COMPARATIVE ANALYSIS OF ORGANIZATION

AND PERFORMANCE OF AFRICAN COTTON SECTORS

THE ECONOMICS OF ROLLER GINNING TECHNOLOGY AND IMPLICATIONS FOR AFRICAN COTTON SECTORS

Prepared for the World Bank by

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Abbreviations and Acronyms

AFIS	Advanced Fiber Information System (Uster Technologies AG)
ARS	Agricultural Research Service (USDA)
BCGA	British Cotton Growers Association
BPH	Bales per Hour
CFC	Common Fund for Commodities
CFDT	Compagnie Française pour le Développement des Fibres Textiles
CFR (C+F)	Cost and Freight
CIS	Community of Independent States
cts/lb	Cents per Pound
DR	Double Roller
ELS	Extra Long Staple
ESA	East and Southern Africa
est.	Estimated
EXW	Ex-works
G.	Gossypium
G&P	Ginning and pressing
GM	Genetically Modified
GOT	Ginning outturn ratio
GPT	Gram per Tex
HD	High density
hp	Horsepower
HS	High Speed
HVI	High Volume Instrument
ICAC	International Cotton Advisory Committee
kg	Kilogram
ksh	kg of lint per saw per hour
kWh	KiloWatt per hour
lb	Pound
L/C	Lint cleaner
LS	Long Staple
M	Middling
mm	Millimeter
NM	New Mexico

t	Metric ton
N/A	Non available
Ne	English yarn count
RG	Roller Gin
Rp	Rupee
rpm	Revolutions per minute
SCCL	Sudan Cotton Company Ltd
SCF	Seed coat fragment
SFC	Short fiber content
SG	Saw Gin
SITC	Standardized Instrument for Testing of Cotton
SJV	San Joachin Valley (California)
SLM	Strict Low Middling
SM	Strict Middling
sqm	Square meter
SR	Single Roller
SSA	Sub-Saharan Africa
TCB	Tanzanian Cotton Board
UD	Universal Density
UHML	Upper High Mean Length
UNIDO	United Nations Industrial Development Organization
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
US$	U.S. dollar
WACIP	West African Cotton Improvement Program (USAID)
WCA	West and Central Africa

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Foreword

The World Bank has carried out a comparative study of cotton sector reforms in Sub-Saharan Africa (SSA), based on detailed case studies in nine of the main cotton producing countries: Benin, Burkina Faso, Cameroon and Mali in West and Central Africa (WCA); and Mozambique, Tanzania, Uganda, Zambia and Zimbabwe in Eastern and Southern Africa (ESA). The purpose of this study was to draw practical insights from the diversity of experiences, so that policy makers can ground their political decisions in a solid understanding of the key strengths and weaknesses of the sectors in which they operate, of the likely effects of specific changes, and possible ways forward.

The first phase of the study entailed desk reviews of the nine cotton sectors of the study sample, and discussion of the main findings. The second phase of the study consisted in revising/completing the case studies through field visits and carrying out the comparative analysis of reform outcomes based on a methodological framework including a typology of cotton sectors and approaches to link sector types to observed performance.

The third phase of the study consists in studies and complementary work on selected topics identified by the main report, including this study/survey on the economics of roller ginning technology.

The study identified five types of cotton sectors, based on sector structure: (i) national monopolies (Mali and Cameroon), in which one firm has an exclusive right to purchase all cotton nationwide, (ii) local monopolies (Burkina Faso, Mozambique), in which more than one firm have such an exclusive right each within a given geographic area (iii) concentrated sectors (Zambia and Zimbabwe until recently), in which a small number of firms compete for the purchase of cotton and the right to transact with producers for the coming season, (iv) competitive sectors (Tanzania, until recently Uganda), in which a large number of firms compete for seed cotton on the basis of price at harvest time, and finally (v) hybrid types, which emerge either out of attempts to liberalize a national monopoly (Benin) or to solve the problems unleashed by liberalization in a competitive sector (Uganda). The conceptual framework for this comparative analysis rests in the idea that economic systems benefit from both competition and coordination, but that in the real world of imperfect markets and weak states there is likely to be a trade-off between them.

In a large measure, the analysis showed that sector structure has a major and predictable influence on performance. Competitive sectors pay higher prices to farmers, because of the intense competition between ginners, but are weak on input credit provision, extension and quality. National and local monopolies are the most able to provide input credit and extension to a large number of farmers, resulting in higher average yields, but are facing problems of cost inefficiency and managerial dysfunctions. Concentrated systems can do well on quality management and, to a certain extent delivery of services to farmers, but are more unstable than other systems and require a high level or coordination and well designed regulations. The study emphasized also the importance of quality as a competitiveness factor, due to the increasing demand for quality from the market.

The comparative study identified the choice of ginning technology as an important factor of performance and competitiveness of the cotton sectors. The study sample included countries with different ginning technologies. WCA countries, among which all WCA countries with national and local monopolies, have been exclusively using saw gins, while roller ginning is used in some ESA countries, especially those with competitive structure (Uganda and Tanzania). In ESA countries, several of the new entrants in cotton sectors have also started operating with roller gins. This finding revealed the need to better understand the possible linkage between cotton sector structure and ginning technology, as well as the incidence of ginning technology per se on sector performances and the linkage between ginning technology and quality performances.

This study on the economics of roller gins aims at providing answers to these questions. It also aims at providing an improved understanding of the economics of roller ginning for policy makers designing and implementing sector strategies, as well as for stakeholders and decision-makers contemplating investment in the cotton sector. It finally aims at identifying to which extent roller gins can improve the cost efficiency of the cotton sectors where it is not used, and to what extent it can facilitate the introduction of some competition in cotton sectors.

It is worth noting that such a study fills a gap in knowledge on the economics of cotton sectors in Sub-Saharan Africa, as, in the abundant literature that has been dedicated to cotton in recent years, there is no synthetic and operational document that objectively compares the pros and cons of the available ginning technologies in the sub-Saharan African context, and how they perform in different institutional settings.

The report is organized in three sections. Section 1 documents the history and current state of ginning technology in the world, including a basic technical description of roller and saw technologies, an overview of the ginning process by country and its recent developments. Section 2 compares the performance of roller and saw technologies in terms of investment and processing costs, operational requirements, quality and prices of lint. Section 3 assesses the relevance for Sub-Saharan countries, in particular WCA countries, of investing in roller ginning, and the incidence that such an investment could have on the sector structure.

Executive Summary

State of Ginning Technology in the World

All the currently available ginning machinery in the world is based on two fundamental principles of separating lint from seeds: roller ginning, which was invented in antic times in India, and saw ginning, invented in the 18th century in Great Britain, especially for ginning American short staple cotton. Two main types of roller gins are currently used: double roller gins (DR) in which two leather rollers, pressed against a stationary knife, rotate in opposite directions; rotary knife roller gins (or rotobar), which combines a stationary knife with a rotary knife thus allowing a higher ginning speed. Important technological improvements have taken place in recent years for both systems: high versions of rotobars have been developed in the US and in Turkey; also automated feeding and cleaning systems have been developed both for double roller and rotobar technologies.

Today, most DR manufacturers are located in India, while Turkey manufactures both DR and rotobars. The largest saw gin manufacturers are located in the US, which manufactures also rotobars.

Roller ginning is a slower and more labor intensive process than saw ginning, but it preserves better the quality of the lint. Roller gin is the only technology used for extra long staple irrigated cotton (*Gossypium barbadense*), as saw gins would result in fiber breakage. World extra long staple cotton production is marginal compared to upland cotton (*Gossypium hirsutum*) production (0.75 and 25.25 millions tons, respectively, in 2007/08). Saw gins are usually preferred for upland cotton, but 20% of the world upland cotton production is roller ginned.

The main producer of roller ginned upland cotton is India, where manually fed DR gins are still predominant, although being progressively replaced by autofeeders DR gins, less labor intensive and which reduce contamination. The second largest producer is Turkey, where DR gins equipped with cleaning device are progressively being replaced by rotobars with automated feeding control. In the USA, roller gins are increasingly used for upland cotton, to cope with more stringent demand for quality lint.

In East and Southern Africa, the Indian model has prevailed in some countries (Uganda and Tanzania), but saw gins are also operating. A number of new roller gins have also been installed in Zambia and Zimbabwe. In West and Central Africa, where, in most countries, cotton was introduced by the French parastatal CFDT, only saw gins are operating, because roller gins were originally viewed as impractical, cost inefficient and not suitable for the medium-short staple upland varieties grown at that time. These monopolistic cotton companies adopted the US model and imported US made saw gin systems.

The proportion of roller ginned upland cotton is given on the table below for the main producing countries:

	Upland Production (thousand tons lint)	Roller Ginned (%)
India	5,275	79%
Turkey	675	85%
Tanzania, Zimbabwe, Uganda, Zambia	320	36%
Myanmar	65	77%
California & Arizona	260	15%
Other Countries	18,655	0.4%
Total	25,250	20%

The ginning technology and the scale of operations are mostly determined by the variety grown, production and harvesting conditions, and economic factors. The cotton sector structure also influences the choice of the ginning technology. The capital cost has been restrictive for the introduction of high-productivity saw gins in countries where production was low and scattered. Conversely, low-productivity roller gins were not adopted in countries where large volumes had to be processed rapidly.

The minimal capital cost of setting up a ginnery is substantially higher for saw gins than for roller gins. The choice between more or less labor-intensive options depends on the availability of labor and its cost relative to energy costs. Roller gins are generally the preserve of smaller companies, although numerous stands can be linked together and the supply of cotton automated.

Comparative Performance of Roller and Saw Ginning

The methodological approach for comparing economic performances of roller and saw ginning was to compare cost or competitiveness factors that are directly depending upon the ginning technology, and not the total industrial cost, which includes processes upstream and downstream ginning itself that are not directly related to the ginning technology used. Factors taken into consideration for the comparison were investment costs for a given ginning capacity, ginning outturn ratio, labor, energy and maintenance requirements, and quality premiums directly related to the technology used.

Six models of ginneries have been selected for comparison, two for each of the three technologies identified:

(1) two models based on the standard saw gin stands manufactured in the US operating in most WCA (116-saw and 170-saws);

(2) two models based on rotobar gin stands manufactured in Turkey (standard and high speed);

(3) two models based on double roller gin stands manufactured in India (a manual DR gin and a Jumbo DR autofeeder gin).

The individual gin stands have the following capacities (in kg of lint ginned per hour):

Double Roller Gin		Rotobar		Saw Gin	
Standard	**Jumbo**	**Standard**	**High Speed**	**116-saw**	**170-saw**
50	**75**	**225**	**360**	**2,025**	**3,400**

For the sake of comparison all ginneries are supposed to have the same capacity (15 bales/hour, corresponding to the output of a standard press), and the same ancillary equipment (unloading, separator/feeder, conditioning, pre-cleaners, conveyors, lint-cleaner, press and baling equipment). The technical performances of each type specified by the manufacturer were crosschecked with experiences of ginners in various countries, both in Africa and in other parts of the world (Turkey, India and USA).

Due to the lower productivity of roller gins, the number of gin stands and the floor area required for installation of the gins are much higher for roller gins (especially DR gins) than for saw gins. Despite a lower cost for the gin stands themselves, the investment cost directly related to the ginning technology is therefore twice higher for a rotobars as compared to a saw gin, and three times higher for DR gins. The related investment and capital cost ranges from US$0.5 to US$1.3/kg of lint.

Variable costs (energy, seasonal labor, maintenance) are also higher for roller gins. Roller gins are more labour intensive, due to the greater number of stands and to lower automatization than saw gins and seasonal labour required by bale produced ranges from 0.3 man-hours in the case of a saw gin to 0.6 man-hours for standard rotobars, to 2 man-hours for Jumbo DR gins and 5 man-hours for standard DR gins. Energy required to operate the gin stands and to move the cotton along the ginning chain is also higher for roller gins, due to the higher number of stands and to the longer distance on which the seed cotton has to be moved. Maintenance is easier for RG, but spare parts are more expensive, resulting in higher maintenance costs (1.5 cent/kg against 1cent/kg for SG).

On the other hand, the ginning outturn ratio, all other things being equal, is higher for a roller gin than for a saw gin, as it removes more fiber. Assuming, based on experience, a GOT for rotobars 1.5 percentage points higher, and for DR gins 2 percentage points higher than for saw gins, those differentials translate into a reduction in the cost of seed cotton per kg of lint amounting to 3 US$ cents/kg for rotobars and to 4 cents for DR roller gins. Altogether, higher maintenance, labor and energy costs for roller gins are largely offset by the saving on seed cotton (due to higher GOT ratio), and the total variable costs are 1.5 to 2 cents/kg higher in SG, as shown in the table below:

Ginning variable costs at average value of factors (US$ ct/kg lint)	Double Roller Gin		Rotobar		Saw Gin	
	Standard	Jumbo	Standard	High Speed	116-saw	170-saw
Seasonal labour	0.67	0.27	0.08	0.07	0.05	0.04
Energy	3.14	3.14	2.25	2.05	1.63	1.46
Maintenance	0.67	0.67	0.67	0.67	0.44	0.44
Seed cotton	83.33	83.33	84.34	84.34	87.50	87.50
Total variable costs	**87.81**	**87.41**	**87.33**	**87.12**	**89.63**	**89.44**

The ginning technology has a recognized impact on quality, as roller ginning damages less the lint than saw ginning. All other things being equal, roller ginned upland cotton has a longer staple length, less short fibres, and seed coat fragments and neps, which are important quality criteria. This improved quality translates in a quality premium, under the condition that merchants are confident that the lint is not contaminated, which is often the case when the roller gin is manually fed. Therefore modern ginneries equipped with roller gins and auto feeding systems fetch a premium of 3.5 cents/kg of lint at current lint prices, whereas manually fed gins attract no premium.

The economic comparison is summarized in the table below:

Cost differential at average value of factors Base: 170-saw (US$ cent/kg lint)	Double Roller Gin		Rotobar		Saw Gin	
	Standard	Jumbo	Standard	High Speed	116-saw	170-saw
Variable costs	-1.63	-2.03	-2.11	-2.32	0.18	0.00
Fixed costs	0.78	0.47	0.59	0.54	0.08	0.00
Incremental value of production ct/kg lint	0.00	3.31	3.31	3.31	0.00	0.00
Net income differential	**0.86**	**4.87**	**4.84**	**5.09**	**-0.27**	**0.00**

Altogether, DR standard gins have an overall small comparative advantage on saw gins (0.86 US$ cents/kg of lint). The advantage is much more substantial for Jumbo DR gins and for rotobar gins (4 to 5 US$ cents/kg). The main source of increased competitiveness for roller gins is the quality premium it can generate. The overall economic advantage for roller gins (except standard DR gins) is far from negligible, as it represents about 3% of current international prices for cotton (65 cents per pound). If passed on to producers, it would represent an increase of 7% of prices paid to producers. If it is retained by ginners, it represents a considerable increase in the value added.

In conclusion, the economic advantage of roller gins (Jumbo DR with auto feeder and rotobar gins) versus saw gins is far from being negligible, provided necessary conditions are met to capture the benefits of the technology.

The benefits of roller ginning are likely to increase in the future as the demand for quality is becoming more stringent in relation with the growing requirements of textile technologies, and as spinners (notably in China, by far the main market) are getting more familiar to roller ginned cotton and appreciate its quality and “spinnability”.

Conclusions and Recommendations

Historical trends influence the choice between the two ginning technologies. The improvement in the roller ginning technology, the increase in staple length of cotton, and the increasing importance given to quality by the textile industry tend to reverse the traditional advantage of saw ginning for upland cotton.

The table below summarizes the pros and cons of roller ginning versus saw ginning:

	Roller Ginning	**Saw Ginning**
Basic principle for separating lint from seeds	Gripping and stretching fiber through rollers/blades	Pulling fiber with saws through ribs
Process	Rather simple; slower but gentle	More complex; faster but harsher
Operational requirements	Easier to operate; not suitable for short fiber; less efficient for cleaning trashy cotton; reclaiming carryover of unginned cotton at high speed	Closer supervision needed; not suitable for extra-long fiber; efficient for cleaning trash
Capacity per gin stand	40 to 110 kg lint/hr (SR-DR); 175-225 (rotobars); 360 to 1,000 (HS rotobars)	1,800 to 3,400 kg lint/hr
Ginning outturn	+ 1.5 to 2 percentage points gain vs RG	Depending on variety
Investment costs	No economies of scale; construction costs increase with capacity (floor area)	Prohibitive for small capacity; economies of scale
Labor costs	Higher (0.5-2 man-hour/ bale)	Lower (0.3-0.4 man-hour/bale)
Energy costs	Higher (85-135 kWh/t lint)	Lower (60-70 kWh/t lint)
Maintenance	Easy but more costly (roller replacement)	More complex; cost increases with age of gin
Quality of lint	Longer fiber (1/32 inch gain vs SG); better uniformity in length; less short fiber and neps; less clean with rougher appearance (preparation); higher risk of contamination (manual feeding)	Shorter staple length (fiber breakage); lower uniformity; more short fiber and neps; cleaner with smoother (combed) appearance
Quality of seeds	Cleaner (no delinting needed)	More linter on seeds
Price of lint	Potential gain of 1.5 cent per lb over same cotton saw ginned	Depending on seed cotton ginned

Relevance of Roller Ginning for SSA Countries

Roller ginning is more effective on longer staple cotton, which partly explains why saw ginning was preferred in the past in most SSA countries. The average staple length has however substantially increased in the last decade, due to the new varieties introduced, and most production is now 1-3/32 inch or longer, which makes it quite suitable for roller ginning. Furthermore, as it reduces fiber breakage, roller ginning results *per se* in an increase in the average staple length, and therefore in a better cotton value. The same cotton classed as 1-3/32 inch when saw ginned could be classed as 1-1/8 inch if roller ginned, and thus qualify for the more demanding but more remunerative market of finer yarns, to which SSA cotton has little access at present. Roller ginning can therefore substantially improve the market access for SSA cotton and bring a quality premium if the cotton is not contaminated.

Other characteristics of SSA cotton production make it quite suitable for roller ginning. One of the drawbacks of roller ginning is that it is less effective than saw ginning for removing trash from seed cotton. This drawback is indeed a limiting factor in countries where cotton is mechanically picked, which increases trash content. This drawback is much less limiting in the SSA context, as all African cotton is hand picked and therefore relatively clean. Additionally, roller ginning requires a lower moisture content than saw ginning, which is quite an advantage in Africa, where dry conditions prevail during most of the ginning season.

Altogether, roller ginning appears to be quite relevant in SSA, as it can potentially improve the quality of the fiber, increase the overall competitiveness of African cotton, since the characteristics of African cotton are becoming particularly suitable for roller ginning.

Ginning Technology and Sector Structure

There is obviously a linkage between the sector structure and the ginning technology. One of the characteristics of roller ginning is that, in contrast to saw ginning, there are limited economies of scale between a large ginnery and a small ginnery, as the capacity per gin stand is much smaller, and as the capacity of a roller gin ginnery depends on the addition of more or less ginning stands. Due to these characteristics, roller ginning is more competitive friendly, as evidenced by the fact that African countries which have introduced it had all a competitive structure. In a competitive sector, private firms tend to minimize total investments. They also go for smaller units to reduce the risk of over-capacity and try to be close to production zones in order to improve their competitive advantage. Large ginneries can be considered in areas where the production density is high, as it is the case in the main production areas in WCA monopolistic systems, due to the fact that a large proportion of farmers have access to input credit and extension services. Smaller ginneries are clearly better adapted to areas with a lower production density, as it is often the case in competitive or concentrated sectors, as evidenced by the comparative study conducted by the World bank.

In the current context of production crisis, WCA monopolistic cotton sectors are indeed facing a ginning overcapacity problem. The option of introducing roller ginning is nevertheless to be considered for the medium or long term, both for economical and structural purposes. Beside increases in competitiveness, it would allow smaller ginneries enter the market, and thus facilitate the introduction of some competition among ginners and the transition to more competitive systems. It would also facilitate the development of niche market (like organic or fair trade cotton) and the entry of farmer groups/associations into the ginning industry.

The Way Forward

Although there are technical and organizational issues that need to be addressed to introduce roller ginning in SSA countries, there is every reason to believe that roller gins could optimize quality management in ginning, improving lint quality and consistency, and generate significant productivity gains in African countries.

It would therefore seem quite relevant for the African cotton sectors' stakeholders to invest in roller ginning. However, so far, no investment in roller ginning has been made or given consideration to in WCA countries.

The choice of ginning technology would seem to be an issue for private ginners. Notwithstanding, a public effort is needed to raise the awareness of ginners on the potential benefits of roller ginning, and to monitor prices paid by ginners to ensure transmission of additional returns to producers.

To this end, a pilot project should be undertaken to evaluate the performance of existing roller ginning technology and demonstrate its viability under real WCA conditions, in comparison to saw ginning.

This pilot project would be in line with national cotton development strategies to improve the quality of lint, increase incomes at the village level by adding value to cotton, and improve the competitiveness of the commodity.

1. The State of Cotton Ginning Technology in the World

1.2. Brief History of Ginning

1.2.1. Ginning in the Early Days

Cotton fibers must be separated from the seed before they can be spun to yarn and used to manufacture textile goods. Ginning is the process of separating cotton fibers from the seeds. Devices for separating cotton fiber from seed have existed since 4000 BC.

The first method of separating the cotton seed from the fiber was with the human fingers. The seed was simply removed by hand. 'Pinch ginning' was extremely time-consuming as one person could only gin about 0.3 kg of per day.

The oldest mechanical method known for separating the fibers from the seeds is the single roller gin. It used a smooth roller pushed by hand or feet ("foot roller gin") over the cotton against a hard and smooth surface, usually a flat rock. The action of the roller against the smooth surface would literally squeeze the seed from the lock of cotton. This method was relatively efficient in separating the lint from the seed. However, the work was very slow and tedious, and yielded about 0.5 kg of lint per day.

A two-roller system was invented in India by 1000 BC. The "Churka" gin consisted of two small diameter wooden cylinders held together by a frame and rotated by a crank. One person fed the cotton with one hand and turned a crank at the same time. Counter-rotating at the same speed, the rollers would squeeze the cotton boll[1] as it passed between them, pinching and pulling the fibers without crushing the seeds. The Churka increased the daily production of one person to about 2 kg of lint. The Churka Gin was used for centuries in India, and was most efficient and considerably easier to perform when handling "naked" seeded varieties with loosely attached fibers.

1.2.2. The Invention of Saw Ginning

Demand for cotton by English textile factories increased during the 18th century. In America, Sea Island cotton, a long staple variety[2], could only be grown successfully in a narrow band along the Carolina and Georgia Coast but could not be grown successfully in the interior. The more robust short staple, "fuzzy" seeded varieties[3] (upland cotton), could be more widely cultivated. However, their fibers were shorter in length, reducing yarn and cloth quality, and resisted separation when passed through the roller gin, since they were tightly attached to the seed surface. Consequently, the fiber was generally pulled from the seed by hand, which was time consuming and labor intensive.

[1] The capsule or pod of the cotton plant.
[2] Belonging to the *Gossypium barbadense* species.
[3] *Gossypium hirsutum* species.

Eli Whitney invented the cotton engine, or “gin” for short, in 1794, based on the principle of carding of the New England textile machinery. It used wire teeth (spikes) hammered into a hand-driven rotating wooden cylinder to snare the cotton fibers and pull them through a grate. The wooden lots in this grate were too narrow for the cotton seed to pass, so that the fibers were pulled away from the seeds. A revolving brush, operated via a belt and pulleys, then removed the lint from the spikes. The new machine pulled the short staple fiber from the seed more quickly than the roller gin's pinching action. It was 50-100 times faster than hand ginning.

Henry Ogden Holmes received a patent in 1796 for an improved gin that used saws rather than spikes to remove the fibers from the seed. The saws were spaced on a shaft to provide openings that allowed the clean seed to drop out to the bottom. Holmes’ invention made ginning a continuous rather than a batch process, and greatly increased capacity. The saw gin could produce up to 25 kg of lint daily, making cotton production profitable in the southern states.

The basic principles developed by Whitney and Holmes, enhanced quantity over quality, and marked the beginning of the modern cotton industry. The development of the saw-gin type cotton gin resulted in a dramatic increase in cotton production in the United States.

The saw gin was especially effective in separating the hard-to remove seeds in upland cottons. However, this type of gin could not be used on Sea Island cotton as it damaged the long silky fibers. Roller gin manufacturers found their products restricted to the limited market for long-staple cotton. Textile manufacturers adapted to the shorter, lower quality fiber.

1.2.3. Improvements in Roller Ginning

In 1840, Fones McCarthy invented a more efficient roller gin which consisted of a single leather ginning roller, a stationary knife, and a reciprocating knife, which pulled the seed from the lint as the lint was held by the roller and stationary knife. The McCarthy ginning roller was much greater in diameter than the Churka type roller and hence had greater capacity[4]. This new type of roller gin, referred to as the McCarthy gin, became as popular in many countries as the Whitney saw gin was in the USA. Between 1840 and 1940, various improvements were made in single and double roller gins. The reciprocating knife roller gin of the McCarthy design is capable of producing 70 to 90 kg of extra-long staple (ELS) lint per hour (and 35 to 45 kg of ginned upland).

Although the McCarthy gin was a major improvement over the Churka type gin, machine vibration due to the reciprocating knife along with maintenance problems did not permit to reach high ginning rates. In the late 1950s and early 1960s, a rotary-knife roller gin (Rotobar) was developed by the USDA Southwestern Cotton Ginning Research Laboratory. The Rotary Knife Gin Stand uses a large diameter roller and a stationary knife to exert a pulling action on the fibers in a manner very similar to that of the McCarthy Gin. However, a small diameter rotary knife replaced the reciprocating knife to provide the necessary seed pushing action at the point of ginning. The rotary knife roller gin stand allowed increased ginning rates, 4-7 times that of the McCarthy Gin (225 to 350

[4] Single Roller McCarthy Gins stayed at 40 inches in length until the 1940s.

kg of extra-long staple lint per hour, and 100 to 175 kg of upland lint). It is today the only roller-type gin used in the United States for Pima extra long staple cotton.

1.3. Roller and Saw Ginning Technologies

The fiber-seed attachment force differs for varieties, field conditions, moisture content, and other factors, but is typically about 55% of the breaking force, suggesting that the fibers could normally be removed from the seed without breakage. All the currently available ginning machinery in the world is based on two fundamental principles for separating lint from seeds, roller ginning and saw ginning. The gin stand, whether saw or roller, removes (pulls) the fiber from the seed and is the heart of the ginning system. A basic technical description of the roller and saw technologies is given in Appendix 1.

1.3.1. Roller Ginning

Roller ginning is the most primitive way of removing lint from seeds. There have been many variations and refinements in the machines working in many countries around the world but the fundamental principle of a harsh pulling of fibers from the seed coat has not changed. Fibers are gripped between rollers, blades or a roller and a blade and stretched to be separated from seeds. The space through which fibers are stretched is so narrow that it does not permit seeds passing through with lint. The process is comparatively slow but considered to be gentle.

Roller-type gins include the reciprocating knife single roller (McCarthy roller gin), the double roller and the rotary knife roller (Rotobar).

In a double roller (DR) gin, two leather rollers, pressed against a stationary knife, rotate in opposite direction. When the seed cotton is fed to the gin, fibers adhere to the rough surface of the roller and are carried in between the fixed knife and the roller, and partially gripped between them. Oscillating knives beat the seeds from top and separate the fibers, which are gripped from the seed end. The seeds are carried forward on the roller and doffed out of the machine. Fiber comes out from the bottom side.

The McCarthy roller gin utilizes a leather roller to draw the fibers between a fixed knife and the roller. The pulling action of the roller on the fibers combined with the pushing action of the moving knife are required to remove the fibers from each seed. The seed then falls through a seed grid and the fibers are removed from the roller by a rotating doffer.

In a rotary knife roller gin, seed cotton is applied to the ginning roller, with the separation of fiber and seed taking place as the lint is pulled under the stationary knife. The rotary knife directs seed cotton to the ginning point, sweeps cottonseed away from the ginning point, and releases the seed cotton that was not fully ginned to be drawn back to the tip of the stationary knife for further ginning.

The number of roller gin stands installed determines the capacity of the ginnery (provided that it is not limited by the capacity of the bale press).

Roller ginning systems in the US normally include similar seed cotton cleaning as used for upland cotton. Cleaning equipment may include cylinder cleaners, stick machines, and revolving screen (impact) cleaners, depending on seed cotton cleanliness (whether it is machine picked or hand picked.) Tower dryers and hot-air cylinder cleaners are commonly used for seed cotton drying. Lint cleaning in roller gins is different from saw gins and varies among locations. The most common lint-cleaning sequence utilizes incline, impact, and air-jet cleaners. Saw-type lint-cleaners are only used for machine-picked cotton to remove motes[5], broken seed, entanglements and pin trash not removed in seed cotton cleaning. Roller ginned cotton is baled using the same pressing equipment as upland cotton.

1.3.2. Saw Ginning

In saw gins, the cotton lint is removed from the seed by pulling it with saw teeth through metallic ribs. Each saw passes between two stationary steel ribs spaced so as to allow the lint to pass through while preventing the cottonseed from doing so. The principal parts of a saw gin are saws, ribs and a brush or a blast of air for cleaning the lint from the saws. Saw ginning is faster but fiber characteristics are more damaged than in roller ginning.

The number of saws, ranging from 90 to 200, determines the size and the capacity of a single gin stand. The number of gin stands installed and the number of saws per stand determine the capacity of a ginnery, which is also limited by the capacity of the baling press and of the feeding and cleaning machinery.

1.3.3. Recent Developments in Ginning Technology

The process of ginning and pressing cotton is standard and time tested. Nevertheless, significant technological advancements have taken place in the area of technology during the last decade which has resulted in improved productivity. Efforts have continuously been made to improve the fundamentals of ginning without sacrificing efficiency, while preserving the intrinsic quality of fibers, obtaining the maximum length of fiber without breakage, producing lint free of trash and contaminants, undamaged clean seeds, at the lowest cost per unit ginned. The approach has been to make the process as gentle as possible and to reduce the harshness of saw gins, and to increase the productivity of roller gins. The focus is no longer on basic ginning mechanism but on combining ginning with auxiliary functions, and integrating them into a comprehensive ginning system.

Extensive research carried out on cage ginning has been discontinued. The principle was to use an air stream to separate fibers from seeds, with a series of rollers mounted on the outer surface of a circular-rotating cage. The quality of fibers was better than with saw ginning, but it was not possible to remove all lint from the seeds.

In the late 1990s, the Templeton Rotary Gin has been designed to produce roller gin quality long staple cotton at the speed of a saw gin, to simplify the technology used in cotton ginning and reduce the cost of ginning. It used eight knives to create eight places to gin instead of one knife and one ginning place in roller gins. However, due to feeding problems this gin could not be commercialized.

[5] A small group of short fibers attached to a piece of the seed or to an immature seed; motes may be cleaned and baled.

Efforts have been made to measure and use color, trash and moisture measurements online to monitor and adjust the ginning process. USTER® INTELLIGIN monitors the ginning process through a system of online sampling stations. The sensing technology is similar to the one used in HVI. Online measurements provide information on moisture, color and trash for adjusting processing.

Power roll technology was developed by engineers at the Cotton Production and Processing Research Unit of the USDA-ARS. It uses a powered paddle roll to turn the cotton in the roll box of the gin stand and bring it into contact with the gin saw cylinder. As the teeth of the saw capture more cotton fiber, a three stand gin plant which normally runs at 36 bales per hour could now run consistently at 42 bales per hour.

Much emphasis has been placed on lint cleaners, both in research and new product development. There has been a trend to limit the stages of saw lint cleaners to improve turnout and reduce fiber damage, while increasing the usage of air-jet cleaners[6].

1.3.4. High-Speed Roller Ginning

Over the last five decades, the USDA-ARS Cotton Ginning Research Laboratory in Mesilla Park (New Mexico has been instrumental in the development of the modern rotary-knife roller gin and has performed extensive research on roller gins in an effort to optimize their performance. Since the mid 1980's, Mesilla Park researchers, have investigated a variety of components of roller ginning operation, not only to make it more effective on Pima cotton, but also as a potential cost-effective alternative for ginning upland cotton for a more quality oriented market.

The most recent research applied many of the concepts learned in previous studies to modify a conventional rotary-knife roller gin stand into a "high-speed" version, through the increase of rotary knife and ginning roller speeds and the increase of pressure between the ginning roller and stationary knife. Other changes to the conventional machinery set-up included modifications to the extractor feeder above the gin stand, increased horsepower for the ginning roller drive, and a cooling system with blower for the ginning roller, to preserve ginning roller life. The work was carried out on the three major brands of late-model roller gins (Continental, Consolidated, and Lummus). Lummus engineers, worked closely with USDA/ARS researchers to design conversion kits for upgrading existing late-model roller gins and feeders (regardless of manufacturer) to the high-speed configuration.

When ginning upland cotton, the high-speed roller gin stand ginned at a rate comparable to saw ginning, 4 bales per hour versus a standard rate of about one bale per hour. The high-speed roller gin stand had the same horsepower requirement of a saw gin stand. Roller ginning, when compared to saw ginning, produced upland fiber that was about one staple length[7] longer, had fewer short fiber[8] and neps[9], had higher turnout, but contained

[6] Recent developments include the Lummus Sentinel LC that eliminates the need for batt forming feed works that can cause fiber damage and the Continental Louvermax lint cleaner that adjusts the number of grid bars to improve turnout.

[7] Staple length is the average length of the longer one-half of the fibers (Upper Half Mean Length – UHML). It is reported in both 100ths 32nds of an inch.

more foreign matter in the lint and cottonseed. At higher speeds, seed damage and carry-over increase.

According to the manufacturer, the new Lummus Series 2000 Rota-Matic TM Roller Gin and Feeder, has a processing capacity up to three times higher than previously attainable on both upland and ELS cottons.

Since 1996, a Turkish textile and gin machinery manufacturer, Balkan Makina, Aydin, has designed and developed a full line of cotton ginning machinery, including pre-cleaning, lint-cleaning and rotary-knife roller gin machinery[10], It was primarily sold in Turkey to clean machine-picked cotton but also exported to Azerbaijan and Sudan. The capacity of the rotobar is one bale per hour. The high-speed model[11]can reach 3 bales per hour but the manufacturer recommends not to exceed 1.6 bales per hour, in order not to increase the carry-over and damage to seeds (seed coat fragments[12]).

The Indian manufacturer Bajaj Steel Industries Ltd has developed a complete ginning system based on improved double roller gins, including cleaning, conveying and pressing. The capacity of the Jumbo double roller is rated between 65 and 105 kg of lint per hour depending on the type of cotton.

1.3.5. Ginning Equipment Manufacturers

Located in the USA, the largest saw-type gin manufacturers, Lummus[13] and Continental Eagle, also manufacture rotary knife roller gins. Most double roller gin manufacturers are located in India (Bajaj[14], etc). There are several manufacturers of saw and double roller gins in China. Turkey manufactures double rollers (Sumer) and rotary knife rollers (Balkan Makina). The major ginning equipment manufacturers are listed in Appendix 2.

1.4. Ginning in the World

Compared to saw ginning, roller ginning is a gentler way of separating the cotton lint from the seed. However, the low capacities typically obtained with roller gins provide an economic barrier to a more widespread use.

1.4.1. Ginning Process by Country

The most commonly produced and traded cotton lint variety in the world belongs to the species *Gossypium hirsutum*, which is also known as upland cotton. Saw gins are

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[8] ½ inch (12.7 mm) or shorter.

[9] Small tangled knots of fibers. Neps in the lint are undesirable because they appear as defects on the yarn and fabrics.

[10] Rotobar designed and improved from the Consolidated rotary knife roller.

[11] 350 rpm vs 120 rpm.

[12] Also known as seed coat neps, seed coat fragments (SCF) are contaminants in cotton lint. Harsh ginning can increase their size and number.

[13] According to the manufacturer, there are over 400 Lummus rotary knife roller gins in the USA and some other countries.

[14] According to the manufacturer, there are over 45,000 Bajaj double roller gins operating in India and several countries around the world.

generally used to process the fuzzy seed upland cotton, which has a short to medium-long staple length (less than 1 inch to 1-7/32 inch), wherever it is grown. Therefore, the saw-type cotton gin is, by far, the prevalent type of ginning in the world, notably in China, the United States, Pakistan, Brazil, Uzbekistan, West and Central Africa (WCA), Australia, Greece and Syria. However, saw-ginning does contribute to fiber damage (increased short fiber[15] content, reduced uniformity[16], and increased neps), which lowers mill efficiency and yarn quality, especially in spinning mills equipped with modern technology.

Extra Long Staple cottons (ELS 1-3/8" inch and above) belong to the species *Gossypium barbadense*, and accounted for 3 percent of world cotton production in 2007/08[17]. While it is possible to gin these black seed types of cotton, which are commonly referred to as a variation of Egyptian cottons, with a saw gin, the resulting quality is substantially lower than that obtained with roller gins. With saw gins fiber breakage results in a shorter staple. Therefore, roller-type gins (using either a reciprocating knife or a rotary knife) are used to process Egyptian, American-Egyptian, Pima and Sea Island cottons, which are normally used for producing very fine high quality yarns[18]. Conversely, roller ginning is not efficient for short and medium-short staple upland varieties (1-1/16 inch or shorter).

Notwithstanding, in two of the major cotton producing countries, India and Turkey, roller-gin equipment is in preference for processing upland cotton. Upland cotton is also roller ginned in several smaller producing countries in Asia and Africa.

According to the ICAC Secretariat, about 15% of the world cotton production was ginned on roller gins in 1995/96. This share increased to an estimated 22% of the world production (26.2 million tons) in 2007/08. In addition to the 750 000 tons of ELS cottons, about 5 millions tons, or 20% of the 25.25 million tons of upland cotton, were roller ginned.

Table 1 - Roller Ginning of Upland Cotton (2007/08)

[15] Fiber shorter than ½ inch (12.7 mm).

[16] Length uniformity is the ratio between the mean length and the upper half mean length of the fibers.

[17] ELS cottons are produced in Egypt (30%), USA (25%), China (20%), India (10%), Sudan, Turkmenistan, Israel, Peru, Uzbekistan, Tajikistan and a few other countries.

[18] Ne 80 and above. The count of yarn is a numerical expression of fineness. The English count is the number of 840-yard (768 m) bundles of yanr required to weigh one pound.

	Upland Production (thousand tons lint)	Roller Ginned (thousand t)	(%)
India	5,275	4,150	79%
Turkey	675	575	85%
Tanzania	145	75	52%
Myanmar	65	50	77%
USA *	4,000	40	1%
Zimbabwe	125	20	16%
Uganda	12	11	92%
Zambia	40	10	25%
Kenya	10	10	100%
Bangladesh	9	9	100%
Sudan	14	5	36%
Other Countries **	14,880	45	0.3%
Total	25,250	5,000	20%

* 15% of Acala production in California & Arizona is roller ginned.

** Afghanistan, Indonesia, Iran, Laos, Madagascar, Nepal, Nigeria, Sri Lanka, Thailand, etc.

Sources: ICAC for production and consultant's estimates for RG

Roller gins are used for hand-picked (Asia, Africa), and machine-picked cotton (USA, Turkey). Double roller gins are extensively used in India, Turkey and ESA.

The roller gins in Asia, Africa and Turkey are mainly reciprocating knife type roller gins. Rotary knife or rotobar gins with automatic feed control are used for all long staple cotton in the USA and Central Asia.

India, the second largest producer, consumer and exporter of cotton, concentrates 83% of the world production of roller ginned upland cottons, followed by Turkey (12%). An estimated 79% of the production of upland cottons is roller ginned in India[19]. There were 3,342 ginning and pressing installations operating during the 2001/02 season, including 177 saw gin factories[20]. Roller gins are considered more suitable for ginning superior/medium long staple cotton, while saw gins are usually preferred for ginning short and medium staple cotton.

Turkey does not grow ELS cotton, and 85% of the production is roller ginned. In 2000/01, there were 669 gins, including 32 saw gins. Some roller-gin units are very old, but they are preferred because of their ability to preserve the original fiber lengths. Investments were made in saw ginning to increase processing capacity, and because of its

[19] Bajaj contends there are 70,000 double roller gin stands used in India that produce 94% of the total production.

[20] 2,318 ginning only, 902 ginning and pressing facilities (+ 122 pressing only) + 678 closed.

ability to produce cleaner lint and its superior performance in ginning seed cotton with rain moistened/damaged, or with high thrash content.

In the USA, 976 gins were operating in 2007/08, including 21 saw gins processing mostly ELS Pima cotton.

In China, old roller gins were replaced by saw gins during the first phase of modernization of the Chinese ginning industry that started in 1955. Higher-capacity saw gins were adopted during the second phase of modernization/liberalization that began in the 1980s. Roller gins are still used to process ELS cottons grown in the Xinjiang region.

In Pakistan, some of the 2% of total production which is ginned on roller gins belongs to *Gossypium arboreum*. In total, there are 8 roller gins (and over 1,200 saw gins), some of them engaged in ginning only *Gossypium hirsutum* and *Gossypium arboreum*.

In India and Iran, where *G. arboreum* and *G. herbaceum* are grown on a significant area, a large quantity of short staple cotton is ginned domestically on small roller gins.

In Australia, there are 2 mixed roller/saw combinations (out of 37 gins).

The above review of ginning technology in the world shows that, contrary to common belief, roller gins can be used for medium staple upland cotton.

Genetically engineered cotton resistant to insects was first commercialized in 1996, and 10 countries had authorized commercial production of biotech (GM) cotton in 2008. The ICAC Secretariat estimates that 47% of world cotton area was planted to biotech varieties in 2007/08, and this area accounted for about half of world production and exports.

So far, biotechnology applications have been limited to developing insect-resistant and herbicide-tolerant varieties, and other forms of biotech cotton are not expected to be released in the near future. As genes inserted into the varieties do not affect fiber characteristics, all considerations and recommendations made in this study apply equally to conventional and biotech cotton varieties.

1.4.2. Roller Ginning in Africa

Egypt, the world largest producer of ELS cotton does not grow upland cottons and is only using roller gins, most of which were installed at the beginning of the 20th century.

Sudan used to gin all its production (ELS Barakat) with roller gins until the mid-1990s. Saw gins were installed to increase capacity for ginning medium-long staple upland Acala.

In Tanzania and Uganda, ginning has historically been dominated by roller gins in the hands of cooperatives. Saw gins were introduced in Tanzania (and to a much lesser extent in Uganda) for higher output as a large number of private buyers and ginners entered the sector and increased competition for seed cotton procurement.

In Uganda there were 40 gins in 2007/08 (ICAC), including one saw gin used for producing cotton sold in the sub-region.

In Tanzania, the 63 gins listed by the Tanzanian Cotton Board (TCB) include 41 roller gins and 22 saw gins, but not all of them are functional. 14 gins built between 1923 and

1966 (12 DR and 2 SG) have not been modernized and are probably idle. 40 of the gins (20 RG and 20 SG) have been modernized or installed between 1994 and 2006. Saw ginneries have between 2 and 5 gin stands and an average rated capacity of 90 180-kg bales per day, while the roller ginneries have between 22 and 40 roller gin stands, with a rated daily capacity of 6 bales per gin stand. The largest SG has a daily capacity of 480 bales with 2 stands, while the largest RG reaches 432 bales, with 36 stands.

In 2006, there was only one roller gin in both Zambia and in Zimbabwe, and, respectively, 13 and 15 saw gins.

Like WCA countries, Malawi, Mozambique and South Africa have only saw gins.

In Kenya, roller technology has been employed since 1935. Very little investment in new technology and upgrade of existing machinery has occurred.

1.4.3. Recent Trends in Roller Ginning

During the last 10 years, developments in roller ginning technology, or more precisely developments towards the integration of roller ginning into a single system, helped various countries in Asia and East Africa particularly India to increase their ginning capacity. The trend is to integrate all operations[21] into a single process, with no manual handling of material at any stage of the process. Another significant trend is the increasing use of roller gins (double roller and rotary knife type) for both fuzzy and black-seed varieties of medium and long staple cottons to cope with the more stringent demand for quality lint in the world market.

In the USA, there is an increasing trend towards roller ginning of medium-long staple varieties. Dunavant of California started roller ginning Acala in Arizona in the 80s. Since 2000, several producers[22], have replaced their saw gin stands with high capacity roller gin stands (1 for 3 for the same capacity) to process both Pima and Acala varieties.

India

Until the 1990s, most of the roller gins (single or double roller) in India were inefficient and costly. 70% of the ginning mills did not have any method of controlling moisture content of the cotton, and half of the ginning mills did not have any pre-cleaning facilities. 85% of the cotton was manually carried from the storage point to the ginning mills. Many roller gin installations had no cleaners and were often fed manually. Lint was also often conveyed by hand to the press. As a result, Indian cotton had the reputation of being the most contaminated origin in the world. Tiny units producing trashy and contaminated cotton and units doing pressing and baling only were incompatible with a quality-driven market for textiles. In contrast, saw gins had auto-feeder mechanisms and pre-cleaning equipment, which contributed to the reduction in contamination, by reducing human contact and handling.

[21] Feeding, drying, pre-cleaning, ginning, lint-cleaning, pressing and baling.

[22] Significantly, the largest cotton farm in the US (J.G. Boswell, Co.) discontinued the use Lummus SG and installed 3 plants equipped with 24 RG from Consolidated.

In 2000, the Government of India launched a mission called 'Technology Mission on Cotton' (TMC) to modernize and upgrade 500 ginning and pressing (G&P) factories in eight years, out of the 4,000 units in the country, in order to increase their productivity and improve the quality of cotton. One of the main purpose of modernization/upgrade of ginneries was to produce cottons free of trash and contamination through the automatization of cotton feeding and handling to replace manual labor operations. Ginners were offered a subsidy of up to Rp 2.7 million (about $60,000). Basically, the modernization consisted in integrating the double roller gin stands into a complete ginning system with auto feeder system, pneumatic conveyors for seed cotton and lint, seed cotton pre-cleaners and lint cleaners, humidifiers, and automatic hydraulic cotton baling press. Cleaner cotton also reduces maintenance requirements. Small units have a minimal processing capacity of 3-4 bales (170 kg) per hour with 12 standard double rollers. Large units have a minimal processing capacity of 6-8 bales (170 kg) per hour with 24 standard double rollers, 18 Jumbo double roller or three 90-saw gin stands.

Turkey

During the last decade, machine picking quickly replaced manual picking of seed cotton in most cotton growing areas of Turkey. Most double roller gin plants were equipped with additional pre-cleaning and lint-cleaners devices manufactured by Balkan to reduce thrash content in machine picked cottons. As a larger volume of cotton was picked in a shorter period of time, the capacity of several gins was increased by replacing old roller gins with complete ginning systems for machine-picked cottons based on rotobar gins with automatic feed control, also manufactured by Balkan. The largest cooperative, Taris, installed a large saw-gin plant to increase its capacity.

Africa

Sudan is growing both ELS (Barakat) and upland (Acala) cotton varieties. In the 1990s, the Sudan Cotton Company Ltd (SCCL) invested in saw gins to increase its capacity and in 2004/05 there were 2 saw gins in addition to the 10 roller gins. SCCL has undertaken to upgrade and increase its ginning capacity[23]. Balkan Makina is installing 10 gin plants in five different locations, each having one roller gin line and one saw gin line of the same capacity[24]. As cotton is hand picked, the gins are equipped with super jets instead of saw-type lint cleaners.

A number of new gins have been installed during the last decade in ESA countries. Roller gins are generally installed to reduce the investment cost, and eventually to preserve fiber quality, while saw gins are installed when there is a need to process large volumes rapidly.

In Tanzania, two of the major ginners, Alliance Ltd and Olam Tanzania, have installed roller gins of the same capacity than their existing saw gins in the same location[25]. They

[23] With IDB (Islamic Development Bank) financing.
[24] 30 bales per hour; each, with two 200-saw stands from Brazil and 22 rotobars, respectively.
[25] Alliance: 4 x 108-SG Lummus (1999) + 40 DR Bajaj (2006); Olam: 5 x 108-SG Lummus (1994) + 36 DR Bajaj (2006).

give preference to the roller gin for quality and outturn and use the saw gin only when needed to gin volume. Alliance has paired Indian-made Jumbo double rollers with US-made pre-cleaning and lint-cleaning equipment. Olam installed a Indian-made pre-cleaners and a secondhand Continental press.

In Zambia and Zimbabwe, a number of new roller gins have being installed. However, most ginning capacity in these countries still consists of saw gins.

In Zambia, Alliance has set up a 40-DR plant and reserved space to add another 40 stands within short time if needed. The leading ginner (Dunavant) is considering an investment in roller ginning.

In Zimbabwe, there are currently 5 roller gins and 15 saw gins. Alliance has installed a 60 DR plant with US pre-cleaning. Cottco is planning to expand the capacity of its Lummus RG plant (12 rotobars) located in the North from 10,000 tons to 25,000 tons with the high speed technology to process the longer staple variety (LS92).

Bajaj has exported double roller gins to Kenya, Madagascar, Nigeria, Tanzania, Uganda, Zambia and Zimbabwe.

In WCA countries there was no new investment in ginning during the last decade, except in Burkina Faso (modern saw gins from the US and Brazil). There is now an overcapacity in all countries.

Other Countries

One high speed Lummus roller gin and feeder has been installed in Brazil to process upland cotton in order to produce a premium fiber for the market. The double roller ginning technology has recently been adopted in Peru. Bajaj has exported double roller gins to Bangladesh, Indonesia, Myanmar, Nepal and Sri Lanka.

1.4.4. Cotton Sector Structure, Ginning Technology and Scale of Operations

The ginning technology and the scale of operations are mostly determined by the variety grown, production and harvesting conditions, and economic factors. The cotton sector structure also influences the choice of the ginning technology. High capacity saw gin plants are better adapted to monopolistic sectors with densely concentrated production, while smaller roller gin plants are better adapted to competitive sectors.

The capital cost has been restrictive for the introduction of high-productivity saw gins in countries where production was low and scattered. Conversely, low-productivity roller gins were not adopted in countries where large volumes had to be processed rapidly. Roller ginning was widely considered a primitive technology, labor-intensive, and not suitable for upland varieties.

The minimal capital cost of setting up a saw gin is substantially higher for saw gins than for roller gins. The choice between more or less labor-intensive options depends on the availability of labor and its cost relative to energy costs. Roller gins are generally the preserve of smaller companies, although numerous stands can be linked together and the supply of cotton automated.

USA

Production, climatic and economic conditions prevailing in the US imposed the choice of high capacity gins:

▪ large scale farms,

▪ high volume machine-picked in a short period of time,

▪ lack of cheap labor,

▪ availability of capital and energy,

▪ necessity to gin production in less than 100 days due to climatic conditions (frost and rain in winter).

Although machines replaced workers, labor remains the most important variable ginning cost in the USA[26]. As larger gins have lower costs (Appendix 4), the number of operating gins in the US is continuously declining[27]. Gins belong to individual farmers, cooperatives or cotton merchants.

Turkey

Gins in Turkey belong to cooperatives and to private ginners. Saw gins were installed by the largest cooperatives to increase their processing capacity.

Developing Countries

Opposite conditions prevail in most developing countries:

▪ smallholder farms,

▪ low volume (hand picked),

▪ availability of cheap labor,

▪ energy non-available or non-affordable,

▪ longer ginning season (dry and frost free).

India

Established in 1902 to increase cotton production for the United Kingdom, the British Cotton Growers Association (BCGA) promoted the installation of ginneries in the British Empire. In India[28], roller gins were installed in rainfed areas where cotton production was scattered around, while some saw gins were set up in irrigated areas with higher yields. Most of the roller gins were manually operated, with one workman or each stand to feed and stir the cotton. The recent modernization results in a significant increase in the capacity of the Indian ginneries[29]. The largest plants set up have a capacity of up to 2,700

[26] US$8 per bale in 2008 out of US$21.

[27] The number of gins dropped from 2,000 in 1982 to 710 in 2008, and the average output (per gin) rose from 5,750 bales (1,300 t) to 19,000 bales (4,300 t in 67 days).

[28] Before partition between India and Pakistan.

[29] An overall improvement in cotton quality and a considerable reduction in contamination have also been achieved.

bales per day[30]. Ginneries belong to private ginners competing with each other for seed cotton.

ESA Countries

The « Indian model » with roller gins prevailed in Uganda, Tanzania, and Kenya, as the capital cost of saw ginning was prohibitive for the small volume processed by most ginners. Large ginning companies in the monopolistic and concentrated sectors of Zimbabwe and Zambia installed US made saw-gins. Liberalization of the cotton sectors in the 1990s led to a rapid entry of private small-scale roller-gin plants competing with established, large-scale saw-gin plants, also private. Many of the new investors had little or no experience in ginning. Larger ginners (less opportunistic) first invested in saw-ginning in order to be able to capture more volume. More recently, quality-conscious ginners installed automated roller gin plants.

WCA Countries

The Compagnie Française pour le Développement des Fibres Textiles (CFDT) was established in 1949 to promote cotton production in the French colonies of Africa. Roller ginning was viewed as impractical and uneconomical, and not suitable for the medium-short staple upland varieties grown (1-1/32 to 1-1/16 inch) at that time. The monopolistic cotton companies adopted the « US model » and imported US-made saw ginning equipment. The location and capacity of the gins were based on transportation costs (seed cotton collection and lint exports). A typical plant in WCA countries has 3 to 5 high-capacity (158 or 161-saw) gin stands. So far, no investment in roller ginning has been made or given consideration to in WCA countries, even in countries where ginning has been liberalized.

2. Comparative Performance of Roller and Saw Ginning

The objective of this section is to compare, in the context of Sub-Saharan African cotton, the potential performances of saw and roller gins, as concerns investment costs, operating costs and value of production (in relation to quality performances). For the need of the analysis, three types of gin plants have been considered:

- a ginnery equipped with standard saw gins as operating in most WCA countries,
- a ginnery equipped with rotary knife roller gin stands,
- a ginnery equipped with double roller gins.

The purpose of the analysis is not to assess the total processing costs of those three models, which depend on a number of factors irrelevant to the type of gins used, but to assess specifically the differences in cost and income items which are potentially directly affected by the ginning technology, and identified as follows:

- investment cost and ginning capacity,

[30] With 4 bale presses of 35 BPH each.

▪ ginning outturn ratio,

▪ seasonal labor and energy requirements for operating the gins,

▪ maintenance costs of gin stands,

▪ quality premium.

The analysis is aimed at assessing the comparative advantage or disadvantage and the differential in ginning cost and profitability between comparable ginning plants using saw gin and roller gin technologies. To make the comparison possible, all models are assumed to have the same total capacity (implying that the number of gin stands will differ, depending of the unit ginning stand capacity for each technology). It is also assumed that, beside the gins, all models have the same ancillary equipment (pre-cleaners, conveyors, lint-cleaner and press).

Data have been collected mainly from equipment manufacturers and from interviews with ginners, in particular in Turkey and East Africa, from USDA and ICAC and from the World Bank study on cotton sectors in Africa.

2.1. Capacity and Investment Costs

2.1.1. Capacity

Saw gin stands have a higher processing capacity than roller gins. Roller-ginning rate is limited by the rate that fibers adhere to the roller. The rotary-knife roller or rotobar gin stand is a higher-capacity option versus its reciprocating-knife counterpart (single or double roller).

The capacity of a saw-gin stand depends on the number of saws, their speed and their diameter. The nominal capacity is generally expressed in kg of lint per saw per hour (ksh), and varies from 10 to 21, depending on the type of machines.

The capacity of a gin plant depends on the number of gin stands installed in parallel. The ginning capacity of the ginnery is also limited by that of the bale press and of other components such as feeders, conveyors and cleaners. The actual capacity depends on variety, quality and type of cleaned and open seed cotton and is subject to the appropriate feeding rate of the gin stand and to the correct moisture content of the seed cotton. Standard nominal capacities are as follows for the most common types of saw gins:

▪ 139 saw-gin (Chinese): 1,800 kg per hour

▪ Imperial III 116-saw (Lummus): 2,000 kg (9 bales) per hour

▪ Golden Eagle 161-saw (Continental): 3,400 kg (15 bales) per hour

▪ Imperial III 170-saw (Lummus): 3,400 kg (15 bales) per hour

For roller gins, average nominal capacities per type of gin stand (as rated by manufacturers) are the following:

▪ Single roller (Nipha): 40-60 kg of ELS lint per hour

▪ Standard Double Roller (Bajaj): 40-70 kg of lint per hour

- Jumbo Double Roller (Bajaj): 65-110 kg of lint per hour[31]
- Rotary-knife roller gin (Swan Cotton): 80-180 kg per hour
- Rota-Matic (Lummus): up to 170 kg (0.75 bale) upland per hour[32]
- Phoenix Rotobar (Continental): up to 225 kg upland (1 bale) per hour[33]
- Rotobar gin (Balkan): 225 kg (1 bale) upland per hour
- High Speeed Rotobar (Balkan): 360 kg upland (1.6 bales) per hour[34]
- High-Speed RG Series 2000 (Lummus): 1,000 kg upland (4.5 bales) per hour

The capacity is expressed in kg of lint ginned per hour (the output), which means that the capacity in terms of seed cotton processing (the input) decreases as the ginning outturn (GOT)[35] increases. In other words, the processing capacity of a gin stand is 20% higher with a ginning outturn of 35% than with a ginning outturn of 42%.

The capacity of most gin plants is limited by the capacity of the bale press. Capacities of bale presses range from 5 to 45 bales of 500 lbs per hour[36].

2.1.2. Gin Costs

Costs of gins vary with the capacity of the equipment and the country of origin. US-made equipment is much more costly than equivalent equipment from China and Brazil for saw gins, and rotobars from Turkey are about twice cheaper than their equivalent from the US. With reduction in production in many countries, particularly in the US, a lot of secondhand ginning machines are available in the market.

Indicative investment costs are as follows[37]:

Roller Gins

- Single roller gin stand (Indian): $3,000
- Double roller gin stand (Indian): $4,000
- Jumbo double roller gin stand/auto feeder (Indian): $5,000

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[31] Up to 160 kg Egyptian ELS per hour.
[32] Up to 340 kg ELS (1.5 bales) per hour.
[33] Up to 435 kg ELS (2 bales) per hour.
[34] Nominal capacity is 3 bales per hour but the manufacturer recommends not to exceed 1.6 BPH as it increases carry over and seed coat fragments.
[35] The GOT is the percent lint in seed cotton as it is delivered to the ginnery, and it is determined by the lint percentage, the weight of leaf trash and the moisture content before and after ginning. The method of picking exerts significant influence on the ginning outturn. The foreign matter includes losses in the form of undeveloped seeds or motes.
[36] Universal density (28 cubic feet or 448 kg/m3) and standard dimensions.
[37] Costs of Indian equipment are expressed as costs including transport and delivery; costs for other origins are ex-factory cost, which should be increased by an estimated 20% for transport and installation.

▪ Rotobar gin stand (Turkish): $30,000 EXW

▪ High speeed rotobar (Turkish): $50,000 EXW

▪ Rotobar (US): $100,000 EXW

***Saw Gins*[38]**

▪ 116-saw gin stand including feeder (US): $180,000 EXW

▪ 170-saw gin stand including feeder (US): $265,000 EXW

▪ 200-saw gin including feeder (Brazil): $150,000 EXW

It should be reminded that the cost of the gin stands is only a portion of the equipment cost of modern ginnery. When cotton was hand picked and carefully handled, the only machines needed in a ginning system were a gin stand and a baling press. Less careful hand harvesting methods and mechanical harvesters caused more moisture and foreign material (trash) to be mixed with the seed cotton. Thus, seed cotton cleaning and drying equipment and lint cleaners were developed to compensate for the faster and less careful harvesting methods.

Carefully picked and graded seed cotton has a low trash content and would require minimal seed cotton cleaning equipment and no lint cleaners[39]. The ancillary equipment installed in ginneries varies considerably and is largely determined by the amount of foreign matter in seed cotton[40].

A typical ginning plant consists of the following sequence of machines (details in Appendix 3):

▪ unloading equipment,

▪ separator/feeder,

▪ pre-cleaning equipment (seed cotton cleaners),

▪ conditioning equipment (dryers, humidifiers),

▪ feeding/ginning equipment,

▪ post-cleaning equipment (lint cleaners),

▪ pressing and baling equipment.

2.1.3. Definition of Gin Plant Models

[38] For roller gins, the feeder system is included in the ginning equipment (except for manually operated gins); for saw gins, the cost of the feeder has to be added to the cost of the gin.

[39] Although lint cleaners are sometimes installed to improve preparation.

[40] Handpicked cotton contains less than 50 kg per ginned bale of 225 kg, spindle picked cotton content about 100 kg of foreign matter per bale and stripped picked cotton more than 300 kg per bale.

For the saw gin type, the base model is the 170-saw gin stand manufactured in the US (Lummus), which is similar to the most frequently used gin stand in WCA (cost: $265,000 ex-factory EXW; nominal capacity: 3,400 kg/hour); it is also interesting to compare the performances of this base model with a saw gin stand of lower capacity, a 116-saw, also manufactured in the US (cost: $180,000 EXW; nominal capacity: 2,025 kg/hour).

For the rotobar type, the comparison with US manufactured gins is less relevant, as US gins are mainly designed for long fiber cotton, and are not widely used in countries outside the US. Two gin stand types are selected as models: a standard rotobar manufactured in Turkey (cost: $30,000 EXW; nominal capacity: 225 kg/hour) and a high speed rotobar, also manufactured in Turkey (cost: $50,000 EXW; nominal capacity: 360 kg/hour).

For the double roller type, the study considers a standard Indian made manual DR (cost: $4,000; nominal capacity: 50 kg/hour) and a Jumbo DR gin, also manufactured in India, and equipped with an auto feeder (cost: $5,000; nominal capacity: 75 kg/hour).

In order to take into account the supposed lower reliability of the Indian model (which partly compensates for its lower cost), it is assumed that the real capacity is 85% of nominal capacity for DR Indian made gins, and 90% for rotobar gins made in Turkey and for saw gin made in the US.

In all models, the ginning plant is assumed to have a nominal capacity of approximately 15 bales/hour (which corresponds to the capacity of a standard US manufactured baling press and that of a 170-saw gin), i. e. 3,400 kg /hour or about 10,000 tons of lint per year[41]. The real capacity is calculated by applying the coefficient defined in the previous paragraph.

2.1.4. Construction Costs

Because of the smaller capacity of roller gins, the greater number of gin stands increases considerably the space required for the machines in a roller gin plant, as compared to a saw gin plant of same capacity. The floor area required by a saw gin stand is roughly 25 sqm for a 170-saw gin and 20 sqm for a 116-saw gin. It is 18 sqm for a rotobar (or for a HS rotobar), the capacity of which is five to ten times lower. The comparison is even less favorable for a standard DR gin, which requires a floor area of roughly 13 sqm for a capacity five times lower than a rotobar.

For an equal overall nominal capacity of about 10,000 tons of lint/year:

▪ the standard DR plant model will need 68 gin stands and a floor area of 900 sqm,

[41] On the basis of an operating time of 21 hours/day, in 3 shifts, and 140 days of operation per year.

▪ the Jumbo DR plant model will need 45 gin stands (rounded to 46, as roller gin plants need to have an the same number of gin stands on each of the two lines operating in parallel) and a floor area of 675 sqm,

▪ the standard rotobar plant model will need 15 gin stands (rounded to 16) and a floor area of 275 sqm,

▪ the HS rotobar plant model will need 9 gin stands (rounded to 10) and a floor area of 175 sqm,

▪ the 116-saw plant model will need 2 gin stands and a floor area of 40 sqm,

▪ the 170-saw plant model will need only one gin stand and a floor area of 25 sqm.

The above estimates only take into consideration the floor area required for the gin stands and their feeders, and not the area required for the other components of the processing chain (assumed to be similar in all models). It shows however that the type of gin used has a considerable impact on the the floor area requirement, and therefore on the construction cost and conveying equipment (number of motors, length of belt conveyors). Based on a standard construction cost of $800/sqm, the incremental construction and conveying equipment cost (for a 15 BPH capacity plant) is $500,000 when comparing a standard DR plant to a rotobar plant, and $700,000 when comparing a standard DR plant to a 116-saw plant.

2.2. Ginning Outturn

The ginning outturn (GOT) of a ginnery is determined by the lint percentage[42] of the variety, the weight of foreign matter and trash in seed cotton and the moisture content before and after ginning. The method of picking exerts significant influence on the ginning outturn. A variety with a lint percent of 40% would be expected to give a ginning outturn of about 38% if hand-picked[43]. Using lint-cleaners or super jet after ginning reduces the ginning outturn by 1 to 1.5%.

All other things being equal, roller ginning is a softer process than saw ginning, and it eliminates less foreign matter, resulting in a better ginning outurn for the ginner (but, conversely, more trash for the end-user). According to ginners in ESA countries, the ginning outturn is 1.5% to 2% higher with double roller gins than with saw gins, for the same seed cotton[44]. According to Bajaj, experiments conducted on cotton from Zimbabwe also show that their double roller gins provide an outturn of 43%, versus 41% for saw gins. This is also corroborated by a comparative experiment conducted by the USDA on upland cotton resulted in a ginning outturn of 38.4% with a standard saw gin and of 40% with a conventional rotary knife roller gin.

According to Bajaj, the double roller gin removes more fibers, which contributes to the higher GOT, and at the same time leaves less lint on the seeds than saw gins (8% against

[42] The percent of lint in clean seed cotton and is determined by the weight of lint per seed.
[43] 36% if spindle picked and only 28% if stripper picked.
[44] In Tanzania, respectively 35% with RG versus 33% with SG. In Zimbabwe, 42% with SG versus 40% with SG.

12% of the weight of the ginned seeds). Cleaner seeds can be used without delinting, which is an additional advantage for roller gins, although difficult to quantify.

Based on those data, it can be assumed that DR plants would have a ginning outturn ratio two percentage points above a saw gin plant (for instance 42% instead of 40% based on usual African GOT), while a rotobar would have a ratio 1.5 percentage point above a saw gin plant. This difference in GOT translates into a reduced cost of seed cotton per ton of lint produced in roller gins. This cost reduction is significant, about 4cts/kg of lint (comparing a DR plant to a saw gin plant), as shown on table 2.

2.3. Processing and Maintenance Costs

Generally speaking, variable ginning costs affected by the type of gins are seasonal labor, energy and maintenance costs. There is a trade-off between labor and energy costs, for feeding, handling and moving cotton along the ginning system. The ginners' choice depends on the availability of labor and its relative cost compared to the cost of energy. Baling and pressing costs are also significant but they are not dependent on the type of ginning. Details on variable costs are presented in Appendix 4.

2.3.1. Labor

In the USA, by 1880, most hand labor operations had been replaced by mechanical screw processes, gin feeders and pneumatic cotton handling systems. In contrast, ginning remained very labor-intensive in India until the very recent modernization/upgrading of ginneries. Manual labor has a negative impact on regularity of the feeding rate and on the quality of cotton, as it increases contamination.

Typically, labor cost is higher for roller ginned cotton as compared to saw ginned cotton. This is due to the greater number of gin stands and of the generally less automated degree of operations, notably feeding of gin stands.

According to Bajaj, in an old Indian ginnery the estimated labor requirement was about 21.5 man-hours per bale of lint (Indian bales weighing 170 kg). In an automatic double roller ginning plant, the labor requirement comes down to about 2 man-hours per bale.

According to Olam, their roller gin plant in Tanzania requires 35 workers, against 20 for the saw gin plant of the same nominal capacity of 15 bales per hour[45]. This is equivalent to 2.3 and 1.3 man-hours per bale, respectively.

In Sudan, the roller gin plant installed by Balkan will require 15 people for high speed rotobars, while the saw gin plant will operate with 12 people. For a similar output of 30 bales per hour (500 lbs), this translates into 0.5 and 0.4 man-hours per bale, respectively.

In a modern automated saw gin with 3 gin stands and a capacity of 45 bales per hour, there are 15 workers per 8-hour shift, equivalent to 0.3 man-hours per bale.

Based on those data, one can estimate the seasonal labor at 5 man-hours/bale in the standard manual DR model, 2 man-hours/bale in the Jumbo auto feeder DR model, 0.6 man-hours in the rotobar model, 0.5 man-hours in the HS rotobar model, 0.4 man-

[45] In Tanzania, a worker costs $2 per day, while the price of energy is about $0.60 per kWh.

hours/bale in the 116-saw gin model and 0.3 man-hours/bale in the 170-saw gin model. Considering an average cost of $2/day in the African context, the difference in seasonal labor cost between the most labor intensive type (standard DR) and the least one (170-saw) is close to 0.6 cents/kg of lint.

2.3.2. Energy

Energy consumption (electricity from utility network or fuel for generator) in a ginning plant varies with its capacity and its degree of automatization. In a modern saw gin plant, energy consumption of the gin stands account for less than 25% of the total consumption, while cotton flows and cleaners absorb 60%[46].

The various types of gin stands have the following power requirements (as rated by manufacturers)[47]:

▪ Single roller (Nipha):	3 HP
▪ Standard Double Roller (Bajaj):	5 HP
▪ Jumbo Double Roller (Bajaj):	7.5 HP (950-1000 rpm)
▪ Rota-Matic (Lummus):	15 HP
▪ Phoenix Rotobar (Continental):	15 HP (+ feeder 0,5 HP)
▪ Rotobar gin (Balkan):	15 HP
▪ High Speeed Rotobar (Balkan):	25 HP
▪ High-Speed RG Series 2000 (Lummus):	50 HP
▪ 116-saw (Lummus)	100 HP (+ feeder 5 HP)
▪ Golden Eagle 161-saw (Continental):	150 HP (+ feeder 20 HP)
▪ Imperial III 170-saw (Lummus):	150 HP (+ feeder 20 HP)

Based on those specifications, the power ginning requirement would vary from 5 hp/stand for standard DR to 170 hp/stand for a 170-saw gin. Taking into account the processing capacity of each model, a 170-saw has the lowest energy consumption/ton of lint (37 kWh/ton), while a standard DR plant has the highes (75 kWh/ton) t. It should also be taken into account the incremental energy consumption related to the larger distances on which the cotton seed has to be conveyed in roller gin plants. Based on the conveying distance in each model, the energy required for moving cotton within the plant amounts to 60 kWh/ton of lint for a 170-saw plant, 70 kWh for a 116-saw plant, 85 kWh for a HS rotobar plant, 100 kWh for a rotobar, and 135 kWh for DR models.

The energy cost per ton of lint produced is thus substantially higher in roller gin plants (and particularly in DR plants) and lower in saw gin plants. Assuming that electricity from the network is the sole power source (which is the case in a majority of African gin

[46] 10-12 volumes of air are needed to move 1 volume of seed cotton.

[47] 1 horse power (HP) = 0,746 kW; a power generator typically consumes 0.27 liters of gas to produce 1 kWh of electricity.

plants) and assuming an average price of $0.15/kWh, the cost differential between the standard DR and the 170-saw amounts to 1.5 cent/kg of lint. It would be 2.5 cents/kg in case of electricity produced by a generator.

2.3.3. Maintenance

Roller gins, particularly single and double roller gins, are less complex mechanically than saw gins, which makes them easier to maintain without specialists. However, according to ESA ginners, maintenance costs are higher for roller gins than for saw gins.

The ginning roller is the most important and expensive component in the roller gin stand. Roller-covering material for double rollers is usually made of leather, while roller for rotary-knife rollers and rotobars are made from layers of woven cotton fabric bonded together with a rubber compound. Leather roller shafts cost about $200 and should be changed every 150-300 bales depending on the seed cotton ginned. Rubber+cotton rollers cost $1,000 in Turkey and must be changed every 1,000 bales. Bearings should be changed periodically. Double roller gins need approximately 20 g of grease per hour.

In a saw gin, saws should be replaced every 10,000 to 15,000 bales (2,250-3,400 tons of lint per set or 25 tons for each saw)[48]. The cost of saw range from $2 to $12, depending on the quality of steel used (heat treated or not), the country of origin, and their diameter[49]. Ribs should be changed after processing 60 tons seed cotton each. The cost of ribs ranges from $6 to $24.

Including other miscellaneous spare parts, the maintenance cost of a roller gin can be estimated around 1.5 ct/bale, and 1ct/bale for a saw gin (including maintenance of the feeder).

2.4. Quality and Impact on Lint Prices

Roller ginned upland cotton has a longer staple length, less short fiber, seed coat fragments and neps than the same cottons ginned with saws. As such, roller ginned cotton deserves a price premium. Yet, roller ginned cotton often gets contaminated at the gin, and the presence of foreign matter (real or suspected) can offset the premium.

According to ginners in ESA countries, roller ginned cotton can fetch a premium of up to 2 cents over the same cotton ginned with saws. However, merchants are very selective in choosing the ginners they purchase from. No premium is offered for cottons ginned in old roller gins which are manually fed from a platform above the gin stands, as this is likely to increase contamination. Fully automatic feeding systems avoid additional contamination.

In India, many ginners are getting premiums ranging from Rs 150 to Rs 500 per bale ($3-10/bale or 0.8-2.5 cent/lb) for clean cotton processed in modernized units.

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[48] Saws can also be sharpened after processing 2,000 to 4,000 bales.

[49] The cost of steel in a saw increases used by the square of the diameter; whereas the number of teeth increases only in direct proportion to the diameter. Lummus gins use 12-inch saws, while Continental gins use 16-inch saws.

In Turkey, cotton ginned with rotobar ginning systems is sold at a premium of 1.5 cent/lb over cottons processed in old roller gins. Saw ginned cotton is sold at a discount of about 1 cent/lb to roller ginned cotton.

In California, roller ginned upland Acala can fetch a premium of up to 7-10 cents per pound over saw ginned Acala, when Pima prices are relatively high[50].

Based on a current C+F price of 60 cents/lb, a roller gin plant would therefore attract a premium of 1.5 cents/lb (equivalent to 3.5 ct/kg or 2.5% of the price) over the same quality of seed cotton processed by a saw gin. This premium would however probably not apply to the standard DR model, because of a potential contamination risk linked to manual feeding.

2.5. Synthesis of the Cost/Benefit Analysis

The synthesis of the cost/benefit analysis is given in the table below and can be summarized as follows:

Contrarily to a common belief, the investment (and capital cost) per kg of lint produced is higher in roller gins than in saw gins, due to the fact that they require more space and conveying equipment, because of the limited capacity of gin stands; the disadvantage for roller gins would be reduced for a plant of smaller capacity than the one considered in the analysis, suggesting that the economic performance of roller gins is higher for small processing units, and that economies of scale are more limited than for saw gins.

The comparison between a 170-saw gin and a DR standard gin shows a small economic advantage of 0.85 ct/kg for the latter, mainly due to a higher GOT, which is not fully offset by higher energy, seasonal labor, maintenance and construction costs.

The advantage for roller gins is much more substantial when comparing jumbo DR gins or rotobar gins to 170-saw gins, as the gain reaches 5 cents per kg, about 3% of current international prices (65 cents per pound). The main sources for a higher competitiveness are (a) the higher GOT for roller gins and (b) the quality premium fetched by roller ginning if performed under adequate conditions. The negative incidence of the higher variable costs (energy, seasonal labor and maintenance) and of higher investment requirements is minimal.

Altogether, the economic advantage of roller gins (Jumbo DR with auto feeder and rotobar gins) versus saw gins is far from being negligible, provided necessary conditions are met to capture the benefits of the technology:

If the economic advantage (5 cents per kg) was fully passed on to producers, considering an average producer price of seed cotton between 65 and 78 US$ cents per kg of lint equivalent, roller ginning would enable the ginners to increase the producer price by 6 to 7%, without affecting their net margin. This could be crucial for producers in those ranges of price, very close to their breakeven point, in particular in WCA.

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50 ELS Pima prices are less volatile than upland prices, usually ranging from 110 to 125 cents per pound.

The potential increase in the value of cotton due to roller ginning that could be passed on to farmers would add to the potential increase resulting from quality improvement, and especially from the elimination of contamination. At typical producer prices of 25 to 32 cents per kg of seed cotton, the estimated 10 cent per pound increase in the price of lint that is fully passed on to farmers would increase farmer prices by 30 to 40 percent[51].

If the economic advantage were entirely retained by the ginner, it would considerably increase the net value added at the ginning stage, which was estimated, under 2006 conditions[52], between 0 and 14 cents per kg of lint in monopolistic WCA cotton sectors, and between 24 and 41 cents per kg in competitive and concentrated ESA cotton sectors.

[51] Organization and Performances of Cotton Sectors in Africa; World Bank publication; 2008.
[52] Ibid.

Table 2 - Comparative Economic Analysis of Roller and Saw Ginning

		Double Roller Gin		Rotary-knife Roller Gin		Saw Gin	
For a plant with an approximate capacity of 15 bales/hour		India		Turkey		USA	
		Standard	Jumbo	Rotobar	HS Rotobar	116-saw	170-saw
Investment cost/gin stand ($)		4,000	5,000	36,000	60,000	216,000	318,000
	unit	Manual	Auto feeder				
Capacity/gin stand							
Capacity/gin stand	kg lint/hour	50	75	225	360	2,025	3,400
Average bale weight	kg/bale	225	225	225	225	225	225
Capacity/gin stand	bale/hour	0.2	0.3	1.0	1.6	9.0	15.1
Number of gin stands	number	68	46	16	10	2	1
Capacity/year							
Number of working hours/year	hours/year	2,940	2,940	2,940	2,940	2,940	2,940
Annual plant theoretical capacity	tonnes/year	9,996	10,143	10,584	10,584	11,907	9,996
Capacity coefficient	real/nominal (%)	85%	85%	90%	90%	90%	90%
Annual plant real capacity	tonnes/year	8,497	8,622	9,526	9,526	10,716	8,996
Annual real capacity/gin stand	tonnes/year	125	187	595	953	5,358	8,996
Investment costs							
Investment cost in gin stands	$	272,000	230,000	576,000	600,000	432,000	318,000
Ginning floor area	sqm	900	675	275	175	40	25
Construction cost/sqm	$/sqm	800	800	800	800	800	800
Construction cost for ginning area	$	720,000	540,000	220,000	140,000	32,000	20,000
Operation parameters							
Power for ginning	hp/gin stand	5	7.5	15	25	105	170
Power for ginning	kWh/gin stand	4	6	11	19	78	127
Power for ginning	kWh/t lint	74.6	74.6	49.7	51.8	38.7	37.3
Power for cotton flows	kWh/t lint	135.0	135.0	100.0	85.0	70.0	60.0
Seasonal labor	man-hour/bale	5	2	0.6	0.5	0.4	0.3
Maintenance	$/bale	1.5	1.5	1.5	1.5	1	1
Ginning outturn ratio	%	42.0%	42.0%	41.5%	41.5%	40.0%	40.0%
Average cost of factors							
Lint value C+F	ct/lb	60	61.5	61.5	61.5	60	60
Lint value C+F	$/kg lint	1.32	1.36	1.36	1.36	1.32	1.32
Energy cost ($/kWh)	$/Kwh	0.15	0.15	0.15	0.15	0.15	0.15
Labor cost ($/hr)	$/hour	0.3	0.3	0.3	0.3	0.3	0.3
Cost of seed cotton	ct/kg seed cotton	35	35	35	35	35	35
Ginning variable cost at average value of factors							
Seasonal labour	ct/kg lint	0.67	0.27	0.08	0.07	0.05	0.04
Energy	ct/kg lint	3.14	3.14	2.25	2.05	1.63	1.46
Maintenance of gins	ct/kg lint	0.67	0.67	0.67	0.67	0.44	0.44
Seed cotton	ct/kg lint	83.33	83.33	84.34	84.34	87.50	87.50
Total variable cost ($/t lint)	ct/kg lint	*87.81*	*87.41*	*87.33*	*87.12*	*89.63*	*89.44*
Ginning capital and depreciation cost							
Life time of ginning equipment	years	10.00	10.00	10.00	10.00	10.00	10.00
Depreciation of ginning equipment	ct/kg lint	0.32	0.27	0.60	0.63	0.40	0.35
Depreciation of construction cost	ct/kg lint	0.42	0.31	0.12	0.07	0.01	0.01
Capital cost for ginning equipment	ct/kg lint	0.16	0.13	0.30	0.31	0.20	0.18
Capital cost for construction	ct/kg lint	0.42	0.31	0.12	0.07	0.01	0.01
Total capital and depreciation cost	*ct/kg lint*	*1.33*	*1.03*	*1.14*	*1.09*	*0.63*	*0.55*
Cost differential at average value of factors (base=170-saw gin)							
Variable costs	ct/kg lint	-1.63	-2.03	-2.11	-2.32	0.18	0.00
Fixed costs	ct/kg lint	0.78	0.47	0.59	0.54	0.08	0.00
Incremental value of production	ct/kg lint	0.00	3.31	3.31	3.31	0.00	0.00
Net income differential	**ct/kg lint**	**0.86**	**4.87**	**4.84**	**5.09**	**-0.27**	**0.00**

2.6. Operational Requirements

2.6.1. Seed Cotton

A simple gin machine sequence is required to gin clean cotton. Trashy cotton requires a more extensive machine sequence[53]. Roller ginning is less efficient than saw ginning in processing trashy and immature hand-picked seed cotton.

The moisture content of seed cotton is critical for efficient gin operation and to preserve intrinsic fiber quality. The ideal moisture range for cotton ginning is 6.5-8% for upland cotton and 5-6% for Egyptian/Pima cotton[54].

When gin machinery is used in the recommended sequence, 75-85% of the foreign matter is usually removed from cotton. Cleaning is more efficient in dry cotton, but drying fiber lower than 4% can cause increased static electricity problems and fiber breakage because fiber strength is inversely related to moisture content. On the other hand, cotton that is too moist doesn't separate into locks but remains in wads, which can choke the ginning machinery.

Seed cotton cleaners do not cause much quality damage, but any cleaning has the potential to increase neps or short fibers. As a result, choosing the degree of gin cleaning is a compromise between fiber trash content and fiber quality. Lint cleaners may be necessary to eliminate broken or crushed seeds, seed coat fragments for varieties with fragile seeds, or to improve the preparation[55] of lint, especially with high ginning speeds. The use of lint cleaners or super jet cleaners typically improves the quality of lint (by half a grade) and the price of lint by 0.5 cent per pound (by gaining half a grade), but reduces the ginning outturn by up to 1.5%.

2.6.2. Gin Operations

Quality preservation during ginning requires the proper selection and operation of each machine in a ginning system. These decisions are based on the quality of cotton coming into the gin and the amount of trash and moisture content. The more uniform these parameters, the more consistent the ginning process.

The capacity of the ginning system and the quality and potential spinning performance of the lint depend on the operating condition and adjustment of the gin stands. It is important to maintain the gin stand in good mechanical condition, to gin at recommended moisture levels, and not to exceed the nominal capacity of the gin stand or other components of the system. The quality of the cotton may be reduced if in stands are overloaded. Short fiber content increases if the ginning rate exceeds the manufacturer's

[53] Roller ginning systems for machine-picked cotton include seed cotton conditioning, pre-cleaning equipment and post-cleaning equipment similar to those used with saw gins.
[54] The moisture content of 8 to 9% in baled cotton is acceptable and results in improved mill performance.
[55] Preparation refers to the degree of smoothness or roughness with which the cotton is ginned, and the relative “neppiness” or “nappiness” of the ginned lint.

recommendations. Short fiber also increases as saw speed increases. Increased ginning rate also increases yarn imperfections. Seed damage can also result from excessive ginning rate, especially when the seeds are dry. Ginning causes “neppiness” in cotton lint. Maintaining proper moisture and eliminating unnecessary processing steps during ginning reduces nep formation.

Roller gins, particularly single and double roller gin stands, are less complex and easier to operate and repair than saw gins that need closer supervision. Maintenance of knives, knife-to-roller distances and speed control are essential for good ginning. Overginning will produce fiber knots, which are difficult to process in the mill.

One characteristic of high-capacity roller ginning is carry-over of partially and unginned seed cotton. Two factors contribute to carry-over: trash intermingled with seed cotton and non uniform feed of seed cotton from the feeder. An intermediate process, known as reclaiming, is necessary to separate carried over seed cotton from the ginned seed and re-introduce it to the ginning process. Current reclaiming technology is adequate only for cottons with little or no trash, dry and warm, single-locked, with robust and substantial seeds.

Maintaining saws in good condition and properly adjusted is critical for the quality of saw ginned lint.

3. Links between Ginning Technology and Sector Type and Opportunities of Roller Ginning for African Cotton

3.1. Ginning Technology and Sector Structure

It is striking to note that the sub-Saharian African countries where roller ginning has been introduced are countries which have – or which had in the past- a competitive sector structure (Tanzania, Uganda, and, to a lesser extent and more recently, Zambia and Zimbabwe), while roller ginning has not been developed in countries with local or national monopolies. This does not necessarily means that the ginning technology is linked to sector structure, as historical factors have also played a role. The first explanation for the development of roller ginning in Tanzania and Uganda is indeed that a number of ginners of Indian origin are operating in these countries, and that they have spontaneously transferred the Indian technology, often buying second hand equipement from India. In contrast, in WCA countries, where cotton was developed by the French parastal CFDT, the Indian technology was not considered as an option, and there was a clear will to adopt the American saw gin technology, considered as the most up-to-date one and the most suitable for the upland short fiber cotton varieties introduced at that time in Western Africa from the United States.

Beyond this historical explanation, the attitude of ginners towards roller ginning is clearly different, depending on the type of the cotton sector in the country. In competitive sectors, small scale ginners, who are predominant, want to minimize their initial investment cost, because their capital is limited, in order to minimize their fixed costs and thus be more competitive, and in order to reduce their exposure to the risk of overcapacity. In monopolistic sectors, the risk of overcapacity is reduced (as no newcomer can enter the sector) and ginners have less incentives to minimize their fixed costs, as they do not have to compete between each others. Small scale ginneries are therefore often preferred in competitive countries, while monopoly ginners tend to prefer large scale ginneries, from which they expect economies of scale and an easier management of cotton flows and quality. The capital constraint is also in general less severe for monopoly ginners, who have an easier access to bank financing, as their supply is secured. In WCA countries, where monopoly ginners were historically state-owned, ginneries were often, in the 70s and in the 80s, financed with a government guarantee, and had therefore less capital constraints.

Although the investment cost per kg of lint produced is higher in roller gins, there is no economy of scale in this technology, as the capacity of a roller gin ginnery depends on the addition of more or less ginning stands, and as the unit capacity of a ginning stand is much smaller than in a saw ginnery. Ginners who want small scale ginneries tend therefore to opt for roller ginning rather than saw ginning. This is currently illustrated in Uganda, which is moving from a concentrated towards a competitive sector open to a large number of newcomers, and where most of these newcomers have opted for roller ginning.

In short, ginners in competitive sectors are more sensitive to the scalability of roller gins, which enables them to operate, under competitive conditions, smaller scale ginneries, while in monopoly sectors ginners have less reasons for such a choice. The sector type does therefore influence the ginning technology adopted by ginners.

Another side of the possible linkage between sector types and ginning technology is the question of whether a ginning technology is conducive to a specific sector type. This question has different aspects. One one hand, it is clear that, in order to to have a real competition between ginners, farmers need to have a choice between a number of ginneries. Small scale ginneries and therefore the roller ginning technology, are more competitive friendly than saw ginning, which requires larger ginneries. There is however no reason to believe, as will be developed in the next section, that concentrated or monopolistic sectors work better with saw ginning.

Another aspect of the same question pertains to quality. Roller ginning can produce higher quality fiber, but this translates into higher price only under the condition that the cotton is clean and not contaminated and that the ginner has a reputation of quality. The comparative study on sector types has shown that quality control is more difficult in competitive sectors, because there is less traceability of seed cotton and because competition between ginners makes them less stringent on quality. In this respect, it is more difficult for competitive sectors to take the full benefit of the quality advantage of roller ginning.

3.2. Relevance of Roller Ginning for SSA Countries

3.2.1. Growing Importance of Quality Factors

It has long been known that the roller ginning process does less damage than saw ginning when separating fiber from the cotton seeds. Yet roller ginning was considered impractical for upland cotton and uneconomical due to its limited processing capacity. The development of rotobars and double rollers equipped with autofeeders has increased the productivity of roller ginning during the last decade.

Increasing quality demands are being placed on the entire textile supply chain, from the raw material to end products. Thus, the importance attached to lint quality by international spinners has risen in recent years. In short, the increasingly stringent demand for quality cotton can be summarized by the following motto « fiber, only fiber, but more than just fiber ».

The trend in spinning technology toward more automation and higher speeds makes improvements in quality and consistency a vital issue for the future of African cotton sectors. African cotton has two potential competitive advantages in the world market: the intrinsic quality of its fiber (the fiber properties) and the fact that it is handpicked. As demand for quality cotton becomes more stringent, the benefits of roller ginning African upland cottons increase.

The price of cotton is still largely determined by fiber staple length, grade[56], color[57], micronaire[58] and strength[59]. Roller ginned cotton is significantly longer than the same cotton saw ginned, while micronaire and strength are not affected by the type of gin. New technologies place increasingly severe technical demands on textile fibers, raising the importance of other properties of cotton, particularly length uniformity, short fiber content, nep count, seedcoat fragments[60], and spinning performance. These properties are better preserved by roller ginning.

The fastest growing and most remunerative market for upland cotton is for higher grades and longer cottons used for producing ring spun combed yarns for the woven and knitted apparel sector. In that segment, the modern high-speed machinery requires better fiber characteristics:

- Grade: Strict Middling-White
- Staple length: 1-1/8 or longer
- Uniformity ratio: 83% or better

[56] Grade is not an intrinsic value; it is a commercial value based on a visual assessment of lint color, trash content and preparation.
[57] Color is determined by the degree of reflectance (Rd) and yellowness (+b). Reflectance indicates how bright or dull a sample is and yellowness indicates the degree of color pigmentation.
[58] The micronaire is a measure of fiber fineness and maturity.
[59] The strength reported on terms of grams per tex is the force in grams required to break a bundle of fibers one tex unit in size. The tex unit is equal to the weight in grams of 1,000 meters of fiber.
[60] Neps and seed coat fragments are responsible for up to 50% of yarn imperfections.

▪ Short fiber content: 5% or less

▪ Nep count: 200 per g or less

The roller gin process results in an appearance of the lint that is not as smooth as that of the saw-ginned lint. A few years ago, most spinners outside India and Turkey had no experience with roller ginned upland cotton, and were reluctant to use it because of its preparation. Recently, India became the second largest exporter of cotton lint in the world after the US, and the major competitor for SSA cotton exporting countries, with very attractive prices. As a result, many spinners in importing markets, notably in China, are becoming used to processing roller ginned cotton, and appreciate its quality and spinnability.

3.2.2. Roller Ginning Can Add Value to SSA Cotton

With roller gins, most African upland cotton could reach the specifications needed for fine combed yarns, whereas saw ginning of upland cottons results in less than optimum fiber lengths, increased short fiber and nep contents.

Over the last decade, the average staple length of sub-Saharan African cottons has increased, and most production is now 1-3/32 inch or longer. Roller ginning of shorter staple varieties can be problematic, but a cotton that is classed as 1-3/32 inch when saw ginned would be classed as 1-1/8 inch when roller ginned. Longer staple varieties grown in a few countries[61] that are classed as 1-5/32 inch when saw ginned would be classed as 1-3/16 inch when roller ginned, and would thus qualify for the more demanding but more remunerative segment of finer yarns.

Roller gins are more efficient with clean cottons[62], and less effective than saw gins for removing trash[63]. As all African cotton is handpicked it is relatively clean. In addition, dry conditions prevail during most of the ginning season in Africa, and roller ginning requires a lower moisture content than saw ginning[64].

Therefore, most African Upland cotton would be suitable for roller ginning. However, roller gins would require automatic feeding to capture quality premiums. Cotton prices are not solely determined by intrinsic fiber properties and lint cleanliness. Contamination of lint by non vegetal foreign matters is the most serious problem facing African cotton, and is crucial in pricing. Cotton that is contaminated or that is suspected of being possibly contaminated can only be sold at a discount that could offset the advantage conferred by roller ginning. Manual feeding of roller gin is being abandoned in India and should be banned in SSA because it potentially increases contamination[65]. Price premiums and

[61] Cameroon and Zimbabwe.

[62] Although machine-picked cotton can also be roller ginned after having been pre-cleaned.

[63] Saw ginned lint is cleaner than roller ginned lint, but often contains fine trash which is more difficult to remove in the spinning mill than larger particles typically remaining in roller ginned lint.

[64] Humidifiers are required to reach the optimal moisture content for cleaning, ginning, pressing and baling.

[65] In addition, manual feeding does not allow an optimal feeding rate of the roller gin stands.

discounts attached to internationally traded cotton derive partly from the reputation of national origins, which can be damaged by poor shipments from a few ginners.

3.2.3. Specific Interest of Roller Ginning for WCA Countries

WCA cotton production dropped since 2004/05 and a rapid rebound to its peak level seems unlikely. The development strategy in the cotton sector is likely to shift from mass production to a more selective strategy giving priority to increased competitiveness through productivity and quality over quantity. At first sight, the current overcapacity will prevent additional investment in ginning in the years to come. Nevertheless, the lower production can provide an opportunity for replacing saw gin stands with roller gin stands in some ginneries that need to be modernized.

As the proportion of farmers growing cotton tends to decrease in WCA due to growing selectivity and shifting to other crops, smaller roller gin plants may reduce transport costs as compared to larger scale saw gins plants. Large gins in WCA were primarily located in order to minimize seed cotton transportation costs because the volume transported and the cost per ton-kilometer is much higher than for lint. The reduced density of production could benefit smaller gin plants, as high-capacity saw gin plants will be penalized by the increase in seed cotton transportation costs[66].

In addition, with their limited capacity, roller gins could also provide an opportunity for small ginners working in close connection with fair trade and organic cotton producers to meet the required specifications for those niche markets and encourage their development.

In the current context of production crisis, WCA monopolistic cotton sectors are indeed facing a ginning overcapacity problem. Nevertheless, the option of introducing roller ginning should be considered for the medium or long term, both for economical and structural purposes. While improving competitiveness, it could allow smaller ginneries to enter the market, and thus facilitate the transition to more competitive systems. It could also facilitate the development of niche markets (organic and fair trade cotton) and the entry of farmer groups/associations into the ginning industry.

3.2.4. Overall Advantage of Roller Ginning

The costs/benefits analysis is clearly in favor of roller ginning compared to saw ginning in SSA. As roller ginned cotton is longer, has a better uniformity and contains less short fibers, seed coat fragments and neps, it could command a premium of up to 2 cents per pound (4.4 cents/kg) over the same cotton saw ginned cotton, which is about 3% of current international prices. Compared to saw gins, roller gins have a higher ginning outturn, which represents an increase in lint production of 3.5% to 6%, depending on the variety and on the type of roller gin. The quality premium combined with the higher ginning outturn more than offset the higher investment and operational costs of roller gins[67].

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[66] The average distance from farms to the gin will increase to fulfill the gin capacity.

[67] For a capacity of 15 bales per hour (3.4 tons lint/hour), which is the minimum capacity of a US-made hydraulic universal or standard density press.

Historical trends are influencing the choice of ginning technology. The improvements in the roller ginning technology, the increase in length of fiber of African upland cotton and the increasing importance given to quality by the textile industry tend to reverse the traditional advantage of saw ginning for upland cottons in favor of roller ginning, resulting in a potential 7%-increase in the value of cotton that could be passed on to farmers.

In conclusion, roller ginning technology has a very significant potential for improving the competitiveness of SSA cotton sectors, through value addition rather than cost reduction.

3.3. The Way Forward

Improving competitiveness is crucial for the survival of the African cotton sector, and quality management has been identified as one of the most important areas of improvement for SSA cotton exporting countries.

The efficiency of the ginning industries is critical to the competitiveness and the sustainability of the cotton sector overall. Optimizing the costs/benefits of ginning implies revisiting policies on the choice of technology and the size of the ginneries.

Based on the findings of a comparative study on India, Turkey and Egypt, the UNIDO study of identification of strategies for developing the cotton value chain in WCA recommended the roller ginning technology for a more detailed evaluation.

Although there are technical, organizational issues that need to be addressed to introduce roller ginning in SSA countries, there is every reason to believe that roller gins could optimize quality management in ginning, improving lint quality and consistency, and generate significant productivity gains in African countries.

It would therefore seem quite relevant for the African cotton sectors' stakeholders to invest in roller ginning. The choice of technology in a given industry would seem to be an issue for private investors, namely for the owners of ginneries. However, so far, no investment in roller ginning has been made or given consideration to in WCA countries, even in countries where ginning has been liberalized, except by the promoters of small scale projects aimed at niche markets.

Policies and programs aiming at improving the quality of lint and the competitiveness of cotton as well as critical issues such as technology transfer, can be handled at national level[68]. Every innovation has to stand the test of real-life conditions, and a public effort is needed to raise the awareness of ginners on the potential benefits of roller ginning for ginning outturn and lint quality, and to monitor prices paid by ginners to ensure transmission of additional returns to producers.

[68] Along those lines, the Government of India set up a Technology Mission on Cotton (TMC) in 2000. Considering that quality and price-competitiveness were vital for the survival of the cotton industry, an important sector of the Indian economy and an important foreign-exchange earner for the country, the scheme has achieved remarkable success in increasing production, productivity and quality of cotton in India.

To this end, a pilot project aiming at demonstrating the viability of the roller ginning technology under real WCA conditions should evaluate the performance of existing roller ginning technology in terms of cotton quality preservation, productivity, costs and financial returns to cotton ginners and growers, in comparison to saw ginning technology.

The first phase of the project would consist in:

▪ checking the ginning outturn and testing the lint produced from representative samples of seed cotton from WCA ginned on roller gins in Turkey (rotobars) and India (double rollers);

▪ organizing a visit for WCA cotton ginners and producer association interested to Tanzania, where both technologies are used, to make them aware of the potential benefits of roller ginning for quality, and, therefore, for cotton pricing.

If the predicted quality performance of roller ginning technology is confirmed, a small scale pilot testing facility will be set up to test the double roller and rotary knife technologies under real conditions.

The second phase of the pilot project would:

▪ monitor and evaluate costs, productivity, quality and returns of roller gins;

▪ identify constraints and weaknesses of the technology;

▪ compare the results of the costs/benefits analysis to those of the conventional saw gins under the same conditions;

▪ conduct a feasibility study on the use of roller gins at the village level for non-conventional cotton produced for niche markets (fair trade and organic);

▪ disseminate results.

This pilot project would be in line with national cotton development strategies to improve the quality of lint, increase incomes at the village level by adding value to cotton, and improve the competitiveness of the commodity. As such, it could be considered by the CFC (Common Fund for Commodities), who finances multi-country development projects for smallholder farmers, as well as small and medium enterprises involved in commodity production, processing and trade in developing and least developed countries[69].

Roller ginning technology could also be promoted through public-private partnership. The second phase of the pilot project would be funded by a cost-sharing arrangement

[69] This project could also be considered by the USAID funded-WACIP (West African Cotton Improvement Program), who designed and implemented a regional training course focused on mastering ginning efficiency and cotton quality, and has funded new equipment to improve cotton quality.

between a government and private investors wanting to invest in ginning[70] under the condition that all data on performance and costs would be made publicly available.

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[70] In India, TMC Mini-Missions III and IV offered financial assistance to ginners for modernizing and upgrading ginning and pressing factories. Ginners found the cost-sharing scheme offered by the Indian Government very attractive.

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Appendix 1: Basics of Ginning Technologies

Roller-type Gins

Reciprocating Knife Single Roller Gin (McCarthy Roller Gin)

The principle of the McCarthy roller gin is to rotate an approximately 8” diameter ginning roller covered in a packing material, having cohesive properties similar to cotton itself, against a stationary blade. The tip of the blade is approximately tangent to the surface of the roller, which is held under force against the blade while rotating. This point of tangency is known as the ginning point. A movable bar, often referred to as a “pick,”is strategically located adjacent to the ginning point, where it is driven to reciprocate linearly in such a way as to dislodge ginned seeds from the ginning point. Seed cotton feeds to the ginning roller in such a fashion the ginning roller “grabs” the lint, pulling the seed lock towards the ginning point. The stationary blade is set so as to allow the lint to pass along with the surface of the ginning roll under the stationary blade, leaving the ginned seed at the ginning point. The reciprocating blade stroke length is dependent on fiber length, and its frequency is relative to the surface speed of the ginning roller.

Double Roller Gin

In a double roller (DR) gin, two spirally grooved leather rollers, pressed against a stationary knife with the help of adjustable dead loads, are made to rotate in opposite direction at a definite speed. The three beater arms (two at end and one at the center of beater shaft) are inserted in the beater shaft and two knives (moving knives) are then fixed to the beater arms with proper alignment. This assembly is known as beater assembly, which oscillates by means of a crank or eccentric shaft, close to the leather roller. When the seed cotton is fed to the machine in action, fibers adhere to the rough surface of the roller and are carried in between the fixed knife and the roller such that the fibers are partially gripped between them. The oscillating knives (moving knives) beat the seeds from top and separate the fibers, which are gripped from the seed end. The process is repeated a number of times till all spinnable fibers are separated from the seeds, which are carried forward on the roller and doffed out of the machine. The ginned seeds drop down through the slots provided on the seed grid, which is part and parcel of the beater assembly, which also oscillates along with the moving knife. Fiber comes out from the bottom side and falls either below on the floor for manual collection, or on a lint slide and to a belt conveyor installed along a series of Double Rollers.

Rotobar or Rotary Knife Roller Gin

Rotary-knife roller gin stands separate fiber from seed by using the frictional forces between a moving roller and fixed stationary-knife surface. The principle behind the high-capacity roller gin is to rotate an approximately 15”diameter ginning roller, covered in a packing material, having cohesive properties similar to that of the McCarthy design, against a stationary blade. As the ginning roller turns, it is forced against a stationary knife blade, much as the ginning roller in the McCarthy design. The tip of the stationary blade is relatively tangent to the surface of the ginning roller. A rotary knife, approximately 2¾” in diameter, is strategically located a short distance from and tangent to the ginning point.

During normal ginning, the roller-to-fiber force is greater than the stationary-knife-to-fiber force; therefore, the fiber sticks to the roller surface and slips on the stationary knife surface. Cotton is ginned as fibers adhered to the roller surface slip under the stationary knife which holds the seed. The rotary knife clears the stationary knife edge of accumulated seed cotton and ginned and partially-ginned seed. Partially ginned seed are either pulled back to the stationary knife or swept along with the seed and later reclaimed. At the ginning point, seed cotton trash is separated with about 45 to 50 percent going with the lint and the remainder with the seed. The carryover reclaimer removes un-ginned and partially-ginned cotton from the seed flow and returns them to the distributor for ginning.

Saw-type Gins

A saw-gin stand consists of a set of round saws rotating at a high speed between parallel metal bands called ginning ribs. The saw teeth pass between the ribs at the ginning point, where the leading edge of the teeth is approximately parallel to the rib to pull the fibers from the seed rather than cutting them.

Saw gin stands typically have 30.5 to 45.7 cm (12 to 18 inches) diameter saws spaced from 0.5 to 1 inch apart with as many as 200 saws stacked on a single mandrel. Each of these saws project through ginning ribs, grasp fiber, and pull the fiber from the seed as they are too large to pass through the opening in the ginning ribs. The speed of the saws depends upon the type of the ginning machinery. In the brush system, the saws operate at a speed of 350 to 450 revolutions per minute (rpm). In an air blast system, the saws run at a much higher speed of 500 to 700 rpm, and in modern saw gins at 1,000 to 1,200 rpm. The ribs are shaped such that as the lint is engaged, the partially stripped/ginned seeds are pressed forward and upward by the pressure of other seeds which in turn are brought forward by the saw teeth. The diameter of seeds generally follows a normal bell shaped distribution, and occasionally a small seed escapes the gin stand and is removed by the moting sections of the gin stand or by a subsequent lint cleaner.

On traditional gin stands, cotton enters the stand through a huller front. The saws grasp the cotton and draw it (in locks) through a widely spaced set of ribs known as huller ribs. This causes hulls and sticks to fall out of the machine. The locks of cotton are drawn into the bottom of the roll box through the huller ribs. Newer gin stand designs have eliminated the huller front, sending the seed cotton directly into the roll box from the feeder apron. This change increases stand capacity, but eliminates some seed cotton cleaning.

The actual ginning process (separation of lint and seed) takes place in the roll box of the gin stand. When all the long fibers are removed, the seeds slide down the face of the ginning rib between the saws and fall by gravity onto a seed conveyor under the stand. Lint is removed from the saw by a rotating brush (doffer brush or by an air blast). It is then conveyed to the next machine in the ginning system, usually a lint cleaner.

Appendix 2: Major Ginning Equipment Manufacturers

Saw Gins

▪ BC Supply, Lubbock, Texas, USA
▪ Busa Industria e Comercio de Maquinas Agricolas Ltda, Brazil
▪ Continental Eagle Corporation, Prattville, Alabama, USA
▪ Hebei Hanwu Cotton Machinery Corporation, Handan, Hebei, China
▪ Lummus Corporation, Savannah, Georgia, USA
▪ Sinocot, China Cotton Industries Ltd, Beijing, China
▪ Swan Cotton Industrial Machinery Stock Co. Ltd, Jinan, Shandong, China

Double Roller Gins

▪ Avi Ginning Machinery Pvt Ltd, India, Ahmedabad, Gujarat, India
▪ Bajaj Steel Industries Limited, Nagpur, Maharashtra, India
▪ Bhagvati Engineering Works, Ahmedabad, Gujarat, India
▪ Delegent Ginning Machinery Pvt Ltd, Ahmedabad, Gujarat, India
▪ Nipha Group Industries, Kolkata, West Bengal, India
▪ Jadhao Gears PVT ltd, Amravati, Maharashtra, India
▪ Sinocot, China Cotton Industries Ltd., Beijing, China
▪ Sumer Makina Fab., Istanbul, Turkey
▪ Swan Cotton Industrial Machinery Stock Co. Ltd, Jinan, China

Rotary Knife Gin

▪ Balkan Textile and Cotton Gin Machinery Co. Ltd (Balkan Makina), Aydin, Turkey
▪ Continental Eagle Corporation, Prattville, Alabama, USA
▪ Lummus Corporation, Savannah, USA

Appendix 3: Typical gin process and equipment

A ginning plant consists of the following sequence of operations:

Feeding

Gin machinery operates more efficiently when the cotton flow rate is constant. In early gins the flow rate was often erratic because of the variable work rate of the person unloading the wagon. The automatic feed control was developed to solve this problem by providing an even flow of cotton to the gin's cleaning and drying system.

Pre-cleaning

The next process utilizes mechanical devices (cleaners such as stick machine, cylinder cleaner[71] and impact cleaner, cyclones[72] and extractors) designed to remove impurities like motes (immature seeds), cotton burrs[73], sticks, stems, sand and dirt, and similar trash in seed cotton before ginning. This process generally combines conditioning (drying or adding moisture) and pre-cleaning.

Drying/conditioning

Tower driers are not required for drying seed cotton in the SSA context. If the cotton is very dry, it may be necessary to use humidifiers to add water, so as to maintain a moisure content of 6.5 to 8% for saw ginning and 5 to 6% for roller gins.

Extractor feeder

The primary function of an extractor-feeder is to feed seed cotton uniformly to the gin stand at controllable rates. Seed cotton cleaning is a secondary function. At the "gin feeder," the seed cotton is separated so that single locks of seed cotton are fed into and through the "gin stand."

Gin stand

The gin stand, whether saw or roller, removes (pulls) the fiber from the seed and is the heart of the ginning system.

Post-cleaning (lint cleaning)

The lint cleaner provides the first opportunity for combing and cleaning of the cotton fiber and separates the foreign material into a separate process stream of by-products called motes. Gins typically use two types of lint cleaners, air jet and saw. These cleaners were developed specifically for combing and final cleaning to remove foreign matter left in the ginned lint, such as small leaf particles, seed coat fragments, motes, sticks and grass. Lint cleaners can improve the grade of cotton by removing foreign matter if the cotton has the necessary color and preparation characteristics. But fiber

[71] A machine with rotating spiked drums that open the locks and clean the cotton by removing dirt and small trash.

[72] A centrifugal air pollution control device for separating solid particles from an air stream.

[73] The rough casing of the boll; often referred to as hulls after separation from the seed cotton.

length and several other important quality factors can be damaged by excessive lint cleaning, especially when the cotton is too dry (<5% moisture content). However, for roller-ginned cotton, the lint cleaner is composed of three machines: a cylinder cleaner, an impact cleaner and an air-jet cleaner.

After ginning and lint cleaning, the combed lint is pneumatically conveyed to a “condenser,” which forms the cotton lint into a “batt” and then meters and feeds the stream of batted lint down a “lint slide” into the bale press.

Pressing and baling

The function of trampers is to loosely press the cotton into the press box as it is received from the condenser.

The function of the bale press is to produce uniform, compact, densely- packed bales of cotton lint that go to warehouses for storage or directly to textile mills for processing (spinning) into yarn.

Cotton must be baled and packaged to protect it from contamination during transportation and storage. The U.S. textile industry has required that bales be packaged a standard dimension and density of 28 pounds per cubic foot (448 kg/m3). This standard bale sof 500 lbs supports storage, handling and process uniformity throughout the marketing and processing system.

Appendix 4: Ginning Variable Costs

The USDA is conducting annual surveys of ginning costs. In 2007, for an average volume of about 29,000 bales (6,600 t), the average variable cost was $21.58 per bale (4.3 cents/lb or 9.5 cents/kg).

Table 3 - Ginning Variable Costs in the USA (USA; 2007)

	$/bale	cts/lb	cts/kg	%
Bagging & ties	4.16	0.8	1.8	19%
Repairs	4.76	1.0	2.1	22%
Electricity	3.89	0.8	1.7	18%
Dryer fuel	1.84	0.4	0.8	9%
Seasonal labor	6.93	1.4	3.1	32%
Total variable costs	21.58	4.3	9.5	100%

Source: USDA

Variable costs decrease with the annual volume ginned. In 2004, gins with an annual volume of 40,000 or more bales per year have an average cost of $17.40 per bale, while gins averaging less than 15,000 bale per year have an average cost of $24.14 per bale.

Table 4 - Gin Variable Costs by Annual Volume (USA; 2004)

Bales ginned (thousands)	15 or less	15-<25	25-<40	40 or more
Bagging & ties	3.85	3.73	3.69	3.62
Repairs	3.94	4.24	3.56	3.34
Electricity	4.42	3.71	3.20	3.08
Dryer fuel	2.25	1.88	1.80	1.94
Seasonal labor	9.45	8.07	6.40	5.66
Total variable costs ($/B)	23.91	21.63	18.65	17.64

Source: USDA

Cost comparisons by gin capacity better represent gin plant equipment and facilities that allows for the improved plant efficiencies derived from increased volume. Capacity based costs are similar to volume based costs, with larger gins having lower variable costs, primarily as a result of reduced labor cost. This is not true in all cases, especially when gins have unused capacity. The hourly cost of operating a particular gin is basically constant regardless of the processing rate[74].

[74] A 30-bale per hour gin requires no more energy or labor to process 30 bales per hour than to process 20 bales per hour.

Table 5 - Variable Costs by Gin Capacity (USA; 2001)

Bales per hour	<15	15-25	>25
Bagging & ties	3.46	3.36	3.25
Repairs	4.56	3.58	4.36
Electricity	4.29	3.78	3.37
Dryer fuel	1.52	1.13	1.14
Seasonal labor	8.74	6.38	5.59
Total variable costs ($/B)	22.57	18.23	17.71

Source: USDA

California, the largest producer of ELS (Pima) cotton in the US, has the greater number of roller gins. On average, the total variable cost for roller ginning is higher than for saw ginning due to higher energy (dryer fuel[75] and electricity) and labor costs.

Table 6 - Comparison of Variable Costs for Saw and Roller Ginning (California)

$/bale	2001		2004	
	RG	SG	RG	SG
Bagging & ties	3.03	3.33	3.84	3.84
Repairs	3.02	3.36	3.80	3.86
Electricity	6.30	5.79	5.08	4.90
Dryer fuel	2.44	1.53	4.78	3.05
Seasonal labor	6.42	6.04	10.09	6.22
Total variable costs	21.21	20.05	27.59	21.87

Source: USDA

[75] Moisture content of seed cotton must be lower for roller ginning than for saw ginning. California had a very wet harvest season in 2004 and dryer fuel costs more than doubled over the 2001 survey results.

The cost of maintenance increases with the age of the gin.

Table 7 - Cost of Maintenance

Age of ginnery	0-5 years	5-10 years	10-20 years	20-30 years
Cost of repairs	5-10 $/t	10-15 $/t	15-20 $/t	20-25 $/t

High trash contents increase the repair and maintenance costs, contributing to higher ginning costs.

Ginning variable costs in India are about 3 times lower than in the USA, about 3.8 cents per kg of lint in a modernized gin, including:

- labor: 0.6 ct/kg (16%)
- power: 1.3 ct/kg (34%)
- bagging & ties: 1.3 ct/kg (34%)
- grease & lubricants: 0.1 ct/kg (2%)
- maintenance: 0.3 ct/kg (9%)
- miscellaneous 0.2 ct/kg (5%)

Appendix 5: Impact of Ginning Technology on Cotton Quality

Fiber length and length uniformity are the most important properties for ring spinning. These characteristics are strongly affected by the type of ginning, whether roller or saw. In contrast, the most important parameter for rotor (open-end) spinning is fiber strength, a property which is not significantly affected by the ginning process.

Lint Quality

Roller gins preserve fiber length, whereas saw gins have the inherent disadvantage of breaking fiber, increasing short fiber[76] content and creating neps, which are detrimental to lint spinnability. Old single roller gins had a very slow and very gentle process. Being faster, the process of modern double roller and rotobars is less gentle to the fiber.

According to ginners in ESA, roller ginned upland is 1/16 inch longer than the same cotton saw ginned. In Tanzania, in the 2 locations where roller gin and saw gins co-exist, lint that is classed as 1-3/32 inch (1-1/8" shy) when it is saw ginned, is classed 1-1/8" full when roller ginned (double rollers), and can be sold on the premium market for higher grades. It is the same in Zimbabwe, and the medium long LS variety is classed as 1-5/32 inch when it is saw ginned, is classed 1-3/16" when roller ginned (rotary-knife).

In an experiment conducted by the USDA in 2004 on U.S. upland cottons, ginning outturn, color grade, length, uniformity, nep count, and short fiber content were improved by roller ginning compared with standard saw ginning processing. However, roller ginned cotton had more trash.

[76] Fiber less than ½ inch long (12.7 mm).

Table 8 - Comparison of quality parameters for saw and roller ginning (US upland)

	Roller Gin	Saw Gin
HVI		
Length (UHML, mm)	31.0	29.6
Uniformity	84.6%	82.9%
Short fiber content	7.4%	8.9%
Reflectance (Rd)	78.0	76.8
AFIS		
Length (mm)	27.0	25.9
Upper quartile length	32.1	31.5
Short fiber content	6.4%	8.5%
Immature fiber content	11.3%	11.9%
Neps/g	166	261
Seed coat neps/g	42.5	43.2
Total trash count/g	981	790

Source: USDA

HVI data from upland samples ginned on the high speed roller gin in Brazil in 2007 were compared with sample data taken from a saw gin located next to the high speed roller gin. length The average upper-half-mean length is 30.6 and 29.8 mm for roller ginned versus saw ginned respectively for the 10 samples. The average short fiber content (SFC) is 6.3 and 7.3% for roller ginned versus saw ginned respectively. The uniformity index (UI) is 86.8 versus 85.2 for roller ginned versus saw ginned respectively.

Table 9 - Comparison of quality parameters for saw and roller ginning (Brazilian upland)

	HS Roller Gin	Saw Gin
Length (UHML, mm)	30.6	29.8
Uniformity	86.8%	85.2%
Short fiber content	6.3%	7.3%

Source: USDA

There is no significant difference in fiber properties between roller ginned upland cotton ginned at the standard and elevated speeds.

According to Bajaj trials conducted on Indian cotton using the three types of gins gave the following results:

- Bajaj double roller gin: 32.59 mm (90 neps/g)
- Rotobar gin: 31.52 mm
- Saw gin: 30.27 mm (225 neps/g)

Saw ginned lint is more suitable for spinning coarse yarn, and roller ginned lint more suitable for finer yarns. Roller gin is not suitable for processing short staple cottons.

Compared to saw ginned lint, the grade of roller ginned cotton may be marginally better because it is whiter, although it contains more leaf and foreign matter. Saw ginned lint is cleaner, but contains finer particles of trash that are more difficult to remove.

Saw-ginned cotton has a totally different appearance from roller-ginned cotton. It looks fluffy, cleaner and has a more regular and smooth surface. Roller-ginned cotton is irregular in appearance, and can be characterized as striped and knotty. Anecdotal evidence suggests that the micronaire of roller ginned cotton may be slightly higher due to its preparation.

It is well known in the spinning industry that roller ginning is less damaging to the cotton fiber than saw ginning. Reduced neps and short fiber content, compared to saw ginned cotton, enables spinners to produce a higher quality yarn. According to an Indian spinner, roller ginned Acala from California can be used for producing yarn counts 70's and up to 80's, whereas saw ginned Acala is limited to yarn counts 50's with acceptable quality.

Some spinners prefer saw ginned cotton because it is cleaner and has a smoother combed aspect. Many spinners used to be reluctant to use Indian roller ginned handpicked cotton because it has more trash a rougher preparation, and a very bad reputation for contamination. However, the spinners who were traditionally attracted by its price realized that roller ginned runs better than saw ginned cotton in the spinning mill[77]. Indian cotton is now well accepted in China, the largest market for lint exports.

Cotton Seed Quality

Roller ginned seeds are cleaner (with less linter left) than saw ginned seeds. As a result, those seeds can be processed by oil mills without prior delinting, which reduces cost and should justify a premium over saw ginned seeds. Rotary knife gins can cause seed breakage and unginned cotton going with seed.

[77] Particularly type Shankar-6 staple length 1-1/8 inch.