibre grown in the area. However, ginners in the private sector often are guided by the existing ginning technologies prevalent in the area mainly due to operational reasons or national standards/grades fixed for the cotton sale and trade practices in that region.

Factors that Significantly Influence Fibre Quality and Trash Levels

National standards for cotton trash

Most countries do not have well-defined standards for trash percentage and cotton. In these countries, cotton is traded based on outdated practices that were established before cleaning systems were upgraded. In some cases, the authorities involved in drafting national standards for cotton trash and other fibre parameters could be influenced by what is done in other countries, where the cotton parameters may be very different. For example, in India, the authorities drafting the standards for cotton parameters as per Bureau of Indian Standards may have been influenced by the standards prevailing in United States of America. The problem is that US cotton is machine picked, while in India it is handpicked. In the USA, machine-picked cotton might have 15% trash, while in India, the trash levels could be less than 2% due to handpicking. Thus, the trash percentage mentioned in the standards for various grades of cotton might be the same in both countries — for example, 3% final trash in lint for grade-1 cotton, while for grade 6 it could be 12%. Spinning mills follow these standards for arbitration and reference; therefore, if they allow up to 3% trash in grade-1 cotton — and the ginner has access to clean-cotton with 1% to 2% trash — the ginner might be inclined to allow up to 3% trash content to make more money. In many countries where spinning mills accept cotton with up to 8% trash as normal, ginners tend to maintain trash levels of 8% because they don't earn a premium for providing clean cotton.

An argument is being advanced that these standards are optional rather than mandatory. However, if spinning mills do not reference standards in their regular documentation, resolving disputes could become difficult. Further, these standards are also used as benchmark standards for importing cotton from overseas. Ideally, however, it would be appropriate to prepare different standards for machine-picked and handpicked cotton.

If the national or international standard for grade-1 cotton is fixed at 1% and the number of grades could be increased — such as grade-2 for 2% trash, grade-3 for 3% trash, and so on — the prices in the market would be fixed for such grades. At present, grades start at 3% trash. With such revised standards in operation, spinning mills could get cotton with a low trash cotton at a better price through brokers or centralized sales organizations. These standards could then be strictly enforced for all similar types of cotton. In the case of clean, handpicked cotton, if trash percentage were fixed as 1%, ginners would have to clean the cotton to that standard. It's not a common occurrence but at present, special prices are fixed for cotton with low trash only when the spinners and ginners deal directly with, and trust, each other. Interestingly, there is hardly any standard in the world that starts from, even or specifies, cotton trash at rates of 1% or less. In the absence of such high standards, there is no incentive to produce clean cotton even when it is very much possible.

Trading pattern of cotton bales

In many countries, cotton is sold through sales organizations or brokers who are not ready to make any extra effort in cleaning, due to the lack of any incentives for doing so. They do not get any additional revenue for higher-quality clean cotton, especially when a uniform price is offered across the board for cotton bales of a specific fibre quality in a region, irrespective of the trash levels. Such practices prompt ginners to maintain their trash percentage at higher levels, thus contributing to the deterioration of the fibre parameters. The broker or parent sales organization offers a common price for an entire lot based on a particular standard, such as grade-1 cotton up to 3% trash, but do not offer any premium if a ginner offers lower the percentage to 2% or less. As mentioned earlier, this provides no incentive for ginners to adopt practices to reduce the trash content below 3%. If other ginners have already established a price for cotton with 3% trash, no one would work harder to deliver cotton lint with less than 3% trash.

Sampling of cotton bales

In most countries, lint samples are only taken from random bales, not each one. This lowers the level of trust, thereby reducing prices. In the USA, samples are drawn from every bale and sent to testing centres established by the USDA, which greatly enhances accuracy and improves trust, resulting in better prices.

Unskilled manpower for operation of ginneries

The settings and maintenance of ginning machinery have a significant effect on efficiency, energy consumption and processing costs, in addition to affecting the quality of the fibre. Gin setting is an art that can be perfected through practice under the supervision of skilled trainers. The skill of the operators influences the quality of bales produced by a ginnery. However, the availability of trained gin workers is low. Many ginneries operate with unskilled manpower, resulting in deterioration of fibre quality parameters and increasing the likelihood of trash and contamination in bales. Hence, it is essential that facilities should be established for the training of ginning operators, and the resulting trained workers should be employed to maintain fibre quality.

The Impact on Costs and Fibre Parameters When the Wrong Ginning Technology is Used

The selection of a ginning technology should depend upon factors such as harvesting practices, trash content, moisture content, fibre length, fuzziness, strength, etc. — not primarily on capital costs, the funding institution or sponsoring country. Generally, ignorance of the appropriate ginning technologies for specific types of cotton varieties in the region of a ginning factory greatly affects the quality of bales. It is important to understand the four main ginning technologies and their influence on fibre quality parameters.

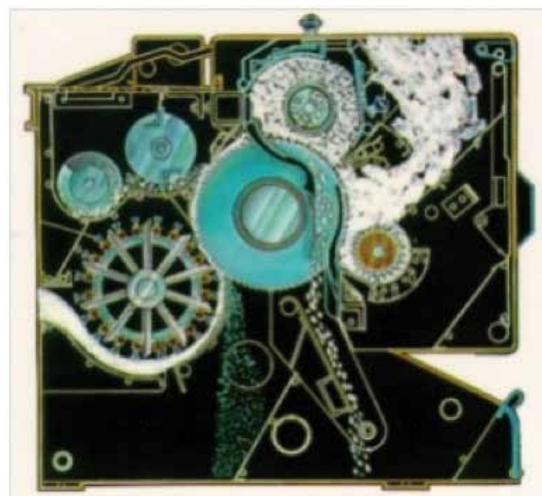
Figure 1. Saw gin machine

Saw ginning

Two types of saw ginning are used: (i) brush doffing and (ii) air blast. Further, some saw gins use 16-inch saws while others use 12-inch saws, which have different economics. Saw ginning is more suitable for upland cotton fibres (<29 mm), which adhere strongly to the seed and require higher force to detach them. Saw ginning constitutes about 50% of the world cotton ginning industry. The productivity per unit of electrical consumption is higher in brush-type saw gins than in air-blast type saw gins. In the past, there was more space between the two saws than there is in today's gins, in which the saws are closer to obtain the highest capacities.

Figure 2. Working principle of air blast type saw gin

Figure 3. Working principle of brush type saw gin



Several studies have shown that saw-ginned lint is shorter (0.5 mm to 1 mm), less uniform and contains more neps than roller-ginned lint. Saw-ginning technology is suitable for high-strength and high-maturity cotton varieties with length of up to 29 mm. If longer (>29 mm) fibres are ginned on saw gins, the fibre length is reduced and has less value. Residual lint on the seed is higher as well, making delinting necessary and adding to costs.

Double-roller ginning

This ginning technology is suitable for clean cotton — with length >28 mm, medium strength and micronaire in the range of 2.2 to 4.2 — and preserves fibre parameters near to their maximum. The method can be used either for fuzzy long-staple varieties or Sea Island black/naked seeded varieties. Seeds obtained from double-roller gins have lower fuzz on the seed, which can be directly crushed for oil milling without the need for delinting. Studies show that the oil-to-seed ratio is high. Further, the fibre obtained has fewer neps. Double-roller ginning technology is extensively used in India and East Africa and has about a 35% share in the global ginning sector.

Figure 4. Double roller gin with auto feeder

Figure 5. Working principle of double roller gin

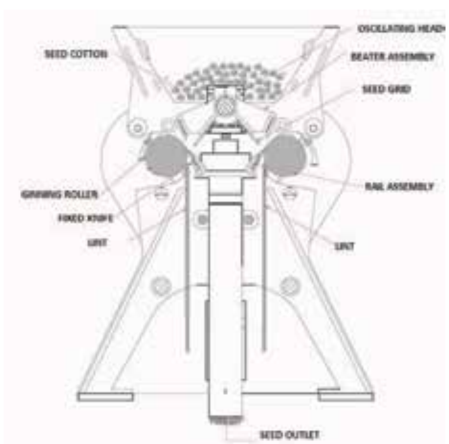


Figure 6. View of a double roller gin plant

Rotobar rotary-knife roller ginning

This technology is suitable for Sea Island or long-staple cotton in which the fibre does not strictly adhere to the seed and the lint can be pulled off, leaving the seed naked. The production rate of lint is much higher (400 kg to 800 kg per hour for extra-long staple cotton) than other roller-ginning machines, which have a production rate of about 50 kg to 150 kg of lint per hour. However, if rotobar ginning is used for fuzzy seed cotton, the production rate is almost cut in half. The production rate per unit of power consumption for fuzzy seed cotton is lower for rotary-knife roller gins, which use a 15 HP electrical motor, than for double-roller and single-roller gins, which utilise a 5 HP electrical motor. Further, seed fragments get mixed with ginned seeds and raw seed cotton, which makes the technology less preferred for fuzzy seed cotton.

Figure 7. Rotobar gin

Figure 8. Working principle of rotobar gin

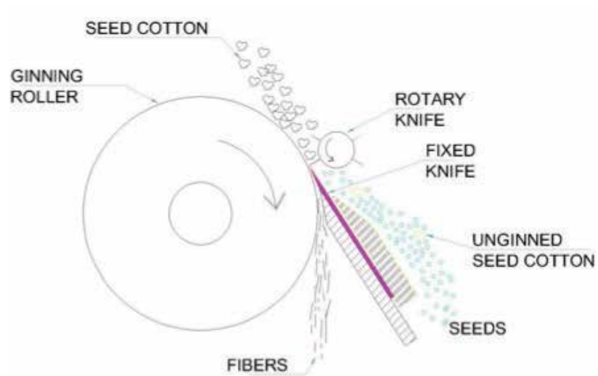


Figure 9. View of a rotobar ginning plant

Figure 10. Working principle of single roller gin

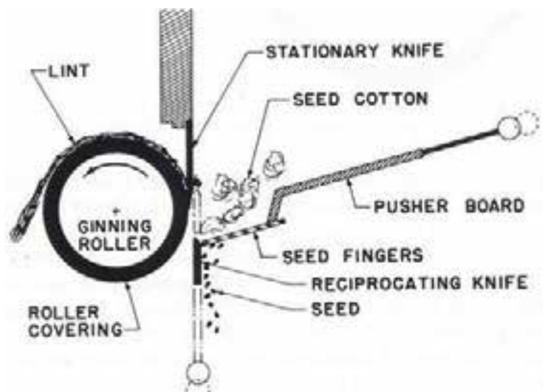


Figure 11. A single roller gin

Single roller McCarthy ginning

Single-roller ginning is one of the oldest technologies wherein rollers separate fibres from the seed by pulling them gently. This technology has long been the preferred method for ginning extra-fine, extra-long-staple fibres such as Sea Island, Egyptian and Pima cottons (Bennett 1956). While it is possible to gin all types of cotton on single-roller gins, the technology is better suited for long and extra-long cotton varieties because it retains maximum natural fibre parameters. Single-roller gins can handle higher trash levels and also gin both fuzzy seed or sleek/ black seed varieties. However, one major disadvantage of the single-roller gin is its lower ginning capacity — about 25 kg to 40 kg of lint per hour — despite the use of a 5 HP electrical motor, the same kind used in double-roller gins. Lint production (as determined by unit of electricity consumption per square meter of space) is low and operating and maintenance costs are high compared to other technologies.

Figure 12. View of a single roller ginning plant

Major Cost Factors in the Conventional Ginning Factories

Capital cost for ginning and pressing factories

Capital cost differences are mainly due to the different needs and layouts of various ginning factories.

Seed-cotton unloading and storage section

Unloading of seed cotton can be done using installations such as telescope, tractor attachments and automated

Figure 13. Unloading of seed-cotton by tractor attachment

Figure 14. Unloading of seed-cotton by telescope

Figure 15. Vertical flow dryer

Figure 16. Open spreading of cotton in storage area

Figure 17. Desired cleaning setup for handpicked seed cotton

Figure 18. Cleaning & conveying setup for machine picked seed-cotton

unloading by the hydraulic movable base of cotton-carrying vehicles. The need for such installations depends largely on the availability of manpower and the comparative cost-effectiveness of the unloading methods.

Seed-cotton drying section

Seed cotton is dried either by spreading the lots in open areas under sunlight or by blowing hot air over it. Cotton drying in ginneries is largely ignored even when moisture levels being higher than recommended. This reduces gin productivity and the quality of fibres, since cleaning and ginning machines operate optimally at 6% to 8% moisture content.

Seed-cotton conveying and cleaning section

Handpicked cotton has low trash levels and is generally clean. Such cotton rarely requires conveying and cleaning. Machine-picked cotton, on the other hand, contains trash and needs to be conveyed and cleaned before it is ginned. The selection of seed-cotton conveying and cleaning equipment should be determined by the harvesting method. In many countries (especially in West Africa, where cotton is handpicked and has low trash levels), full sets of cleaning and conveying machines — which are otherwise used for mechanically picked cotton — have been installed improperly. These systems not only waste capital and increase maintenance costs, but also damage fibres to some extent.

Figure 19. Seed-cotton feed control

Figure 20. Seed-cotton feeding through central distribution conveyor

Uniform seed-cotton feeding systems

Manual feeding of seed cotton in ginneries raises manpower requirements and processing costs, in addition to leaving more trash in the fibre than automated feeders. Additionally, manual feeding of seed cotton onto belt conveyors and suction systems results in heterogeneous feeding to ginning machines, reducing gin productivity by about 20% and increasing processing costs. A cotton-dispenser-cum-cotton-feed-control system has recently been introduced in ginneries across the world to provide uniform feeding of cotton. This feeding system reduces manpower requirements and reduces power consumption by about 25%. It also filters out foreign matter from seed-cotton lots. The cotton-dispenser-cum-cotton-feed control system could be employed in ginneries to improve cotton quality and to reduce power requirements, manpower and capital investment.

Figure 21. Seed-cotton feeding through trolley system

Figure 22. Seed-cotton dispenser with stone remover

Seed-cotton cleaning system

Seed-cotton cleaning is a very important aspect in maintaining the quality of cotton processed in gins. There are a number of machines available for cleaning seed cotton, including cylinder-type cleaners, stick machines, impact cleaners, and extractor cleaners, among others. The selection of cleaners for a gin is determined by the amount of trash present in seed cotton. Normally, handpicked cotton has about 1% to 3% trash content, which can be easily cleaned using a line of cylinder-type cleaners with 4 to 6 spiked cylinders.

Cleaning of semi-closed bolls

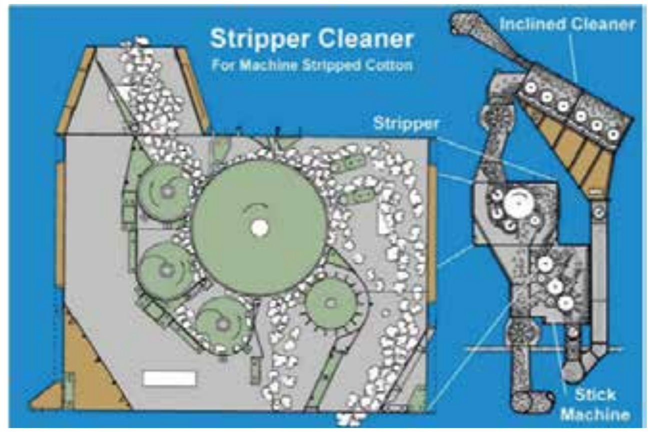
Some cotton varieties in India, such as V797, CJ73, Wagad, Kalagin, produce bolls that do not open fully so the cotton cannot be easily picked. Similar cottons are also produced in Pakistan and Turkey. Bolls along with burrs are separated from plants and routed to special cleaning machines, which break the pods and sift the material to separate relatively clean fibres.

Figure 23. Pre-cleaner for handpicked cotton

Figure 24. Impact cleaner for leaf trash

Figure 25. Stick machine for cleaning machine picked seed-cotton

Figure 26. Stripper cleaner for cleaning machine picked seed-cotton



Figures 27. Pod & leafy trash cleaning machines for semi-open boll seed-cotton

Figure 28. Rotobar gin

Figure 29. Brush type saw gins

Figure 30. Air-blast type saw gin

Figure 31. Individual gin lint suction system

Figure 32. intermittent lint suction system (ILSS)

Seed-cotton ginning machinery section

Different types of ginning machines are suitable for different types of fibres. Therefore, proper selection of ginning machines is extremely important to ensure good-quality fibres and to minimise processing costs. Choosing the wrong machines can result in negative consequences. For example, if a single-roller or rotobar gin is chosen for fuzzy seed, it may consume more electrical power and reduce efficiency, causing a substantial spike in costs. Similarly, if a saw-ginning machine is used for long- and extra-long-staple cotton, it may cause damage to fibres and reduce yields. If roller ginning is selected for seed cotton with extra-strong fibre and a length below 28 mm, it will result in higher processing costs.

Conveying from the gin to the lint-cleaning section

There are several different methods for conveying lint from the gin to cleaners, such as the continuous individual gin lint suction system, the intermittent lint suction system, belt conveyors, etc. Proper selection of conveying systems can preserve fibre quality, reduce power consumption and minimise costs.

Lint-cleaning section

Different methods of lint cleaning are available across the world. Some of the common lint-cleaning methods include spiked cylinder, saw type, and air jet. The degree of cleaning differs depending upon the fibre, trash and moisture content. Proper selection of lint-cleaning equipment can save significant wastage of energy, reduce fibre damage and optimize processing costs.

Figure 33. Lint conveying from each gin through belt

Figure 34. Spiked cylinder lint cleaner for handpicked cotton

Figure 35. Saw type lint cleaner for machine picked cotton

Figure 36. Centrifugal (Air-jet type) lint cleaner

Figure 37. Hot air humidification system used for restoration of lint moisture

Cotton lint moisturizing and conditioning section

Moisture content of 8% to 9% in lint is ideal for the formation of bales in proper shape and size, with minimal energy consumption. Pressing cotton that has less than 8% moisture content increases energy consumption and reduces the density of pressed bales that increases transportation cost. Nevertheless, there are instances in ginneries where cold atomised water is sprinkled over lint to increase its moisture content. However, cotton's natural wax layer prevents water from penetrating into fibres. This results in an accumulation of water on the surface of cotton fibres, leading to formation of fibre lumps in bales, yellowing and degradation of fibre, and other problems. As a result, spraying cold water totally defeats the purpose of enhancing moisture content and actually results in losses. The best practice for increasing moisture in cotton is by induction of hot, humid air over lint, reducing surface tension and enabling moisture to penetrate the cotton fibres as air passes through the lint.

The hot-air humidification system improves cotton's moisture content, strength and grade, enabling the ginner to get a higher price for higher-quality lint. Thus, hot-air humidification systems should be installed in ginneries to reduce energy consumption during bale pressing, decrease transportation costs, improve bale quality, and get better prices.

Cotton lint baling section

Modern up-packing/down-packing oil hydraulic, door-less, double-box and single-stage presses are used in ginneries for bale formation. Modern baling presses are commonly employed with online bale handling, weighing and bagging systems that reduce manpower requirements in ginneries. When there are more cotton bale presses than the gin can use, there is a waste of power and higher capital costs. Therefore, it is important that the baling press capacity matches that of the ginning capacity. Different countries have different sizes and different weights for cotton bales, whereas the uniform standard bales (as per ISO 8115) could be used worldwide to reduce packing costs as well as enable bale-opening machinery to be standardised across the world. A bales size of 42 inches by 21 inches complies with the principle that length and width should be in proportion to 2:1 for best space utilization. Proper compression — about 500 kg/m^3 and uniform weight of 227 kg (500 pound) — will save on shipping costs. The production of uniform bale-presses worldwide would reduce the capital cost of setting up of bale-presses as well.

Manual loading of cotton bales and non-standard sizes of bales

The weight of cotton bales in different countries appears to have been standardized considering the strength of manpower to load them on vehicles, since many persons are required for loading and unloading. For example, the weight of a bale is 80 kg in China, which can be lifted by two persons; the weight is 165 kg to 175 kg in India, which is lifted by four persons whereas the weight of a bale in Africa ranges from 150 kg to 300 kg, also to be lifted only by 4 persons. The alternative mechanical methods such as forklifts and tractor attachments have now been introduced and can greatly reduce manpower. Further, if a common standard size and weight of cotton bale is adopted worldwide, it would be easy to develop cost-effective handling devices.

Figure 38. Down packing baling press

Figure 39. Up packing baling press

Figure 40. Manual packing bale press

Figure 41. Bales press with bale bagging arrangement

Figure 42. Bale loading by forklift

Conveying of cotton seed from gins to the storage and packing section

There are different kinds of seed-conveying and packing methods, including:

- bucket elevators,
- screw conveyors,
- root blowers,
- seed blowers,
- manual bagging at multiple points,
- manual weight adjustment, and
- online weighing and bagging.

A careful selection of cost-effective methods will simplify the operation and provide substantial savings on manpower costs.

Fire-detection and diversion systems

Ginneries are prone to catch fire, which results in significant financial losses. The risk of fire hazard is further aggravated due to increased automation and the use of large volumes of air for material-handling systems. Recently, sensor-based fire-detection and diversion systems have been introduced to mitigate the risk of fires. This system also significantly reduces the manpower needed to douse a fire and to clean the premises after an accident.

Figure 43. Cotton seed conveying

Figure 44. Cotton seed conveying root blower

Figure 45. Cotton manual seed bagging

Figure 46. Cotton seed bagger

Electricity consumption per unit of production

Higher electricity consumption per unit of production is also one of the major contributors in increasing the cost of cotton processing. The recent adoption of new methods has resulted in substantial power savings. Fox example, until 2012, a double-roller gin plant for handpicked cotton that operates at about 15 bales per hour *BPH) used to have a connected load of about 600 HP, but it has now

Figure 47. Fire detection and diversion system for ginneries

Figure 48. Seed-cotton suction

been reduced to 400 HP for the same capacity. Some of the recent developments that have taken place in the recent past include:

Seed-cotton suction systems have been replaced with seed-cotton dispenser systems with tractor attachments

This has resulted in a reduction of electrical motor power, from more than 50 HP to about 20 HP, for the entire system in 15 BPH per plant.

Individual double-roller gin feeding distribution conveyors have been replaced with central distribution conveyor systems

This has resulted in a substantial savings of about 20 HP in installed electrical power required.

Figure 49. Seed cotton dispenser cum stone removing system

Figure 50. Seed cotton feeding by tractor attachment

Figure 51. Individual lane distribution screw conveyor

Lint-suction systems have been replaced by intermittent lint-suction systems

This has reduced the installed electrical power requirements from 30 HP to 10 HP for a 15 BPH plant.

Belt conveyors have replaced conveying of seed cotton by suction

This has resulted in reduction of about 50 HP electric power for a normal 15 BPH factory.

Figure 52. Central screw conveyor & seed-cotton feeding system

Figure 53. Conventional cotton lint suction system

Figure 54. Intermittent lint suction system

Conveying of lint by suction has been replaced with belt conveyors system

The electricity costs for conveying lint from one point to the other by suction are high because the systems require high air volume. For example, a plant with a 15 BPH capacity requires about 100 HP for two suction systems. With belts, the same task can be accomplished using only 6 HP.

Figure 55. Seed cotton suction system

Companies that manufacture ginning machinery are conducting further research to minimise power consumption in the ginneries.

Manpower cost per unit of production

Manpower is a significant contributor to the final cost of cotton. Operating a conventional ginning factory with a capacity of 15 BPH might require 100 or more people. New developments from ginning equipment manufacturers have resulted in substantial reduction of manpower requirements. These significant changes include:

Tractor-mounted buckets feeding through dispenser units have replaced seed-cotton suction systems

Previously, it took about 10 people to handle each suction system feeding the average 15 BPH ginning factory. Now, due to the introduction of a dispenser system, only 2 people are needed.

Online bagging and weighing of cotton bales is replacing manual weighing

Previously, four people were required to handle manual bagging and weighing of each bale; now only one person is needed.

Online bagging and weighing of 'cotton seeds' is replacing manual bagging and weighing

Earlier, a large number of people were required to fill bags and weigh 'cotton seeds'. However, online bagging is now available, substantially reducing manpower requirements.

Waste of lint and damage to fibre quality

Cotton conveying, cleaning, ginning and pressing machinery should be carefully selected based on all of the parameters to obtain the best results. An incorrect selection affects most of the spinning parameters as fibre rupture in blow room increases, blow room waste

Figure 56. Lint conveying by belt

increases, count strength product (CSP) goes down, and the average speed of ring frame has to be kept low. A lot of lint is wasted when there is excessive conveying and cleaning, and when saw-ginning machinery is used inappropriately for 'hand-picked', clean-cotton. In such cases, the appropriate roller ginning technology should be used. Otherwise, 'hand-picked' clean cotton can suffer damage to fibre quality parameters, including excessive nep formation, length cut and brittleness due to higher speed.

Over capacity installation for ginning & pressing plant

Most of the ginners try to install more bale-pressing equipment than they really need. For example, if ginners currently need a capacity of 10 PBH, they tend to install equipment that can handle 20 BPH, leaving space in the ginning area empty with the intent of future expansion. In many cases, this results in higher capital costs and higher recurring charges due to idle power utilization. It has also been observed that, in many cases, future expansion never happens, and ginning and pressing factories continue to pay extra electricity charges, and additional interest charges on capital spent to create that excess capacity. The planning of ginning and pressing factories should be done based on current needs, without making superfluous arrangements for future expansion. A fresh plant should be considered when necessary.

Ginning different varieties on the same equipment, even when it's not suitable

In areas where short-staple and long-staple varieties are grown, and cotton is machine picked as well as handpicked, careful consideration should be given to the selection of proper ginning technologies for different types of cotton. It might actually be more profitable to build a separate plant for each type of cotton, considering that the price of cotton lost over a period of time may be much higher than the cost of setting up separate ginning facilities.

Underutilisation of by-products and mill waste

The majority of ginners do not properly use the gin's by-products, including cottonseed, linters and comber-noil. They can generate additional revenue and make a gin more competitive.

Recommendations

Best practices to be considered by ginning and pressing factories

- **Purchase of correct machinery**: Machinery for cotton loading and unloading, conveying, drying, cleaning, ginning, humidification, baling and handling should be selected based on a variety of parameters such as practical capacity requirements, level of drying and cleaning required, the suitability of ginning technology for the fibre parameters, the lowest electrical power consumption per unit of production, the lowest capital costs, and the lowest manpower requirements.
- **Future expansion provision**: Expansion in a plant should be avoided until the need is clear and immediate.
- **Adoption of new technologies**: Gin owners should use the latest methods, equipment for handling, conveying, drying, and cleaning, and other fibre-friendly technologies.
- **Skilled manpower**: Skilled manpower for operation of the ginning and pressing machinery should be appointed or trained if necessary.
- **Upgrading machinery**: Existing ginneries should replace their old equipment that is less efficient for cotton handling, drying, conveying, cleaning, ginning, humidification, etc. Advanced, cost-effective, fibre-friendly machinery is available and must be deployed.
- **Increased interaction between ginners, spinning mills and buyers:** Ginners and cotton associations throughout the world should regularly interact with spinning mills and other buyers to understand their requirements and consider their feedback. This would encourage spinning mills to offer better prices for fibre that meets their exact requirements, which in turn will enhance their efficiency.
- **Optimised utilization of by-products:** Ginners should also concentrate on proper utilisation of by-

products such as cottonseed, comber noil and linters, which can add significant revenue.

Best practices by government authorities and market

- **Preparation of trash standards**: Trash standards of baled cotton grades should be established so that trash for grade-1 cotton should be specified as maximum permissible limit of 1% — and consecutive grades for 2% and 3% and so on, up to a maximum permissible trash percentage — so that premium options are available for clean cotton. For example, at present, the Indian Standard for bales BIS 12171 specifies permissible trash as 3% for extra-long staple (32.5 mm and above), 5% for long and medium staple, 6% for medium and short staple, and 10% for closed boll cottons.
- **Standardisation of cotton bale sizes and weight**: There should be an international consensus between all the cotton-producing countries to adopt uniform bale sizes and bale weights over a period of 10 years. A suitable size and weight should be selected, such as a bale size of 42 inches by 21 inches and bale weight 227 kg (500 lb). Governments should establish regulations to ensure adoption of the uniform bale size and weight. Cotton associations worldwide should promote this, so that uniformity is achieved over a period of time, which will benefit the entire cotton value chain.
- **Sampling of each bale:** Governments should establish testing centres in each reasonable catchment area for cotton ginning and make it mandatory that samples are drawn from each bale and tested at centralised laboratory, as is being done in the United States. Cotton bales should be traded based on test reports from these independent testing centres. This should be done as soon as possible.

Conclusion

This article emphasizes that the competitiveness of cotton can be enhanced by implementing appropriate and suitable ginning and bale-pressing technologies. The recommendations and best practices listed in this article could be adopted to:

- reduce capital costs, power usage and manpower expenses,
- preserve fibre parameters,
- utilise by-products,
- harmonise bale weights,
- develop international standards for trash percentage, and
- test individual bale samples to ensure sustainability and profitability of cotton processing.

These practices, in conjunction with new uses for cotton, will help to improve its competitiveness dramatically.

References

Anthony, W.S. 1994. Overview of the ginning process. In Cotton ginners handbook, Agricultural handbook number 503, 43-46. Anthony W.S., and W.D. Mayfield, eds. Washington, D.C.: USDA, ARS.

Anthony, W.S., and W.D. Mayfield. 1994. Cotton ginners handbook, Agricultural handbook number 503. USDA, ARS, Washington, D.C.

Arude, V.G., S.K. Shukla, D.N. Makawan, T.S. Manojkumar, and J.M. Nath. 2010. Modernization of Indian roller gins and the effect on cotton fibre quality. Journal of Agricultural Mechanization in Asia, Africa and Latin America (AMA). 41(2):43-47.

Arude, V.G., S.K. Shukla, and T.S. Manojkumar. 2008. Cotton ginning : technology, trouble shooting and maintenance. ICAR-CIRCOT, Mumbai, India.

Estur, G., and N. Gergely. 2010 The economics of roller ginning technology and implications for African cotton sector. Africa Region Working Paper Series No. 129 (a). USA.

Faulkner, W.B. 2008. Comparison of picker and stripper harvesters on irrigated cotton on the high plains of Texas. Texas A&M University, Biological and Agricultural Engineering

Faulkner, W.B., J.D. Wanjura, B.W. Shaw, and E.F. Hequet. 2007. Effects of harvesting methods on foreign matter content, fiber quality, and yarn quality from irrigated cotton on the high plains. ASABE.

Harmancioglu, M., and N.E. Maustafa. 1981. Influence of cotton ginning techniques on the open end spinning processes and on properties of open-end yarns. Melliand Textilberichte (English Edition). 2:135-139. 169-173.

Hughs, S.E., W.F. Lalor, and F.T. Wahba. 1988. Relationship of ginning and fiber properties to dyeing imperfections. Textile Research Journal. 58:557-565.

Hughs, S.E., and C.G. Leonard. 1986. Roller versus saw ginning of long-staple upland cotton. The Cotton Gin and Oil Mill Press. 87:8-10.

Iles, G. 1912. Leading american inventors. Hony Holt and Company, New York.

Le, S. 2008. Lint cleaning with two air-jet cleaners in series. The Journal of Cotton Science. 12:246–252.

Mangialardi, G.J. 1995. Effect of roller ginning on market and spinning value of Mid South grown cottons. The Cotton Gin and Oil Mill Press. 96:12-19.

Mangialardi, J., G. J., and W.S. Anthony. 2004. Cotton saw gin stand developments. USA: Educational N.C.C.

Mayfield, W.D., and W.S. Anthony. 1994. Development of the cotton gin. In Cotton Ginners Handbook. Agricultural Handbook Number 503. Anthony W.S., and W.D. Mayfield, eds. Washington, DC,: USDA, ARS.

Indian Standard for Cotton Bales – Specification IS12171.

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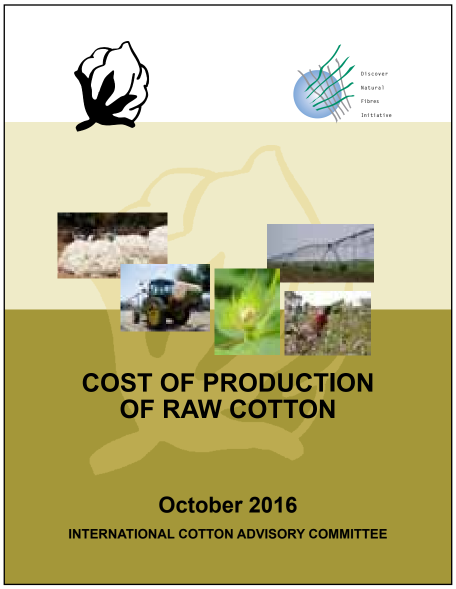

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