The Spinnability of Genetically Modified Cotton Compared with Acala Cotton

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Date of Examination: 15/6/2014
Dedication

To my mother, father and my small family for their endless support.
Acknowledgements

I would like to thank Sur Textile Factory in Hassahisa for supplying the desired Bt cotton and Acala cotton. Special thanks to Dr. Asim Mahgoub, member of the board of directors and to Engineer Abdella Mohamed Abdella, the technical manager. My thanks also extended to Mr. Babiker Omer of the Sudanese Brazilian company for suggesting the Bt cotton.

Since this work was conducted in Sur Textile Factory in Hassahisa I would like to thank all who helped me in this factory and express my gratitude for their kind treatment specially Eng. Siddig Mussabal for his great assistance.

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The Spinnability of Genetically Modified Cotton Compared with Acala Cotton

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Abstract

Cotton is the most important commercial crop in Sudan, often referred to as the White Gold. The introduced new raw material *Bacillus thuringiensis* (Bt) cotton was important raw material to the local industry. The provision of information about the spinning potential of the Bt cotton became necessary and more needed so as to direct the industrial effort to obtain benefits from it. The present study was aimed to determine the spinnability and the count limit that can be produced from Bt cotton compared with the traditional cotton Acala (Hamid variety) under certain conditions. The procedure applied was to produce a range of counts from coarse to fine yarns including the local commercial counts from the two types of cotton on rotor open end spinning machine. The machine was adjusted to the same technical variables as near as possible to the commercial production settings for both types of cotton. These variables were rotor speed, rotor diameter, twist factor, winding angle and the opening roller speed. The spinning machine was fed with slivers after the second passage of drawing with the linear density (0.1Ne) for the two types of cotton. The feed speed, delivery speed and the draft were changed with the count change. This study was conducted in two main parts. The first included the commercial range of counts which were (8, 12, 16, 20, 26 and 30Ne) by using rotor speed, (68500 rpm), rotor diameter (35 mm) and twist factor 4.5. The second part included finer counts in an attempt to reach the exact fiber limit under different manufacturing conditions, such as the rotor speed (74500 rpm), rotor diameter (30 mm) and twist factor 4.7 so as to maintain good yarn quality and properties. These counts were (32, 34 and 36Ne). The ends breakage and the atmospheric conditions were reported. Laboratory checking and data analysis to the products have been performed. The change in yarn properties with progressive change in count has been reported. The count limits for both cottons in each part has been suggested. Analysis of the results for the Bt cotton and Acala cotton showed that the difference between the two types of yarns tenacity was not significant in all the produced counts from the two parts except count (8Ne) in which the Acala yarns were better in tenacity. At the same time the Acala yarns elongation in the first range of counts except count (30Ne) was significantly better than the Bt yarns elongation. It can be suggested that the Acala yarns may be preferred in later processes such as weaving, knitting, etc, which need elasticity to minimize ends breakage. Meanwhile in the second part, the elongation was the same for both types of cotton in all the counts produced. Also the results showed that the new raw material, Bt cotton, can be operated with the same manufacturing conditions as the Acala cotton. The count limits were suggested in the two parts of the study for both types of cotton. Count (30Ne) was the count limit in the first part as for both types of cotton the tenacity has dropped. Count (36Ne) was the count limit in the second part for the two types of cotton at which the yarn reported drop in properties. This is reflected in the low twist of the Bt yarns and fiber breakage of the Acala yarns.
لا المقدرة الغزلية للقطن المحور وراثياً مقارنة بقطن الأكا

عزة أحمد حمد أحمد

مستخلص

يعتبر القطن من المحاصيل التجارية المهمة في السودان، لذا يطلق عليه اسم الذهب الأب. حديثاً تم دخول القطن المحور وراثياً كمادة خام جديدة في صناعة الغزل المحلية. احتاجت هذه الخطوة الهامة إلى توفير المعلومات الفنية عن اداءه في الصناعة وخواص الخيوط المنتجة منه، وذلك حتى يتضمن توظيف الجهد الصناعي للاستفادة الكاملة منه. هدف هذه الدراسة لتوضيح المقدرة الغزلية للقطن المحور وراثياً مع توفير المعلومات الفنية عن اداءه وتوسيح المدى الأقصي للنمر التي يمكن إنتاجها منه ومقارنته مع القطن التقليدي الأكا تحت ظروف تصنيعية محددة. الطريقة التي اتبعها تشمل تطبيقات الدراسة كانت إنتاج مدى من النمر المختلفة من الخيوط السميكة في الراقصة شاملة المدى التجاري للنمر لكل من القطن المحور والأكا، وذلك في ماكينة غزل الطرف المفتوح. تم ضبط الماكينة لكل من نوعي القطن بنفس الضبطات الفنية التي كانت أقرب ما يمكن للضبطات المستخدمة في الإنتاج التجاري. وكانت الضبطات الفنية على النحو التالي: سرعة الدوار، قطر الدوار، معامل البرم، زاوية الرص، وسرعة أسطوانة التفتيح. تم تشغيل ماكينة غزل الطرف المفتوح بشريط نمر (Ne = 0.1) بعد مروره بمراحل سحب كل من نوعي القطن. سرعة التغذية، سرعة الإنتاج والسحب كانت تتغير في قيمتها تبعاً لتغير النمر. تم تنفيذ هذه الدراسة في جزئين اساسيين، الأول الذي يحتوي على المدى التجاري للنمر من (Ne = 8) إلى (Ne = 30) والذي تم تشغيله بسرعة دوار (68500 لفة/الدقيقة) وقطر دوار (35 ملم) ومعامل بر (4.5). أما الجزء الثاني فيحتوي على نمر أرفع في محاولة للوصول للحد الفعلي لشعيرات نوعي القطن المستخدمة في ظروف تصنيعية مختلفة. شملت سرعة دوار (74500 لفة/الدقيقة) وقطر دوار (30 ملم) ومعامل بر (4.7). وذلك حتى يتم الحصول على خواص خيوط جيدة. كانت النمر المنتجة هي (Ne = 32، 34، 36). تم تسجيل معدل القطوعات ودرجات الحرارة والرطوبة. كما تم إجراء الفحص المعملي وتحليل البيانات للخيوط المنتجة. مع تسجيل كل التغييرات في الخواص مع تغير النمر. كما تم الإشارة إلى الحد الأقصي للنمر في كل من جزيئي الدراسة. تحليل النتائج لكل من القطن المحور وراثياً وقسط الأكا أوضح أنه لا يوجد اي اختلافات معنوية بين متانة النوعين من الخيوط في كل النمر المنتجة ما عدا النمر السلمي (Ne = 8) حيث كانت متانة الأكا أفضل. في ذات الوقت أن القطن المحور وراثياً وقسط اكا كان ارضي أنه لا يوجد أي اختلافات معنوية بين متانة النوعين من الخيوط في كل النمر المنتجة ما عدا النمر السلمي (Ne = 8). أضفت من متانة القطن المحور وراثياً مما يدل على أن الأكا قد يكون منسف في العملية الصناعية مثل النسيج والترموه ل Trọngته التي تقلل الخيوط. أما في المدى الرفيع من النمر وجد أن لا فرق في استتغلال الخيوط. كذلك أوضح أن النمر المحور وراثياً يمكن تشغيله بنفس الضبطات الفنية التي تستخدم لقطن الأكا. وتم الإشارة إلى الحد الأقصي للنمر في جزيئي الدراسة حيث كانت (Ne = 36) هي الحد في الجزء الأول عندما سجلت هذه النمر تدهوراً في متانة الخيوط لنوعي القطن. وكانت (Ne = 30) هي الحد في الجزء الثاني حيث سجلت تدهوراً في الخواص كالبرم بالنسبة للقطن المحور وتوصف الشعرات في الأكا.
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CHAPTER ONE

INTRODUCTION

1.1 General Introduction:
Genetically modified plants expressing Bacillus thuringiensis (Bt) genes have been developed in different crops for resistance to insect pests, and some of them have been deployed successfully on a commercial scale for pests control in a number of countries, including the United States, Australia, China, Mexico, Argentina, South Africa, and India. Over the last few years, the technology spreaded rapidly among large and small farms (Mayee, 2002 and Firoozabady, 1987).

Cotton is a long duration crop and is attacked by large number of insect pests throughout its growth and development. The three bollworms, American bollworm Helicoverpa armigera, Pink bollworm Pectinophora gossypiella and the Spotted bollworms Earias vittella and Earias insulana are major pests and cause serious threat to cotton production resulting in significant yield losses (Kranthi, 2012). Before the introduction of Bt cotton, insecticide quantity applied on cotton was the highest, relative to other cultivated crops. Cotton bolls are highly vulnerable to hidden insects such as the American bollworm, Pink bollworm and Spotted bollworm. Bollworms, especially the Pink and Spotted bollworms are hidden feeders and generally do not come into direct contact with insecticide sprays. The American bollworm which comes into contact with insecticides, partially, has developed resistance to almost all the insecticides recommended for its control in all regions of the world (Kranthi, 2012).

In Sudan, cotton has been grown for centuries. The cotton plant is indigenous and a number of its wild relatives (members of the genus Gossypium) existed in various parts of the country. Commercial growing of the crop started in 1867. However, the big jump was in 1926, which marked the official start of functioning of the Gezira Scheme. The bulk of the production is exported, (90%), in a highly competitive world market (Abdelatif and Babiker, 2012). Sudan cotton suffered mainly from low yields due to stickiness (Fadlalla, 1998). For this, people preferred new varieties of cotton so as to increase yield and improve quality to meet the recent demand of consumers (Abdelatif
and Babiker, 2012). The Bt cotton is an insect-resistant transgenic crop designed to combat the bollworm. Bt cotton was created by genetically altering the cotton genome to express a microbial protein from the bacterium *Bacillus thuringiensis* (Kranthi, 2012). Two Chinese Bt-cotton genotypes (G. hirsutum) carrying Cry 1A gene; from *Bacillus thuringiensis* (Bt) a hybrid CN-C01 and an open pollinated CN-C02 were approved for commercial production by Chinese National Authority in 2004 and 2008, respectively (El Wakeel, 2014). The two genotypes carry Cry1A gene which is specific toxin against Lepidoptera larvae to protect cotton crop against bollworms. These genotypes were evaluated for two seasons 2010/11 and 2011/12, and in open field trials in six environments, three irrigated and three rain-fed locations in Sudan with two local checks Abdin and Hamid (El Wakeel, 2014). In the year 2012 the area that were planted with Bt cotton by the Sudanese-Brazilian Partnership in Blue Nile was approximately 17,000 feddans and expected to rise up to 70,000 feddans next seasons (Sharief, 2012). The total area planted with Bt cotton in Sudan in 2012 was 53,220 hectares distributed as follow, in the Gezira 17,478 hectares, El Rahad 10,496 hectares, El suki 10,672 hectares and New Halfa 14,574 hectares (El Wakeel, 2014). The Bt system achieves great increase of production. For example, a feddan yields 10 and half Kantars and Kantars is expected to rise up to 17 or 18 Kantars (Sharief, 2012). Cotton is planted this year on 121,500 hectares in rain-fed areas, and 81,000 hectares under irrigation (El Wakeel, 2014). The lint produced by the Bt cotton variety looks and feels like conventional cotton.

It is clear that there is hardly any technology that can be 100% safe to everything, so in this study the aim is to focus on the new raw material Bt cotton and its yarn properties and compare it with one type of Sudanese conventional cotton Acala cotton because of its similar fiber properties with Bt cotton.

**1.2 Problem Identification:**

Since its introduction a lot of attention was given to the Bt cotton advantages and disadvantages from an agricultural point of view, and little was observed from the industrial side in the discussions since there is rare or no technical information about its performance in industry and its yarn properties. So in this study the aim is to investigate the industrial behavior of Bt cotton and its yarn properties and provide information and guide lines which were not readily available in the Sudanese market.
As mentioned before the Bt cotton is a new raw material in Sudan. Also it’s observed that the rotor spinning technology is the technology that is most used currently in the Sudanese spinning factories. In this study the Bt cotton and Acala cotton (Hamid variety) were used as the raw materials and the rotor open end spinning as the spinning technology to determine the spinnability of the newly introduced Bt cotton in the Sudanese textile industry. Also an attempt was made to suggest the count limits that can be produced from Bt cotton within the rotor commercial counts and fine counts. The machine settings and speeds were considered and adjusted to parallel the commercial production settings, as well as the general mill atmospheric condition. Laboratory checking and data analysis to the yarns produced were performed.

1.3 Objectives:

The aim of this study is (1) to provide technical information about the performance of the Bt cotton in industry and to define practically the spinnability of the newly introduced Bt cotton compared with the traditional cotton Acala. (2) To determine the count limit that can be produced from Bt cotton under certain conditions.
CHAPTER TWO

LITERATURE REVIEW

2. 1 Bt cotton:

Bt cotton is a genetically modified cotton crop that expresses an insecticidal protein whose gene has been derived from a soil bacterium called Bacillus thuringiensis, commonly referred to as Bt. Many subspecies of Bt are found in soils and are in general known to be toxic to various genera of insects but safe to other living organisms. Bt was first discovered by a Japanese scientist Ishiwata in the year 1901. Bt has been used as an insecticide for control of stored grain pests since 1938 in France and from 1961 as a registered pesticide in the USA and later in many other countries as sprays in cotton. Bt toxins thus have several decades of proven selective toxicity to insect pests and with established safety record to non-target animals (Kranthi, 2012). The introduction of Bt cotton has provided growers with a new tool for managing bollworms in cotton. Numerous benefits of this technology accrue to the grower, the global cotton industry, and society on many levels; economic, environmental and social. These benefits include direct benefits, such as reduced pesticide use, improved crop management effectiveness, reduced production costs, improved yield and profitability, reduction in farming risk and improvement opportunity to grow cotton in areas of severe pest infestation. Indirect significant benefits of the technology include improved populations of beneficial insects and wildlife in cotton field, reduced pesticides runoff, air pollution and waste from the use of insecticides, improved farm worker and neighbor safety, reduction in labor costs and time, reduction in fossil fuel use and improved soil quality (Rummel, 1994; Flint, 1995 and Bacherel, 1996). For the textile industry the great challenge was the fiber quality properties. The effect of the different transgenic methods on fiber properties such as strength, length, fiber fineness, fiber maturity ratio, fiber uniformity and micronaire, have been investigated by several research workers and compared it with the conventional cotton varieties fiber properties. As the public testing of the transgenic varieties was limited (most of the evaluations are made by the private companies), growers would have to rely on results from industry trials. Growers should also look at
comparisons of yield and fiber quality characteristics against the parent varieties and use their own experiences and observations (Hagedorn, 1998). Numerous scientists have studied the techniques of introduction of genes into cotton. Shirong (2004) found that more than one gene are required to modify fiber traits as these traits are usually controlled by multiple genes. Furthermore it is necessary to know the integration of transgenic into cotton genome, and there are many methods of checking this, such as the Southern blot analysis, Northern blot and Western blot analysis or by protein activity assays. In addition the fiber quality properties including length, strength and fineness should be measured or tested by certain instruments or methods, and carefully compared with those of wild type fibers. Other fiber properties such as heat capacity, elasticity and fiber color can be evaluated according to the aim of the project (Shirong, 2004). The improvements of genetic cotton fiber were investigated by many researchers; who found that the development of cotton fiber is delineated into four distinct and overlapping developmental stages: fiber initiation, elongation, secondary wall biosynthesis and maturation. They also express the processes leading to the production of lint (long) and fuzz (short), and the alter of fiber cell properties (Jinsuk et al., 2007).

The total number of Bt toxin genes was 342 available for researches (Kranthi, 2012) fiber regulatory mechanisms governing and fiber cell elongation were not well understood, the researchers are interested in taking a group of genes studying their influences in fiber properties. For example GhDET2 an Arabidopsis steroid 5d-reductase is considered to catalyze a major rate limiting in brassinosteroid (BR) biosynthesis. This played a crucial role in the initiation and elongation of cotton fiber cells, suggesting that modulation of BR biosynthesis factors may improve fiber quality or yield. Furthermore, seed coat specific expression of GhDET2 increased fiber number and length, (Ming et al., 2007). Another research approach studied the influence of transgenic fiber properties into yarn strength, which differed from one cultivar to another, suggesting an interaction between each cultivar and its environment (El Sourady, 2008). In 2012 scientist found that the use of the TRV-VIGS method (TRV is a Tobacco rattle virus) and VIGS (gene work in cotton leaves,) to investigate the function of KATANIN and WRINKLED1 in cotton plant development. The result was KATANIN produced shorter fibers and
elevated weight ratio of seed oil to endosperm. WRINKLED1 expression resulted in increased fiber length but reduced oil seed content (Jing et al., 2012).

Recent studies looked into the effect of genes in cotton fiber and compared it with the traditional varieties of cotton. Geng et al. (2013) found that, the mature fibers of the transgenic plants were significantly shorter than those of the wild type. Felker (2001) found that the GM cottons have been plagued by short staple length, low strength, high micronaire readings, and to a lesser extent sticky or sooty mould compromised lots. In summary the GM cottons have reduced fiber quality compared with their non-GM counterparts. Fred (2005) found that the largest variations are occurring between strength, micronaire and length. The fiber of conventional varieties was finer (lower micronaire), longer, more uniform and stronger than fiber of transgenic varieties. The trend of increasing micronaire in transgenic varieties appeared to be reversed in 2001 through 2003, but was present again in 2004. Other than in 1996, strength of transgenic entries was less than strength of the conventional. This suggests that improvement of fiber quality has not been a major goal in the development of transgenic varieties (Fred, 2005).

From the industrial side there were very few published research that looked into the performance of transgenic fibers and evaluation in yarn manufacture from older ring spinning to rotor and air-jet. In particular the yarn structure of rotor and air-jet would benefit from fiber with less short fiber content and more uniform length (Deussen, 1992). In 1998, Monsanto Delta and Pine Land Company contracted with the International Textile Center to evaluate the differences in measurable fiber properties and in textile performance between selected cotton (Gossypium) varieties and the existing transgenic variants of these parent varieties. The experimental design, growing and delivering of the ginned cotton samples were done independently by the Delta and Pine Land Company. All processing, testing and evaluation of the cotton fibers were done independently by the International Textile Center. No statistically significant differences were detected in fiber properties or in yarn and fabric quality for the genetically modified cottons versus the parent varieties (Ethridge, 2000).
2.2 Spinning limit:

Spinning limit means the finest yarn number that can be spun satisfactorily from a specified fiber lot and conditions. From the other hand the spinning limit is related to yarn strength, higher strength fibers tend to reduce the end breakage rate and increase the spin limit (Peter, 2003). In the early days of open end spinning 14Ne count was considered the spinning limit for open end yarns. Over the years this limit has been extended almost linearly. Every spinning system produces yarn over a certain count range, and the limit of this range varies from system to system. As an example, in rotor spinning the technologically possible range is 1Ne to 60Ne. However, the technologically possible count range differs from the economic or commercially viable count ranges. The commercial count range is usually narrower, and is limited by quality and cost considerations. The range of count that can be successfully spun and the type of fibers that can be processed testifies to the capability of the spinning system and possibilities of its commercial success. Modern machine manufacturers constantly aim to extend this count range so that it overlaps the medium count range between 20Ne and 30Ne where maximum production takes place for better market penetration (Lawrence, 2003).

Rotor spinning has established itself as a commercially viable technology with much higher productivity than ring spinning for coarse and medium counts. However to get the optimum benefits from this technology, the machine parts and process parameters have to be properly chosen. Rotor speed is an important parameter as it affects productivity of the machine. Several studies have been reported on the effect of rotor speed on yarn properties. Some scientists found that rotor speed has insignificant or marginal effect on yarn strength. But elongation is brought down steeply with increase in rotor speed (Manohar et al., 1983). Yarn irregularity and imperfections increase markedly with increase in rotor speed. With increase in rotor speed fiber individualization and trash removal by opening roller will be inferior. Neps in particular increase steeply with rotor speed. Fibers have also less time to align themselves in rotor groove and fiber alignment will be poor. As a result irregularity and imperfections increase (Grosberg, 1973).
Another important parameter is the rotor diameter. Yarn elongation is very sensitive to rotor diameter and drops markedly with increase in diameter. This is because of higher centrifugal force on yarn tail, which increases wrappers and makes yarn more compact (Manohar et al., 1983). Lower tenacity and lower elongation are expected with higher rotor diameter. While the irregularity and thick and thin places are not much affected, neps increase markedly with increase in rotor diameter. Increase in irregularity due to higher wraps per unit length of wrapper fibers is compensated by the improvement from back doublings with higher diameter and as a result irregularity is unaffected (Koc et al., 2005). Rotor diameter should be sufficiently large to enable formation of fiber ring on the rotor groove. Normally rotor diameter should be at least 1.2 times that of fiber length. Higher rotor diameters should be used as count becomes coarser. Energy consumption and spinning tension increase with rotor diameter and so lower rotor diameters should be used at higher rotor speeds (Trajkovic et al., 2007).

In summary we can say that the spinning limit usually refers to the production of the finest yarn count from a given fiber with acceptable qualities and an end breakage rate below a tolerable threshold. The commercial value of a fiber depends upon its spinning limit. It is important to know why a system fails to spin beyond a certain count on both the coarser and finer sides. A clear understanding of the mechanism of yarn formation and the way the fiber parameters interact with the spinning process can lead to further improvement in the machine design with a view to widening the count range (Lawrence, 2003).

**2.3 Twist loss in rotor spinning:**

Manich (1986) found that increase in twist loss with linear density, twist multiplier, diameter of navel and with grooved navel. Twist loss increases with navels that produce more false twist. Rotors that produce more friction with yarn reduce twist loss. Palamutcu and Kadoglu (2008) reported that lower twist loss with coarser and shorter fibers, which may be because of lower incidence of wrapper fibers. Opening roller teeth type has significant effect on twist loss. Higher opening roller speed improves fiber separation, reduces sheath fibers and as a result improves twist efficiency (Palamutcu and Kadoglu, 2008). Salhotra (1981) also found that twist loss increases with increase in sheath fibers. Further, percentage of sheath fibers increases with fiber length and as a
result longer fibers result in more twist loss. Increase of navel diameter increases twist loss.

2.4 Count limit in rotor open end spinning:

In rotor spinning fiber count and thus the number of fibers in the yarn cross-section probably have the greatest influence on yarn and spinning results. Fiber count (micronaire or dtex) defines the spinning limit, i.e. the ratio of fiber count to yarn count from which stable spinning behavior is assured. Due to the markedly different yarn structure of rotor-spun and ring spun yarn, resulting in less pronounced parallelization of the fibers in rotor spun yarn, the material utilization of fiber tenacity and thus also yarn tenacity (with the same fiber count and thus the same number of fibers in the yarn cross-section) is some 15 - 25% lower than in ring-spun yarn. In order to compensate for these system related differences, i.e. in order to ensure stable spinning conditions and also achieve good yarn tenacity, rotor-spun yarns must be spun with a higher number of fibers at least (90 – 110 or 120) in the yarn cross-section (Rieter/com). The spinning limit (Nm/Ne/tex) can be calculated as follows:

\[
\text{Spinning limit tex (y)} = \frac{dtex(f) \times nf}{10} = \frac{Mic \times nf}{25.4}
\]

\[
\text{Spinning limit Nm (y)} = \frac{10000}{dtex(f) \times nf} = \frac{25400}{Mic \times nf}
\]

\[
\text{Spinning limit Ne (y)} = \frac{5917}{dtex(f) \times nf} = \frac{15030}{Mic \times nf}
\]

nf = number of fibers given for the spinning limit (90 to 110 fibers)

Derived from this, the number of fibers in the yarn cross section (nf) is calculated as follows:

\[
\text{Number of fiber nf} = \frac{tex(y) \times 10}{dtex(f)} = \frac{5971}{Ne(y) \times dtex(f)} = \frac{10000}{Nm(y) \times dtex(f)}
\]

\[
\text{Number of fibers nf} = \frac{tex(y) \times 25.4}{Mic} = \frac{15030}{Ne(y) \times Mic} = \frac{25400}{Nm(y) \times Mic}
\]

nf = number of fibers in the yarn cross-section

Mic = Micronaire       Y = yarn       F = fiber
As indicated earlier, rotor spinning has superior economical advantage over ring spinning in the course to medium counts. In recent years, there have been many attempts to push rotor spinning further into the area of fine counts. When spoken about fine counts, it is generally meant yarns of maximum 40Ne cotton count. In order to produce fine yarn counts on rotor spinning, two main factors must be addressed: (a) machine related factors, and (b) material related factors. Examining the spinning tension of rotor spinning may summarize the machine related factor. This is the tension on the yarn delivered from the rotor affect with the rotor rotational speed in radians/sec, and the rotor radius, and the coefficient of friction between the yarn and the navel surface in contact with the yarn (Rieter/.com).

This determines among other things, strength, evenness, handle, insulating capacity, thread breakage rate, and the spinning limit of the raw material. Accordingly, there are lower limits to the number of fibers in the cross-section, as follows (for normal conditions):

<table>
<thead>
<tr>
<th>Cotton yarns</th>
<th>Ring-spun yarn:</th>
<th>Combed 33 fibers</th>
<th>Carded 75 fibers</th>
<th>Rotor-spun yarn:</th>
<th>Carded 100 fibers</th>
</tr>
</thead>
</table>

The spinning limit can then be calculated approximately by transposition of the equation:

$$nf = \frac{tex\ (yarn)}{tex\ (fiber)}$$

To give

Table (2.1) Count spinning limit (source Rieter/.com).

<table>
<thead>
<tr>
<th>Spinning limit</th>
<th>Micronaire</th>
<th>100% carded cotton (110 fiber/yarn cross section)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Micronaire</td>
</tr>
<tr>
<td>3.2</td>
<td>3.5</td>
<td>4</td>
</tr>
<tr>
<td>1.26</td>
<td>1.38</td>
<td>1.58</td>
</tr>
<tr>
<td>72/43/14</td>
<td>66/40/15</td>
<td>57/34/17</td>
</tr>
</tbody>
</table>
tex \text{ (yarn)} = \text{n}_f \times \text{tex} \text{ (fiber)}

Where \text{n}_f is the number of fibers. However, this formula does not take into account other parameters, such as fiber length, coefficient of friction, etc., which also affect the spinning limit (Cottonguide/.org).

2.5 The spinnability:

Yarn quality is important for end users like knitters and weavers. The fiber properties and process parameters play a great role in determining yarn quality. Performance of spinning cotton is also mainly affected by process parameters and fiber properties. Predicting the degree of spinnability of cotton is crucial. Spinning limits of cotton refers to the finest yarn number that can be spun satisfactorily from given cotton under constant spinning conditions. Traditionally, this is measured by monitoring the end breakage rate while spinning increasingly finer yarns. This method of measuring spinnability of cotton requires running long tests in order to assess accurate cotton spinning performance (Pelin et al., 2008).

Cotton spinnability, or spinning potential, is traditionally determined based on the number of ends down occurring under controlled spinning conditions. No yarn quality considerations are included in this spinning potential concept, which is representative only of the performance of a given fiber during spinning. A new quality potential component is added to the traditional spinnability notion. Spinnability limits are determined on the basis of yarn quality, and a new spinning potential definition that captures both critical aspects of spinning performance and yarn quality is advanced (Mourad, 2008).

2.6 Influence of fiber properties on yarn quality in rotor open-end spinning:

Influence of fiber properties on yarn quality and spinning performance of rotor spinning is critically reviewed based on research and development work over the years.

2.6.1 Fiber fineness:

Fiber fineness has the maximum influence on quality of rotor yarns. This is the best cotton property that almost all of the cotton importers want. Cotton fiber fineness influences the number of fiber in cross-section. A greater number of fibers per cross
section are required in rotor yarns than in ring yarns. Minimum number of fibers to enable spinning increases at high rotor speeds. The finer fiber results the higher number of fiber in yarn cross-sections. Fiber fineness influences primarily:

2.6.2 Fiber maturity:
The maturity of cotton fiber defined in terms of the development of the cell wall. A fully mature fiber has a developed cell wall. On the other hand, an immature fiber has a very thin cell wall. A fiber is to be considered as mature fiber when the cell wall of moisture swollen fiber represents 50% to 80% of the round cross section, as immature fiber represents 30% to 45% and as dead when it represents less than 25%. Immature fibers lead to: A) Napping B) Loss of yarn strength C) High proportion of short fiber D) Varying dye ability. So good cotton properties should include matured cotton fiber (Cottonguide / .org).

2.6.3 Fiber strength:
Stronger the fiber stronger will be the rotor yarn. Since lower strength is one of the drawbacks of rotor yarn, stronger cottons should be used. Louis (1981) reported that fiber strength has more influence on yarn strength than fiber length. Toughness of fiber has a direct effect on yarn and fabric strength. The higher fiber strength results in higher yarn and fabric strength. Very weak cotton tends to rupture during processing both in blow room and carding, creating short fibers and consequently deteriorate yarn strength and uniformity (Cottonguide / .org).

2.6.4 Fiber length:
Fiber length is described as the average length of the longer one-half of the fibers upper half mean length (Handbook, 1995). The quality, count, strength, etc depend on the staple length of the fiber. Higher staple length; higher yarn quality. Staple length influences: A) Yarn evenness. B) Luster of the product. C) Spinning limit. D) Yarn strength. E) Yarn hairiness. F) Handle of the product. The following length grouping is currently used in stating the trade staple or basic cotton properties:
Short Staple: 1 inch or less.

Medium Staple: 1 and 1/32 inch to 1 and 1/8 inch

Long Staple: 1 and 5/32 inch to 1 and 3/8 inch.

Extra Long Staple: 1 and 13/32 inch and above, (Cottonguide /.org).

2.6.5 Fiber color:
The color of cotton samples is determined from two parameters: degree of reflectance (Rd) and yellowness (+b). Degree of reflectance shows the brightness of the sample and yellowness depicts the degree of cotton pigmentation. The color of the fibers is affected by climatic conditions, impact of insects and fungi, type of soil, storage conditions etc. There are five recognized groups of color: white, gray, spotted, tinged, and yellow stained. As the color of cotton deteriorates the process ability of the fibers decreases (Kermit, 1999).

2.6.6 Fiber cleanness:
A trash measurement describes the amount of non-lint materials such as parts of cotton plant in the fiber. Trash content is assessed from scanning the cotton sample surface with a video camera and calculating the percentage of the surface area occupied by trash particles. The values of trash content should be within the range from 0 to 1.6% (Fang, 1999). Rotor spinning is more sensitive to trash and micro dust in cotton. Micro dust and trash increase end breakages and contribute to periodic irregularities in yarns that result in rejections. Irregularity, hairiness, abrasion resistance deteriorate with yarns produced without periodic cleaning of rotor (Barella et al., 1975). Trash content in input sliver should be below 0.2 % to get satisfactory performance. Trash particles get wedged in the rotor and result in periodicity with wavelength equal to rotor circumference. End breaks increase with trash content (Naarding, 1976).

2.6.7 Fiber elongation:
Elongation is specified as a percentage of the starting length. Textile products without elasticity would hardly be usable. They must be deformed and also return to the original shape. The fiber elongation should be at least 1 to 2%. The greater crease resistance of wool compared with cotton arises due to difference in their elongation (Cottonguide /.org).
CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction:

In order to conduct the experiment in real production conditions Sur textile factory in Hassahissa was the choice. The raw material was supplied by generous donation from the factory. The process stages were blow room, carding, drawing and open-end spinning.

3.2 Materials:

In the present study, two types of fibers, Bt cotton (3.2 mic, 26.6 mm) and Acala cotton (Hamid variety) (4.2 mic, 26.7 mm) were used to produce yarns on open end spinning machine using Rieter machine type. Both of these cottons were sampled and tested for fiber properties. The Bt cotton that used in the study came from the Sudanese Brazilian company which grow the Bt cotton as commercial crop in Sudan. The Bt cotton came in four lots (150,151,328 and 329) which were all mixed in the blow room. The Acala cotton came in two lots (47 and 49). The different lots were tested for fiber properties in the laboratories of the Agricultural Research Corporation (ARC) and the fiber properties averages were used in machine settings calculations. The specifications of the cotton which were used in the study are shown in Table (3.1) and Table (3.2) respectively.

**Table (3.1) Bt fiber specification**

<table>
<thead>
<tr>
<th>Cotton</th>
<th>Lot No</th>
<th>UHM</th>
<th>UI%</th>
<th>Mic</th>
<th>HVI</th>
<th>Elong</th>
<th>Rd</th>
<th>b+</th>
<th>Stick</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bt cotton</td>
<td>150</td>
<td>26.6</td>
<td>77.6</td>
<td>3.1</td>
<td>27.4</td>
<td>6.1</td>
<td>74.4</td>
<td>8.9</td>
<td>0</td>
</tr>
<tr>
<td>Bt cotton</td>
<td>151</td>
<td>26.8</td>
<td>78.5</td>
<td>3.2</td>
<td>27.6</td>
<td>6</td>
<td>74.5</td>
<td>9.5</td>
<td>0</td>
</tr>
<tr>
<td>Bt cotton</td>
<td>328</td>
<td>26.4</td>
<td>78.9</td>
<td>3.3</td>
<td>27.8</td>
<td>6</td>
<td>73.6</td>
<td>10.1</td>
<td>0</td>
</tr>
<tr>
<td>Bt cotton</td>
<td>329</td>
<td>26.5</td>
<td>77.9</td>
<td>3.3</td>
<td>27.4</td>
<td>6.1</td>
<td>74.2</td>
<td>9.4</td>
<td>0</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>26.6</td>
<td>78.2</td>
<td>3.2</td>
<td>27.6</td>
<td>6.1</td>
<td>74.2</td>
<td>9.5</td>
<td>0</td>
</tr>
</tbody>
</table>
Table (3.2) Acala fiber specification

<table>
<thead>
<tr>
<th>Cotton</th>
<th>Lot No</th>
<th>UHM</th>
<th>UI%</th>
<th>Mic</th>
<th>HVI</th>
<th>Elong</th>
<th>Rd</th>
<th>b+</th>
<th>Stick</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acala</td>
<td>47</td>
<td>26.8</td>
<td>78.6</td>
<td>4.2</td>
<td>26.9</td>
<td>6.2</td>
<td>73.6</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Acala</td>
<td>49</td>
<td>26.5</td>
<td>77.6</td>
<td>4.2</td>
<td>27.2</td>
<td>6.3</td>
<td>73.9</td>
<td>8.6</td>
<td>0</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>26.7</td>
<td>78.1</td>
<td>4.2</td>
<td>27.1</td>
<td>6.3</td>
<td>73.8</td>
<td>8.8</td>
<td>0</td>
</tr>
</tbody>
</table>

3.3 Preparation:

Opening, blending and cleaning of the fiber are the first processes in the spinning mill. In the mill, bales were laid down in a row to be opened and blended through a range of machines. The opening and blending processes ensure a consistent and homogeneous blend of fibers. It also cleans and removes plant based contaminants such as leaf, sticks, boll parts bark and seed fragments.

The two types of cotton were introduced into opening and cleaning machines line. In Sur Textile factory the blow room opening and cleaning points were as follow:
- Automatic bale opening machine (UNIFLOC).
- Mono cylinder cleaner.
- Aero mixer.
- ERM cleaner.

Once the fiber has been opened, blended and cleaned it is fed to the carding machine using chute feeding machine. This is for good reason as the carding machine individualizes, aligns and further cleans the fibers. Importantly, a large proportion of short fibers and neps are also removed during carding before condensing fibers into a single continuous strand of overlapping fibers called a sliver with the linear density 0.1 Ne.

Drawing is the process where the fibers are blended, straightened and the number of fibers in the sliver reduced in order to achieve the desired linear density. The drawing process also improves the uniformity or evenness of the sliver. The card sliver was passed through two successive drawing processes by using the Rieter type draw frame, the total draft was (6) for the two drawing passages. The spinning machine was fed with
slivers after the second passage of drawing with the linear density 0.1Ne to both types of material.

3.4 Spinning:
To meet the requirements of this study, a range of counts were produced from coarser to fine counts from the two types of fibers. This study was conducted in two parts to produce a range of counts from 8 to 30Ne to represent the rotor commercial counts and from 32 to 36Ne to represent the finer range. This was done using two different rotor speeds and diameters, so as to give each range of counts the suitable manufacturing condition aiming to have good yarn quality and properties. Each count had the same condition and machine setting for both type of materials.

In the rotor open end spinning section, sixteen cans (7Kg in weight) were used, eight for each side of the machine, one used for Bt cotton and the other for Acala cotton.

Part one:
The rotor spinning machine parameters used were as follows:

1. The rotor speed 68500 rpm.
2. The opening roller speed 7700 rpm.
3. The rotor diameter 35 mm.
4. The winding angle 34˚
5. The twist factor 4.5
6. The counts produced were (8, 12, 16, 20, 26 and 30Ne).

The draft, feed speed, delivery speed and twist number were gradually changed in steps so as to produce the desired range of counts. The equations (1 and 2) that were used in machine settings calculations were as follow:

\[
\text{The draft} = \frac{\text{delivery speed}}{\text{feed speed}} \quad \text{......................... (1)}
\]

\[
\text{The twist} = \frac{\text{rotor speed}}{\text{delivery speed}} \quad \text{......................... (2)}
\]

And the results are shown in Table (3.3)
Table (3.3) Machine settings parameters for both cottons in the first part

<table>
<thead>
<tr>
<th>Count (Ne)</th>
<th>8</th>
<th>12</th>
<th>16</th>
<th>20</th>
<th>26</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivery (m/min)</td>
<td>136.6</td>
<td>111.5</td>
<td>96.6</td>
<td>86.4</td>
<td>75.8</td>
<td>70.5</td>
</tr>
<tr>
<td>Feed (m/min)</td>
<td>1.82</td>
<td>1.03</td>
<td>0.67</td>
<td>0.5</td>
<td>0.32</td>
<td>0.26</td>
</tr>
<tr>
<td>Draft</td>
<td>75</td>
<td>108.3</td>
<td>144.2</td>
<td>172.8</td>
<td>236.8</td>
<td>271.1</td>
</tr>
<tr>
<td>Twist (t/m)</td>
<td>501.4</td>
<td>614.2</td>
<td>709.2</td>
<td>793</td>
<td>904.1</td>
<td>971.1</td>
</tr>
</tbody>
</table>

Part two:

1. The rotor speed 74500 rpm.
2. The opening roller speed 7700 rpm.
3. The rotor diameter 30 mm.
4. The winding angle 34°
5. The twist factor 4.7
6. The counts produced (32, 34 and 36 Ne).

The draft, feed speed, delivery speed and twist number were gradually changed in steps so as to produce the desired range of counts, as explained in Table (3.4)

Table (3.4) Machine settings parameters for both cottons in the second part

<table>
<thead>
<tr>
<th>count (Ne)</th>
<th>32</th>
<th>34</th>
<th>36</th>
</tr>
</thead>
<tbody>
<tr>
<td>delivery (m/min)</td>
<td>71.1</td>
<td>69</td>
<td>67.1</td>
</tr>
<tr>
<td>feed (m/min)</td>
<td>0.25</td>
<td>0.21</td>
<td>0.2</td>
</tr>
<tr>
<td>draft</td>
<td>285</td>
<td>328</td>
<td>335</td>
</tr>
<tr>
<td>twist (t/m)</td>
<td>1047.5</td>
<td>1079.7</td>
<td>1111</td>
</tr>
</tbody>
</table>

In this second part processing was continued until a count was reached at a point that the spinning became practically impossible. All counts were practically produced in two separate experiments; the spinning section atmospheric conditions were reported as shown in Table (3.5)
3.5 The end breakage rate:
End breakage rate in rotor spinning depends upon yarn strength and spinning tension. It also depends upon disturbing factors like trash and micro dust, lay of fibers in groove (Das and Ishtiaque, 2004). End breakages will increase with rotor speed if suitable action is not taken on optimizing mixing and parameters of machine, especially rotor diameter. Rotor diameter has to be reduced and optimum navel has to be used, with increase in rotor speed to offset the increase in tension (Das and Ishtiaque, 2004).

The end breakage is a critical spinning parameter that not only affects the production speed but may also indicate the quality of yarn, the mechanical condition of the machines and the quality of raw material. Therefore it is an important parameter which determines the overall working of a spinning mill. In this study the end breakage increased as the count became finer. Also the end breakage increased in the second part of the study when the rotor speed increased. All the observed end breakage rates were described in the following Table (3.6):

### Table (3.6) End breakage rates

<table>
<thead>
<tr>
<th>Count (Ne)</th>
<th>8</th>
<th>12</th>
<th>16</th>
<th>20</th>
<th>26</th>
<th>30</th>
<th>32</th>
<th>34</th>
<th>36</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ends down/hr</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>6</td>
<td>9</td>
<td>10</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>

3.6 Yarn evaluation:
The yarn counts produced from both types of cotton were tested to evaluate yarns properties so as to enable the comparisons between the two types of cotton. The yarn properties that were evaluated in this study were as follow:
3.6.1 Yarn evenness:
The evenness test was conducted with the Uster Evenness Tester in Sur textile factory in Hassahisa. The device parameters were: speed = 400 m/nim, time = 2.5 min, Slot 4/yarn, Yarn tension 25% and the Length was 1000 m.

3.6.2 Yarn tensile property:
This test was conducted with the Uster Tensile tester in Gezira University Textile Faculty Laboratory.
   - Load measuring range: 600 g and 1000 g.
   - Mean time to break about 17 seconds.
   - Test length: 715 mm.

Five cones were tested for each count, the total number of tests were 50 tests. The elongation%, the strength (g) and the R.K.M (g/tex) were calculated from the total sum of the 50 readings. The equations (3,4, 5 and 6) used in the calculations were as follows:

**RKM Calculation**

Breaking Load Pin % = \( \frac{Ps \times 10}{n} + K \) .......................... (3)

\[ P \text{ in GMS} = \frac{P \text{ in } \% \times M \text{ in GMS}}{100} \] ............................... (4)

\[ \text{RKM} = \frac{P \text{ in GMS}}{ Tex} \] ............................... (5)

Where:  
Ps is the device reading.  
\( n \) is the number of tests.  
K is Constant equal + 2.5  
M in GMS is the load weight.  
P in GMS is the breaking force in gram.  
Tex is the yarn count.

**Elongation calculation**

\[ \text{Elongation} \% = \frac{Se \times 10}{n} + K \] ............................... (6)

Where:  
Se is the device reading.  
K is Constant equal + 0.2  
\( n \) is the number of tests.
3.6.3 Yarn twist:
Twist test was conducted in Gezira University Textile Faculty laboratory. Twist counter
test the number of twist of single yarn by untwisting and twisting method:

1- Test length 20cm.
2- Tension device 5 g.

The equations (7 and 8) that used in twist per inch (tpi) calculation were as follow:

\[
TPI = \frac{\text{The dial reading}}{40} \times 2.54 \quad \text{……………………………} (7)
\]

\[
CV\% = \frac{\text{standard division}}{\text{mean}} \times 100 \quad \text{……………………………} (8)
\]

3.6.4 Yarn appearance:
Yarn appearance is one of the parameters for a yarn quality evaluation. In practice, the
yarn appearance was evaluated subjectively by wrapping the yarn in equally spaced
parallel wraps over a board for visual examination and compared the appearance of
irregularities against standard rating photographs which carry out visual determination
of unevenness along the length of a yarn. Yarns wrapped on the board were 25 ends per
inch. The appearance test was conducted in Gezira University Textile Faculty
laboratory.

3.6.5 Yarn thin places (-50%):
The number of places that have the mass reductions of 50% or more with respect to the
mean value Note that (-50%) is the standard sensitivity level used in the test.

3.6.6 Yarn thick places (+50%):
The number of places that have the mass increases of 50% or more with respect to the
mean value Note that (+50%) is the standard sensitivity level used in the test.

3.6.7 Yarn neps:
A nep is a very short thick place in the yarn, a small fault having a length of 2mm
diameter of 3 times or more at a standard setting of 200%.
3.6.8 Yarn CV%:
Yarn evenness is a measure of the level of variation in yarn linear density or mass per unit length of yarn.

3.6.9 Yarn hairiness:
Yarn hairiness is usually characterized by the amount of free fibers protruding from the compact yarn body towards the outer yarn surface. Its determination is essential because it influences the post spinning operation and parameters of the textile product.

3.6.10 Yarn breaking Force (Single yarn strength):
This is the force required to break a strand of single yarn. It is expressed in (g).

3.6.11 Yarn R.K.M:
The yarn R.K.M can be expressed by the Length of yarn in km at which yarn will break of its own weight. This is equivalent to breaking load in g/tex.

3.6.12 Yarn specific strength (Tenacity):
The tensile strength expressed as force per unit linear density is called tenacity. This is normally expressed as gram force per tex (gf/tex).

3.6.13 Yarn elongation %:
Yarn elongation is the measure of the extent of deformation along the axis of a material under a tensile stress expressed as a percentage change in length based on original length of test sample (softtextile.biz).

3.6.14 Atmospheric condition:
The testing work was carried out under the laboratory conditions which were (55%) relative humidity and (24°C) temperature in Sur textile factory laboratory, and (60%) relative humidity and (23°C) temperature in Textile faculty Laboratory University of Gezira.
CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 The first part results:

The results for Bt yarns and Acala yarns that were produced with rotor speed 68500 rpm and rotor diameter 35 mm were summarized and reported in Table (4.1)

Table (4.1) Bt yarns and Acala yarns results in the first part

<table>
<thead>
<tr>
<th>Cotton type</th>
<th>Bt</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Acala</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Count Ne</td>
<td>8</td>
<td>12</td>
<td>16</td>
<td>20</td>
<td>26</td>
<td>30</td>
<td>8</td>
<td>12</td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td>Average Count Ne</td>
<td>7.7</td>
<td>11.5</td>
<td>16.2</td>
<td>19.6</td>
<td>25</td>
<td>29.7</td>
<td>7.9</td>
<td>11.5</td>
<td>15.4</td>
<td>19.6</td>
</tr>
<tr>
<td>Count CV%</td>
<td>1.5</td>
<td>0.8</td>
<td>2.1</td>
<td>1.3</td>
<td>0.2</td>
<td>1.7</td>
<td>0.4</td>
<td>1.3</td>
<td>1.9</td>
<td>2.4</td>
</tr>
<tr>
<td>Strength (g)</td>
<td>763</td>
<td>608</td>
<td>457</td>
<td>409</td>
<td>3138</td>
<td>2514</td>
<td>849</td>
<td>632</td>
<td>513</td>
<td>397</td>
</tr>
<tr>
<td>Strength CV%</td>
<td>4.1</td>
<td>4.5</td>
<td>2.7</td>
<td>3.5</td>
<td>7.2</td>
<td>3.6</td>
<td>7.8</td>
<td>6.9</td>
<td>7.3</td>
<td>6.8</td>
</tr>
<tr>
<td>R.K.M(km)</td>
<td>10</td>
<td>11.9</td>
<td>12.5</td>
<td>13.6</td>
<td>13.3</td>
<td>12.6</td>
<td>11.4</td>
<td>12.3</td>
<td>13.4</td>
<td>13.2</td>
</tr>
<tr>
<td>Elongation %</td>
<td>7.1</td>
<td>6.9</td>
<td>5.6</td>
<td>5.7</td>
<td>5.6</td>
<td>5.5</td>
<td>9.0</td>
<td>8.0</td>
<td>6.5</td>
<td>6.5</td>
</tr>
<tr>
<td>Elongation CV%</td>
<td>7.0</td>
<td>6.5</td>
<td>5.3</td>
<td>5.6</td>
<td>3.8</td>
<td>7.5</td>
<td>2.7</td>
<td>3.0</td>
<td>7.9</td>
<td>3.7</td>
</tr>
<tr>
<td>Twist (tpi)</td>
<td>10.1</td>
<td>13.7</td>
<td>16.6</td>
<td>19.1</td>
<td>21.8</td>
<td>24.1</td>
<td>11.6</td>
<td>13.4</td>
<td>16.5</td>
<td>19.5</td>
</tr>
<tr>
<td>Twist CV%</td>
<td>1.3</td>
<td>2.2</td>
<td>4.0</td>
<td>4.7</td>
<td>3.3</td>
<td>3.4</td>
<td>3.3</td>
<td>5.4</td>
<td>3.2</td>
<td>5.2</td>
</tr>
<tr>
<td>Yarn CV%</td>
<td>14.1</td>
<td>15.2</td>
<td>15.1</td>
<td>14.7</td>
<td>13.9</td>
<td>15.9</td>
<td>15.9</td>
<td>15.6</td>
<td>14.5</td>
<td>15.6</td>
</tr>
<tr>
<td>U%</td>
<td>11.1</td>
<td>11.9</td>
<td>11.9</td>
<td>11.6</td>
<td>11.4</td>
<td>12.5</td>
<td>12.6</td>
<td>12.3</td>
<td>11.5</td>
<td>12.3</td>
</tr>
<tr>
<td>Thin place</td>
<td>2</td>
<td>10</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>17</td>
<td>10</td>
<td>4</td>
<td>21</td>
<td>16</td>
</tr>
<tr>
<td>Thick place</td>
<td>42</td>
<td>37</td>
<td>24</td>
<td>32</td>
<td>87</td>
<td>50</td>
<td>72</td>
<td>53</td>
<td>29</td>
<td>61</td>
</tr>
<tr>
<td>Neps</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>9</td>
<td>24</td>
<td>37</td>
<td>2</td>
<td>2</td>
<td>21</td>
<td>47</td>
</tr>
<tr>
<td>Hairiness</td>
<td>9.8</td>
<td>10.3</td>
<td>8.7</td>
<td>8.3</td>
<td>8.1</td>
<td>7.2</td>
<td>7.9</td>
<td>9.7</td>
<td>8.3</td>
<td>7.2</td>
</tr>
</tbody>
</table>
4.2 Comparison of yarn properties, Bt with Acala:

4.2.1 Yarn strength:

Figure (4.1), shows that the absolute values of yarn strength in grams which indicate a decrease in strength values with increase in yarn count (finer) for both types of cottons. However, to compare the different types of cotton while taking the yarn count in consideration, its best to use the yarn tenacity or R.K.M values. This is shown in Figure (4.2) where the two types of cotton showed an increase in yarn strength as the yarn becomes finer, but this up to a certain limit, then the tenacity appears to reduce with further increase in yarn count Ne. The yarn count at which this change in yarn tenacity is different for the two types of cotton, the Bt cotton peak was in count 20Ne and the Acala cotton peak was in count 16Ne. This could be due to the different micronaire values for Bt cotton (3.2) and Acala cotton (4.2) which make them suitable for the two different yarn counts respectively. Count 30Ne for Bt cotton can be suggested to be the count limit under this experiment condition since the tenacity of the yarn dropped clearly in this count. According to Table (4.1) the Acala cotton count limit suggested to be in count 26Ne as the tenacity value dropped and maintained the same value at count 30Ne and cannot be expected to be improved further in performance in this experiment condition. This is also supported by the deterioration of the other yarn properties when reached count 30Ne. However, the statistical analysis of variance for the R.K.M. Table (4.3- Appendix A) shows that the difference between the Bt cotton and Acala cotton tenacity in all counts was not significant except in count 8Ne in which the tenacity of Acala cotton was better than Bt cotton. This could also be attributed to the same reason as before and it could be said that for the spinning conditions as in this study the Acala cotton was more suitable for the coarse count 8Ne compared with the Bt cotton and the spinning limit for both cottons can be considered to be count 30Ne.
**Figure (4.1)** yarn strength vs count

![Graph showing yarn strength vs count](image)

*Rotor speed 68500 rpm, Rotor diameter 35 mm*

**Figure (4.2)** yarn R.K.M vs count

![Graph showing yarn R.K.M vs count](image)

*Rotor speed 68500 rpm, Rotor diameter 35 mm*
4.2.2 Yarn elongation:

From Figure (4.3) the elongation curves of the two types of cotton show that the elongation is decreased with the increased count Ne which means a negative relation between the elongation and the count. The Acala yarns elongation was higher than Bt yarns elongation and this may be explained by the higher elongation of the Acala cotton fiber. At count 30Ne the two types of yarns have almost the same elongation and consequently there is no significant test applied. However, the statistical analysis of variance of elongation Table (4.4- Appendix A) shows that there was a significant difference between the two types of cotton from count 8Ne to 26Ne. This may well be reflected in the performance of Acala cotton yarns in later processes compared with Bt cotton yarns.

4.2.3 Yarn twist:

The twist number always increases when the yarn cross-section decreases. This is expected and clearly reflected in the graph shown in Figure (4.4). In fact the twist supports the yarn tenacity to a certain limit according to the fiber length. In this study the influence of twist in the Bt cotton appeared in count 20Ne, 13.6 g/tex the highest tenacity, whereas the highest tenacity of the Acala cotton influenced by twist appeared in count 16Ne, 13.4 g/tex. This could be attributed to the difference of the micronaire values of the two cottons. The twist curves in Figure (4.4) show the correspondence of the two types twist in all counts except 8Ne, practically the twist factor applied to both types of yarns was constant equal to (4.5) even though the Acala yarns contained slightly more twist than Bt yarns. This can be retained to the different fiber fineness and its friction inside the rotor. This result was supported by Palamutcu and Kadoglu (2008), who reported that lower twist loss is expected with coarser and shorter fibers. Salhotra (1981) also reported that longer fibers resulted in more twist loss. However, the statistical analysis of variance from Table (4.6- Appendix A) showed that there was no significant difference in twist between all counts. Consequently, it could be said that the performance of the Bt cotton is not different from the Acala cotton in the present condition.
**Figure (4.3)** Yarn elongation vs count

![Graph showing yarn elongation vs count](image)

**Figure (4.4)** Yarn twist vs count

![Graph showing yarn twist vs count](image)
4.2.4 Yarn evenness:

It is difficult to produce fine yarn with small irregularity than for course yarn due to the reduced fiber in cross-section (Furter, 2009). Fine yarns with a low number of fibers in the cross-section have a higher unevenness than coarse yarns. In this study the yarn unevenness does not have a clear trend, from count 8Ne to 16Ne the Acala yarns unevenness decreases as the yarn becomes finer this can be attributed to the decrease in thick places as will be explained in later sections, then the CV% started to increase up to the finer count at 26Ne and retained almost the same value at count (30Ne) although this is higher than the CV% of count 8Ne. On the other hand the unevenness for the Bt cotton although generally lower than the unevenness for the Acala cotton, it showed slight increase in CV% as the yarn became finer up to count 12Ne then remained constant up to count 16Ne. From count 16Ne up to count 26Ne the CV% started to reduce. Finally the fine count at 30Ne showed the highest CV% value. The curves general view was the Acala yarn unevenness was worse than Bt cotton in most of counts. This may be explained by the fiber fineness since the Bt cotton is finer compared with the Acala cotton. This should result in more doubling when comparing individual yarn counts. Count 30Ne reported the highest values of irregularity for the Bt cotton and counts 26 and 30Ne reported the highest irregularity for Acala cotton. The statistical analysis of variance of yarn unevenness Table (4.5 - Appendix A) showed that there was a significant difference between Bt cotton and Acala cotton in CV% in all counts except 16 Ne. It is important to mention that count 16Ne in the statistical analysis of tenacity result in Table (4.3 - Appendix A) also had no significant difference between the two types of cotton yarns. However when looking back at the tenacity results it was observed that Acala cotton gave the highest tenacity value at count 16Ne and at the same time it had the lowest unevenness among all Acala yarns counts.

4.2.5 Yarn thin places:

Figure (4.6) shows that the thin places generally increased with increased count Ne for both types of cotton, the increase was more profound for the Acala type. This may be explained by the decreasing number of fibers in the yarn cross-section when the count became finer so the number of thin places increased. The Bt yarns cross-section consist of more number of fiber than Acala yarns, so the Acala yarns have the higher numbers
of thin places, and this was reflected in higher unevenness in Acala yarns as explained before and higher neps and thick places as will be explained in the following sections.

**Figure** (4.5) yarn unevenness vs count

**Figure** (4.6) yarn thin places vs count
4.2.6 Yarn thick places:
Figure (4.7) shows that the two types of cotton have the same general trend. Firstly, from count 8 to 16Ne, the curve tends to decrease in the thick places when the count became finer. With the Acala yarns this was exactly the same with the unevenness curve for the same counts. In other words the decrease in thick places in Acala yarns was reflected in the decrease in unevenness. Furthermore, the lowest thick places and lowest unevenness for Acala yarn was in count 16Ne, this was translated into the highest tenacity for count 16Ne. Secondly from count 16Ne to count 26Ne, when the yarns became finer, the thick places curves tend to increase, this was also reflected in the unevenness for Acala yarns for the same yarn counts. Finally the thick places dropped with further increase in count till 30Ne. In general the Acala yarn thick places were more than Bt yarns in all counts, this is attributed to the different fiber fineness and to the number of fibers in the yarn cross-section, thick and thin places increases with a decreasing number of fiber in the cross-section. Count 26Ne for both Acala and Bt yarns have the highest number of thick places.

4.2.7 Yarn neps:
Figure (4.8) shows the occurrence of neps with the different yarn counts for both types of cotton. The Bt yarns curve was more clear than Acala yarns one. It tends to increase with further increase in count. The first three Bt yarn counts gave almost the same number of neps, then neps number gradually increased as the yarn became finer. With Acala yarns neps were constant in the first two counts, and then the neps increased with increased count except count 26Ne which has less number of neps than count 20Ne. However, at the same time this count has the highest number of thick places among all yarns. Therefore it could be suggested that this count neps size were small and cause short thick places in the yarn. The higher number of neps of Acala yarns is reflected in the high unevenness compared with Bt ones. Generally in neps areas fibers orientation is erratic which can cause weak places in yarn. This can lead to spinning efficiency loss.
Figure (4.7) yarn thick places vs count

Figure (4.8) yarn neps vs count
4.2.8 Yarn hairiness:

Figure (4.9) show the hairiness curves of Bt and Acala yarns which generally decreased with the increased count Ne. This occurred due to the probability of protruding fibers. Since coarser counts yarn contains more fiber ends in cross-section it can be appreciated that hairiness and fly generation will increase with the course counts, and decrease with fine counts (Lawrence, 2010). Also this may be related to the high twist in fine yarns which reduces the number of protruding fibers and therefore reduces the hairiness in fine counts. Bt yarns have the higher level of hairiness than Acala yarns and this may be due to the fineness of Bt fiber which results in more fibers in yarn cross-section compared with Acala yarns which have less number of fibers in the cross-section. Also this may be as a result of the high acceptable twist in Acala yarns as the Acala yarns gain more twist from the machine than Bt yarns. At 26Ne the two types of yarns were almost the same in hairiness. The statistical analysis of variance Table (4.7- Appendix A) shows that there was a significant difference between the Bt yarns and Acala yarns in hairiness in count 8Ne and 12Ne. But the difference with the rest counts was not significant.
**Figure (4.9)** yarn hairiness vs count
4.3 The second part results:

In this part of the study attempts were made to produce finer yarn counts while maintaining the quality of the produced yarns. To do so it was necessary to increase the rotor speed and reduce the rotor diameter. The twist factor was also changed from (4.5) to (4.7) in an attempt to support the yarn tenacity as it declined in count 30Ne in the first part aiming beyond this to reach the fiber exact limit. The results for Bt yarns and Acala yarns that were produced with rotor speed 74500 rpm and rotor diameter 30 mm were summarized and reported in Table (4.2):

**Table (4.2) Bt yarns and Acala yarns results in the second part**

<table>
<thead>
<tr>
<th>Cotton type</th>
<th>Bt</th>
<th>Acala</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Count Ne</td>
<td>32</td>
<td>34</td>
</tr>
<tr>
<td>Average Count Ne</td>
<td>31.6</td>
<td>33.7</td>
</tr>
<tr>
<td>Count CV%</td>
<td>2.8</td>
<td>2.9</td>
</tr>
<tr>
<td>Strength (g)</td>
<td>245.0</td>
<td>230.5</td>
</tr>
<tr>
<td>Strength CV%</td>
<td>4.1</td>
<td>6.1</td>
</tr>
<tr>
<td>R.K.M (g/tex)</td>
<td>13.1</td>
<td>13.1</td>
</tr>
<tr>
<td>Elongation %</td>
<td>5.1</td>
<td>5.2</td>
</tr>
<tr>
<td>Elongation CV%</td>
<td>3.0</td>
<td>6.4</td>
</tr>
<tr>
<td>Twist (tpi)</td>
<td>22.7</td>
<td>26.1</td>
</tr>
<tr>
<td>Twist CV%</td>
<td>3.8</td>
<td>2.3</td>
</tr>
<tr>
<td>Yarn CV%</td>
<td>16.2</td>
<td>16.7</td>
</tr>
<tr>
<td>U%</td>
<td>12.7</td>
<td>13.1</td>
</tr>
<tr>
<td>Thin place</td>
<td>17</td>
<td>44</td>
</tr>
<tr>
<td>Thick place</td>
<td>70</td>
<td>80</td>
</tr>
<tr>
<td>Neeps</td>
<td>58</td>
<td>64</td>
</tr>
<tr>
<td>Hairiness</td>
<td>7.5</td>
<td>6.8</td>
</tr>
</tbody>
</table>
4.4 Comparison of yarn properties Bt with Acala

4.4.1 Yarn strength:

The absolute values of yarn strength in grams shown in Figure (4.10) indicate that the strength decreased with the increased count. To compare the two types of material in strength, it is meaningful to use the R.K.M values which are shown in Figure (4.11). The tenacity of count 32Ne was the starting point for the two curves. The Acala yarns tenacity increased with the increased count till count 34Ne then the tenacity dropped till count 36Ne. The Bt yarns tenacity was constant between 32 and 34Ne then the tenacity dropped till count 36Ne. This may reflect that the Bt yarns cannot be expected to give further performance under this experiment condition. Therefore the count limit to the Bt yarns can be suggested to be in count 36Ne after which the yarn cannot accept neither more twist nor strength. At the same time the Acala yarns reached its count limit in 36Ne as will be explained later in the discussion of the other properties. This can be supported by the statistical analysis Table (4.3- Appendix A) which proved that there was no significant difference between the two types of yarns in tenacity for all counts. Finally, it was observed that the values of yarn tenacities were higher for both types of cottons in the second part of the study when compared with the values of the finer count in the first part which was 30Ne. This can be explained by the increasing in twist number in part two which assists the yarns to gain more tenacity.
Figure (4.10) yarn strength vs count

Figure (4.11) yarn R.K.M vs count
4.4.2 Yarn elongation:
From Figure (4.12) Acala yarns elongation was constant for all counts from which it could be understood that the Acala fiber reached final point that can no longer expect more performance in elongation. The Bt yarns elongation tend to increase with count till count 36Ne. However, from the statistical analysis of variance in Table (4.4- Appendix A) it was clear that the elongation difference between the two types of yarns was not significant in all counts.

4.4.3 Yarn twist:
The number of twist always increases as the yarn count became finer. This occurs with Acala yarns twist in Figure (4.13) increased when the count became finer. But the Bt yarns twist no longer kept the rule tending to increase with count till 34Ne, and then the yarn twist dropped till count 36Ne. This may show that the Bt fiber twist limit was in count 36Ne and the fiber cannot accept more twist. This may indicate that the yarns spinning limit was reached. In spite of the constant twist factor in both types of yarns, the Acala yarns gain more twist than Bt yarns due to the different fibers fineness. But this increase in twist number was not significant as clear from Table (4.6- Appendix A) which shows the statistical analysis of variance resulting in no significant difference between the two types of yarns twist in all counts.
Figure (4.12) yarn elongation vs count

Figure (4.13) yarn twist vs count
4.4.4 Yarn unevenness:
In fact the finer the yarn, the more irregular it is. This explains why for a given fiber fineness, there is a limit on the finest yarn count that can be produced. In this part of the study when the rotor speed increased to 74500 rpm the yarn unevenness also increased with the increase of yarn count. This is the same as was observed in the first part of the study but with higher magnitude of the values. Figure (4.14) shows the Bt and Acala yarns unevenness which is very clear that the unevenness increased when the count became finer. Furthermore the Acala yarns were with poor evenness and have more thick and thin places along yarn length as will be explained later. With Bt yarns the lowest unevenness was in count 32Ne which also have the lowest numbers in thin places and thick places. The statistical analysis of variance from Table (4.5- Appendix A) showed that the difference between all counts was significant for both types of cottons confirming the poor performance of the Acala cotton compared with the Bt cotton.

4.4.5 Yarn thin places:
Figure (4.15) shows that thin places increased when the count became finer. This was clear with Acala yarns. The Acala yarns had the higher numbers of thin places resulting in high unevenness for Acala yarns compared with Bt yarns. High rotor speed increased thin and thick places (Lawrence, 2010). The Bt yarns count 34Ne and 36Ne had the same number of thin places.
**Figure** (4.14) yarn unevenness vs count

**Figure** (4.15) yarn thin places vs count
4.4.6 Yarn thick places:

Figure (4.16) describes the thick places in Bt cotton yarns and Acala cotton yarns. In which the thick places increased in both types of yarns as the count became finer. This could mean that much wrapper fiber were inside the rotor which cause thick places. Increased rotor speed resulted in more wrapper fiber per unit length (Lawrence, 2010). It is important to mention that more end breakages were observed during processing, and practically the ends down increased with finer counts and with the high rotor speed. In conclusion, the Acala yarns suffer from the high thick places, thin places and unevenness compared with the Bt yarns and also suffered from high neps and hairiness as will be described latter. All these evidences could mean that the Acala count limit was reached.

4.4.7 Yarn neps:

The neps gave higher values in this part compared with the neps values in the first part. This may be attributed to the increase in rotor speed in the second part, because the fibers have less time to align themselves in the rotor groove. Acala yarns contain more neps, thin places, thick places and unevenness than Bt yarns. The highest number of neps was in Acala count 36Ne, which at the same time contained the higher number of thin places, thick places and unevenness. Neps may restrict twist propagation, which, for fine yarn count, can result in high ends breakage rate. Thus, neps may limit the fineness of count that can be spun (Lawrance, 2010).
Figure (4.16) yarn thick places vs count

Figure (4.17) yarn neps vs count
4.4.8 Yarn hairiness:

Figure (4.18) shows the Bt and Acala yarns hairiness which tend to decrease with finer count with Bt yarns. The view is different with Acala yarns which its hairiness increases with count in 32 and 34Ne. Then the hairiness decreases with count in 36Ne. In this part of the study, count 32Ne the Bt yarn hairiness was higher than Acala yarn as in the first part yarns. This was due to the number of fibers in the cross-section. But in count 34 and 36Ne the Acala yarns hairiness was higher than Bt yarns in an opposite view from the first part. This may suggest that the high rotor speed causing high wrapping fibers in Acala yarns which appear in more uncontrollable fiber ends. Also the high twist factor in the second part affects the Acala yarn hairiness which increased more than Bt yarns hairiness. This result was supported by Lin et al. (2004) who stated that the increase in twist multiplier increases the hairiness. When the twist factor increases with increased rotor speed, the Acala fiber seemed to be broken under the high twist and speed. This was reflected in the high hairiness of Acala yarns. So it can be suggested that the Acala spinning limit was reached in this part. The statistical analysis of variance in Table (4.7-Appendix A) shows that the difference between the two types of cotton was not significant.
Figure (4.18) yarn hairiness vs count
4.5 The appearance test results:

The appearance of cotton yarn is one of the important qualities affecting its commercial value as it influences, to a great extent, the general appearance of fabric made out of it. The appearance grade of cotton yarn is evaluated by visual comparison of black-board wrappings of yarn with photographic standards, taking into account the various factors, such as the regularity, freedom from foreign matter, neppiness and hairiness of the yarn. The number above the critical nep size directly affect the yarn quality and appearance, which is compared to the critical size limit for a given yarn count. It is to be noted that neps below critical nep size will not influence yarn quality and appearance significantly (David, 2013).

In this study all the yarns from the two parts were wrapped in appearance tester black boards with spacing of 25 yarns per inch. Then compare them with the standard photographic boards. The result of visual evaluation of yarn board’s appearance for Bt cotton yarns and Acala cotton yarns matched with the standard board number (2). This test was done with the attendance of three separate observers so as to get a confident result. Also the yarns boards were captured by a camera photos which were included with in the Appendix B.
CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion:

The study revealed that the produced yarns from the Bt cotton fiber with specific characteristic that was used in this study have the same tenacity as the Acala cotton yarns in almost all the counts that were produced in the two parts. However, the Acala yarns are more suitable in performance, and may be more preferred in later textile processes, as the Acala yarns were significantly better in elongation than Bt yarns in the first part counts, which include the commercial range of counts (16Ne to 26Ne) that were much demanded in the local yarn market.

The twist in the two types of yarns was the same in all counts. So it can be concluded that when operating the Bt cotton with the same manufacturing condition as the traditional cotton Acala, the same results may be obtained.

The Bt cotton yarns have good yarn evenness properties compared with Acala cotton yarns for all counts and under the different conditions as indicated by the two parts.

More specifically, in the first part of the study, the important finding was the count limits for Bt cotton and Acala cotton. Count (30Ne) was suggested to be the count limit for Bt cotton and Acala cotton as the tenacity dropped and high number of thin, thick places, neps and unevenness were reported in this count. In the second part count (36Ne) was suggested to be the count limit for both types of cotton. This was proved by the reduction in twist in count 36Ne from Bt cotton, and the fiber breakage in count 36Ne Acala cotton which was reflected in the hairiness result.

The findings in this study were compatible with the commercial range of counts. As the suitable counts that can be produced from the Bt cotton with the same fiber properties as in this study were; (12, 16, 20 and 26Ne) and (8, 12, 16, 20, and 26Ne) from Acala cotton. All these counts were within the commercial range.
Finally the industrial behavior of the Bt cotton may qualify it to be used as an ideal raw material for certain counts with good properties, and the Bt cotton can be operated at similar manufacturing condition as the traditional Acala cotton.

5.2 Recommendations:
According to the results of this study, the following recommendations are suggested
   1. The Bt cotton can be used as a suitable raw material in the spinning mills.
   2. The Bt cotton can be used to produce certain counts according to its fiber properties test.
   3. To enhance the industrial information about the Bt cotton it is recommended to extend the study to include the ring spinning performance.
   4. To examine the Bt cotton benefits if it is blended with Acela cotton.
References:


33. Ming Luo et al., (2007): *GhDET2, a steroid 5α-reductase, plays an important role in cotton fiber cell initiation and elongation*, Article first published online: 12 JUN.
45. www.softtextile.biz/yarntechnicalterms Jan 2014
Appendix A

The statistical analysis results:

An analysis of variance (ANOVA) was performed to determine the statistical significance of any differences observed between the properties of Bt yarns and Acala yarns. The t-test was applied for each count to give clear idea about the relationship between the two types of fibers.

Table (4.3) Analysis of variance of yarn R.K.M

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<th>20</th>
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Table (4.4) Analysis of variance of yarn Elongation

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Table (4.5) Analysis of variance of yarn CV%

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Table (4.6) Analysis of variance of yarn twist

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**Table** (4.7) Analysis of variance of yarn hairiness

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S: significant difference between the two means

NS: no significant difference between the two mean
Appendix B

**Yarn appearance photographs**

(4-1) Count 8Ne appearance

(4-2) Count 12Ne appearance

(4-3) Count 16Ne appearance

(4-4) Count 20Ne appearance

(4-5) Count 26Ne Acala yarn

(4-6) Count 26Ne Bt yarn
(4-7) Count 30Ne appearance

(4-8) Count 32Ne appearance

(4-9) Count 34Ne appearance

(4-10) Count 36Ne appearance