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Effects of the Origin of the Honeydew Contamination on Cotton Spinning Performances

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ABSTRACT

Spinning experiments were conducted to study the impacts on fiber processing of alternative types of honeydew contamination and confirm the hypothesis that trehalulose (mostly present in whitefly honeydew) is the main source of concern when attempting to spin sticky cottons. Spinning tests using Suessen Fiomax 1000 and Suessen EliTe frames showed that both types of honeydew are, at least partially, cleanable and that the whitefly honeydew droplets are broken into smaller particles during the opening, blending, carding, and drawing operations. Regarding yarn quality, except for the yarn nep count, aphid honeydew contamination did not translate into negative effects on both yarn quality and productivity up to 26 high speed stickiness detector (H2SD) spots. For whitefly-contaminated cotton even 12 H2SD spots had a drastic negative impact, producing unacceptable yarn quality and productivity. Therefore, the threshold for acceptable performance in the mill for whitefly-contaminated cotton should be set well below 12 H2SD sticky spots.

Cotton fiber quality determines the type of yarn and fabric that can be produced. Parameters such as fiber length, strength, and micronaire can be measured precisely and accurately with high volume instruments (HVI). These instruments, as well as the operating procedures associated with them, are well described and standardized. HVI data are used all over the world by the textile industry to buy cotton and to manage the mixes in the textile mills. Important, although not yet completely standardized, factors are measurement, characterization, and quality control standards for lint contaminants, especially stickiness.

Cotton stickiness is mainly caused by excess sugars on the lint, either from the plant itself or from insects, with the later being by far the most common source of contamination. The composition of insect honeydew is quite complex. Hendrix *et al.* reported that only a few of the sugars in whitefly or aphid honeydew are found in the insect diet; most sugars in these secretions are produced by the insect from phloem sap [6]. Among these sugars, melezitose and trehalulose are specific to insects and are not found in the plant. The presence of these sugars on the lint reveals that the lint contamination comes, at least partially, from insect honeydew. A high percentage of melezitose along with a low percentage of trehalulose reveals the presence of aphid honeydew, whereas with both melezitose and trehalulose present and trehalulose being dominant,

whitefly honeydew contamination is indicated. The other sugars are generally found on both non-contaminated and honeydew-contaminated cottons.

Cotton stickiness is a very serious problem for the textile industry, affecting cotton growers, cotton ginners, and spinners [7, 12]. During the transformation process of sticky cottons from fiber to yarn—that is, opening, carding, drawing, roving, and spinning, the machinery is contaminated to different degrees depending on the processes involved and the location within the machines. This affects processing efficiency as well as the quality of the products obtained. Numerous investigations have been conducted to elucidate the factors affecting the behavior of cotton contaminated with stickiness. In textile mills, the method mainly used to reduce the impact of stickiness is blending sticky cotton with non-sticky cotton [7, 10]. Gutknecht *et al.* [4] reported that stickiness caused by honeydew depends on the relative humidity, which is a function of both water content and temperature of the air, in which the contaminated cotton is processed. Frydrych *et al.* [3] reported that stickiness measured with the thermodetector is dependent on the relative humidity. Price [11] noticed that sticky cotton (with 1.2% reducing sugar content) stored at high relative humidity (21.1°C, 80% RH) gave more problems during processing than the same sticky cotton stored at low relative humidity (23.9°C, 55% RH). However, at low relative humidity the fibers are more rigid and will increase the friction forces creating static electricity [9]. Therefore, it will require more energy to draw the lint.

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Stickiness has also been reported to cause a build-up of residues on the textile machinery, which may result in irregularities or excessive yarn breakage [5, 18]. When processing low-to-moderately contaminated cotton blends, residues will slowly build up. This translates into a decrease in productivity and quality forcing the spinner to increase the cleaning schedule.

Fonteneau-Tamine *et al.* [1], studied 26 bales of Sudanese sticky cotton, and reported that textile machinery performance decreased when sticky cottons were processed. When more than 50 sticky spots were measured with the high speed stickiness detector (H2SD), and relative humidity was between 45 and 50% during opening and carding, then carding was not possible. In addition, stickiness significantly reduced the productivity at well below the 50 H2SD spots limit. The authors have shown that the roving frame appeared to be the most sensitive of all the machinery involved in the fiber-to-yarn transformation. For the same bales of Sudanese cotton Fonteneau-Tamine *et al.* [2] reported that cotton stickiness not only affects productivity but also the quality of the end products. Although a clear decrease in productivity was noticed for both the carding and drawing operations, it did not translate into a measurable decrease in sliver quality. It is only from the roving process onward that there is a stickiness-induced decrease in regularity. The CV% of the roving mass is slightly higher, thus increasing the irregularity of the yarn on the ring spinning frame. When considering actual spinning, the quality of ring spun yarn is more susceptible to stickiness than that of rotor spun yarn. The authors have found that, the regularity, imperfections, and tensile properties clearly highlight this difference between the two processes. The CV% of mass, number of thin places, number of thick places, and number of neps in the ring spun yarn increases significantly with the number of H2SD sticky points. The tensile properties of the ring spun yarn decrease as stickiness increases. By contrast most of the quality characteristics of the rotor spun yarn are unaffected by cotton stickiness.

In previous research, we have reported that trehalulose, the dominant whitefly sugar, accumulated on the textile equipment [8]. Therefore, cotton contaminated with aphid honeydew (melezitose being the dominant sugar) should cause less disruption of the spinning process than cotton contaminated with whitefly honeydew (trehalulose being the dominant sugar). The objective of this work was to confirm this hypothesis on modern spinning equipment.

Materials and Methods

EXPERIMENT 1

In this experiment, the spinning tests were performed on a Saco Lowell ring spinning frame and a Rieter R20

rotor spinning frame. One bale contaminated with aphid honeydew and one bale contaminated with whitefly honeydew were selected for this preliminary test. The bale contaminated with aphid honeydew had H2SD readings of 21 whereas the one contaminated with whitefly honeydew had 73. From these bales and one bale of non-sticky cotton, four mixes referenced Aph10, Aph20, WF10, and WF20 were prepared. The mix Aph10 was obtained by mixing 150 lbs of aphid honeydew-contaminated cotton with 150 lbs of non-sticky cotton. The mix Aph20 consisted of 300 lbs of aphid honeydew-contaminated cotton. The mix WF10 was obtained by mixing 43 lbs of whitefly honeydew-contaminated cotton with 257 lbs of non-sticky cotton. Finally, the mix WF20 was obtained by mixing 86 lbs of whitefly honeydew-contaminated cotton with 214 lbs of non-sticky cotton. The HVI results and H2SD readings for chute, card web, sliver DI, and sliver DII are summarized in Table I.

The four mixes were ring and rotor spun following the protocol outlined in Figure 1. The yarn count for both ring and rotor spinning was 26.84 tex (22 Ne). The yarn quality was checked for each doff produced (26 doffs for the ring spun yarn and 20 doffs for the rotor spun yarn).

EXPERIMENT 2

In this experiment, the spinning tests were performed on a Suessen Fiomax 1000 and a Suessen EliTe compact ring spinning frame. One bale contaminated with aphid honeydew and one bale contaminated with whitefly honeydew were selected for this test. In addition, two bales with slight contamination having fiber properties close to their corresponding sticky bales were selected for mixing with the contaminated bales. The bale contaminated with aphid honeydew had H2SD readings of 45.8 whereas the one contaminated with whitefly honeydew had 26.1. Trehalulose and melezitose contents are given in Figure 2.

From these bales, eight mixes were prepared. Four mixes referenced Aph3, Aph11, Aph20, and Aph26 were aphid honeydew-contamination type. Four mixes referenced WF4, WF12, WF20, and WF26 were whitefly honeydew-contamination type. Each sample was tested with HVI, high performance liquid chromatography (HPLC), and H2SD. On HVI, four replications were performed for micronaire and color and 10 replications for length and strength, whereas nine replications per sample were performed on H2SD and three on HPLC (Table II). The HVI readings were obtained from the chute samples (five samples per mix) whereas the H2SD data were calculated from the results obtained from the bales constituting the mixes (Table II).

The eight mixes were ring spun following the protocol outlined in Figure 1, but with a few changes. First, the ring

TABLE I. HVI and H2SD readings of the four mixes. (Aph = aphid honeydew-contaminated cotton, WF = whitefly honeydew-contaminated cotton, the two digits following the letters refers to the stickiness levels around 10 sticky spots and around 20 sticky spots).

Mix ID	Machine position	Mike	UHML mm	Unif. %	Strength cN/tex	Elon. %	Leaf	Rd %	+b	H2SD
Aph10	Raw									10.5
Aph10	Chute	4.5	24.9	78.6	23.4	6.8	1.0	75.6	11.0	12.7
Aph10	Card web	4.5	24.9	80.2	24.9	6.7	1.0	75.6	11.1	12.1
Aph10	Sliver DI	4.5	25.1	81.3	26.5	5.9	1.0	75.6	11.0	15.1
Aph10	Sliver DII	4.5	25.7	82.1	28.2	5.7	1.0	75.6	11.1	14.8
Aph20	Raw									21.0
Aph20	Chute	4.6	24.4	79.3	23.7	7.2	1.0	76.0	10.4	20.3
Aph20	Card web	4.4	24.6	80.0	25.3	6.7	1.0	75.8	10.4	21.2
Aph20	Sliver DI	4.5	25.1	80.8	26.1	6.1	1.0	75.9	10.4	21.9
Aph20	Sliver DII	4.6	25.4	81.6	26.5	5.6	1.0	76.0	10.4	23.4
WF10	Raw									10.5
WF10	Chute	4.8	25.4	79.3	22.9	6.7	1.0	76.1	10.8	15.3
WF10	Card web	4.7	25.4	80.2	24.7	6.5	1.0	76.0	10.7	16.6
WF10	Sliver DI	4.8	25.7	81.4	26.6	5.7	1.0	76.2	10.8	21.0
WF10	Sliver DII	4.8	26.2	81.8	27.8	5.5	1.0	75.7	10.5	19.9
WF20	Raw									20.9
WF20	Chute	4.9	25.7	79.3	22.7	6.6	1.0	76.1	10.8	29.5
WF20	Card web	4.8	25.7	79.9	24.7	6.5	1.0	75.8	10.9	35.8
WF20	Sliver DI	4.8	25.9	80.9	26.7	5.8	1.0	75.6	11.1	31.9
WF20	Sliver DII	4.8	26.7	82.3	28.8	5.7	1.0	75.8	11.1	32.1

spinning frames were Suessen Fiomax 1000 and Suessen EliTe instead of Saco Lowell and Rieter R20. Second, the yarn count was 16.4 tex (36 Ne). The yarn quality was checked for each doff produced (8 mixes $\times$ 30 doffs $\times$ 2 spinning technologies = 480 yarn tests).

Results and Discussion

EXPERIMENT 1: SACO LOWELL RING SPINNING FRAME VERSUS RIETER R20 ROTOR SPINNING FRAME

For the samples taken at the chute, the HVI fiber properties (Table I) of the four mixes were extremely close in terms of length, length uniformity, strength, and colorimetry. The micronaire was slightly higher for the mixes WF10 and WF20. Therefore, based on the HVI properties only, the yarns obtained from these mixes should be quite close in terms of quality.

It should be noticed that the H2SD reading had the tendency to increase during the process (Table I). For the two aphid-type mixes (Aph10 and Aph20), it increased by 4.3 and 2.4 points, respectively. However, for the two whitefly-type mixes (WF10 and WF20), the H2SD readings increased by 9.4 and 11.2 points. To explain this, we can hypothesize that some of the aphid honeydew droplets were broken during the process. However, for the whitefly honeydew, a higher percentage of droplets were broken. Therefore, the honeydew could be, at least partially, cleanable for both types of contamination. This hypothesis will be validated in the following sections.

The average yarn quality data are summarized in Table III. It should be noted that the yarn quality of the

mix Aph20 was slightly better than the yarn quality of Aph10. This could be attributed to the fact that the fiber quality of the contaminated cotton was slightly better than that of the non-contaminated cotton. After mixing with the non-sticky cotton, the mix Aph10 probably had a slightly lower quality than the mix Aph20 even if the HVI could not detect it. For both spinning technologies, the cotton mix Aph20 (contaminated with aphid honeydew) gave a better yarn than the cotton mix WF20 (contaminated with whitefly honeydew). Since the fiber properties of mix Aph20 and WF20 were very similar, these differences could essentially be attributed to the origin of the contamination. The analysis of these data revealed that for the ring spun yarn (Table IV) the correlation coefficients between yarn parameters and doff number (time related) show that: (1) the cotton mix Aph10 gave a better yarn than the cotton WF10. The same observation was valid when comparing Aph20 to WF20. These differences could not be attributed to the fiber properties, so the origin of the contamination could be the cause. (2) A weak positive correlation between yarn CV% and doff number was found, but the slopes of the regression lines were not statistically different. The yarn imperfections (thin places, thick places, and neps) followed the same trend, but even though a positive correlation was found, the increase in yarn CV% was only about 1/100 of a unit per doff. (3) A stronger positive correlation between yarn hairiness and doff number was found. The accumulation of sugars on the ring spinning frame was probably the cause of this behavior. The slopes of the regression lines were not statistically different and even though a positive correlation was found the increase

FIGURE 1. Outline of the mechanical process for the spinning trials.

FIGURE 2. Trehalulose and melezitose content (expressed in % of the fiber weight) for two contaminated bales.

in yarn hairiness was less than 1/100 of a unit per doff. (4) No correlation between yarn tenacity and doff number was noticed.

For the rotor spun yarn (Table V), the correlation coefficients between yarn parameters and doff number (time related) show that: (1) there was no deterioration of the yarn quality over time for the mix Aph10. (2) There was a correlation between yarn CV% and doff number for the mixes Aph20, WF10, and WF20, which was mainly due to an increase in the number of very small defects (neps 140%) for the mixes Aph20 and WF10 and to an increase in all types of neps for the mix WF20. The mix WF20 had a higher slope for the CV% than WF10, revealing a larger deterioration of yarn quality over time. (3) There was quite strong correlation between yarn hairiness and doff number for the mixes Aph20, WF10, and WF20. As for the

TABLE II. HPLC, H2SD readings, and HVI of the eight mixes. (Aph = aphid-contaminated cotton, WF = whitefly-contaminated cotton, the two digits following the letters refers to the stickiness levels).

Mix ID	Mix type	HPLC [‡]	H2SD	Mike	UHML mm	Unif. %	Strength cN/tex	Elon. %	Leaf	Rd %	+b
Aph3	Aphid honeydew contamination	0.224	2.5	4.0	30.0	83.1	31.7	5.5	1.0	79.9	11.1
Aph11		0.279	11.2	4.0	30.2	83.4	31.7	5.6	1.0	79.8	11.1
Aph20		0.334	19.8	4.1	30.2	83.2	31.5	5.5	1.0	79.6	11.0
Aph26		0.376	26.3	4.0	30.5	83.4	31.7	5.6	1.0	79.4	10.9
WF4	Whitefly honeydew contamination	0.164	4	4.5	27.9	82.2	29.0	5.7	1.0	75.7	10.4
WF12		0.348	11.7	4.7	27.7	81.4	28.0	5.9	1.0	75.8	10.2
WF20		0.533	19.5	4.8	27.7	81.3	27.6	6.1	1.2	75.7	10.0
WF26		0.691	26.1	4.7	27.9	81.6	28.2	6.0	1.2	75.8	10.3

[‡] Percentage total sugars, expressed in percentage of the fiber weight.

TABLE III. Average yarn quality parameters for the four mixes.

	Ring spinning								Rotor spinning							
	Aph10		Aph20		WF10		WF20		Aph10		Aph20		WF10		WF20	
CV%	24.4	b [‡]	23.8	a	24.9	c	25.3	d	14.14	b	14.07	a	14.13	b	14.47	c
Thin places/km	1197	b	1074	a	1328	c	1403	d	9	a	9	a	8	a	11	b
Thick places/km	1688	b	1517	a	1945	c	2080	d	48	b	39	a	52	c	61	d
Neps 140%/km	1653	b	1174	a	2198	c	2516	d	654	c	464	a	599	b	759	d
Neps 200%/km	390	b	216	a	619	c	746	d	44	b	20	a	52	c	66	d
Neps 280%/km	88	b	35	a	186	c	228	d	6	b	2	a	12	c	13	c
Hairiness	6.03	a	5.99	a	6.15	b	6.20	c	4.1	b	4.0	a	4.2	c	4.3	d
Elongation (%)	5.6	b	5.9	a	5.3	c	5.2	d	6.7	b	6.8	a	6.4	c	6.3	d
Tenacity (cN/tex)	12.1	a	12.1	a	12.1	a	12.0	a	12.1	a	11.9	b	11.8	b	11.3	c

[‡] Values not followed by the same letter are significantly different with $\alpha = 5\%$ (according to the Newman-Keuls test).

CV%, the mix WF20 had a higher slope for hairiness than the mix WF10. (4) There was quite strong negative correlation between yarn tenacity, yarn elongation, and doff number for the mix WF20.

In terms of ring spun yarn quality with the Saco Lowell ring spinning frame, it seems that there was a slight deterioration in yarn quality over time for all mixes. There were no significant differences between cottons contaminated with whitefly honeydew and cottons contaminated with aphid honeydew. Nevertheless the average number of ends-down for the aphid-contaminated cotton was 114 for 1000 spindle hours while it was 183 for the whitefly-contaminated cotton. For the rotor spun yarn quality with the Rieter R20 rotor spinning frame, there was no quality deterioration over time for the mix Aph10 and a slightly higher yarn CV% and hairiness over time for the mix Aph20. Slight quality deterioration was also noticed for the mix WF10. For the mix WF20, with the exception of thin places, stickiness negatively affected all quality parameters. In addition, the average number of ends-down for the aphid-contaminated cottons was 264 for 1000 rotor hours whereas it was 638 for the whitefly-contaminated cottons. This suggests that, for a given H2SD reading, there would be a lower productivity with whitefly-contaminated cottons.

In addition, the examination under the microscope of ends-down showed that there were fiber entanglements prior to the actual yarn breakage. Some of these yarn entanglements were examined with a scanning electron microscope. Figure 3 shows representative micrographs of the nep-like structure obtained from the mixes Aph20 and WF20. The difference between aphid contamination and whitefly contamination is clear. The micrograph of the nep resulting from the aphid honeydew-contaminated cotton mix shows fibers entangled with crystals. However, the micrograph of the nep resulting from the whitefly honeydew-contaminated cotton mix shows fibers stuck together by an amorphous substance.

In conclusion, there are two important hypotheses that need to be confirmed on an independent set of samples: (1) both aphid and whitefly honeydew could be, at least partially, cleanable; and (2) for a given H2SD reading, there will be a lower contamination threshold between problems and no problems at the mill with whitefly honeydew-contaminated cottons than with aphid honeydew-contaminated cottons. It should also be pointed out that the very slight negative effects measured on the ring spinning yarn quality with moderate levels of stickiness were obtained on a Saco Lowell spinning frame, which is an older generation of ring spinning

TABLE IV. Correlation coefficients between yarn properties and doff number for ring spun yarns (24 df: r is significant at the 5% level if $r > 0.388$)

Parameter	Mix ID	r	Slope	+95% Cnf. Lmt	-95% Cnf. Lmt
CV%	Aph10	0.433	0.007	0.001	0.014
	Aph20	0.531	0.012	0.004	0.019
	WF10	0.154			
	WF20	0.490	0.012	0.003	0.020
Thin places/km	Aph10	0.554	3.5	1.3	5.7
	Aph20	0.527	3.1	1.0	5.1
	WF10	0.240			
	WF20	0.606	4.6	2.0	7.1
Thick places/km	Aph10	0.464	2.2	0.4	3.9
	Aph20	0.699	3.9	2.2	5.6
	WF10	0.264			
	WF20	0.575	3.3	1.3	5.3
Neps 140%/km	Aph10	0.480	3.1	0.7	5.5
	Aph20	0.704	5.8	3.3	8.3
	WF10	0.345			
	WF20	0.700	6.4	3.7	9.2
Neps 200%/km	Aph10	0.377			
	Aph20	0.611	1.1	0.5	1.7
	WF10	0.264			
	WF20	0.579	1.8	0.7	2.9
Neps 280%/km	Aph10	0.078			
	Aph20	0.445	0.2	0.0	0.4
	WF10	0.190			
	WF20	0.209			
Hairiness	Aph10	0.446	0.004	0.001	0.008
	Aph20	0.745	0.009	0.006	0.012
	WF10	0.810	0.009	0.006	0.012
	WF20	0.668	0.007	0.004	0.011
Elongation (%)	Aph10	-0.212			
	Aph20	-0.443	-0.007	-0.013	-0.001
	WF10	-0.041			
	WF20	0.013			
Tenacity (cN/tex)	Aph10	0.207			
	Aph20	-0.228			
	WF10	0.173			
	WF20	0.354			

equipment. In order to study the quality of the yarn produced from modern ring spinning equipment, the Saco Lowell frames were replaced with a Suessen Fiomax 1000 and a Suessen EliTe (compact spinning). Experiment 2 was undertaken using modern ring spinning equipment to confirm the two hypotheses made earlier, namely that honeydew could be cleanable and aphid honeydew could cause less disruptions of the spinning process than whitefly honeydew.

EXPERIMENT 2: SUESSEN FIOMAX 1000 VERSUS SUESSEN ELITE COMPACT RING SPINNING FRAMES

The HVI fiber properties of the four aphid mixes were extremely close in terms of micronaire, length, length uniformity, strength, and colorimetry. The same was true for the whitefly mixes (Table II). Therefore, within a group and based on the HVI fiber properties only, the yarns

obtained from these mixes should be quite close in terms of quality.

The H2SD measurements were performed on raw cotton, chute, card sliver, DI sliver, and DII sliver. As shown in Table VI, the H2SD reading tended to increase during the process. For the aphid-type mixes, it increased only slightly whereas for the whitefly-type mixes the number of sticky points more than doubled as illustrated in Figure 4. The total sugars content (HPLC determination) expressed as a percentage of the fiber weight, tended to decrease during the process for both types of mixes (Table VII). For the stickiest cottons, about one-quarter of the sugars were removed (Figure 5). These results confirmed our early hypothesis that both types of honeydew were, at least partially cleanable, and that the whitefly honeydew droplets were broken into smaller particles during fiber processing, considerably increasing the number of sticky points that could be in contact with the spinning equipment. The drastic increase in the number of sticky spots along the

TABLE V. Correlation coefficients between yarn properties and doff number for rotor spun yarns (18 df: r is significant at the 5% level if $r > 0.444$).

Parameter	Mix ID	r	Slope	+95% Cnf. Lmt.	-95% Cnf. Lmt.
CV%	Aph10	0.281			
	Aph20	0.560	0.006	0.002	0.010
	WF10	0.477	0.005	0.001	0.010
	WF20	0.856	0.018	0.013	0.023
Thin places/km	Aph10	-0.370			
	Aph20	0.039			
	WF10	-0.301			
	WF20	0.425			
Thick places/km	Aph10	0.032			
	Aph20	0.013			
	WF10	0.255			
	WF20	0.481	0.4	0.1	0.8
Neps 140%/km	Aph10	0.328			
	Aph20	0.371			
	WF10	0.601	2.3	0.8	3.9
	WF20	0.808	8.8	5.6	11.09
Neps 200%/km	Aph10	0.045			
	Aph20	0.032			
	WF10	0.196			
	WF20	0.455	0.5	0.1	0.9
Neps 280%/km	Aph10	-0.280			
	Aph20	-0.254			
	WF10	-0.002			
	WF20	-0.191			
Hairiness	Aph10	0.018			
	Aph20	0.664	0.002	0.001	0.003
	WF10	0.761	0.002	0.001	0.003
	WF20	0.913	0.006	0.005	0.007
Elongation (%)	Aph10	-0.265			
	Aph20	0.171			
	WF10	0.040			
	WF20	-0.772	-0.010	-0.014	-0.006
Tenacity (cN/tex)	Aph10	-0.006			
	Aph20	-0.098			
	WF10	-0.243			
	WF20	-0.686	-0.022	-0.034	-0.011

processing line associated with the whitefly honeydew-contaminated cottons translated into a higher probability of contact between sticky spots and spinning equipment; therefore it renders this type of cotton more problematic to run.

The average yarn quality data are presented in Tables VIII and IX. Four statistical analyses were performed, one for aphid-contaminated cotton spun on the Suessen Fiomax 1000, one for aphid-contaminated cotton spun on the Suessen EliTe, one for whitefly-contaminated cotton spun on the Suessen Fiomax 1000, and finally one for whitefly-contaminated cotton spun on the Suessen EliTe. For the yarn spun on the Suessen Fiomax 1000 ring spinning frame and for aphid mixes, even though there were statistically significant differences between the mixes, only the nep count (+200% setting) was large enough to have practical impacts. It showed a clear tendency to increase with increasing levels of stickiness (+27% between Aph3 and Aph26). However,

whitefly-contaminated cotton mixes caused more problems during the spinning process than aphid-contaminated mixes. Indeed, mixes WF20 and WF26 would not spin and mix WF12 had an unacceptable number of ends-down per 1000 spindle hours. The yarn quality of mix WF12 was very poor for all parameters when compared with mix WF4. There was a 189% increase in thin places, 78% increase in thick places, 53% increase in neps (+200% setting) and 11% decrease in yarn tenacity. Even 12 H2SD sticky spots from whitefly, which was quite a low contamination level, were unacceptable.

For the yarn spun on the Suessen EliTe ring spinning frame and for aphid mixes, the effect of increasing stickiness levels was basically identical to that observed on the Fiomax 1000 spinning frame. As before, the nep count (+200% setting) had a clear tendency to increase with increasing levels of stickiness (+30% between mix Aph3 and mix Aph26). However, whitefly-contaminated mixes caused much more of a problem during the spinning

Yarn nep from the mix Aph20

Yarn nep from the mix WF20

FIGURE 3. Scanning electron microscopy micrographs of rotor spun yarn neps.

TABLE VI. Evolution of the H2SD readings along the processing line.

Mix ID	H2SD readings					Ratio DII/Raw
	Raw cotton	Chute	Card sliver	DI sliver	DII sliver	
Aph3	2.5	2.1	1.4	1.92	2.4	
Aph11	11.2	18.5	16.0	15.1	15.3	1.37
Aph20	19.8	24.8	20.2	21.4	22.8	1.15
Aph26	26.3	31.8	31.2	31.9	32	1.22
WF4	4	1.8	9.6	2.1	2.1	
WF12	11.7	23.7	28.4	28.5	29.9	2.56
WF20	19.5	31	54	44	50	2.56
WF26	26.1	47.4	56.2	55.1	54.7	2.10

TABLE VII. Evolution of the HPLC total sugars (expressed in percentage of the fiber weight) along the processing line.

Mix ID	HPLC total sugars content (% of the fiber weight)					
	Raw cotton	Chute	Card sliver	DI sliver	DII sliver	Ratio DII/Raw
Aph3	0.224	0.180	0.195	0.193	0.196	0.875
Aph11	0.279	0.287	0.235	0.226	0.231	0.828
Aph20	0.334	0.262	0.254	0.261	0.264	0.790
Aph26	0.376	0.315	0.270	0.271	0.274	0.728
WF4	0.164	0.144	0.202	0.154	0.145	0.884
WF12	0.348	0.304	0.307	0.305	0.307	0.882
WF20	0.533	0.386	0.480	0.391	0.387	0.726
WF26	0.691	0.627	0.490	0.472	0.512	0.740

FIGURE 4. H2SD readings: aphid honeydew contaminated cotton versus whitefly honeydew-contaminated cotton on raw cotton and DII slivers.

FIGURE 5. HPLC total sugars (expressed in percentage of the fiber weight).

TABLE VIII. Average yarn quality parameters for the eight mixes spun on the Suessen Fiomax 1000 ring spinning frame.

	Suessen Fiomax 1000													
	Aph3		Aph11		Aph20		Aph26		WF4		WF12		WF20	WF26
CV%	17.7	b [‡]	17.9	c	17.8	b	17.6	a	18.6	a	21.0	b	Would not spin	Would not spin
Thin places/km	34	b	40	c	35	b	29	a	74	a	214	b		
Thick places/km	586	a	621	b	662	c	620	b	668	a	1188	b		
Neps 140%/km	2705	a	2826	b	3000	c	3037	c	3298	a	4756	b		
Neps 200%/km	931	a	993	b	1147	c	1181	d	993	a	1525	b		
Neps 280%/km	373	a	396	b	483	c	501	d	313	a	461	b		
Hairiness	3.9	b	4.4	c	3.8	a	3.8	a	4.5	a	4.8	b		
Elongation (%)	6.0	a	5.7	c	5.9	b	5.9	b	5.7	a	5.1	b		
Tenacity (cN/tex)	18.9	a	18.9	a	18.5	c	18.7	b	16.3	a	14.5	b		
Ends down	14.5		16.4		12.6		3.9		6.8		133.3			

[‡] Values not followed by the same letter are significantly different with $\alpha = 5\%$ (according to the Newman-Keuls test).

TABLE IX. Average yarn quality parameters for the eight mixes spun on the Suessen EliTe compact ring spinning frame.

	Suessen EliTe														
	Aph3		Aph11		Aph20		Aph26		WF4		WF12		WF20		WF26
CV%	17.7	b [‡]	17.5	a	18.2	c	17.7	b	18.6	a	20.5	b	22.7	c	Would not spin
Thin places/km	40	b	30	a	50	c	31	a	71	a	164	b	374	c	
Thick places/km	586	a	589	a	708	c	654	b	658	a	1106	b	1696	c	
Neps 140%/km	2590	a	2688	b	2877	c	2970	d	3151	a	4595	b	5902	c	
Neps 200%/km	925	a	1017	b	1099	c	1199	d	982	a	1500	b	2089	c	
Neps 280%/km	395	a	439	b	473	c	534	d	333	a	488	b	671	c	
Hairiness	3.6	b	3.5	a	3.8	c	3.5	a	3.9	a	4.0	b	4.1	c	
Elongation (%)	6.3	a	6.3	a	5.9	c	6.2	b	6.0	a	5.6	b	5.3	c	
Tenacity (cN/tex)	19.6	a	19.6	a	19.5	a	19.3	b	17.2	a	15.8	b	14.3	c	
Ends down	16.4		13.5		23.2		7.7		25.1		31.9		125.6		

[‡] Values not followed by the same letter are significantly different with $\alpha = 5\%$ (according to the Newman-Keuls test).

process than aphid-contaminated mixes. Indeed, mixes WF26 would not spin and mix WF20 had an unacceptable number of ends down for 1000 spindle hours. The yarn quality of mixes WF12 and WF20 was very poor for all parameters when compared with WF4. For mix WF12, there was a 96% increase in thin places, 68% increase in thick places, 53% increase in neps (+200% setting), and 8% decrease in yarn tenacity when compared with mix WF4. For mix WF20, there was a 427% increase in thin places, 158% increase in thick places, 113% increase in neps (+200% setting), and 17% decrease in yarn tenacity when compared with mix WF4. Even though compact spinning appeared to handle moderate levels of whitefly honeydew better than regular ring spinning, the yarn quality was still unacceptable. Figure 6 illustrates the difference between aphid honeydew and whitefly honeydew for the yarn CV%.

In conclusion, except for the yarn nep count, aphid honeydew contamination did not translate into negative effects on either yarn quality or productivity up to 26 H2SD sticky spots. However, for whitefly-contaminated cotton even

12 H2SD sticky spots had a drastic negative effect, producing unacceptable yarn quality and productivity. Thus, the threshold for acceptable performance in the mill for whitefly-contaminated cotton should be set at a number much below 12 H2SD spots.

Conclusions

When cottons were separated by type of honeydew contamination, in terms of ring spun yarn quality with the Saco Lowell ring spinning frame, it seems that there was slight yarn quality deterioration over time for both whitefly and aphid honeydew-contaminated mixes. There were no significant differences between cottons contaminated with whitefly honeydew and cottons contaminated with aphid honeydew. Nevertheless, for a given H2SD reading, there will be a lower productivity with whitefly-contaminated cottons. For the rotor spun yarn quality, with the Rieter R20 rotor spinning frame, there was no quality deterioration over time for the mix contaminated with aphid honeydew and having 10 H2SD spots. There was slightly

Aphid-contaminated mixes on Fiomax 1000 **Whitefly-contaminated mixes on Fiomax 1000** **Aphid-contaminated mixes on EliTe** **Whitefly-contaminated mixes on EliTe**

FIGURE 6. Evolution of the yarn CV% for eight cotton mixes and two spinning technologies.

higher yarn CV% and hairiness over time for the mix contaminated with aphid honeydew and having 20 H2SD sticky spots. Slight yarn quality deterioration was also noticed for the mix contaminated with whitefly honeydew and having 10 H2SD spots. For the mix contaminated with whitefly honeydew and having 20 H2SD spots, with the exception of thin places, stickiness negatively affected all quality parameters including productivity.

Spinning tests on both Suessen Fiomax 1000 and Suessen EliTe frames showed that both types of honeydew were, at least partially cleanable, and that the whitefly honeydew droplets were broken into smaller particles during the opening, blending, carding, and drawing operations. The drastic increase in the number of sticky spots along the processing line with the whitefly honeydew-contaminated cottons translated into a higher probability of contact between sticky spots and spinning equipment; therefore

it rendered this type of cotton more problematic to run. Regarding yarn quality, except for the yarn nep count, aphid honeydew contamination did not translate into negative effects on yarn quality and productivity up to 26 H2SD sticky spots. For whitefly-contaminated cotton even 12 H2SD sticky spots had a drastic negative effect, producing unacceptable yarn quality and productivity. Thus, the threshold for acceptable performance in the mill for whitefly-contaminated cotton should be set at a number much below 12 spots, which from a practical point of view means that any level of stickiness coming from whitefly honeydew contamination is unacceptable.

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