

Optimization of appropriate boron fertilization application range for cotton (*Gossypium hirsutum* L.) based on two varieties in boron-deficient soils

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Abstract

Boron (B) deficiency critically constrains cotton productivity in China's major cotton-growing regions, where soil available B levels widely fall below the sufficiency threshold ($< 0.5 \text{ mg kg}^{-1}$). This multi-site study (2020–2021) quantified the optimal B application ranges for two regionally adapted cultivars (CCRI 425 and Siza 3) through field trials and column experiments across three B-deficient sites in Jiangsu Province. Quadratic regression modeling of seed cotton yield responses identified distinct optima: $1.90\text{--}2.36 \text{ kg B ha}^{-1}$ for CCRI 425 and $2.05\text{--}2.36 \text{ kg B ha}^{-1}$ for Siza 3, achieving yield increases of 14.7–25.9% compared to B-free controls. Within these ranges, key agronomic traits demonstrated peak performance: boll shedding rates decreased by 11.3–42.0%, boll number increased by 12.4–22.0%, and boll size expanded by 16.9–30.8%. The coefficient of variation for boll number (4.2–6.6%) substantially exceeded that of boll weight (0.9–2.2%), identifying boll number as the primary yield determinant. Vertical canopy analysis revealed that middle strata (FB5–8) accounted for 48.2% of the total yield and was more sensitive in response to B fertilizer, likely attributable to restricted B phloem mobility. These findings provide a scientific framework for precision B management, balancing yield maximization with nutrient stewardship in B-deficient cotton systems.

Introduction

Cotton (*Gossypium hirsutum* L.) constitutes a vital global source of textile fibers, edible oils, industrial feedstocks, and livestock feed protein (Li et al., 2023). In China, cotton production is geographically concentrated within three major agroecological zones: the Northwest Inland Cotton Belt, the Yangtze River Valley Cotton Zone, and the Yellow River Basin Cotton Region (Li et al., 2016; Xu & Wang, 2017). Following nationwide agricultural restructuring initiatives, cotton cultivation areas have demonstrated a consistent annual decline (Feng et al., 2024; Wang et al., 2022). Remarkably, aggregate production has remained stable through compensatory yield intensification, achieving 3.6% annual productivity gains per unit area (Feng et al., 2022). The current national average yield of $1,933 \text{ kg ha}^{-1}$ masks significant regional disparities, with suboptimal productivity levels persisting in both the Yellow River and Yangtze River basins (Tang et al., 2024; Wang et al., 2022), indicating significant potential for yield optimization through improved agronomic practices (Zhang et al., 2024).

Boron (B), an essential micronutrient for vascular plants, plays pivotal roles in numerous physiological and biochemical processes (Riaz et al., 2018). Its multifunctional characteristics include: regulation of meristematic cell division and elongation, mediation of phenolic compound metabolism and lignin biosynthesis (Dong et al., 2022), maintenance of plasma membrane integrity and cell wall architecture (Voxeur & Fry, 2014), and modulation of auxin and cytokinin signaling pathways (Chen et al., 2022). These fundamental processes directly influence reproductive development, particularly pollen tube growth, floral organogenesis, and ultimately, yield formation (Gimeno et al., 2012; Garcia-Sanchez et al., 2020). Since its identification as an essential element in 1923, B deficiency has been documented in over 300 crop species across over 80 nations (Shorrocks, 1997). China contains the world's largest B-deficient arable area, with with > 33 million hectares of arable land exhibiting B deficiency (Liu et al., 2024). The Yangtze and Yellow River cotton-growing areas are particularly impacted, where suboptimal soil available B concentration ($< 0.5 \text{ mg kg}^{-1}$) constitute a primary constraint on yield potential (Lu et al., 2023). Recent field trials demonstrate that boric acid application at 13.5

kg ha⁻¹ increases cotton yield by 17% in the Yangtze River Valley (Li et al., 2016), confirming B deficiency as a critical limiting factor in these production systems.

Contemporary physiological research indicates that B exhibits limited phloem mobility in cotton (Landi et al., 2019), necessitating continuous soil availability throughout the growing season due to the cotton's infinite growth habit. While plants primarily absorb B as boric acid and borate ions, the high solubility of these compounds renders them susceptible to leaching through precipitation and irrigation events (Brdar-Jokanovic, 2020; Garcia-Sanchez et al., 2020), thereby exacerbating soil B depletion under intensive cultivation regimes (Dhassi et al., 2019). Although B supplementation effectively addresses deficiency, the therapeutic-to-toxic threshold is remarkably narrow (Dridi et al., 2018; Lopes et al., 2023). Excessive B application or irrigation with B-rich water induces phytotoxicity manifestations (Pennisi et al., 2006) including: growth inhibition, morphological aberrations (Simón-Grao et al., 2018), and marginal leaf chlorosis/necrosis (Saraf et al., 2017). Comprehensive soil analysis across China's cotton belt have established four distinct B availability zones, high-response zone (< 0.2 mg kg⁻¹): Characterized by "bud abortion" and "flower shedding", yielding > 20% increases with B supplementation, significant-response zone (0.2–0.5 mg kg⁻¹): Exhibiting petiolar annular formations, yielding 10–20% improvements, moderate-response zone (0.5–0.8 mg kg⁻¹): Occasional petiolar rings, < 5% yield enhancement, potential-response zone (> 0.8 mg kg⁻¹): Yield response dependent on fertilizer formulation and application timing (Xu & Wang, 2017). Notably, substantial genotypic variation exists in B utilization efficiency among cotton cultivars, with nutrient-efficient genotypes demonstrating superior adaptation to low-B environments (Pommerrenig et al., 2018; Liu et al., 2024).

The optimization of B management strategies with the objective of enhancing cotton yield represents a significant research focus within the domain of crop nutrition research. However, the considerable heterogeneity in soil B availability across geographic regions and soil texture classes poses significant challenges for B management in cotton production systems. Cotton is a crop that has been cultivated across a wide range of ecological zones on a global scale. It is notable that the conditions under which cotton is cultivated vary considerably, with significant differences in the application B fertilizer. Given the polygenic inheritance of yield-related traits and the critical influence of B management, this investigation aimed to: (1) determine the yield potential of two conventional varieties for two conventional cultivars across different soil conditions in B-deficient regions, (2) establish yield-maximizing B application ranges through nonlinear regression analysis of experimental data, (3) validate the optimal B application range through yield component analysis (boll density, boll mass, biomass allocation, and abscission rates) of column planting trials. The ultimate objective was to develop soil-specific B management protocols for maximizing seed production, thereby providing scientific basis for precision nutrient management in B-deficient agroecosystems.

1. Materials and methods

1.1 Experimental design

The study utilized two cotton cultivars: early-maturing CCRI 425 (98-day growth cycle) and medium-early maturing Siza 3 (130-day growth cycle). Filed trials were conducted during the 2020 growing season at two locations in Jiangsu Province, China: Dafeng Original Seed Farm (33°20'N, 120°46'E), Yancheng, and Old Agricultural Technology Grain Growing Family Farm, Laowei Village (32°92'N, 119°85'E), Xinghua. A split-plot

design was implemented with main plots as cultivar treatments (CCRI 425 vs. Siza 3), and subplots as seven B application rates (0, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5 kg B ha⁻¹). Borax (sodium tetraborate decahydrate, Na₂B₄O₇·10H₂O; 11.3% B content) was homogenized with dry topsoil (0–20 cm depth) and applied as basal fertilizer. Plot dimensions and planting densities differed between locations, at the Yancheng site, subplots measured 15 × 3 m with planting densities of 37,050 plants ha⁻¹ for Siza 3 and 90,000 plants ha⁻¹ for CCRI 425, while at the Xinghua location, subplots of 15 × 2.4 m were planted with both cultivars at a uniform density of 49,500 plants ha⁻¹. All treatments were replicated three times. Conventional agronomic practices except B management were applied consistently.

In 2021, follow-up experiments with CCRI 425 were conducted in controlled conditions using polyvinyl chloride (PVC) columns (49 cm height × 23 cm diameter) within a rainout shelter at Nanjing Agricultural University's Pailou Experimental Station (118°50'E, 32°02'N). Seven B treatments replicated three times. Irrigation protocols were modified while maintaining other field-derived parameters.

The nutrient status of the topsoil (0–20 cm) layer before the experimenting is shown in Table S1. The soil available B content at the Yancheng, Xinghua, and Nanjing trial sites was 0.36, 0.31, and 0.24 mg kg⁻¹, respectively. All sites were classified as mildly B-deficient (0.2–0.5 mg kg⁻¹) with distinct soil textures: loam (Yancheng), sandy loam (Xinghua), and clay (Nanjing). Meteorological data are presented in Fig. S1.

1. 2 Measurements

Yield and yield component: For field trials, seed cotton yield was quantified at physiological maturity through complete boll harvest from 4 m² (2 × 2m) quadrats per plot. For column trials, ten uniformly growing plants per treatment were sampled at boll maturation, with air-dried bolls counted and weighed.

Phenological monitoring: Ten representative plants per block were tagged for longitudinal assessment of floral development (total flower count, pigmentation stages at 1st–3rd fruiting nodes), boll formation dynamics (total boll count, nodal distribution), and boll shedding rate (%). Measurements were recorded at 15-day intervals from first flowering.

Biometric analysis: At 10, 17, 24, 31, and 38 days post-anthesis (DPA), 4–6 bolls from 4th–6th fruiting branches were sampled per treatment for dimensional analysis (length × width) and biomass accumulation.

1.3 Statistical analysis

Data processing utilized: Microsoft Excel 2022 for preliminary calculations, SPSS 20.0 for ANOVA with LSD post-hoc testing (α = 0.05), and Origin 2025 for graphical representation and nonlinear regression modeling. Optimal B application rates were determined through quadratic regression analysis of yield response curves.

2. Results

2.1 Response of seed cotton yield and yield components to B fertilizer in field trials

Seed cotton yields for both cultivars across field experimental sites exhibited a consistent single-peak response to increasing B application rate (0–3.5 kg B ha⁻¹), characterized by initial increases followed by

subsequent declines. At the Yancheng trial site, maximum yields for CCRI 425 and Siza 3 were observed at 2.5 kg B ha⁻¹, which represented increases of 25.89% and 17.34%, respectively, compared to the no B application. Similarly, at the Xinghua site, peak yields occurred at 2.0 kg B ha⁻¹, corresponding to yield enhancements of 14.74% and 20.58% relative to the control. Notably, cultivar CCRI 425 achieved its highest yield (4,065 kg ha⁻¹) at the Yancheng site with 2.5 kg B ha⁻¹ (Table 1).

Among yield components, the coefficient of variation (CV) for boll number (4.2%–6.6%) considerably exceeded that for seed cotton weight per boll (0.9%–2.2%). Analysis of variance (ANOVA) revealed that cultivar had a significant effect ($p < 0.05$) on both yield and yield components, whereas B application significantly influenced only yield and boll number.

2.2 Optimal B application rates for two cotton varieties in field trials

Seed cotton yield exhibited an initial increase followed by a subsequent decrease with elevated B application rates. A quadratic regression model was employed to characterize the relationship between B application rates (independent variable) and seed cotton yield (response variable) for both cultivars across two experimental sites. The downward-opening parabolic relationships yielded coefficients of determination (R^2) exceeding 0.82 ($p < 0.05$), revealing a critical agronomic threshold beyond which yield returns to B application diminished. CCRI 425 achieved maximum yields of 3,115.8 and 3,982.1 kg ha⁻¹ at B application thresholds of 1.90 and 2.35 kg B ha⁻¹ in Xinghua and Yancheng, respectively (Fig. 1a). Similarly, Siza 3 reached peak yields of 3,557.0 and 3,298.3 kg ha⁻¹ at 2.05 and 2.36 kg B ha⁻¹ in Xinghua and Yancheng, respectively (Fig. 1b). These results indicate optimal B application ranges of 1.90–2.35 kg B ha⁻¹ for CCRI 425 and 2.05–2.36 kg B ha⁻¹ for Siza 3.

2.3 Agronomic trait responses to B application within optimal threshold ranges

Boll shedding rates displayed a parabolic response to increasing B application levels, initially decreasing before rising at higher concentrations. Quadratic regression analysis identified the B application rates for minimum boll shedding rates: CCRI 425 exhibited minimum shedding (31.7% and 37.5%) at 1.90 and 1.99 kg B ha⁻¹ in Xinghua and Yancheng, respectively (Fig. 2a). Similarly, Siza 3 showed minimal shedding 25.8% and 46.6% at 2.01 and 2.32 kg B ha⁻¹ in the respective locations (Fig. 2b).

Cotton boll numbers exhibited significant variation ($p < 0.05$) across developmental stages in response to B fertilizer. Quadratic regression models indicated a non-linear relationship, with boll numbers initially increasing then decreasing under elevated B application rates, and peaking within the optimal B ranges for both cultivars. CCRI 425 attained maximum boll counts of 13.8 and 10.7 per plant in Xinghua (2.06 kg B ha⁻¹) and Yancheng (2.24 kg B ha⁻¹), respectively (Fig. 3a). Siza 3 achieved peak boll production of 15.2 and 13.0 per plant at 1.99 kg B ha⁻¹ in both locations (Fig. 3b).

Boll dimensions displayed significant developmental-stage-dependent responses to B application. At 38 DPA, maximum boll size of CCRI 425 and Siza 3 varieties was significantly increased by 16.9%–17.7% and 30.0%–30.8%, respectively, under B application treatment compared to no B application. With the exception of Siza 3 in Yancheng, quadratic models demonstrated maximum boll size attainment within optimal B ranges. CCRI 425 exhibited peak boll sizes of 19.3 cm² (Xinghua: 2.11 kg B ha⁻¹) and 18.1 cm² (Yancheng: 1.98 kg B ha⁻¹)

(Fig. 3c), while Siza 3 reached maxima of 15.1 cm² (Xinghua: 2.03 kg B ha⁻¹) and 14.8 cm² (Yancheng: 1.65 kg B ha⁻¹) (Fig. 3d).

2.4 Validation of optimal B application rate in column planting trials conducted in Nanjing

Vertical distribution analysis of fruiting branches revealed distinct canopy-layer responses to B application in Nanjing. The lower canopy (FB1–4) contributed 22.81% of total yield, achieved maximum productivity (22.90% increase) at 2.5 kg B ha⁻¹. Similarly, the middle canopy (FB5–8), accounting for 48.22% of total yield, peaked at 17.40% higher productivity under this rate. The upper canopy (FB9+), representing 28.96% of yield, was optimized at a 22.57% increase with 2.5 kg B ha⁻¹. B application exerted significant influences ($p < 0.05$) on both boll number and seed cotton weight per boll across canopy layers. The CV for boll number substantially exceeded that of seed cotton weight, with lower canopy branches exhibiting higher boll densities compared to central and upper strata. Relative to the no B application, the maximum increases in boll number (14.7%) and seed cotton weight per boll (4.6%) were observed predominantly at 2.5 kg B ha⁻¹ (Table 2).

For CCRI 425, seed cotton yield per plant in Nanjing exhibited a parabolic response characterized by an initial increase followed by a decline with escalating B application. Quadratic regression analysis identified a peak yield of 57.6 g plant⁻¹ at 2.25 kg B ha⁻¹, aligning with the previously determined optimal range (Fig. 4a). Quadratic models for CCRI 425 further demonstrated critical agronomic optima within the validated B application range: Minimum boll abscission rate (56.40%) at 2.17 kg B ha⁻¹ (Fig. 4b), Maximum boll number (11.9 per plant) at 2.15 kg B ha⁻¹ (Fig. 4c), peak boll size (21.3 cm²) at 1.97 kg B ha⁻¹ (Fig. 4d).

3. Discussion

Since B was first identified as an essential micronutrient for plant growth, B deficiency has emerged as a critical global production constraint, currently affecting hundreds of crop species across more than 80 countries (de Bang et al., 2021; Lilay et al., 2024). Field trials of B application to cotton in China demonstrated seed cotton yield increase of 17% (Li et al., 2016), confirming that B deficiency is still a key limiting factor in China's cotton production system. Although supplemental B fertilizer is considered an important strategy to mitigate the decline in cotton yield in B-deficient areas, the unusually narrow range of adequacy between B deficiency and toxicity thresholds for B fertilizer management in cotton (Brdar-Jokanovic, 2020). Under-application limits yield potential, while cumulative effects of over-application or long-term application may lead to phytotoxicity in subsequent crops (Bogiani et al., 2014). Given this precision-dependent balance, where B deficiency (< 0.5 kg B ha⁻¹) and toxicity (> 2.0 kg B ha⁻¹) thresholds differ by only a few ppm, precise optimization of B fertilization is required to maximize yields while promoting efficient use of B fertilizer resources. Furthermore, substantial heterogeneity in soil B availability across geographic regions and soil texture classes poses a major challenge for B management in cotton production systems. As a globally grown crop spanning numerous ecological zones, cotton is grown under markedly different environment conditions, each with different climatic regimes, soil properties and fertilizer application rates (Garcia-Sanchez et al., 2020).

This study investigated two conventional cotton cultivars extensively cultivated in Jiangsu Province, planted across two geographically distinct long-term intensively cultivated fields with contrasting soil types. Pre-

experimental soil analyses confirmed deficient soil available B levels (Table 1), in the range of soil available B in regions demonstrating significant B fertilization responsiveness (Xu & Wang, 2017). Both cultivars exhibited marked yield responses to B supplementation, with seed cotton yields increasing by 25.89% (CCRI 425) and 17.34% (Siza 3) in Yancheng, and 14.74% (CCRI 425) and 20.58% (Siza 3) in Xinghua relative to B-free controls. These results establish B as the key yield-limiting factor under these edaphic conditions. This is related to the primary physiological function of B in maintaining cell wall structural integrity through the formation of the boronic acid dimeric rhamnogalacturonan-B (RG-B) complex, which stabilizes the pectin network and regulates cell wall porosity, and whose main functions are cell wall formation and cell division (Gimeno et al., 2012). Previous studies have characterized the anatomical disruption caused by B deficiency, particularly the formation of brown petiole rings, as leading to impairment of phloem transport and photosynthetic efficiency, ultimately affecting reproductive organ development and seed cotton productivity (Li et al., 2017; Lilay et al., 2024). In addition, B is involved in multiple metabolic pathways, including nucleic acid and carbohydrate metabolism, protein synthesis, phosphorus cycling, phenolic compound metabolism, and phytohormone regulation (Papadakis et al., 2018), which results in enhanced plant defense against abiotic stresses such as salt stress, drought, and heavy metal overload, providing yield stability in cotton.

The critical role of B in facilitating photoassimilate translocation from source leaves to reproductive sinks (Panter et al., 2023) ensures proper boll development and biomass accumulation (Wahid et al., 2020), aligning with the observed yield enhancements. In this study, the CV for boll number significantly exceeded that of boll weight across B treatment (Table 2), which is because boll number is more responsive to environmental fluctuations due to its sensitivity as a real-time indicator of plant physiological status. This differential response underscores boll number as the principal determinant of seed cotton yield. Boll shedding, a natural adaptive mechanism in cotton, typically accounts for 70% of the total number of nodes (Ertek & Kanber, 2003). In response to biotic and abiotic stresses, the internal development of plants and external stimuli will affect the expression of genes, leading to changes in hormones and enzymes and other endogenous substances, resulting in a significant increase in the rate of abscission (Zhao et al., 2024), so the growth and development of bolls have a direct impact on the cotton yield. Mechanistically, B enhances reproductive structure development and assimilate partitioning to fruiting organs (Padbhushan & Kumar, 2015; Wahid et al., 2020), directly correlating with the reduced boll abscission rates observed in this study. Prior research on sandy loam soils demonstrated that foliar B application (1.0 kg B ha^{-1}) maximized boll numbers, achieving 63–75% increases over controls (Mehran et al., 2023; Wahid et al., 2020), corroborating our findings.

Fertilizer efficiency models provide a robust framework for optimizing the relationship between fertilizer inputs and crop productivity. Q modeling has become an established analytical approach in studies examining single-nutrient management (Luo et al., 2024). Under controlled fertilization conditions, crop yield response is influenced not only by B application rates but also by the indigenous soil B supply, which represents the baseline plant-available B content prior to fertilization and constitutes a key determinant of crop yield response. While current understanding of indigenous B supply's role in developing effective management strategies remains preliminary (Ahmed et al., 2018). Cotton yield response to B application varied significantly across trial sites, mainly attributed to differences in native B supply levels. While seed cotton yield exhibited a positive quadratic relationship with B application in the results of this study ($R^2 > 0.82$ across field trials), diminishing yield gains occurred beyond optimal thresholds due to non-linear dynamics. This pattern likely reflects limitations in soil B bioavailability, cultivar-specific uptake saturation, and potential phytotoxicity at

supraoptimal concentrations (Simón et al., 2013). The Q models effectively quantified regional yield variability by capturing these non-linear dynamics. Maximum yields of CCRI 425 occurring at B application rates of 1.9 and 2.36 kg B ha⁻¹ in Xinghua and Yancheng and at 2.05 and 2.36 kg B ha⁻¹ in Siza 3, highlighting the necessity of balancing soil B availability with cultivar-specific demand to optimize yield and resource efficiency.

Column-planting trials for CCRI 425 in Nanjing (2.25 kg B ha⁻¹) verified the theoretical optimum application rate, confirming cultivar-specific B requirements while revealing significant intraspecific differences across locations (Fig. 3). These variations reflect differential B stress tolerance thresholds. The observed rate discrepancies between Yancheng and Xinghua further demonstrate how edaphic and climatic factors mediate B efficacy. Available B content, organic matter, pH and texture as key determinants of soil properties affecting B fertilizer use efficiency. Yield response was inversely related to soil available B levels, peaking in B-deficient soils, where supplemental B compensated for inherent limitations (Cordeiro et al., 2022). Conversely, high natural B levels increased toxicity risk and reduced agricultural efficiency (Niaz et al., 2013). Organic matter exhibited parabolically related to efficiency, peaking at moderate concentrations due to its dual role as a B reservoir versus immobilization agents (Atique ur et al., 2018). Soil texture significantly moderated B retention, with coarse-textured soils exhibiting lower efficacy due to leaching, while fine-textured soils maintained better nutrient retention (Cordeiro et al., 2024). B bioavailability was pH-dependent, with maximal uptake occurring under acidic to weakly alkaline conditions and sharply decreasing at higher soil pH. Thermal and hydrological conditions strongly influenced B utilization (Yeates et al., 2010; Dusenget al., 2019). The optimal temperature range (25–30 °C) enhanced metabolic activity and photosynthetic efficiency and maximized yield response. Suboptimal temperatures (< 25 °C) limited root growth and stomatal conductance and reduced B effectiveness. Notably, the sustained increase in yield at supraoptimal temperatures (> 30 °C) may be attributed to B-induced activation of antioxidant enzymes and carbohydrate metabolism, which mitigated heat-induced oxidative stress. Extreme water conditions, either in excess (promoting leaching) or deficiency (reducing bioavailability), emphasize the need for balanced water management. These findings reinforce the imperative for soil-specific B management strategies to maximize cotton productivity (Liu et al., 2024).

Column-planting trials in Nanjing elucidated vertical canopy partitioning of B responses, with middle (FB5–8) and upper (FB9+) canopy boll production demonstrating greater B sensitivity than lower strata (FB1–4) (Table 3). Given the middle canopy's disproportionate contribution to total yield (48.22%), B application primarily modulated yield-determining components in these strata. This vertical response gradient constitutes a novel finding, potentially linked to restricted B phloem mobility impeding redistribution to lower canopy organs (Landi et al., 2019; Oikonomou et al., 2019). Further investigation is warranted to elucidate the physiological mechanisms underlying this stratification.

4. Conclusion

The application of supplemental B fertilizer significantly modulates yield components, particularly boll number, thereby enhancing seed cotton yield. Through integration of quadratic modeling, the optimal B application rates for yield maximization were established as 1.90–2.36 kg B ha⁻¹ for CCRI 425 (14.74–25.89% yield increase), 2.05–2.36 kg B ha⁻¹ for Siza 3 (17.34–20.58% yield increase). Within these ranges, critical agronomic traits, including boll number, boll shedding rate and boll size, exhibited optimal performance,

aligning with physiological thresholds for reproductive efficiency. Vertical canopy analysis demonstrated that the most substantial response of B fertilization on seed cotton yield was the middle canopy seed cotton yield, and the yield component with the same most significant variance was the number of cotton bolls. These findings underscore the importance of cultivar- and site-specific B management strategies to reconcile yield optimization with nutrient use efficiency in intensive cotton production systems.

Declarations

Ethics approval and consent to participate Not applicable.

Consent for publication All co-authors have consent for submission of manuscript.

Availability of data and materials All relevant data are within this article.

Competing interests The authors declare no conflict of interest.

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Tables

Table 1 Effect of boron rate on cotton yield and yield components (Yancheng, and Xinghua, CCRI 425 and Siza 3)

Cultivars	B rate (kg B hm ⁻²)	Yancheng			Xinghua		
		Boll number (10 ⁴ no.hm ⁻¹)	Seed cotton weight boll ⁻¹ (g)	Seed cotton yield (kg hm ⁻¹)	Boll number (10 ⁴ no.hm ⁻¹)	Seed cotton weight boll ⁻¹ (g)	Seed cotton yield (kg hm ⁻¹)
CCRI 425	0	81.9 e	3.9 a	3229 e	61.3 d	4.5 a	2800 c
	1.0	89.1 d	4.0 a	3588 d	64.3 bc	4.6 a	2980 b
	1.5	92.7 c	4.1 a	3833 bc	65.3 b	4.6 a	3023 b
	2.0	97.2 b	4.1 a	4012 a	71.2 a	4.5 a	3213 a
	2.5	99.9 a	4.1 a	4065 a	69.3 a	4.5 a	3104 a
	3.0	96.3 b	4.1 a	3973 ab	66.8 b	4.5 a	3012 b
	3.5	89.1 d	4.1 a	3710 c	63.3 c	4.4 a	2832 c
	CV (%)	6.6	1.8	7.8	5.2	1.4	4.8
Siza 3	0	50.7 c	5.7 a	2895 d	54.4 d	5.5 a	3003 e
	1.0	53.7 b	5.7 a	3073 c	60.3 b	5.5 a	3360 c
	1.5	54.8 b	5.7 a	3171 b	62.8 b	5.4 a	3454 b
	2.0	57.0 a	5.8 a	3341 a	66.3 a	5.4 a	3621 a
	2.5	57.0 a	5.9 a	3397 a	64.8 a	5.5 a	3571 a
	3.0	54.4 b	5.9 a	3257 ab	61.3 b	5.5 a	3429 c
	3.5	52.2 bc	6.0 a	3149 bc	57.9 c	5.5 a	3236 d
	CV (%)	4.2	2.2	5.3	6.6	0.9	6.2
Variety (V)		***	**	***	*	*	*
Boron (B)		***	ns	***	***	ns	***
V×B		***	ns	***	*	ns	*

Coefficient of variation, CV (%) = Standard deviation/Average ×100%; Different lowercases within the same variety and column indicate significant difference at 0.05 probability.

Table 2 Effect of boron rate on cotton yield and yield components (Nanjing, CCRI 425)

B rate (kg B hm ⁻²)	Boll number (number plant ⁻¹)				Seed cotton weight boll ⁻¹ (g)				Seed cotton yield (g plant ⁻¹)			
	FB1-4	FB5-8	FB9+	Total	FB1-4	FB5-8	FB9+	Average	FB1-4	FB5-8	FB9+	Total
0	2.2 c	4.5 b	2.8 c	9.5 c	5.0 b	5.3 b	5.0 b	5.1 a	11.0 d	23.8 c	14.0 c	48.85 d
1.0	2.4 b	4.8 a	3.0 b	10.2 b	5.1 ab	5.4 ab	5.1 ab	5.2 a	12.2 c	25.9 b	15.3 b	53.46 c
1.5	2.5 ab	4.9 a	3.2 a	10.6 a	5.2 a	5.5 a	5.1 ab	5.3 a	13.0 bc	26.9 ab	16.3 a	56.27 b
2.0	2.6 a	4.9 a	3.2 a	10.7 a	5.2 a	5.6 a	5.2 a	5.3 a	13.5 b	27.4 a	16.6 a	57.60 a
2.5	2.6 a	5.0 a	3.3 a	10.9 a	5.2 a	5.6 a	5.2 a	5.3 a	13.5 a	28.0 a	17.1 a	58.68 a
3.0	2.5 ab	5.0 a	3.3 a	10.8 a	5.1 ab	5.5 a	5.1 ab	5.2 a	12.7 c	27.5 a	16.8 a	57.03 a
3.5	2.4 b	4.8 a	3.1 ab	10.3 b	5.0 b	5.5 a	5.0 b	5.1 a	12.0 c	26.4 b	15.5 b	54.08 c
CV%	5.6	3.5	5.7	4.6	1.7	1.9	1.6	1.6	7.2	10.1	9.2	10.0

Coefficient of variation, CV (%) = Standard deviation/Average ×100%; Different lowercases within the column indicate significant difference at 0.05 probability.

Figures

Figure 1

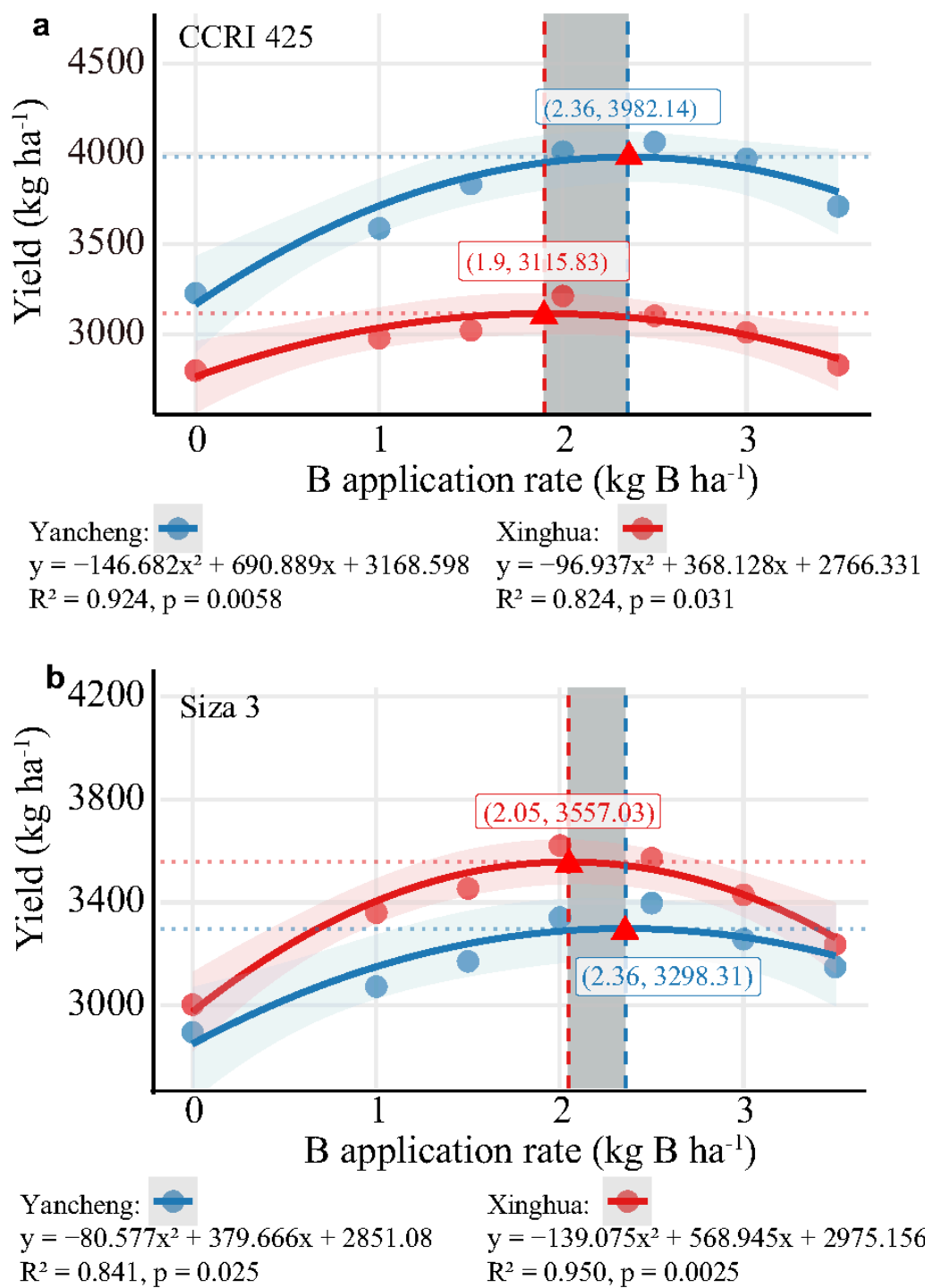


Figure 1

Quadratic relationship between B application rate and seed cotton yield. Response curves of CCRI 425 (a) and Siza 3 (b) at Yancheng and Xinghua.

Figure 2

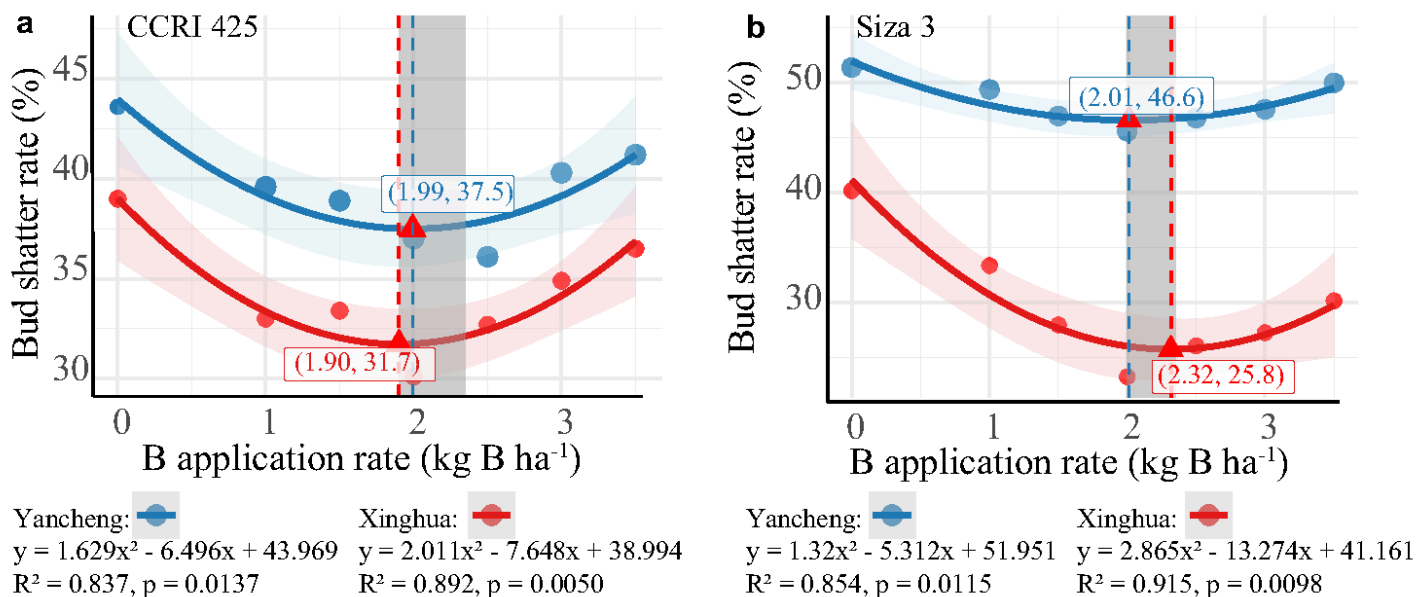


Figure 2

Quadratic relationship between B application rate and bud shatter rate. Response curves of CCRI 425 (a) and Siza 3 (b) at Yancheng and Xinghua. The gray area shows the range of B application rates at the maximum seed cotton yield for CCRI 425 and Siza 3 at the two experimental sites, respectively.

Figure 3

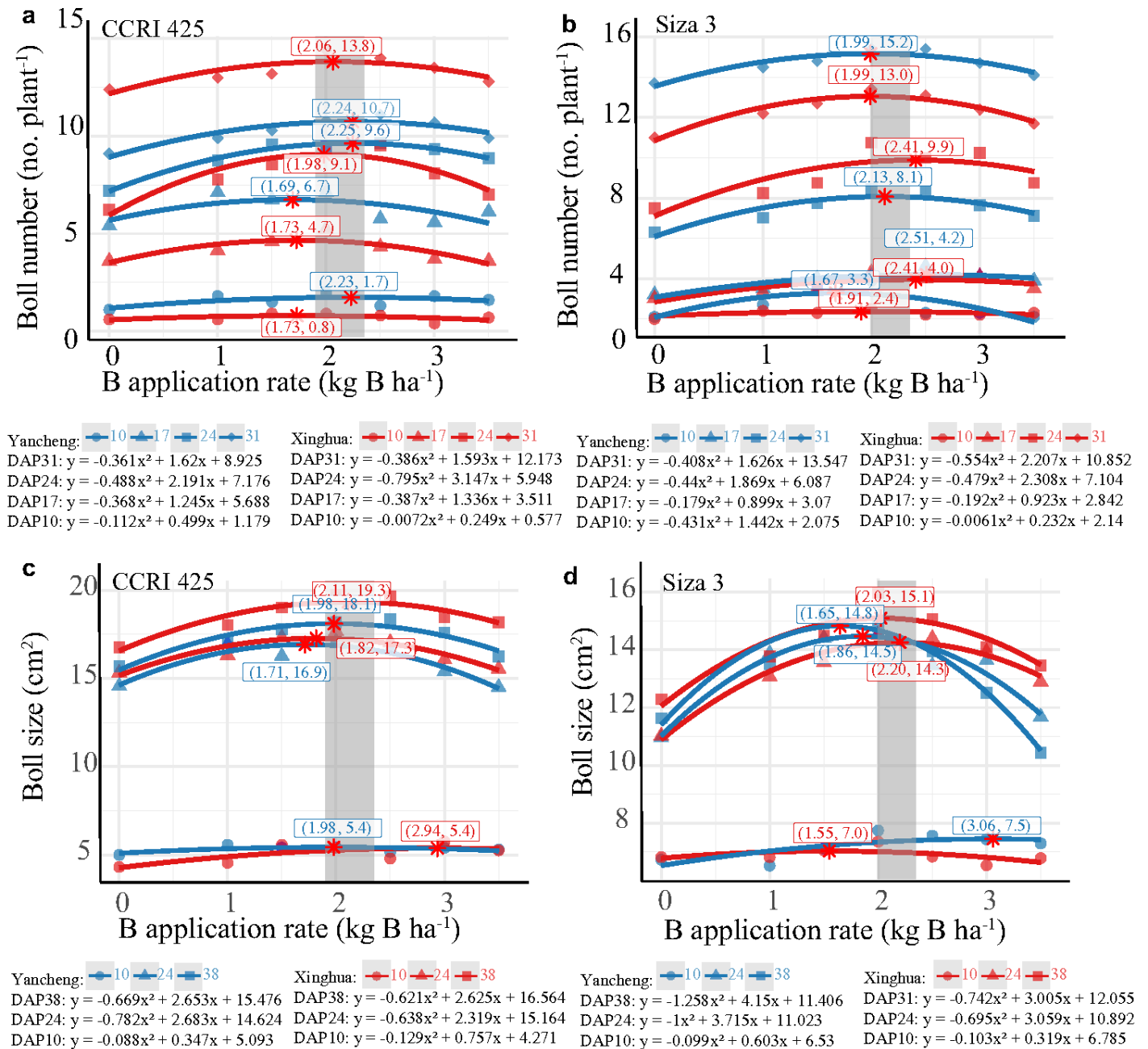


Figure 3

Quadratic relationship between B application rate and boll number, and boll size. Response curves of CCRI 425 (a & c) and Siza 3 (b & d) at Yancheng and Xinghua. The gray area shows the range of B application rates at the maximum seed cotton yield for CCRI 425 and Siza 3 at the two experimental sites, respectively.

Figure 4

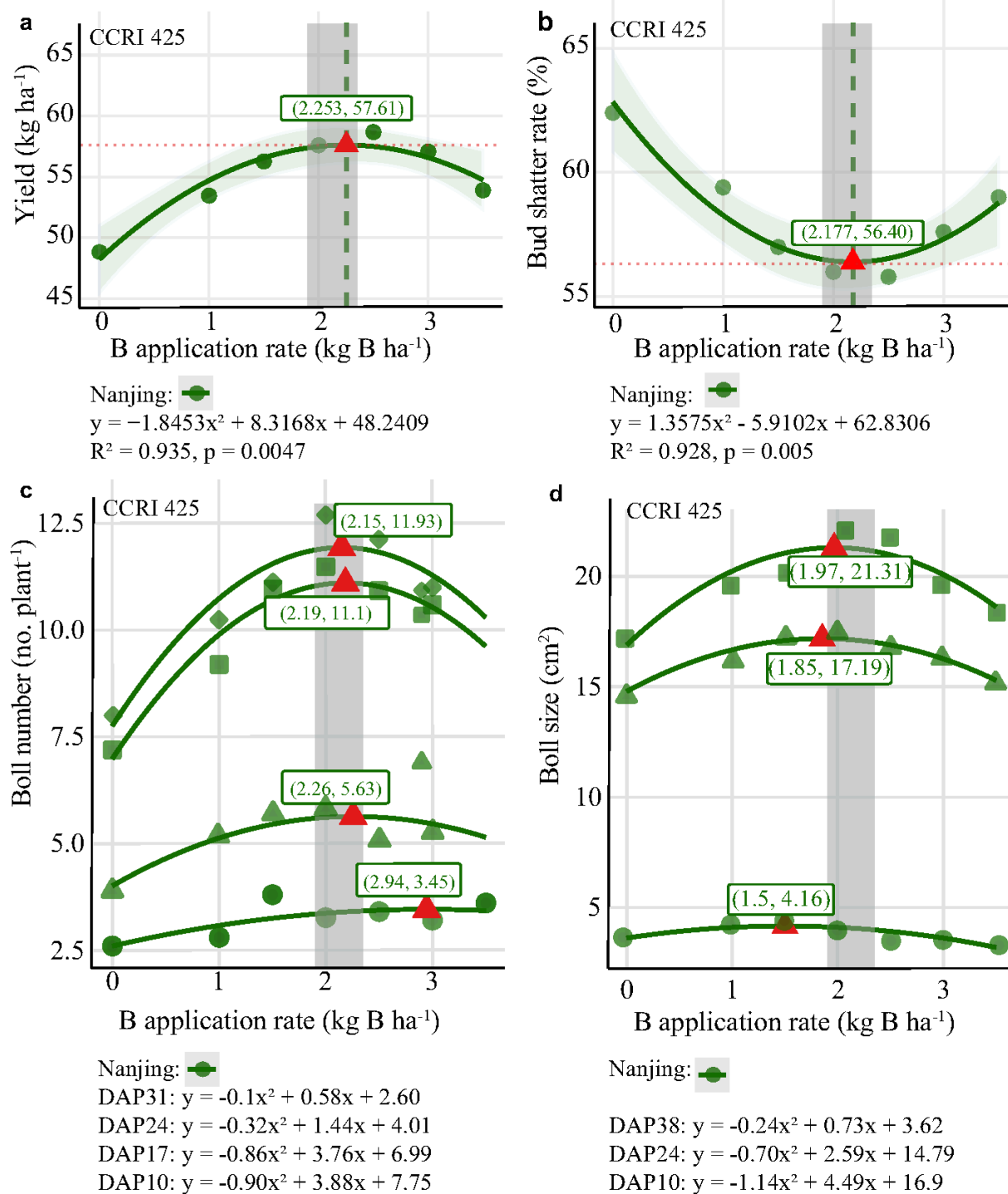


Figure 4

Quadratic relationship between B application rate and seed cotton yield (a), and bud shatter tare (b), and boll number (c), and boll size (d) for CCRI 425 at Nanjing. The gray area shows the range of B application rates at the maximum seed cotton yield for CCRI 425 at the two experimental sites.

Supplementary Files

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