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Need for a change in cotton R&D policies

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The views expressed in this column are his own and not that of Cotton Association of India)

Is Indian cotton R&D heading in the right direction? Have we succeeded in developing varieties and production systems that can give us high yields and better quality cotton? Can we ever dream to become global leaders in cotton with the current R&D policies? The answer is 'NO'.

All is not well: Despite having the best of all global technologies, Indian cotton yield ranks 33rd in the 80 cotton growing countries http://www.indexmundi.com/agriculture/?commodity=cotton&graph=yield Indian cotton R&D walks through a strange predicament of 'claims of successes in a maze of failures'. Though claims are made that our yields doubled after Bt cotton hybrids were introduced in 2002, the fact remains that our yields are still low compared to rest of the world. We ranked 50th prior to 2002, but ranked 33rd now with the best of technologies including Bt cotton hybrids. It is interesting that the quality of Indian cotton may only be better than Pakistan and few other countries. Nobody seems to have a clue now, as to how we can increase our yields after a stagnation of 8-9 years. The big question is -what ails us? It is probably 'the frog in the well' syndrome that keeps us in the comfort zone of thinking and believing that 'all is well' even when the country is stagnant at low yields and stuck with poor quality fibre.

EXPERT's Column

Dr K.R. Kranthi

Low Yield and Lame Excuses: With the best of technologies India attained 'record' yields of 500-540 kg lint per hectare. The pooled average of rest of the world (79 countries excluding India) is 940 kg lint per hectare. The Indian cotton yield is less than one-fourth of Australia's national average of 2361 kg/ha and one third of the average of about 1500 kg/ha harvested by Brazil, Mexico, China and Turkey. The yield in Maharashtra is 330 kg/ha in 40 lakh hectares and ranks 50th in 80 countries, but behind several poor rain-fed African countries such as Mali, Ghana, Benin, Burkina Faso, Cameroon, Senegal and Sudan. Even Pakistan and Bangladesh have better yields than India. The low yields in India are blamed on poor management practices, poor extension, poor weather, rain-fed farming etc. These, at best can be classified as 'lame excuses'. The fact could be that, Indian cotton yields are low because we pursued wrong R&D policies.

Poor quality cotton: Hybrid cotton currently occupies more than 95% of India's total cotton area. Prior to 2002, before Bt cotton was introduced, when only 40% of the area was under hybrid cotton, long staple cotton constituted 38% of the total production. By 2012, long staple cotton was more than 90% of the total cotton produced, mainly because of the 93% area occupied by Bt cotton hybrids, most of which produce long staple fibre. The Confederation of Indian Textile Industries (CITI) estimate that in the 25.8 m bales utilisation capacity, the current requirement of the Indian textile Industry is 37% long and extra-long staple cotton, 53% medium staple and 10% short staple. The textile industry has specific requirements of raw cotton quality for spinning and weaving. It is estimated that the textile industry in India needs about 136 lakh bales of medium staple cotton with 26-28 mm of 24 g/tex (ICC mode) and micronaire of 4.0. But the market is flooded with 80-90% long staple cotton with low strength, poor micronaire, immature fibre, sometimes with neps and motes. Majority of the current Indian cotton hybrids produce 30-31mm fibre which have lesser strength of 19-22 g/tex and declining micronaire values of 3.3 to 3.6 especially in the later pickings. This problem is characteristic of Indian hybrid cotton, because boll production extends 100 to 120 days of the crop growth. This leaves a wider window with variable soil moisture and nutrient availability, thus leading to differential fire quality in bolls produced by the same plant at various times in a staggered manner. It is not uncommon to find farms cultivating F-2 seeds either purchased from the market as 'spurious' brands or using their own seeds. Such cotton fields invariably produce bolls with varying fibre traits. Interestingly, all the major cotton producing countries, such as USA, Australia, Brazil and China have developed good varieties with fibre traits ideally catering to the demands of the textile industry. Raw cotton also caters to the requirements of the 'non-woven' segment of the industry, mainly technical textiles, absorbent cotton, surgical cotton etc. Over the past century, there have been tremendous advances in plant breeding to cater to the needs of the textile sector. However, the expectations of the textile industry appear to remain unfulfilled. Strangely, though the requirement of non-woven sector has a demand of about 20 lakh bales in India alone, there seems to be no effort to even to understand their requirements.

The wrong myths: Listed below are several myths that have propelled wrong policies in India:

Myth 1-Hybrids are for high yields: Even with 95% of the area under hybrid cotton in India has not resulted in high yields. Hybrids are cultivated only in India. All other cotton growing countries cultivate only varieties and at least 32 countries produce significantly more than India. Australia harvested national average is more than 6000 kg seed-cotton per hectare using 'varieties' (not hybrids) as compared to 1500 kg seed cotton produced with hybrids in India. China, Brazil, Mexico and Turkey having harvested 4500 kg seed cotton per hectare only with varieties. Brazil has varieties with more than 75% area under non-Bt cotton. Hybrids are developed for more number of bolls per plant. India harvests low yields because it is difficult to get more bolls per plant without extra care and additional inputs. About 30 bolls per plant at a national average of 12,500 hybrid cotton plants per hectare results in a yield of 1500 kg seed cotton (about 500 kg lint) per hectare. To double the yield 60 bolls per plant are required, which is not conceivable at the national scale, especially in rain-fed regions, with any of the current practices. Unfortunately, most of the hybrids show hybrid vigour in production of excessive foliage that consumes more water and nutrients and result in plant stress at boll formation stage. The excessive foliage results in more humidity, diseases and insect pests. There is not even a single district in India that has an average of more than 3000 kg seed cotton per hectare with hybrids. Thus, there is no reason to believe that India can improvise the yields any further over and above the 1500 to 1600 kg per hectare if we continue with hybrid cotton.

Myth 2 -High yields in irrigated cotton: Cotton needs less water and is drought tolerant. While irrigation at early crop stage can be harmful, late irrigation only extends the crop growth phase and relatively higher yields can be expected with the extended cotton with additional inputs. High yields of more than 4500 kg seed-cotton can be obtained in rain-fed farming as is the case with many parts of the world including USA, Mexico, China and Brazil.

Myth 3 -Low yields due to rain-fed farming: High yields of more than 5000 kg seed cotton are obtained in many countries under rain-fed conditions with varieties. The general belief is that the yields are low because India has 60% area under rain-fed cotton. Interestingly, USA also has 60% area under rain-fed cotton, but harvests double the yield per hectare compared to India. Brazil has 98% area under rain-fed farming, but harvests three times the yield compared to India. Some say that the yields in Brazil are high because of the high rainfall at more than 1600 mm. But, cotton in Brazil is planted during mid-monsoon to utilise only 700-800 mm rain water. The paradox is that cotton is a drought tolerant crop with a need for only 250 mm water. However, adequate amount of soil moisture or supplemental irrigation of 6 mm per day at peak boll formation phase generally results in higher production. It is important to note that excess water is bad for cotton. The low yields in India are not because of rain-fed farming. It is the unsuitability of majority of the hybrids under marginal soils in rain-fed conditions, especially in AP, Karnataka, Maharashtra and Madhya Pradesh that result in low yields. It is the unsuitability of hybrid cotton in 100% irrigated North India that results in low yields.

If India has to increase the yields by three times from 1500 kg to 4500 Kg seed-cotton per hectare, some significant changes must be made in its R/D policies as suggested below:

1. **Back to varieties, but at high density:** It is important to work towards reorienting plant breeding strategies to develop early maturing compact varieties suitable for high density planting of 250,000 plants per hectare in marginal soils in rain-fed farms at a spacing of 40x10 cm. It is possible to obtain high yields of 5000 kg per hectare with just five bolls (4.0 g boll) per plant at 250,000 plants per hectare. Globally the average density is 110,000 plants per hectare with plant to plant spacing is 8 or 10 cm, whereas the average

density in India is is 12,500 plants per hectare at a spacing of 30 to 90 cm between plants.

2. **Breeding for few bolls with quality fiber and resistance to pests and diseases:** It is relatively much easier to breed for high quality fiber of 30 mm with 25 g/tex and 4.0 micronaire, uniform and synchronous maturity and resistance to insect pests and diseases, if the expectation from each plant is only 8-10 bolls. Plant protection will be easier if the varieties can be converted to Bt. Thus plant breeders should focus on developing short duration (130-140 days) compact varieties with 8-10 bolls of superior fibre quality, resistant to sucking pests and diseases that will give high yields with high density planting. Thus far, plant breeders in India have been struggling unsuccessfully to develop varieties/hybrids with 100-150 bolls or more per plant with superior fibre traits, synchronous maturity combined with resistance to diseases and pests.
3. **Location specific breeding:** Many private sector Bt hybrids grown in Maharashtra are actually developed for irrigated deep soils and fertile regions of Gujarat and Andhra Pradesh. The hybrids developed for irrigated high input conditions are not suited for rain-fed regions, but are sold in Maharashtra. More than 95% cotton in Maharashtra is rain-fed. Thus there is a mismatch between the hybrids developed for irrigated regions being unsuitable for rain-fed areas of Maharashtra. Some on-farm demonstrations are also shown to farmers by private companies and Government agencies using hybrids cultivated with pre-monsoon sowing on ridges, under drip irrigation, fertigation, plastic mulching and high input use of fertilisers, manures, micronutrients, pesticides and irrigation during boll formation stage to get 3000 to 4000 kg seed cotton per hectare. Such demonstrations mislead farmers, since the conditions of deep soils, drip, etc., are not at all possible to be replicated in more than, may be 10% of Maharashtra or many other rain-fed farms. It is important to place emphasis on breeding varieties suited for specific locations such as rain-fed or irrigated farms and also for soil types and ecological conditions.
4. **Hybrids only for high input farming:** Hybrids respond well to fertilisers and water. The hybrid vigour in foliage results in the need for pesticides to control insect pests and diseases. The generally longer duration with irrigation can result in higher yields. Thus hybrids may be cultivated by farmers who can afford high level of inputs under irrigated conditions for longer durations of 180-200 days crop.
5. **Only short duration varieties/hybrids in rain-fed farms:** Ideally, the best results in rain-fed farms can be obtained through early dry-sowing of short duration (130-140 days) compact varieties that are resistant to sucking pests and diseases. Sowing can be done on ridges at 45x10 cm or 60x10 cm to circumvent drought or excess rains. Dry sowing or early sowing of the short duration non-Bt varieties helps to escape bollworm attack and also to avoid moisture stress during boll formation stage. Early maturing Bt hybrids may also be cultivated in rain-fed regions under high density, if the seed cost is affordable.
6. **Cotton hybrids unsuitable in North India:** Hybrids were not popular in North India prior to the Bt-era mainly due to the fact that hybrids were unsuitable for double cropping systems. The yields in North India are significantly 25-30% less than the yields in Pakistan, primarily because Pakistan has been cultivating varieties and not hybrids. Pakistan is also able to take up wheat cultivation after early harvest of the Bt cotton varieties. The area of wheat in North India is declining because of the extended duration of Bt cotton hybrids, which do not easily facilitate sowing of wheat by mid-November. High density planting of varieties in North India has been giving excellent results and should be explored further with compact varieties that are resistant to the leaf curl virus diseases (CLCuD). The disease resurfaced because of the hasty approval of several untested Bt cotton hybrids for cultivation in North India.
7. **High yields with desi cotton at low production costs:** In view of the high demand for non-woven cotton, the short staple desi varieties can be promoted to obtain high yields through low production costs. The desi species are highly tolerant to drought, water logging, insect pests and diseases and thus need least inputs. Under high density planting, many desi varieties can yield up to 4000 kg seed-cotton per hectare with least expenditure and efforts.
8. **GEAC should approve only genes/events not varieties or hybrids:** It is strange that for more than 10 years the Genetic Engineering Appraisal Committee (GEAC) under the Ministry of Environment and Forests is approving hybrids for commercial cultivation in various parts of the country. The GEAC has thus far approved 1128 Bt cotton hybrids, many of which are susceptible to several insect pests and diseases, thus creating problems for farmers across the country. It is widely believed that the resurgence of the dreaded CLCuD (Cotton Leaf Curl Virus) in North India after 2007 is a result of such indiscriminate release of hybrids without stringent evaluation for susceptibility, as per the prevalent norms under the coordinated trials of the ICAR. It is extremely important to ensure that the approval of any variety or hybrid must be done only after proper multi-location testing for 2-3 years and endorsement by agricultural scientists of the all India coordinated cotton improvement project under the ICAR.

Breeding for Improved Yarn Quality: Importance of Non-HVI Fiber Properties

Upland cotton, Gossypium hirsutum L., ranks fourth in planted area in the United States, behind corn, wheat, and soybeans. The cotton industry in the United States, from field to fabric, has direct business revenue that exceeds $27.6 Billion and has an estimated total economic impact in excess of$120 Billion. The United States is the world's largest exporter of raw cotton fiber, followed by Australia, Brazil, India, Uzbekistan, and African Franc Zone. Almost all world trade of cotton is for spinning yarns used in making woven and knitted fabrics. In response to the demand for cottonfabric, worldwide consumption of cotton fiber has more thandoubled from 1960 to 2011. Though cotton fiber consumption has increased, cotton has lost half its market shares to competition from synthetic fibers. It should be noted that the cotton's share of U.S. apparel imports is currently about 55%. While consumers desire the comfort of cotton fabrics, spinning mills enjoy the predictability of manufacturing yarns from synthetic fibers. In order to remain competitive with man-made fibers, cotton fiber must exhibit reduced variability so that it may perform predictably at the mill. This can be achieved by breeding for an improved distribution in fiber quality using non-HVI fiber qualities.

While consumers demand cotton yarns, variability in cotton fiber quality makes it a challenging natural raw material to transform into a consistent industrial product. Natural variability in cotton fiber quality can translate into imperfections in spun yarns. Imperfections in the yarns, in turn, result in imperfection in the finished textiles. Textiles that exhibit imperfections are less desirable and must be discounted if they are to be sold. Discounts from imperfections in cotton yarns result in lost profits for the spinning industry. In addition to impacting the value of finished yarns and textiles, variability in cotton fiber impacts processing. Yarn imperfections translate into weak points which increase yarn breakages and lower productivity at the mill. In order to mitigate the risk to profits from a naturally variable fiber, spinning mills try to purchase cotton bales that exhibit a fiber quality profile sufficient for their needs. In turn, growers depend on breeders to provide varieties that produce cotton fiber that meets the quality profiles needed in the markets they serve.

Breeding for improved spinning performance and yarn quality poses a formidable challenge. Spinning trials demand a great deal of time and money, making them impractical in a sizeable breeding program. Therefore, breeding lines are not screened based on their spinning performance. Instead, breeders interested in selecting cotton varieties with improved spinning performance make their selections indirectly, based on fiber quality parameters. The most common source of fiber quality parameters is the High Volume Instrument (HVI). HVI is a classification tool originally developed to replace hand classers in cotton marketing. Despite their origins in cotton marketing, HVI fiber quality parameters are used as an evaluation tool in most breeding programs worldwide. HVI results are popular because the test is relatively fast and inexpensive. However, selections based on fiber quality parameters should be done with the aim of improving yarn quality. It is important to ask if fiber quality parameters provided by HVI testing, a tool designed primarily for marketing cotton, are adequate for selecting elite cotton lines for improved spinning performance.

The speed of HVI classification depends on following the tradition of hand classing. HVI fiber quality testing methods are designed to mimic the bundle testing used by hand classers. Much like a hand classer holding a bundle of fibers between his fingers, upper half mean length and length uniformity are both measured from a beard of cotton fibers held in the HVI comb. After being evaluated for length, the beard is clamped and broken to evaluate the strength and elongation of the fiber bundle. HVI is only able to measure the length and strength of fiber extending from the comb and does not characterize the complete distribution of fibers within the sample. In addition, HVI testing is unable to separately evaluate maturity and fineness of the fiber within a sample, two of the most important cotton fiber properties for producing quality yarns. In order to expedite testing, a flow of air through a plug of fiber is used by HVI to obtain micronaire, a composite measure of maturity and fineness. While these measurements are fast, they cannot characterize the important within-sample variations in cotton fiber quality. Yet, capturing within-sample variability of a bale is critical for predicting spinning performance. In effect, high-speed HVI fiber quality assessment is achieved at the expense of a more complete characterization of withinsample variability of fiber quality.

Yarn Strength

The shortcomings of HVI bundle testing have been masked by some historical success in improving fiber bundle strength and upper half mean length. Weak yarns in the textile mills reduce profits by breaking and slowing production levels. Therefore, the primary emphasis of yarn quality improvement has traditionally been placed on improving yarn strength. Many bundle fiber quality parameters, including HVI tenacity, are useful for explaining variability in yarn strength. In turn, advancements in yarn strength have resulted from improved breeding efforts based on HVI length and strength. Therefore, the increasing averages since 1980 of HVI length and strength for the USDA cotton classing office in Lubbock, Texas are a real success story. Nevertheless, the inability of HVI to capture the within-sample variability in these fiber properties limits potential improvements. Fiber-tofiber variability within the cross section of the yarn can cause weak points in the yarn structure where breaks can occur, slowing production. However, bundle strength from HVI does not capture the strength distribution of individual fibers within the sample. Breeding based on within-sample variability in fiber strength can enable improvements beyond what is possible with HVI bundle strength.

Another important yarn tensile property is the total workto- break (i.e., the total force required to rupture the yarn). Work-to-Break is a function of both yarn strength and yarn elongation. Yarn elongation is highly correlated with fiber bundle elongation, yet this property has been neglected by the cotton breeding sector, and a mechanism for further improvements in spinning performance has been forfeited. This forfeiture is due, in large part, to the lack of a widely available elongation calibration standard for HVI systems.

Yarn Evennes

The market value of cotton yarns is impacted by more than just tensile properties. Variability in yarn evenness properties (i.e. coefficient of variation of the mass per unit length, numbers of thin places, thick places, neps, and hairiness) has a large impact on the value of the yarn. These imperfections degrade fabric appearance and/or feel, which limit the fabrics to lowervalue markets. Yarn imperfections such as these are largely caused by within-sample variability in fiber quality that is not revealed by HVI classification.

While most breeders depend on HVI fiber quality parameters exclusively, many spinning mills have long known of the need for distributional data to augment the HVI data. The Advanced Fiber Information System (AFIS) was originally developed to provide spinning mills with additional information about within-sample variability. The AFIS individualizes fibers and utilizes a sensor box, containing two electro-optical sensors, in order to evaluate length, maturity, and fineness of individual fibers within the sample. In addition, AFIS uses an airflow and electro-optical sensor to characterize trash particles and other contaminants within the sample that are aerodynamically dissimilar to the fibers. The within sample variability of each fiber property is summarized by AFIS in a set of fiber quality parameters and individual histograms. In this way, AFIS provides a much more complete characterization of fiber quality within the sample.

An Illustration Using Fiber Length

The difference between HVI and AFIS is stark when seen in graphic form. Figure 4 is a graphical representation of all length related parameters characterized by HVI classification while Figure 5 illustrates all of the fiber length attributes characterized by AFIS testing. HVI provides

Figure 4

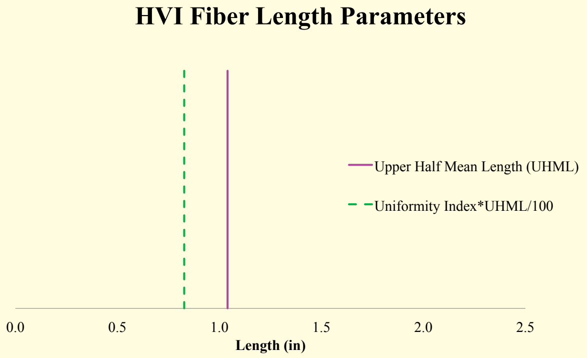
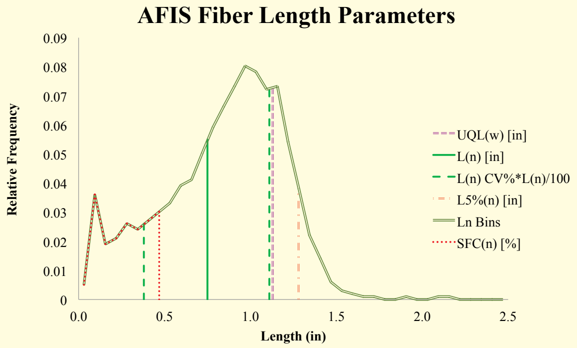

HVI Fiber Length Parameters

Figure 5


AFIS Fiber Length Parameters

two parameters that describe the longest fibers in the sample while AFIS provides 45 unique parameterizations of the complete distribution of fiber quality within a sample. These charts highlight the potential for significant differences in spinning performance from cotton varieties developed using only the HVI and those developed using both the HVI and the AFIS.

Implications for Cotton Breeding Programs

Cotton producers require varieties which have the potential to produce fiber of a quality that enables them to sell into the highest-valued markets possible. The basic objective of this paper is to present the limitations of bundle testing while highlighting the efficiency of alternative fiber quality evaluation systems in breeding programs. This will be done through three experiments designed to reveal the practical advantages and limitations of augmenting HVI data with additional fiber measurements. The first experiment will demonstrate the practical limitations of HVI classification. The second will present a statistical evaluation of the improvements provided by augmenting the HVI data. The third experiment will explore the feasibility of a cost-reducing protocol for obtaining AFIS data that serves the needs of cotton breeders.

Experiment I – Practical Limitations of Fiber Quality Evaluation Systems

In the first example, two sets of 4 bales (each set is made of 4 bales from the same field but separate modules) are used to demonstrate the practical limitations of screening breeding lines with HVI parameters. Both sets in this example were sampled and evaluated for both HVI and AFIS fiber quality parameters. Table I summarizes the HVI fiber qualityparameters for the bales used in this example.

Based on HVI classification, set A and set B appear to be very similar. Both sets exhibit a combination of good length and less than ideal micronaire. Based on these conventional HVI parameters, these two sets of cotton would be expected to produce similar quality yarns.

Table II contains a summary of the AFIS fiber quality parameters for the same two sets as Table I. While HVI length is based on the length of the longest fibers extending from the fiber clamp, AFIS mean length is derived from the complete distribution of fiber length in the sample and includes the short fibers. The AFIS fiber quality parameters reveal that the average fiber length in set B is slightly shorter than set A, and that set B has slightly higher percentage of short fibers. AFIS also provides additional measurements of contaminants, which reveal that set B has many more neps and more trash when compared to set A.

These apparently conflicting results lead to a natural question. Which of these fiber quality evaluation systems is capturing the true spinning potential of these bales? To evaluate spinning performance for carded yarns, fibers from each bale were used to produce ring-spun yarns from 12Ne through 30Ne, with a step-wise increase toward finer yarns of 2Ne. (Note: 4 bales per set = 4 replications for fiber testing and spinning). The results of the spinning trial are summarized in Figures 6-8.

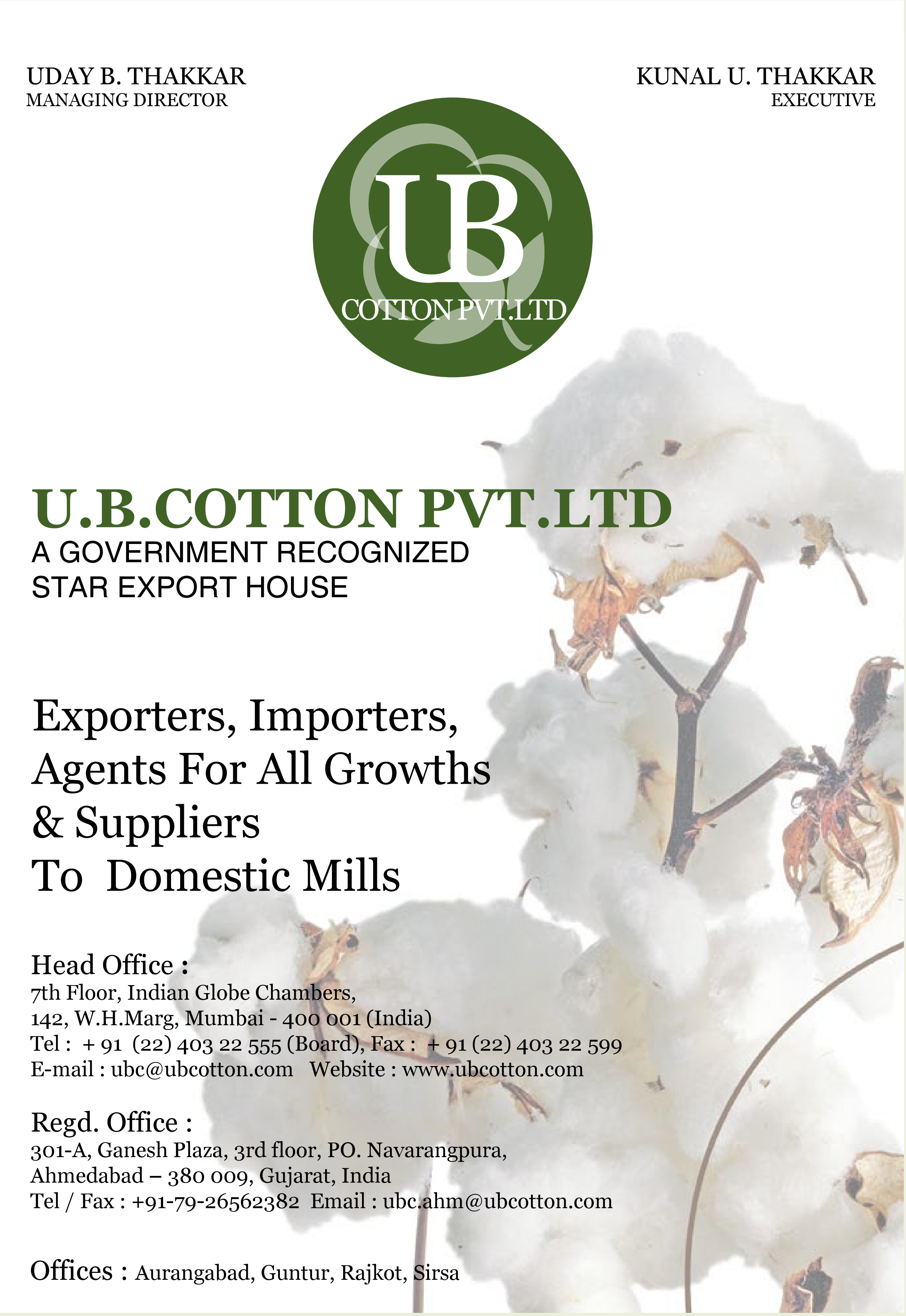
Table I. HVI data on the 2 sets of 4 bales selected for Example 1

Set	Micronaire	Length (inch)	Uniformity (%)	Strength (g/tex)	Elongation (%)	Rd (%)	+b
A	3.5	1.18	82.7	29.2	9.8	81.2	8.6
B	3.2	1.17	81.9	28.4	9.8	78.8	8.8

Table II. Main AFIS data on the 2 sets of 4 bales for Experiment 1

Code	Neps (Count/g)	L(n) (inch)	SFC(n) (%)	VFM (%)	H (mtex)	IFC (%)	MR
A	333	0.76	30.6	1.71	152	8.8	0.81
B	566	0.74	32	3.38	148	9.9	0.81

L(n) = Length-by-Number SFC(n) = Short Fiber Content-by-Number VFM = Visible Foreign Matter
H = Fineness IFC = Immature Fiber Content M R = Maturity Ratio



HVI fiber quality parameters should at least relate well to yarn tensile properties. The work-to-break of the yarns produced by each cotton bale at each count is summarized in Figure 6. These results show no substantial differences in yarn strength between Sets A and B for any count.

Now consider the results for yarn evenness and imperfections. While often overlooked in breeding, these fiber quality parameters significantly impact the value of spun yarns. Yarn evenness is commonly expressed as the coefficient of variation in the yarn mass, or CVm%, while the total imperfection index, IPI, provides a summary index of the aforementioned yarn imperfections.

Figure 6

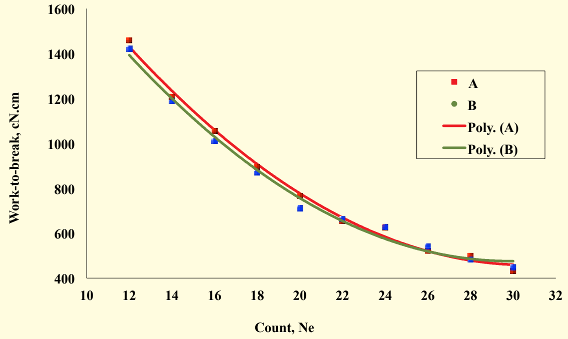


Figure 7

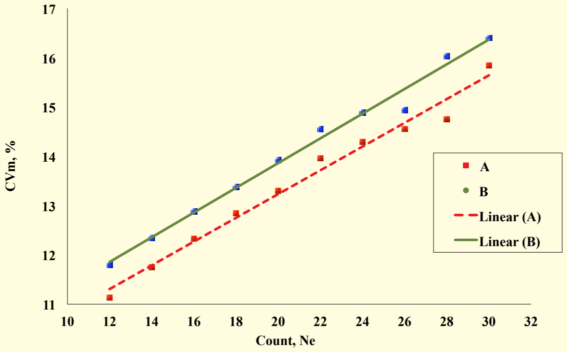


Figure 8

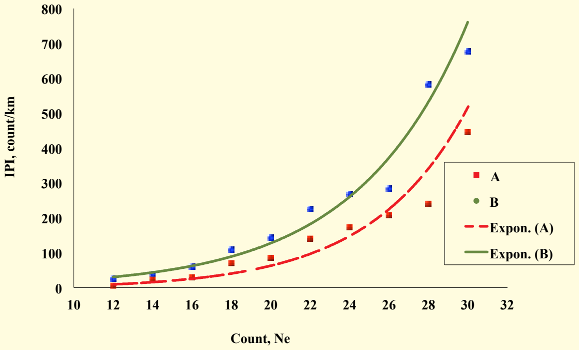


Figure 7 summarizes the CVm% of the yarns produced with these two sets of bales at each count. Despite the similarity in HVI characteristics, the yarns produced by the bales are not the same quality. In both cases there is a level shift, with the bales exhibiting superior AFIS fiber quality parameters having lower variations in yarn mass for every count.

Figure 8 summarizes the IPI results. The bales with superior AFIS characteristics had consistently fewer imperfections, with the differences increasing along with the yarn counts. The difference in IPI for the two sets increases with finer yarn counts.

These results indicate that exclusive use of HVI does not entail much risk when selecting bales to produce yarns with improved strength. However, for selecting bales that can be used to produce yarns with a low variation in mass, and with small numbers of imperfections, the AFIS can greatly reduce the risk of failure. The risk of relying exclusively on HVI for bale selection increases for finer yarn counts desirable in high value markets. This example indicates that breeding for spinning performance in high-value markets requires information about the within-sample distribution of fiber quality in addition to HVI classification.

Experiment II – The Efficacy of Fiber Quality Evaluation Systems For Improving Yarn Quality

In this second example, 110 cotton bales were selected to represent a wide range in variability of fiber quality within and between bales. The commercial bales represent several years and locations from across the United States cotton belt. Each commercial bale was tested on HVI to obtain the standard bundle properties. In addition to HVI testing, each bale was tested for within-sample variability in fiber quality on the AFIS. The tests confirmed that the bales covered a wide range of fiber properties. Each bale was spun into carded 30Ne ring spun yarns, which were tested for tensile properties on the Uster Tensorapid and for evenness and imperfections on the Uster Tester 3.

The relationship between the fiber quality profile for each bale and yarn quality produced was investigated with a partial least squares regression (PLSR). First, the fiber quality attributes were grouped into two subsets. The first subset, HVI, is composed of the most commonly used HVI fiber quality parameters. The second subset, HVI&AFIS, also includes the basic HVI parameters with the addition of AFIS fiber quality parameters. Each of the two fiber quality subsets were then used to separately characterize the fiber and yarn quality complex.

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Because HVI data are so widely available, both regression models of the fiber and yarn quality complex include HVI fiber quality parameters as predictor variables. In this way, any differences in the two models must be attributed to the addition of non-HVI fiber quality parameters in the second model.

The amount of variation in yarn tensile properties explained by both sets of fiber qualities is compared, where the improvements provided by the non-HVI fiber properties are apparent. There are clear differences in the performance of HVI and non-HVI fiber quality parameters when predicting yarn tensile properties. The model constructed with HVI bundle parameters characterizes anywhere from 61% of the variation in yarn elongation to 72% of the variation in yarn strength. However, augmenting the model with non-HVI fiber qualities provided by AFIS helps explain from 80% of variation in yarn elongation, up to 87% of variation in yarn strength. The augmented model explains 31% more variation in yarn elongation than the traditional HVI classification parameters. This translates into 76% of the variation explained in yarn work-to-break.

The differences are even larger when considering explained variation in yarn imperfections. The model constructed with HVI fiber quality parameters alone fails to explain even 50% of the total variation of two critical yarn imperfection parameters, thick places and neps. In contrast, the model augmented with non-HVI fiber quality attributes explains 82.8% of the variation in yarn CVm% and at least 78% of the remaining yarn imperfection parameters considered in this study. The model augmented with non-HVI fiber qualities explains 79% more of the variation in yarn neps over traditional HVI parameters.

Experiment III: AFIS As a Breeding Tool (1 vs. 3 reps)

The third experiment presented in this paper investigates a protocol for using AFIS testing as a tool for screening in a breeding program. It has been determined that accuracy and repeatability with AFIS measurements normally requires 3 replications of 3,000 fibers. Breeding lines are often screened by selecting the top lines based on their rank in the breeding population. The purpose of this section is to evaluate the feasibility of reducing the number of replications with the AFIS, while still achieving an adequate ranking of the breeding lines.

Under the standard AFIS 3-replication protocol, about 50 samples can be tested in a day after checks have been run. Therefore, AFIS typically runs at a rate of about 7.14 samples per hour. The rate of AFIS testing can potentially be tripled under a single replication protocol, to about 21 samples per hour. If this is feasible for purposes of rankings lines in breeding programs, the cost of AFIS testing could be significantly reduced.

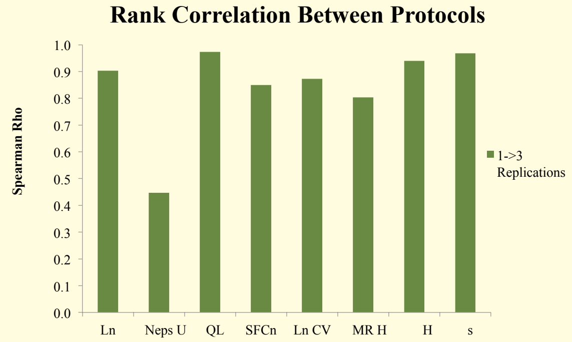
260 breeder samples were selected to represent the variability expected in the average breeding program. Each breeder sample was tested with the standard AFIS protocol of 3 replications of 3,000 fibers. The samples were then ranked based on the individual AFIS fiber quality attributes. After ranking, an alternative AFIS protocol was run with 1 replication of 3,000 fibers. The rank of the samples identified by the alternative protocols was then compared to the rank of the samples identified by standard AFIS protocol. The results are used to investigate the potential of single AFIS runs for ranking selections for screening in a breeding program.

Spearman's correlation coefficient can be used as a measure of how well rank is preserved from one measurement to the next. Under this interpretation, a high Spearman's correlation coefficient between the two protocols is desirable in a breeding program in order to provide sufficient selection pressure. Genetic gain in a breeding program depends on selection pressure. A higher rank correlation for particular AFIS parameters implies that little selection pressure is lost from implementing the alternative protocol for those parameters.

The rank correlations for several AFIS fiber quality reported in Figure 11. The length parameters measured under the two protocols, mean length by number and coefficient of variation in length, have a rank correlation of 0.87 and 0.9 respectively. This reveals that much of the rank is preserved among these two length parameters moving from a 3-replication protocol to a single replication. Measurements of short fiber content under the two protocols also exhibit a high rank correlation of 0.85. However, a rank correlation of 0.45 indicates that the measurement of neps requires more replications.

Of heightened interest is the loss in selection intensity incurred by implementing the single replication protocol. The selection intensity is demonstrated for the cotton used in this experiment

Figure 11



by identifying the top 10% of the breeder samples tested under the separate protocols. An example of selection intensity is shown for maturity ratio, length-by-number, and standard fineness in Figures 12 through 14 respectively. In each of the figures, the standard 3-replication protocol is considered the true rank order of the samples. The top 10% of the breeder samples under the 3- replication protocol are represented by hollow circles, while the 10% threshold measured by the single replication protocol is indicated by a solid line. If the two protocols provide the same selection pressure for the samples, the solid line will demarcate the hollow circles from the filled circles.

Figures 12 through 14 show the comparisons for maturity ratio, length-by-number, and standard fineness, as measured by both the 3 replication protocol and the single replication protocol. When measuring maturity ratio, the alternative protocol properly identified al+most 60% of the top 10% of the breeder samples identified by the standard protocol (Figure 12). For both mean length-by-number and standard fineness, the single replication protocol identified 81% of the top 10% of the breeder samples identified by the standard protocol (Figures 13&14). These results indicate that AFIS testing without replication may be able to provide suitable selection pressure while increasing fiber quality evaluation throughput.

Figure 12

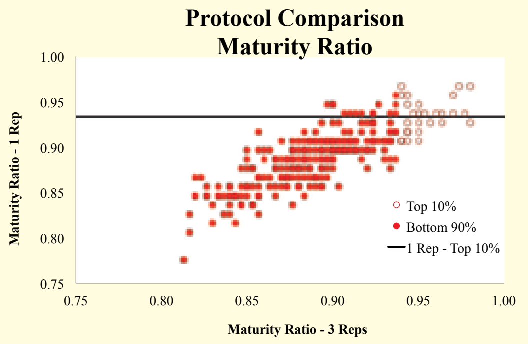


Figure 13

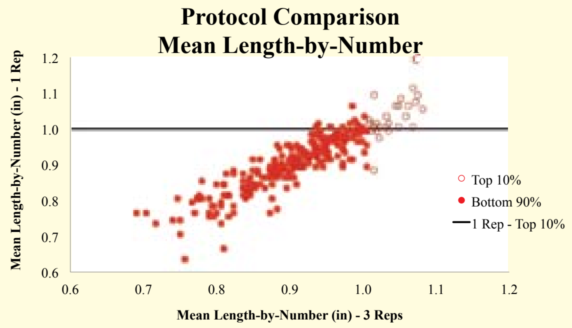
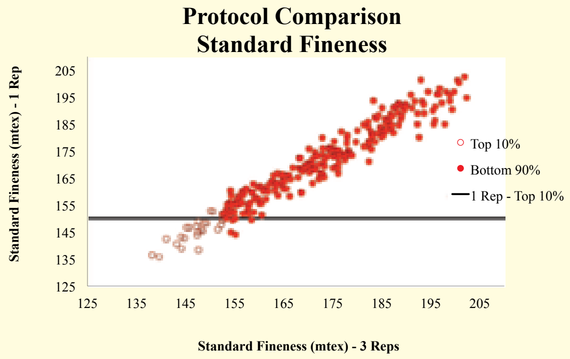


Figure 14



It is important to note that the gains in speed for this testing are at the expense of statistical power. While it may facilitate selection of lines with the potential for improved yarn quality in a breeding program, reducing replications of AFIS testing is unlikely to have the same usefulness in most scientific research.

Conclusion

This paper has shown the following:

- HVI classification may not be sufficient for detecting substantial differences in the spinning performance of cotton bales. HVI classification data should be augmented with non-HVI fiber qualities in order to select lines that perform well in high-value spinning markets.
- The lack of an elongation calibration standard severely limits the potential of HVI fiber qualities for improving yarn tensile properties.
- Including AFIS fiber quality parameters provides a substantial improvement over HVI classification alone for screening breeding lines. Even though AFIS does not provide a direct parameterization of fiber tensile properties, AFIS parameters are able to increase the amount of explained variation in yarn tensile properties. It is imperative to augment HVI fiber quality parameters with non-HVI fiber quality parameters when selecting lines with reduced imperfections.
- For purposes of ranking lines in cotton breeding programs, a 1-replication measurement protocol may be adequate, thereby reducing the time and expense associated with adding the AFIS data to the programs.

The experiments related here are part of a large and growing body of data showing that non-HVI fiber property measurements are needed to achieve future genetic breakthroughs in fiber quality. These breakthroughs will be necessary to strengthen cotton's competitiveness vis a vis the large and growing array of synthetic fibers vying to serve the global yarn spinning industry.

(Source: The ICAC Recorder)

UPCOUNTRY SPOT RATES

(Rs./Qtl)

Standard Descriptions with Basic Grade & Staple in Millimetres based on Upper Half Mean Length [By law 66 (A) (a) (4)]							Spot Rate (Upcountry) 2013-14 Crop DECEMBER 2013					
Sr. No.	Growth	Grade Standard	Grade	Staple	Micronaire	Strength /GPT	23rd	24th	25th	26th	27th	28th
1	P/H/R	ICS-101	Fine	Below 22mm	5.0 – 7.0	15	10826 (38500)	10826 (38500)		10826 (38500)	10939 (38900)	10939 (38900)
2	P/H/R	ICS-201	Fine	Below 22mm	5.0 – 7.0	15	11023 (39200)	11023 (39200)		11023 (39200)	11135 (39600)	11135 (39600)
3	GUJ	ICS-102	Fine	22mm	4.0 – 6.0	20	8014 (28500)	8043 (28600)		8323 (29600)	8464 (30100)	8689 (30900)
4	KAR	ICS-103	Fine	23mm	4.0 – 5.5	21	9364 (33300)	9505 (33800)		9645 (34300)	9701 (34500)	9786 (34800)
5	M/M	ICS-104	Fine	24mm	4.0 – 5.5	23	10123 (36000)	10208 (36300)	H	10348 (36800)	10348 (36800)	10461 (37200)
6	P/H/R	ICS-202	Fine	26mm	3.5 – 4.9	26	10770 (38300)	10826 (38500)		10995 (39100)	11079 (39400)	11304 (40200)
7	M/M/A	ICS-105	Fine	26mm	3.0 – 3.4	25	10236 (36400)	10264 (36500)	O	10376 (36900)	10432 (37100)	10573 (37600)
8	M/M/A	ICS-105	Fine	26mm	3.5 – 4.9	25	10404 (37000)	10432 (37100)		10545 (37500)	10601 (37700)	10742 (38200)
9	P/H/R	ICS-105	Fine	27mm	3.5 – 4.9	26	10939 (38900)	10995 (39100)	L	11164 (39700)	11248 (40000)	11529 (41000)
10	M/M/A	ICS-105	Fine	27mm	3.0 – 3.4	26	10376 (36900)	10404 (37000)		10517 (37400)	10573 (37600)	10770 (38300)
11	M/M/A	ICS-105	Fine	27mm	3.5 – 4.9	26	10573 (37600)	10601 (37700)	I	10714 (38100)	10770 (38300)	10911 (38800)
12	P/H/R	ICS-105	Fine	28mm	3.5 – 4.9	27	11135 (39600)	11192 (39800)		11360 (40400)	11445 (40700)	11726 (41700)
13	M/M/A	ICS-105	Fine	28mm	3.5 – 4.9	27	10714 (38100)	10742 (38200)	D	10854 (38600)	10911 (38800)	11051 (39300)
14	GUJ	ICS-105	Fine	28mm	3.5 – 4.9	27	10882 (38700)	10911 (38800)		11023 (39200)	11051 (39300)	11192 (39800)
15	M/M/A/K	ICS-105	Fine	29mm	3.5 – 4.9	28	10854 (38600)	10882 (38700)	A	10995 (39100)	11051 (39300)	11192 (39800)
16	GUJ	ICS-105	Fine	29mm	3.5 – 4.9	28	11023 (39200)	11051 (39300)		11164 (39700)	11192 (39800)	11332 (40300)
17	M/M/A/K	ICS-105	Fine	30mm	3.5 – 4.9	29	10939 (38900)	10967 (39000)	Y	11107 (39500)	11164 (39700)	11304 (40200)
18	M/M/A/K/T/O	ICS-105	Fine	31mm	3.5 – 4.9	30	11135 (39600)	11164 (39700)		11304 (40200)	11332 (40300)	11473 (40800)
19	K/A/ T/O	ICS-106	Fine	32mm	3.5 – 4.9	31	11698 (41600)	11698 (41600)		11810 (42000)	11838 (42100)	11979 (42600)
20	M(P)/K/T	ICS-107	Fine	34mm	3.0 – 3.8	33	18278 (65000)	18447 (65600)		18447 (65600)	18165 (64600)	18165 (64600)

(Note: Figures in bracket indicate prices in Rs./Candy)