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DISPARITY IN GROWTH, YIELD AND FIBER QUALITY OF COTTON GENOTYPES GROWN UNDER DEFICIENT AND ADEQUATE LEVELS OF BORON

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ABSTRACT

Balanced boron (B) supply is essential for growth, yield and fiber quality of cotton crop. The wide disparity in genotypic response and narrow range between B deficient and toxic levels in soil makes it difficult to achieve the quality cotton production. A field study was conducted during Kharif season 2013 to compare ten cotton genotypes of Pakistan for their production and quality traits by growing under B deficient and B adequate conditions. Treatments for B rates i.e. B deficient (control) and B adequate (2.0 kg B ha^{-1}) were applied in main plots and ten cotton genotypes were grown in sub-plots arranged in split plot design with three repetitions. Boron application produced variable effects on growth, yield and fiber quality of cotton genotypes, but the degree of effects was varied from genotype to genotype. Adequate application of B significantly enhanced plant height (8.4%), sympodia per plant (6.4%), bolls per plant (10.0%), boll weight (8.6%), seed-cotton yield (18.7%), leaf B content (14.1%), lint production (5.2%) and reduced the microniare value by 7.1% of all genotypes. Cotton genotypes significantly varied among each other in all the growth, yield and quality traits, except fiber length under both B regimes. Genotype CIM-589 produced the maximum bolls per plant, the highest seed-cotton yield per plant and retained the highest B in its leaves under both B conditions. The best fiber quality was produced by IR-NIBGE 1524 with longest fibers under B deficiency condition. Our findings confirm that the adequate level of B nutrition had pronounced effects on various growth and yield associated traits as compared to fiber quality traits of cotton genotypes.

Keywords: boron levels, cotton genotypes, growth and yield, fiber quality

INTRODUCTION

Pakistan is the 4th largest producer, 3rd largest exporter and 4th largest consumer of cotton in the world (Ahmed *et al.,* 2011). The low seed-cotton yield (730 kg ha^{-1}) and poor fiber quality are the major constrains being faced by the country (GoP, 2017). There are many reasons for low yield and poor fiber quality of cotton including environmental factors (temperature, drought, salinity), poor quality seed, etc. (Khuda Bakhsh *et al.,* 2005). Besides these factors, B is one of

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the major yield and quality limiting factors in cotton (Yeates *et al*., 2010). Boron is an essential micronutrient, required during all growth stages of cotton especially at fruiting stage (Rashidi *et al.,* 2011). Boron requirement of cotton is comparatively higher than the cereal crops (Zhao and Oosterhuis, 2002). Boron deficiency decreases the photosynthetic rates and carbohydrate transportation from leaves to fruits at early growth stage (Zhao and Oosterhuis, 2002) and increases squares and bolls shedding at maturity, which ultimately affect the fiber quality (Sankaranarayanan *et al.,* 2010). Its deficiency is more common in some cotton growing areas of world including Pakistan, where 50% of cotton cultivated area is deficient in B (Rashid *et al.,* 1997; Zhao and Oosterhuis, 2003; Ahmed *et al.,* 2013).

Boron deficiency in cotton is difficult to overcome due to its narrow range between toxic and deficient limits and wide genotypic variation. So the adequate dose of B for one cotton genotype can be insufficient or its' continuous application can be toxic to other genotype, thus ultimately affects the yield and fiber quality (Rashid, 2006). Boron deficiency or adequacy produced variable effects on growth, yield and fiber quality of cotton genotypes (Ahmad *et al.* 2009). Similarly, severity of B deficiency symptoms widely varied with the cotton genotypes (Bogiani and Rosolem, 2012). Zancanaro and Tessaro (2006) compared the Brazilian cotton cultivars under field conditions and found that ITA-90 had exposed high intensity of deficient symptoms than cv. Fibermax 966. Moreover, Ahmed *et al.* (2009) found that cotton genotypes VH-183 and VH-206 were most responsive to foliar applied B than other genotypes. These narrow ranges of B tolerance among the cotton genotypes and in critical limits of B in soil make it difficult to manage by soil or foliar application. Hence, categorization of cotton genotypes on the basis of B-use-efficiency and their adaptation can be safe alternate approaches for B management. Cotton genotypes may hereditarily vary in their B requirement. So the low or adequate supply of B can produce variable effects on growth, yield and fiber quality of cotton genotypes. Therefore, present field study was undertaken to evaluate the effect of B deficiency and adequacy on growth, yield and fiber quality trait of selected cotton genotypes of Pakistan. The knowledge obtained by this study will be helpful in selection of cotton genotypes with potential of B-use-efficiency.

MATERIALS AND METHODS

This field experiment was undertaken at Latif Experimental Farm, Sindh Agriculture University, Tandojam [25.4365N/68.5419E] during Kharif 2013.Ten cotton genotypes viz. IR-NIBGE-1524, IR-NIBGE-901, MNH-886, CIM-598, SAU-1, Shahbaz, Sohni, Chandi, NIAB-777 and NIAB-846, collected from various cotton breeding Institutes of Pakistan were grown at two levels of B i.e. control (without B application) in B deficient soil (0.39 mg B kg^{-1}) and B adequate soil (fertilized with 2.0 kg B ha^{-1}). Generally, soils containing <0.45 mg kg^{-1} of diluted HCl extracted B are categorized as B deficient and the soils containing >1.0 mg kg^{-1} of diluted HCl extracted B are B adequate (Estefan *et al*., 2013). The experiment was carried out in split plot design with three repeats. Boron rates were applied in main plots (350 m^2) and cotton genotypes were sown in sub plots (24 m^2). Seven rows (4 m in length) of each genotype were sown in plots by maintaining 30 cm plant to plant and 75 cm row to row distances. The recommended dose of fertilizer i.e. nitrogen (150 kg ha^{-1}), phosphorus (75 kg ha^{-1}) and potassium (60 kg ha^{-1}) was applied to crop as urea (46% N), single super phosphate (18% P_2O_5) and sulphate of potash (50% K_2O). The adequate level of B in soil was maintained with the application of 2 kg B ha^{-1} as borax (11.3% B). All phosphorus, potassium and boron along with half of nitrogen were applied as a basal dose at the time of sowing, while the remaining half of nitrogen was applied at the time of boll opening (Zial-ul-hassan *et al*., 2014). All the cultural practices i.e. irrigation, weeding, and pest control was carried out as per recommendation throughout the life span of crop. The clayey soil in experiment was non saline (EC: 1.6 dS m^{-1}), slightly alkaline (pH: 7.9), highly calcareous ($CaCO_3$ 15.7%), low in organic matter (0.82%) and deficient in total nitrogen (0.064%), $NaHCO_3$-extractableable phosphorus (6.9 mg kg^{-1}) and diluted HCl B (0.39 mg kg^{-1}), but adequate in AB-DTPA extractable potash (168 mg kg^{-1}). Most recent fully mature leaves from main stem were collected at first square stage, processed and used for B analysis. Crop was harvested at maturity and growth and yield traits like plant height, sympodia per plant, bolls per plant, boll weight and seed-cotton yield per plant were noted. The samples of seed-cotton were separated into lint and seed using single roller laboratory gin and then ginning out turn (GOT) was calculated. Fiber quality traits viz. fiber length, fiber fineness, fiber strength and micronaire were analyzed on High Volume Instrument (HVI), manufactured by M/S Zellwegar Uster Ltd., Switzerland. The instrument was calibrated as per the instruction manual (M/S Zellweger Ltd., 1994) followed by the standard procedure as described by ASTM standard (1997). The statistical software, Statistix 8.1 was used for data analysis through analysis of variance and correlation analysis (Steel *et al*., 1997).

RESULTS

The results showed that the adequacy of B nutrition significantly (*P<0.05*) influenced the growth, yield and fiber quality traits of cotton genotypes, except fiber length (Table 1). Genotypes considerably (*P<0.05*) varied for growth, yield and fiber traits at both B regimes. The interactive effect of both sources of variation was also highly significant, therefore, affected the growth, yield and fiber quality of cotton genotypes in different ways.

Table 1. Mean squares from analysis of variance for different parameters of cotton genotypes at deficient and adequate B regimes

Parameter	**Boron (B) Levels**	**Genotypes (G)**	**B × G**
Plant height	1568.20**	1578.78**	158.17**
Bolls per plant	468.99**	515.89**	NS
Boll weight	1.37**	0.88**	0.12**
Sympodia per plant	49.72**	133.89**	NS
Seed-cotton yield	18195.50**	4856.40**	326.90*
Leaf B content	1412.88**	398.82**	48.25**
Lint (%)	70.31**	64.42**	1.54**
Fiber length	NS	NS	NS
Microniare	2.17**	0.98**	0.47**

* and **represent significance levels at alpha 0.05 and 0.01, obtained through Honestly Significant Difference (HSD) test, whereas, NS represents non-significance

Plant height

The adequate supply of B nutrition enhanced the cumulatively plant height of all the genotypes by 8.4% as compared to B deficient level (Figure 1). Genotypes responded differently for plant height under both B conditions. IR-NIBGE-901 produced the tallest plant height (138.5 cm), whereas, the dwarf plant height (83.7 cm) was noted in SAU-1under B deficient level (Figure 2). Similarly, at adequate B level, tallest plant height (148.2 cm) was recorded in same genotype IR-NIBGE-901 and shortest (93.4) in NIAB-777.

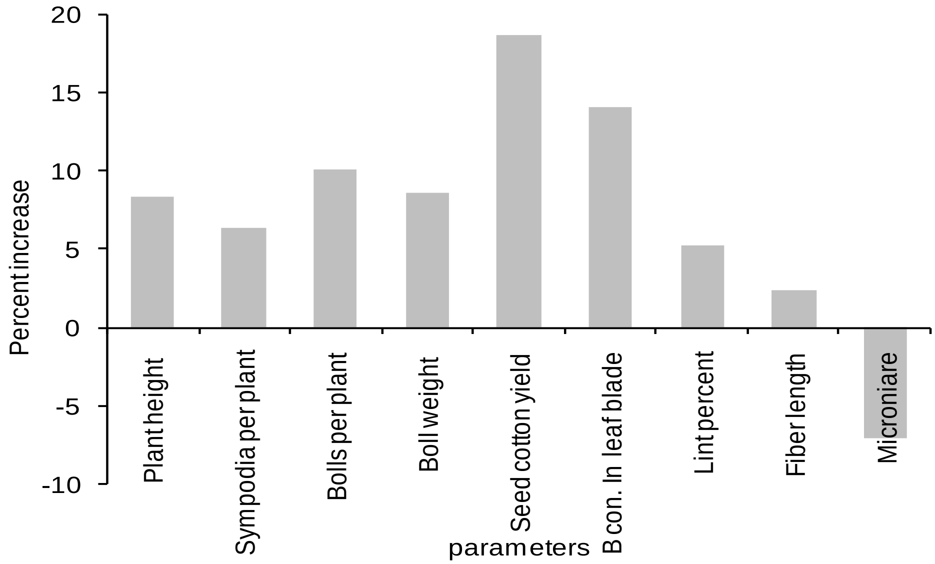

Figure1. Growth, yield and fiber quality of cotton genotypes as affected by adequate supply of B

Sympodia

The adequate B nutrition augmented the sympodia per plant of cotton genotypes by 6.4% as compared to B deficient conditions (Figure 1). However, genotypes varied in the production of sympodial branches at both B regimes. Under B deficient condition, the maximum (30.7) sympodia plant^{-1} were recorded in NIAB-846, whereas, the minimum (8.5) sympodia in SAU-1. At adequate B condition, the highest (33.0) sympodia plant^{-1} were noticed in NIAB-777, whereas the least (20.3) sympodia plant^{-1} were observed in SAU-1 (Figure 3).

Bolls

Cotton genotypes widely varied in the production of bolls per plant under both B regimes. Genotype CIM-598 produced the maximum (69.0) bolls plant^{-1}, while MNH-886 produced minimum (35.9) bolls plant^{-1} under B deficiency stress. Similarly, under adequate B condition, genotypes CIM-598 produced the maximum (71.0) bolls plant^{-1} and MNH-886 produced the minimum (42.8) number of bolls plant^{-1} (Figure 4). The adequacy of B nutrition in soil enhanced the number of bolls per plant in all the genotypes by 10.0% over B deficiency (Figure 1).

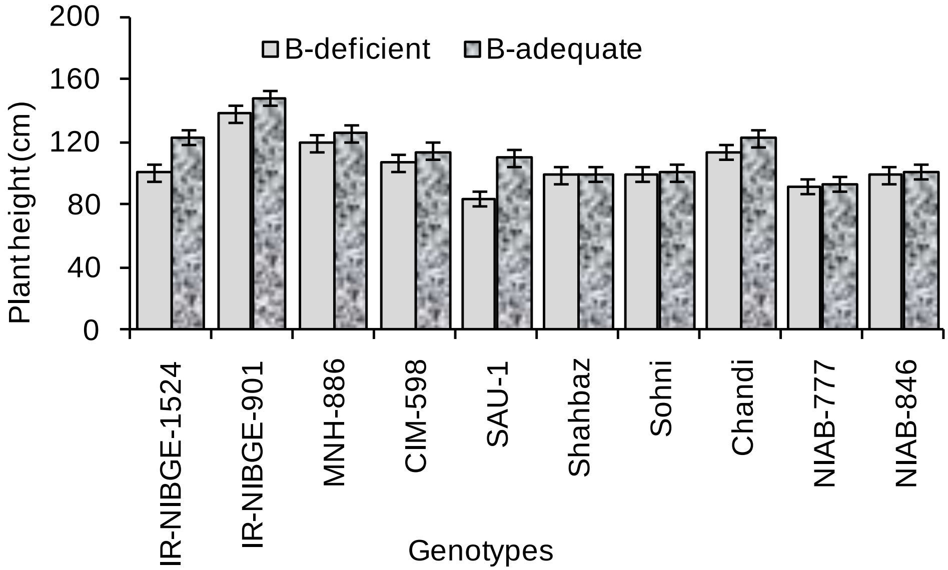

Figure 2. Plant height of cotton genotypes under deficient and adequate B regimes

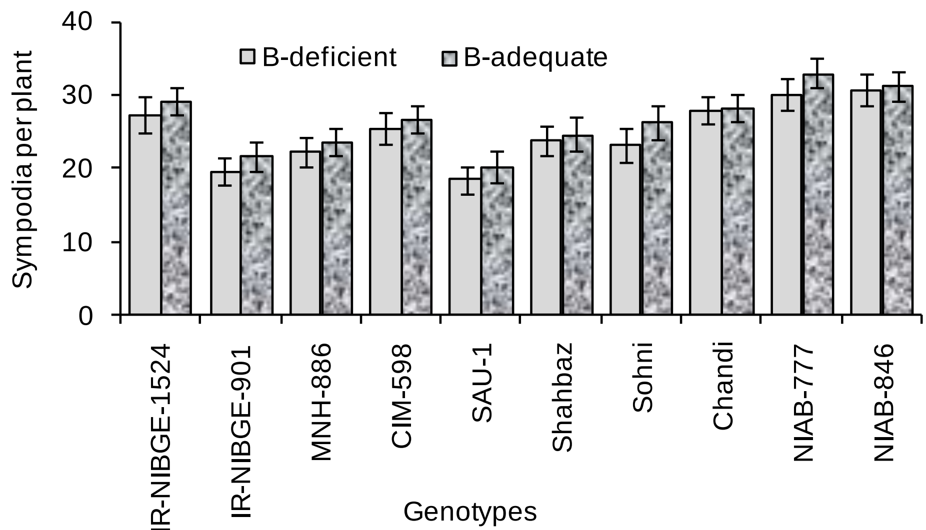

Figure 3. Sympodia per plant of cotton genotypes under deficient and adequate B regimes

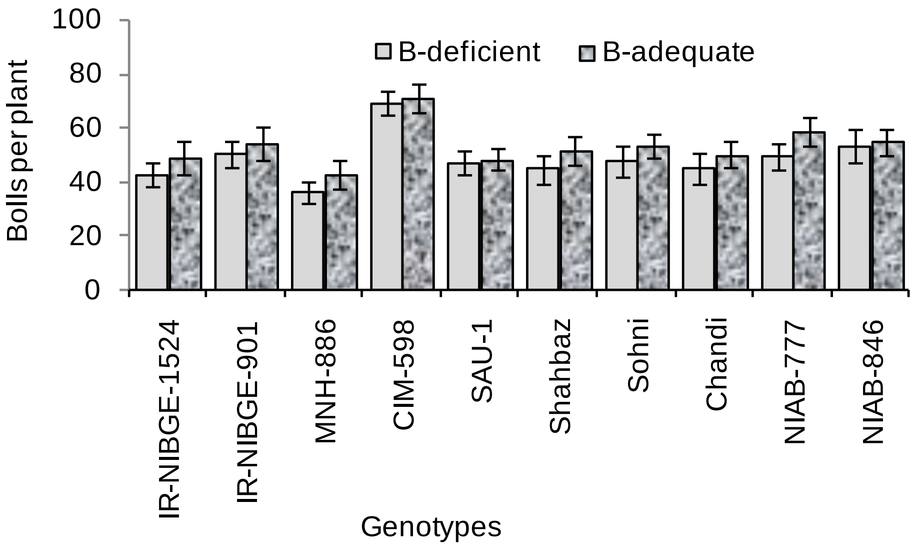

Figure 4. Bolls per plant of cotton genotypes under deficient and adequate B regimes

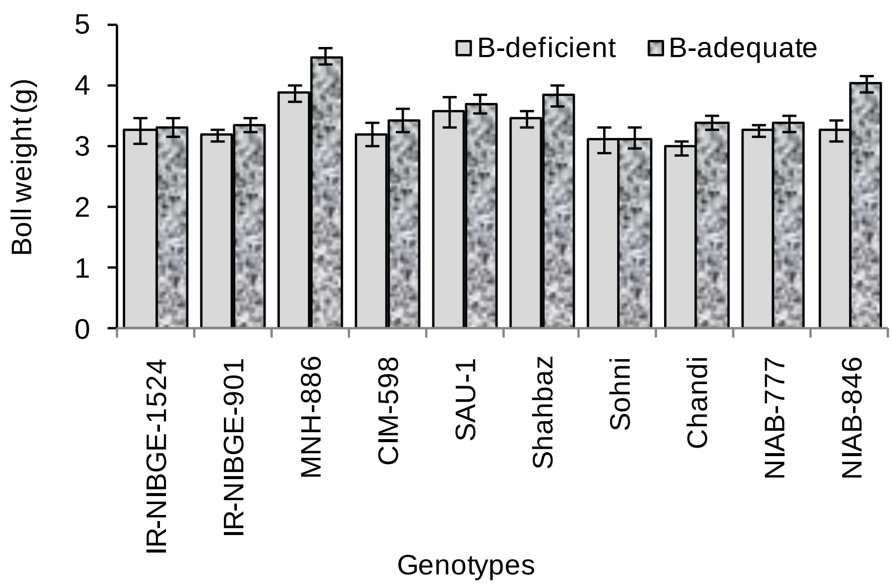

Figure. 5. Boll weight of cotton genotypes under deficient and adequate B regimes

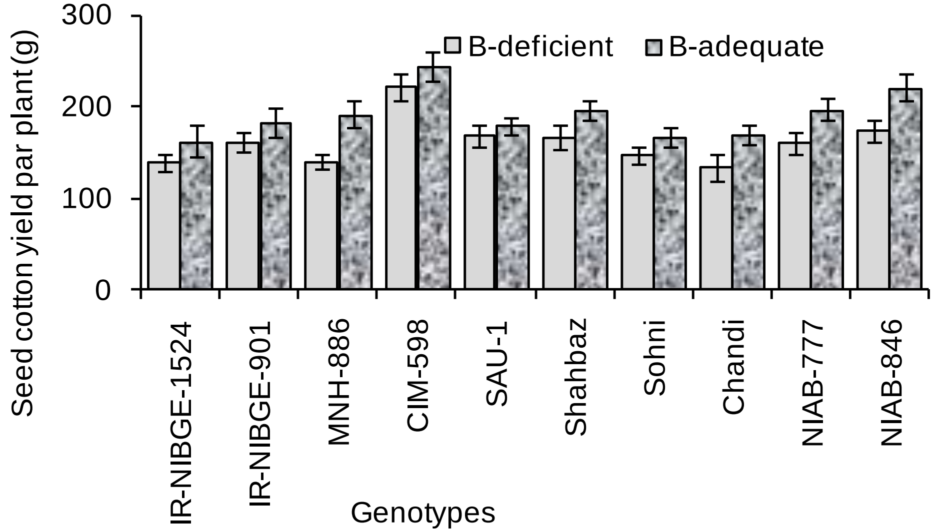

Figure 6. Seed-cotton yield of cotton genotypes under deficient and adequate B regimes

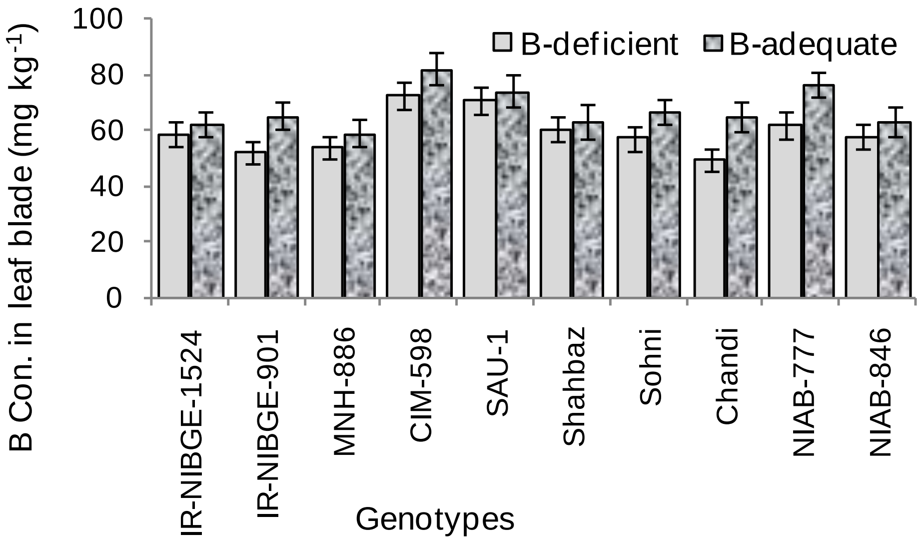

Figure 7. Leaf blade B content of cotton genotypes under deficient and adequate B levels

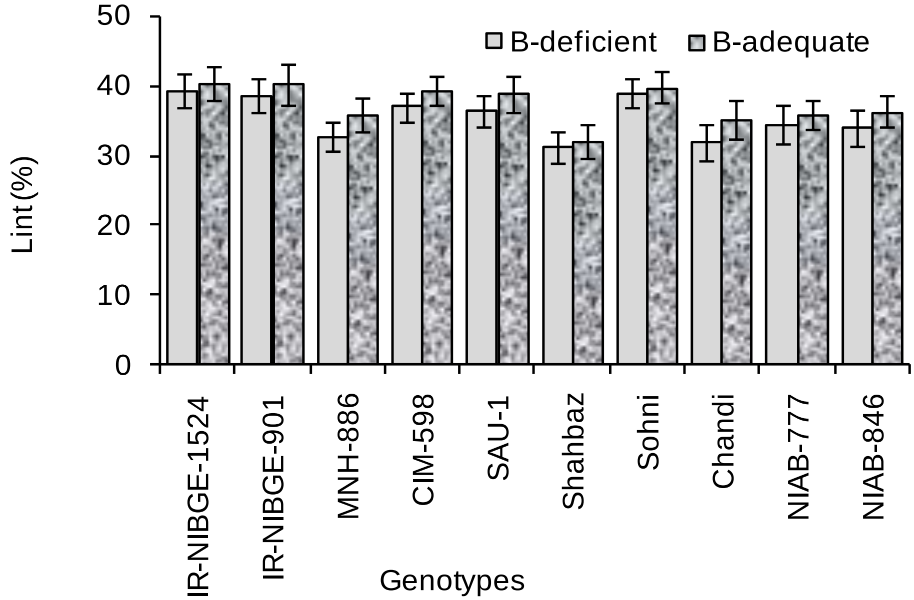

Figure 8. Lint percent of cotton genotypes under deficient and adequate B regimes

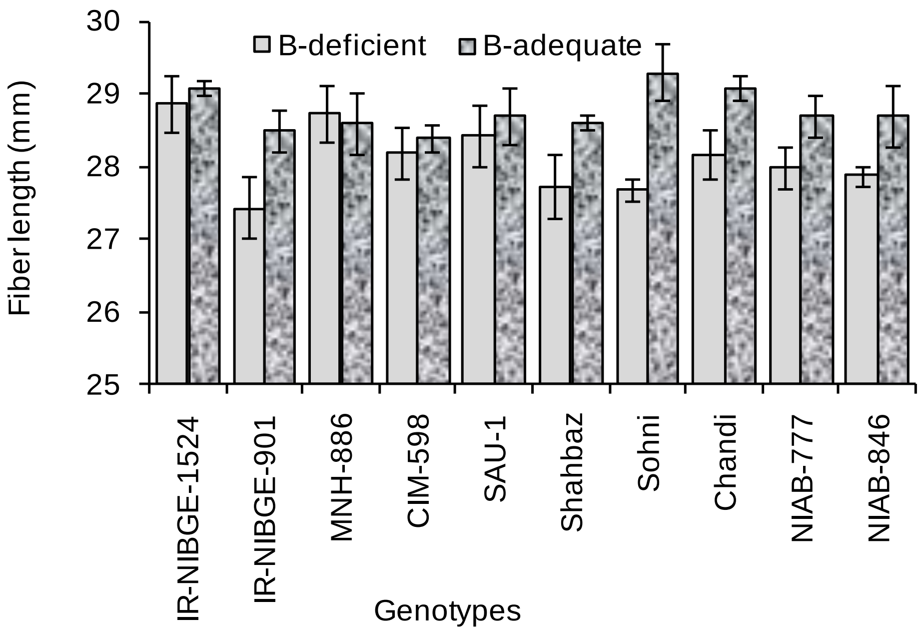

Figure 9. Fiber length of cotton genotypes under deficient and adequate B regimes

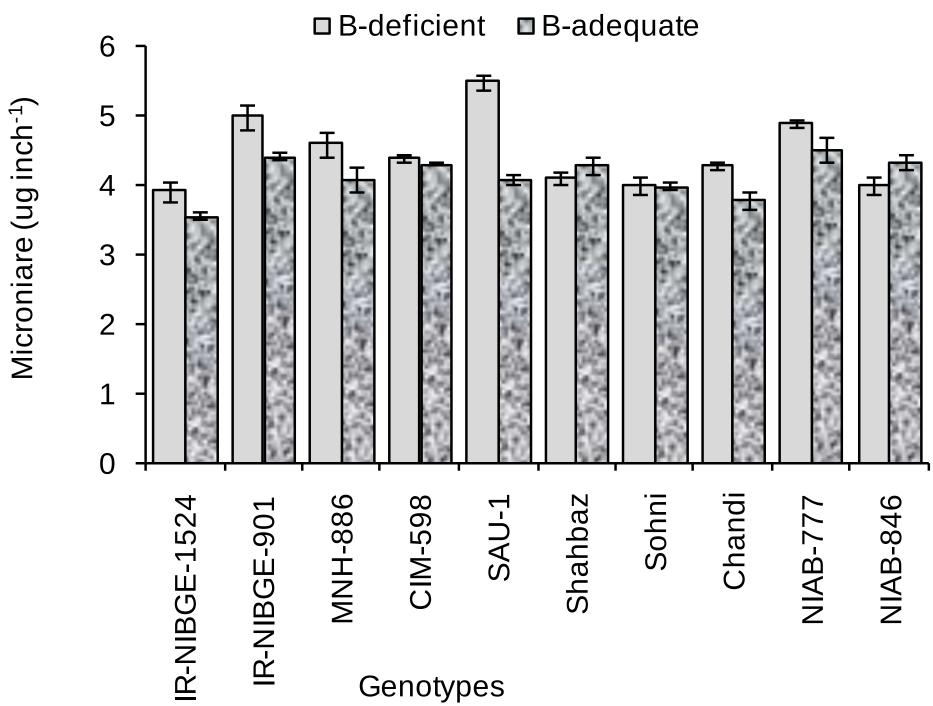

Figure 10. Microniare of cotton genotypes under deficient and adequate B regimes

Boll weight

The adequate supply of B produced variable effects on boll weight and increased the boll weight of all cotton genotypes by 8.6% over B deficiency stress (Figure 1). The cotton genotypes varied widely in their boll weights under both B regimes. The heaviest boll weight of 3.9 g was noted in genotype MNH-886 and the lightest boll weight of 3.2 g in CIM-598 under B deficient condition. However, highest boll weight of 4.5 g was observed in MNH-886 and lowest (3.1 g) in Sohni genotype under B deficient regime (Figure 5).

Seed-cotton yield

Cotton genotypes differed in the production of seed-cotton yield per plant under both B conditions. Boron application to soil increased seed-cotton yield per plant of all cotton genotypes by 18.7% as compared to the control (Figure 1). Among the tested genotypes, CIM-598 produced the highest seed-cotton yield per plant (221.3 g), while the least seed-cotton yield per plant (133.8 g) was recorded in Chandi under B deficient level. Under B adequate supply, again CIM-598 produced the utmost seed-cotton yield per plant (244.6 g), whereas the least (162.0 g) was noted in IR-NIBGE-1524 (Figure 6).

Boron content in leaf blade

Boron accumulation of leaf blade in cotton genotypes varied with B levels. At B adequate level, B content in leaf blade of all the cotton genotypes was increased by 14.1% as compared to B deficiency stress (Figure 1). The cotton genotype Chandi accumulated least B (49.2 µg g^{-1}) in leaf blade, whereas highest B accumulation (72.4 µg g^{-1}) was recorded in CIM-598 in B deficient fields. In B adequate fields, the minimum (59.1 µg g^{-1}) leaf blade B content was observed in MNH-886 and maximum (82.3 µg g^{-1}) in CIM-598 (Figure 7).

Lint percentage

Boron adequacy could not affect the fiber quality of cotton genotypes as much as it was observed in plant growth. The degree of lint production varied with cotton genotypes and B levels. Adequate supply of B augmented the lint production by 5.2% over B deficiency stress (Figure 1). The cotton genotype Shahbaz was recorded as the lowest lint producer at both B levels with lint production of 31.2% at B-deficient level and 32.1% at B-adequate level. However, the highest lint production of 39.3% (at B-deficient level) and 40.3% (at B-adequate level) was obtained in IR-NIBGE-1524 under both B regimes (Figure 8).

Fiber length

Adequate supply of B could not produce variable effects on fiber length of cotton genotypes. B adequacy increased fiber length by 2.3% over the control (Figure 1). Under B deficient conditions, genotype IR-NIBGE-901 produced the shortest fibers (27.4 mm). The longest fibers (28.9 mm) were noticed in IR-NIBGE-1524. The shortest fiber length of 28.4 mm was observed in CIM-598 and the longest fiber length (29.3 mm) was in Sohni at adequate supply of B (Figure 9).

Microniare

Microniare value of cotton fiber of genotypes was also affected with the B levels and reduced by 7.1% under adequate supply of B as compared to B deficiency stress (Figure 1). The minimum microniare (3.9 µg $inch^{-1}$) was noted in cotton genotype IR-NIBGE-1524 and maximum (5.5 µg $inch^{-1}$) in SAU-1 under B deficient condition. Under B adequate conditions, minimum microniare (3.6 µg $inch^{-1}$) was recorded in IR-NIBGE-1524 and maximum (4.5 µg $inch^{-1}$) was in NIAB-777 (Figure 10).

DISCUSSION

This study explored the variation in cotton genotypes for growth, yield and fiber quality due to B deficient and B adequate soil conditions. The study also demonstrated the role of B in cotton production as reported by various scientists (Gormus, 2005; Gupta and Hitesh, 2013). Increase in cotton yield with B application under B deficient condition is well known (Rashid, 2006; Rochester, 2007; Satya *et al*., 2009). However, very little information is available about the variation in fiber quality of cotton genotype of Pakistan under B deficient and adequate conditions.

Boron deficiency affected the growth, yield and fiber quality of all cotton genotypes, but the degrees of effects varied among the genotypes. Among the cotton genotypes, IR-NIBGE-901 produced tallest (138.5 cm) plant height; NIAB-

846 formed maximum (30.7) sympodia per plant; CIM-598, retained maximum (69.0) bolls per plant; MNH-886 produced highest (3.9 g) boll weight and CIM-598 produced maximum (221.3g) seed-cotton yield per plant under B deficient environment. However, under B adequate field conditions, the tallest plant height (148.2 cm), highest sympodia plant^{-1} (33.0), maximum bolls plant^{-1} (71.0), heaviest boll weight (4.5 g) and maximum seed-cotton yield per plant (244.6 g) were noted in IR-NIBGE-901, NIAB-777, CIM-598, MNH-886 and CIM-598, respectively (Figure 2, 3, 4, 5, 6). Boron deficiency adversely affected most of the growth traits and reduced plant height, sympodia per plant, bolls per plant, boll weight and seed-cotton yield per plant of all cotton genotypes by 8.4, 6.4, 10.0, 8.6 and 18.7%, respectively (Figure 1). Among the growth traits, bolls per plant were the most affected traits with 10.0% reduction. This might be due to the decrease in Indole Acetic Acid (IAA), which ultimately leads to increase in the concentration of abcisic acid in abcisic layer. Thus, B deficiency, increases the shedding of bolls. Agarwala and Chatterjee (1996) found that adequate supply of B increase the supply of IAA. Further, Jarvis and Booth (1981) stated that IAA and B act synergistically in beans (*Vigna radiata*). Moreover, B deficiency decreases lignin, pectin, cellulose and hemicellulose, thus affects the plant growth (O'Neill *et al.,* 2004). Boron and some glycol proteins are involved in membrane processes which are associated with cell growth (Redondo-Nieto *et al.,* 2007). Boron deficiency rapidly declined the expression of many genes in Arabidopsis roots (Camacho-Cristobal *et al.,* 2008), hence, retarded the root growth (A and L, 2002; Martín-Rejano *et al.*, 2011). Shah *et al.* (2015) concluded that adequate supply of B enhanced the growth and yield of cotton genotypes. The results also validated by the findings of many scientists, who reported that seed-cotton yield enhanced with the increase of boll weight, bolls per plant, B uptake, B use efficiency (Zhao and Oosterhuis, 2003; Mohsen *et al.,* 2013).

Likewise, growth and yield, B deficiency also affected leaf B content and fiber quality of cotton genotypes, but the degree of effects was varietal dependent. Adequate supply of B enhanced the leaf B content, lint percentage and fiber length of cotton genotypes by 14.1, 5.2, and 2.3% respectively. However, microniare was reduced by 7.1% (Figure 1). Among the genotypes, CIM-598 produced highest leaf B content (72.4µgg^{-1}) and IR-NIBGE-1524 produced longest fibers (28.9 mm) and minimum microniare (3.9 µg inch^{-1}) at B deficient condition. At B adequate level, CIM-598 accumulated maximum B in leaf (82.3 µg g^{-1}); Sohni produced the longest fibers (29.3 mm), whereas the least microniare (3.6 µg inch^{-1}) was noted in IR-NIBGE 1524 (Figure 7, 9, 10). Genotype IR-NIBGE-1524 formed maximum lint 39.3% and 40.3% under B deficient and adequate levels, respectively (Figure 8). In cotton, reproductive growth is more sensitive to B deficiency than the vegetative growth as B is involved in pollen germination and pollen tube development (Scaife and Turner, 1984; Robbertse *et al.,* 1990; Muntean, 2009; Gupta and Hitesh, 2013). The results were confirmed by the findings of Ahmad *et al.* (2009) who reported that the foliar application of B enhanced the seed-cotton yield, ginning outturn and staple length of cotton genotypes but the degrees of effects were varied with genotype to genotype. Similarly, soil applied B produced little effects on fiber length, fiber fineness, and uniformity ratio and fiber strength (Abid *et al.,* 2007).

CONCLUSION
Boron application produced positive effects on growth and yield but less extent on fiber quality of cotton genotypes. Genotypes responded differently under both B regimes. Among all genotypes CIM-598 was identified as the best genotypes with highest seed-cotton yield under both B regimes. Moreover, IR-NIBGE 1524 was found as the best fiber quality producing cotton genotype. The information generated from our study provides a valid knowledge about cotton genotypes being grown in Pakistan and researchers/breeders can utilize germplasm to develop more efficient cotton genotypes endowed with desired yield and quality traits.

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