COTTON FIBRE QUALITY: HOW MUCH COMES FROM THE FIELD?

C. A. Rosolem
Department of Crop Science, College of Agricultural Sciences, São Paulo State University, Botucatu, São Paulo, Brazil. E-mail:rosolem@fca.unesp.br

ABSTRACT

Cotton quality has different meanings for farmers and industry. For farmers high cotton quality means more income and for the industry it means fewer losses. So it is important for farmers to manage cotton fields for the best possible attainable quality, but it is important for the industry to acknowledge that there are many uncontrollable factors affecting fibre quality. Fibre quality varies among cotton fields, plants and bolls. Even in one seed different fibre quality may be found. Fibre quality is under genetic control, and cotton fields can be managed for best quality. However, the weather has an important unpredictable effect on quality.

INTRODUCTION

Ideal cotton (*Gossypium hirsutum* L.) fibres should be “as white as snow, as strong as steel, as fine as silk and as long as wool”. Even if all the steps involved were perfectly known and controlled this would not be easy. Each cotton fibre is a single elongated epidermal cell developed off the outer integument layer of the cotton seed coat, composed of almost sheer cellulose. It develops in two overlapping phases: fibre elongation with primary wall synthesis, and fibre thickening, or maturation, when the secondary wall is synthesized and deposited in the fibre inner space called lumen (Ryser, 1985). Fibre elongation begins shortly after anthesis and continues for three or four weeks, growing mainly in length at this stage. Two weeks after anthesis cellulose fibrils begin to be deposited with different orientations in secondary fibre walls, so that the empty inner space (lumen) almost disappear. Thus, the degree of microfibril deposition determines the maturity of the fibre, its resistance and micronaire. As the quality of the fibre produced depends on the transport of sucrose for the fruit to be transformed in cellulose, anything that affects photosynthesis during fibre development will impair both cotton yield and fibre quality. Hence, environmental variations within the plant canopy, among the individual plants, and within and among fields ensure that the fibre population in each boll, indeed on each seed, encompasses a broad range of fibre properties and that every bale of cotton contains a highly variable population of fibres (Bradow and Davidonis, 2000).

GENETICS X ENVIRONMENT

Cotton quality, mainly fibre length and diameter, is largely dependent on genetics. Fibre maturity properties are also under genetic control, but as they depend on photosynthate deposition in the cell wall they are more sensitive to environmental stress. Most fibre properties have reasonable heritability, but each one is under additive genetic control, with many genes for each treat, and hence quantitatively inherited. For instance length, strength and fineness each are influenced by 12 to 21 Quantitative Trait Loci (Park et al. 2005). Although a good genetic variation in cotton fiber properties is available for plant breeders to explore, there are negative associations between cotton agronomic characteristics and fiber quality traits, and the breeder's challenge is to overcome these negative associations. Given that each fiber trait is multigenic and each parent of a population can carry different genes, it should not be surprising that the association between yield and fibre quality will vary (Constable and Bange, 2007).

In spite of these negative correlations, progress has been made combining high yields and fibre quality. Bolls developing on healthy plants produce longer, stronger and more mature fibre. Fortunately for the entire cotton industry, when producers strive for maximum yield, they are also striving for maximum quality. Invariably, the top producing areas of the U.S. also produce the highest quality fibre (Hake and Jordan, 1992).

WEATHER AND QUALITY

Since the fibre is primarily cellulose, fluctuations in plant photosynthesis and carbohydrate production will affect fibre growth and development. Therefore, fibre quality is affected by most factors which influence plant growth. It has been reported that temperature and plant water status affect fibre growth and eventually length (Hesketh and Low, 1968, Ramey, 1986). Fibre thickening is affected mainly by temperature and radiation (Hesketh and Low, 1968, Pettigrew, 1995), and micronaire correlates directly with the amount of photosynthesis observed 15-45 days after anthesis.

Cotton net photosynthesis is responsive to temperature, with a maximum occurring below the average of 30 ^{o}C (Perry et al., 1983). However, as to fibre quality, night-time temperatures are also very important (Gipson and Ray, 1970), because low temperatures overnight alter the pattern of concentric deposition of cellulose, resulting in immature and less resistant fibres (Haigler et al. 1991). Thus, it is possible the occurrence of fibre quality problems due to the occurrence of low night temperatures even though the average temperatures are close to otptimum. Night-time temperatures below 17.5 ° C result in fibres with very low micronaire (Gipson and Ray, 1970).

The response of cotton fibre length, strength and micronaire are to the average or minimum temperature ranges from linear to parabolic. The environmental conditions occurring from 3 to 25 days after anthesis impact length (Stewart, 1986), while cellulose deposition on the secondary wall is affected 15 to 45 days after anthesis (Bauer et al., 2000). Not only fibre elongation rate decreases with night temperature, but also the final length. Depending on the availability of other factors, low temperatures will only delay the time of fibre growth, without much effect on the final length. Therefore, as there are always many fruits developing at the same time, the main effect of low temperatures on fibre length will be on uniformity and/or percentage of short fibres, and hardly on the average length. The strength and micronaire are defined from the end of the elongation phase to the phase of secondary wall deposition, with most of the increase in fibre weight occurring between 25 and 75 % of the growth period of the bolls. Due to the extended flowering period of cotton plants, exposing the fruits to variable environment stress, quality is not uniform throughout the plant. What sets the average quality of the harvested cotton is therefore a weighted average of what has happened during the development of each fruit.

The formation of cotton fibre is primarily a process of cellulose synthesis and the primary source of carbon sucrose. Sucrose is degraded by sucrose synthase, thus providing glucose, the skeleton unity for cellulose synthesis. Night-time temperatures below 22.0 ^{o}C inhibit significantly the rate of cellulose synthesis and deposition in cotton fibre walls, which ultimately adversely affect productivity and fibre quality. Hence, the occurrence of low temperatures during fibre maturation can result in sucrose accumulation and eventually in appearance of "sticky cotton", a serious problem which decreases cotton quality and value.

Shading of the crop during flowering and boll loading for some time can affect fibre quality. Shading decreases photosynthesis, and less carbohydrate increases shedding of reproductive structures, shifting the plant boll load towards the apices. Thus, in addition to a possible decrease in yields, the increased proportion of fruits developing late in the season, under lower temperatures and less water available will result in more immature fibres, and a decrease in resistance and micronaire (Zhao and Oosterhuis, 2000).

Considering the needs of the fibres during their growth and maturation, it is expected that both water excess and lack may result in lower quality. With little rain the lack of water may impair photosynthesis and therefore cellulose accumulation. On the other hand, excess rain with cloudy weather decreases photosynthesis due to shading, thus decreasing fibre quality.

CROP MANAGEMENT AND QUALITY

Fibre properties as length, maturity, micronaire are yield components. Hence most of management factors which optimize yields will also result in better fibre quality. Planting cotton before or after the best recommended time will result in most of fibre development under marginal temperatures, light incidence and/or water availability, and lower quality. Nutrient deficiencies can reduce fibre length and maturity, but this has not been a widespread problem for fibre quality. However, it doesn’t mean that nitrogen or potassium fertilizer treatments will necessarily improve fibre length (Constable and Bange, 2007). Nitrogen excess can result in lower fibre quality and “sticky cotton” by delaying plant maturity (Girma et al. 2007).

Crop defoliation must be done timely to preserve fibre quality. If it is delayed fibre will deteriorate from climate exposure, and if it is done to early micronaire will be affected due to cessation in carbohydrate transport (Siebert et al., 2006).

High density and narrow row cotton production systems have variable effects on fibre quality, depending on the region and on time of planting. Any management which delays crop maturity can lead to reduced fibre weight, maturity and micronaire due to exposure of a greater proportion of the crop to unfavourable weather.

CONCLUSION

Cotton fibre is largely under genetic control, and breeding programs strive to raise cotton yields and keep up with the industry demands for quality. Fortunately this has been achieved. However, fibre quality also depends on the environment and on crop management. Crop management for high yields is fully compatible with high fibre quality, but the environment is not always predictable or manageable. Hence there will always be some fibre quality variability coming from the field, which must be understood, evaluated and valued by the cotton market.

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