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EVALUATING BORON-USE-EFFICIENCY OF TWENTY COTTON GENOTYPES OF PAKISTAN

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ABSTRACT

Boron (B) deficiency has been identified as a major yield limiting factor for sustainable cotton production around the globe, including Pakistan. Identification and adoption of B-use-efficient cotton genotypes is therefore crucial for low-B-input sustainable cotton production. A pot experiment was conducted in a completely randomized design with four repeats to categorize 20 selected cotton genotypes of Pakistan for their B-use-efficiency involving deficient (0 $kgha^{-1}$) and adequate (2 $kgha^{-1}$) levels of B. The cotton genotypes were ranked following two different methods to ensure ranking validity. Boron deficiency generally reduced biomass production and B uptake of all cotton genotypes. However, B-use-efficient cotton genotypes accumulated more B and produced more biomass under B-deficiency stress. Boron deficiency reduced plant height, number of leaves per plant, leaf area, shoot dry weight, shoot B accumulation and shoot B uptake of all genotypes (by 6, 14, 15, 8, 26 and 31%, respectively). Genotype CRIS-342 was ranked as ‘non-efficient’ due to its low biomass production under B-deficiency stress. Interestingly, cotton genotype IR-NIBGE-1524 exhibited wide adaptation at both the levels of B and hence ranked ‘efficient-responsive ’cotton genotype. The study concluded that the IR-NIBGE-1524 could be the most potential candidate for both the low- and high-B-input sustainable agriculture.

Keywords: B uptake, B-use-efficiency, cotton genotypes ranking, genotypic variation.

INTRODUCTION

Boron is one of the essential micronutrients for cotton growth and development. It is involved in many physiological and biochemical processes like root elongation, nucleic acid, proteins, amino acids, sugar, starch, auxin and phenol metabolism, flower formation, seed production and membrane function (Taiz and Zeiger, 2002; Rashid, 2006; Gupta, 2007; Ahmed *et al*., 2009; Wimmer *et al*., 2009; Shaaban, 2010). Consequently, boron is required at all growth stages, especially at fruiting stage of cotton crop (Rashidi and Gholami, 2011). Boron deficiency can significantly reduce the cotton yields without showing any deficiency symptoms

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(Satya *et al*., 2009). However, under severe deficiency plant expose retarded internodal growth, deformed and stunted bolls and root growth inhibition (Gupta, 2007). Boron is special among the plant nutrients because there is very narrow range between deficient and toxic levels (Miwa *et al.,* 2007). Many cotton areas of world, especially calcareous soils are suffering from boron deficiency (Zhao and Oosterhuis, 2003; Ahmed *et al.,* 2013). In Pakistan, its deficiency is wide spread and about 50% of the cotton fields are reported as B deficient (Rashid *et al.,* 1997). General recommendation of boron was suggested for all the cotton genotypes in Pakistan, which can be risky due to its toxic effects (Rashid, 2006). A wide range of genotypic variation in relation to B-efficiency has been found in numerous crop species. Sometimes the range of genotypic variation within species can be so wide that ranking of species may change with the genotypes being compared. Rerkasem (1990) and Rerkasem *et al.* (1993) found change in order of B-efficiency among soybean (*Glycine max*), green gram (*Vigna radiata*) and black gram (*Vigna mungo*) by selecting different genotypes for comparison. Similarly, it is general concept that wheat has a high tolerance to low soil B (Martens and Westermann, 1991) has to be revised following identification of a wide range of B-efficiency among wheat genotypes (Rerkasem, 1990; Rerkasem *et al.,* 1993; Rerkasem and Loneragan, 1994). Some of which are more in-efficient than dicotyledons. Zhang *et al*. (2007) reported a wide variation among four conventional and Bt. cotton genotypes under K deficient conditions. Recently, Zia-ul-hassan *et al*. (2011) categorized 25 cotton genotypes by using potassium deficient and adequate levels and ranked cotton genotype NIBGE-2 as “efficient- responsive”, CIM-506 as “non-efficient” and Desi okra as “non-responsive” genotypes. Different methods of categorization are used for the ranking of crop gentoypes. Gerloff (1977) categorized the crop varieties into efficient, non-efficient, responsive and non-responsive on the basis of nutrient use efficiency. Later on, Gill *et al*. (2004) applied a method of index scoring to classify the wheat cultivars on the basis of phosphorus uptake and use efficiency.This method ranked the genotypes in a wide range of groups, including medium category.This pot experiment was undertaken to evaluate 20 selected cotton (*Gossypium hirsutum* L.) genotypes of Pakistan their boron use efficiency and biomass production and to categorize the cotton genotypes, as efficient, medium efficient and highly efficient.

MATERIALS AND METHODS

Location

A pot experiment was conducted in a wire-house at the Department of Soil Science, Sindh Agriculture University, Tandojam [25.42557N/68.54060E] during Kharif 2012.

Pot experiment and crop growth

Pure seed of 20 cotton genotypes was collected from major cotton research Institutes and organizations of Pakistan viz. Genotypes IR-NIBGE-1524, IR-NIBGE-3 and IR-NIBGE-901 from National Institute for Biology and Genetic

Engineering (NIBGE) Faisalabad; FH-114 and MNH-886 from Ayub Agriculture Research Institute (AARI) Faisalabad; CIM-506 and CIM-598 from Cotton Institute Multan (CIM); SAU-1 and SAU-2 from Sindh Agriculture University (SAU) Tandojam; Sindh-1 and Shahbaz from Agriculture Research Institute (ARI) Tandojam; Sadori, Sohni, Chandi and NIA Ufaq from Nuclear Institute of Agriculture (NIA) Tandojam; NIAB-78, NIAB-777 and NIAB-846 from Nuclear Institute for Agriculture and Biology (NIAB) Faisalabad; CRIS-134 and CRIS-342 from Cotton Research Institute Sakrand (CRIS). Three seeds of each genotype were sown at an equal distance in polythene lined plastic pots filled with 15 kg soil.The soil, filled in pots was clay loam in texture, non-saline (ECe 1.9 dS m^{-1}), slightly alkaline (pH 8.2) and highly calcareous ($CaCO_3$ 13.2 %) in nature.The soil was deficient in organic matter (0.77%), Kjeldahl nitrogen (0.064%), $NaHCO_3$-extractable phosphorus (7.2 mg kg^{-1}) and diluted HCl boron (0.42 mg kg^{-1}), but adequate in NH_4OAc- extractable potassium (203 mg kg^{-1}). Two levels of B (control) without B and 2.0 kg B ha^{-1}) and 20 cotton genotypes were arranged according to complete randomized design with three repeats. Both levels of B were managed by applying borax (11.3% B) fertilizer. The recommended basal dose of nitrogen (200 kg ha^{-1}), phosphorus (100 kg ha^{-1}) and potash (70 kg ha^{-1}) was applied in the form of urea (46% N), single super phosphate (18% P_2O_5) and sulphate of potash (50% K_2O), before the sowing of crop.

Growth observations and harvesting

Plants were allowed to grow in pots for five weeks then harvested. The harvested seedlings were thoroughly washed with deionized water, followed by blotted drying, and used for observations like plant height, then separated into leaves and stems to record the fresh weights of leaves and stems and leaf area of each plant by using leaf area meter. Plant material was dried at 70^0C in a forced air oven till constant weight then dry weights of leaves and stems were recorded.

Boron accumulations and B relations

Boron concentration in plant shoot was determined by ashing 1.0 g of plant material in muffle furnace at 550^0C for 6 h, followed by the dissolving of material in 10 ml of 0.36 N H_2SO_4 solution then water bathed for 20 minutes. After cooling material was filtered in 50 ml volumetric flasks and volume was raised with deionized water. The extract was used for B analysis (Ryan *et al*., 2001). Boron relations were calculated by employing the following formulae:

B uptake = Dry weight ×B concentration (Nawaz *et al.*, 2006; Zhang *et al.*, 2007).
B use efficiency = Total dry weight ÷Total B uptake (Zhang *et al*., 2007).
B use efficiency = Shoot dry weight ÷Shoot B concentration (Siddiqi and Glass, 1981).

Categorization of cotton genotypes

The index scoring technique was employed to categorize the cotton genotypes (Gill *et al.,* 2004). The genotype was ranked as high if $x > \mu + STD$, low if $x < \mu$ –

STD and medium for the remaining values, where x represents the genotype mean for certain parameter, μ is for the population mean of that parameter and STD is the standard deviation of μ. The genotype means were classified into three different groups like low, medium and high by allotting the index scores of 1, 2, and 3, correspondingly. Finally, the cotton genotypes were ranked by using their index scoring ranges and scatter diagrams were developed by employing Microsoft Excel (Microsoft Corp, Redmond, WA, USA).

RESULTS

Biomass production

Biomass production, B uptake and B-use-efficiency of all cotton genotypes were affected with the B rates. A wide genotypic variation among the cotton genotypes was observed by their existence in low, medium and high index scores and their dissimilarities in biomass production at each rate of B (Table1).

Plant height

Plant height (cm) of cotton genotypes varied from 24.0 for SAU-1 to 35.7 for Sindh-1, with a mean of 31.1 at deficient level of B. It ranged from 27.2 for CRIS-342 to 37.6 for IR-NIBGE-901, with a mean of 33.1 at adequate level of B (Table 1). At deficient level of B, relative value for plant height was 94, showing a reduction of 6% to adequate B level, i.e. 100 (Fig. 1).

Number of leaves per plant

Number of leaves per plant of cotton genotypes ranged from 9.5 for Chandi to 23.4 for NIAB-846, with a mean of 17.5 at deficient B level. At adequate level of B, it varied from 15 for MNH-886 to 23.9 for IR-NIBGE-1524, with a mean of 20.4 (Table 1). Boron deficiency decreased number of leaves per plant by 14% compared to adequate level of B (Fig. 1).

Leaf area

Leaf area (cm^2 $plant^{-1}$) of cotton genotypes varied from 566.1 (CRIS-342) to 1380.8 (NIAB-78), with a mean of 936.3 at deficient B level. It varied from 671.1 for CRIS-342 to 1998.1 for IR-NIBGE-524, with a mean of 1095.2 at adequate B level (Table 1). The relative value of leaf area at B deficient level was 85. The leaf area reduced by 15% at B deficiency stress compared to adequate level of B. (Fig. 1).

Shoot dry weight

Shoot dry weight (g $plant^{-1}$) of cotton genotypes at deficient B level varied from 5.7 for CRIS-342 to 11.7 for Chandi, with a mean of 9.3. At adequate level of B shoot dry weight ranged from 7.7 for IR-NIBGE-901 to 12.3 for IR-NIBGE-1524, with a mean of 10.1 (Table 1). The relative value for shoot dry weight at deficient

B level was 92 which reflected that shoot dry weight of cotton genotypes reduced by 8% due to B deficiency stress (Fig. 1).

Shoot B concentration

Shoot B concentration (µg g^{-1}) of cotton genotypes ranged from 62.5 for NIAB-777 to 110.4 for Shahbaz, with mean of 78.9 at deficient B level. It ranged from 71.8 for NIA-Ufaq to 145.9 for Shahbaz, with a mean of 104.1 at adequate B level (Table 2). Boron deficiency stress reduced shoot B concentration by 26% as compared to adequate level of B (Fig. 1).

Table 1. Biomass productions of 20 cotton genotypes under deficient and adequate B in soil (Def. B and Adq. B are deficient B and adequate B, respectively). Values in bold following a genotype mean within each column are index scores (see Materials and Methods). Genotype means followed by similar index scores in a column are like in performance.

Genotype	Plant height (cm)				No. of leaves plant^{-1}				Leaf area plant^{-1} (cm^2)				Shoot dry weight (g)			
	Def. B	**IS**	Adq. B	**IS**	Def. B	**IS**	Adq. B	**IS**	Def. B	**IS**	Adq. B	**IS**	Def. B	**IS**	Adq. B	**IS**
IR-NIBGE-1524	30.4	**2**	35.1	**2**	16.7	**2**	23.9	**3**	1161.4	**3**	1998.1	**3**	11.6	**3**	12.3	**3**
IR-NIBGE-3	32.9	**2**	32.6	**2**	22.1	**3**	22.1	**2**	861.2	**2**	1044.5	**2**	8.9	**2**	9.6	**2**
IR-NIBGE-901	30.8	**2**	37.6	**3**	15.3	**2**	15.4	**1**	739.0	**2**	765.2	**1**	7.2	**1**	7.7	**1**
FH-114	32.7	**2**	32.7	**2**	23.0	**3**	23.0	**2**	1050.0	**2**	1055.4	**2**	10.1	**2**	10.2	**2**
MNH-886	28.3	**1**	33.2	**2**	13.5	**2**	15.0	**1**	755.6	**2**	787.2	**2**	7.0	**1**	7.8	**1**
CIM-506	31.9	**2**	31.5	**2**	18.0	**2**	18.1	**2**	751.7	**2**	752.5	**1**	7.9	**2**	8.0	**1**
CIM-598	32.7	**2**	36.1	**3**	16.2	**2**	21.6	**2**	985.5	**2**	1439.8	**3**	10.0	**2**	10.2	**2**
SAU-1	24.0	**1**	32.7	**2**	11.7	**1**	15.8	**1**	837.8	**2**	1159.9	**2**	6.0	**1**	8.3	**1**
SAU-2	33.8	**2**	33.9	**2**	18.0	**2**	18.1	**2**	1003.9	**2**	1022.1	**2**	9.8	**2**	11.8	**3**
Sindh-1	35.7	**3**	35.8	**3**	13.5	**2**	20.3	**2**	703.8	**1**	704.7	**1**	8.6	**2**	10.7	**2**
Shahbaz	32.3	**2**	32.4	**2**	19.8	**2**	19.8	**2**	990.3	**2**	1030.8	**2**	10.1	**2**	10.3	**2**
Sadori	33.6	**2**	33.7	**2**	23.0	**3**	23.0	**2**	869.9	**2**	1254.7	**2**	10.8	**2**	11.0	**2**
Sohni	30.4	**2**	30.4	**1**	14.9	**2**	16.2	**1**	811.3	**2**	1021.0	**2**	8.8	**2**	8.9	**2**
Chandi	30.0	**2**	35.1	**2**	9.5	**1**	18.5	**2**	1142.1	**3**	1188.3	**2**	11.7	**3**	11.9	**3**
NIA Ufaq	31.2	**2**	34.6	**2**	15.8	**2**	23.4	**3**	972.5	**2**	1178.1	**2**	10.3	**2**	11.7	**3**
NIAB-78	34.0	**3**	33.9	**2**	22.5	**3**	22.4	**2**	1380.8	**3**	1393.9	**2**	11.3	**3**	11.4	**2**
NIAB-777	32.7	**2**	32.8	**2**	21.2	**2**	23.0	**2**	1109.1	**2**	1028.1	**2**	10.3	**2**	10.3	**2**
NIAB-846	30.2	**2**	30.1	**1**	23.4	**3**	23.6	**3**	1191.2	**3**	1364.2	**2**	10.4	**2**	10.7	**2**
CRIS-134	29.8	**2**	31.7	**2**	18.0	**2**	22.9	**2**	842.3	**2**	1044.5	**2**	8.9	**2**	10.4	**2**
CRIS-342	25.5	**1**	27.2	**1**	14.4	**2**	21.2	**2**	566.1	**1**	671.6	**1**	5.7	**1**	8.9	**2**
Minimum	24.0		27.2		9.5		15.0		566.1		671.6		5.7		7.7	
Maximum	35.7		37.6		23.4		23.9		1380.8		1998.1		11.7		12.3	
Mean (u)	31.1		33.1		17.5		20.4		936.3		1095.2		9.3		10.1	
(STD)	2.8		2.4		4.1		3.0		198.7		309.5		1.8		1.4	
u + STD	34.0		35.5		21.6		23.4		1135.0		1404.7		11.0		11.6	
u - STD	28.3		30.8		13.4		17.3		737.5		785.7		7.5		8.7	

Table 2. Shoot B content, B uptake and B-use-efficiency of 20 cotton genotypes under deficient and adequate B in soil (Def. B and Adq. B are deficient B and adequate B, respectively). Values in bold following a genotype mean within each column are index scores (see Materials and Methods). Genotype means followed by similar index scores in a column are like in performance.

Genotype	Shoot B Conc. ($\mu g\ g^{-1}$)				Boron uptake of shoot ($\mu g\ plant^{-1}$)				BUE (mg SDW mg^{-1} SBU)			
	Def. B	**IS**	Adq. B	**IS**	Def. B	**IS**	Adq. B	**IS**	Def. B	**IS**	Adq. B	**IS**
IR-NIBGE-1524	75.1	**2**	93.8	**2**	868.9	**2**	1156.8	**2**	0.154	**3**	0.131	**3**
IR-NIBGE-3	80.8	**2**	91.6	**2**	719.7	**2**	883.8	**2**	0.111	**2**	0.105	**2**
IR-NIBGE-901	67.9	**2**	103.0	**2**	488.9	**1**	792.0	**1**	0.106	**2**	0.075	**1**
FH-114	78.5	**2**	98.7	**2**	791.5	**2**	1008.0	**2**	0.128	**2**	0.103	**2**
MNH-886	68.4	**2**	80.8	**1**	475.5	**1**	629.6	**1**	0.102	**2**	0.096	**2**
CIM-506	65.7	**1**	94.3	**2**	520.0	**1**	750.4	**1**	0.120	**2**	0.084	**2**
CIM-598	68.3	**2**	116.7	**2**	683.1	**2**	1187.5	**2**	0.147	**2**	0.087	**2**
SAU-1	101.1	**3**	107.7	**2**	607.5	**2**	899.3	**2**	0.059	**1**	0.077	**2**
SAU-2	66.5	**2**	96.1	**2**	648.6	**2**	1134.9	**2**	0.147	**2**	0.123	**3**
Sindh-1	81.3	**2**	103.0	**2**	695.7	**2**	1105.2	**2**	0.105	**2**	0.104	**2**
Shahbaz	110.4	**3**	145.9	**3**	1119.7	**3**	1508.6	**3**	0.092	**2**	0.071	**1**
Sadori	68.8	**2**	103.0	**2**	743.3	**2**	1128.3	**2**	0.157	**3**	0.106	**2**
Sohni	89.6	**2**	116.7	**2**	788.9	**2**	1037.2	**2**	0.098	**2**	0.076	**1**
Chandi	72.6	**2**	114.5	**2**	850.6	**2**	1366.4	**3**	0.161	**3**	0.104	**2**
NIA Ufaq	89.6	**2**	71.8	**1**	922.5	**3**	840.3	**2**	0.115	**2**	0.163	**3**
NIAB-78	87.5	**2**	105.5	**2**	987.8	**3**	1204.9	**2**	0.129	**2**	0.108	**2**
NIAB-777	62.5	**1**	110.3	**2**	642.5	**2**	1139.1	**2**	0.164	**3**	0.094	**2**
NIAB-846	68.8	**2**	103.2	**2**	718.5	**2**	1109.6	**2**	0.152	**3**	0.104	**2**
CRIS-134	91.6	**2**	121.2	**3**	815.9	**2**	1266.1	**2**	0.097	**2**	0.086	**2**
CRIS-342	83.4	**2**	103.0	**2**	477.0	**1**	918.7	**2**	0.069	**1**	0.087	**2**
Minimum	62.5		71.8		475.5		629.6		0.059		0.071	
Maximum	110.4		145.9		1119.7		1508.6		0.164		0.163	
Mean (u)	78.9		104.1		728.3		1053.3		0.121		0.099	
(STD)	12.9		15.5		172.9		215.9		0.031		0.022	
u + STD	91.9		119.5		901.2		1269.2		0.151		0.121	
u - STD	66.0		88.6		555.4		837.4		0.090		0.077	

B uptake

Shoot B uptake ($\mu g\ plant^{-1}$) varied from 475.5 for MNH-886 to 1119.7 for Shahbaz, with average of 728.3 at B deficient level. However, at adequate B level, it ranged from 629.6 for MNH-886 to 1508.6 for Shahbaz with a mean of 1053.3 (Table 2). B deficiency decreased B uptake of shoot. Shoot B uptake reduced by 31% under B deficiency stress relative to adequate B level (Fig. 1).

B use efficiency

Boron use efficiency (g dry weight mg^{-1} B uptake) varied from 0.059 for SAU-1 to 0.164 for NIAB-777, with an average of 0.121 at B stress condition. At adequate

B level, B use efficiency ranged from 0.071 for Shahbaz to 0.163 for NIA Ufaq, with a mean of 0.099 (Table 2). It has been observed that cotton genotypes showed higher B use efficiency at B deficient level related to adequate level of B (Fig. 1). Boron use efficiency of cotton genotypes at both deficient and adequate level was compared by using the formula (g^2 shoot dry weight mg^{-1} shoot B concentration) as reported by Siddiqi and Glass (1981).

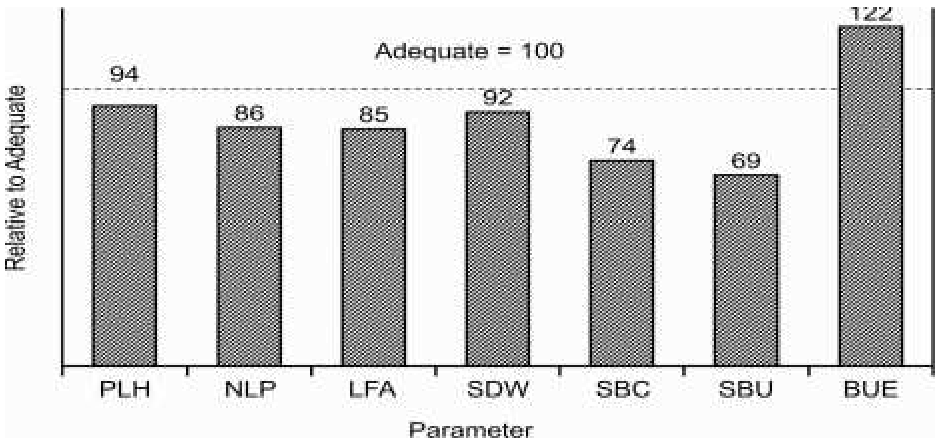

Figure 1. Performance of cotton genotypes at deficient relative to adequate level of B in pot study (PLH, NLP and LFA are plant height [cm], number of leaves per plant and leaf area [cm^2 $plant^{-1}$], respectively). SDW: shoot dry weight (g); SBC: shoot B concentration (µg g^{-1}); SBU: shoot boron uptake (mg $plant^{-1}$); BUE: B use efficiency (g DW mg^{-1} B uptake).

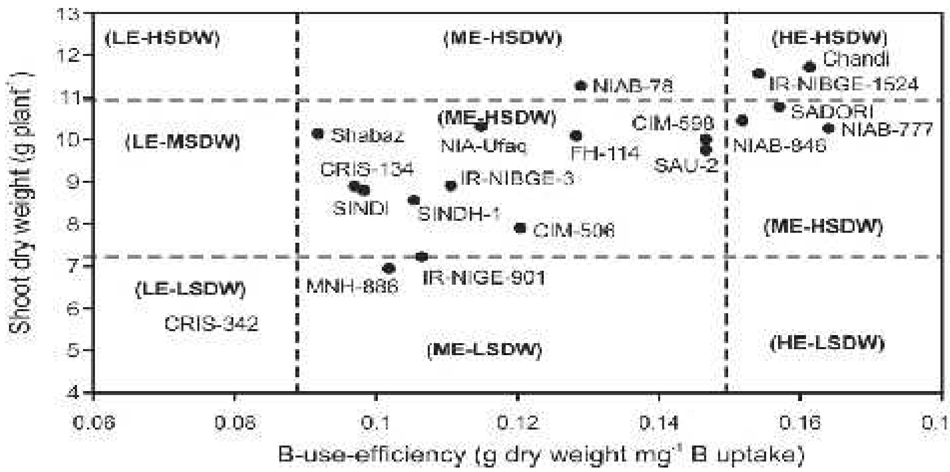

Figure 2. Ranking of 20 cotton genotypes based on their B use efficiency at deficient B level (LE: low-efficient, ME: medium-efficient, HE: highly-efficient, LSDW: low shoot dry weight, MSDW: medium shoot dry weight, HSDW: high shoot dry weight). B use efficiency was calculated by the formula suggested by Siddiqi and Glass (1981). The ranking of genotypes was carried out by using the method of Gill *et al.* (2004).

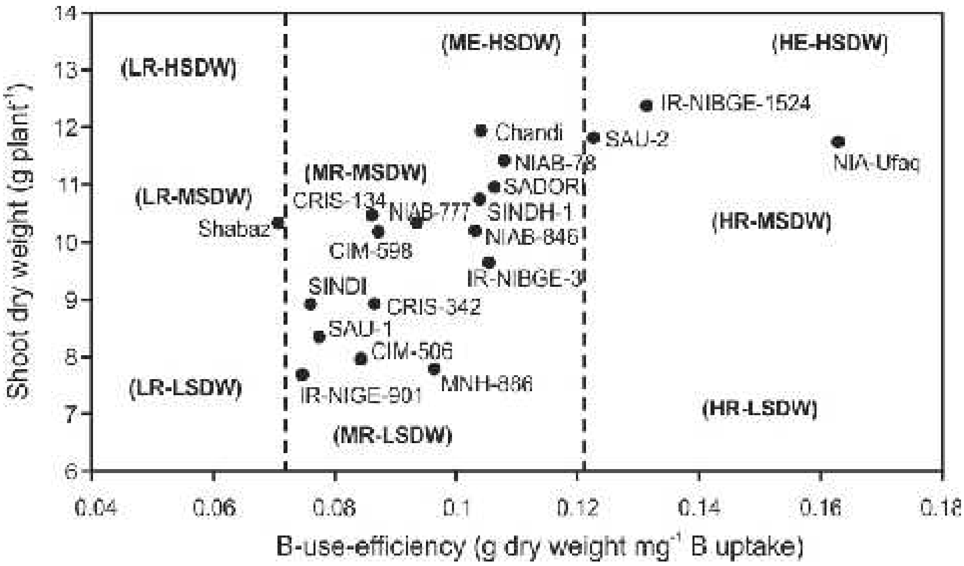

Figure 3. Ranking of 20 cotton genotypes based on their B-use-efficiency at adequate B level (LE: low-efficient, ME: medium-efficient, HE: highly-efficient, LSDW: low shoot dry weight, MSDW: medium shoot dry weight, HSDW: high shoot dry weight). B-use-efficiency was calculated by the formula suggested by Siddiqi and Glass (1981). The ranking of genotypes was carried out by using the method of Gill *et al.* (2004).

Categorization of cotton genotypes

Cotton genotypes were ranked at both deficient and adequate levels of B by employing the method as described by Gill *et al.* (2004). Most of the cotton genotypes were found as "medium-efficient" at deficient B level. Nevertheless, CRIS-342 was ranked as "low-efficient", whereas, NIAB-846, NIAB-777, Sadori, Chandi and IR-NIBGE-1524 were ranked as "highly-efficient" (Fig. 2; Table 3). On the other hand, at adequate level of B only Shahbaz was ranked as "low-efficient", while SAU-2, NIA-Ufaq and IR-NIBGE-1524 were classed as "high-efficient". The remaining all the genotypes were categorized as "medium-efficient" (Fig. 3; Table 3).

DISCUSSION

Biomass production, B uptake and B-use-efficiency of all cotton genotypes was decreased under B deficient stress (Fig. 1). The deviation in growth and biomass production showed differential adaptation of cotton genotypes under different B levels and validated the findings, emphasizing the significance of adequate B nutrition of cotton (Ahmad *et al.,* 2009; Bogiani and Rosolem, 2012). The reduction in growth and biomass production under B deficient stress perceived the important role of B in physiological, biochemical and metabolic functions and many enzymatic activities (Taiz and Zeiger, 2002; Ahmed *et al*., 2009; Hansch and Mendel, 2009; Wimmerr *et al*., 2009; Shaaban, 2010). In cotton, B deficiency reduced plant height, leaf area, photosynthetic rate, fruiting site and biomass production during squaring (Zhaoand Oosterhuis. 2003). Comparatively, plant height, number of leaves per plant, leaf area and shoot dry weight of all cotton genotypes reduced by 6, 14, 15 and 8%, respectively at B deficient level compared to B adequate level (Fig. 1; Table 1).

Table 3. Ranking of 20 cotton genotype at deficient and adequate B regimes (LE: low-efficient, ME: medium-efficient, HE: highly-efficient, LSDW: low shoot dry weight, MSDW: medium shoot dry weight, HSDW: high shoot dry weight). The ranking of genotypes was carried out by using the method of Gill *et al.* (2004).

Varieties	Deficient	Adequate
IR-NIBGE-1524	HE-HSDW	HR-HSDW
IR-NIBGE-3	ME-MSDW	MR-MSDW
IR-NIBGE-901	ME-LSDW	MR-LSDW
FH-114	ME-MSDW	MR-MSDW
MNH-886	ME-LSDW	MR-LSDW
CIM-506	ME-MSDW	MR-LSDW
CIM-598	ME-MSDW	MR-MSDW
SAU-1	ME-MSDW	MR-LSDW
SAU-2	ME-MSDW	HR-HSDW
Sindh-1	ME-MSDW	MR-MSDW
Shahbaz	ME-MSDW	LR-MSDW
Sadori	HE-MSDW	MR-MSDW
Sohni	ME-MSDW	MR-MSDW
Chandi	HE-HSDW	MR-HSDW
NIA Ufaq	ME-MSDW	HR-HSDW
NIAB-78	ME-HSDW	MR-HSDW
NIAB-777	HE-MSDW	MR-MSDW
NIAB-846	HE-MSDW	MR-MSDW
CRIS-134	ME-MSDW	MR-MSDW
CRIS-342	LE-LSDW	MR-MSDW

A wide range of genotypic variation in B efficiency has been found in numerous species of crops and other domesticated plants (Rerkasem, 1990; Rerkasem *et al.,* 1993). Boron efficient cotton genotypes accumulate more B in different floral parts especially in stamen and pistil from B deficient medium compared to B inefficient genotypes (Jian *et al.,* 2004). In this study,“highly-efficient” cotton genotypes i.e. NIAB-777, NIAB846, Sadori, Chandi and IR-NIBGE-1524 took up more B from B deficient medium than “low-efficient” genotype CRIS-342, while, at B adequate level IR-NIBGE-1524, SAU-2 and NIA-Ufaq were found as “highly-efficient” and Shahbaz as “low-efficient” (Fig. 2; Table 2). These results were supported by the findings of Renildes *et al.* (2008) who reported that cotton genotypes BRS Aroeira and BRS Sucupira responding more to applied B as compared to BRS Ipe and ordered the cultivars on the basis of B-use-efficiency as BRS Aroeira> CNPA 8H = BRS Antares > BRS Sucupira> BRS Ipe. Harite (2008) also found variability in eight cotton cultivars and reported that Gürel Bey and Gossipolsüz Nazilli were the most tolerant and Nazilli 39 was the most sensitive against boron toxicity. All the cotton genotypes were categorized on basis of their B use efficiency into three different groups i.e. “low-efficient”, “medium-efficient” and “highly-efficient” at both regimes of B. Genotype IR-NIBGE-1524 was ranked as “efficient-responsive” (Fig. 3 and 4). Comparatively, this genotype has wide range of adoptability and tolerant to biotic and abiotic stresses (PAEC, 2009).

CONCLUSION

Among all the tested cotton genotypes, the cotton genotype IR-NIBGE-1524 appears to be the only “efficient-responsive” genotype that could be successfully adopted in low and high boron input sustainable cotton production. In addition this genotype can also be considered for future breeding programs, to develop new B-use-effcient cotton gentoypes.

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