STUDIES ON THE OCCURRENCE OF CONVOLUTIONS IN THE FIBERS OF SOME EGYPTIAN COTTON VARIETIES

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INTRODUCTION

The cotton crop plays a leading role in the national economy of the Arab Republic of Egypt. Besides being the main cash crop for the farmer and the main foreign currency earner for the country, it is the principal raw material for the largest national industry, i.e. the textile industry.

Up to the beginning of the twentieth century, cotton was facing the competition of other natural fibers, but cotton was coming out triumphantly without much difficulty, because of the relatively easy processes utilized for obtaining textiles from it and the additional factor of low production costs. But more recently, cottoh have been facing an increasingly tougher competition from man-made fibers. This compells cotton producers as well as manufacturers for increased improvement in cotton quality.

There are several approaches for improving cotton quality; the most important of which are through breeding new cotton varieties for better quality, and through chemical processing of cotton fabrics to impart new properties such as "Wash and Wear". Chemical treatments, for improving the quality and prospects of cotton fabrics are handicaped with the fall in strength, elongation and toughness

REVIEW OF LITERATURE

1- Cotton fiber growth and structure :

The most complete account of the origin and growth of cotton fibers has been given in the comprehensive studies of Balls(9) who worked upon Egyptian cotton (G. barbadense), and whose findings were confirmed by Anderson and Kerr (5), who worked upon American Upland Cotton (G. hirsutum). As a result of this work, fiber growth is known to occur in two fairly distinct stages; the first growth stage corresponds to the fiber elongation and the primary wall formation, and the second growth stage corresponds to the secondary wall formation.

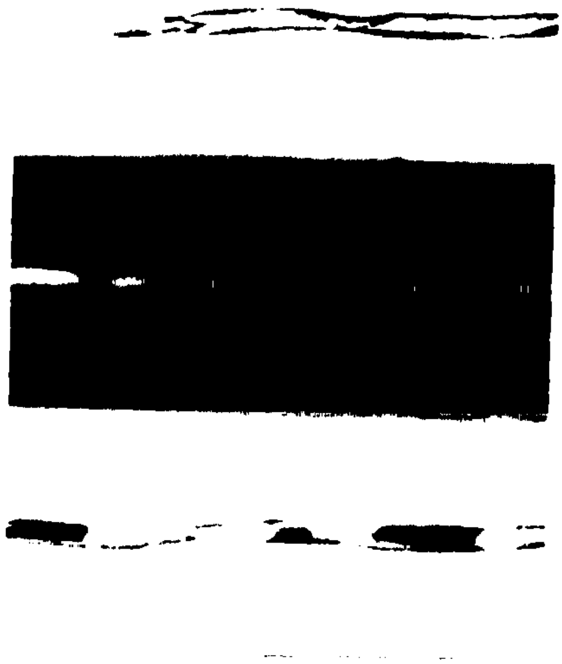
It is now agreed that the cotton fiber cell arises from the epidermis of the cotton seed-coat (3). Each cotton fiber originates as an outgrowth from a single epidermal cell of the seed-coat. The first evidence of the formation of the cotton fiber is the appearance on the day of flowering of a slight swelling of the outer wall of these epidermal cells. The swellings elongate rapidly and on the day after flowering they already produced delicate tubular out-growth, i.e. the young fiber cells. The diameter of the mature cotton fiber is reached soon after it is originated, but elongation of the cell continues for a period of 15 - 20 days, when it ceases abruptly. The period of elongation seems to be determined by species as well as environmental factors (34).

At the end of the first growth stage, when the elongation ceases abruptly, another period of cellulose deposition, in successive layers on the inner surface of the primary wall, take place and contimues until a few days before the ball opens. Under certain conditions, the deposition of the secondary wall may be completed on, or about the thirtieth day after flowering, or in other circumstances, it may contimue up to about the sevent-eight day after flowering. The fact that the rate of cellulose deposition falls-off about the thirty-fifth day efter flowering has been demonstrated by several authors. (3,13, 14). Cellulose deposition does not fill completely the cell cavity; this results in the presence of the lumen in almost all the fibers. During the period of growth, the fiber retains its cylindrical shape, and, because of the limited size of the ball and the crowded conditions inside it, the fiber usually does not grow in a straight line, but changes its direction back and forth many times. As soon as the boll opens, the fiber dries and as a result it looses its circular cross-section and convolutes upon itself many times (13, 14).

A typical mature cotton fiber consists of a primary wall (covered with the cuticle), a secondary wall, and finally a lumen. In the cotton fiber, the primary wall, together with the cuticle, is the only covering for the protoplasm during the first period of cell elongation and development. The cuticle is very thin, considerably less than 0.25 u thick (45). It has been defined as a semi-elastic, retaining membrane which confirms to all changes in the size of the fiber, but does not expand past the predetermined maximum set when the fiber was growing and in a state of turgor (43).

The cuticle is extremely tightly moulded to the primary wall, and although it has a rough surface (52) , it remains unbroken, except over the grossest fiber faults. The cuticle consists of wax (5), a large proportion of pectic material (5, 41), and some incrusting mineral matter.

The primary wall may be defined as the limiting



ig(I)-Raw mature fiber mounted in water and photographed under various lighting conditions. Top, ordinary light, showing convolutions. Middle, between crossed Nicols, showing bands of extinction, i,e. reversals. Bottom, between crossed Nicols with selenite plate, showing differences in color in regions adjacent to extinction bands (cited from Mathew's Textile Fibers, 1954).

Occurrence of structural reversals :

Two general types of reversals have been observed (7); a) the commonest type of reversals is the one in which the spiral strands simply change their direction by bending around in the form of an arc, (b) the second type is the one in which one set of spiral strands end and a second system of spiral strands running in the opposite direction begins, the two ends of the thread-like strands of the two systems overlap at the place of the reversal. Although reversals may be found along the entire length of the individual fiber, the frequency of reversals, in general, is about 50 % greater in the tip one-third of the fiber than in the base two thirds. The coefficient of variation for reversals frequency for individual fibers was found to be in the range of 20 - 25 %.

The average number of structural reversals varies considerably and seems to be a varietal characteristics. Meredith (38, 39), reported about 20 structural reversals per cm. for and American Upland cotton. Orr and Grant (41) reported values varying from 20 to 31 reversals per cm. for cottons of a wide range of physical properties. On the other hand, Betrabet (14), published a table of [illegible] (Gossypium hirsutum [illegible] strains in which the reversals ranged from [illegible] per cm. El-Shawat (4) found the number of structural reversals for the Egyptian varieties and hybrids to range from 12.9 to 31.[illegible] reversals per cm.

The number of reversals was found to be independent of the age of the boll (12), as soon as secondary thickening begins, the full and final number of reversals is present.

Wakeham (53) found that the fibers from large bolls posses less reversals than fibers from small bolls from the same variety and under the same environmental conditions, the differences were statistically significant.

Many researchers (14, 16, 21, 43) found that the average number of the spiral reversals is related to genetic origin, and to a lesser extent to growth environment. Iyenger (31), found that the number of structural reversals is dependent upon heredity and is a quantitative character.

The effect of environment on the occurrence of reversals within varieties was studied (22). The number [illegible] reversals was [illegible] affected by the environmental conditions in some varieties, but other varieties were not affected. Also the humidity has a great effect on the number of reversals, higher humidity conditions resulted in a substantial increase in the number of reversals.

The frequency of reversals varies considerably with environment, but environmental factors responsible for the variation are obscure and inconsistent among cottons (22). The spread of the data with growth environment prevents positive indentification of varieties by reversal frequency.

Structure of reversals :

Based on the pains taking research of many investigators working on the fine structure of cotton fiber and cellulose (7, 14, 26), it was confirmed that the secondary wall consists of macro-fibrils spiralling around the fiber axis. These macro-fibrils, which are visible with the optical microscope are made up of smaller sub-microscopic micro-fibrils, which in turn are composed of cellulose molecules. The cellulose molecule is a chain of glucose residues in the form of D-glucopyranose units linked to other through β-1-4 linkages, which in the native state may be thousands of units long. These chains orient themselves roughly in the direction of the fibril axis. In some regions the chains have reached such a high degree of order that they form crystalline regions, which diffract X-rays in the same manner as macrocrystals. These crystallites are smaller than the total length of the average cellulose molecules. This means that the same chain molecule may pass through several crystalline regions. Between these regions the chain molecule will be in a so-called amorphous regions.

Wakeham and Spicer (54) have reported from evidence obtained from moisture and hydrolysis effect on the strength of cotton fibers at and between reversals, that the cellulose in the regions of reversals is more highly crystalline than the cellulose between the reversals. Increasing the moisture content of the fiber was found to increase the fraction of fibers breaking at the reversals and also increases the strength of the cotton fiber. In some way or another this effect takes place by strengthening the weakest linkages, which have been shown to involve fiber reversals at least in some cases. But if the reversals are preferentially affected in this manner, the fraction of breaks at the reversals would be expected to decrease rather than to increase. This indicates that moisture affects primarily those weakest linkage which occur between the reversals. Furthermore X-ray and structural considerations suggest that the moisture effects take place mainly in the less ordered or non-crystalline regions because water molecules cannot readily enter the crystalline cellulose. They concluded, therefore, that it is logical to state that the reversals, which are not preferentially strengthened, are more highly crystalline than is the remainder of the fiber. Also the higher crystallinity at the reversals is further supported by the experiment in which fibers were mildly hydrolyzed.

X-ray diffraction patterns taken for single fibers at and between reversals showed that the cellulose is more highly oriented at the reversal points than that in the remainder of the fibers (53). The same interpretation has been reached by Orr and Grant, (41) from optical evidence.