Regional Distribution Characteristics of Cotton Fiber Quality Traits in China' s Main Cotton-Producing Areas (Postprint)

Authors: Xu Naiyin, Li Jian

Date: 2017-11-07T00:00:00+00:00

Abstract

China' s main cotton-producing regions and their sub-regions exhibit distinct regional characteristics in cotton fiber quality. Timely evaluation of the current status of fiber quality development in various cotton regions helps stabilize advantageous cotton production areas and promote the development of characteristic cotton production areas. This study employed GGE biplot analysis to examine the interaction patterns between environments and fiber quality traits across sub-regions in the national cotton variety regional trials from 2011 to 2015, and comparatively analyzed the fiber quality characteristics of various main cotton-producing regions and sub-regions. The results showed: 1) At the scale of main cotton-producing regions, the Yangtze River cotton region exhibited the best fiber length and strength, both meeting the Grade II standard of national cotton variety approval, while its micronaire value and spinning consistency index were intermediate; the Yellow River cotton region had relatively good fiber length and strength, but its micronaire value was relatively high; the Northwest Inland cotton region showed the best performance in micronaire value and spinning consistency index, with fiber length and micronaire value meeting the Grade II standard of national cotton variety approval, but its fiber strength performed the poorest among the three major cotton regions. 2) At the cotton sub-region scale, fiber length performance was best in the lower and upper Yangtze River sub-regions, slightly poorer in the Loess Plateau sub-region, and relatively good in the remaining sub-regions; fiber strength performance was best in the lower Yangtze River, middle Yangtze River, Huaibei Plain, Nanxiang Basin, and Loess Plateau, while slightly poorer in the Southern Xinjiang cotton region, upper Yangtze River, and Northern Xinjiang cotton region; micronaire value performed best in the Northern Xinjiang cotton region, Southern Xinjiang cotton region, and upper Yangtze River, while being relatively high in the Loess Plateau, Huaibei Plain, middle Yangtze River, and North China Plain. 3) In terms of comprehensive fiber quality performance, the Northern Xinjiang

cotton region, lower Yangtze River, upper Yangtze River, and Southern Xinjiang cotton region exhibited the best comprehensive performance, followed by the Huaibei Plain, middle Yangtze River, and Nanxiang Basin, while the North China Plain and Loess Plateau were slightly poorer. This study demonstrates the application effectiveness of the 'environment-trait' functional mapping of GGE biplot in evaluating regional characteristics of fiber quality, which can provide theoretical basis for the development of advantageous cotton production areas in China and rational cotton utilization by textile enterprises, and holds guiding significance for the ecological zoning of cotton fiber quality across the nation.

Full Text

Regional Distribution Characteristics of Cotton Fiber Quality Traits in Main Cotton Production Areas of China

XU Naiyin, LI Jian
(Key Laboratory of Cotton and Rapeseed, Ministry of Agriculture / Institute of Industrial Crops, Jiangsu Academy of Agricultural Sciences, Nanjing 210014, China)

Abstract

Significant regional characteristics of cotton fiber quality are evident in China's main cotton production areas and their subregions. Timely evaluation of fiber quality development status in each cotton region facilitates the stabilization of advantageous production areas and promotes the development of specialized cotton regions. This study employed GGE biplot analysis to examine the interaction patterns between subregional environments and fiber quality traits from national cotton regional trials conducted between 2011 and 2015, comparing fiber quality characteristics across main production areas and subregions. The results indicated: (1) At the scale of main production areas, the Changjiang River Valley exhibited the best fiber length and strength, both meeting the Class II standard for national cotton variety registration, while micronaire value and spinning consistency index were moderate. The Huanghe River Valley showed good fiber length and strength but high micronaire values. The Northwest Inland area demonstrated the best micronaire value and spinning consistency index, with fiber length and micronaire reaching Class II standards, though fiber strength was the poorest among the three regions. (2) At the subregional scale, fiber length was optimal in the lower and upper reaches of the Changjiang River Valley, slightly poorer in the Loess Plateau, and relatively good in other subregions. Fiber strength performed best in the lower and middle reaches of the Changjiang River Valley, Huaibei Plain, Nanxiang Basin, and Loess Plateau, but was slightly inferior in the southern Xinjiang region, upper Changjiang reaches, and northern Xinjiang. Micronaire value was optimal in northern Xinjiang, southern Xinjiang, and the upper Changjiang reaches, while the Loess Plateau, Huaibei Plain, middle Changjiang reaches, and North China Plain showed higher values. (3) For comprehensive fiber quality performance, northern Xinjiang, lower Changjiang reaches, upper Changjiang reaches, and southern Xinjiang performed best, followed by Huaibei Plain, middle Changjiang reaches, and Nanxiang Basin, with North China Plain and Loess Plateau performing relatively poorly. This study demonstrates the effectiveness of the "environment-trait" GGE biplot functional map for evaluating regional fiber quality characteristics, providing a theoretical basis for developing advantageous cotton production areas and rational cotton utilization by textile enterprises, and offering guidance for ecological regionalization of cotton fiber quality in China.

Keywords: Cotton (Gossypium hirsutum L.); GGE biplot; Fiber quality; Main cotton production area; Regional trial; Environment by trait interaction

---

1. Materials and Methods

1.1 Data Sources

Data were obtained from fiber quality records of national cotton regional trials in three main production areas (Changjiang River Valley, Huanghe River Valley, and Northwest Inland) between 2011 and 2015. Detailed information on trial groups, cultivars, and test sites is provided in Table 1 . All field experiments at each site employed a randomized complete block design with three replications and plot areas of 20 m^2. In addition to yield, agronomic traits, and disease resistance assessments per national protocol, 50 normally opened bolls from middle fruiting branches were collected at peak boll opening stage. After sun-drying, seed cotton ginning, and lint processing, fiber samples were tested by the Cotton Quality Supervision, Inspection and Testing Center of the Ministry of Agriculture. Measured traits included fiber length, uniformity index, strength, elongation, micronaire value, reflectance, yellowness, and spinning consistency index. Field management practices including cultivation methods, planting density, fertilization, and pest control followed local high-yield protocols. This study analyzed fiber quality data from 755 individual site trials organized into 46 trial groups across the three main cotton production areas to characterize regional distribution patterns.

1.2 Cotton Region Classification

China' s three main cotton production areas—Changjiang River Valley, Huanghe River Valley, and Northwest Inland—are each subdivided into distinct subregions [1]. Based on national cotton regional trial groupings, site distributions, and traditional regional divisions, this study analyzed fiber quality data for the upper, middle, and lower Changjiang reaches, Nanxiang Basin, Huaibei Plain, North China Plain, Loess Plateau, and northern and southern Xinjiang subregions [1].

Subregion codes and their corresponding geographic coverage are detailed in Table 2 .

1.3 Statistical Analysis Methods

First, the "which-won-where" function of the "environment-trait" GGE biplot (ET biplot) was employed to analyze interaction patterns between subregional environments and fiber quality traits based on comprehensive performance during 2011-2015 [13,18-19,23]. In this visualization, connecting the outermost environment icons (subregions) forms a polygon containing all environments. Perpendicular lines from the biplot origin to each polygon side divide it into sectors, with traits in the same sector forming a trait combination. The environment at the polygon vertex within each sector represents the "winning environment" where that trait combination performs best [23]. Second, the "ranking" function of the ET biplot [13,23-24] was used to compare and rank subregions based on fiber length, strength, micronaire value, and spinning consistency index. Concentric circles centered on target traits facilitate visual comparison—shorter distances between subregion icons and the center indicate better trait performance [18,25]. Finally, DPS© software performed ANOVA and LSD multiple comparisons of main fiber quality traits among main production areas and subregions to characterize regional features [26].

2. Results

2.1 Fiber Quality Characteristics of China' s Three Main Cotton Production Areas

Mean values and significance tests for fiber quality indices across the three regions (Table 3) revealed significant differences (Table 3). Specifically: (1) The Changjiang River Valley showed the highest fiber length, strength, and uniformity index, with moderately high micronaire values but poorest elongation. Fiber length was significantly higher than in the Huanghe River Valley but not significantly different from the Northwest Inland region. Strength and uniformity index were significantly higher than both other regions. Micronaire value was slightly lower than the Huanghe River Valley but significantly higher than the Northwest Inland region. Elongation was significantly lower than in the other two regions. (2) The Huanghe River Valley ranked lowest in fiber length, micronaire value, reflectance, yellowness, and spinning consistency index, with moderate strength performance. Fiber length, reflectance, and spinning consistency index were significantly lower than in both other regions. Strength was significantly lower than the Changjiang River Valley but higher than the Northwest Inland region. Micronaire value and yellowness did not differ significantly from the Changjiang River Valley but were significantly worse than the Northwest Inland region. (3) The Northwest Inland region exhibited the best micronaire value, elongation, reflectance, yellowness, and spinning consistency index, with moderate fiber length but poorest strength. Micronaire value, reflectance, elongation, and spinning consistency index were significantly superior to both other regions. Yellowness was significantly better than the Huanghe River Valley and comparable to the Changjiang River Valley. Strength was significantly lower than both other regions. Fiber length was slightly lower than the Changjiang River Valley but significantly higher than the Huanghe River Valley. Overall, the Northwest Inland region demonstrated the best comprehensive fiber quality, followed by the Changjiang River Valley, then the Huanghe River Valley. Each region exhibited distinct characteristics: the Changjiang River Valley had optimal fiber length and strength (meeting Class II standards) with moderate micronaire and spinning consistency index; both the Changjiang and Huanghe River Valleys met Class II standards for length and strength but only Class III for micronaire; the Northwest Inland region showed optimal micronaire and spinning consistency index with moderate length (meeting Class II standards) but poorest strength (Class III only).

2.2 Interaction Between Subregions and Fiber Quality Traits in Main Cotton Production Areas

GGE biplot analysis of fiber quality traits from 2011–2015 national trials revealed that nine ecological subregions across the three main cotton areas could be divided into five "trait-environment" combinations (Figure 1 [Figure 1: see original paper]): (1) The lower Changjiang reaches subregion showed optimal fiber length and uniformity index; (2) The middle Changjiang reaches subregion exhibited highest fiber strength; (3) The Loess Plateau subregion displayed highest micronaire value and yellowness; (4) The southern Xinjiang region showed longest elongation with low micronaire values; and (5) The northern Xinjiang region demonstrated highest spinning consistency index and reflectance. These results indicate significant genotype-by-environment interactions, with notable quality variations among subregions within the same main region and regional overlaps in quality performance across different main regions. Specifically, the upper and lower Changjiang reaches showed optimal fiber length and uniformity; the middle Changjiang reaches and Nanxiang Basin, along with Huaibei Plain in the Huanghe River Valley, exhibited similar performance with relatively high strength and micronaire values; the North China Plain and Loess Plateau subregions in the Huanghe River Valley showed high micronaire values; and fiber quality differed between early-maturing northern Xinjiang and early-medium maturing southern Xinjiang subregions. Thus, traditional three-region classifications do not fully align with fiber quality performance, necessitating further analysis of ecological subregion characteristics.

2.3 Performance of Main Fiber Quality Traits Across Ecological Subregions

The concentric circles centered on main quality traits in the GGE biplot of subregion-by-trait interactions provide intuitive visualization of trait responses. Shorter distances between subregion icons and the center indicate higher phenotypic values. Figure 2 [Figure 2: see original paper] shows: (a) Fiber length was best in the upper and lower Changjiang reaches, followed by northern Xinjiang, Huaibei Plain, middle Changjiang reaches, and Nanxiang Basin, with southern Xinjiang, North China Plain, and Loess Plateau performing relatively poorly. (b) Fiber strength was highest in the middle Changjiang reaches and Huaibei Plain, poorest in the Northwest Inland region, and moderate in remaining subregions. (c) Micronaire value was optimal in the Northwest Inland region, good in the upper and lower Changjiang reaches, moderate in Nanxiang Basin and North China Plain, and relatively poor in the middle Changjiang reaches, Huaibei Plain, and Loess Plateau. (d) Spinning consistency index was best in the upper and lower Changjiang reaches and northern Xinjiang, good in Huaibei Plain, middle Changjiang reaches, Nanxiang Basin, and southern Xinjiang, and relatively poor in North China Plain and Loess Plateau.

2.4 Fiber Quality Characteristics of Ecological Subregions in Main Cotton Production Areas

Mean values and significance tests across subregions (Table 4) revealed significant differences at the 5% level. Specifically: (1) Fiber length was best in the lower and upper Changjiang reaches, both averaging above 30 mm and significantly different from all subregions except northern Xinjiang. The Loess Plateau subregion, with fiber length below 29 mm, differed significantly from all subregions except North China Plain. Southern Xinjiang, Huaibei Plain, middle Changjiang reaches, Nanxiang Basin, and North China Plain showed good performance with fiber lengths between 29–30 mm. The ranking was: lower Changjiang > upper Changjiang > northern Xinjiang > southern Xinjiang > Huaibei Plain > middle Changjiang > Nanxiang Basin > North China Plain > Loess Plateau. (2) Strength in the lower Changjiang reaches, middle Changjiang reaches, Huaibei Plain, Nanxiang Basin, and Loess Plateau exceeded 30 $cN \cdot tex^{1}$, meeting Class II standards. The lower and middle Changjiang reaches and Huaibei Plain showed significantly higher strength than other subregions except Nanxiang Basin and Loess Plateau. Southern Xinjiang, upper Changjiang reaches, and northern Xinjiang showed slightly lower strength but still above 28 $cN \cdot tex^{1}$ (Class III). The ranking was: lower Changjiang > middle Changjiang > Huaibei Plain > Nanxiang Basin > Loess Plateau > North China Plain > northern Xinjiang > upper Changjiang > southern Xinjiang. (3) Micronaire values below 5.0 (Class II) in northern Xinjiang, southern Xinjiang, and upper Changjiang reaches were significantly different from other subregions except Nanxiang Basin. The Loess Plateau, Huaibei Plain, middle Changjiang reaches, and North China Plain showed high micronaire values without significant differences among them but significantly higher than other subregions except lower Changjiang. The ranking was: northern Xinjiang > southern Xinjiang > upper Changjiang > Nanxiang Basin > lower Changjiang > North China Plain > middle Changjiang > Huaibei Plain > Loess Plateau. (4) Spinning consistency index was significantly higher in northern Xinjiang, lower Changjiang reaches, and upper Changjiang reaches compared with North China Plain and Loess Plateau, with other subregions showing moderate values. The ranking was:

northern Xinjiang > lower Changjiang > upper Changjiang > southern Xinjiang > Huaibei Plain > middle Changjiang > Nanxiang Basin > North China Plain > Loess Plateau. Overall, while fiber length varied, all subregions except Loess Plateau met Class II standards. An undesirable positive correlation existed between strength and micronaire—northern Xinjiang, southern Xinjiang, and upper Changjiang reaches had micronaire values below 5.0 but strength below 30 cN · tex ^{1}. Comprehensive fiber quality was best in northern Xinjiang, lower Changjiang reaches, upper Changjiang reaches, and southern Xinjiang, good in Huaibei Plain, middle Changjiang reaches, and Nanxiang Basin, but relatively poor in North China Plain and Loess Plateau.

3. Discussion

3.1 Regional Characteristics of Fiber Quality in China' s Three Main Cotton Production Areas

The three main cotton production areas—Changjiang River Valley, Huanghe River Valley, and Northwest Inland—exhibit substantial differences in climate, ecology, and cultivation conditions [14]. Cotton fiber quality development is significantly influenced by environmental factors [2,7] and shows notable genotype-by-environment interactions [5], resulting in distinct regional distribution patterns [7-9]. Previous studies have documented historical fiber quality characteristics [7-9,13-17], but lacked analysis of current status during the 12th Five-Year Plan period and cross-subregional comparisons. This study analyzed recent progress in regional fiber quality characteristics using national cotton regional trial data, offering stronger representativeness and reliability. Results show the Changjiang River Valley currently has the best fiber length and strength (both meeting Class II standards) with moderate micronaire and spinning consistency index. The Huanghe River Valley shows good length and strength but high micronaire values. The Northwest Inland region demonstrates optimal micronaire and spinning consistency index, with length and micronaire meeting Class II standards but poorest strength among the three regions. These findings differ slightly from earlier research but better reflect current status and trends using the latest data from 2011-2015 national trials.

3.2 Regional Characteristics Among Subregions in Main Cotton Production Areas

Main cotton production areas are divided into subregions based on geography: the Changjiang River Valley includes upper, middle, and lower reaches plus Nanxiang Basin; the Huanghe River Valley comprises Huaibei Plain, North China Plain, and Loess Plateau; and the Northwest Inland includes southern and northern Xinjiang [1]. Environmental differences among subregions differentially affect fiber development [14,27], creating significant quality variations [5,8-9,13]. Previous provincial studies have identified subregional quality differences [8,9,13,15-17,30], but cross-regional comparative studies remain rare. This study employed the GGE biplot "environment-trait" functional map to explore interactions between subregional environments and fiber quality indices during 2011-2015, providing intuitive visualization of subregional responses and enabling cross-regional comparisons. Results demonstrate clear geographic patterns: fiber length was optimal in lower and upper Changjiang reaches; strength was best in lower Changjiang reaches, middle Changjiang reaches, Huaibei Plain, Nanxiang Basin, and Loess Plateau; micronaire value was optimal in northern Xinjiang, southern Xinjiang, and upper Changjiang reaches; and comprehensive quality was best in northern Xinjiang, lower Changjiang reaches, upper Changjiang reaches, and southern Xinjiang. These clear relationships between ecological subregions and fiber quality traits provide valuable guidance for developing advantageous cotton production areas.

References

[1] Cotton Research Institute of Chinese Academy of Agricultural Sciences. Chinese Cotton Cultivation[M]. Shanghai: Shanghai Science and Technology Press, 2013

[2] Smith C W, Braden C A, Hequet E F. Genetic analysis of fiber length uniformity in upland cotton[J]. Crop Science, 2010, 50(2): 567-573

[3] Read J J, Reddy K R, Jenkins J N. Yield and fiber quality of upland cotton as influenced by nitrogen and potassium nutrition[J]. European Journal of Agronomy, 2006, 24(3): 282-290

[4] Ma F Y, Zhu Y, Cao W X, et al. Modeling fiber quality formation in cotton[J]. Acta Agronomica Sinica, 2006, 32(3): 442-448

[5] Xu N Y, Zhang G W, Li J, et al. Investigation of cotton mega-environment based on fiber strength selection and GGE biplot[J]. Chinese Journal of Eco-Agriculture, 2012, 20(11): 1500-1507

[6] Xu N Y, Li J, Zhang G W, et al. Evaluation of regional cotton variety trial environments based on cotton fiber micronaire selection by using GGE biplot analysis[J]. Chinese Journal of Eco-Agriculture, 2013, 21(10): 1241-1248

[7] Xu N Y, Chen X S, Di J C, et al. Studies on the regional characteristics of cotton fiber quality in Yangtze Valley[J]. Cotton Science, 2003, 15(4): 221-226

[8] Li X Y, Qin W B, Sun G Q, et al. Study on ecological distribution of Xinjiang cotton fibre quality[J]. Journal of Xinjiang Agricultural University, 2003, 26(4): 20-27

[9] Tang S R, Yang F X, Zhou G Y, et al. Regional distribution characteristics of cotton fiber quality in the Yellow River Valley[J]. China Cotton, 1997, 24(6): 11-12

[10] Adugna W, Labuschagne M T. Cluster and canonical variate analyses in multilocation trials of linseed[J]. The Journal of Agricultural Science, 2003, 140(3): 297-304

[11] Long R L, Bange M P, Gordon S G, et al. Fiber quality and textile performance of some Australian cotton genotypes[J]. Crop Science, 2010, 50(4): 1509-1518

[12] Foulk J, Meredith W, McAlister D, et al. Fiber and yarn properties improve with new cotton cultivar[J]. Journal of Cotton Science, 2009, 13(3): 212-220

[13] Xu N Y, Li J. Ecological regionalization of cotton fiber quality based on GGE biplot in Yangtze River valley[J]. Acta Agronomica Sinica, 2014, 40(5): 891–898
[14] Xiong Z W, Gu S H, Mao L L, et al. Spatial distribution characteristics of China cotton fiber quality and climatic factors based on GIS[J]. Chinese Journal of Applied Ecology, 2012, 23(12): 3385–3392
[15] Fu X Q, Long T F, Liu X F, et al. Analyses on main indexes of cotton fibre quality and discussion on the sub-regions in Henan Province[J]. Cotton Science, 2004, 16(3): 142–146
[16] Wang X D, Yu B X, Xia R B, et al. Cotton fiber quality regional distribution characteristics in the cotton planting region in Zhejiang Province[J]. Zhejiang Agriculture Science, 1994(1): 3–7
[17] Yu L X, Tang S F, Wang S H, et al. Ecological classification of the fiber quality of upland cotton in Hubei Province[J]. Cotton Science, 1993, 5(2): 15–20
[18] Yan W K. Optimal use of biplots in analysis of multi-location trial data[J]. Acta Agronomica Sinica, 2010, 36(11): 1805–1819
[19] Yan W K, Kang M S, Ma B L, et al. GGE biplot vs. AMMI analysis of genotype-by-environment data[J]. Crop Science, 2007, 47(2): 643–655
[20] Yan W K. GGEbiplot —A windows application for graphical analysis of multienvironment trial data and other types of two-way data[J]. Agronomy Journal, 2001, 93(5): 1111–1118
[21] Yan W K, Cornelius P L, Crossa J, et al. Two types of GGE biplots for analyzing multi-environment trial data[J]. Crop Science, 2001, 41(3): 656–663
[22] Yan W K, Hunt L A, Sheng Q L, et al. Cultivar evaluation and mega-environment investigation based on the GGE biplot[J]. Crop Science, 2000, 40(3): 597–605
[23] Yan W K. Crop Variety Trials: Data Management and Analysis[M]. Oxford, UK: Wiley-Blackwell, 2014
[24] Yan W K, Frégeau-Reid J, Pageau D, et al. Genotype-by-environment interaction and trait associations in two genetic populations of oat[J]. Crop Science, 2016, 56(3): 1136–1145
[25] Yan W K. GGE Biplot vs. AMMI graphs for genotype-by-environment data analysis[J]. Journal of the Indian Society of Agricultural Statistics, 2011, 65(2): 181–193
[26] Tang Q Y, Zhang C X. Data Processing System (DPS) software with experimental design, statistical analysis and data mining developed for use in entomological research[J]. Insect Science, 2013, 20(2): 254–260
[27] Han H J. Effects of climatic-ecologic factors on cotton yield and fibre quality[J]. Scientia Agricultura Sinica, 1991, 24(5): 23–29
[28] Ma S P, Cai P, Xiong Z W, et al. The current situation and international position of Chinese cotton fiber quality[J]. China Cotton, 2002, 29(10): 12–19
[29] Tang S R, Yang W H. Status and analysis of cotton fiber quality distribution in China and suggestions[J]. Cotton Science, 2006, 18(6): 386–390
[30] Zhu S L, Li D Q, Hua G X, et al. Study on relationship of cotton fiber quality and environments in different ecological areas in Jiangsu Province[J]. Acta

Gossypii Sinica, 1991, 3(1): 53-62