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RESEARCH ARTICLE

Effects of plant density on cotton yield components and quality

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Abstract

Yield and fiber quality of cotton even varies within locules in a boll, but it is not clear how yield components and quality parameters are altered across seed positions of a locule (SPL). A field experiment was arranged in a split plot design with transgenic insect resistant Bt (*Bacillus thuringiensis*) cotton hybrid cultivar CRI75 and conventional cultivar SCRC28 as the main plots, and three plant densities (15 000, 51 000 and 87 000 plants ha^{-1}) as the subplots in 2012 and 2013 at Anyang, Henan Province, China. Cotton was hand harvested by node and fruiting position, and then seeds of the first fruiting position bolls from nodes 6–10 were separated by SPL. The effects of plant density on lint yield, fiber quality, especially across SPL were determined. It was showed that plant densities of 51 000 and 87 000 plants ha^{-1} increased lint yield by 61.3 and 65.3% in 2012 and 17.8 and 15.5% in 2013 relative to low plant density (15 000 plants ha^{-1}), however, no significant difference was observed between 51 000 and 87 000 plants ha^{-1}. The number of bolls (boll density) increased while boll weight decreased as plant density raised, and no significant changes occured in lint percentage in 2013 but increased with plant density in 2012. The number of bolls in upper nodes and distal fruiting positions, the number of seeds per boll, seed area (SA) and seed vigor index increased with decreasing plant density. Seed area was found to be greater from the base to the middle compared to the apex of a locule. Mote frequency (MF) increased as plant density increased, and fiber quality was the best at the middle of the locule regardless of plant density. As the number of fibers per seed area is genetically determined, adjusting plant density to produce more seeds and greater seed area can be a potentially promising alternative to improve lint yield in cotton. These findings might be of great importantance to cotton breeding and filed management.

Keywords: cotton, plant density, yield, quality, seed position

1. Introduction

Cotton (*Gossypium hirsutum* L.) is an important cash crop worldwide, and Chinese cotton currently accounts for approximately 30% of the world's total production (Dai and Dong 2014). Improvement in cotton yield and quality through optimal management practices is the eternal goal of cotton agronomists.

Cotton yields can be divided into individual yield components of the number of bolls (boll density), boll weight and

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lint percentage (McCarty *et al*. 2008). Worley *et al*. (1974) indicated that boll density was the largest contributor to lint yield. However, because cotton fiber is an extension of a seed's epidermal cell, the most basic component of lint yield can be further dissected into smaller units such as seed number per boll (Worley *et al*. 1974) and number of fibers per seed (Clement *et al*. 2014). Bednarz *et al*. (2007) showed that the seed size affected the number of fibers per unit seed surface area and lint mass (Imran *et al*. 2012). Cotton fiber quality also depends on fiber properties such as average fiber length, fiber uniformity, micronaire value, and fiber strength (Bradow *et al*. 1997). However, Smith and Coyle (1997) noted that fiber length and strength were negatively correlated with basic within-boll yield components.

Cultivar selection (Kabiri *et al*. 2012; Braunack 2013) and plant density manipulation (Narkhede *et al*. 1996; De Oliveira *et al*. 1999; Bednarz *et al*. 2006; Liu *et al*. 2012) have been widely used as the most effective agronomic practices in many countries. Numerous studies have been conducted on the effects of plant density and cultivar on cotton yield components (Bednarz *et al*. 2006a, 2007; Feng *et al*. 2010) and fiber quality parameters (Bednarz *et al*. 2006b; Feng *et al*. 2011). Bednarz *et al*. (2000) have shown that the number of bolls per plant was influenced by plant density. Boll weight and micronaire were generally higher at lower plant density (Jones and Wells 1998). Yang *et al*. (2014) indicated that a rational plant density provided a better canopy micro-environment to gain higher yield. Moreover, the morpho-yield traits and fiber quality parameters are a function of the cultivar (Khan and Hassan 2011). An appropriate plant density may not only maximize cotton yield and fiber quality for a given cultivar but also reduce inputs by minimizing seed use without sacrificing yield. Boroomandan (2009) suggested that the number of seeds in a pod was quadratically related with plant density in soybean, showing that yield components within-fruit may be altered by plant density. However, few studies have focused on the differences in within-boll yield components under different plant densities, especially the seed and lint yield per seed as well as seed and fiber quality across seed positions in cotton locule. Also, cotton lint yield and fiber quality are integrated through whole-plant and within-boll yield components and quality parameters; thus it is necessary to study how the most basic within-boll yield components and fiber quality parameters are influenced by plant density and cultivar. The objective of this investigation was, therefore, to determine how (i) yield components, seed quality and fiber quality parameters across all seed positions were altered with plant density and (ii) these parameters vary across seed positions.

2. Materials and methods

2.1. Experimental site

The field experiment was conducted in 2012 and 2013 at the experimental farm of the Institute of Cotton Research, Chinese Academy of Agricultural Sciences, Anyang, Henan Province, China (36°06´N, 114°21´E). The field has a medium loam soil with total N of 0.66 g kg^{-1}, P of 0.01 g kg^{-1} and K of 0.11 g kg^{-1}. The average temperatures from April to October were 22.3°C in 2012 and 21.6°C in 2013; sunshine duration was 1 092 h in 2012 and 1 157 h in 2013; active accumulated temperatures (≥15°C) were 4 338°C in 2012 and 3 998°C in 2013; and the total rainfall was 408.2 mm in 2012 and 480 mm in 2013.

2.2. Treatments, experimental design and management

The experiment was arranged into a split plot using a randomized complete block design with three replications. The main plots consisted of two transgenic insect resistant Bt (*Bacillus thuringiensis*) cotton (*Gossypium hirsutum* L.) hybrid cultivar CRI75 and conventional cultivar SCRC28 and the subplots consisted of three plant densities (15 000, 51 000 and 87 000 plants ha^{-1}). The sub-plot was 8 m wide and 8 m long, consisting of 10 cotton rows with row spacing of 80 cm. The commercial Bt (*Bacillus thuringiensis*) cotton cultivar SCRC28 and the hybrid Bt cotton cultivar CRI75 were sown on 19 April, 2012 and 18 April, 2013. Each subplot was thinned to the targeted plant density at the three true leaves stage.

For both years, the land was ploughed and irrigated in early spring before sowing. The field received a basal application of 225 kg ha^{-1} N, 150 kg ha^{-1} P_2O_5 and 225 kg ha^{-1} K_2O before sowing. Supplemental irrigation was provided at approximately 45 mm, by flooding the furrows during the flowering stage. Other field managements were conducted according to local agronomic practices.

2.3. Data collection

Seed cotton in each sub-plot was hand harvested three times, before the 20th October for the pre-frost seed cotton. Lint yield and lint percentage for each subplot was determined after ginining. At each harvest, 50 open bolls of seed cotton were randomly harvested and weighed after drying, and then the average boll weight and number of bolls per unit ground area were determined based on the three harvests. During harvest, 20 plants from the middle portions of the two central rows in a subplot were manually