

Full Length Research Paper

Sowing date and boll position affected boll weight, fiber quality and fiber physiological parameters in two cotton (*Gossypium Hirsutum* L.) cultivars

Wenqing Zhao, Youhua Wang, Hongmei Shu, Jian Li and Zhiguo Zhou*

College of Agriculture, Nanjing Agricultural University, Nanjing 210095, P. R. China.

Accepted 14 May, 2012

To study the effects of sowing date and boll position on fiber quality and the physiological mechanism, field experiments were conducted using two cotton cultivars (Kemian 1 and Sumian 15) with two sowing dates (normal sowing date 25 April, and late sowing date 25 May) at Nanjing (118°50'E, 32°02'N), Jiangsu, China, in 2006 and 2007. Cotton bolls were divided into three parts (low, middle and upper) according to the fruiting branch sympodial positions. Boll weight, fiber quality (bundle strength, span lengths, micronaire), and fiber physiological parameters (cellulose content, callose content, and sucrose transformation rate) were detected, respectively. Boll weight and fiber strength were affected by sowing date, boll position, and sowing date × boll position. Comparing to the normal sowing date, late sowing date declined boll weight, fiber strength, cellulose content, and sucrose transformation rate. The cellulose content and sucrose transformation rate changed with boll position, and consequently resulted in the change of boll weight and fiber strength. In normal sowing date, cotton boll in middle positional sympodial branch had the highest cellulose content, sucrose transformation rate, boll weight, and fiber strength. In late sowing date, cotton boll in low positional sympodial branch had the highest cellulose content, boll weight and fiber quality. The results indicated that the change of fiber yield and quality in sowing dates and boll positions were because the synthesis of cellulose, callose and sucrose were changed. Increasing the cellulose content and sucrose transformation rate can improve yield and fiber quality in late sowing date or sub-optimal environmental conditions.

Key words: Cotton, sowing date, boll position, boll weight, fiber quality, cellulose content, callose content, sucrose transformation rate.

INTRODUCTION

Cotton fiber is an important raw material for the textile industry. Both fiber yield and quality are important to cotton fiber value evaluation. Over the years, genetic improvements in yield and fiber quality traits by cotton breeders have made cotton lint more desirable to the

textile industry, but adverse management and environmental conditions can still have a damping effect and mask any genetic improvements in yield and fiber quality (Pettigrew, 2001).

Sowing date is one of the most important management factors involved in producing high-yielding and high quality cotton (Dong et al., 2006). However, cotton growers often lost the optimal sowing date waiting for the harvest of preceding full-season winter crops. Former studies indicated that late sowing usually resulted in reduced yield and declined fiber quality (Bauer et al., 2000; Bange and Milory, 2004; Davidonis et al., 2004; Dong et al., 2006). The changed yield and fiber quality

*Corresponding author. E-mail: giscott@njau.edu.cn. Tel: 86-25-84396813. Fax: 86-25-84396813.

Abbreviations: DPA, Days post anthesis; LPSB, low positional sympodial branch; MPSB, middle positional sympodial branch; UPSB, upper positional sympodial branch.

were due to suboptimal weather conditions in late sowing date (Gormus and Yucel, 2002). Besides crop management, the physical environment had profound influence on cotton boll growth and development, which induced by fruiting sites (Davidonis et al., 2004). Bradov et al. (1997) indicated that fiber length varied among fruiting sites. Wang et al. (2009) indicated that fiber strength varied among the boll inserted location. Extensive investigations have been carried out on the effects of sowing date or boll position on cotton fiber development respectively, and Davidonis et al., (2004) investigated boll location \times planting date effects on fiber quality. They believe that both sowing date and boll position significantly affect fiber quality, but there have been a limited number of studies exploring the physiological reason.

Yield and fiber quality are determined by fiber development progress: fiber initiation, cell elongation, secondary wall deposition, and maturation (Kim and Triplett, 2001). Fiber elongation and secondary wall deposition are most important to yield and quality. In fiber elongation, fiber elongated and primary cell wall formed. In the secondary wall deposition, a thick secondary cell wall composed of almost pure cellulose by partitioning about 80% of available carbon into cellulose were synthesized (Haigler et al., 2001; Salnikov et al., 2003), and the characteristic of cellulose accumulation determined the quality of fiber secondary wall (Saxena and Brown, 2000; Williamson et al., 2002). Substantial quantities of β -1, 3-glucan (callose) also contained in fiber cell wall during this period (Scheible and Pauly, 2004). Callose is actually similar to cellulose in structure, and both polymers are synthesized with UDP-glucose as substrate, but increased ratio of callose in fiber cell wall will deteriorate fiber quality. Sucrose as the initial carbon source is degraded by sucrose synthase to provide UDP-glucose for cellulose and callose synthesis (Delmer and Amor, 1995; Haigler et al., 2001). In mature fiber, the primary cell wall and cuticle together make up approximately 2.4% of the total wall thickness. The remaining 98% of a fiber cell is the cellulosic secondary wall which is deposited during fiber secondary wall deposition. Therefore, any environmental factor that affects photosynthetic carbon fixation and cellulose synthesis will also modulate cotton fiber wall thickening and, consequently, fiber quality. While the changes in levels of cellulose, callose and sucrose during fiber development are documented, it is not known whether these transient levels differ among various sowing dates and boll positions.

Thus, cellulose, callose and sucrose are important matters in fiber development and may highly relate to the final fiber quality. So, the objective of this research was to determine the changes of cellulose, callose and sucrose in different sowing dates and boll positions during fiber development and their relationship with the fiber quality properties. The research results should help getting intensive insights into the effects of the main agronomic

techniques on cotton fiber yield and quality.

MATERIALS AND METHODS

Plant material and experimental design

Field experiments were conducted at Jiangsu Academy of Agricultural Sciences, Nanjing (118°50'E, 32°02'N), Jiangsu (the Yangtze River Valley), China in 2006 and 2007. The soil at the experimental site was yellow-brown soil (Dystrudept) with 17.8 g kg⁻¹ organic matter, 0.9 g kg⁻¹ total N, 74.6 mg kg⁻¹ available N, 37.1 mg kg⁻¹ available P, and 214.0 mg kg⁻¹ available K contained in 20 cm depth of the soil profile.

The selected representative cotton cultivars (Kemian 1 and Sumian 15) were planted widely in the Yangtze River Valley in China in 2006 and 2007. Cotton was designed to sow in a nursery bed both in the normal season on 25 April, and the late sowing date on 25 May in the Yangtze River Valley. Cotton seedlings with three true leaves were transplanted to field with the planting density of 37,500 plants ha⁻¹. Each plot was 4 m wide and 15 m long. Treatments were assigned randomly in the field, and each treatment had 3 replications.

Sample collection and analysis

Cotton flowers were labeled at anthesis, and the bolls were collected from the first or the second node positions on low (2 to 3), middle (6 to 8) and upper (11 to 12) positional sympodial branches once every 6 days from 9 days post anthesis (DPA) until boll opening. In the Yangtze River Valley, the numbers of sympodial branches of cotton plant were about sixteen. Cotton boll samples were collected at 9:00 to 11:00 am. Fibers were removed manually from the seed without removing the seed coat. Fibers from different locules of eight bolls were used for dry weight measurement. Fresh and dry weights of separated fibers were recorded before and after oven drying to a constant weight at 40°C. Dry weight was expressed as fiber boll⁻¹ (that is, total amount of fibers obtained from one boll) (Gokani and Thaker, 2002).

Dry fibers were digested in an acetic-nitric reagent, and the cellulose content was measured with anthrone according to the method described by Updegraff (1969). Callose content was determined by the method reported by Kohle et al. (1985) with minor modification. About 0.5 g dry weight (DW) fiber samples were soaked for 2 h in 10 ml of ethanol to remove autofluorescent soluble materials. The suction-dried fibers were transferred into a glass potter homogenizer and disintegrated in 5 ml of 1 M NaOH. The resulting suspension was incubated at 80°C for 30 min in order that the callose would be solubilized and centrifuged (15 min, 4,000 g). The supernatant fluid was measured with aniline blue according to the method described by Zhang et al. (2009). Fluorescence of the assay was read in a HITACHI 850 spectrofluorometer (excitation 400 nm, emission 510 nm, slit 10 nm). Calibration curves were established using solution of the callose pachyman (4-20 μ g ml⁻¹) in 1 M NaOH. Sucrose was extracted and quantified by a modified method of Pettigrew (2001). About 0.3 g DW fiber samples were extracted with three successive 5 ml washes of 80% ethanol. The ethanol samples were incubated in an 80°C water bath for 30 min. Then the samples were centrifuged at 10,000 g for 10 min, and three aliquots of supernatant were collected together for sucrose measurement. The sucrose assay was conducted according to the method described by Hendrix (1993). At the end of the season, the remaining tagged bolls in each plot were harvested soon after the boll opening. Boll weight was determined by total seed cotton weight/total boll number (g boll⁻¹). The bolls from each plot were ginned separately. Fiber bundle strength, span lengths, micronaire was tested with high volume instrument (HVI).

Table 1. The flowering date and the period of cotton boll in different sympodial positions of 25 April and 25 May sowing date in 2006 and 2007.

Sowing date	2006			2007	
	Fruiting branch	Flowering date	Boll period (days)	Flowering date	Boll period (days)
25 April (N)	LPSB	15 Jul	45	15 Jul	45
	MPSB	29 Jul	51	25 Jul	45
	UPSB	13 Aug	57	12 Aug	51
25 May (L)	LPSB	29 Jul	51	12 Aug	51
	MPSB	13 Aug	57	22 Aug	57
	UPSB	25 Aug	63	1 Sep	63

LPSB is low positional sympodial branch; MPSB is middle positional sympodial branch; UPSB is upper positional sympodial branch.

Data analysis

Statistical analysis was performed by applying multiple comparisons of means of each sowing date and boll position using the Least Significant Difference (L.S.D.) test at the confidence level of 95%. Analysis of data was carried out with SPSS statistic package, Version 11.0, and the difference between mean values greater than the L.S.D._(0.95) was determined as significant. The coefficient of variation (CV) was calculated as the ratio of the standard deviation (including all sowing dates and boll positions) to the mean.

RESULTS

Sowing date and boll position effects on flowering date and boll period

The flowering date and boll period were affected by sowing date and boll position (Table 1). Late sowing (25 May) delayed flowering date and prolonged boll period of the boll developed in the same branch position, compared to normal sowing (25 April) in two years. Within each sowing date, the boll in upper positional sympodial branch (UPSB) generally had the longest boll period, followed by middle positional sympodial branch (MPSB) and low positional sympodial branch (LPSB). Although the bolls developed at different sowing dates and boll positions, the period of bolls flowered at the same day was similar (Table 1), which indicated that the difference of boll period was due to the changed environmental conditions at various flowering date (Table 1) (Stewart et al., 2000).

There were no significant differences between two cultivars on the flowering date and boll period at the same sowing date and boll position in two years, which showed that the two cotton cultivars (Kemian 1 and Sumian 15) had the similar development process.

Sowing date and boll position effects on boll weight and fiber properties

The sowing date and boll position effects were significant for boll weight, fiber strength, and micronaire (Table 2).

And sowing date × boll position significantly affected boll weight and fiber strength.

Bolls developed in normal sowing date has higher boll weight, longer and stronger fiber in MPSB and UPSB, and lower micronaire in any boll position. In normal sowing date (25 April), bolls developed in MPSB had the highest boll weight, fiber length, and fiber strength. In late sowing date (25 May), bolls developed in LPSB had the highest boll weight, fiber length, fiber strength, and they decreased with the increased fruiting branch. Within each sowing date, bolls developed in LPSB had lowest micronaire, and it increased as fruiting branch increase.

Boll weight of two cotton cultivars had different range among sowing date and boll position. Boll weight of Kemian 1 ranged within 5.23 to 4.40 g and 5.24 to 4.76 g respectively in the two years, higher than that of Sumian 15 which ranged within 5.22 to 4.19 g and 5.16 to 4.18 g respectively, in the two years. The coefficients of variance of boll weight in Sumian 15 among sowing dates and boll positions were bigger than that of Kemian 1 (Table 2). Similar results were observed in fiber strength. This indicated that Sumian 15 was more sensitive to the changed sowing dates and boll positions than Kemian 1 in boll weight and fiber strength.

Sowing date and boll position effects on dry weight of cotton fiber

Fiber dry weight of the two cotton cultivars changed following a typical sigmoidal curve as fiber developed (Figure 1). The fiber dry weight differed significantly ($P < 0.05$) between sowing dates (analyze data not shown). In the same position, bolls developed in normal sowing date had higher fiber dry weight. Within 15 DPA, fiber dry weight was low ($0.30 \text{ g fiber boll}^{-1}$), it increased sharply up to 45 DPA ($2.00 \text{ g fiber boll}^{-1}$), and declined slightly thereafter. Delaying the sowing date reduced the final fiber dry weight, which was determined by the delayed development process and the decreased rate of fiber dry weight accumulation.

There were differences among three boll positions. The change range of dry weight among sowing dates and boll

Table 2. Effects of sowing date and boll position on boll weight (g), fiber length (mm), fiber strength (cN tex⁻¹) and micronaire in 2006 and 2007.

Cultivar	Sowing date	Boll position	Boll weight		Fiber length		Fiber strength		Micronaire	
			2006	2007	2006	2007	2006	2007	2006	2007
Kemian 1	25 April (N)	LPSB	4.99±0.06 ^b	5.08±0.04 ^b	29.5±1.2 ^a	29.7±0.3 ^a	33.60±0.38 ^b	33.82±0.47 ^b	4.73±0.06 ^b	4.72±0.06 ^a
		MPSB	5.23±0.04 ^a	5.24±0.00 ^a	29.4±0.2 ^a	30.5±0.6 ^a	36.88±0.34 ^a	37.40±0.88 ^a	4.70±0.06 ^b	4.74±0.08 ^a
		UPSB	4.93±0.03 ^b	5.13±0.07 ^{ab}	30.7±0.9 ^a	29.9±0.7 ^a	33.63±1.09 ^b	34.71±0.50 ^b	4.83±0.00 ^a	4.80±0.09 ^a
	25 May (L)	LPSB	5.01±0.05 ^a	5.00±0.10 ^a	29.7±0.5 ^a	29.8±1.6 ^a	34.34±0.38 ^a	33.30±0.66 ^b	4.77±0.06 ^c	4.87±0.07 ^b
		MPSB	4.68±0.02 ^b	4.92±0.09 ^a	29.8±0.4 ^a	29.0±0.2 ^a	35.04±0.39 ^a	34.81±0.93 ^a	4.90±0.06 ^b	4.91±0.10 ^{ab}
		UPSB	4.40±0.06 ^c	4.76±0.05 ^b	28.9±1.4 ^a	28.5±0.0 ^a	32.56±0.65 ^b	31.62±0.40 ^c	5.03±0.06 ^a	5.00±0.07 ^a
	Sowing date		**	**	ns	*	**	**	**	**
	Boll position		**	*	ns	ns	**	**	**	*
	Sowing date × boll position		**	*	ns	ns	**	**	ns	ns
CV%			5.95	3.36	1.97	2.33	4.54	5.60	2.43	2.22
Sumian 15	25 April (N)	LPSB	4.94±0.11 ^b	4.93±0.13 ^b	28.9±0.3 ^a	28.7±0.5 ^b	29.76±0.53 ^b	29.18±1.32 ^b	4.67±0.06 ^{ab}	4.69±0.15 ^b
		MPSB	5.22±0.08 ^a	5.16±0.07 ^a	29.1±0.8 ^a	29.9±0.3 ^a	31.41±0.50 ^a	31.65±0.20 ^a	4.53±0.10 ^b	4.64±0.00 ^b
		UPSB	4.93±0.04 ^b	5.11±0.09 ^{ab}	28.5±0.3 ^a	28.0±0.5 ^b	26.68±0.03 ^c	29.40±0.50 ^b	4.77±0.06 ^c	4.83±0.03 ^a
	25 May (L)	LPSB	4.69±0.13 ^a	4.92±0.09 ^a	28.3±0.2 ^a	28.5±1.0 ^a	28.48±0.30 ^a	27.93±0.79 ^a	4.90±0.06 ^b	4.89±0.08 ^b
		MPSB	4.62±0.21 ^a	4.58±0.08 ^b	28.0±0.5 ^{ab}	28.3±0.9 ^a	28.68±0.15 ^a	28.37±0.11 ^a	4.93±0.12 ^{ab}	4.95±0.02 ^{ab}
		UPSB	4.19±0.26 ^b	4.18±0.08 ^c	27.3±0.9 ^b	27.4±0.4 ^a	24.57±0.37 ^b	24.50±0.62 ^b	5.07±0.06 ^a	5.05±0.05 ^a
	Sowing date		**	**	**	*	**	**	**	**
	Boll position		**	**	ns	**	**	**	**	**
	Sowing date × boll position		*	**	ns	ns	*	**	ns	ns
CV%			7.38	7.69	2.99	2.95	8.45	8.23	4.47	3.21

CV (%), coefficient of variation. LPSB is low positional sympodial branch; MPSB is middle positional sympodial branch; UPSB is upper positional sympodial branch. Values followed ± are data errors. Values followed by the different letters within the same column are significantly different at 0.05 probability level. Each data represents the mean of four replications. *Significant at P < 0.05; ** Significant at P < 0.01; ns, not significant.

positions differed significantly (P < 0.05) between two cultivars, the change range of Sumian 15 was larger than Kemian 1.

Sowing date and boll position effects on fiber cellulose content and callose content

Our experiments showed that fibers of all treatments had similar content of cellulose at 9 DPA.

After 15 DPA, the fiber for normal sowed cotton had higher cellulose content than that for late sowed cotton at the same boll position. Immature fibers have relatively thin secondary cell walls that contain less cellulose than the cell walls of more mature fiber (Bradov et al., 1997). At mature stage (50 DPA), fiber in the normal sowed cotton had 7.8% greater cellulose content than that in late sowed cotton (Figure 2). In three boll positions, cellulose content in fibers of MPSB was

higher than that of LPSB and UPSB in normal sowing date, whereas in late sowing date, fibers of LPSB had the highest cellulose content. In the two tested cotton cultivars, Sumian 15 had the higher change range from normal sowing date to late sowing date.

A single-peak curve represented the change in callose content during fiber development, the maximum callose content was reached at 15 and 21 DPA, and then declined at 33 DPA and was

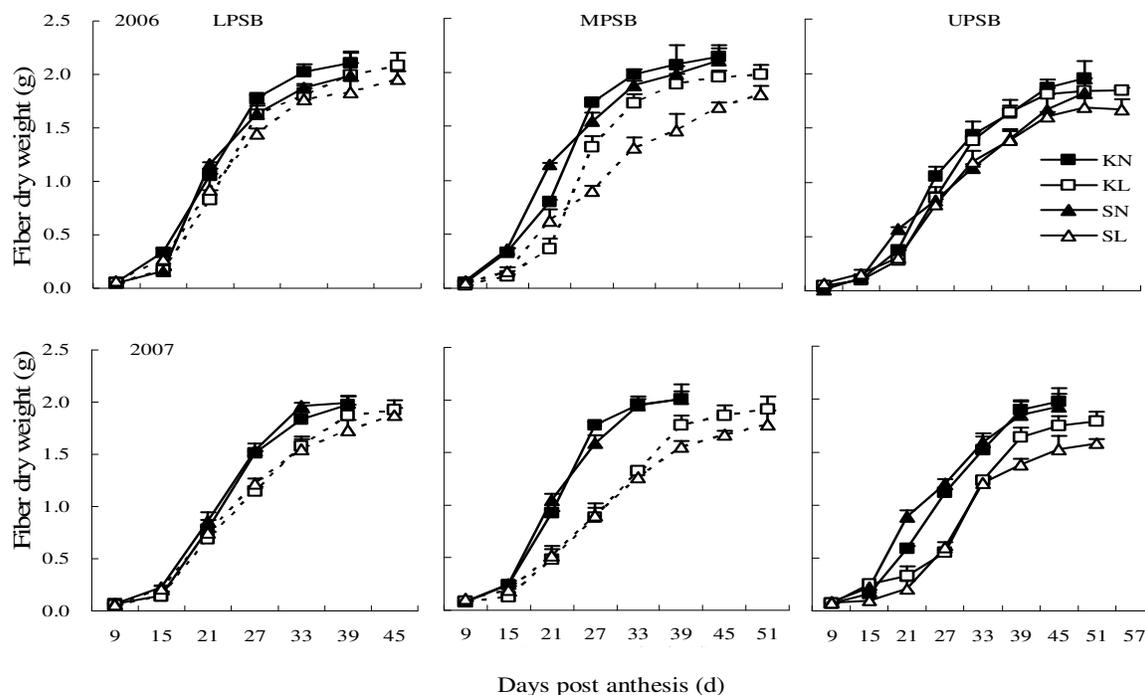


Figure 1. Changes in fiber dry weight (g fiber boll⁻¹) with days post anthesis in two cotton cultivars in 2006 and 2007. KN is Kemian 1 in normal sowing date (25 April), KL is Kemian 1 in late sowing date (25 May), SN is Sumian 15 in normal sowing date, SL is Sumian 15 in late sowing date. LPSB is low positional sympodial branch; MPSB is middle positional sympodial branch; UPSB is upper positional sympodial branch. Vertical bars represent standard errors.

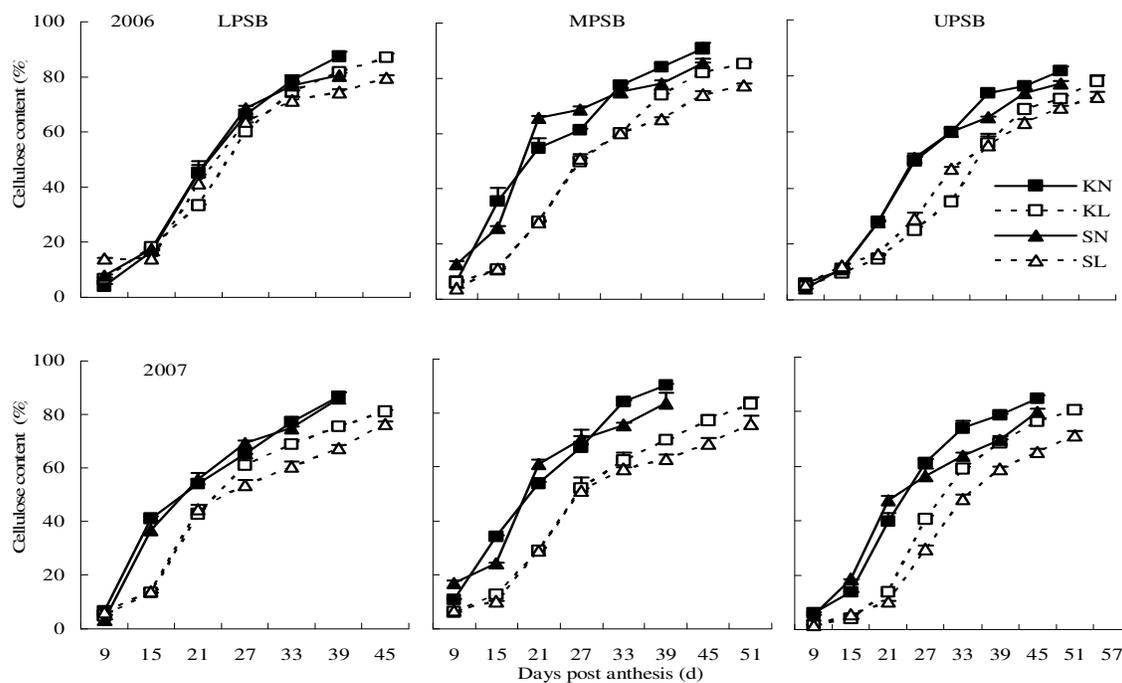


Figure 2. Changes in cellulose content (%) with days post anthesis in two cotton cultivars in 2006 and 2007. KN is Kemian 1 in normal sowing date (25 April), KL is Kemian 1 in late sowing date (25 May), SN is Sumian 15 in normal sowing date, SL is Sumian 15 in late sowing date. LPSB is low positional sympodial branch; MPSB is middle positional sympodial branch; UPSB is upper positional sympodial branch. Vertical bars represent standard errors.

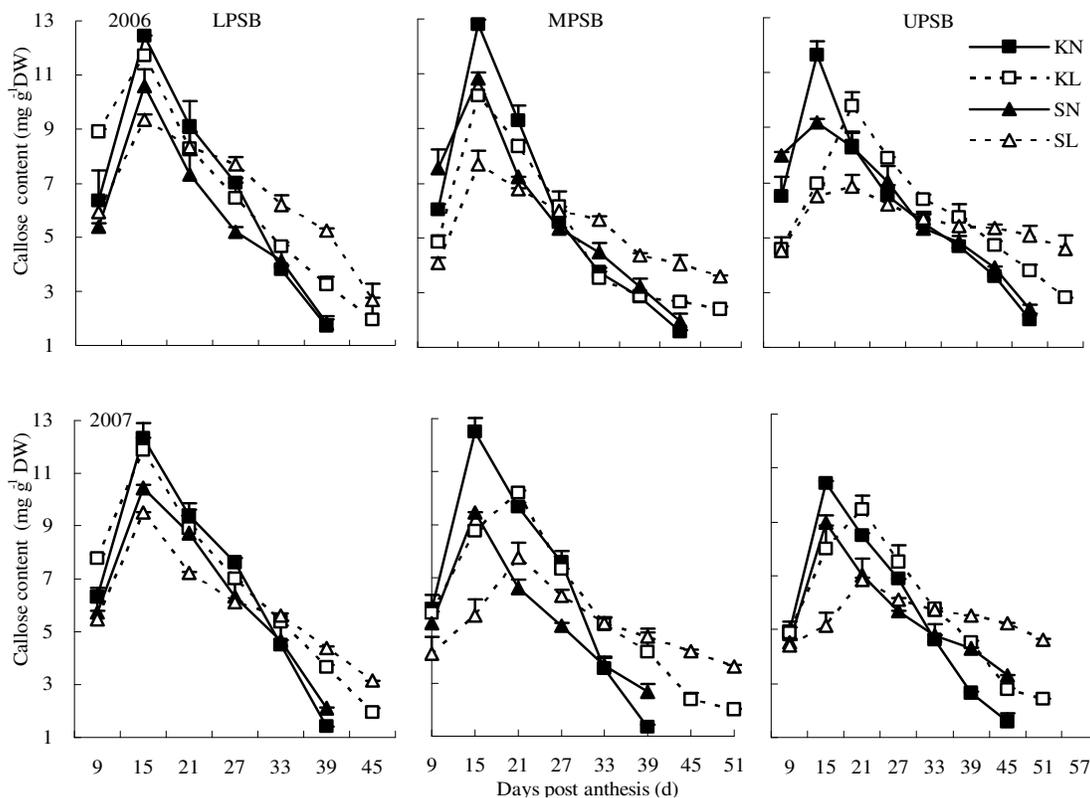


Figure 3. Changes in callose content ($\text{mg g}^{-1}\text{DW}$) with days post anthesis in two cotton cultivars in 2006 and 2007. KN is Kemian 1 in normal sowing date (25 April), KL is Kemian 1 in late sowing date (25 May), SN is Sumian 15 in normal sowing date, SL is Sumian 15 in late sowing date. LPSB is low positional sympodial branch; MPSB is middle positional sympodial branch; UPSB is upper positional sympodial branch. Vertical bars represent standard errors.

Table 3. Effects of sowing date and boll position on fiber dry weight, cellulose content and callose content in mature fiber in 2006 and 2007.

Cultivar	Sowing date	Boll position	Fiber dry weight		Cellulose		Callose	
			2006	2007	2006	2007	2006	2007
Kemian 1	Sowing date		**	**	**	**	*	**
	Boll position		**	**	**	**	ns	*
	Sowing date × boll position		**	**	**	*	ns	ns
Sumian 15	Sowing date		**	**	**	**	**	**
	Boll position		**	**	**	**	**	**
	Sowing date × Boll position		**	**	**	ns	*	ns

* Significant at $P < 0.05$; ** Significant at $P < 0.01$; ns, not significant.

maintained at a low level until fiber matured (Figure 3), this result was similar to Zabotin et al. (2002). Callose content was affected by sowing date. At the same boll position, late sowing reduced the maximum value of callose content in fiber, but it increased the value of callose content in the mature fiber. This indicated that late sowed cotton had lower transformation rate of callose during fiber development. From the results of three positions in 2006 and 2007, the difference of

normal sowed cotton and late sowed cotton was changed with boll position. The difference became larger as the boll position turns higher.

The compositions of cell wall in mature fiber (the last harvest fiber) directly determined the fiber quality. Fiber dry weight and cellulose content in mature fiber were significantly affected by sowing date and boll position, callose content was only affected by sowing date (Table 3). And the change range of mature fiber dry weight,

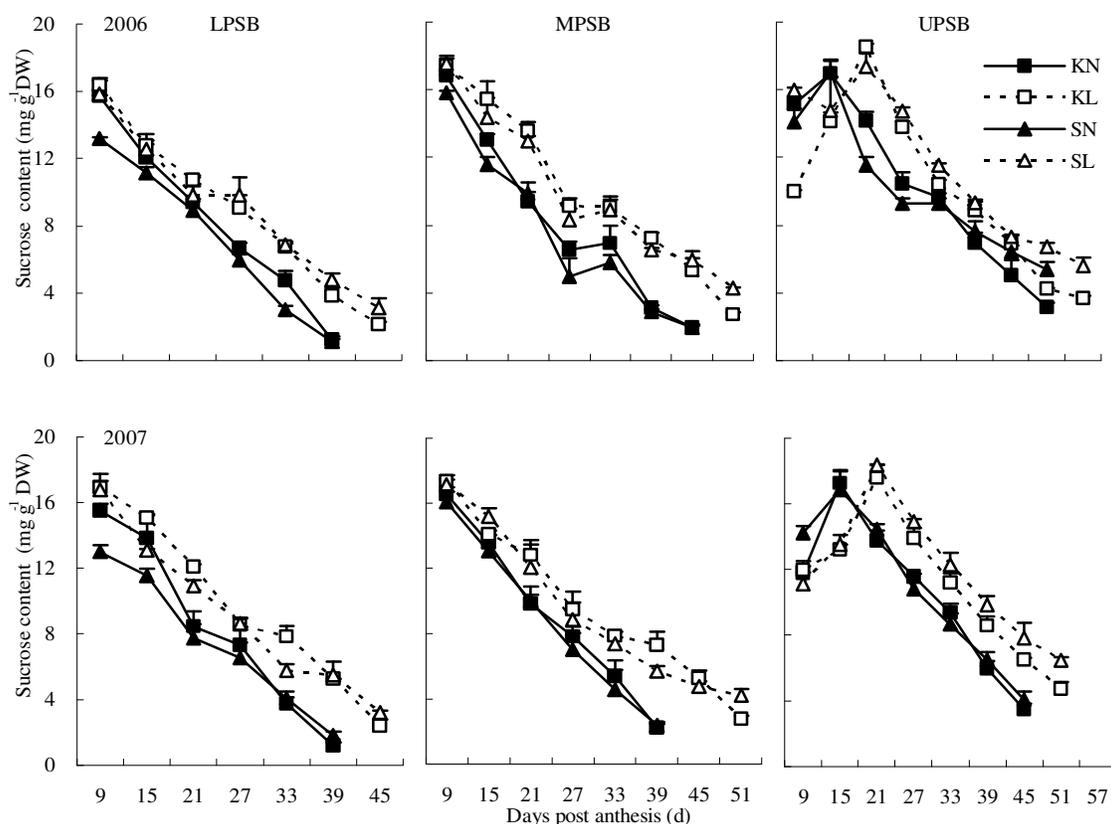


Figure 4. Changes in sucrose content ($\text{mg g}^{-1}\text{DW}$) with days post anthesis in two cotton cultivars in 2006 and 2007. KN is Kemian 1 in normal sowing date (25 April), KL is Kemian 1 in late sowing date (25 May), SN is Sumian 15 in normal sowing date; SL is Sumian 15 in late sowing date. LPSB is low positional sympodial branch; MPSB is middle positional sympodial branch; UPSB is upper positional sympodial branch. Vertical bars represent standard errors.

cellulose content and callose content of sumian 15 were larger than that in Kemian 1.

Sowing date and boll position effects on fiber sucrose content and sucrose transformation rate

The change trends of sucrose content in all tested fibers looked very similar except the fibers of UPSB (Figure 4). During cotton fiber development, sucrose content in cotton fibers declined from 9 DPA in LPSB and MPSB, but from 15 or 21 DPA in UPSB (Figure 4).

Sucrose transformation rate of cotton fiber reflects the sucrose transforming capacity during cotton fiber development (Shu et al., 2009). Significant difference in sucrose transformation rate occurred among various sowing dates, boll positions and sowing date \times boll position (Table 4). In normal sowing date, sucrose transformation rate in fiber of MPSB were the highest. Late sowing reduced sucrose transformation rate in cotton fiber (Table 4), and the UPSB had the lowest sucrose transformation rate.

The coefficients of variance of the sucrose transformation

rate of Sumian 15 among sowing dates and boll positions was higher than that of Kemian 1 (Table 4). This was positively related to the change of cellulose content among sowing dates and boll positions.

DISCUSSION

Numbers of studies have reported that sowing date affected cotton yield and fiber quality, but the results were always inconsistent (Porter et al., 1996; Dong et al., 2006; Wang et al., 2009). In our experiment, sowing dates significantly affected cotton boll weight and fiber quality especially fiber strength. Boll weight and fiber strength decreased in late sowing date due to the low boll period temperature in the sowing date (Pettigrew 2001; Davidonis et al., 2004).

In the same sowing date, boll weight and fiber quality were affected by boll position. In normal sowing date, the bolls in MPSB had the highest boll weight and the best fiber quality. Whereas in late sowing date, boll weight and fiber strength decreased as the fruiting branch position increased. The different trends of boll weight and fiber

Table 4. Effects of sowing date and position on sucrose transformation rate (%) in 2006 and 2007.

Sowing date	Boll position	Kemian 1		Sumian 15	
		2006	2007	2006	2007
25 April (N)	LPSB	86.19 ± 1.37 ^b	85.26 ± 0.65 ^a	84.46 ± 1.18 ^a	82.05 ± 1.67 ^b
	MPSB	88.59 ± 1.27 ^a	86.61 ± 1.11 ^a	87.80 ± 1.42 ^a	85.25 ± 0.08 ^a
	UPSB	81.24 ± 0.93 ^c	85.77 ± 1.16 ^a	70.61 ± 1.38 ^b	75.75 ± 0.81 ^c
25 May (L)	LPSB	86.80 ± 0.39 ^a	82.44 ± 1.04 ^b	77.25 ± 3.12 ^a	68.23 ± 1.36 ^b
	MPSB	84.35 ± 1.06 ^b	84.19 ± 0.57 ^a	77.50 ± 0.74 ^a	75.34 ± 0.66 ^a
	UPSB	80.07 ± 1.02 ^c	80.59 ± 0.72 ^c	67.88 ± 1.80 ^b	64.76 ± 0.91 ^c
Sowing date		**	**	**	**
Boll position		**	**	**	**
Sowing date × boll position		**	*	*	*
CV%		3.93	2.68	9.89	10.40

CV (%), coefficient of variation. LPSB is low positional sympodial branch; MPSB is middle positional sympodial branch; UPSB is upper positional sympodial branch. Values followed ± are data errors. Values followed by the different letters within the same column are significantly different at 0.05 probability level. Each data represents the mean of four replications. *Significant at $P < 0.05$; ** Significant at $P < 0.01$; ns, not significant.

quality among different fruiting branches in different sowing dates suggested that boll position and sowing date had interaction effects on boll weight and fiber quality. Deteriorated environment in late sowing date could reduce the effect of the boll position, and this result was similar to the research of Shan et al. (2002), Jiang et al. (2006), and Wang et al. (2006). Fiber quality is determinate by the fiber cell development process, which involving lots physiological events (Haigler et al., 2001; Delmer and Haigler, 2002). In this present research, parameters of the key physiological matters changes (cellulose, callose and sucrose) in fiber development changed in different sowing dates or boll positions, which consequently led to the changes of fiber dry weight and quality. In late sowing date, sucrose content and callose content increased, but sucrose transformation rate and cellulose content decreased. This may be related to the deteriorated environmental condition in the late sowing date. The deteriorated environment induced callose synthesis of changed the membrane-associated sucrose synthase (M-SuSy) to soluble sucrose synthase (S-SuSy), and then reduced the substrate UDP-glucos for cellulose synthesis (Haigler et al., 2001), thus the cellulose content decreased and callose content increased. Meanwhile, sucrose in fiber cell is degraded by sucrose synthase (SuSy) to provide UDP-glucose for cellulose synthesis (Delmer and Amor, 1995; Haigler et al., 2001). As sucrose content increased and the sucrose transformation rate must had been lowered, so we can infer that in late sowing date cotton plant, there was enough sucrose in cotton fiber, but it could not be fluently used in cellulose synthesis as in normal sowing date (Shu et al., 2009). Previous studies have proved that the lower the amount of cellulose accumulated in fiber cell, the lower the fiber strength was (Liaktas et al., 1998; Martin and Haigler, 2004). Therefore, the changes of

cellulose, callose and sucrose, including their accumulation parameters may cause changes of the final fiber weight and fiber quality.

On the same sowing date, boll position significantly influenced the fiber dry matter and parameters the cellulose, callose and sucrose accumulation. In normal sowing date, the bolls in MPSB had the highest cellulose content and sucrose transformation rate. Whereas in the late sowing date, cellulose content and sucrose transformation rate decreased with the increased fruiting branch. The influence of sowing date and boll position on cellulose content and sucrose transformation rate was accord with the influence of sowing date and boll position on boll weight and fiber strength.

The response of cellulose content, callose content and transformation rate to the changed sowing dates and boll positions differed between Kemian 1 and Sumian 15 in this study (Tables 2 to 4), Sumian 15 was sensitive, Kemian 1 was partially tolerant to the changed sowing dates and boll positions. Similar phenomenon was also observed in boll weight and fiber quality. This result indicated that different genotypes adopted different physiological strategies under different environmental conditions (Hund et al., 2008). These results also indicated that response of boll weight and fiber quality to environmental factor and boll positions are related to the accumulation parameters of fiber development (cellulose, callose and sucrose). Thus, boll weight and fiber quality were affected by sowing date and boll position, and the accumulation parameters of cellulose, callose and sucrose were important factors relating to fiber quality. To improve the boll weight and fiber quality, two ways can be adopted, one is selecting optimum sowing date, and the other is breeding new cultivars which were insensitivity to environment. If selecting the latter ways, the fiber physiological parameters should be concerned.

Conclusion

Sowing date, boll position, and sowing date × boll position affected boll weight and fiber quality. Late sowing decreased cotton fiber yield and quality, which were due to bad environmental condition. Boll position affected cotton development, but the influence in different sowing dates was different. Selecting suitable sowing date is very important to optimize climatic environment in respect to growth, yield and fiber quality. Fiber yield and quality differed in different sowing dates and boll positions. It may be related to the change in synthesis of cellulose, callose and sucrose during the fiber development in different sowing dates and boll positions. Increasing the cellulose content and sucrose transformation rate can improve yield and fiber quality in late sowing date or sub-optimal environmental conditions. Understanding the effects of sowing date and boll position on cotton fiber development will help in getting deeper insight into the formation of cotton fiber yield and quality.

ACKNOWLEDGEMENTS

This work was funded by the National Natural Science Foundation of China (Grant Nos. 30600378, 30771279) and the Jiangsu Province Natural Science Foundation (Grant Nos. BK2006141).

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