Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA)
Available online at www.inia.es/sjar

Spanish Journal of Agricultural Research 2009 7(4), 913-918
ISSN: 1695-971-X

Short communication. Deterioration of cotton fibre characteristics caused by cotton leaf curl disease

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Abstract

The effect of cotton leaf curl disease found at Burewala (Pakistan) on the ginning out turn (GOT) and the physical and chemical characteristics of cotton fibre was evaluated by comparing healthy and cotton leaf curl disease (CLCuD)-infected plants of four cotton varieties. A highly susceptible response to CLCuD was found in all varieties tested. The disease incidence ranged from 42.6 to 81.4%. Significant differences were observed between the fibre of healthy and diseased cotton plants, of all varieties, for GOT, fibre length, fibre uniformity index, short fibre index, fibre fineness, fibre bundle strength, reflectance degree (Rd-value), yellowness (+*b* value) and maturity ratio. The cv. CIM-473 exhibited the highest reduction in all the quality parameters studied with the exception of Rd-value which was the lowest in cv. NIAB-999. The disease also significantly affected cellulose, protein, wax and pectin content. CLCuD adversely deteriorated the cotton fibre characteristics, however the varietal difference exists. The varieties with less deteriorated fibre by CLCuD should be an essential criterion for the selection of resistant germplasm against CLCuD.

Additional key words: Begomovirus, Burewala strain, CLCuD, fibre deterioration, *Gossypium hirsutum*.

Resumen

Comunicación corta. Deterioro en las fibras de algodón causado por la enfermedad del enrollado de la hoja del algodón

En Burewala (Paquistán) se evaluó el efecto de la enfermedad del enrollado de la hoja del algodón (CLCuD) sobre el porcentaje de hilas en las semillas (GOT) y las características físico-químicas de la fibra de algodón, comparando cuatro variedades de plantas de algodón sanas y con la enfermedad. Todas las variedades estudiadas fueron altamente susceptibles a CLCuD. La incidencia a la enfermedad varió entre el 42,6 y el 81,4%. Se observaron diferencias significativas entre las fibras de las plantas sanas y enfermas, en todas las variedades, para GOT, longitud, índice de uniformidad, índice de fibras cortas, finura, fuerza de los paquetes de fibras, reflectancia (valor Rd), amarilleamiento (valor +*b*) y madurez de las fibras. El cv. CIM-473 fue el que más redujo los parámetros de calidad estudiados, a excepción del valor Rd, que fue menor en el cv. NIAB-999. La enfermedad también afectó significativamente al contenido en celulosa, proteínas, ceras y pectinas. Las variedades con fibras menos deterioradas por CLCuD deben ser tenidas en cuenta en la selección de germoplasma contra el CLCuD.

Additional key words: Begomovirus, cepa Burewala, CLCuD, deterioro de la fibra, *Gossypium hirsutum*.

Cotton (*Gossypium hirsutum* L.) is an important fibre crop and a major contributor to Pakistan's foreign exchange earnings. It supplies 1,240 ginning mills and 453 textile units consisting of 50 composite and 403 spinning units. Approximately 68% of the country's total exports are linked directly or indirectly with cotton and it employs 40% of the total workforce in the manufacturing sector (Anon, 2004). The multiplier effect of employment in this sector is enormous and is currently fuelling the countries economy. In 1991-92, Pakistan achieved a record production of 12.8 million bales of cotton. In 1992-93 production fell to 9.1 million bales

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Received: 13-01-09; Accepted: 31-08-09.

Abbreviations used: AFIS (advanced fibre information system), CLCuD (cotton leaf curl disease), GOT (ginning out turn), HVI (high volume instrument), NIAB (Nuclear Institute for Agriculture and Biology).

due to attack by cotton leaf curl disease (CLCuD). This downward production trend has continued and production in 1994-95 was 7.9 million bales (Ahmad *et al*., 2002).

The disease CLCuD was first reported in Pakistan in the late 1960s, but it remained as a minor sporadic problem for the following 20 years. In 1988, a small plot of a newly released cotton variety (S-12) was severely affected by CLCuD, signalling the start of an epidemic (Briddon, 2003). Economic losses, in Pakistan, due to CLCuD are estimated to be US$5 billion between 1992 and 1997 (Briddon and Markham, 2000).

Cotton germplasm from various sources was tested in severely affected areas and a number of resistant varieties were released to combat the disease (Akhtar *et al*., 2002). Unfortunately, during the 2001 growing season symptoms of CLCuD were observed on all hitherto resistant cotton varieties at Burewala, in Vehari District. By 2002 the disease symptoms had spread throughout the district suggesting that the resistance had been overcome (Akhtar *et al*., 2002; Mansoor *et al*., 2003a).

Symptoms of CLCuD include severe vein thickening, leaf curling, thickening, rolling and size reduction. Spiral twisting of leaf petioles, internode shortening, plant stunting and production of leaf and vein enations are also observed (Akhtar *et al*., 2008). The disease CLCuD is associated with different virus species of the «cotton leaf curl» complex (genus *Begomovirus*, family *Geminiviridae*) (Fauquet *et al.,* 2008). The species of this complex are transmitted, in nature, by whitefly (*Bemisia tabaci*) and have a monopartite ssDNA genome. Further, the disease is associated with the presence of symptom modulating satellite molecules designed as DNA β. An additional satellite-like component, DNA 1, is also found in diseased plants, although not required for disease development (Briddon, 2003; Mansoor *et al*., 2003b).

Cotton fibre is a versatile and widely used material, but the extent of cotton fibre characteristic deterioration due to CLCuD, found in Burewala, has not been established. Therefore, this study was undertaken to determine the impact of the disease on fibre quality of cotton varieties. Findings from this study may provide knowledge not only to cotton growers but also to breeders, field technicians, scientists and mill managers to aid future planning.

Plants of four cotton varieties susceptible to the type of CLCuD found in Burewala, NIAB-111, NIAB-999, CIM-473 and CIM-506 were sown in the field in May 2004, at the Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, Pakistan. Distances between rows and between plants in the row were 0.76 and 0.46 m, respectively. Conventional agronomic practices were followed to keep the crop in good condition. Plants were infected with CLCuD about 4-6 weeks after sowing under natural exposure to the vector *Bemisa tabaci.* Symptomatic infected plants were labelled and plots were treated with standard plant protection measures to avoid losses and fibre quality deterioration due to insect pests. Symptoms of CLCuD were recorded using the rating system of Akhtar *et al*. (2008) to calculate the percentage disease index (DI) and the reaction of the different cotton varieties.

At the end of the experiment (November-December 2004), mature bolls were collected separately from both healthy and infected plants of each variety. The seed cotton for each sample was undusted, cleaned and ginned in a standard roller gin in a miniature-ginning machine to study ginning out turn (GOT) percentage and fibre physico-chemical characteristics. Lint obtained was weighed and the GOT (%) estimated using the formula: [(lint weight/seed weight) × 100], using the standard technique of the ASTM Committee (1997a).

Fibre length, fibre uniformity index and short fibre index were measured with a high volume instrument (HVI) length strength module-910, using an optical technique. Fibre strength and fibre length measurement were determined on the same module simultaneously. The micronaire value was estimated on micronaire module-920, by measuring the escape of air through a plug of a weighted cotton sample. The HVI module-930 assembled with HVI-900SA was used to measure the lightness or reflectance degree in Rd-value and yellowness in Hunter's colorimeter scale as +*b* value. Testing procedures were those recommended by the ASTM Committee (1997b). Fibre maturity was measured by the Advanced Fibre Information System (AFIS F&M Module) provided by M/S Zellweger-Uster Ltd. (Switzerland) (ASTM Committee, 1997b).

Fibre cellulose, wax and protein content were estimated by standard AOAC (1984). Pectin percent was determined by extracting pectic substances with 0.05 N HCl and pectin calculated as calcium pectate, which was precipitated from the HCl extract as recommended by Kertesz (1951).

A completely randomized design was used in the analysis of variance for testing differences among treatments for DI and the fibre quality characteristics as suggested by Faqir (2000). Duncan's Multiple Range test was used for individual comparison of means

Table 1. Field response of four cotton varieties naturally infected with cotton leaf curl disease (CLCuD)

Variety	Number of plants observed	CLCuD infected plants	Infection type range	Disease index (%)[1]	Disease reaction
NIAB-111	463	216	5-6 E[2]	42.6^{b}	Highly susceptible
NIAB-999	399	332	5-6 E	81.4^{a}	Highly susceptible
CIM-473	410	275	5-6 E	59.4^{ab}	Highly susceptible
CIM-506	436	257	5-6 E	52.4^{b}	Highly susceptible

[1] Any two means not sharing a common letter differ significantly at $\alpha = 0.05$ level of probability. [2] E = enation (finlike outgrowths on the lower side of infected leaves).

among varieties for DI and various quality characters. The data were subjected to statistical analysis employing the MSTAT-C program (MSTAT-C Development Team, 1993).

The disease CLCuD was found in all cotton varieties tested with a similar infection type range but with variable incidences of infected plants and DI values (Table 1). Cultivar NIAB-999 showed the maximum DI (81.4%) followed by CIM-473 (59.4%), CIM-506 (52.4%) and NIAB-111 (42.6%). However, all four cotton varieties tested showed the same disease reaction *i.e.,* they were highly susceptible. Plants infected with CLCuD showed downward cupping of younger leaves, followed by either an upward or downward curling of leaf margins, swelling and darkening of veins and vein enation frequently developed into cup shaped leaf like structures in all four varieties. Leaves from infected plants became thickened and more brittle than those of healthy plants. Severely infected plants showed leaf rolling and reduced size, with spirally twisted leaf petioles, fruiting branches and main stem. Internode length was reduced and plants affected early were stunted and this adversely affected yield. Field symptoms of diseased plants resembled those reported by Akhtar *et al*. (2008).

The CLCuD infected plants of the four test varieties showed an overall decrease of GOT% of 13.9% compared to healthy plants. The maximum decrease, over healthy plants, was in CIM-473 as 18.5% followed by NIAB-999, CIM-506 and NIAB-111 as 13.3, 12.7 and 11.2%, respectively (Table 2).

There were significant differences between healthy and diseased plants of the four cotton varieties in values of all fibre physical characteristics evaluated (Table 2). Fibre length of all test varieties was negatively affected by CLCuD. There was an overall length reduction of 5.03%. Cultivar CIM-473 showed the maximum reduction at 6.5%. This was followed by CIM-506,

Table 2. Effect of cotton leaf curl disease on physical and chemical characteristics of the fibre of four cotton varieties

Characteristics	NIAB-999			NIAB-111			CIM-506			CIM-473			Mean % DOH
	H	D	% DOH	H	D	% DOH	H	D	% DOH	H	D	% DOH	
GOT (%)^{a}	36.4^{c}	31.5^{g}	13.3	38.0^{a}	33.8^{e}	11.2	37.3^{b}	32.6^{f}	12.7	34.8^{d}	28.3^{h}	18.5	13.9
Fibre length (mm)	27.9^{d}	26.7^{e}	4.4	30.0^{a}	28.9^{c}	3.7	29.6^{b}	28.0^{d}	5.6	28.0^{d}	26.2^{f}	6.5	5.03
Fibre uniformity index	82.0^{a}	78.8^{d}	3.9	81.8^{a}	79.9^{b}	2.3	79.5^{c}	76.9^{e}	3.3	79.9^{b}	76.0^{f}	4.8	3.6
Short fibre index	7.5^{h}	8.6^{g}	–12.7	8.8^{f}	9.6^{e}	–8.7	10.1^{c}	11.3^{a}	–12.4	9.9^{d}	11.9^{b}	–19.8	–13.4
Fibre fineness (µg inch^{-1})	4.6	3.9	15.2	4.1	3.6	12.2	4.3	3.7	14.0	4.7	3.9	17.0	14.6
Bundle strength (g tex^{-1})	25.4^{b}	22.2^{e}	12.8	23.6^{c}	22.1^{e}	6.3	23.1^{d}	21.0^{f}	9.1	26.7^{a}	22.2^{e}	16.8	11.2
Rd-value	69.4^{a}	64.4^{c}	7.3	67.4^{b}	64.1^{d}	4.9	62.5^{e}	59.9^{g}	4.1	61.3^{f}	58.5^{h}	4.6	5.2
+b-value	7.66^{f}	8.97^{c}	–18.8	8.04^{e}	8.77^{d}	–9.1	8.07^{e}	9.07^{b}	–12.4	8.07^{e}	9.17^{a}	–13.6	13.5
Fibre maturity (%)	85^{a}	80^{d}	5.9	80^{d}	78^{e}	2.5	83^{c}	80^{d}	3.6	84^{b}	78^{e}	7.1	4.8
Cellulose (%)	90.12^{a}	88.99^{b}	1.25	87.30^{d}	86.23^{f}	1.23	87.20^{d}	86.80^{e}	0.46	88.35^{c}	86.94^{de}	1.60	1.14
Protein (%)	1.380^{e}	1.358^{f}	1.59	1.820^{a}	1.800^{b}	1.10	1.600^{c}	1.580^{d}	1.25	1.240^{g}	1.230^{h}	0.81	1.19
Wax (%)	0.480^{g}	0.470^{h}	2.08	0.650^{a}	0.640^{b}	1.54	0.580^{c}	0.570^{d}	1.72	0.520^{e}	0.510^{f}	1.92	1.80
Pectin (%)	0.810^{g}	0.798^{h}	1.48	1.120^{a}	1.100^{b}	1.79	0.990^{c}	0.980^{d}	1.01	0.89^{e}	0.88^{f}	1.12	1.35

H: healthy. D: diseased. % DOH: percent decrease over healthy. GOT: percentage of ginning out turn. Any two mean values not sharing a letter in common differ significantly at $\alpha = 0.05$ level of probability.

NIAB-999 and NIAB-111 respectively. A negative effect of CLCuD on fibre uniformity index was also observed. The maximum decrease was in CIM-473 at 4.8% and the minimum in NIAB-111 as 2.3%. Cultivars NIAB-999 and CIM-506 showed 3.9 and 3.3% reductions in fibre uniformity index respectively. The maximum decrease in fibre fineness value was in CIM-473 (17.0%) while the minimum was in NIAB-111 (12.2%). Overall fibre bundle strength of all test varieties decreased 11.2%. Variety CIM-473 showed the maximum decrease of 16.8% followed by NIAB-999, CIM-506 and NIAB-111 respectively. The maximum decrease in Rd-value was in NIAB-999 as 7.3% followed by NIAB-111, CIM-473 and CIM-506 as 4.9, 4.6 and 4.1% respectively. Adverse effects of CLCuD were also seen in short fibre index and +*b* value. The maximum increase in short fibre index was in CIM-473 (19.8%) followed by NIAB-999 (12.7%), CIM-506 (12.4%) and NIAB-111 (8.7%). The maximum increase in +*b* value was in NIAB-999 as 18.8% while the minimum was in NIAB-111 as 13.6%. Cultivar CIM-473 showed the maximum decrease of 7.1% in fibre maturity ratio. It was followed by NIAB-999 (5.9%), CIM-506 (3.6%) and NIAB-111 (2.5%) (Table 2).

There were significant differences between healthy and diseased cotton, plants of all varieties, for cellulose, protein, wax and pectin content (Table 2). There was an overall decrease of cellulose content of 1.14% in diseased plants. The maximum decrease was in CIM-473 (1.60%) followed by NIAB-999, NIAB-111 and CIM-506 respectively. There was an overall decrease of 1.19% in protein content. Cultivar NIAB-999 showed the maximum decrease in protein content as 1.59%; it was followed by CIM-506 (1.25%), NIAB-111 (1.10%) and CIM-473 (0.81%). Maximum decrease in wax content was in NIAB-999 (2.08%) while CIM-473, CIM-506 and NIAB-111 showed decreases of 1.92, 1.72 and 1.54% respectively. For all varieties the overall decrease in wax content was 1.80%. Pectin analysis showed an overall decrease of 1.35% over all varieties with the maximum decrease in NIAB-111 as 1.79% followed by NIAB-999, CIM-473 and CIM-506 respectively.

Improvement in textile spinning machinery has had an important impact on the entire cotton fibre industry, particularly in the demand for high quality cotton fibre. Fibre characteristics that have vital importance in spinning are staple length, fibre strength, fineness, uniformity and maturity (Arioli, 2005). Long staple, fine fibre produces more uniform and stronger yarn. Moreover, minimum twist insertion further increases production output. Good fibre strength generally gives higher yarn strength and less trouble in spinning. Immature cotton fibres have neither adequate strength nor adequate longitudinal stiffness. Maturity affects processing behaviour because immature fibres break frequently during the process and have a tendency to form neps, which tangle around and adversely affect yarn and fabric appearance (Gamble, 2004; Arioli, 2005; Montalvo, 2005).

Fibre length affects yarn strength, yarn appearance, processing waste and running quality. Generally more uniform fibres produce yarns of greater strength. Therefore cotton fibre length is a property of commercial value as price is generally based on this character. The importance of fibre length to textile processing is significant. Longer fibres produce stronger yarn by allowing them to twist around each other more times. Longer fibres can produce finer yarns to give more valuable end products (Gamble, 2004; Arioli, 2005; Montalvo and Hoven, 2005).

Fibre maturity and fineness contribute appreciably to nep counts, as very fine immature fibres always produce greater number of neps in the yarn and result in a lower yarn strength and low appearance grades. The non-lint contents of raw cotton gives an accurate estimate of the amount of trash in the bales and analysis of waste is generally of great interest in quality and cost control (Gamble, 2004; Arioli, 2005; Montalvo, 2005; Montalvo and Hoven, 2005). This study showed that CLCuD caused plant deterioration, which ultimately affected fineness of fibres in bolls. The decrease in GOT and in the physical and chemical quality characteristics of CLCuD-infected plants found here is in agreement with the findings of Anon. (1994, 1995); Ali *et al*. (1995); Ahmad (1999); Khan *et al*. (2001) and Ahmad *et al*. (2002), highlighting how this depends on cotton variety and environmental factors.

Cotton fibre is a versatile, and widely used, material which is 87-90% cellulose. Its spinning performance is affected by the fibre surface characteristics (El-Moghazy *et al.,* 1998; Gamble, 2004). The fibre surface is comprised of primary cell wall and is composed mainly of pectin and hemicellulose and a waxy cuticle as well as metabolic residues which include electrolytes and sugars. As these outer surface fibre components are in direct contact with neighbouring fibres, their physical dimension and chemical composition may have a larger impact on spinning performance than is reflected by their low overall abundance relative to cellulose. Cellulose content is positively correlated and showed a significant effect on staple length, fibre maturity ratio and fineness (Khan, 1994).

Cook (1993) reported that cotton fibre was 1.0 to 1.5% protein, 0.5% wax and 1.0% pectin that increased with increased fibre immaturity while protein was negatively correlated with the uniformity ratio (Hussain, 1994). Similarly, Hussain (1994) and El-Mogahzy *et al*. (1998) reported that the higher the protein contents the finer will be the yarn count. This can provide an environment in which fibre chemical characteristics can contribute to yarn strength (Khan, 1994). In this work the cellulose, protein, wax and pectin contents of CLCuD infected plants were adversely affected in all the test cotton varieties.

In conclusion, the disease CLCuD has a significant effect on GOT and other cotton fibre quality traits, both physical and chemical, that could ultimately affect yarn quality parameters. As cotton is universally used because of its adaptability to many uses and its comparative inexpensiveness, it can be grown around the world and converted into useful items. Its superior natural, physical, mechanical and chemical properties are incomparable with other natural and synthetic fibres. These properties are adversely affected by attack by CLCuD.

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