Neps: How Do They Impact Cotton Quality?

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Abstract

Neps cause significant financial losses to the textile industry. This paper defines different types of cotton neps, their sources and measurements, and the current state of knowledge about research on neps. Generally, a nep is defined as an entanglement of fibers, that can be caused by environmental factors during growth, processing or are inherent to particular varieties. Biological neps are caused by trash particles entangled in the cotton and result in small dark specks in the greige fabric, but are generally removed by wet processing. Mechanical neps can be found in ginned lint, card web, yarns and cloth and are strongly influenced by mechanical processing. Classically, neps are measured by counting them in a card web, but now AFIS™ can be used for high-speed measurement of neps in fiber samples. The Uster Evenness Tester measures neps in yarns as short thick spots. Image analysis is being used to quantify white speck neps on dyed fabric. White speck neps contain immature clusters of fibers and are often not visible as defects until dyeing, rendering the fabric unsuitable for commercial use, resulting in large financial losses. It has been estimated that the U.S. textile industry has had financial losses as high as $200 million per year due to white specks. Initial research has shown strong correlation between AFIS™ card sliver data and white speck content of fabric. More research is necessary to establish relationships between bale data and the quality of the finished product. Technology to measure more attributes of cotton on a larger scale is becoming available and research is needed to determine the accuracy of this data. The U.S. & Australia will be collaborating in research to: 1) gain fundamental knowledge of the nature and behavior of cotton and neps; 2) gather baseline data on the level and characteristics of neps in Australian cotton; and 3) predict white specks on fabric using high speed fiber data.

Introduction

The growers and the mills are seeking fibers that derive the greatest profit. Although they would like to see a better cotton fiber developed, and have more knowledge of the relationship between fiber parameters and performance, they do not have the resources to do this on their own. In the U.S., the government has taken a number of measurements to assess fiber quality and develop improvements. For example, the Agriculture Marketing Service (AMS) of the USDA measures what are perceived to be the important quality measurements on all cotton produced in the USA. Our research unit (Cotton Fiber Quality, Southern Regional Research Center, Agricultural Research Service, U.S. Dept of Agriculture) interacts with AMS, seeking to improve the means for these measurements and to determine which measurements are most useful. Due to research efforts, cotton has evolved substantially over the last 50 years, mainly to generate cotton lines with improved yields and significantly stronger fiber. Stronger fibers are better suited to the high-speed machinery for production of yarn and fabric, and produce garments that are more resistant to tearing, keeping cotton, a renewable resource, competitive with synthetics. Cotton Inc. and the National Cotton Council often cooperate with or support our research, particularly the assessment of the quality of a bale, relating fiber quality to yarn and fabric quality, understanding the impact of environmental history on cotton's development, improvement of cotton varieties and mechanical processing (field, gin and mill) effects on cotton quality.

Why are Neps Important?

Neps are quality defects that have been found in cotton from the field to the finished fabric. The "neppiness" of cotton is of great interest to buyers because neps have such a strong influence on the quality of cotton textiles. Poor quality cotton means poorer quality products, and financial losses to the textile industry.

Synthetic fibers, direct competition to cotton, are uniform within and between batches. This makes them attractive to textile manufacturers, although they produce textiles with reduced consumer appeal. Uncertainty of the cotton lint quality is therefore a particular problem. In the face of uncertainty, buyers tend to value cotton lint conservatively to reduce their risk. Buyers are known to bypass regions and entire countries after a bad experience rather than risk a repeat problem. The lower end of any commodity market tends to be very crowded, and returns are much less.

What is a nep? This seems like a simple question, because neps have been discussed for most of the history of the cotton industry. In a very broad sense, a nep is a small site of imperfect cotton. Mechanical, biological and white speck neps are all quality defects, however, white speck neps are the worst type of nep in terms of dollars lost by the ultimate customers of ginning; the textile mills. It has been estimated that in the US textile industry, white speck neps are responsible for $200M in losses per year[1]. Combing can be used to remove neps, but there is an added expense of additional processing and fiber losses (both neps and good fiber). Mechanical and biological neps are easy to detect at the card and can readily be combed to improve the yarns and fabrics. Prediction of white speck neps is more difficult and often does not show up until the fabrics are dyed (Figure 1), long after combing can be applied. These factors make the early prediction of white speck neps extremely important to minimize defects.

An exact definition and classification of neps is difficult, because terminology in the industry tends to be poorly defined, and tends to differ between industry sectors and regions. There are many different types of neps; they are measured at different points in processing and by different methods. The different terminologies used to describe neps are often very vague and confusing. One of the outcomes of this complicated nature of neppiness is that comparing levels of neppiness through different stages in the cotton production chain is difficult. This paper will attempt to clarify the different types of neps and the current methods of measurement and some of the different sources of neps.

Definitions and Causes

General

The ASTM definition of a nep, "one or more fibers occurring in a tangled and unorganized mass"[2], is only useful as a general description of a nep, it tells us little about the origins or cause of the nep. The definition further states that "seedcoat and mote fragments with lint or fuzz attached are not neps."[2] However, many published reports count all fiber entanglements, including seed-coat fragments, as neps. Hebert [3] divided neps into two groups - mechanical and biological. People in the cotton ginning sector tend to speak of mechanical neps. The Cotton Ginner's Handbook[4] defines a nep as "a small, pinhead-sized entanglement of fibers in cotton that show up in ginned lint, card web, yarns and cloth". This definition, like the ASTM definition, only covers mechanical neps. Another type of nep, white speck neps, are produced by underdeveloped or immature fibers. These different types of neps are due to variety, field conditions, mechanical processing or some combination of factors.

Mechanical Neps

Mechanical neps were counted for many years by producing a card web and hand counting them over a black background (Figure 2).[5] Mechanical action on fibers during harvesting, ginning, opening, cleaning and carding form mechanical neps. As Alon and Alexander pointed out, processing of fibers (i.e., lint cleaning, carding, and drawing) tends to produce neps through a stress buildup/sudden release mechanism, which induces buckling along the fiber length.[6] Long, fine fibers have a low longitudinal rigidity, and are more likely to entangle with other fibers and on themselves to form mechanical neps. Coarse fibers or fibers with thick secondary walls are less prone to forming mechanical neps during processing. These mechanical neps are responsible for physical defects in yarns and fabric, particularly in premium fine fabrics.

It's been said of cotton "When it's in the boll, that is as good as it's ever going to be". Cotton fiber undergoes one or more stages of picking or stripping, module compression, pneumatic and mechanical transport, extraction and cleaning, ginsawing, bale compression, mill opening, mill cleaning, carding, and weaving. These processes are typically energetic and sometimes harsh. They often involve tension up to breaking point and may also include frictional heating for example, at the seed roll cover. Cotton fiber is not fragile but it isn't indestructible either, so every operation adds its own bit of physical and latent damage to the fiber. When ginning too dry, cotton becomes weaker at very low moisture content, and is more likely to break during mechanical processing. Under these circumstances, cotton tends to recoil and entangle into neps under these circumstances (Figure 3).

There is a paradox in cotton ginning. Cotton can be "ginned for grade" (*i.e.* to suit current cotton classing practice) or it can be ginned to produce the highest quality yarn and textile. The principal problem lies in lint cleaning, which greatly improves preparation, color, and trash content, while increasing short fiber content, decreasing fiber length, and increasing neps. It has been shown in various studies that using no lint cleaners produces the highest quality cotton at the textile mill, but using two or even three lint cleaners ("ginning for grade") produces the highest bale value[789]. Because the direct customer of the ginner is the grower, gins will tend to "gin for grade". This quality problem is unlikely to improve until industry-wide cotton classing practices change.

Biological Neps

Biological neps are caused by "trash" which remains in cotton lint through gin extracting, gin cleaning, and mill cleaning and results in a small dark speck in the greige fabric. In cotton, the "trash" is composed of biological components of the cotton plant (undeveloped seeds, motes, small bits of seed coat, or particles of leaf appearing as dark specks[10]. (Figures 4 & 5) Seedcoat fragments (SCFs) are defined as a portion of cottonseed, usually black or brown in color, broken from a mature or immature seed, to which fiber and linters may or may not be attached.[11] This type of nep is difficult to remove since the fibers attached to the seedcoat can become entwined with the good fibers, locking the seedcoat into the textile structure. Cotton variety had the strongest influence on the number of SCFs[12]. The fiber to seed attachment played an important role in the development of SCF production[12]. The larger the fiber to seed attachment force, measured by the Fiber to Seed Attachment Force Tester, the larger the number of SCFs[12]. Over-zealous "stopping" and defoliation in the field can cause leaves and bracts to fragment into very fine particles of trash during harvesting etc which are difficult to remove, and show up as biological neps in fabric. Cotton fiber at a moisture content of 15% is 1.7 times stronger than the same fiber at 4% moisture content [4]. This extra strength can result in the fiber removing a seedcoat fragment when separating at the gin saw, instead of breaking close to the seed. These fragments are very persistent through all extracting and cleaning processes on lint, and show up as biological neps in fabric.

White Speck Neps

Until recently, white speck neps weren't classified on their own. Merchants, classers, and researchers reported all types of neps as a single value mixing mechanical and biological neps together. However, when attention was focused on what was causing dyeing defects in fabrics it was revealed that there was another classification of neps. White specks are dye resistant neps on fabric (Figure 6a & 6b) which are the result of undyed particles or neps originating at the fiber growing stage. It has only been in the last five years that this new type of was characterized[1]. The cotton fiber is a single cell, and should have a well-developed secondary cell wall without being too coarse. The fiber's diameter is fixed early and is mainly due to variety. Clusters of immature fiber can be found in the seedcotton, and the degree of fiber development, or fiber maturity, depends on a number of factors, especially genotype and environment. Secondary wall development is needed to properly absorb dyes. Under-developed secondary wall leads to white specks in dyed fabric. Immature fibers have a very low cellulose content compared to their mature counterparts and are not able to take up as much dye. Due to their thin secondary walls, these fibers are flat, ribbon like, and optically reflect light, which makes them appear white in color. They tend to be very fine fibers and are prone to mechanical nepping during processing, typically worsening with increased mechanical processing. Immature fibers tended to clump together and stay together throughout processing. There was a dual effect, with these fibers showing up in mechanical neps and as unsightly white specks (called "white speck neps") in dyed fabrics. In one study 96% of all neps in one study contained some immature fibers, and 50% of all neps contained only immature fibers[3]. Sufficient knowledge of the effect of mechanical processing on white specks is needed, and several studies have begun to research these relationships [1, 7, 8, 9, 14].

Individual varieties have been found to have particularly strong tendencies to produce higher levels of immature cotton. It is likely that in the future this tendency will have a greater importance in the selection of new varieties. Different varieties also mature at different rates. Some mature over a shorter period and there is only a limited "tail" (time frame where some bolls are still maturing, after most bolls have fully matured). Others mature over a longer period, and the "tail" drags out longer. These differences, increases the range of maturities in harvested bolls, and increases the tendency to produce high levels of white speck. If a plant is stressed during certain critical periods, for example by a shortage of water, some of the immature seeds within a boll may be aborted. The immature fiber attached to those seeds has only the primary wall laid down at this stage, and the fiber does not develop the mature secondary wall that other living seeds on the plant produce. When that cotton is harvested, the immature fibers are mixed in with mature fibers and usually result in neps during further processing. In addition, the aborted seed is usually too small to be removed by the ginsaws, and persists through processing to produce a biological nep. It is possible that a crop of cotton which "just makes it" through a bad season may not have "made it" at all, and a white speck problem is likely.

It has been estimated that 30% of white speck neps are caused by the cotton variety, 30% by environmental factors during growth, and 40% by processing once harvested[13]. Mechanical cotton pickers suit the industry well, but they lack the selectivity of manual workers as used in some countries. Almost all bolls are harvested, regardless of maturity. Unambiguously immature bolls are removed by the rock and green boll trap early in the ginning process, but others may be partially mature and may be knocked open during the extraction of trash. When this happens, the immature fiber in those bolls mixes with mature fibers and will usually result in neps during further processing. This effect is particularly bad in "second pick" seedcotton.

Sometimes, in the face of impending wet weather or other picking problems, farmers will choose to pick earlier than is desirable from an agronomic point of view. At other times, wet weather happens and it is impossible to pick for a time. Either of these two cases affects the quality of fiber arriving at the gin. Early picked cotton contains more immature bolls than cotton allowed to mature properly, and more immature fiber arrives at the gin. Late picked cotton is even worse, for two possible reasons. The bolls that are maturing in the "tail" of the process may be marginal bolls with a higher proportion of aborted seeds and immature fiber.

Also, lint exposed to sunlight and moisture becomes weaker and more susceptible to damage by later mechanical processing[14].

Measurement - How is the "Neppiness" of Cotton Determined?

Fiber

The card web has been in existence for many years, and is useful for counting mechanical and biological neps in lint but with today's high speeds it is used on a limited scale. A sample of lint is carded out into a web and the neps are counted against a black background as in Figure 1. White speck neps are difficult to estimate in fiber form, since they do not appear until the fiber is dyed. The neppiness of cotton lint can be inferred by measuring other attributes of the cotton, particularly its fineness and maturity. This inference is accurate because the underlying physical problem is principally immature fibers, as is clearly seen in Figures 6a and more dramatically in 6b. There is a variety of methods for determining fineness and maturity, such as micronaire, the AFIS™ F&M module, or the "Shirley STM" as widely used in the textile industry. The AFIS™ instrument has a module for counting neps in samples of lint and giving their average size, the figure usually quoted in Australia when reporting neppiness. AFIS™ analyzes thousands of individual fibers at high speed. Research has shown strong correlation between AFIS™ card sliver data and white speck content of fabric (Bel-Berger et al, unpublished). Initial research of bale fibers has shown good relationships between immature fiber measurements and white speck content but more in-depth studies should be done (Bel-Berger et al, unpublished).

The micronaire test measures the rate at which air flows under pressure through a plug of lint compressed into a chamber. The rate of airflow depends on the resistance offered by the total surface area of fibers. The total surface area depends on the fineness of the fiber and the thickness of the fiber wall. The micronaire value is affected by both maturity and fineness. As fiber fineness for a particular variety remains reasonably constant, a reduction in micronaire is most likely reflecting fiber immaturity.[15] When comparing unknown varieties, it is more difficult to use micronaire as an indicator of maturity. High Volume Instruments (HVI's) that are operated by the Agricultural Marketing Service (AMS) in the U.S. measure micronaire, but the HVI micronaire doesn't always indicate the level of immaturity as well as we would like.

In the U. S., all cotton is tested by HVI's that are operated by AMS. These machines assess nearly 20 million bales of cotton each year to determine micronaire, length and strength. All Australian cotton, approximately 1.25 million bales, is also tested using the HVI instrumentation prior to marketing. Nevertheless, there is a substantial need to improve these measurements in order to maintain cotton's competitive position. Typically, the textile mills select large numbers of bales based on their micronaire readings and combine them in hopes of getting homogeneous fabric production. Still, there are substantial year-to-year variations, making it difficult to produce a consistent item from year-to-year.

Yarn

Once made into yarn, the neppiness of cotton is usually measured by calculating the regularity of thickness of the yarn and by counting the number of thick/thin sections ("slubs") per length of yarn.

Fabric

Once made into fabric, the number of physical defects per unit area can be counted, or the percentage of area showing as white after dyeing can be measured (Figure 1). Necessarily the latter involves computer image analysis for accuracy and repeatability. This is required if the percentage white area in the textile is to be relied on as a reference. However, quantifying the neps in fabric after the production losses have occurred does not answer all of the textile industry's problems. The exception to this is when relating the level of neps back to various measured attributes of lint using statistical techniques. This analysis reveals which lint attributes have a strong relationship with, for example, the level of white speck neps, and which attributes have a weak relationship and can be eliminated from the analysis. The statistical analysis provides equations for predicting the level of white speck neps under similar conditions in the future. Once in possession of data relating to attributes of the lint, the likely neppiness of the future fabric can be calculated.

Future Research Directions

Addressing the problem of neps in cotton is becoming unavoidable. Technology to measure more attributes of cotton on a larger scale is becoming available, and buyers have the incentive to make the investment. Cooperative research funded by the Cotton Research and Development Corporation, and the US Department of Agriculture, Agricultural Research Service is currently underway as part of the response to this problem. The research effort involves personnel principally at the National Centre for Engineering in Agriculture in Toowoomba and the ARS's Southern Regional Research Center in New Orleans. This work seeks three main outcomes:

1) Fundamental knowledge of the nature and behavior of cotton and neps will be gained.

2) Baseline data on the level and characteristics of neps in Australian cotton will be gathered, to show the industry where it stands now and as a reference for improvement.

3) Information on how to predict white specks in fabric from fiber measurements.

This research should result in the buyer having more information that will be relevant in the buying decision. Even if the result is that the cotton is marginal, the buying decision is less risky and there is less reason for the pricing decision to be conservative. Also, there is less potential for dissatisfaction after the fact. For example, a long, strong, and fine cotton may have a high immature fiber content which in turn, based on the attributes of the lint, gives it a high probability of becoming a white speck problem after dyeing. However, if the fabric is directed to, white shirting, toweling, or sheeting fabrics, and industrial uses, the white speck neps never arise as visible defects. The long, strong, and fine nature of the cotton can be realized as a price premium, sidestepping any discounts. By knowing more about the relationship between cotton data product quality, cottons could be routed to their best application.

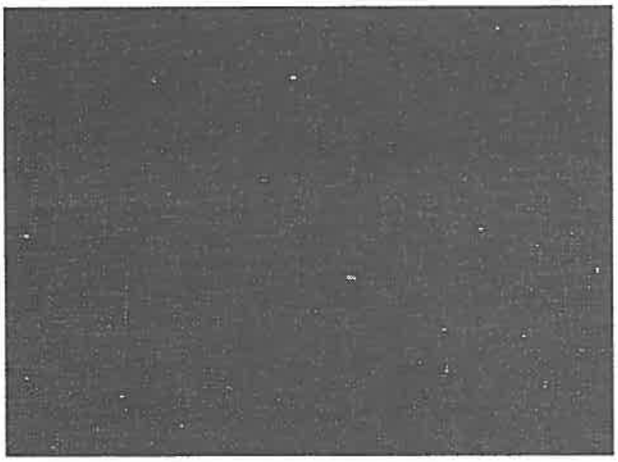


Figure 1: Dyed fabric with high level of white specks[16]

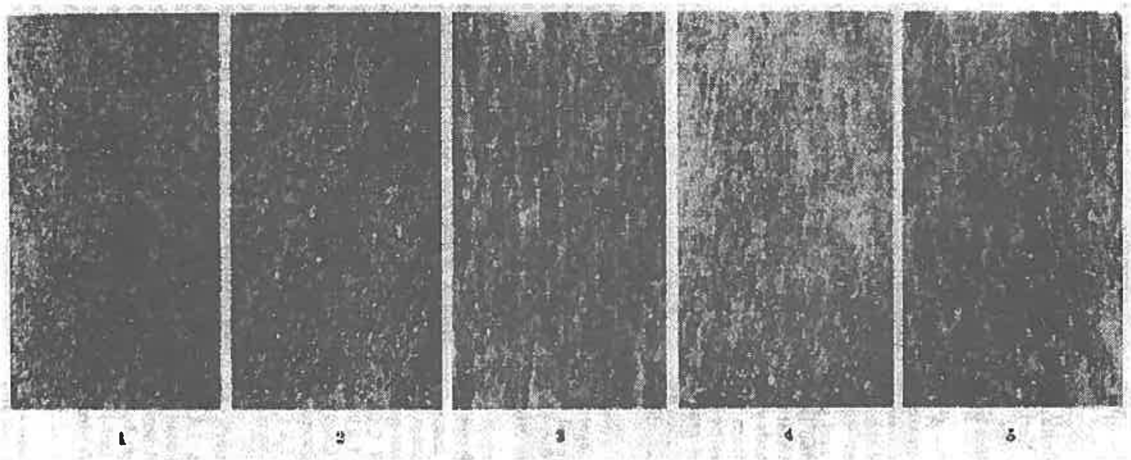


Figure 2: Grading webs for neps.[5]

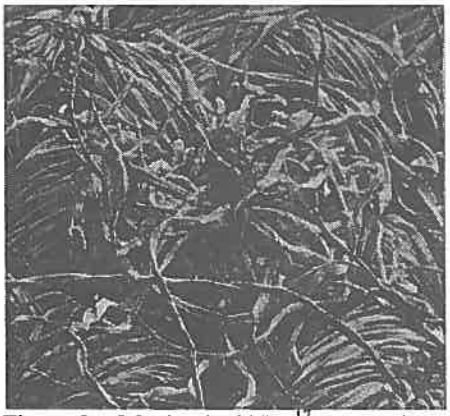
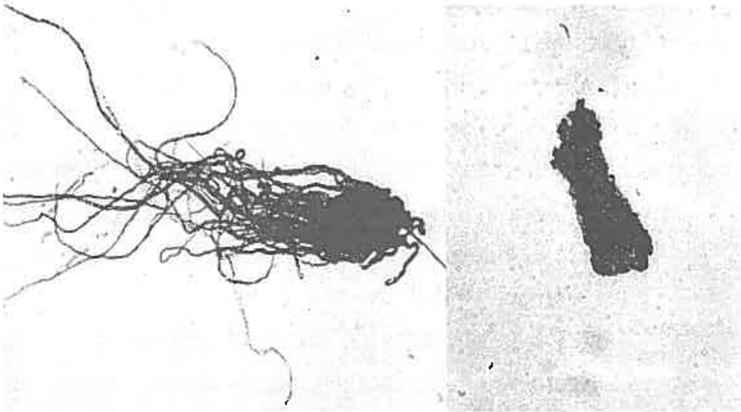
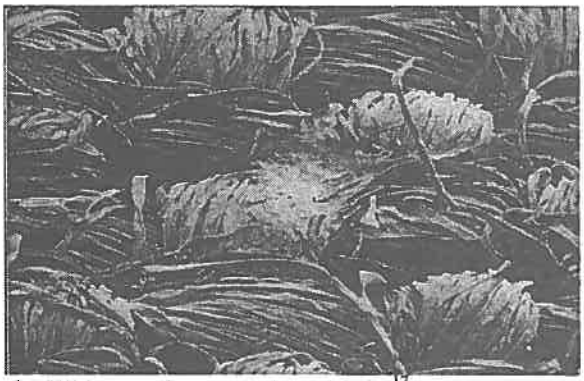


Figure 3: Mechanical Nep[17]



Figures 4 &5: Seedcoat fragment (Biological neps) & leaf Figure[18]



6a: White speck nep on dyed fabric [17].

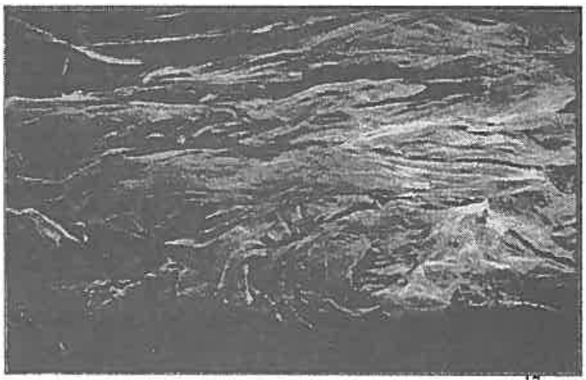


Figure 6b: High magnification of white speck nep[17]

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[16] Fabric Scanned by Terri Von Hoven, Agricultural Research Service, US Department of Agriculture, Southern Regional Research Center, Cotton Fiber Quality Research, New Orleans, LA, USA

[17] Figures 3, 6a and 6b photomicrographs by Bruce Ingber, Agricultural Research Service, US Department of Agriculture, Southern Regional Research Center, Cotton Fiber Quality Research, New Orleans, LA, USA

[18] Figures 4 & 5 by Jacques Hebert, Agricultural Research Service, US Department of Agriculture, Southern Regional Research Center, Cotton Fiber Quality Research, New Orleans, LA, USA