

Research Article



Growth, Yield and Sucrose Percent Response of Sugarcane to Zinc and Boron Application

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Abstract | Zinc (Zn) and boron (B) are restrictive micronutrients in production regions of the sugarcane in Pakistan. This study focused on hypothesis that application of both Zn and B play a key role in getting better sugarcane yield and superiority. Experiment was conducted under field condition during 2016-17 and repeated in 2017-18 at Sugarcane Research Institute, Tandojam, Sindh, Pakistan. Crop in 1st year was planted on an experimental field by shifting on another adjacent field in 2nd year, which was fallow. The sugarcane variety PSTJ-41 was used for the study of Zn and B as soil and foliar application. Zn levels included: 0 kg ha⁻¹ (control), 15 k.g ha⁻¹ (soil application) and 0.2% (foliar application). Boron levels consisted: 0 kg ha⁻¹ (control), 1 k.g ha⁻¹ (soil application) and 0.1% (foliar application). Soil application of Zn and B were done at three times off sowing, whereas, foliar applications of both were done as spray over foliage after three months of planting when plant height was about 75 cm. Application of Zn was done in the shape of Zinc Sulphate (ZnSO₄) whereas, Boron in the shape of Borax (Na₂B₄O₇·10H₂O). The statistical analysis of pooled data of two years experiments indicated that growth, yield, quality and plant nutrients contents of sugarcane were affected appreciably (P<0.05) by Zn and B as judged to check plots. Zn at 15 kg ha⁻¹ (soil applied) resulted in enhanced traits particularly cane yield (111.9 t ha⁻¹), brix (23.1%), and plant nutrients content such as N (2.4 %), K (0.7 %), Zn (68.5 ug g⁻¹) and B (31.7 ug g⁻¹). Similarly, foliar application of B at 0.1 % produced highest attributes specifically cane yield (107.4 t ha⁻¹), brix (21.9%), and plant nutrients content i.e. N (2.3 %), K (0.7 %), Zn (68.5 ug g⁻¹) and B (31.7 ug g⁻¹). Amongst interactive effects, the interaction of Zn at 15 k.g ha⁻¹ (soil applied) × B at 0.1 % (foliar applied) gave increased parameters distinctively cane yield (119.0 t ha⁻¹), brix (24.0 %), and plant nutrients content viz. N (2.5 %), K (0.9 %), Zn (73.9 u.g g⁻¹) and B (35.0 ug g⁻¹). However, it is supposed that integrated grouping of Zn at 15 k.g ha⁻¹ (soil applied) and B at 0.1% (foliar applied) proved the best combination for attaining highest yield of sugarcane in agro-ecological conditions of Tandojam.

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Introduction

Sugarcane (*Saccharum officinarum* L.) is a cash produce of our country (GoP, 2018). Sugarcane is also cultivated worldwide in more than 105 countries

(Hussain et al., 2015). According to area under cultivation, Pakistan is the 5th position in cane acreage and production and almost 8th biggest consumer of sugar in the world (FAO, 2017). Cane is the main and overwhelming raw material used. It could be a key

source of profit and business for cultivating society of the nation (Ehsanullah et al., 2016). In our country area under cultivation of sugarcane is 1.131 million hectares and cane production of 73.6 million tonnes. Its surplus input in agriculture and GDP as 3.4 and 0.7 percent, correspondingly (GoP, 2017). Reason of sugarcane growing is to make sugar and sugary products (Naqvi, 2005). In Pakistan the average sugarcane yield is low as match up to other countries like Australia, Brazil, USA, China and India (MNFSR, 2013). Reasons of low yield include conventional planting methods, inappropriate seed rate, improper fertilizer application, poor irrigation management, insect pests, diseases, weeds, high cost of inputs, delayed harvesting, lack of agricultural education, credit shortage, natural calamities etc. (Baloch et al., 2002; Malik and Gurmani, 2005). Role of micronutrients is very important for growth and development of crop despite their requirements in a very minute quantity (Jabran et al., 2017). In the same way, Lifang et al. (2001) disclosed that inadequate supply of nutrients has greatest impact on reducing sugarcane yields. Sugarcane production and yield is considerably inclined by application of iron along with zinc. Quality traits i.e. sucrose % revealed major variations upon the boron application at 10 kg ha⁻¹ succeeded by FeSO₄ spray 2% twofold after 30 and 60 days of sowing (Madhuri et al., 2016). Foliar applications are used to supply micronutrients more rapidly for correction of severe deficiencies and considered as a tool to improve nutrient-use efficiency (Jabran et al., 2017). Foliar application of ZnSO₄ 0.5% made cane produce (Chandra, 2005). Ghaffar et al. (2011) stated that Zn and Fe application in count to macro-nutrients (NPK) has increased production of sugarcane. The present study was conducted by taking into account the significance of sugarcane and its response under micronutrients, the study was conducted to determine proper Zn and B requirements for enhanced growth, production and sucrose percentage of sugarcane within the agro-ecological conditions of Tandojam.

Materials and Methods

The experiment was undertaken to assess the consequence of foliar and soil applied micronutrients (Zn and B) on growth, yield and sucrose percentage of sugarcane. Field area of Sugarcane Research Institute, Tandojam, Sindh, Pakistan was used for conducting experiments for two consecutive years

during autumn 2016-17 and 2017-18. The soil of trial region was clay loam, which acquiescent to USDA framework fit in to Order *Aridisols* and Sub-group *Typic Camborthids*. The experimental field was ploughed two times with disc harrow, irrigated, dried to workable condition, leveled and finally seedbed was prepared by plowing with cultivator. The experiment was laid out under randomized complete block design (RCBD) having three replications. Plot size was 13 m x 2.3 m (30 m²). The crop in the 1st year was planted on one plot of experimental field whereas during 2nd year the crop was planted on adjacent fallow plot of same experimental field. The sugarcane candidate variety PSTJ-41 was planted on 22nd 2016 and 25th September 2017, respectively. The field area was well managed prior to planting. After intense tillage operations with mould board plow, crosswise disc harrow, succeeded by rigorous smoothing was done to bring the soil to the condition suitable for cultivation. Ridger was used for making furrows. The experiment was comprised of three levels of each Zn and B. The suggested measurements of NPK fertilizers were also dispensed in shape of Urea, DAP (diammonium phosphate) and SOP (sulphate of potash). All P and K, and 1/3rd of N were used at the time of planting. The left over two splits of N were used at 1st earthing-up (3 1/2 months after sowing) on 7th January, 2017 and 9th January 2018. In the same way second split dose was applied in next earthing-up (about 45 days after initial earthing up) on 23rd February, 2017 and 24th February 2018. All routine cultural practices like weeding, hoeing and herbicide application were kept common and consistent for all the plots. Applications of micronutrients Zn and B were done in the form of zinc sulphate (22% Zn) and Borax (11.36% B). Zn and B (Soil application) were applied at the time of sowing at the amount of 15 and 1 kg ha⁻¹ in respective treatment plots while control plots got nothing. Application of Zn and B (foliar) at the requisite rates was sprayed on leaves at 75 cm height of crop on 23rd December, 2016 and 22nd December 2017, correspondingly. Zn and B were sprayed at 0.2% and 0.1%. The propagatory material was taken from upper 2/3rd portion of stalk of eight months old cane. Cane setts were soaked in Topsin-M at 150 g 100⁻¹ L water to protect them from many cane diseases like sugarcane smut. Dry method of planting was adopted for growing canes with ear-to-ear planting pattern. The cane setts were placed in furrows at depth of 6-8" and masked with 5-6 cm soil. Immediately after covering the setts water was let

into furrows. Irrigation was applied keeping in view the soil condition and crop need as farmer practice. In summer (April-August) irrigation was applied at the interval of 7-10 days while in winter (November-March) at the interval of 10-15 days. Over all 28 irrigations have been implemented during the growing season (12 months). The herbicide (CLIO Combo pack at 3.75 k.g ha⁻¹ was applied one month after planting when sufficient *moisture* was present in the soil. The insecticide Lorsban at 5 L ha⁻¹ was applied at 1st irrigation to manipulate termites. Trichogramma cards were stapled against the borers. Insecticide Furadan 3G (Carbofuran) was televised at 30 kg ha⁻¹ in case borers were not controlled by Trichogramma cards. Harvesting was done when crop was physiologically mature i.e. ripening phase completed and brix was above 20%. The crop was harvested manually on 28th December, 2017 and 31st December, 2018, respectively.

Physico-chemical analysis of soil

Three soil samples were taken by hand auger at the profundity of 45 cm from five locations of experimental area earlier than planting and after reaping of crop. The samples had been air-dried, ground, sifted (2 mm) and placed in plastic containers. Later than various physical and chemical properties of soil were tested from these samples adopting procedure suggested by Rayan et al. (2001). Soil texture was measured by the Bouyoucos hydrometer method. Electrical conductivity (EC) and soil pH was measured in 1:2 soil/distilled water using EC and pH meters, respectively. Walkley and Black (1934) process was followed for the determination of organic matter content. Total N was calculated. However, soil was extracted for determining extractable P and K using Ammonium bicarbonate di-ethylene triamine penta acetic acid (AB-DTPA). B was determined by dry ashing in a muffle furnace (Bench Top Preiser, FB1410M) and measured colorimetrically by usage of azomethine-H (Keren, 1996). For Zn, the material was assimilated in a 5:1 acid mixture (HNO₃:HClO₄), and the assimilate was diluted to 100 ml with distilled water. Zn was measured by way of atomic absorption spectrophotometer (AA-7000, Shimadzu, Japan) (Wright and Stuczynski, 1996). The details of physico-chemical evaluation of soil are specified in Table 1.

Statistical analysis

Facts gathered from experiment was statistically analyzed by way of utilizing computer software Statistix

version 8.1 (Statistix, 2006). The difference between treatment means was evaluated by LSD test when P value was significant at alpha 0.05.

Table 1: Average physico-chemical properties of experimental soil (2016-17 and 2017-18).

Soil Parameter	Values
Soil texture	
Sand (%)	19.5
Silt (%)	42.0
Clay (%)	38.5
Textural class	Silty clay loam
Soil chemical analysis	
EC (dS m ⁻¹)	0.23
Soil pH	8.20
Organic matter (%)	0.83
Total N (%)	0.09
Available P (mg kg ⁻¹)	8.80
Extractable K (mg kg ⁻¹)	0.88
Extractable Zn (mg kg ⁻¹)	0.40
Extractable B (mg kg ⁻¹)	0.11

Results and Discussion

Bud sprouting (%)

Statistical evaluation of figures showed that significant ($p < 0.05$) effect was caused by Zn on sprouting of buds whereas, a non-significant ($p > 0.05$) by B and the interaction of Zn and B (Table 2). Zn 15 k.g h⁻¹ give the best sprouting of buds, accompanied via 0.2% Zn foliar application having statistical equality with each other while lowest sprouting of buds was noticed in 0 kg ha⁻¹ Zn. Boron 1 kg ha⁻¹ derivatives greatest sprouting of buds seconded by 0.1% B foliar application and 0 kg B ha⁻¹. The interaction of Zn 15 kg ha⁻¹ × B 1 kg ha⁻¹ produced enhanced sprouting of buds preceded by Zn 15 kg ha⁻¹ × B 0.2% whereas diminished results were recorded in Zn 0 kg ha⁻¹ × B 0 kg ha⁻¹. This might be attributed to vital role of Zn in development and enhancement of sugarcane plants. The possible reason of better sprouting of buds with application of Zn might be fulfillment of plant requirement because mostly zinc stays bound to the solid particles of soil and exists in unavailable forms. Quantitative and qualitative parameters of sugarcane were significantly affected by different levels of Zn (Ghaffar et al., 2011). Jabran et al. (2017) revealed that micronutrients (Zn and B) are also essential in plant improvement even though required in low extent.

Weather data

Month	Week	2016-17				Month	Week	2017-18			
		Temperature (°C)		Relative humid- ity (%)	Rainfall (mm)			Temperature (°C)		Relative hu- midity (%)	Rainfall (mm)
		Min.	Max.					Min.	Max.		
Sep. 16	I	23.5	35.2	67.8	0.0	Nov. 17	i	15.9	35.4	51.3	0.0
	Ii	23.2	36.0	64.9	0.0		ii	13.4	32.0	55.9	0.0
	Iii	22.8	38.7	60.4	0.0		iii	9.9	27.0	48.3	0.0
	Iv	22.6	37.2	63.1	0.0		iv	10.7	30.4	48.6	0.0
Oct.16	I	23.4	38.3	59.4	0.0	Dec. 17	i	8.5	25.1	46.6	0.0
	Ii	21.5	37.3	57.0	0.0		ii	6.6	22.9	58.7	0.0
	Iii	19.6	36.6	57.3	0.0		iii	8.4	24.9	54.1	0.0
	Iv	18.9	36.1	53.5	0.0		iv	7.1	25.9	50.2	0.0
Nov. 16	I	14.7	35.5	52.8	0.0	Jan. 18	i	5.0	25.5	50.7	0.0
	Ii	13.1	32.2	48.0	0.0		ii	8.6	25.7	50.2	0.0
	Iii	12.1	32.0	50.0	0.0		iii	9.1	26.3	52.2	0.0
	Iv	11.6	30.5	57.4	0.0		iv	9.3	28.1	52.1	0.0
Dec. 16	I	12.1	30.3	52.6	0.0	Feb. 18	i	10.1	25.4	48.4	0.0
	Ii	12.8	28.1	60.0	0.0		ii	10.4	26.2	48.2	0.0
	Iii	10.4	27.8	49.9	0.0		iii	11.7	32.1	50.4	0.0
	Iv	9.6	27.9	57.4	0.0		iv	15.2	31.4	58.1	0.0
Jan. 17	I	9.0	20.8	71.5	0.0	Mar. 18	i	15.4	34.3	52.8	0.0
	Ii	6.1	21.3	58.7	0.1		ii	16.2	34.8	49.1	0.0
	Iii	6.4	21.9	55.2	0.0		iii	15.1	34.8	45.1	0.0
	Iv	7.3	24.3	57.6	0.3		iv	16.1	40.6	35.7	0.0
Feb. 17	I	8.6	24.6	52.0	0.0	Apr. 18	i	19.5	39.9	46.1	0.0
	Ii	7.7	26.1	45.7	0.0		ii	20.3	39.7	43.0	0.0
	Iii	12.6	30.2	50.4	0.0		iii	19.3	38.8	33.7	0.0
	iv	10.9	31.7	47.1	0.0		iv	21.4	42.7	44.5	0.0
Mar. 17	i	11.7	31.6	46.7	0.0	May. 18	i	23.3	40.9	48.4	0.0
	ii	10.8	30.6	42.8	0.0		ii	23.8	41.9	44.1	0.0
	iii	16.1	34.7	50.6	0.0		iii	23.3	41.9	31.6	0.0
	iv	18.7	39.8	46.7	0.0		iv	23.8	43.3	41.0	0.0
Apr. 17	i	19.4	38.6	42.5	0.0	Jun. 18	i	25.5	40.6	52.4	0.0
	ii	16.7	42.9	34.1	0.0		ii	26.1	39.2	57.7	0.0
	iii	21.2	40.4	45.7	0.0		iii	25.5	39.1	56.9	0.0
	iv	22.0	38.9	46.2	0.0		iv	24.9	37.2	63.9	1.0
May. 17	i	22.1	42.2	46.6	0.0	Jul. 18	i	25.6	38.3	59.8	0.0
	ii	24.2	41.8	49.5	0.0		ii	25.5	37.0	62.0	0.7
	iii	24.5	40.5	48.8	0.0		iii	25.1	36.4	68.6	0.0
	iv	25.9	41.9	55.6	0.0		iv	24.8	36.4	63.0	0.0
Jun. 17	i	25.5	40.0	60.6	0.0	Aug. 18	i	24.2	36.0	61.8	0.0
	ii	26.1	39.7	57.5	0.0		ii	24.5	35.2	68.7	0.0
	iii	26.1	38.6	60.7	0.0		iii	24.1	36.3	66.6	0.4
	iv	26.5	38.9	62.4	0.7		iv	23.0	36.3	63.5	0.0
Jul. 17	i	25.6	37.3	64.8	0.0	Sep. 18	i	22.4	36.1	63.1	0.0
	ii	25.2	37.2	64.5	0.8		ii	22.9	35.2	63.0	0.0
	iii	25.0	36.6	70.7	1.4		iii	21.8	37.2	59.1	0.0
	iv	25.4	35.7	69.3	0.3		iv	22.8	38.8	57.1	0.0
Aug. 17	i	25.1	35.8	67.5	0.0	Oct. 18	i	20.0	40.2	57.3	0.0
	ii	24.8	35.9	65.0	0.0		ii	18.1	35.6	49.4	0.0
	iii	24.6	37.5	63.0	0.4		iii	17.5	35.9	45.8	0.0
	iv	24.7	36.2	68.5	10.0		iv	16.8	37.9	48.9	0.0
Sep. 17	i	24.1	35.0	68.5	0.0	Nov. 18	i	14.4	32.9	47.3	0.0
	ii	23.1	35.6	70.4	0.0		ii	15.3	32.5	59.4	0.0
	iii	23.2	37.9	62.6	0.0		iii	15.3	30.9	59.9	0.0
	iv	21.9	36.5	61.7	0.0		iv	14.8	30.1	60.8	0.0
Oct. 17	i	20.8	37.8	58.0	0.0	Dec. 18	i	13.3	29.5	61.3	0.0
	ii	19.4	39.6	51.0	0.0		ii	11.1	24.9	63.9	0.0
	iii	19.3	39.0	48.8	0.0		iii	6.8	24.0	57.9	0.0
	iv	18.3	37.2	55.0	0.0		iv	6.5	25.4	55.6	0.0

Plant population (000 ha⁻¹)

Analysis of variance showed that a considerable ($p < 0.05$) result was induced by Zn on plant population (000 h⁻¹) while, non-significant ($p > 0.05$) by B and interaction (Table 2). Zn 15 kg ha⁻¹ gave most productive plant population followed by 0.2% Zn foliar application having statistical parallelism with each other while lowest plant population was noticed in 0 kg ha⁻¹ Zn, where Zn was not applied. Boron 1 kg ha⁻¹ resulted in best plant population followed by 0.1% B foliar application and 0 kg B ha⁻¹. The interaction of Zn 15 kg ha⁻¹ × B 1 kg ha⁻¹ produced improved plant population lead by Zn 15 kg ha⁻¹ × B 0.2% whereas reduced results were recorded in Zn 0 kg ha⁻¹ × B 0 kg ha⁻¹ that contrasted considerably from all other treatments. The reason behind improved plant population might be due to the essential role of Zinc in a broad variety of biochemical processes that have an effect on growth, development, and reproduction and almost all characteristics of cellular metabolism. These results are in uniformity with Wang et al. (2005) who evaluated the best possible rate of Zn application for sugarcane production and specified that Zn in the form of ZnSO₄ can considerably promote sugarcane production.

Crop growth rate (g m⁻² day⁻¹)

Facts concerning crop growth rate (g m⁻² day⁻¹) exhibited noteworthy ($p < 0.05$) effect by Zn and B and non-significant ($p > 0.05$) by interaction (Table 3). Zn 15 kg ha⁻¹ resulted in increased crop growth rate preceded by 0.2% Zn foliar application having statistical equivalence with each other while lowest crop growth rate was noticed in 0 kg ha⁻¹ Zn. 0.1% B foliar application resulted in greatest crop growth rate next to Boron 1 kg ha⁻¹ and 0 kg B ha⁻¹. The interaction of Zn 15 kg ha⁻¹ × B 1 kg ha⁻¹ produced amended crop growth rate followed by Zn 15 kg ha⁻¹ × B 0.1% whereas weak results were examined in Zn 0 kg ha⁻¹ × B 0 kg ha⁻¹. The reason behind enhanced crop growth rate could be due to the foliar application of zinc that increases the enzymes activity and leads to easy translocation of assimilate from leaf to grain. These results are further invigorated by Panhwar et al. (2003) who reported that foliar application of zinc sulfate had more useful outcomes than soil application when farm yard manure, quite well rotten sheep or goat manure at the time of land preparation is assimilated.

Leaf area (cm²)

Leaf area (cm²) responded significantly ($p < 0.05$) to Zn, B and their interaction (Table 3). Zn 15 kg ha⁻¹

gave dynamic leaf area followed by 0.2% Zn foliar application having statistical evenhandedness with each other while lowest leaf area was noticed in 0 kg ha⁻¹ Zn. Boron 0.1% foliar application profoundly enhanced the leaf area followed by 1 kg ha⁻¹ B and 0 kg B ha⁻¹. The interaction of Zn 15 kg ha⁻¹ × B 1 kg ha⁻¹ produced superior leaf area pursued by Zn 15 kg ha⁻¹ × B 0.1% whereas dwindled results were recorded in Zn 0 kg ha⁻¹ × B 0 kg ha⁻¹. The possible reason of superior leaf area with application of Zn might be due to its performance in the vital plant capabilities like photosynthesis, protein and chlorophyll production.

Cane length (cm)

Cane length is a prime yield supervening part in sugarcane. Statistical analysis of data showed that significant ($p < 0.05$) effect on cane length (cm) was caused by Zn and B and non-significant ($p > 0.05$) by interaction (Table 4). Zn 15 kg ha⁻¹ gave vigorous cane length followed by 0.2% Zn foliar application having statistical equality with each other while declined cane length was seen in 0 kg ha⁻¹ Zn. Boron 0.1% foliar application produced greatest cane length seconded by 1 kg ha⁻¹ B and 0 kg B ha⁻¹. The interaction of Zn 15 kg ha⁻¹ × B 1 kg ha⁻¹ revealed improved cane length headed by Zn 15 kg ha⁻¹ × B 0.1% whereas moderate results were recorded in Zn 0 kg ha⁻¹ × B 0 kg ha⁻¹. The increase in cane length may be endorsed to additional vegetative growth due to availability of balanced Zn application because Zn plays a major part in the production of growth substances. Parallel outcomes were quoted by Mariano et al. (2011) who reported that stalk technological quality improved with Zn fertilization, furthermore it is providing residual effect as well as increasing the above ground biomass. Khan et al. (1997) and Soomro et al. (2005) also reported that plant height was improved due to foliar application of micronutrients over the control treatment.

Cane girth (cm)

Cane girth (cm) become affected significantly ($p > 0.05$) by Zn and B but their interaction was appeared to be non-significant (Table 4). Zn 15 kg ha⁻¹ accorded highest cane girth followed by 0.2% Zn foliar application having statistical egalitarianism with each other while lowest cane girth was observed in 0 kg ha⁻¹ Zn. Boron 1 kg ha⁻¹ and 0.1% foliar application resulted in greatest cane girth succeeding by 0 kg B ha⁻¹. The interaction of Zn 15 kg ha⁻¹ × B 1 kg ha⁻¹ produced better cane girth preceded by Zn 15 kg ha⁻¹ × B 0.1% whereas shortest cane girth was

observed in Zn 0 kg ha⁻¹ × B 0 kg ha⁻¹. The results showed that when Zn was added in the nutrient program, a noticeable increase in the cane girth was observed. Although, the effect of boron on cane girth was also seen, but in fact there was petite need of boron was seemed. The results have similarities with the findings of Naemat et al. (1992) and Khan et al. (1997) who confirmed that with the foliar application of micronutrients there was crucial enhancement in cane diameter.

Tillers stool⁻¹

Effects of Zn and B were significant ($p < 0.05$) for the tillers stool⁻¹ whereas interactive effects of the treatments were found to be non-significant (Table 5). Zn 15 kg ha⁻¹ gave highest tillers stool⁻¹ followed by 0.2% Zn foliar application having statistical equality with each other while lowest tillers stool⁻¹ was seen in 0 kg ha⁻¹ Zn. Boron 0.1% foliar application resulted in greatest tillers stool⁻¹ seconded by 1 kg ha⁻¹ B and 0 kg B ha⁻¹. The interaction of Zn 15 kg ha⁻¹ × B 1 kg ha⁻¹ exposed improved tillers stool⁻¹ headed by Zn 15 kg ha⁻¹ × B 0.1% whereas moderate results had been recorded in Zn 0 kg ha⁻¹ × B 0 kg ha⁻¹. The improved tillers stool⁻¹ possibly will be due to the role of Zn to play a vital role in a wide range of processes, such as growth hormone production and internode elongation. The results are well supported by the findings of Shafique (2015) who described that with the increased number of zinc levels, number of tillers also increased simultaneously; though application of boron did not show clear consequences on the number of tillers stool⁻¹ in sugarcane.

Internodes cane⁻¹

Figures given in Table 5 exposed that effect of Zn and B was significant ($p < 0.05$) for internodes cane⁻¹ while their interaction was non-significant (Table 5). Zn 15 kg ha⁻¹ gave utmost internodes cane⁻¹ followed by 0.2% Zn foliar application having statistical equality with each other while lowest internodes cane⁻¹ was observed in 0 kg ha⁻¹ Zn. Boron 0.1% foliar application resulted in greatest internodes cane⁻¹ followed by 1 kg ha⁻¹ B and 0 kg B ha⁻¹. The interaction of Zn 15 kg ha⁻¹ × B 1 kg ha⁻¹ produced improved internodes cane⁻¹ lead by Zn 15 kg ha⁻¹ × B 0.1% whereas reduced results were recorded in Zn 0 kg ha⁻¹ × B 0 kg ha⁻¹. The possible reason of superior internodes cane⁻¹ with application of Zinc might be due to its involvement in formation of chlorophyll and carbohydrate. The results are in uniformity with Ghaffar et al. (2012) who explained that with the application

of Zn, quantitative parameters of sugarcane including cane diameter, number of internodes and stripped cane weight were affected significantly. Soomro et al. (2005) also reported that with the foliar feeding of micronutrients, more number of internodes per stalk were examined with over control.

Millable canes (000 ha⁻¹)

Number of millable cane per unit area is one of the foremost yield issues of sugarcane on which the yield depends. Millable canes (000 ha⁻¹) were affected significantly ($p < 0.05$) by Zn and B but their interaction was not significant ($p > 0.05$) (Table 6). Zn 15 kg ha⁻¹ gave maximum millable canes followed by 0.2% Zn foliar application having statistical equality with each other while lowest millable canes were noticed in 0 kg ha⁻¹ Zn. Boron 0.1% foliar application resulted in greatest millable canes followed by 1 kg ha⁻¹ B and 0 kg B ha⁻¹. The interaction of Zn 15 kg ha⁻¹ × B 1 kg ha⁻¹ produced improved millable canes lead by Zn 15 kg ha⁻¹ × B 0.1% whereas reduced results were recorded in Zn 0 kg ha⁻¹ × B 0 kg ha⁻¹. The promising reason of superior millable canes with application of Zn might be due to its fundamental role in plant functions like photosynthesis, protein and chlorophyll synthesis. The data of our experiment indicated that Zn at 15 kg ha⁻¹ significantly affected the number of millable canes of the crop. As reported by Tunio et al. (2004) that increasing rate of Zn was inversely proportional to the average number of millable canes.

Cane yield (t ha⁻¹)

Cane yield (t ha⁻¹) was significant ($p < 0.05$) regarding Zn and B effects, however, interactive effects were also significant (Table 6). Under Zn 15 kg ha⁻¹ maximum cane yield was observed, along with 0.2% Zn foliar application having statistical impartiality with each other while lowest cane yield was noticed in 0 kg ha⁻¹ Zn. Boron 0.1% foliar application resulted in greatest cane yield followed by 1 kg ha⁻¹ B and 0 kg B ha⁻¹. The interaction of Zn 15 kg ha⁻¹ × B 0.1% produced improved cane yield lead by Zn 15 kg ha⁻¹ × B 1 kg ha⁻¹ whereas reduced results were recorded in Zn 0 kg ha⁻¹ × B 0 kg ha⁻¹. The results proved that when Zn was applied a noticeable improvement in the cane yield occurred, which enhanced the number of shoots and millable canes in the treated plots significantly. Similarly, Rohtash and Singh (1997) also reported that Zn application at 25 kg ZnSO₄ ha⁻¹ increased cane yield which might be due to the favorable effect of Zn on the biosynthesis of plant hormone, Indole Acetic Acid, which in turn increased the plant height, number of internodes and millable canes.

Table 2: Bud sprouting (%) and plant population (000 ha⁻¹) of sugarcane as affected by Zn and B application.

Zinc levels	Bud sprouting (%)				Plant population (000 ha ⁻¹)			
	Boron levels				Boron levels			
	0 kg ha ⁻¹	1 kg ha ⁻¹	0.1%	Mean	0 kg ha ⁻¹	1 kg ha ⁻¹	0.1%	Mean
0 kg ha ⁻¹	64.3	71.3	71.7	69.1 b	63.7	67.0	70.7	67.1 b
15 kg ha ⁻¹	80.0	84.3	82.7	82.3 a	76.0	82.7	77.0	78.6 a
0.2%	74.7	80.7	81.0	78.8 a	74.7	75.3	76.0	75.3 a
Mean	73.0	78.8	78.5	-	71.5	75.0	74.6	-
Variables	S. E	p-value	LSD (5%)		S. E	p-value	LSD (5%)	
Zn levels	3.8740	0.0099	8.2126		2.8523	0.0030	6.0467	
B levels	3.8740	0.2747	-		2.8523	0.4176	-	
Zn × B	6.7100	0.9907	-		4.9404	0.6755	-	

Table 3: Crop growth rate (g m⁻² day⁻¹) and leaf area (cm²) of sugarcane as affected by Zn and B application.

Zinc levels	Crop growth rate (g m ⁻² day ⁻¹)				Leaf area (cm ²)			
	Boron levels				Boron levels			
	0 kg ha ⁻¹	1 kg ha ⁻¹	0.1%	Mean	0 kg ha ⁻¹	1 kg ha ⁻¹	0.1%	Mean
0 kg ha ⁻¹	5.1	5.7	6.1	5.6 c	452.7 f	476.0 f	553.7 e	494.1 c
15 kg ha ⁻¹	7.4	9.4	8.8	8.5 a	641.3 d	893.7 a	827.0 b	787.3 a
0.2%	6.6	7.6	8.5	7.6 b	595.3 de	722.3 c	752.0 c	689.9 b
Mean	6.4 B	7.6 a	7.8 a	-	563.1 B	697.3 a	710.9 a	-
Variables	S. E	p-value	LSD (5%)		S. E	p-value	LSD (5%)	
Zn levels	0.3004	0.0000	0.6369		14.729	0.0000	31.224	
B levels	0.3004	0.0004	0.6369		14.729	0.0000	31.224	
Zn × B	0.5204	0.1995	-		25.511	0.0002	54.082	

Table 4: Cane length (cm) and cane girth (cm) of sugarcane as affected by Zn and B application.

Zinc levels	Cane length (cm)				Cane girth (cm)			
	Boron levels				Boron levels			
	0 kg ha ⁻¹	1 kg ha ⁻¹	0.1%	Mean	0 kg ha ⁻¹	1 kg ha ⁻¹	0.1%	Mean
0 kg ha ⁻¹	160.7	188.7	218.7	189.4 c	2.2	2.2	2.3	2.2 c
15 kg ha ⁻¹	289.0	343.3	327.0	319.8 a	2.5	2.9	2.8	2.7 a
0.2%	258.3	300.7	310.3	289.8 b	2.5	2.6	2.7	2.6 b
Mean	236.0 b	277.6 a	285.3 a	-	2.4 b	2.6 a	2.6 a	-
Variables	S. E	p-value	LSD (5%)		S. E	p-value	LSD (5%)	
Zn levels	8.9764	0.0000	19.029		0.0558	0.0000	0.1184	
B levels	8.9764	0.0001	19.029		0.0558	0.0207	0.1184	
Zn × B	15.548	0.3779	-		0.0967	0.1899	-	

Table 5: Tillers stool⁻¹ and internodes cane⁻¹ of sugarcane as affected by Zn and B application.

Zinc levels	Tillers stool ⁻¹				Internodes cane ⁻¹			
	Boron levels				Boron levels			
	0 kg ha ⁻¹	1 kg ha ⁻¹	0.1%	Mean	0 kg ha ⁻¹	1 kg ha ⁻¹	0.1%	Mean
0 kg ha ⁻¹	4.7	5.0	5.3	5.0 b	20.3	22.3	25.0	22.5 c
15 kg ha ⁻¹	5.7	7.7	7.3	6.9 a	28.7	35.3	32.7	32.2 a
0.2%	5.7	6.3	7.0	6.3 a	25.7	29.3	31.3	28.8 b
Mean	5.4 b	6.3 a	6.5 a	-	24.9 b	29.0 a	29.7 a	-
Variables	S. E	p-value	LSD (5%)		S. E	p-value	LSD (5%)	
Zn levels	0.3318	0.0001	0.7034		1.1449	0.0000	2.4270	
B levels	0.3318	0.0045	0.7034		1.1449	0.0014	2.4270	
Zn × B	0.5747	0.3089	-		1.9830	0.3300	-	

Table 6: Millable canes (000 ha⁻¹) and cane yield (t ha⁻¹) of sugarcane as affected by Zn and B application.

Zinc levels	Millable canes (000 ha ⁻¹)				Cane yield (t ha ⁻¹)			
	Boron levels				Boron levels			
	0 kg ha ⁻¹	1 kg ha ⁻¹	0.1%	Mean	0 kg ha ⁻¹	1 kg ha ⁻¹	0.1%	Mean
0 kg ha ⁻¹	63.3	75.3	85.3	74.6 c	58.0 f	72.7 e	90.3 d	73.7 c
15 kg ha ⁻¹	100.7	117.7	111.7	110.0 a	102.0 c	114.7 a	119.0 a	111.9 a
0.2%	98.0	103.0	110.3	103.8 b	100.7 c	105.0 bc	113.0 ab	106.2 b
Mean	87.3 b	98.7 a	102.4 a	-	86.9 c	97.4 b	107.4 a	-
Variables	S. E		p-value	LSD (5%)	S. E		p-value	LSD (5%)
Zn levels	2.5060		0.0000	5.3124	2.6026		0.0000	5.5173
B levels	2.5060		0.0000	5.3124	2.6026		0.0000	5.5173
Zn × B	4.3404		0.0771	-	4.5079		0.0091	9.5563

Table 7: Brix and puriy (%) of sugarcane as affected by Zn and B application.

Zinc levels	Brix (%)				Purity (%)			
	Boron levels				Boron levels			
	0 kg ha ⁻¹	1 kg ha ⁻¹	0.1%	Mean	0 kg ha ⁻¹	1 kg ha ⁻¹	0.1%	Mean
0 kg ha ⁻¹	17.0	19.3	20.3	18.9 c	49.7 e	53.7 e	69.3 d	57.6 c
15 kg ha ⁻¹	22.3	24.0	23.0	23.1 a	74.3 bcd	84.7 a	79.3 ab	79.4 a
0.2%	21.3	22.0	22.3	21.9 b	71.0 cd	75.7 bc	77.0 bc	74.6 b
Mean	20.2 b	21.8 a	21.9 a	-	65.0 c	71.4 b	75.2 a	-
Variables	S. E		p-value	LSD (5%)	S. E		p-value	LSD (5%)
Zn levels	0.3876		0.0000	0.8216	1.6355		0.0000	3.4671
B levels	0.3876		0.0000	0.8216	1.6355		0.0000	3.4671
Zn × B	0.6713		0.0586	-	2.8328		0.0009	6.0052

Table 8: N content (%) and K content (%) of sugarcane as affected by Zn and B application.

Zinc levels	N content (%)				K content (%)			
	Boron levels				Boron levels			
	0 kg ha ⁻¹	1 kg ha ⁻¹	0.1%	Mean	0 kg ha ⁻¹	1 kg ha ⁻¹	0.1%	Mean
0 kg ha ⁻¹	0.6 f	2.0 e	2.1 cde	1.6 c	0.2 f	0.3 f	0.4 ef	0.3 c
15 kg ha ⁻¹	2.2 cd	2.5 a	2.4 ab	2.4 a	0.5 de	0.9 a	0.8 ab	0.7 a
0.2%	2.2 cd	2.2 de	2.3 bc	2.2 b	0.5 de	0.6 cd	0.7 bc	0.6 b
Mean	1.7 b	2.2 a	2.3 a	-	0.4 b	0.6 a	0.6 a	-
Variables	S. E		p-value	LSD (5%)	S. E		p-value	LSD (5%)
Zn levels	0.0493		0.0000	0.1045	0.0411		0.0000	0.0871
B levels	0.0493		0.0000	0.1045	0.0411		0.0001	0.0871
Zn × B	0.0853		0.0000	0.1809	0.0711		0.0255	0.1508

Table 9: Zn content (ug g⁻¹) and B content (ug g⁻¹) of sugarcane as affected by Zn and B application.

Zinc levels	Zn content (ug g ⁻¹)				B content (ug g ⁻¹)			
	Boron levels				Boron levels			
	0 kg ha ⁻¹	1 kg ha ⁻¹	0.1%	Mean	0 kg ha ⁻¹	1 kg ha ⁻¹	0.1%	Mean
0 kg ha ⁻¹	0.9 f	4.3 ef	5.0 e	3.4 c	0.4 g	5.7 f	12.1 e	6.1 c
15 kg ha ⁻¹	60.5 d	73.9 a	71.0 ab	68.5 a	27.6 c	35.0 a	32.4 ab	31.7 a
0.2%	58.8 d	67.1 c	67.7 bc	64.5 b	24.0 d	27.9 c	29.8 bc	27.2 b
Mean	40.1 b	48.4 a	47.9 a	-	17.3 c	22.9 b	24.8 a	-
Variables	S. E		p-value	LSD (5%)	S. E		p-value	LSD (5%)
Zn levels	1.0431		0.0000	2.2114	0.7599		0.0000	1.6109
B levels	1.0431		0.0000	2.2114	0.7599		0.0000	1.6109
Zn × B	1.8068		0.0165	3.8302	1.3161		0.0016	2.7901

Quality parameters

Brix (%) and purity (%) both responded significantly ($p < 0.05$) to Zn and B levels, their interaction for brix was significant, however, interactive effects for purity was nonsignificant ($p > 0.05$) (Table 7). Zn 15 kg ha⁻¹ gave highest brix and purity followed by 0.2% Zn foliar application having statistical consensus with each other while lowest brix and purity was observed in 0 kg ha⁻¹ Zn. Boron 0.1% foliar application demonstrated greatest brix and purities recorded by 1 kg ha⁻¹ B and 0 kg B ha⁻¹. The interaction of Zn 15 kg ha⁻¹ × B 1 kg ha⁻¹ exposed improved brix and purity headed by Zn 15 kg ha⁻¹ × B 0.1 % whereas moderate results were recorded in Zn 0 kg ha⁻¹ × B 0 kg ha⁻¹. The promising reason of greater quality attributes were favorably due to the zinc which is key constituent of many enzymes and proteins. Singh et al. (1997) too perceived an increase in brix content of sugarcane, when zinc was applied as a basal dose. Thangavelu (2007) observed that Zn fertilization in addition to NPK considerably increases brix and pol % juice of cane as compared to those with zero fertilizers or supplied most effective with NPK. Dhanasekaran and Bhuvaneswari (2004) also noticed that percent purity of cane juice significantly increased when Zn and Fe was implemented both alone and in combination.

Nutrient content parameters

The perusal of data showed that N content (%), K content (%), Zn content (ug g⁻¹), B content (ug g⁻¹) has been significantly ($p < 0.05$) affected by Zn, B and their interaction (Tables 8 and 9). Zn 15 kg ha⁻¹ gave highest N, K, Zn and B content followed by 0.2% Zn foliar application having statistical equality with each other while lowest N, K, Zn and B content was noticed in 0 kg ha⁻¹ Zn. B 0.1% foliar application proceeded with greatest N, K and B content followed by 1 kg ha⁻¹ B and 0 kg B ha⁻¹. In case of Zn content B 1 kg ha⁻¹ gave highest results followed by B 0.1% foliar application, while least was observed in 0 kg ha⁻¹ B. The interaction of Zn 15 kg ha⁻¹ × B 1 kg ha⁻¹ induced improved N, K, Zn and B content lead by Zn 15 kg ha⁻¹ × B 0.1 % whereas reduced results were recorded in Zn 0 kg ha⁻¹ × B 0 kg ha⁻¹. The interaction of Zn 15 kg ha⁻¹ × B 1 kg ha⁻¹ produced superior N, K, Zn and B content pursued by Zn 15 kg ha⁻¹ × B 0.1 % whereas dwindled results had been recorded in Zn 0 kg ha⁻¹ × B 0 kg ha⁻¹. The possible reason of superior nutrient content parameters might be due to part of Zn as it is an critical aspect of different enzyme that are responsible for driving many metabolic reactions in all crops.

Conclusions and Recommendations

Growth, yield, and quality of sugarcane were affected significantly by Zn, B application and their interaction. Zn 15 kg ha⁻¹ (Soil application) conferred enhanced cane yield (t ha⁻¹) and brix (%). Foliar application of boron 0.1% resulted in highest cane yield (t ha⁻¹) and Brix (%). Interaction of Zn 15 kg ha⁻¹ × 0.1% B proved appropriate for improved yield and quality of sugarcane.

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This is exceptional research article and arranged from PhD thesis work conducted at Sindh Agriculture University, Tandojam, Pakistan.

Novelty Statement

Little research work has been done on effects of Zinc and Boron on sugarcane particularly in our conditions. This research will help in understanding the role of Zinc and Boron in sugarcane.

Author's Contribution

N. Mangrio designed and performed overall process of study. M.N. Kandhro guided scholar throughout experiment and write-up process. A.A. Soomro contributed in data analysis and writing of manuscript. N. Mari provided facility for experiment and helped in collection of data. Z.H. Shah contributed in interpretation of results and preparation of research article.

Conflict of interest

The authors have declared no conflict of interest.

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