PREDICTING YARN QUALITY:
AN INDISPENSABLE TOOL FOR COTTON BREEDERS

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Cotton breeders face the task of developing cultivars that will perform well in the field, at the gin, and in textile processing. Predicting the process ability of the raw material is probably the most challenging task. Indeed, producing yarn from each entry in a breeding program is not possible because of the limited quantity of lint available. Hence, how could we predict the industrial yarn quality of a breeding line without spinning the lint into yarn? To answer this question, two sets of commercial cotton bales were selected based on their distinct physical properties. The results obtained show that the combination of HVI and AFIS data allows us to predict quite accurately yarn quality (ring spun yarn) for commercial bales. Such models, if confirmed on an independent set of samples could be invaluable for the cotton breeding industry.

Cotton breeders face the task of developing cultivars that will perform well in the field, at the gin, and in textile processing. Predicting the process ability of the raw material is probably the most challenging task. Indeed, producing yarn from each entry in a breeding program is not possible because of the limited quantity of lint available. In addition, the cost would be prohibitive, hindering the cotton breeding efforts of both private and public sectors. Hence, how could we predict the industrial yarn quality of a breeding line without spinning the lint into yarn?

In order to make cultivar selections, breeders must first know which fiber quality attributes produce high quality yarns for their targeted market (May and Jividen, 1999, Meredith et al., 1991, Meredith, 2005). They must strive to deliver fibers that perform better in textile manufacturing. This is critical for effective competition with man-made fibers and with international growths of cotton. Knowing what fiber quality attributes have the greatest potential to produce high quality ring spun yarns is also critical for spinning mills.

Modern fiber quality evaluation instruments provide repeatable measurements of a full spectrum of fiber quality that can potentially be related to yarn quality. Spinning and weaving are performed at high speeds. This could result in excessive end downs for cottons with poor tensile properties. Because breakages may cause work stoppages and slowed production, there has been and emphasis on predicting ring-spun yarn tensile properties. It has been reported that fiber quality attributes measured by High Volume Instrument (HVI) have a strong relationship with ring spun yarn tensile strength. For example, El Mogahzy et al. (1990) showed that cottons with improved Upper Half Mean Length (UHML), tenacity, micronaire, and length uniformity can be used to produce yarns with a higher break skein factor. Using the

Advanced Fiber Information System (AFIS), Krifa et al. (2001) reported that yarn tenacity was affected by the amount of seed coat fragments in the raw material.

Predicting yarn tensile properties is important but offers an incomplete picture of how fiber quality impacts yarn quality. High quality yarns should also have a low number of imperfections such as thin places, thick places, and neps. The number of thin and thick places in the yarn has been shown to be related to HVI Micronaire and Uniformity. Relationships of these two yarn parameters with AFIS Fineness and Sutter-Web array Short Fiber Content (SFC) have also been documented (Thibodeaux et al., 2008). The literature shows that while HVI measurements are adequate for predicting yarn tensile properties, they are inadequate for yarn evenness related parameters.

Therefore, one of the basic objectives of our research is to study the spinability of cottons (carded and combed ring spun yarns), and to derive from this research recommendations as to which fiber parameters need to be improved through breeding, agronomic practices, and/or material handling (harvesting and ginning). The first step for this type of research is to evaluate the advantages and limitations of the two main cotton fiber testing equipments, i.e., High Volume Instrument (HVI) and Advanced Fiber Information System (AFIS) for predicting yarn quality. As mentioned earlier, producing yarn from each entry in a breeding program is not possible because of the limited quantity of lint available and the cost. To alleviate this technical difficulty, a solution could be to predict yarn quality from a selected number of fiber properties.

MATERIAL AND METHODS

To determine the relationships between fiber properties and yarn quality, two sets of commercial cotton bales were selected based on their distinct physical properties. A representative sample of approximately 50 kg was taken from each bale for processing. Raw cotton, chute, card sliver, DI sliver, and DII sliver lint samples were collected. The cotton samples were tested on High Volume Instruments (HVI 900A, Uster, Knoxville, TN), with 10 length and tenacity measurements and 4 micronaire measurements. They were also tested on the Advanced Fiber Information System (AFIS, Uster, Knoxville, TN), with 5 replications of 3,000 fibers. Tables I through III summarize maximum, minimum, and average values of the physical properties of these samples.

<u>First experiment:</u> A total of 8 bales were selected for this experiment. The results obtained on 4 of them will be presented in this paper. A complete HVI and AFIS fiber quality profile was done for each bale. Then, carded and combed ring spun yarns (Suessen Elite 1000) were produced: 12Ne through 30Ne with a step of 2Ne were produced for the carded yarns, and 18Ne through 36Ne with a step of 2 for the combed yarns with 3 combing noils levels (15, 20, and 25%).

Table I. HVI data on the 4 bales selected.

Code	Mic.	Length inch	Unif. %	Strength g/tex	Elon. %	Rd %	+b
09BP	3.5	1.18	82.7	29.2	9.8	81.2	8.6
09BS	3.2	1.17	81.9	28.4	9.8	78.8	8.8
11VCP	4.3	1.19	81.8	29.6	7.4	83.1	8.1
11VCS	4.2	1.17	80.6	29.8	7.3	81.5	8.8

Table II. Main AFIS data on the 4 bales selected

Code	Neps Count/g	L(n) inch	SFC(n) %	VFM %	Fine. mtex	IFC %	MR
09BP	333	0.76	30.6	1.71	152	8.8	0.81
09BS	566	0.74	32.0	3.38	148	9.9	0.81
11VCP	332	0.79	25.9	0.97	161	7.6	0.87
11VCS	432	0.79	25.9	0.94	157	8.4	0.87

Second experiment: Seventy four commercial cotton bales were selected. For each bale a complete fiber quality profile was done (HVI, AFIS). Then, carded and combed ring spun yarns (Suessen Elite 1000) were produced (30Ne, knitting twist). The summary statistics are presented Table III. All HVI fiber quality parameters represent a large range of fiber properties.

Table III. HVI and AFIS (5 reps) fiber properties obtained on samples from 74 commercial bales. The shaded region shows the opening and card waste as well as the noils percentages (constant settings of the comber).

	Average	Minimum	Maximum
Micronaire	3.61	2.61	4.50
UHML, inch	1.19	1.11	1.26
Uniformity, %	82.6	79.7	84.4
Strength, g/tex	30.0	24.5	34.8
Elongation, %	9.0	5.4	11.5
Reflectance, %	80.3	73.0	85.3
Yellowness	8.0	6.4	9.7
Neps, count per Gm	447	239	1013
Mean length by weight, inch	0.99	0.89	1.07
Length by weight CV, %	37.3	32.6	42.6
UQL by weight, inch	1.23	1.15	1.32
Short Fiber Content by weight, %	10.3	6.2	16.6
Mean length by number, inch	0.75	0.62	0.86
Length by number CV, %	56.4	48.5	65.7
Short Fiber Content by number, %	31.1	21.7	43.0
Visible Foreign Matter, %	2.24	0.73	4.88
Seed Coat Neps, count per gram	21	8	38
Fineness, mtex	150	131	172
Immature Fiber Content, %	9.2	6.3	12.6
Maturity Ratio	0.82	0.74	0.91
Standard Fineness, mtex	183	168	203
Opening waste, %	2.86	1.55	5.04
Card waste, %	3.91	2.51	5.77
Noils, %	18.0	12.6	26.8

RESULTS AND DISCUSSION

First experiment**:** The examination of Table I shows that the bales 09BP and 09BS are quite similar. Both have a low micronaire and a very good UHML. Based on HVI data only, the differences observed between these two bales should not translate into large differences in ring spun yarn quality. The AFIS data (Table II) show that bale 09BS has significantly more neps than 09BP, a shorter mean length by number, and a higher trash content. The bales 11VCP and 11VCS have a better micronaire than the two previous bales, and a very good UHML. Again, based on HVI only, the differences observed between these two bales should not translate into large differences in ring spun yarn quality. The AFIS data show that 11VCS has more neps than 11VCP. As discussed earlier, yarn tensile properties can be reasonably well predicted from HVI data. Figures 1 and 2 show that, as expected, the carded yarn work-to-break for the two sets of two bales are very similar across the full range of yarn counts produced. Similar results were obtained on combed yarns (data not shown).

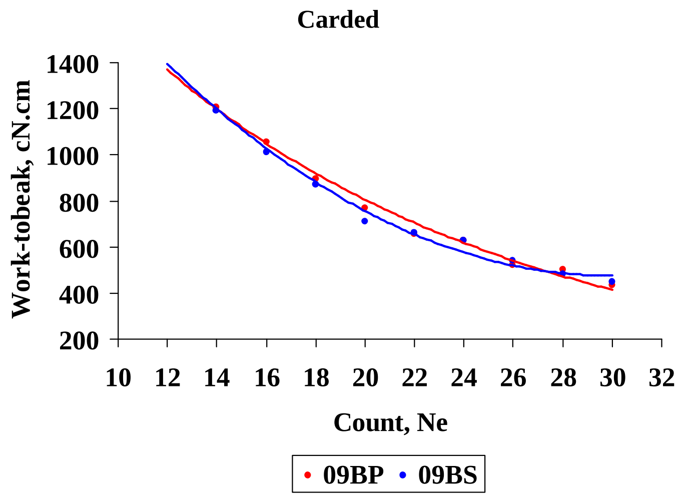

Figure 1. Work-to-break vs. Yarn count (carded ring spun yarn, knitting twist) for the bales 09BP and 09BS

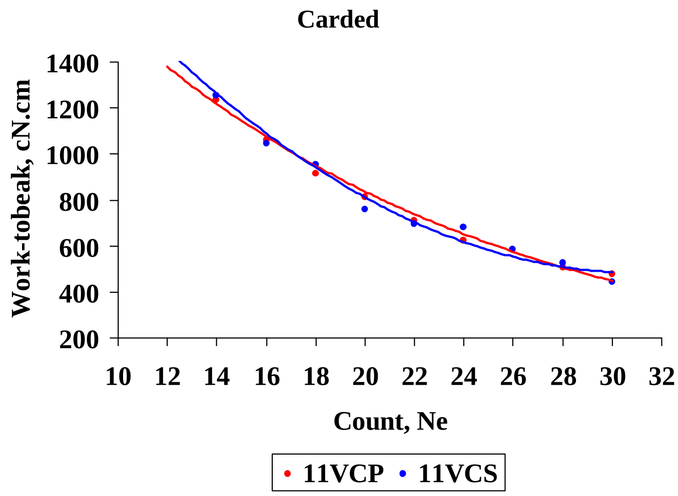

Figure 2. Work-to-break vs. Yarn count (carded ring spun yarn, knitting twist) for the bales 11VCP and 11VCS

The situation is quite different for yarn evenness related parameters as shown in Figures 3 through 6. For the two sets of two bales, there are clear differences between the bales for each couple in terms of both Uster CVm and Uster IPI (total number of imperfections). Figures 3 and 4 show parallel lines, the Uster CVm of 09BS is always higher than the one of 09BP. The difference between the two cottons is nearly constant. The same is true for the second set of bales and for the combed yarns (data not shown). For the total imperfections, the differences between the two bales within a set increase as the yarn count increases. Finer is the yarn larger is the difference. The same was observed on combed yarns (data not shown). This illustrates the limitations of HVI quite well. Indeed, yarn evenness is not predictable based on HVI data alone.

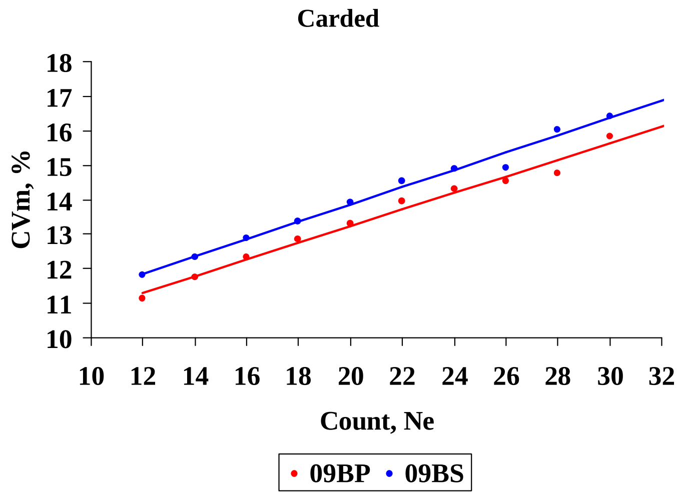

Figure 3. Uster CVm vs. Yarn count (carded ring spun yarn, knitting twist) for the bales 09BP and 09BS

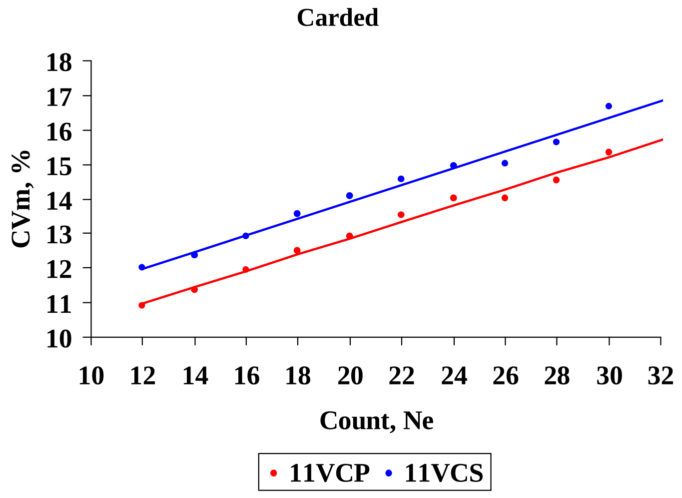

Figure 4. Uster CVm vs. Yarn count (carded ring spun yarn, knitting twist) for the bales 11VCP and 11VCS

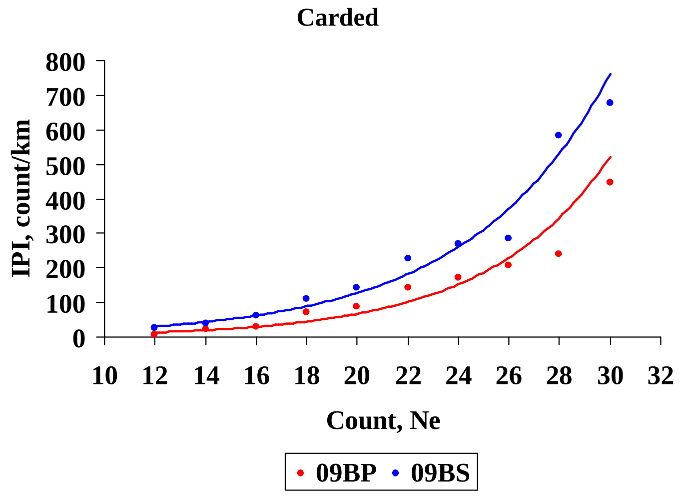

Figure 5. Uster IPI (total imperfections) vs. Yarn count (carded ring spun yarn, knitting twist) for the bales 09BP and 09BS

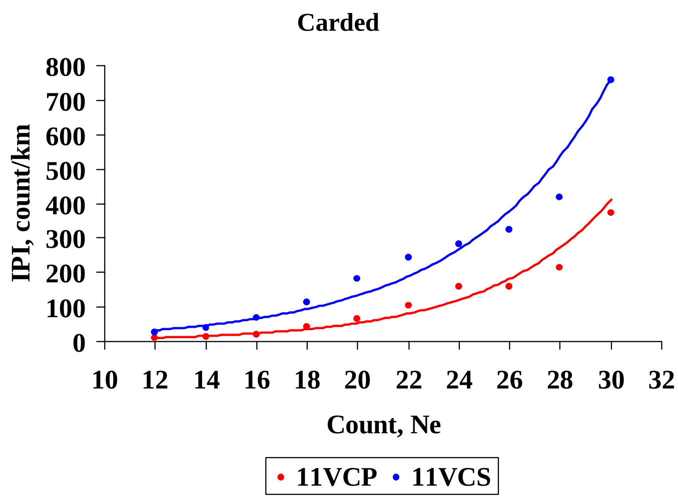

Figure 6. Uster IPI (total imperfections) vs. Yarn count (carded ring spun yarn, knitting twist) for the bales 11VCP and 11VCS

Second experiment: Our goal with this second experiment was to investigate the potential of the AFIS as a tool to predict yarn quality. For this, a set of 74 commercial bales representing a large range of fiber properties especially for micronaire and AFIS maturity was selected (Table III). Table IV and Figures 8 through 11 show the summary of the multiple regression analyses (backward stepwise regression) for ring spun carded yarns (30Ne with a knitting twist). The main yarn quality parameters were predicted from the HVI and AFIS fiber properties. We choose a knitting twist because we hypothesize that the weaving twist produces yarns that are less sensitive to fiber quality than the knitting twist. In addition, we also included in some models the Noils percentages, and the opening and carding wastes. The reason being that the AFIS samples are quite small (15,000 fibers for the length distributions, and 2.5 grams for the trash content determination) making it difficult of obtain a fully representative sample of the bale being tested. Hence, we substituted the noils percentages for the AFIS short fiber content in some models and the opening and card waste to the AFIS visible foreign matter content. Also, as regular classing office data does not report bundle elongation because of the lack of calibration cottons for elongation, models were built both with and without HVI bundle elongation.

Table IV. Seventy four commercial bales – Ring spun yarn carded 30Ne – Knitting Twist - Multiple regressions summary (backward stepwise) – Adjusted R^2

	HVI without elongation	HVI With elongation	AFIS + HVI	AFIS + HVI + Noils + Opening waste + Card waste
CSP	0.657	0.657	0.881	0.909
Elongation	0.615	0.741	0.872	0.887
Tenacity	0.642	0.860	0.877	0.899
Work	0.489	0.511	0.717	0.746
CV%	0.498	0.498	0.833	0.909
Thin places	0.475	0.475	0.771	0.814
Thick Places	0.333	0.333	0.767	0.875
Neps 200%	0.398	0.398	0.789	0.806
Hairiness	0.635	0.635	0.694	0.865

The results are quite clear, adding AFIS data to HVI data improves the predictions of all yarn quality parameters measured, especially yarn evenness related parameters. Substituting noils and processing wastes for short fiber content and visible foreign matter also improves the quality of the predictions but, with the exception of hairiness, this improvement is somewhat modest. This modest improvement indicates that the AFIS measurements of short fiber content and VFM are quite good in predicting yarn evenness but that they can probably be improved with a larger sample size. The relationship between AFIS short fiber content and combing noils is surprisingly good (Figure 7). Indeed, let us assume a cotton sample with the following fiber properties: 10% short fiber content by weight, mean length by number of 0.75 inch, and fineness of 150 mtex. If 15,000 fibers have been measured with the AFIS, it would correspond to a weight of 42.9 mg. Hence, about 4.3 mg of those are short fibers. This is to compared to 100 pounds of lint processed through our short staple spinning facility with an average noils percentage of 18% (about 1.8 kg of noils for 10 kg of lint being combed).

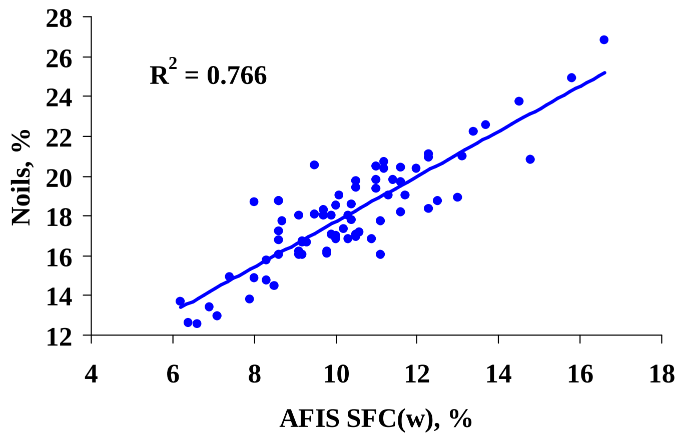

Figure 7. Combing noils vs. AFIS short fiber content by weight

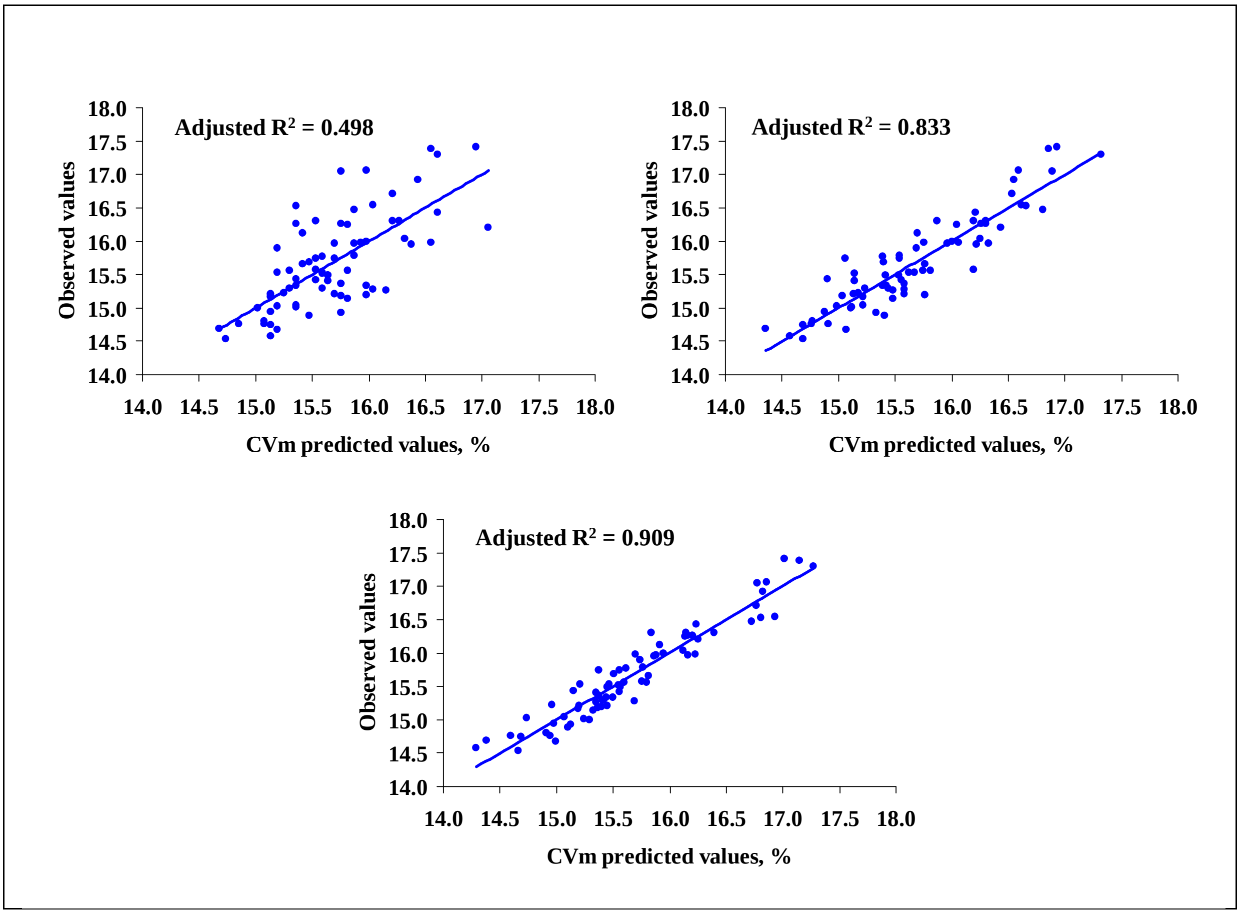

Figure 8. Uster CVm Observed values vs. Predicted values (top left = predictors HVI only, top right = predictors HVI + AFIS, bottom = predictors HVI + AFIS + Noils + Card & Opening wastes). It should be noted that redundant variables were systematically removed from the models.

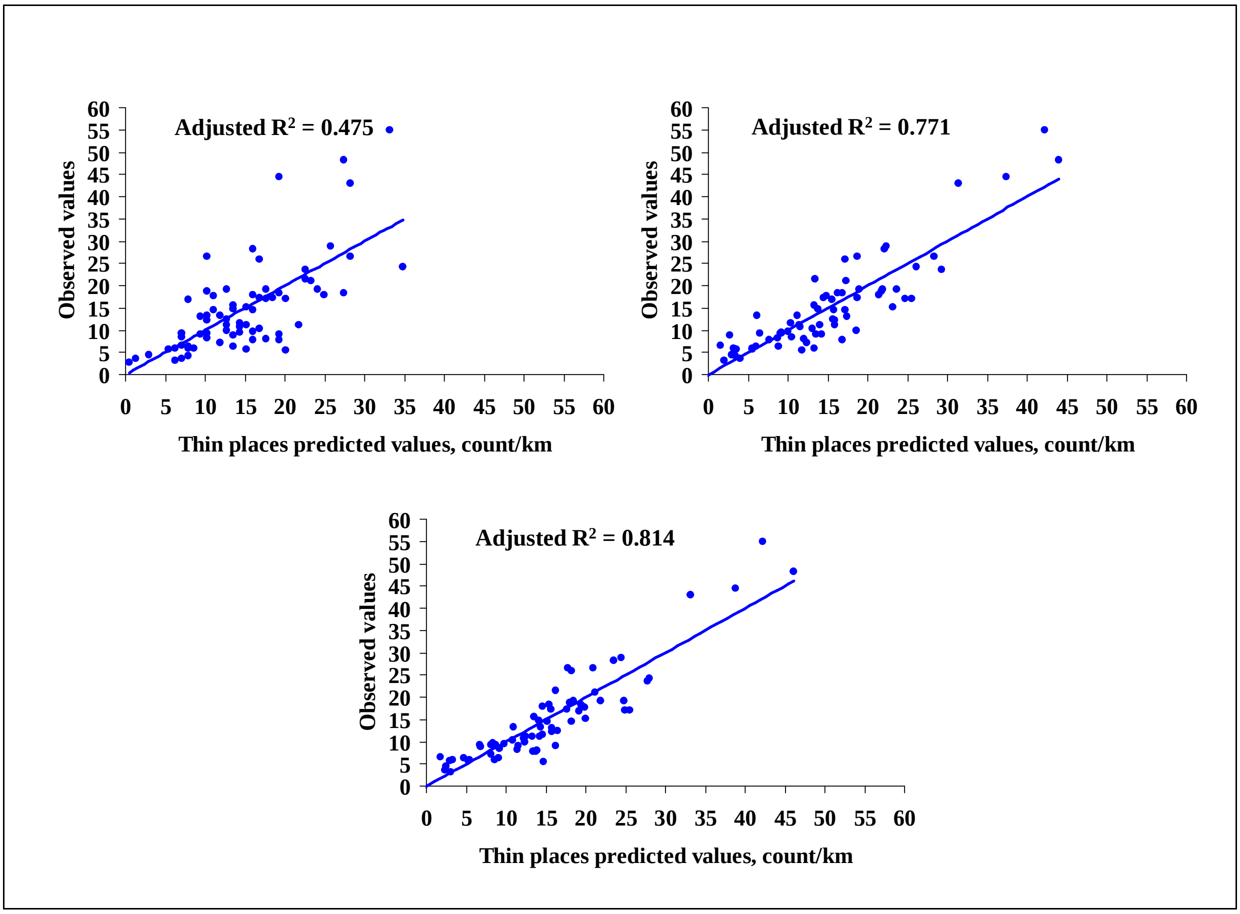

Figure 9. Uster Thin places (-50%) Observed values vs. Predicted values (top left = predictors HVI only, top right = predictors HVI + AFIS, bottom = predictors HVI + AFIS + Noils + Card & Opening wastes). It should be noted that redundant variables were systematically removed from the models.

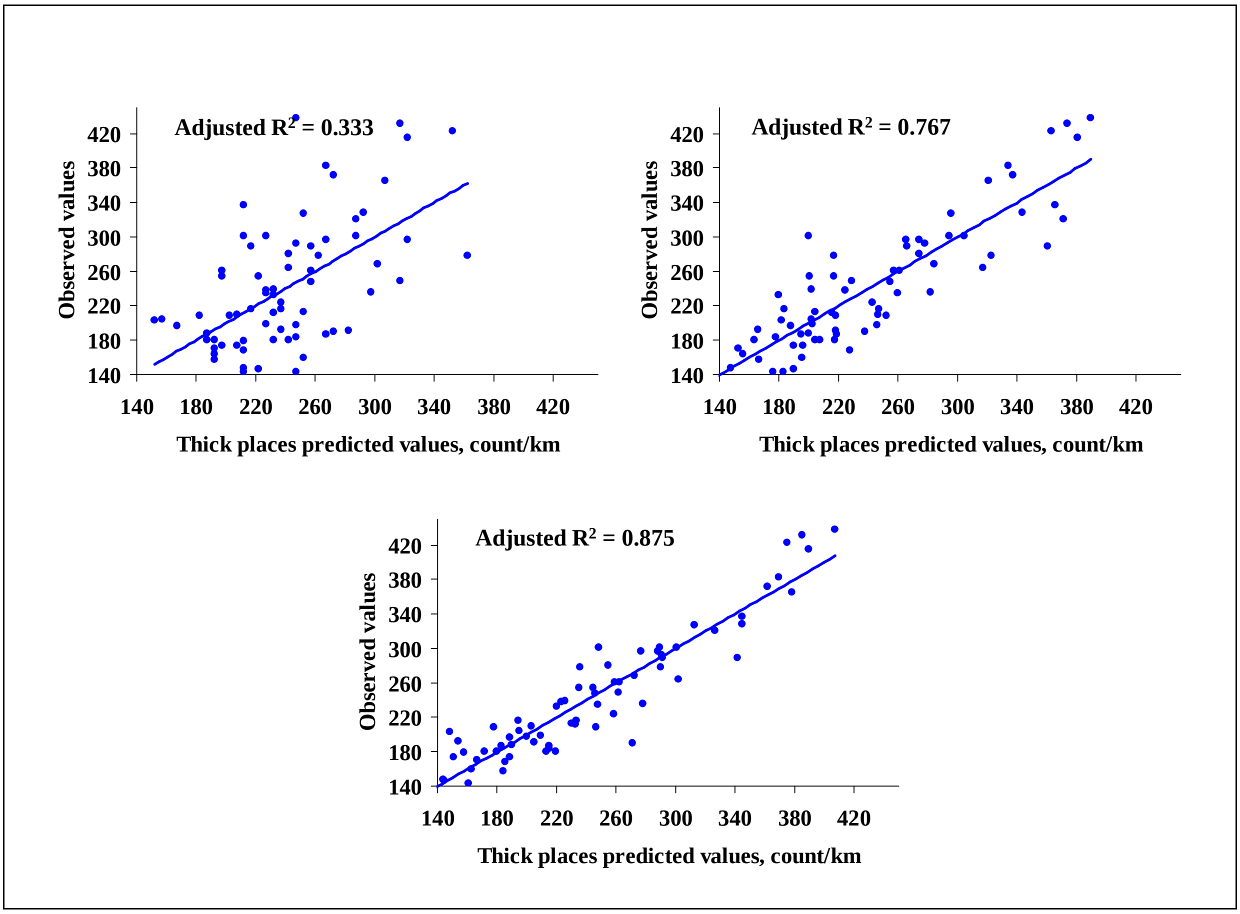

Figure 10. Uster Thick places (+50%) Observed values vs. Predicted values (top left = predictors HVI only, top right = predictors HVI + AFIS, bottom = predictors HVI + AFIS + Noils + Card & Opening wastes). It should be noted that redundant variables were systematically removed from the models.

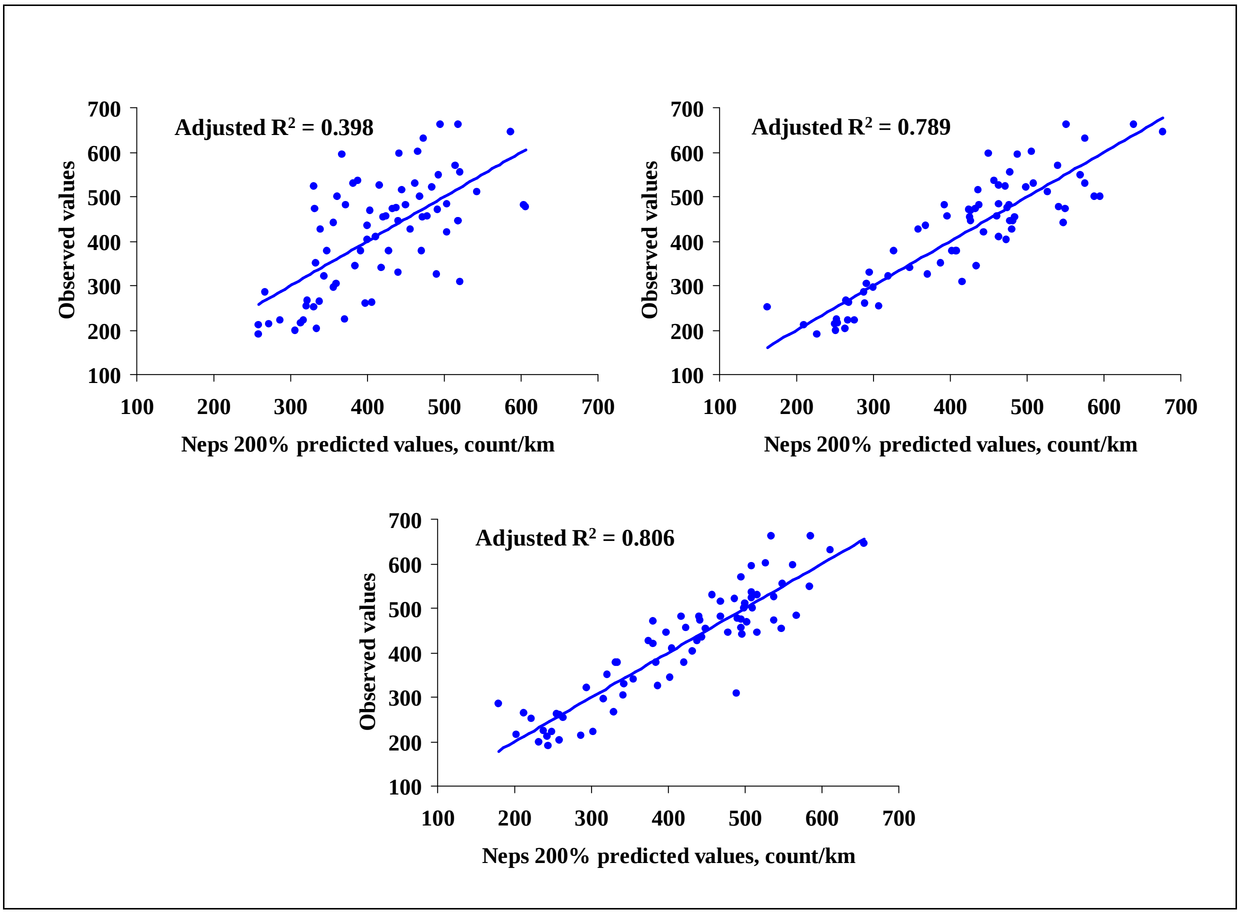

Figure 11. Uster Neps (+200%) Observed values vs. Predicted values (top left = predictors HVI only, top right = predictors HVI + AFIS, bottom = predictors HVI + AFIS + Noils + Card & Opening wastes). It should be noted that redundant variables were systematically removed from the models.

CONCLUSIONS

In conclusion, the combination of HVI and AFIS data allows us to predict yarn quality (ring spun yarn) for commercial bales quite accurately. A better measurement of both short fiber content and trash content should allow us to predict nearly perfectly yarn quality of ring spun yarns (we used noils percent instead of AFIS SFC and opening plus carding wastes instead of AFIS VFM in this study). Such models, if confirmed on an independent set of commercial bales could be invaluable for cotton breeders.

Breeder samples often contain more trash particles than commercial bales because they are ginned on small scale ginning equipment. The presence of excessive trash content in the lint could have a very negative effect on the quality of predictions for all yarn evenness related parameters. This is due to both less accurate AFIS readings with trashy cottons and more trash remaining in the lint after carding (translating in poorer yarn evenness). It is therefore essential to expand this research to include breeder type samples if we want to breed for improved yarn quality and remain competitive on the international market.

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